centodecimo

110° CONGRESSO NAZIONALE
Società Italiana di Fisica

SOCIETÀ ITALIANA DI FISICA

Bologna, 9-13 settembre 2024

Distretto Navile dell'Università
Edificio UE1

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



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A cura di Barbara Alzani, Marco Bellacosa e Giovanna Bianchi Bazzi
Redazione dei testi a cura di Barbara Ancarani e Marco Bellacosa
Progetto grafico a cura di Simona Oleandri
Società Italiana di Fisica

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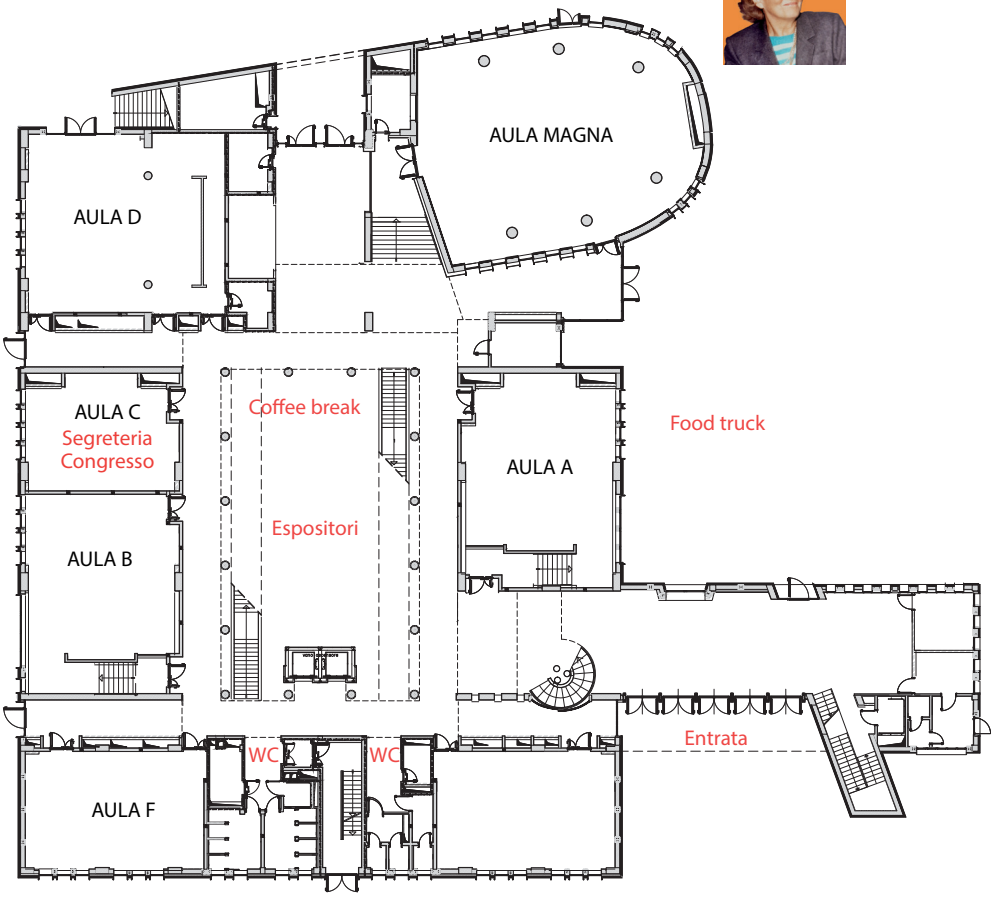












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SIMPOSI

Fisica Statistica e Sistemi Complessi

Optometria

Supercalcolo:" Emerging data and computing technologies for frontier physics"

INFORMAZIONI GENERALI

Sede del Congresso

La cerimonia di inaugurazione si terrà il 9 settembre alle ore 9.00 presso la Sala Bolognini del Complesso di San Domenico in Piazza S. Domenico, 13.
I lavori del Congresso si svolgeranno presso il nuovo Distretto Navile - Edificio Ue1 dell'Università, Via della Beverara 123/1, Bologna.

Iscrizioni

Quote di iscrizione al Congresso per i Soci (*)	
Socio Ordinario	€ 110,00
Socio under 40	€ 95,00
Socio Invitato (neolaureato in Fisica)	€ 95,00

(*) Per i Relatori su Invito e i Chair si applica la stessa quota dei Soci Ordinari

Quote di iscrizione al Congresso per i non Soci	
Partecipante Ordinario	€ 180,00
Partecipante under 40	€ 155,00

Le iscrizioni devono essere effettuate online entro le ore 12:00 del 2 settembre 2024.
La quota dà diritto alla cartella congressuale contenente il volume degli Atti del Congresso con i riassunti delle relazioni e delle comunicazioni. Per partecipare ai lavori congressuali è necessario essere muniti di targhetta nominativa che attesti la registrazione al Congresso.

Relazioni Generali, Relazioni su Invito e Comunicazioni

Nel programma sono segnalate dai seguenti simboli:

- ■ Relazioni Generali
- ▲ Relazioni su Invito
- ● Comunicazioni

Per la presentazione orale delle relazioni su invito e delle comunicazioni gli autori avranno a disposizione rispettivamente 20 minuti + 5 di discussione per le relazioni su invito e 10 minuti + 2 di discussione per le comunicazioni, compatibilmente con il programma della Sessione. L'autore, il cui nome figura sottolineato, sarà il presentatore della comunicazione. Almeno uno degli autori, possibilmente il presentatore, deve essere Socio della Società Italiana di Fisica.

Migliori comunicazioni

Un'apposita commissione segnalerà al Consiglio di Presidenza della SIF un certo numero di comunicazioni (il 20% circa) per ogni sezione giudicate migliori sulla base del contenuto e/o dell'esposizione. Per i presentatori che vinceranno sono previsti premi e/o la pubblicazione degli articoli in un fascicolo speciale de Il Nuovo Cimento, garantendo una pubblicazione on-line in "open access". La premiazione dei relatori avrà luogo durante la cerimonia inaugurale del Congresso Nazionale SIF del 2025.
Esclusivamente gli iscritti al Congresso avranno la possibilità di partecipare alla selezione.

Si ringraziano i seguenti enti e aziende che, con il loro patrocinio e il loro contributo finanziario e operativo, hanno reso possibile l'organizzazione del Congresso

Accademia delle Scienze dell'Istituto di Bologna
Alma Mater Studiorum Università di Bologna
Associazione "Physicists for Tango"
CINECA
CNR IMM – Consiglio Nazionale delle Ricerche – Istituto per la Microelettronica e Microsistemi di Bologna
Collegio Superiore dell'Università di Bologna
Comitato Nazionale Marconi 150
Comune di Bologna
Conservatorio di Musica Giovan Battista Martini di Bologna
CREF – Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi"
Dipartimento di Fisica e Astronomia "Augusto Righi" dell'Università di Bologna
Dipartimento di Ingegneria dell'Energia Elettrica e dell'Informazione "Guglielmo Marconi" dell'Università di Bologna
EPJ – European Physical Journal
Essse Caffè
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Fondazione del Monte di Bologna e Ravenna
Fondazione Guglielmo Marconi
Fondazione ICSC – Centro Nazionale di Ricerca in HPC, Big Data e Quantum Computing
GSSI – Gran Sasso Science Institute
Hoepli
IEEE Photonics Society – Italy Chapter
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INAF OAS – Istituto Nazionale di Astrofisica – Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
INFN – Istituto Nazionale di Fisica Nucleare
INGV – Istituto Nazionale di Geofisica e Vulcanologia
INRiM – Istituto Nazionale di Ricerca Metrologica
Regione Emilia-Romagna
Teatro Duse
Zanichelli

Si ringraziano i seguenti espositori

A.D.S. International
AISF – Associazione Italiana Studenti di Fisica
CUSB – Centro Universitario Sportivo Bologna
CAEN
CREF – Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi"
CTAO – Cherenkov Telescope Array Observatory
EPS Young Minds – European Physical Society
Pubblicazioni INGV
Pubblicazioni SIF
Springer

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Complesso San Domenico - Sala Bolognini **ore 9:00 – 10:30**

CERIMONIA DI INAUGURAZIONE
INTRODUZIONE DEL PRESIDENTE
Prof. Angela Bracco

PREMIAZIONI:

Premio "Enrico Fermi"

Premio "Friedel-Volterra" (SIF-SFP) 2023

Premio per la Didattica o la Storia della Fisica

Premio per la Comunicazione Scientifica

Premio "Laura Bassi" per le Donne nella Fisica *early career & mid to full career*

Premio SIF-SoNS "Neutrons Matter"

Premio "Giuliano Preparata"

Premio "Paolo Mazzoldi"

Premio "Sergio Panizza e Gabriele Galimberti"

Borsa "Ettore Pancini"

Premi per giovani laureati in Fisica dopo il maggio 2017 e dopo il maggio 2021

Premi per le Migliori Comunicazioni al Congresso Nazionale 2023

Soci Benemeriti della SIF

Complesso San Domenico - Sala Bolognini **ore 10:40 – 11:50**

Presiede: Bracco A. (Università di Milano)

Relazione Generale

Latest results from AMS on the International Space Station.
Battiston R.
Università di Trento e INFN TIFPA
The Alpha Magnetic Spectrometer (AMS) is a particle physics detector designed to operate as an external module on the International Space Station (ISS). AMS was launched by the Space Shuttle Endeavour and installed on the upper Payload Attach Point of the ISS in 2011. The results and discoveries obtained from the over 210 billion cosmic rays up to multi-TeV energies collected by AMS in the last thirteen years will be presented.

Un breve video di saluto di S.C.C. Ting (MIT, Boston, USA) verrà trasmesso all'inizio della Relazione.

Complesso San Domenico - Sala Bolognini **ore 11:50 – 12:30**

Sezione II
Fisica della materia
Presiede: Fabris S. (IOM-CNR, Trieste)

Relazione Generale

Molecules in the solid state for quantum technologies.
Toninelli C.
Istituto Nazionale di Ottica CNR-INO c/o LENS, Sesto Fiorentino, FI
In this contribution, the generation of quantum states of light from single molecules is discussed, tailored to multiple and diverse applications. We will focus on the use of polycyclic aromatic hydrocarbons (PAH), embedded in host matrices. These molecules, due to their small size and well-defined properties, serve as nanoscopic sensors for pressure, strain, temperature, and various fields. The contribution discusses recent advancements in coupling single PAH molecules to photonic structures to enhance and control their interaction with light. Notably, two-photon interference experiments between photons emitted by different molecules on the same chip are presented, posing a fundamental challenge in solid-state platforms for photonic quantum technologies. Multiple milestones are achieved, including addressing several molecules simultaneously as on-demand single-photon sources, independently tuning their frequencies optically, and conducting real-time measurements of two-photon interference. Additionally, the communication explores the use of organic molecules as nanoscopic thermal sensors, enabling semi-invasive local temperature measurements in a temperature range (from 3 K to 30 K) unattainable by most commercial technologies. These results offer insights into the local phononic environment in complex structures and an unexplored temperature regime.

Aula Magna **ore 15:00 – 19:30**

Sezione I
Fisica nucleare e subnucleare
Presiede: Montanari A. (INFN, Sezione di Bologna)

Relazioni su invito

▲ **ATLAS Physics Highlights.**
Coccaro A.
INFN, Sezione di Genova
La presentazione illustrerà una panoramica dei più recenti e importanti risultati riportati dalla collaborazione ATLAS nei settori della fisica di precisione del Modello Standard e delle ricerche di nuova fisica, con enfasi per gli aspetti più innovativi in termini sia di ricostruzione dello stato finale che di metodologie di analisi.

▲ **Recenti risultati di fisica dell'esperimento CMS a LHC.**
Primavera F.
Università di Bologna e INFN, Sezione di Bologna
In seguito alla scoperta del bosone di Higgs, la collaborazione CMS ha intensificato il suo programma di ricerca di fisica ad ampio spettro, sia attraverso il miglioramento delle misure di precisione dei processi del Modello Standard, sia esplorando un numero crescente di modelli oltre di esso. Se da una parte, infatti, la precisione nella conoscenza dei fenomeni del Modello Standard rappresenta una sfida, in quanto pone i confini alla capacità predittiva del modello stesso, dall'altra, risultano fondamentali le ricerche dirette di nuova fisica, siano esse la scoperta di nuove particelle, o la misura di nuovi decadimenti o proprietà non previste per le particelle esistenti. In questa comunicazione verranno presentati i risultati più significativi recentemente ottenuti dai dati del Run2 di LHC in collisioni protone protone a 13 TeV, e dai dati del Run3 a 13.6 TeV. Questi risultati copriranno diversi temi che vanno dallo studio delle proprietà del bosone di Higgs, alle misure di precisione del settore elettrodebole e di fisica del flavour, fino alle ricerche dirette di fisica oltre il Modello Standard.

▲ **The LHCb experiment towards its culmination phase.**
Punzi G.
Dipartimento di Fisica, Università di Pisa, Italy
LHCb has been the dedicated experiment for flavor physics at the LHC for over a decade. It has contributed to the HEP field with the first observation of CP violation in the charm sector, best measurements of CKM parameters and rare decay modes, discovery of tens of new states in heavy hadron spectroscopy, and a variety of other original measurements. All these results have been obtained by collecting data at a much reduced luminosity with respect to the LHC potential, adding up to a total sample of less than 10 fb^{-1}. Based on the accumulated experience, the LHCb collaboration is now working at pushing the capabilities of the detector to their extreme, in an upgrade path of increasing luminosity towards a final target of a 300 fb^{-1} total sample. This path goes through the current Run 3 of the LHC, with a renewed apparatus where for the first time all events from each collision are fully reconstructed; through Run 4 with preparatory detector enhancements; to Run 5 where a much finer-grained detector, capable of precision timing and equipped with the largest data-processing system in HEP will target the ultimate precision in flavor physics observables.

▲ **The ALICE experiment at the LHC: Highlights and prospects.**
Terrevoli C.
INFN, Sezione di Bari
ALICE is a general-purpose experiment, dedicated to the study of the hot and dense QCD medium, the quark-gluon plasma, created in ultra-relativistic heavy-ion collisions at the LHC. During the Run 1 and Run 2 data-taking periods of the LHC, it has demonstrated its excellent capability in investigating the strongly interacting matter not only in nucleus-nucleus collisions, but also in proton-nucleus and proton-proton collisions. Following major upgrades implemented from 2019 to 2021, ALICE was able in Run 3 to collect data at a rate that was more than ten times higher than in Run 2, reaching up to 500 kHz for proton-proton collisions and 50 kHz for Pb-Pb collisions. Providing also an improved pointing resolution, these upgrades offer the capability for more precise measurements. In this contribution, we will discuss an overview of selected highlights from recent measurements, performed in Run 2 and in Run 3, that represent significant steps towards our understanding of the QCD matter. Additionally, we will briefly explore the prospects for the LHC Run 4 and beyond, where additional upgrades projects are anticipated.

Comunicazioni

● **Measurements of the production of light (anti)nuclei with ALICE at the LHC.**
Calivà A.
Università di Salerno e INFN, Sezione di Napoli, Gruppo Collegato di Salerno
One of the key challenges for modern nuclear physics today is to understand the production mechanism of light (anti)nuclei in high-energy hadronic collisions. The phenomenological models typically used to describe the available experimental data provide very different interpretations of the microscopic process that leads to the formation of bound states. The ALICE Collaboration has significantly contributed to this research field with systematic and multi-differential measurements of the production yields of (anti)nuclei in different collision systems and center-of-mass energies provided by the Large Hadron Collider (LHC). In this contribution, recent highlights from ALICE on the measurements of the production of light (anti)nuclei will be presented.

● **Search for dark sectors and dark photons decaying into lepton jets with the atlas experiment.**
Ricci B.
Università degli studi di Udine e INFN, Sezione di Trieste, Gruppo Collegato di Udine
Several extensions of the Standard Model provide for the existence of a Dark Sector weakly coupled to the Standard Model via the "vector portal". Depending on the structure of the Dark Sector and its coupling with the Standard Model, some dark states can be produced in accelerators and can decay into Standard Model particles, forming an important part of physics research in the ATLAS experiment at CERN for research of physics Beyond the Standard Model. The simplest extension of the Standard Model is with the addition of a U(1) gauge group and therefore of a new vector boson, the Dark Photon. At the Large Hadron Collider it is also possible to study the case of the "Higgs portal", which allows the Higgs boson to decay into Dark Sector particles and therefore also into Dark Photons. This work presents the search for the Dark Photon, with a mass from 17 MeV, which rapidly decays in the innermost part of the ATLAS detector (prompt decay) into jets of collimated electrons and/or muons (lepton-jets). The analysis is performed by studying the entire Run-2 dataset at a center-of-mass energy of 13 TeV in proton-proton collisions.

Testing new ML approach to unfolding in the ATLAS experiment.
Cresta T.
Università di Pavia e INFN, Sezione di Pavia
Data collected by every physics experiment are affected by the non uniform or distorted response of the detectors. This translates into reconstructed distributions that do not blindly match the physical underlying distributions. It is especially true and important at high energy, like the ones at which operates the ATLAS experiment, where the detectors are really complex and high precision is required in the measurements. Data Unfolding identifies a class of techniques that aim at manipulating and cleaning the distributions measured by taking into account all detector effects. The most common algorithm currently used at the LHC is the Iterative Bayesian Unfolding (IBU), but recently some other methods have been proposed based on Machine Learning. In this contribution an introduction to the concept of unfolding and the IBU algorithm will be given. Some possible improvements to the algorithm and alternative methods will be discussed. The results obtained with these different approaches will be presented for the W+c and Z+bb ATLAS analyses, since they involve unfolding for both one dimensional and bi-dimensional variables.

Higgs boson pair production in the $bb\tau\tau$ final state with ATLAS detector.
Belotti G.
Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa
The production of a pair Higgs boson (HH) is a rare process in the Standard Model and it is a sensitive probe of the Higgs boson trilinear self-coupling and of the shape of the Higgs field potential. This communication will summarize the latest ATLAS results on HH production in the $bb\tau\tau$ final state, along with recent ideas to enhance its performance, and will also cover the projected sensitivity for Run3 and the High Luminosity LHC phase. The contribution will explore the synergies with other processes in the $bb\tau\tau$ final state which could serve as cross checks for the HH measurements: the production of a pair of Z bosons (ZZ) and the associated production of a Higgs boson with a Z boson (ZH).

A study of the measurement of the τ lepton anomalous magnetic moment in high energy lead-lead collisions at LHC.
Casali F. ([1]), Verducci M. ([1]), Roda C. ([1]), Cavasinni V. ([1]), Vignaroli N. ([2])
([1]) *Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa*
([2]) *Dipartimento di Matematica e Fisica, Università del Salento e INFN, Sezione Lecce*
The τ lepton anomalous magnetic moment: $a_\tau = \frac{g_\tau - 2}{2}$ was measured, so far, with a precision of only several percents despite its highly sensitivity to physics beyond the Standard Model such as compositeness or Supersymmetry. A new study is presented to improve the sensitivity of the a_τ measurement with photon-photon interactions from ultra-peripheral lead-lead collisions at LHC. The theoretical approach used in this work is based on an effective Lagrangian and on a photon flux implemented in the MadGraph5 Monte Carlo simulation. Using a multivariate analysis to discriminate the signal from the background processes, a sensitivity to the anomalous magnetic moment $a_\tau = 0^{-0.019}_{+0.011}$ is obtained at 95% CL with a dataset corresponding to an integrated luminosity of 2 nb^{-1} of lead-lead collisions and assuming a conservative 10% systematic uncertainty. The present results are compared with previous calculations and available measurements.

Studio di un algoritmo di fit cinematico per la ricerca di coppie di bosoni di Higgs nel canale $b\bar{b}\gamma\gamma$ ad ATLAS.
Orlandini R., Di Micco B., Montereali F.
Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre

La ricerca di coppie di bosoni di Higgs, prodotti a LHC, è un passo fondamentale per lo studio e la comprensione del potenziale del campo di Higgs, responsabile della rottura spontanea di simmetria elettro-debole. Infatti, l'osservazione di questo raro fenomeno permetterebbe di misurare l'accoppiamento tri-lineare di bosoni di Higgs e, conseguentemente, di avere una stima del termine cubico del potenziale. Tuttavia, a causa del basso numero di eventi attesi, una delle attività principali attuali è sviluppare ed ottimizzare algoritmi di analisi volti ad aumentare la sensitività degli esperimenti. In questo contributo saranno esposti l'implementazione e alcuni risultati di un algoritmo molto promettente impiegato nel canale di decadimento di due bosoni di Higgs in coppie di fotoni e b-jets ad ATLAS basato su un fit cinematico. Questi è infatti in grado di migliorare la risoluzione della componente adronica del decadimento grazie all'imposizione di vincoli cinematici sui singoli eventi così da migliorare la capacità di rigettare il fondo gamma-gamma non risonante, consentendo di determinare intervalli di confidenza più stringenti sul parametro di accoppiamento tri-lineare.

Double Higgs boson production search with photons in the final state with CMS experiment.

Del Vecchio M. for the CMS Collaboration
Sapienza Università di Roma e INFN, Sezione di Roma

One of the least constrained parameters of the Higgs boson sector is the strength of his trilinear self-interaction. In the Standard Model, its value is completely determined, defining the complete shape of the Higgs field potential: a measurement of this parameter is then a fundamental test of the SM. The main handle to constrain it at the LHC is the HH production, which is likely not within the reach with the current LHC phase-1 integrated luminosity. Still, beyond SM models (BSM) predict enhanced HH production, as well new massive particles which can decay to HH into the same final states. The HH $\rightarrow$ 2 photons 2taus is a good compromise between moderate branching ratio and clean final state: the analysis strategy with the LHC Run3 data recently collected is presented, both for the SM non-resonant case, projecting results to HL-LHC luminosity, as well as for BSM scenarios.

Progressi nell'uso del MIP timing detector per la ricostruzione degli eventi ad HL-LHC in CMS.

Delli Gatti R. per la CMS Collaboration
Università di Trieste e INFN, Sezione di Trieste

Il nuovo rivelatore per misurare il tempo delle particelle minimo ionizzanti Mip Timing Detector, in costruzione nell'ambito del programma di aggiornamento del rivelatore Compact Muon Solenoid (CMS) al Large Hadron Collider (LHC), permetterà di misurare il tempo delle tracce con una risoluzione temporale di 30-40 ps. L'uso di queste informazioni avrà un ruolo chiave nel compensare il deterioramento delle prestazioni degli algoritmi di ricostruzione dovuto al drastico aumento delle collisioni multiple (pileup), oltre a fornire uno strumento utile all'investigazione diretta di nuovi canali di fisica con particelle a vita lunga. Questa presentazione discute gli studi in corso per l'ottimizzazione della ricostruzione degli eventi mediante l'uso delle misure di tempo, tanto dal punto di vista delle prestazioni di fisica che computazionali.

Performance in high-rate background of triple-GEM detectors for the ME0 system of the CMS Phase-2 Upgrade.

Nenna F. CMS Collaboration
Univ. di Bari e Sez. dell'INFN

The High-Luminosity LHC will deliver proton-proton collisions at 5-7.5 times the nominal LHC luminosity, with an expected number of 140-200 pp-interactions per bunch crossing. To

maintain the performance of muon triggering and reconstruction under high-rate background, the forward part of the Muon spectrometer of the CMS experiment will be upgraded with Gas Electron Multiplier (GEM) detectors. The ME0 station will be made of stacks of six triple-GEM detectors each and will extend the pseudo-rapidity coverage of the muon system up to $|\eta < 2.8|$. A dedicated rate capability study and a timing analysis are required for ME0 system to work in this challenging region. We present the integration of a final-design prototype of a six-layered ME0 stack, along with performance measurements for muon segment reconstruction efficiency and timing, conducted both with cosmics and in test beam at the CERN SPS. We also present rate capability measurements carried out in high-rate gamma background scenarios at the CERN Gamma Irradiation Facility. Our findings confirm that the ME0 design meets Phase-2 CMS muon system upgrade requirements, paving the way for its mass production in fall 2024.

Ricerche di nuova fisica con oggetti pesanti ad alto boost di Lorentz in eventi con jet.

Favilla L. per la CMS Collaboration
INFN, Sezione di Napoli

Le ricerche di nuova fisica nel regime con un elevato boost di Lorentz sono una parte cruciale del programma di fisica di LHC, in quanto potrebbero rivelare la presenza di nuove risonanze pesanti, previste da modelli di fisica oltre il Modello Standard a masse elevate. Nella collaborazione CMS, numerosi algoritmi di boosted-jet tagging sono stati sviluppati per identificare jet adronici che originano appunto dal decadimento di particelle del Modello Standard come quark top, bosoni di Higgs o bosoni vettori, e impiegati in una varietà di analisi. In questo contesto, saranno descritte tecniche di apprendimento automatico, o Machine Learning, sono state applicate di modo da sfruttare al meglio l'informazione dei componenti dei jet, e la loro applicazione in analisi di fisica. Questo talk riassumerà la performance di questi algoritmi in analisi eseguite sui dati di collisione del Run-II di LHC ad un'energia nel centro di massa di 13 TeV.

Enhancing ATLAS sensitivity to LLPs using ToF to the Muon Spectrometer.

Nechaeva S.
Dipartimento di Fisica, Università e INFN, Sezione di Bologna

Charged long-lived particles (LLPs) with lifetimes of 10 ns or more can be detected by ATLAS by exploiting their large ionizing energy loss inside the detector media, or by measuring their Time-of-Flight (ToF) to the calorimeters or the Muon Spectrometer. A search using ToF information from the ATLAS Muon Spectrometer and the ATLAS calorimeters to determine particle speed β and ionizing energy loss information in the ATLAS Inner Detector can unlock a significant improvement in sensitivity to LLPs particles over a vast region of the parameter space. This talk will review existing ATLAS results obtained by similar searches using the Run 2 data, and will discuss the design and preliminary findings of the new analysis targeting Run 3 data.

Measurement of ϕ-meson pairs with ALICE at the LHC to investigate strangeness production.

Rubini N.
INFN, Sezione di Bologna

Recent measurements from high-multiplicity proton-proton collisions have revealed that several phenomena reminiscent of Quark-Gluon Plasma (QGP) behaviour also extend to small collision systems. One notable observation is the increased production of strange and multi-strange hadrons compared to their non-strange counterparts which evolves continuously from

small to large collision systems. The nature of this effect in small systems still poses an open question. In this context, the ϕ meson emerges as a particularly valuable probe for examining strangeness enhancement and production altogether. A more thorough understanding of the producing mechanism for the ϕ meson is bound to help in validating or refuting specific phenomenological models. This contribution will present recent ALICE results concerning the production of ϕ-meson pairs as a function of multiplicity in pp collisions at $\sqrt{s} = 5$ and 7 TeV. The combined measurement of the inclusive ϕ meson and ϕ-meson pairs puts state-of-the-art phenomenological models under test in a novel way. The predictions from these models will be presented and tested against the measurements.

Testing the presence of QGP in small systems using (multi-)strange hadron correlations with a ϕ meson with ALICE.

Cannito S. on behalf of the ALICE Collaboration
Università di Trieste e INFN, Sezione di Trieste

In collisions of heavy nuclei, the enhanced production of (multi-)strange hadrons relative to the e^+e^- baseline is assumed to be a signal of Quark-Gluon Plasma (QGP) production. In proton-proton (pp) collisions, the general assumption has been that temperature and density are too low to form the QGP. Nonetheless, it was revealed at the LHC that small collision systems exhibit several of the same characteristics observed in nucleus-nucleus collisions. Strangeness enhancement has been correctly reproduced by core-corona models and by models of microscopic interactions of strings or clusters. In the first, droplets of QGP can form down to the smallest collision systems, in the second, colour strings or clusters modify the fragmentation dynamics. To disentangle these two different approaches, new observables are presented. Correlations between ϕ and (multi-)strange hadrons are shown to separate effectively between the two types of models which are implemented in EPOS4 and Pythia 8.3 with rope hadronization. Novel rapidity correlations for the production of K0S mesons as function of the event multiplicity are measured in pp collisions at $\sqrt{s} = 13.6$ TeV by the ALICE Collaboration.

Femtoscopic measurement of proton source in hadronic collisions with ALICE.

Tomassini S.
Dipartimento di Fisica, Università di Bologna e INFN, Sezione di Bologna

The study of momentum correlations of nucleon pairs can provide input for describing the formation of light nuclei, such as deuterons, by the coalescence of protons and neutrons into bound states. This contribution shows new results of proton-proton correlations measured in pp collisions at $\sqrt{s} = 900$ GeV, as well as a centrality-dependent analysis of Pb-Pb collisions at $\sqrt{s} = 5.36$ TeV, using data collected by the upgraded ALICE experiment during Run 3 data-taking period at the LHC. The femtoscopy technique measures the momentum correlations among protons emitted after the hadronization phase. The spatial properties of the proton-emitting source are extracted and the measured source size is used as an input parameter for modeling the coalescence. These measurements contribute to the characterization of the proton-emitting source size in different collision systems for different collision energies and provide insight into the microscopic description of the strong nuclear force and the physical processes that occur in hadronic collisions.

Aula 1D **ore 15:00 – 19:30**

Sezione II
Fisica della materia
Presiede: Tafuri F. (Università di Napoli Federico II)

Relazioni su invito

▲ **Measuring charge carrier excitations (phonons, plasmons and excitons) in suspended 2D materials, metals and superconductors by electron energy loss spectroscopy and by optical infrared spectroscopy.**
Mauri F.
Università La Sapienza
Electron energy loss spectroscopy (EELS) in the transmission electron microscope (TEM) makes finally possible to measure the dispersion of charge excitations of mono-layers suspended in vacuum. EELS of freestanding neutral graphene demonstrates the importance of many-body effects (e-e repulsion and excitonic attraction) in the description of the prominent electronic excitations, the onset and of the π-plasmon. TEM-EELS is capable to measure the phonon dispersions of mono and few-layer flakes of graphene and h-BN. In particular, the h-BN data demonstrate the peculiar LO-TO phonon splitting, linear in the phonon momentum, predicted to occur in 2D membranes. The coupling between TEM electron-beam and the phonons can be described, from first principles, defining, for each atom, a momentum-dependent effective charge vector $Z(q)$. In insulators, in the limit of small momentum ($q > 0$), such charges are closely related to the better-known Born effective atomic tensors, that describe the coupling between IR light and optical phonons. In the same regimes, $Z(q)$ can also be used to efficiently compute, within DFT, the quadrupole and octupole atomic tensors in systems containing hundreds of atoms. Finally, the momentum-dependent charges can also be used to extend the definition of Born effective charges to metals, and thus to describe, from first principles, the optical vibrational signature in the reflectivity of metals and superconductors. In contrast to the insulating cases, Born effective charges of metals crucially depend on the collision regime of conducting electrons (from the undamped, collisionless regime to the overdamped, collision-dominated limit). Such an approach enables the interpretation of vibrational reflectance measurements of both superconducting and bad metals, as I illustrate for the case of strongly electron-phonon-coupled superhydride H_3S. I acknowledge support from the MORE-TEM ERC-SYN project, grant agreement No. 951215.

▲ **The rich physics of bilayer kagome metals.**
Di Sante D.
Department of Physics and Astronomy, University of Bologna, Italy
Long-range electronic order descending from a metallic parent state constitutes a rich playground to study the intricate interplay of structural and electronic degrees of freedom. Kagome materials appeared as the perfect stage for such explorations. Specifically, RV_6Sn_6 (R = rareearthatom) bilayer kagome metals are topological systems with Dirac-like itinerant states, van Hove singularities and correlated flat bands. Interestingly, within this family, ScV_6Sn_6 also features a charge density wave (CDW) phase that affects the susceptibility, the neutron scattering, and the specific heat, and whose motif differs significantly from that of the siblings AV_3Sb_5 (A = K, Rb, Cs) and FeGe. As such, in this presentation, I will give an overview about the rich physics recently unveiled in bilayer kagome metals, and will also

discuss about the dynamics of that CDW phase. Specifically, while there is no consensus yet on its microscopic origin, with contradicting affirmations supporting both electron-electron and electron-phonon interaction, we reveal a prominent role played by the structural degrees of freedom in the stabilization of the charge order.

▲ **Enhanced light-matter interaction and polariton Bose-Einstein condensation with photonic bound states in the continuum.**

Zito G., Romano S., Miranda B., Schiattarella C., Mocella V., Rendina I.
Istituto di Scienze Applicate e Sistemi Intelligenti

Bose-Einstein condensation (BEC) is a fundamental phenomenon that can be used for quantum processing, cryptography and simulators. BEC can also be achieved in polaritons, *i.e.*, excitons in strong coupling with photons in optical microcavities. In this case, room temperature (RT) condensation can be realized in principle, owing to the ultralow effective mass of polaritons and large exciton binding energy in some two-dimensional (2D) materials. Thus far, however, polariton BEC in 2D atomic crystals has been demonstrated only at cryogenic temperatures, whereas at room temperature, only polariton formation by strong coupling has been observed. Here, we first discuss the theoretical framework of supercritical coupling of photonic bound states in the continuum (BIC) for enhancing light-matter interaction. Then, we present our experimental findings on BIC-driven polariton BEC formation within a 2D transition metal dichalcogenide at room temperature. Our results shed light on the manipulation of the polariton emission by virtue of the BIC, opening new pathways for harnessing RT polariton BEC in advanced materials.

▲ **Nucleation of bubbles of true vacuum in a false vacuum (metastable) superfluid.**

Ferrari G. ([1])([2]), Zenesini A. ([1])([2]), Berti A. ([1]), Cominotti R. ([1]), Rogora C. ([1]), Moss I. G. ([3]), Billam T. P. ([4]), Carusotto I. ([1]), Lamporesi G. ([1])([2]), Recati A. ([1])
([1]) *Pitaevskii BEC Center, CNR-INO e Dipartimento di Fisica, Università di Trento, Trento, Italy*
([2]) *Trento Institute for Fundamental Physics and Applications, INFN, Sezione di Trento, Italy*
([3]) *School of Mathematics, Statistics and Physics, Newcastle University, Newcastle upon Tyne, UK*
([4]) *Joint Quantum Centre, JQC, Durham-Newcastle, School of Mathematics, Statistics and Physics, Newcastle University, Newcastle upon Tyne, UK*

Metastability stems from the finite lifetime of a state when a lower-energy configuration is available but only by tunneling through an energy barrier. In classical many-body systems, metastability naturally emerges in a first-order phase transition. A prototypical example is a supercooled vapor. The extension to quantum field theory and quantum many-body systems has attracted significant interest in the context of statistical physics, protein folding, and cosmology, for which thermal and quantum fluctuations are expected to trigger the transition from the metastable state (false vacuum) to the ground state (true vacuum) through the probabilistic nucleation of bubbles. However, the theoretical progress in estimating the relaxation rate of the metastable field through bubble nucleation has not been validated experimentally. Here, we experimentally observe bubble nucleation in isolated and coherently coupled atomic superfluids, and we support our observations with numerical simulations. The agreement between observations and instanton theory confirms our understanding and promotes coherently coupled atomic superfluids as simulators of out-of-equilibrium quantum field phenomena.

Comunicazioni

Probing strong electron-phonon coupling in graphene by resonance Raman spectroscopy with infrared excitation energy.

Sotgiu S., Venanzi T., Graziotto L., Macheda F., Ouaj T., Stellino E., Fasolato C., Postorino P., Mišeikis V., Metzelaars M., Kögerler P., Beschoten B., Coletti C., Roddaro S., Calandra M., Ortolani M., Stampfer C., Mauri F., Baldassarre L.

Sapienza, Università di Roma

Resonance Raman spectroscopy has been a key asset to study the interplay between electronic and vibrational properties of graphene and other two-dimensional materials. Here, we report on resonance Raman spectroscopy measurements with excitation photon energy down to 1.17 eV on mono and bilayer graphene, to study how low-energy carriers interact with lattice vibrations. Thanks to the excitation energy close to the Dirac point, we unveil in the monolayer a giant increase of the intensity ratio between the double-resonant 2D and 2D′ peaks with respect to that measured in graphite. In bilayer graphene, the low excitation energy hampers some of the resonant Raman processes giving rise to the 2D peak. Consequently, the subfeatures composing the 2D mode are spectrally more separated with respect to visible excitations. We follow the excitation energy dependence of the intensity of each sub-structure and, comparing experimental measurements on bilayer graphene with *ab initio* theoretical calculations, we trace back such modifications on the joint effects of probing the electronic dispersion close to the band splitting and enhancement of electron-phonon matrix elements.

Quantum and classical correlations close to a Mott insulator.

Sordi G.

Department of Physics, Royal Holloway, University of London, Egham, Surrey, UK

Quantum and classical correlations among electrons in interacting systems generate remarkable phases of matter. Quantum information theory provides new concepts, based on the entanglement, for characterizing phases of matter and phase transitions in such systems. I shall show that entanglement-related properties shed new light on the pseudogap and on the strongly correlated superconductivity emerging from a doped Mott insulator. I shall review recent work on this problem in the context of the two-dimensional Hubbard model at finite temperature, solved with cluster dynamical mean-field theory and with a focus on key measures of correlations —thermodynamic entropy, local entropy, and total mutual information. I shall show that the unveiled links between quantum and classical correlations provide a unified framework for the phenomenology of hole-doped cuprates and predictions for ultracold atoms in optical lattices.

Surface superconductivity on time-reversal symmetric Weyl systems: A self-consistent approach.

Trama M. ([1]), Könye V. ([1]), Fulga I. C. ([1]), van den Brink J. ([1])([2])

([1]) *Institute for Theoretical Solid State Physics, IFW Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, Dresden, Germany*

([2]) *Institute for Theoretical Physics, TU Dresden, Dresden, Germany*

The recent discovery of the superconducting surface on the time-reversal symmetric Weyl semimetal $PtBi_2$ has raised the question of the origin of such a phenomenon. Indeed, such a compound exhibits a critical temperature difference between the surface and the bulk of about an order of magnitude. Here we propose an explanation for this phenomenon using a time-reversal symmetric Weyl model for a finite system, invoking standard local *s*-wave

singlet pairing as the superconducting coupling. Our self-consistent calculation predicts a different critical temperature for the surface and the bulk, leading to the possibility of superconductivity in only few layers of the material. We also predict a temperature dependence on the penetration of surface superconductivity, suggesting a competition between two order parameters.

Surface potential of topological materials by Kelvin probe and photoemisison microscopy.

Gunnella R. ([1]), Rauf M. ([1]), Azizinia M. ([1]), Salvato M. ([2]), Castrucci P. ([2]), Amati M. ([3]), Gregoratti L. ([3])

([1]) *SST, Università di Camerino*

([2]) *Dipartimento Fisica, Università di Roma Tor Vergata*

([3]) *Sincrotrone Trieste*

The atomic composition and electronic structure of topological insulators (TI) Bi_2Se_3 grown by the two-temperature physical capor deposition on n-type Si patterned substrates, have been followed in detail during slight variation of the growth temperatures and values of thickness close to that of the topological transition (about 6 nm), by means of submicron lateral probe photoemission with enhanced surface sensitivity (less than 1 nm). The latter results, including composition and electronic structure, will be cross-checked with Kelvin probe AFM microscopy to finely tune the interaction at the surface of the metallic resonant probe with growth and morphological parameters.

Emerging Majorana bound states in superconducting Haldane nanoribbons.

Traverso S. ([1]), Traverso Ziani N. ([1])([2]), Sassetti M. ([1])([2]), Dominguez F. ([3])

([1]) *Dipartimento di Fisica, Università degli Studi di Genova, Genova, Italia*

([2]) *CNR-SPIN, Genova, Italia*

([3]) *Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany*

In the rich landscape of quantum technologies, topological insulators and topological superconductors play a major role as promising platforms for applications in spintronics, superconducting spintronics and topologically protected quantum computation. In particular, in the context of the latter, the ability to manipulate Majorana Bound States (MBSs) would represent a major advancement. In this communication, we describe a novel approach to the design of MBSs, based on the dimensional reduction of two-dimensional nodal topological superconductors. We consider, as a paradigmatic example, zigzag nanoribbons of the superconducting Haldane model. We show that in the quasi-1D limit a complex phase diagram emerges, characterized by topological regions hosting MBSs in finite-size flakes. Our results are supported by the study of the conductance in NS junctions, which, in the topological regime, is found to be sharply quantized to $2e^2/h$, even in the presence of disorder. We thus unveil a novel physical mechanism, in which quantum confinement is responsible for gapping out the 2D topological nodal phase and for the subsequent appearance of Majorana bound states in the quasi-1D setup.

The mLPDA approach: The case of study of Josephson critical currents in ultracold atomic superfluid sytems.

Piselli V. ([1]), Pisani L. ([2]), Calvanese Strinati G. ([1])([3])

([1]) *School of Science and Technology, Physics Division, Università di Camerino, Camerino, MC, Italy*

([2]) *Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
([3]) *CNR-INO, Istituto Nazionale di Ottica, Sede di Firenze, Firenze, Italy*
In this contribution, we develop a new approach to deal with systems where pairing fluctuations and spatial inhomogeneities are treated on equal footing. We include pairing fluctuations over and above mean-field on the LPDA (Local Phase Density Approximation) equation, which is a highly non-linear second-order differential equation for the order parameter obtained by performing a suitable coarse graining on the Bogoliubov-de Gennes equations. The resulting approach is referred to as mLPDA (where m stands for modified) approach. We used the mLPDA approach to perform a systematic study of the Josephson effect occurring in a system where a barrier is embedded in an otherwise homogeneous superfluid. We further applied this approach to take into account more complex spatial constraints when considering the ultracold atomic systems realized experimentally, where the Josephson critical current was measured at low temperature as a function of coupling and at unitarity as a function of temperature. The favourable comparison with experimental data validates the mLPDA approach which could be used to investigate novel superfluid systems where inhomegeneity and fluctuations effects play a key role.

Characterization of partially accessible anisotropic spin chains in the presence of anti-symmetric exchange.

Cavazzoni S., Adani M., Bordone P., Paris M.G.A.
Università degli Studi di Modena e Reggio Emilia, Dipartimento di Scienze Fisiche, Informatiche e Matematica
We address quantum metrology of anisotropic spin chains in the presence of anti-symmetric exchange and study if the Hamiltonian parameters may be estimated with precision approaching the limit imposed by quantum mechanics. We focus on the information that may be extracted by measuring only two neighboring spins, rather than a global observable. We evaluate the Quantum Fisher Information (QFI), and the Fisher Information (FI) of a two-spin magnetization measure for all the chain parameters, *i.e.*, the spin coupling, the anisotropy, and the Dzyaloshinskii-Moriya (DM) parameter. We find that the two neighboring spins may be indeed exploited as a probe to characterize global properties of the entire system, as the ratio between the FI and the QFI is always close to 1. The DM term is beneficial for coupling estimation, since it leads to the presence of additional bumps and peaks in the FI and QFI, that may be exploited to improve the robustness of the overall estimation procedure. In multiparameter estimation, the model is compatible but sloppy, *i.e.*, both the Uhlmann curvature and the determinant of the QFI matrix vanish, meaning that not all the parameters of the system are independent.

Phase frustration and pattern formation in liquid-crystal films at the nematic-smectic transition.

Zappone B.
Consiglio Nazionale delle Ricerche-Istituto di Nanotecnologia, CNR-Nanotec
Positional order emerging at the nematic-smectic transition creates periodic textures that can be used as optical micro-arrays, templates for soft lithography, and ordering matrices for functional nanoparticles. While both 1d and 2d patterns have been obtained as a function of the film thickness and applied fields, a clear connection has not been made between pattern formation and the peculiar critical behavior of the nematic-smectic transition, still eluding a comprehensive theoretical explanation. We demonstrate that an intense bend distortion applied to the liquid crystal while cooling from the nematic phase produces a frustrated smectic phase with depressed transition temperature, and a characteristic 1d periodic texture. Using a formal analogy with the normal-superconductor transition of a metal, we identify the 1d

texture as the equivalent of the intermediate state in type-I superconductors. Our findings provide fundamental evidence for theories of the nematic-smectic transition, highlighting the deep connection between phase frustration and pattern formation and new perspectives on the design of functional smectic micro-arrays.

Scaling laws for epidemic propagation on networks.

Scala A.
CNR, Istituto Sistemi Complessi

Understanding the propagation of infectious diseases within and across populations is pivotal for global health security. Among various factors, human mobility plays a crucial role in disease proliferation, making it a key element of epidemiological models and in strategies to contain and mitigate epidemics. We present a theoretical and numerical examination of how mobility between regions affects the propagation delay time of an epidemic —defined as the time required for the disease to emerge in a new city from its initial cases elsewhere— and demonstrate analytically that delay times scale logarithmically with respect to the fraction of the population commuting between two regions.

Towards smart microgel design for tailored volume phase transitions.

Ballin E. ([1])([2]), Brasili F. ([1]), Vialetto J. ([3]), Laurati M. ([3]), Sennato S. ([2]), Zaccarelli E. ([2])
([1]) *Dipartimento di Fisica, Università di Roma La Sapienza, Italia*
([2]) *Istituto dei Sistemi Complessi, ISC-CNR*
([3]) *Dipartimento di Chimica, Università degli Studi Firenze, Italia*

Temperature-responsive microgels are soft colloids made of chemically crosslinked network undergoing reversible Volume Phase Transition (VPT) upon temperature changes. The most studied ones are made of poly-N-isopropylacrylamide (PNIPAM). As temperature rises above $T_c \approx 32\,^{\circ}\mathrm{C}$, PNIPAM microgels go from a swollen hydrated state to a collapsed dehydrated one because of the coil-to-globule transition of the polymer chains. We aim to redesign their internal structure to enhance transition sharpness around T_c and swelling ratio ($\alpha = R_{swollen}/R_{collapsed}$). This is done by using ethylene glycol dimethylacrylate (EGDMA) as crosslinker. The different reactivity between monomer and crosslinker crucially influences the network's microscopic structure. EGDMA-crosslinked microgels exhibit a star-like architecture consisting of a dense core surrounded by sparsely crosslinked chains. Thanks to this structure, EGDMA cross-linked particles retain a higher swelling capacity even at high crosslinker content with respect to standard PNIPAM microgels.

Single-particle diffraction with a hydrodynamic pilot-wave model.

Pucci G. ([1])([2]), Bellaigue A. ([2]), Cirimele A. ([3]), Alì G. ([3]), Oza A. U. ([4])
([1]) *Consiglio Nazionale delle Ricerche-Istituto di Nanotecnologia, CNR-Nanotec, Rende, CS, Italia*
([2]) *Univ Rennes, CNRS, IPR, Institut de Physique de Rennes-UMR 6251, Rennes, France*
([3]) *Dipartimento di Fisica, Università della Calabria, Rende, CS, Italia*
([4]) *Department of Mathematical Sciences & Center for Applied Mathematics and Statistics, New Jersey Institute of Technology, Newark, NJ, USA*

Millimetric liquid droplets can self-propel by virtue of the wave field that they generate by bouncing on a vibrating liquid surface. These walking droplets exhibit several quantum-like behaviors. A seminal experiment suggested that single-particle diffraction may be obtained when a droplet crosses apertures between submerged barriers, a behavior questioned by subsequent experiments. We used a hydrodynamic pilot-wave model to explore the interaction of walking droplets with linear barriers. The statistical distributions of the droplets

are wave-like and generally exhibit multiple peaks depending on the obstacle geometry. We propose a mechanism for this wave-like behavior of such classical particles and provide a detailed comparison with diffraction in optics and quantum mechanics.

Aula 1E **ore 15:00 – 19:30**

Sezione III
Astrofisica
Presiede: Weber J.W. (Università di Trento)

Relazioni su invito

▲ **Detection of high energy cosmic neutrinos with KM3NeT-ARCA: Status and perspectives.**
Riccobene G.
INFN, Laboratori Nazionali del Sud
The discovery of a high-energy neutrino flux by IceCube, the first km3-scale neutrino telescope, paved the way to high-energy neutrino astronomy. While the origin of the neutrino flux is still an open question, IceCube reported neutrino emission from NGC 1068 and TXS 0506+056. In this context neutrino astronomy started to play a leading role in multi-messenger astronomy. The detection of cosmic neutrinos is considered as the "moking gun" for hadron acceleration in cosmic sources. After the shut-down of ANTARES, KM3NeT-ARCA (Astro-particle Research using Cosmics in the Abyss) is nowadays the largest undersea detector in the Northern Hemisphere, capable to optimally look for neutrinos from Galactic sources. ARCA, located at 3500 m water depth, 100 km offshore the Eastern Coast of Sicily, will become soon a cubic-kilometre scale telescope made of 230 detection units, optimised for detector of neutrinos in the TeV-PeV energy range. As of today, ARCA consists of 28 detection units and about 20 more will be installed in summer 2024. The performances of the Detector will be reviewed, along with plans for the completion of the telescope and physics outputs.

▲ **Controparti radio di sorgenti di neutrini ad alta energia.**
Trigilio C.
INAF, Osservatorio Astrofisico di Catania
I neutrini di alta energia sono generati in ambienti astrofisici particolarmente energetici. Tuttavia non è facile identificare le sorgenti di neutrini, considerata la bassa risoluzione spaziale dei telescopi attuali più sensibili, quali IceCube o KM3NeT. La ricerca delle controparti elettromagnetiche è quindi essenziale per individuare la sorgente e quindi per studiare le condizioni fisiche che portano alla generazione dei neutrini. Tra i possibili candidati sono state individuate le blazar, radio sorgenti brillanti, caratterizzate da intensi flares. Alcune evidenze osservative sembrano indicare una correlazione tra questi radio flares, che si manifestano prima ad alta frequenza, e l'emissione di neutrini. Maggiore è la frequenza radio di osservazione, maggiore è la probabilità di osservare simultaneamente neutrini e l'innesco di flares. Osservazioni coordinate con telescopi quali KM3NeT e radiotelescopi che possono effettuare un monitoraggio con cadenza stretta di un campione di potenziali sorgenti di neutrini ad alta frequenza radio è uno degli obiettivi che ci proponiamo nell'ambito del progetto PNRR KM3Net4RR.

Comunicazioni

● **Research of high-energy neutrinos by interacting Supernovae: the case of SN 2023ixf in Messier 101.**
Cosentino S.P. ([1])([2]), Pumo M.L. ([1])([2])([3]), Cherubini S. ([1])([3])
([1]) *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania*

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The supernova (SN) events are among the most powerful and heterogenic multimessenger sources. The wide variability of their electromagnetic and neutrino emission is strongly related to the different SN progenitor's physical properties at the explosion and the SN environment that, in turn, are also linked to the pre-SN stellar evolution. In particular, the collision of the SN ejecta with its surrounding circumstellar medium produces shock waves, which significantly increase the SN electromagnetic emission and accelerate particles, responsible for the delayed high-energy (TeV-PeV) neutrinos (HE-ν) emission. The recent case of SN 2023ixf in the nearby galaxy Messier 101 provided an opportunity to test the observability limits for this type of neutrinos by large-volume observatories such as IceCube and KM3Net. Here, we present a new model that links the HE-ν spectral energy features (measurable with the above mentioned large-volume observatories) with the configuration of the SN progenitor system at the explosion, inferred by the study of the SN electromagnetic emission. The application of our model to SN 2023ixf and the implication of our results will be discussed.

Searching for astrophysical counterparts of high-energy neutrinos.
Nanci C.
INAF, Istituto di Radioastronomia di Bologna
The powerful jets from the class of active galactic nuclei called blazars are predicted to be sites of particle acceleration and high-energy neutrino production. The interest of the multi-messenger community in blazars as possible neutrino sources was powered up in 2017 when a 290 TeV neutrino was detected in proximity of the blazar TXS0506+056, which was also flaring in gamma rays. The high angular resolution observations of the very long baseline interferometry (VLBI) provide crucial tests for the association of neutrinos with blazars. The VLBI technique allows us to study the parsec-scale regions of blazar jets, where particle acceleration occurs. Indeed, VLBI-scale properties in the TXS 0506+056 jet have been connected with the neutrino emission. However, since then, the general picture of the high-energy neutrinos origin and their association with gamma-ray blazars has remained unclear. In this context, we started a VLBI investigation of gamma-ray blazars observed in spatial coincidence with neutrino events. In this contribution, I will present the results of our first explorative VLBI follow-up campaign, focusing on a few peculiar and promising targets.

Multiwavelength study of a new extragalactic neutrino candidate.
Fogliacco S. ([1]), Viale I. ([1]), Prandini E. ([1]), Cerasole D. ([2]), Cicciari G.M. ([3]), Loporchio S. ([2]), Mallamaci M. ([3]), Mangano S. ([4]), Maraventano C. ([3]), Marsella G. ([3]), Righi C. ([6]), Sciaccaluga A. ([5])([6])
([1]) *Università di Padova e INFN, Sezione di Padova*
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([3]) *Università di Palermo e INFN, Sezione di Palermo*
([4]) *CIEMAT, Madrid, Spain*
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We present a study of the very-high energy (VHE; E¿100 GeV) gamma-ray emission of the blazar PKS 1424+240 observed with the MAGIC telescopes. Blazars are a subclass of jetted active galaxies characterized by intense and variable emission across the spectrum, particularly in the radio, optical x-ray and gamma-ray wavelengths. Firstly discovered at VHE by VERITAS and then confirmed by MAGIC, PKS 1424+240 is a VHE source with

redshift $z = 0.603$, which makes it one of the most distant VHE blazars known to date. The source has been recently associated by IceCube with a neutrino excess at 3.3σ level, making it a good candidate to be considered as an extragalactic neutrino source, similarly to the blazar TXS 0506+056. In this contribution, we present the MAGIC and multiwavelength data analyses during a particularly bright phase, in 2017. We characterize spectral and flux variability at different frequencies. The final aim of this work is to model a possible neutrino and electromagnetic emission in the jet of PKS 1424+240 with a lepto-hadronic model, based on the interactions of electrons and protons co-accelerated in the jet with external photon fields.

● **Utilizzo di reti neurali per l'analisi dei dati del rivelatore di superficie dell'Osservatorio Pierre Auger per lo studio della composizione dei raggi cosmici di altissima energia.**

Conte M.
Dipartimento di Fisica, Università del Salento e INFN, Sezione di Lecce

L'analisi dei segnali del rivelatore di superficie dell'Osservatorio Pierre Auger, in Argentina, offre un'opportunità unica per studiare le caratteristiche degli sciami atmosferici estesi generati dai raggi cosmici ad altissima energia. Il recente upgrade dell'Osservatorio ha previsto l'aggiunta di rivelatori a scintillazione (Surface Scintillator Detector) sulla maggior parte delle già esistenti stazioni Cherekov (Water Cherenkov Detector) e, insieme ad una nuova e più efficiente elettronica di acquisizione, si propone di migliorare la separazione tra componente muonica ed elettromagnetica degli sciami secondari prodotti in atmosfera. In questa presentazione si investiga l'uso delle reti neurali di tipo non supervisionato, come le Self Organizing Maps (SOM), grazie ad una versione più efficiente delle SOM, appositamente progettata per l'esecuzione su GPU. Si esamina poi l'utilizzo di reti supervisionate adatte allo studio di serie temporali, per predire la componente muonica a partire dai segnali simulati. Attraverso queste analisi è possibile studiare le diverse componenti degli sciami atmosferici e la loro composizione chimica, al fine di comprendere l'origine dei UHECRs.

Relazioni su invito

▲ **Present and future of the search for neutrinoless double beta decay.**

Di Marco N.
Gran Sasso Science Institute e INFN, Laboratori Nazionali del Gran Sasso

The search for neutrinoless double beta ($0\nu\beta\beta$) decay is considered as the most promising way to prove the Majorana nature of neutrinos as well as to give indication on the mass hierarchy and on the absolute mass scale. The discovery of $0\nu\beta\beta$ decay would moreover open the way for theories predicting the observed matter anti-matter asymmetry of the Universe being a consequence of lepton number violation through leptogenesis. A number of worldwide experimental efforts are ongoing or planned to shed light on this elusive process. In this contribution, we will review the key features of the $0\nu\beta\beta$ decay experimental search, the present experiments, and the future generation aiming to reach sensitivities on the decay half-life of the order of 10^{28} yr.

Comunicazioni

● **Study of the T2K HA-TPC Spatial Reconstruction performance with a new ML algorithm.**

Feltre M.
Università degli Studi di Siena e INFN, Sezione di Padova

In recent years, the T2K Collaboration has developed new gas-based Time Projection Chamber (TPC) detectors to be used in the Near neutrino Detector located at the J-PARC laboratory in Japan. The design of the new TPCs (HA-TPCs), which will enable the study

of particles generated at large angles by neutrino interactions, includes a large active volume defined by rectangular cross-section Field Cages with lightweight composite material walls. Amplification and readout of the primary ionization electrons are achieved by means of MicroMegas (MM) sensors with Resistive Plane Embedded into the Anode (ERAM). The installation of both HA-TPCs is expected to be completed in the first half of 2024 as part of the upgrade of the Near Detector, which includes a new target and tracking system. This communication will focus on the commissioning performances of the HA-TPCs at CERN and J-PARC, with a newly developed Machine Learning technique for track reconstruction. Its performance will be compared with the standard reconstruction method already validated on Monte Carlo simulations and on data using both cosmic rays and events from beam neutrino interactions.

Study of signal formation in the ERAMs of T2K TPC.

D'Ago D. ([1])([2]), Collazuol G. ([1])([2]), Feltre M. ([2])([3]), Levorato S. ([2])

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In recent years, the near detector of the T2K experiment underwent an important upgrade of part of its equipment, which involved the construction of a set of new instruments. As a part of the upgrade, two gaseous TPCs, placed above and below the active target, will enable the study of particles generated at large angles by neutrino interactions. Each High Angle TPC (HA-TPC) includes a large active volume defined by rectangular cross-section Field Cages with lightweight composite material walls and two readout planes instrumented with eight Resistive Micromegas each. A deep knowledge of this detector is crucial to achieve good performance. This communication reports the studies that are being carried out in order to get a deep comprehension of the signal formation in an ERAM detector operating with the T2K gas mixture; in particular, the aim of the study is to determine the effect of the ions on the electron spread in the resistive layer and the consequent electric signal generation. Results of the measurements of the ion drift velocity in non-resistive Micromegas with different gas mixtures are presented, as well as preliminary results of Monte Carlo simulations.

XLZD: A next-generation liquid xenon observatory for dark matter and neutrino physics.

Mancuso A.

INFN, Sezione di Bologna

Liquid xenon time projection chambers are nowadays recognized as the leading technology for dark matter detection. The XENONnT and LZ experiments have been exploring the parameter space for WIMPs and other rare events for decades, and present currently the best limit worldwide. In this contribution I will present the forthcoming phase of the project: XLZD, which from the merging of the two leading experiments XENONnT and LZ, aims at designing and building the ultimate liquid xenon dark matter detector. XLZD will feature a 60-ton active mass, with reduced Rn and neutron backgrounds, leaving neutrinos as the main background. It will explore the entire WIMP parameter space down to the neutrino fog limit and, at the same time, it will also present good sensitivity to neutrino-less double-beta decay of ^{136}Xe, and the possibility to study solar neutrinos with unprecedented sensitivity.

Modello termico di rivelatori bolometrici di grande massa.

Serino R.
Dipartimento di Fisica, Università di Milano-Bicocca e INFN, Laboratori Nazionali del Gran Sasso

L'esperimento CUORE (Cryogenic Underground Observatory for Rare Events), situato presso i Laboratori Nazionali del Gran Sasso, utilizza rivelatori criogenici per lo studio della fisica degli eventi rari, in particolare il doppio decadimento beta senza emissione di neutrini $0\nu\beta\beta$. Il tema principale della presentazione sarà il lavoro fatto per comprendere e sviluppare un modello accurato della risposta di ciascun rivelatore, al fine di correlare il rilascio di energia delle particelle con l'impulso termico prodotto, attraverso la costruzione di una funzione di trasferimento apposita. È stata condotta un'analisi approfondita sui diversi cristalli così da correlare i parametri derivanti dal fit degli impulsi con le proprietà fisiche del sistema, come capacità e conduttanze termiche. L'elaborazione di un modello termico coerente, flessibile e predittivo per tali rivelatori riveste un ruolo cruciale. Questo non solo consente un'analisi avanzata dei dati, ma ci guida nella scelta dei dettagli costruttivi del rivelatore, permettendo l'ottimizzazione di importanti parametri come risoluzione energetica e tempo di risposta, a vantaggio dei futuri esperimenti.

Tecniche di machine learning per la decorrelazione del rumore in CUORE.

Cosoli A.
Dipartimento di Fisica, Università di Milano-Bicocca

L'obiettivo dell'esperimento CUORE (Cryogenic Underground Observatory for Rare Events), installato presso i Laboratori Nazionali del Gran Sasso, è cercare il doppio decadimento beta senza emissione di neutrini, utilizzando rivelatori criogenici operati a 15 mK. Per raggiungere questo obiettivo è necessaria un'alta risoluzione energetica e quindi massimizzare il rapporto segnale/rumore. La presentazione verterà sui modelli di Machine Learning sviluppati al fine di sperimentare nuove tecniche di denoising. Tali algoritmi puntano a ricostruire un segnale pulito a partire da un segnale rumoroso. Data l'alta statistica necessaria per l'addestramento dei modelli è necessario simulare i dati, in questo caso gli impulsi termici. A partire dai fit degli impulsi sono stati estrapolati i parametri descrittivi delle forme d'onda e usando gli spettri di potenza del rumore misurati per i rivelatori è stato possibile generare dei datasets contenenti dati sintetici con le stesse caratteristiche di quelli reali. Verranno quindi illustrati i modelli sviluppati, i test eseguiti e le rispettive prestazioni, nonché le possibili applicazioni a CUORE ed altri rivelatori criogenici.

Performance of the ICARUS trigger system at the booster and NuMI neutrino beams.

Triozzi R.
Dipartimento di Fisica e Astronomia, Università e INFN, Sezione di Padova

The ICARUS-T600 liquid argon time projection chamber (LArTPC) detector is taking data at shallow depth as the far detector of the Short Baseline Neutrino program at Fermilab, to search for a possible sterile neutrino signal at $\Delta m^2 \approx 1\ \mathrm{eV}^2$ with the Booster (BNB) and Main Injector (NuMI) neutrino beams. The ICARUS trigger system exploits the coincidence of the BNB and NuMI beams with scintillation light signals, detected by 360 8" photo-multiplier tubes, and is based on a PMT-multiplicity in limited TPC regions. The trigger efficiency measured with stopping muons saturates at $E_\mu \approx 300$ MeV, covering most of the BNB and NuMI charged-current neutrino interactions. For the latest ICARUS run, special adder boards, performing the analog sum of light signals, were introduced as a complementary trigger to possibly recover low-energy interactions. Finally, the ns-scale timing resolution on the interaction times allows to reconstruct the bunched structures of the BNB and NuMI

beams, with the aim of introducing an off-line time-based trigger to cut in-between bunches, rejecting the cosmogenic background with high efficiency.

Neutrino event detection in ICARUS: Analysis of photomultiplier waveforms and Monte Carlo validation.

Brio V.
INFN, Sezione di Catania

ICARUS, part of the Short Baseline Neutrino experiment at Fermilab, investigates neutrino oscillations and interactions. The experiment utilizes two liquid argon time projection chambers (LArTPCs) with 360 photomultipliers. These chambers detect scintillation light produced when charged particles interact with liquid argon, a process crucial for accurately determining the position and timing of these events. This scintillation light is vital for the precise reconstruction of neutrino events and the effective operation of the detector's trigger system. The PMTs are essential in pinpointing the exact moment of particle interactions and play a crucial role in the system's ability to distinguish between neutrino events and background. In my research, I analyze the waveforms of these light signals to ensure that the data accurately corresponds with Monte Carlo simulations, thereby streamlining the validation of experimental data and enhancing our understanding of the detector's functionality. This work not only improves the accuracy of neutrino event reconstruction but also provides insights that are critical for the ongoing development and calibration of the detection system.

Characterization of the JUNO liquid scintillator optical properties.

Houria F.
Università degli Studi di Milano e INFN, Sezione di Milano

The Jiangmen Underground Neutrino Observatory, JUNO, is a 20 kton liquid scintillator based detector currently under construction in China. Thanks to its large mass and its excellent energy resolution (3% at 1 MeV), it will be able to achieve the determination of the neutrino mass ordering, the precision measurement of the oscillation parameters (θ_{12}, Δm^2_{21}, $|\Delta m^2_{32}|$) and the precision spectroscopy of solar neutrinos. Preliminarly to the data-taking, which is expected to start in 2025, a major effort to characterize the optical properties of the JUNO liquid scintillator (LAB +2.5g/l PPO+3mg/l bis-MSB) is needed. In this presentation I will discuss the results obtained in the University of Milano with the SHELDON (Separation of cHErenkov Light for Directionality Of Neutrino) and the SHELDON-REWIND (REfractive index With INterferometric Devices) projects, concerning the fluorescence, the Cherenkov effect and the scintillator refractive index. In addition, I will present the latest results on the scintillator absorption and emission properties. These studies will be fundamental to understand the JUNO detector response and will be important inputs for the JUNO simulation code.

Aula F **ore 15:00 – 19:30**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Todesco M. (INGV, Sezione di Bologna)

Relazioni su invito

▲ **Locating the melt source feeding distributed volcanism by magma pathway retrogression.**
Rivalta E. ([1])([2]), Mantiloni L. ([2])([3]), Kilgour G. ([4]), Hreinsdóttir S. ([4]), Eccles J. ([5]), Hamling I. ([4]), Rowe M. ([5])
([1]) *Settore di Geofisica, Dipartimento di Fisica e Astronomia, Alma Mater Studiorum Università di Bologna, Italy*
([2]) *Section 2.1 "Physics of earthquakes and volcanoes", Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Germany*
([3]) *Camborne School of Mines, University of Exeter, UK*
([4]) *GNS Science, New Zealand*
([5]) *School of Environment, University of Auckland, New Zealand*
The Auckland Volcanic Field (AVF) is a distributed volcanic field comprising $\simeq 53$ eruptive centres scattered across a $360\,\mathrm{km}^2$ area, housing the city of Auckland, New Zealand's largest with around 1.7 million residents. Given the significant risk to the population, it is imperative to accurately define pre-eruption scenarios for better readiness. Outstanding questions include where the next eruptive fissure might open and how much time might elapse between precursory signals, recognised as such, and eruption. Our study aims to constrain pre-eruption scenarios by developing physics-based models for magma ascent beneath Auckland. We develop a novel approach centered on dyke propagation physics. We employ newly developed 3D numerical codes and a stress model of the area to backtrack magma pathways and locate the melt source feeding the volcanoes. Next, we estimate ascent velocity and discuss learning points regarding the controls on the observed enigmatic spatial vent distribution.

▲ **New developments in the estimation of tephra fallout hazard: An example from Mt. Etna (Italy).**
Scollo S. ([1]), Bonadonna C. ([2]), Garcia A. ([3]), Mereu L. ([3])([4]), Prestifilippo M. ([1]), Romeo F. ([1])([4])([5]), Sandri L. ([3]), Stocchi M. ([3])([6])
([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Italy*
([2]) *Department of Earth Sciences, University of Geneva, Switzerland*
([3]) *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy*
([4]) *CETEMPS Center of Excellence, University of L'Aquila, Italy*
([5]) *Department of Information Engineering, Electronics, and Telecommunications, Sapienza University of Rome, Italy*
([6]) *Department of Earth and Geoenvironmental Sciences, University of Bari "Aldo Moro", Italy*
Explosive eruptions are a significant threat to people living around active volcanoes because they can cause damages to buildings, agriculture and infrastructures, as well as they can have effects on animal and human health. Moreover, fine ash can cover hundreds of kilometres downwind, producing aviation impairments. Although explosive eruptions cannot

be stopped, their impact could be drastically reduced when observations and modelling are strictly combined to forecast ash dispersion. The combined use of different ground-based and satellite-based remote sensing systems can help to estimate with a greater precision the main eruption source parameters (*e.g.*, column height, mass eruption rate, particle size). Once they are assessed, modelling can be used to forecast, during an eruption, the region that will be affected by the tephra fallout. Moreover, after defining several eruptive scenarios, the long-term tephra fallout hazard can be estimated using probabilistic and multi-model approaches. We show new developments at Etna volcano, one of the most active volcanoes in Europe whose recent persistent activity allowed us to test new approaches and improve the hazard estimation.

Comunicazioni

Modeling the priming mechanism of phreatic eruptions.
Stocchi M. ([1])([2]), Houzeaux G. ([2]), Costa A. ([3]), Folch A. ([4]), Massaro S. ([1])([3]), Sulpizio R. ([1])
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([2]) *Department of Computer Applications in Science and Engineering, Barcelona Supercomputing Center, Spain*
([3]) *Istituto nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy*
([4]) *Geociencias Barcelona, GEO3BCN-CSIC, Barcelona, Spain*
To the present date, no phreatic eruption has been successfully forecast, as this kind of eruption lacks clear and univocal precursory signals. Understanding how deep magmatic gas and heat fluxes interact with groundwater systems and prime phreatic eruptions is thus of pivotal importance. Here we present an overview of how the modeling of such systems can be addressed from a physical perspective. Volcanic heat and gases (mainly H_2O and CO_2) released from more or less deep magmatic intrusions can reach a shallow aquifer hosted in a porous medium, thus leading to the formation of a multicomponent (H_2O and CO_2) two-phase system, mainly a water-rich liquid phase. The dynamic and thermodynamic evolution of such a mixture is modeled by a set of conservation laws that have been implemented as a new module for the multiphysics engine Alya. The development of such a model is a key step in understanding how the fluid builds an overpressure that might prime a phreatic eruption.

Analytical solutions for faster inversion of thermo-poro-elastic displacements.
Stissi S.C., Currenti G., Napoli R.
Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italia
Observations and results from numerical modelling have demonstrated that hydrothermal fluid circulations contribute to ground deformation in volcanic areas. Comparison between the observed and the computed displacements provides constraints on the deformation source and helps interpret the volcano internal state. We revised and developed forward analytical solutions to efficiently compute thermo-poro-elastic displacements induced by spherical, cylindrical, ellipsoidal and rectangular prism-shaped sources undergoing pore-pressure and temperature variations, and embedded in an elastic, isotropic and homogeneous half-space. We implemented a software, named THEPORE (THErmo-PORo-Elastic), that collects the solutions and allows for a rapid inversion of the observed displacements. THEPORE represents an excellent tool for providing, at a low computational cost, a first-order estimate of the thermo-poro-elastic deformation source. The software was validated for the inversion of the GPS deformation data recorded at Vulcano Island during the September 2021 unrest, providing a source at a depth of 800 m from the ground surface which underwent a volume change on the order of $10^5\,m^3$.

Reconstructing the 3–5 December 2015 Etna volcanic eruption using inversion and data assimilation methods.

Martinez Montesinos B. ([1]), Mingari L. ([2]), Mari N. ([3]), Caruso E. ([4]), Poret M. ([5]), Taje D. ([5]), Folch A. ([2]), Costa A. ([1])
([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italia*
([2]) *Geociencias Barcelona, GEO3BCN, CSIC, Barcelona, Spain*
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([5]) *Università di Bologna, Bologna, Italia*

In recent years, techniques based on ensemble modelling have been developed to estimate the eruptive source parameters (ESPs) of an eruption from observational data. This is important since the reconstruction of past eruptive scenarios allows estimating the potential ESPs ranges of future events. ESPs are needed as input information to numerical models used for hazard assessment. The novel GNC (Gaussian with non-negative constraints) ensemble-based data assimilation method allows us to enhance ESPs. Starting from a first estimate of eruptive conditions (EC) and perturbing its ESPs, the GNC method creates an ensemble of possible EC. Then, simulations of tephra fallout for each of EC are executed using the model FALL3D. Finally, the method finds an optimal combination of simulations by solving an optimization problem. This provides us with a weight factor for each ensemble member that will be used to assess even the time evolution of the ESPs. In this work, we applied this methodology for reconstructing the eruption that occurred at Etna between 3 and 5 December 2015 from a dataset of measurements of tephra deposits associated with this eruption dispersed from medial to distal zones.

Quasi-analytical models for the velocity of dykes ascending beneath volcanoes.

Spina A. ([1]), Rivalta E. ([1])([2]), Polverari A. ([1])
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Volcanoes are geological structures emerging through the gradual buildup of erupted materials, occasionally altered by rapid or slow phenomena like edifice collapses or caldera formations. Diverse magma compositions and volcano-tectonic settings result in volcanoes portraying a wide range of different shapes. We delve into the stress patterns induced by the gravitational loading on the Earth's crust induced by volcanoes of various shapes. We evaluate the expected magma pathways, assuming they lie perpendicular to the least compressive stress axis. Subsequently, we employ semi-analytical expressions to calculate the velocity of ascending magma batches along these pathways. Applying our model, we determine the velocity of a dyke ascending beneath Mt. Etna and the Campi Flegrei caldera in Italy.

Synergistic approach for a robust reconstruction of eruption plume dynamics: Application to Campanian Ignimbrite super-eruption, Italy.

Martinez Montesinos B. ([1]), Suzuki Y. J. ([2]), Mingari L. ([3]), Costa A. ([1])
([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy*
([2]) *Earthquake Research Institute, The University of Tokyo, Tokyo, Japan*
([3]) *Geociencias Barcelona, GEO3BCN, CSIC, Barcelona, Spain*

Numerical models provide valuable information to civil protection and other stakeholders to help assess the potential impacts of a volcanic eruption. However, these models require as input data multiple eruption source parameters (ESPs) which are poorly constrained, making volcanic hazard assessment challenging. A better characterization of model parameters

can be achieved through the reconstruction of volcanic plume dynamics involved in past eruptions and is crucial in order to reduce model errors and produce reliable assessments of volcanic hazards for future eruptions. In this work, we take advantage of recent advances in computational capabilities and numerical modeling in order to produce a robust reconstruction of the dynamics of past super-eruption plumes. We apply a synergistic approach involving the dispersion model FALL3D for long-range atmospheric transport of volcanic ash, the SK-3D model for simulating the dynamics of eruption columns, and novel inversion methods based on data assimilation techniques to estimate ESPs using geological data of tephra deposits. The proposed strategy is applied to the ~ 39 ka Campanian Ignimbrite super-eruption in Campi Flegrei.

An AI-powered CFD emulator for lava flow modeling.

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The applications of lava flow modeling for assessing flow hazard, impact, and mitigation require varying degrees of accuracy and speed. Computational Fluid Dynamics (CFD) models can provide both accuracy and efficiency in tracking the lava flows evolution. Smoothed Particle Hydrodynamics (SPH) is a Lagrangian mesh-free particle-based CFD method based on a discretization of the Navier-Stokes equations that captures the complexities of real phenomena. While SPH is physically reliable and accurate, it also involves high computational costs. The combination of CFD and Artificial Intelligence (AI), in the so-called emulators, can enhance fluid modeling performance and extend the functionalities, while reducing computational resources. We have developed an AI-CFD emulator and verified its reliability and speed for both inviscid and viscous, as well as isothermal, fluids. Here, we present this emulator extended to replicate the behavior of fluids with temperature-dependent viscosity for describing the evolution of lava flows. We validate the emulator using classical benchmarks (*i.e.*, dam break), and then we assess its ability to generalize for various lava flow cases.

Application of radar to volcanic plumes: Models and algorithms.

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The characterization of explosive volcanic activity needs a more careful retrieval of the eruption source parameters (ESPs). Nowadays, the near real time ESPs quantification is still an open issue because of technology limitations of the sensors employed in the monitoring of eruptive events. The synergic combination of different sensors in the analysis of volcanic plumes is a crucial challenge in the investigation and in the study of the eruptive phases. Among them, the radar, operating at different bands (C, X and L), can provide useful direct and reliable measurements related to ash particles allowing to characterise the volcanic plume and to quantify the ESPs; this can be done mainly thanks to its sensitivity to fine/coarse particulate. In this contribution, we present the main methodologies and algorithms recently developed to estimate some ESPs such as the mass eruption rate, column height and particle size during explosive eruptions of Etna volcano. Finally, the ESP values obtained through radar measurements are compared with those obtained from other remote sensing systems to highlight strengths and limitations.

Enhancing volcano monitoring using multi-satellite sensor data fusion and super-resolution techniques.

Di Bella G., Corradino C., Del Negro C.

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Catania, Italy

The variety of satellites orbiting Earth provides a continuous view of active volcanoes globally. High spatial resolution thermal imaging is crucial for accurately detecting thermal changes, such as those associated with volcanic eruptions. However, high spatial resolution images often have a low temporal frequency, limiting the ability to track the evolution of volcanic events over space and time. Integrating data from multiple satellites is essential to produce more consistent, accurate, and useful information than that provided by any single one. Advanced data fusion techniques, such as super-resolution machine learning algorithms, are employed here to combine data from various satellite thermal sensors with different spatial and temporal resolutions. This integration enhances both the visual quality and quantitative analysis of satellite images. We demonstrate the effectiveness of this approach in fully leveraging all available satellite sensors for high-quality volcano monitoring. By enhancing both spatial and temporal resolutions, it enables a more accurate and timely assessment of volcanic activity, thereby contributing to emergency management and risk mitigation efforts.

Integrating artificial intelligence for monitoring explosive volcanic eruptions using MSG-SEVIRI images.

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Understanding the dynamics of volcanic explosive eruptions is essential for volcanic observatories in their efforts to mitigate associated risks. Machine learning (ML) techniques have emerged as valuable tools for retrieving volcanic cloud parameters from satellite data. ML techniques offer advantages over traditional methods by efficiently learning hidden relationships among numerous sample features. Satellite remote sensing plays a crucial role in monitoring volcanoes across a wide range of wavelengths, including visible, infrared, and near-infrared bands. SEVIRI sensor, on the MSG geostationary satellite, provides invaluable data with high temporal and spectral resolution, enabling comprehensive monitoring of eruptive activity. Middle-infrared (MIR) channels can detect and quantify thermal anomalies, while thermal infrared (TIR) bands can observe and analyze volcanic clouds. We propose a ML-based approach that utilizes SEVIRI images to monitor explosive volcanic eruptions in near real-time. Specifically, we have implemented ML algorithms to detect volcanic thermal anomalies, measure radiant heat flux to quantify them, identify volcanic clouds and retrieve their main components.

Aula 1F **ore 15:00 – 19:30**

Sezione V
Biofisica e fisica medica
Presiede: Casalis L. (Elettra Sincrotrone, Trieste)

Relazioni su invito

▲ **Le sfide dell'intelligenza artificiale nell'imaging medico.**
Retico A.
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L'intelligenza artificiale (AI) rappresenta oggi una soluzione tecnologia di grande impatto in moltissimi ambiti, incluso quello dell'imaging medico. La ricerca di strumenti basati su AI per l'interpretazione automatica di immagini diagnostiche è iniziata più di 40 anni fa. Oggi esistono molte implementazioni dell'AI, basate su machine learning e deep learning, che sfruttano il contenuto informativo dell'imaging medico, andando oltre a quanto l'occhio umano esperto riesca a percepire, per migliorare flussi di lavoro clinici in ambito diagnostico, prognostico e terapeutico. Dato che lo stato di salute di un individuo è codificato da una grande quantità di dati complessi ed eterogenei (*e.g.*, segnali e immagini multidimensionali, dati genetici, parametri clinici, fattori ambientali), i modelli basati su AI sarebbero i candidati ideali per decifrare le correlazioni nascoste tra tutte queste misure complementari. Lo sviluppo di modelli AI multi-input, la necessità di rendere affidabili e generalizzabili questi sistemi e interpretabili i loro risultati, sono le principali sfide da affrontare per rendere l'AI lo strumento chiave per raggiungere l'obiettivo della medicina di precisione.

▲ **Applications of 2D materials in bio-sciences.**
Altucci C.
Dipartimento di Scienze Biomediche Avanzate,Università degli Studi di Napoli Federico II, Italia
Two-dimensional (2D) materials are promising for applications in many fields such as space- and opto-electronics and radiation therapy. Understanding the behaviour of nanostructured 2D nanosheets in a water context when impacted by ionizing radiations is very much timely, since this scenario may occur in patients that are treated with drugs and/or contrast agents containing 2D materials while they are subjected to radiation therapies and diagnostics. We study the effects of ionizing 511 keV photons on 2D-MoS_2 in water for the first time to the best of our knowledge. In addition to the direct interaction between high-energy photons and nanosheets it is found that the indirect interactions between nanosheets and radiolysis products in water play a fundamental role, absolutely novel and peculiar of the water context. A comparison with a radiation transport Monte Carlo simulation allowed determining the elements driving the morphological and spectroscopical changes. As a second timely application we design and characterize novel magnetic nanostructered materials and complexes for magnetic resonance imaging purposes.

▲ **FLASH radiotherapy: Recent challenges and novel dosimetric approaches.**
Romano F.
Istituto Nazionale di Fisica Nucleare, Sezione di Catania
Several preclinical studies worldwide have demonstrated that ultra-high dose rate (UHDR) beams produce an improvement of normal tissue sparing, the so-called FLASH effect, compared to conventional dose-rate RT. To fully understand the mechanisms behind the effect

and to support the future clinical translation of FLASH-RT, novel beam monitoring and dosimetry technologies must be developed. Currently used dosimeters for conventional radiotherapy suffer critical saturation effects at these regimes. Alternative approaches, such as calorimetry or the use of solid-state detectors are currently being investigated and their usage at UHDRs is under assessment. The dosimetric challenges vary considerably depending on the accelerator type and the correspondent beam pulse structure. A reliable measurement of the instantaneous dose rate is also relevant to further investigate the FLASH effect. A status of the current technologies will be reported, including the most recent developments. Future perspectives in terms of dosimetric approaches and on-going initiatives at the national and international level for the clinical translation of FLASH RT will be also discussed.

Comunicazioni

Study of DNA repair in ^{60}Co-irradiated UMR-106 cells in the context of the ISOLPHARM project.

Leso A., Arzenton A., Bortolussi S., Lunardon M., Andrighetto A.
INFN, Laboratori Nazionali di Legnaro e Università degli Studi di Ferrara

In the realm of medical physics and radiobiology, foci assays stand out as a key technique for evaluating DNA damage induced by radiation. They consist in the analysis of repair proteins, such as 53BP1 and H2AX, used as markers for DNA sites of damage. It is possible to visualize and quantify these proteins with immunofluorescence, obtaining insights about radiation-induced damage. This method plays a crucial role in assessing the efficacy of radiation therapies, enhancing the understanding of radiobiological mechanisms. In this context, it becomes essential to develop predictive models able to correlate the revealed quantity of these proteins with the extent of DNA damage. This study aims to apply a mathematical model designed to simulate the cell damage repair within the first day post-irradiation, using experimental data from a foci assay on ^{60}Co-irradiated UMR-106 cells. In order to allow the model implementation, the entire experimental setup was reproduced within a Geant4-DNA application.This work is part of the ISOLPHARM project led by INFN-LNL, which aims to develop innovative radiopharmaceuticals using the Isotope Separation On-Line method at the SPES facility.

Deep Learning methods for 2D *in vivo* dose reconstruction with EPID detector.

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Artificial Intelligence, specifically Deep Learning, has great potential to enhance the efficiency and precision of *in vivo* dosimetry in radiotherapy. Electronic Portal Imaging Devices (EPIDs) play a crucial role in this context. An essential step is modeling their response to estimate 2D dose distributions (Portal Dose, PD). This work introduces a DL-based methodology aimed at converting actual EPID responses into PD images. Our dataset consists of hundreds of EPID-PD pairs of images acquired by irradiating various phantom configurations. PD are generated by using a TPS simulating EPID like a water equivalent device. We developed a U-net to transform EPID images into PD and tracked the mean absolute error as a metric to quantify the difference between the model predictions and targets. The quality of predicted dose distributions was assessed through the gamma-index analysis. Our

preliminary results emphasize the potential of DL methods in predicting the dose delivered to EPID detectors during radiotherapy treatments. In this contribution, we present the methods and the performance of our DL model, with a focus on recent data acquisitions conducted at Careggi Hospital in Florence.

Preliminary evaluation of flash electron radiotherapy in the treatment of uveal melanoma.

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Various *in vivo* studies proved that the FLASH treatment results in a decrease of radiation-induced normal tissue toxicity, compared to conventional treatment, while having the same biological effect on tumoral tissue. The principal aim of this study is to verify the possibility of using FLASH electron radiotherapy as an alternative treatment modality for localized uveal melanoma, the most common type of ocular disease in adults. This will be possible exploiting ElectronFlash (EF) machine, a LINAC for research use only which can deliver high-energy electrons (7 MeV–9 MeV) to the target in both FLASH (> 40 Gy/s up to 5000 Gy/s) and conventional (2 Gy/min) regimes, situated in Santa Chiara Hospital, Pisa. The main steps of the project are: i) validation of the EF simulation, dose distribution calculation and optimization on patient CTs, ii) development of a calculation and optimization tool that implements FLASH sparing effect, according to *in vitro/vivo* experimental results. Finally, iii) development of a robust method of comparison with other treatment modalities, based on radiomics and advanced statistics, also to quantify changes in the follow-up images of future treated patients.

^{59}Co$(\alpha, 2n)$ cross-section measurements for the ^{61}Cu optimization production.

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Copper-61 shows promise as a non-conventional theranostic radionuclide due to its favorable physical properties. With a half-life of 3.33 hours, it emits Auger and IC electrons suitable for radiotherapy, as well as β^+ particles and gammas ideal for diagnostics. Production methods for Cu-61 include proton bombardment on natural Zn or highly enriched ^{64}Zn or ^{60,61,62}Ni targets, or via deuteron-induced reactions on natural nickel targets. However, utilizing alpha particles to bombard ^{59}Co targets offers advantages. This method results in a radionuclide distant from target constituents, simplifying radiochemical separation. Additionally, Co's monatomic nature eliminates the need for enriched targets, reducing production costs. The study aimed to characterize the ^{59}Co$(\alpha, 2n)^{61}$Cu reaction cross-section within a specific energy range and identify contaminating radionuclides like ^{60}Cu, ^{54}Mn, ^{56}Co, ^{57}Co, ^{58}Co

and others. Irradiation took place at the GIP ARRONAX cyclotron in Nantes (France), with subsequent analysis at the Physics Measurement Laboratory of LASA in Segrate (Italy), affiliated with UNIMI and INFN.

Development and characterization of a new parallel-plate ionization chamber for FLASH dosimetry.

Montefiori M. ([1])([2]), Baldini L. ([2]), Bisogni M.G. ([1])([2])([4]), Ciarrocchi E. ([1])([2]), Del Sarto D. ([2]), Felici G. ([5]), Gòmez F. ([6])([7]), Lucchesi L. ([2]), Masturzo L. ([1])([2]), Morrocchi M. ([1])([2]), Paiar F. ([3])([4])([1]), Pensavalle J.H. ([1])([2])([5]), Sgrò C. ([2]), Di Martino F. ([3])([4])

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FLASH radiotherapy offers rapid dose administration (< 200 ms) at ultra-high dose rates (> 40 Gy/s) and doses per pulse (> 1 Gy), reducing healthy tissue damage while maintaining tumor efficacy. Dosimetric challenges limiting the clinical translation persist due to an inadequacy of conventional dosimeters in FLASH regime. A new gas-based parallel-plate ionization chamber (PPIC), the ALLS chamber, addresses these challenges by using low-pressure noble gases to prevent saturation and uncontrolled discharges. This study aims to develop and characterize a PPIC based on the ALLS chamber for measuring FLASH doses per pulse. Numerical simulations of charge transport optimized chamber design and experimental parameters, showing helium (50 mbar) and nitrogen (10 mbar) enable measuring up to 10 and 12 Gy/pulse, respectively, with stable charge collection efficiency. A first PPIC prototype was realized with a suitable structure for low-pressure applications. In this contribution the first experimental results will be shown. Future works aim at adjusting the prototype for low-pressure noble gases, paving the way for experimental validation and dosimetric measurements with FLASH pulsed electron beams.

***In vivo* dose reconstruction with EPID detectors in radiotherapy: Experimental validation of TPS predicted portal dose images.**

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The InTrEPID project aims to develop a 3D *in vivo* dosimetry method using information from EPID images taken during radiotherapy treatment, along with patient anatomy, to reconstruct the delivered 3D dose map. The proposed procedure is fully data driven, being based on advanced deep learning methods. A robust database for training and testing the model was populated using portal dose images calculated by the treatment planning system (TPS) Monaco by Elekta and portal images from EPID. To mimic EPID in TPS, the calculation area was extended beyond the CT-FOV, a 4.5 cm water-equivalent region was added 60 cm below the plan isocenter. The scoring layer of the virtual EPID was placed

in the middle. To validate Monaco software, a diode matrix was placed at the EPID level, ensuring consistency with experimental measurements. One-hundred pairs of EPID images from various phantoms of diverse material densities (lung, solid water, titanium and bone), and corresponding simulated dose images were created. This innovative utilization of TPS Monaco plays a crucial role in the development of accurate dose prediction models, enabling the precise conversion of grayscale EPID images into PD images.

An online beam monitor for flash radiotherapy: The FlashDC project.

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A highly precise characterization of the electron beam is needed to exploit the advantages brought by FLASH effect-based procedures with respect to conventional therapeutical treatments. Standard detectors are unable to provide accurate temporal and spatial information of ultra-high dose rate (over 100 Gy/s) electron beams due to volume recombination effects. A promising solution, called Flash Detector beam Counter (FlashDC), is being developed relying on air fluorescence caused by excitation of nitrogen molecules which provides an isotropic production of optical photons with a spectral peak around 340 nm. A constant fluorescence yield of 4–5 photons per molecule in a range of electron kinetic energies from 10 to 1000 MeV grants a linear response with respect to the beam intensity, also drastically reducing saturation problems. Encouraging results involving FlashDC prototypes have already been obtained within the last two years, confirming linear response with respect to the dose rate per pulse. FLUKA Monte Carlo simulations are being exploited to develop an optimized 2D online beam-monitoring detector allowing for a previously unachieved online beam monitoring for FLASH therapies.

Laser plasma acceleration of very high energy electron (VHEE) beams: Using ultra-high dose rate pulses for *in vitro* radiobiology studies.

Piccinini S. ([1]), Panaino C. ([1]), Andreassi M.G. ([4]), Avella F. ([1])([3]), Baffigi F. ([1]), Bandini G. ([1]), Borghini A. ([4]), Brandi F. ([1]), Fregosi A. ([1]), Fulgentini L. ([1]), Gregocki D. ([1])([3]), Koester P. ([1]), Labate L. ([1])([2]), Palla D. ([1]), Salvadori M. ([1]), Vlachos S. ([1])([3]), Gizzi L.A. ([1])([2])
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VHEE beams (100–250 MeV) are being considered for the treatment of deep-seated tumors with FLASH-radiotherapy (RT). Laser-plasma acceleration (LPA) through the laser wakefield acceleration (LWFA) mechanism has been proposed for compactly delivering VHEE beams. LWFA process enables accelerating gradients orders of magnitude higher than conventional RF-based accelerators. This feature makes laser-driven accelerators potential ideal

candidates to generate VHEE for clinical applications. Moreover, LPA provides inherently ultra-high dose rate (UHDR) electrons beams. DNA damage associated with UHDR irradiation is a crucial radiobiological process to understand the underlying mechanisms associated with FLASH-RT. We will present recent results on the dosimetric characterization and stability control of our VHEE source based on LWFA at ILIL and its application to *in vitro* radiobiology measurements. We investigated the induction of micronuclei in cytokinetic-blocked human blood lymphocytes after irradiation with different doses and dose rates. Beam-line implementation with a magnetic transport line for stabilising beams and our upgrade program for FLASH-RT dose compliance will be outlined.

Adapting an electron linac for minibeam radiotherapy: Design and development.

Deut U.

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The field of radiotherapy has seen significant advancements in the past decade, particularly in the development of high dose rates and spatially fractionated irradiations, showing promising results in sparing non-tumoral tissues. Minibeam radiotherapy is a modality that uses a series of narrow sub-millimetric parallel beams to deliver the dose with a pattern of peaks and valleys. This contribution investigates the realization of electron minibeams at the Elekta SL25 linear accelerator of the INFN and Physics Department of the University of Turin using perforated templates of high-Z material across the range of available energies (6 to 18 MeV). Preliminary Monte Carlo simulations allowed the optimization of the template geometry and the quantification of the minibeam dosimetric parameters in a water phantom. The results indicate that a good peak-to-valley dose ratio can be achieved with minimal contamination from secondary particles. These predictions have been validated with measurements using gafchromic films and silicon particle detectors mounted on a rotating tomographic setup for beam profile monitoring.

First ISOLPHARM preclinical studies with Ag-111 radionuclide.

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Targeted Radionuclide Therapy (TRT) is a consolidated technique for the treatment of cancer. TRT requires the use of drugs labeled with radionuclides that are injected in patients and accumulate in the target tumor site. The supply of radionuclides is a key point for the

spreading of this technique. ISOLPHARM project is investigating a route of production involving the Isotope Separation On-Line (ISOL) technique. The selected Radioactive Ion Beam (RIB) facility for this project is the SPES facility at the Legnaro National Laboratories of the National Institute for Nuclear Physics (INFN-LNL). A wide gamma of neutron-rich isotopes can be produced using the ISOLPHARM method, the most studied radionuclide by the ISOLPHARM Collaboration is Ag-111. Thanks to its beta and gamma emissions and its one-week half-life, it is a good candidate for theranostic applications. In this contribution, preliminary results obtained in the most recent preclinical studies of Ag-111 conducted by the ISOLPHARM Collaboration will be presented.

Scintillator detectors in FLASH radiotherapy.

D'Orazio C.

Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa

Recent advances in ultra-high dose radiotherapy, or FLASH, have shown potential for minimizing healthy tissue damage while effectively treating tumors. FLASH therapy delivers doses over 40 Gy/s within 200 ms, presenting challenges in dosimetry, beam control, and understanding radiobiological effects. To overcome limitations of conventional dosimeters in FLASH therapy, such as saturation effects, two plastic scintillator-based technologies —scintillating foils and fibers— are being explored for real-time 1D and 2D dosimetry. Key features such as energy independence and water equivalence are crucial for clinical detectors. In this contribution, these properties have been investigated using Monte Carlo (MC) simulations within the dose range relevant to the FLASH regime. Additionally, accurate estimation of radiation-induced Cerenkov light in the optical fibers transmitting the scintillator signal to a photodetector is essential, as it can affect detector performance. This is achieved through MC simulations, ensuring precise signal reconstruction and reliable dose evaluation. The simulations results will be compared with experimental data from previous campaigns at electron LINAC FLASH at CPFR.

Characterization of innovative flexible hydrogenated amorphous silicon detectors for precise dosimetry in high dose rate radiation therapy.

Peverini F. per la HASPIDE Collaboration

INFN, Sezione di Perugia, Italia e Dipartimento di Fisica, Università degli Studi di Perugia, Italia

The advancement of high dose rate treatments in radiation therapy, including microbeam radiation therapy (MRT), requires detectors with exceptional dynamic range and spatial resolution for precise dosimetry. This study introduces the development and characterization of novel hydrogenated amorphous silicon (a-Si:H) detectors for therapeutic x-ray beam dosimetry. The detectors are flexible as they are fabricated directly on a flexible polyimide (Kapton) substrate. We assessed fundamental dosimetric parameters such as output factor (OF), dose rate dependence (DPP), energy dependence, and percentage depth dose (PDD). Our a-Si:H detectors showcased excellent dose linearity and sensitivity, influenced by variations in detector thickness, area, and applied bias. Benchmarked against commercial dosimeters, these devices demonstrate comparable dosimetric performances, making them promising candidates for high dose rate applications like MRT due to their accurate performance and radiation resistance.We are also able to perform acquisition with 0V bias, which offers advantages in terms of patient safety, cost efficiency, and measurement accuracy.

Toward a laser-driven VHEE radiotherapy: Design and optimization of a system for beam stabilisation and focalization.

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To date, almost 1/4 of cancer patients worldwide receive radiotherapy (RT) as part of their treatment. A new outbreak in RT research is the FLASH effect, where radiation doses are delivered at ultra-high dose rates. The FLASH effect is linked to reduced toxicity for heathy tissue, leading to improved tumor control. Very high energy electron (VHEE) (100–250 MeV) beams, produced via laser wakefield acceleration, are being considered for their high acceleration gradient, a primary condition for FLASH. To focalize and stabilize the VHEE beam, a set of four magnetic quadrupoles was evaluated to be implemented within the ILIL VHEE beam-line. First the set was designed with a home-made Twiss-parameter engine. Then it was optimized using the Geant4 Monte Carlo code. The beam spectrum used in the simulation was based on experimentally available parameters. For focalization, the beam size is halved along the x and y axes. For stabilization, a potential maximum displacement at crosswire of 10 mm is corrected in all directions. A prototype was built and experimental runs with the quadrupoles are underway at ILIL. A similar concept is being considered for future VHEE-RT in a clinical setting.

A transmission chamber for conventional and ultra-high dose rates relative dosimetry.

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Ultra-High Dose Rates (UHDRs) are an emerging research field in Radiation Therapy (RT): with mean dose rates > 40 Gy/s, the same efficacy on tumoral cells with respect to conventional RT and increased sparing of normal tissue are observed. New technologies for beam monitoring and dosimetry are explored to face UHDRs challenges, and the use of Cherenkov light is a possible candidate. The PhD project aims at developing an Ionization Chamber (IC) for relative dosimetry on both conventional and UHDR RT, inducing minimal perturbation on the beam. The first IC prototype has transparent polycarbonate electrodes, expected to have minimal impact on electron beams. Simulations with Geant4 and preliminary measurements were performed at the Elekta LINAC of the University and INFN Torino to evaluate and confirm the beam perturbation of the IC. Further experiments will follow, exploiting the FLASH operation modality of the LINAC (electron, 10 MeV). At conventional dose rates the PDDs showed a shift around 0.2 g/cm^2 in the R50. Studies and simulations on charge collection time and Cherenkov light emitted from polycarbonate are being performed. The status of the project will be reported.

Aula D **ore 15:00 – 19:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Lucarelli F. (Università di Firenze)
Villa M. (Università di Bologna e INFN, Sezione di Bologna)

Relazioni su invito

▲ **CNAO: Current status and near future.**
Mereghetti A., Pullia M.G.
National Center for Oncological Hadrontherapy, CNAO, Pavia, Italy
The National Center for Oncological Hadrontherapy (CNAO, Pavia, Italy) is one of the four cancer treatment facilities in Europe delivering proton and carbon ion beams for cancer treatment. Beams are accelerated by means of the only hadron synchrotron currently available in Italy, and made available in three treatment rooms, all equipped with fixed beam lines and an active spot scanning system for tumor painting. CNAO is also equipped with an experimental room (XPR) dedicated to non-clinical research activities; since 2022, CNAO routinely welcomes researchers from Italy and abroad to carry out their activities with beams in the XPR. Recently, a new ion source has been installed in CNAO, enriching by far the portfolio of accelerated ion species of interest for clinical and non-clinical research activities, like helium, lithium, nitrogen, oxygen, and iron. CNAO is currently undergoing a massive expansion phase, with the installation of a synchrotron-based, single-room proton-therapy system equipped with a gantry, and a tandem-based machine for boron-neutron capture therapy (BNCT).

▲ **Elettra 2.0: Advancements in synchrotron radiation research.**
Lizzit S.
Elettra Sincrotrone Trieste S.C.p.A.
Elettra 2.0 represents the latest evolution of the Italian third-generation synchrotron radiation facility Elettra, which has been serving scientific and industrial communities since 1993. In 2017, the Italian Government approved the Elettra 2.0 project, which involves replacing the current machine with a low-emittance storage ring, representing a significant milestone in synchrotron research. With its enhanced brightness and coherence, Elettra 2.0 will offer unparalleled opportunities for cutting-edge scientific research across various disciplines. Allocating over 40% of its investment budget to new beamline construction and upgrades, Elettra 2.0 is poised to accommodate up to 32 state-of-the-art beamlines. This diverse portfolio ensures experiments covering a wide range of photon energies, from a few tens of eV to several tens of keV. Researchers in fields including physics, chemistry, biology, medicine, and cultural heritage will benefit from access to advanced experimental techniques. In this contribution, the characteristics of the new machine as well as the capabilities of the beamlines and their potential for performing advanced experiments will be outlined.

▲ **The Drift Tube Linac for the European Spallation Source: Design, construction and commissioning results.**
Grespan F. ([1]), Antoniazzi L. ([1]), Baltador C. ([1]), Bellan L. ([1]), Comunian M. ([1]), Fagotti E. ([1]), Ferrari L. ([1]), Montis M. ([1]), Palmieri A. ([1]), Pisent A. ([1]), Scarpa

D. [1], Mereu P. [2], Nenni M. [2], Mingioni C. [2], Nicoletti E. [2], Bencivenga T. [2]
[1] *INFN, Laboratori Nazionali Legnaro, Legnaro, Italy*
[2] *INFN, Sezione di Torino, Torino, Italy*
The Drift Tube Linac (DTL) for the ESS Linac will accelerate H+ beams of up to 62.5 mA peak current from 3.62 to 90 MeV. The structure consists of five cavities. DTL1 to DTL4 were successfully commissioned to full power and beam current in 2023. DTL5, the last cavity, was installed in the tunnel in September 2023 and will be commissioned at the end of 2024. The contribution wants to overview the activities already done and ongoing on the five DTLs: design, assembly, tuning, conditioning, and beam commissioning.

Comunicazioni

Beam dynamics and spin tracking simulations at the hybrid storage ring for the electric dipole moment investigation.

Piccoli A. [2], Shankar R. [1][2], Lenisa P. [1][2]
[1] *Università degli Studi di Ferrara*
[2] *INFN*
One of the great mysteries of physics is baryon asymmetry, *i.e.*, the imbalance between matter and antimatter in the Universe. Its fulfilment required the violation of the charge conjugation-parity (*CP*) symmetry. The Standard Model (SM) contribution to *CP* violation is too small to explain baryon asymmetry and new sources beyond the SM are needed. The Electric Dipole Moment (EDM) is a powerful probe of *CP* violation beyond the SM and can be experimentally accessed. Any measurement of a non-zero EDM would represent a clear sign of New Physics as well as a possible answer to the puzzling and unsolved baryon asymmetry problem. In the last decades the developments in the storage ring technology have allowed to propose a new method for EDM investigation. In particular, a new concept for a dedicated storage ring has been recently submitted: this proposal foresees the use of electric deflectors for bending and of magnetic elements; this is the reason why this storage ring is referred to as hybrid. As a new generation device, the hybrid storage ring needs to be tested and validated through specific beam dynamics and spin tracking simulations.

MDI studies for 3 TeV Muon Collider.

Castelli L. [1], Lucchesi D. [2][4], Collamati F. [1][3], Calzolari D. [5]
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[2] *Università degli Studi di Padova*
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[4] *INFN, Sezione di Padova*
[5] *CERN, Geneva, Switzerland*
Muon Collider is a project for a future collider able to explore multi-TeV center-of-mass energy with lepton collision. Beam intensities of the order of 10^{12} muons per bunch are needed to achieve the necessary luminosity, generating a high flux of secondary and tertiary particles that reach both the machine elements and the detector region. A strategy to reduce the beam-induced background to manageable levels at 3 TeV center-of-mass energy will be discussed. The configuration of the interaction region will be presented with particular focus on the absorber design, as well as the overall background-mitigation strategy with the relevant detector parameters in mind.

Dynamic simulations for optimizing beam transport in plasma-based accelerators: Preliminary investigations at SPARC_LAB.

Carillo M. [1][2], Anania M.P. [2], Bacci A.L. [5], Biagioni A. [2], Chiadroni E. [1][2], Cianchi A. [4], Costa G. [2], Crincoli L. [2], Curcio A. [2], Del Dotto

A. ([2]), Del Giorno M. ([2]), Di Pirro G. ([2]), Demurtas F. ([1])([2]), Ferrario M. ([2]), Francescone D. ([1])([3]), Galletti M. ([4]), Giannessi L. ([2]), Giribono A. ([2]), Mostacci A. ([1])([3]), Pompili R. ([2]), Romeo S. ([2]), Rossetti Conti M. ([5]), Rossi A.R. ([5]), Vaccarezza C. ([2]), Verra L. ([2]), Villa F. ([2])
([1]) *Sapienza University of Rome, Rome, Italy*
([2]) *INFN-LNF, Frascati, Italy*
([3]) *INFN, Sezione di Roma1, Rome, Italy*
([4]) *University of Rome Tor Vergata, Rome, Italy*
([5]) *INFN, Sezione di Milano, Milan, Italy*

Research on plasma-based acceleration has demonstrated the capability to achieve ultra-high acceleration gradients. However, the path towards realizing a plasma-based accelerator still requires efforts to ensure high-brightness beams, stability, and reliability within the framework of the EUPRAXIA@SPARC_LAB project. A significant enhancement in the efficiency of PWFA has been demonstrated thus far by accelerating a witness bunch in the wake of a higher-charge driver bunch. The transformer ratio, and thus the energy transfer from the driver to the witness beam, can be increased by resonantly exciting the plasma with a properly pre-shaped pilot electron beam. This work presents dynamic simulations aimed at optimizing beam transport in the SPARC_LAB injector. Specifically, a case of identical bunch groups and one case of three driver groups with witnesses are examined. These studies serve as preliminary investigations preceding the experimental measurements presented in the same work.

Innovative crystal-based sources for high-intensity gamma-rays.

Negrello R. ([1]), Bandiera L. ([1]), Canale N. ([1]), De Salvador D. ([2]), Guidi V. ([1]), Klag P. ([3]), Lauth W. ([3]), Malagutti L. ([1]), Mazzolari A. ([1]), Paternò G. ([1]), Romagnoni M. ([1]), Sgarbossa F. ([2]), Sytov A. ([1]), Valzani D. ([2])
([1]) *INFN, Section of Ferrara e University of Ferrara, Ferrara, Italy*
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([3]) *Institut für Kernphysik der Universität Mainz, Mainz, Germany*

The research is focused on finding new ways to generate high-intensity, monochromatic X- and gamma-rays, surpassing the capabilities of existing methods. While Free-Electron Lasers (FEL) have limitations on photon energy, and inverse Compton scattering relies on powerful lasers, the search for alternatives continues. TECHNO-CLS, a PATHFINDER project funded by the European Innovation Council, is dedicated to crafting innovative gamma-ray Light Sources (LSs), utilizing linear, bent, or periodically bent crystals.These systems utilize the electrostatic fields within crystals to achieve sub-millimeter oscillation periods, enabling GeV particle beams to produce high-intensity, monochromatic X- and gamma-rays. CLSs not only offer high adaptability for different applications but also provide a platform for more energy-efficient technologies. We will discuss the fundamental concepts and techniques for utilizing crystal structures to manipulate particle beams, explore the operational principles of crystalline undulators, address the manufacturing challenges they pose, and evaluate their potential as effective and versatile gamma-ray sources.

Aggiornamento dei sistemi di radiofrequenza di basso livello di SPARC_LAB presso i laboratori nazionali di Frascati dell'INFN.

Serenellini B., Bellaveglia M., Cardelli F., Ferrario M., Gallo A., Magnanimi R., Piersanti L., Scarselletta G.
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Italia

SPARC_LAB è una facility nata nel 2004 come attività di R&D per sviluppare un fotoiniettore di elettroni ad alta brillanza dedicato agli esperimenti FEL e all'esplorazione di tecniche

di accelerazione avanzate. La sorgente di elettroni è costituita da un cannone RF in banda S con campo elettrico di picco di 120 MV/m. Le particelle vengono iniettate in due sezioni acceleranti in banda S con solenoidi integrati che permettono la focalizzazione e il controllo dell'emittanza, mentre una successiva sezione in banda C opera da booster per ottenere un'energia cinetica di 150 MeV. La Regione Lazio ha recentemente finanziato il progetto SABINA per il consolidamento di SPARC_LAB. Questo progetto prevede un aggiornamento dell'hardware per la distribuzione dei segnali e del riferimento elettrico, e dei sistemi di Low Level RF (LLRF). Quest'ultimi saranno sostituiti con dispositivi digitali, stabilizzati in temperatura e controllati da FPGA, con l'obiettivo di migliorare le prestazioni in termini di ampiezza, risoluzione di fase e stabilità. Le prime attività per la messa in funzione della macchina dopo l'aggiornamento sono previste a partire dalla seconda metà del 2024.

Energy characterisation of the TOP-IMPLART linac proton beam by radiophotoluminescence of colour centres in lithium fluoride.

Nichelatti E. ([1]), Ampollini A. ([2]), Astorino M.D. ([2]), Bazzano G. ([2]), Nenzi P. ([2]), Nigro V. ([2]), Piccinini M. ([2]), Ronsivalle C. ([2]), Surrenti V. ([2]), Trinca E. ([2]), Vincenti M.A. ([2]), Montereali R.M. ([2])

([1]) *ENEA Nuclear Department, C.R. Casaccia, Rome, Italy*

([2]) *ENEA Nuclear Department, C.R. Frascati, Frascati, Italy*

In recent years, lithium fluoride (LiF) thermally evaporated thin films and commercial crystals have been regularly employed to characterise the energy of the proton beam emitted by the TOP-IMPLART accelerator. This accelerator, currently under development at the ENEA Frascati laboratories for proton therapy applications, features a main beamline delivering a maximum energy of 71 MeV, with an additional bending-magnet vertical beamline providing energies ranging from 3 to 7 MeV for radiobiology experiments. The utility of LiF stems from its ability to form stable point defects, known as colour centres (CCs), within its crystal lattice upon interaction with accelerated ions. Some of these CCs exhibit visible photoluminescence under blue-light optical excitation. The linear relationship between emission intensity and absorbed dose of these CCs, coupled with their broad dynamic range, enables the creation of a luminescent representation of the protons' Bragg curve within LiF. This replica can be detected and fitted to estimate the beam energy spectrum. This contribution offers an overview of this energy diagnostic approach, highlighting its recent advancements and developments.

Design and testing of a compact C-band VHEE FLASH linac for the SAFEST project.

Giuliano L., Alesini D., Cardelli F., Carillo M., Chiadroni E., Faillace L., Ficcadenti L., Migliorati M., Palumbo L., Mostacci A.

La Sapienza, SBAI Department, Rome

FLASH Therapy, a novel cancer treatment technique, aims to control the tumor-grown sparing healthy tissue from radiation damage increasing the therapeutic index. Translating FLASH therapy into clinical practice, especially for treating deep-seated tumors, necessitates achieving Very High Electron Energy (VHEE) levels within the 50–150 MeV range. In collaboration with INFN, Sapienza is developing a compact C-band high-gradient VHEE FLASH linac. This paper provides insights into the design strategy, beam parameters, and electromagnetic characteristics, focusing on prototype testing and tuning conducted at the Sapienza Accelerator Laboratory. The progress of this innovative linac represents a step toward realizing the SAFEST project, an advanced 100 MeV FLASH VHEE source in cancer treatment.

Beam dynamics simulation for a FLASH LINAC.

Farina S., Chiadroni E., Carillo M., Faillace L., Ficcadenti L., Francescone D., Giuliano L., Migliorati M., Palumbo L., Mostacci A.
Sapienza University of Rome

FLASH radiotherapy is an innovative technique in cancer treatment, consisting of the usage of a mean dose rate > 100 Gy/s, an ultra-high instantaneous dose rate > 1 MGy/s, all within a total irradiation time of less than 100 ms. Several pre-clinical studies have demonstrated the efficacy of this method in significantly reducing the toxicity in the healthy tissue while keeping the same efficacy in cancer treatment. A LINAC prototype capable of delivering FLASH radiation is currently being studied at La Sapienza University in collaboration with INFN. This LINAC, comprising two RF C-band cavities (one standing-wave and one traveling-wave), accelerates electrons up to about 28 MeV energy. ASTRA codes were used to simulate the dynamics of a single bunch inside the machine. We optimized the RF parameters, in particular the cavity injection phase, with special attention to the beam capture, spot size and the beam energy that is also affected by the beam-loading effect due to the very high current. Promising results obtained from simulations will be discussed, in accordance with the requirements of a FLASH therapy device.

Simulation study of the radionuclide deposition process on the collection target in the context of the SPES facility.

Chen D. ([1])([2]), Ballan M. ([3]), Donzella A. ([4])([5]), Monetti A. ([3]), Khwairakpam O. ([3]), Lunardon M. ([1])([2]), Andrighetto A. ([3])
([1]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Italy*
([2]) *INFN, Sezione di Padova, Italy*
([3]) *INFN, Laboratori Nazionali di Legnaro, Italy*
([4]) *Dipartimento di Ingegneria Meccanica e Industriale, Università degli Studi di Brescia, Italy*
([5]) *INFN, Sezione di Pavia, Italy*

SPES is a second-generation ISOL facility for the production of Radioactive Ion Beams (RIBs), under the completion stage at INFN-LNL. The produced RIBs will be delivered to experiments such as ISOLPHARM, which is dedicated to the development of innovative radiopharmaceuticals exploiting the high-purity radionuclides produced with ISOL method. For such scope, a system called IRIS will be coupled with the RIB line to handle the collection targets where candidate radionuclides are deposited; among them ^{111}Ag is one of the most promising ones for its potential in therapeutic use. The deposition of radionuclides with mass number = 111 u and the radiological safety issues raised by such an amount of radioactive species are studied, using the Monte Carlo codes FLUKA and PHITS. The workflow takes into account that all physical processes undergone by the RIBs before reaching the IRIS system present a specific efficiency, hence a guideline for estimating the available activities at the end of SPES RIB line is provided. The obtained results will be used for the design of the shielding for handling the IRIS collection targets.

Rogowski coil: Pulsed current diagnostic at limit.

Nassisi V. ([1])([2])([3]), Buccolieri G. ([1])([2]), Paladini F. ([1])([2])
([1]) *Department of Mathematics and Physics, LEAS, University of Salento, Lecce, Italy*
([2]) *INFN, Section of Lecce, Italy*
([3]) *Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy*

The technological evolutions have improved accelerating machines, digital communications, electromagnetic pulse generators and many other devices. In these contexts the use of

Rogowski coils is very important. But it is also important to diagnose shorter and shorter pulses. The latest evolution we realised is that the Rogoswki coil was able to perform precise measurements of sub-nanosecond rise time pulses of about 100 ps ($\sim$ 200 ps input pulse and $\sim$ 300 ps output pulse). Due to the very short pulses, Rogowski coils must be considered as a transmission line and the Laplace transform allows to get the different solutions. The different solutions are obtained introducing some approximation as the resistance of the wire, but responses on the rise time are not allowed. Experimentally, fast Rogowski coil responses are obtained with a low coil ring number device ($n \sim 20$), and, as a consequence, a low attenuation factor is obtained. Measurements performed with a low number of the coils have got a response like the input one, 100 ps. This result points out that the Rogowski rise time is lower than 100 ps. The input pulse was realized by a fast switch (Reed relay h12).

Sybchrotrons in the Caribbean —Two proposals.

Violini G. ([1]), Colon J. ([2]), Mtingwa S. ([3])
([1]) *Centro Internacional de Fisica, Bogota, Colombia*
([2]) *Universidad de Puerto Rico, Rio Piedra, Puerto Rico*
([3]) *LAAAMP, Light Sources for Africa, the Americas, Asia, Middle East and the Pacific*

Due to the unequal distribution of synchrotrons in the world, a number of proposals are being considered in developing countries. LAAAMP has played a major role for promoting this movement. In the Greater Caribbean two proposals are acquiring momentum, a regional one (GCLSI) and a US national one (PULS). They are in many senses complementary, and complementary to SIRIUS in Brazil and to the US synchrotron system.

Analysis of transversal beam dynamics using numerical simulations for sub-relativistic electrons in a dielectric laser accelerator.

Quevedo Diaz. S. ([1]), Mauro G.S. ([1]), Mascali D. ([1]), Torrisi G. ([1]), Sorbello G. ([2]), Bacci A. ([3]), Rossetti Conti M. ([3]), Palmeri R. ([4])
([1]) *INFN-LNS, Catania, Italy*
([2]) *Dipartimento di Ingegneria Elettrica, Elettronica e Informatica, Università degli Studi di Catania, Catania, Italy*
([3]) *INFN, Milano unit, Milan, Italy*
([4]) *IREA-CNR, Naples, Italy*

This study investigates the beam dynamics of tapered co-propagating structures for Dielectric Laser Acceleration (DLA). Using CST Microwave Studio, the electromagnetic fields created in the acceleration structure were simulated. Furthermore, particle in cell simulations in CST allowed us to investigate the beam dynamics of the system. The code package ASTRA was additionally used to carry out single particle and bunch tracking to analyze the behavior of the beam and ensure the proper acceleration and focusing. Asymmetrical and symmetrical structures were simulated to compare and contrast their performance related to figures of merit such as energy gain, transversal emittance, and beam envelope dimensions. We found that the symmetrization of the structure reduces/eliminates the transversal field components of the traveling mode, thus showing a clear improvement in beam transport.

Improving accuracy for future FCC-ee collider.

Marafatto L. ([1]), Zaro M. ([2])
([1]) *Dipartimento Politecnico di Ingegneria e Architettura, Università degli Studi di Udine*
([2]) *Dipartimento di Fisica, Università degli Studi di Milano*

High-energy high-luminosity future circular electron-positron collider FCC-ee would reach a luminosity up to a factor (10^5) higher than at the LEP collider. Together with the improvements of the detector techniques it would allow to reduce an experimental error typically

by a factor of 5-50, and in some cases even by a factor of 200. Researchers agree on the fact that the uncertainty of the corrections due to QED effects would then become for many observables a dominant one. This study explores the necessity of enhancing accuracy in QED corrections for precision measurements at the FCC-ee, emphasizing the insufficiency of Leading Logarithm (LL) accuracy and the need for Next-to-Leading Logarithm (NLL) accuracy to minimize experimental errors.

Muon collider demonstrator facility.

Zuliani D. ([1])([2]), Bartosik N. ([3]), Casarsa M. ([4]), Lucchesi D. ([1])([2]), Pastrone N. ([3]), Sestini L. ([2])
([1]) *Università degli Studi di Padova*
([2]) *INFN, Sezione di Padova*
([3]) *INFN, Sezione di Torino*
([4]) *INFN, Sezione di Trieste*

The muon collider is an alternative solution for future colliders that will allow the study of the Standard Model of Particle Physics with unprecedented precision. To collide muons, it is necessary to produce them, reduce their emittance after production via proton-target interaction, and accelerate them. In particular, the reduction of muon emittance is achieved via ionization cooling, an innovative technique that allows the reduction of the transverse component of muon momenta, while increasing the longitudinal one. A first proof-of-principle of the muon ionisation cooling has been obtained by the MICE experiment, but a full benchmark is needed to probe its feasibility and scalability. Now the International Muon Collider Collaboration is proposing a new facility where it can be fully studied together with other accelerator elements. This contribution will illustrate what the demonstrator facility is with its staging options. Possible hosting sites will be presented including CERN.

Aula B **ore 15:00 – 19:30**

Sezione VII
Didattica e storia della fisica
Presiede: Organtini G. (Sapienza Università di Roma)

Relazioni su invito

▲ **Non-linear viscoelastic properties of a simple mechanical system.**
Battaglia O.R.
Dipartimento di Fisica e Chimica "Emilio Segrè", Università degli Studi di Palermo
One-dimensional mechanical oscillators are valuable for explaining several physical topics. Common subjects include harmonic, nonlinear, and damped oscillator models, hysteresis, entropy and differential equations. An oscillator of great pedagogical value can be built by attaching a mass to a rubber band. This oscillator exhibits higher damping and non-linearity compared to an equivalent oscillator with a spring. Undergraduate students have difficulties when attempting to model damping and non-linearity. Nonlinear effects play a crucial role in many areas of physics, and all physical phenomena are fundamentally nonlinear. The primary objective of this contribution is to elucidate the physical behaviour of rubber bands to allow students to familiarise with viscoelastic and non-linear properties, both in static and dynamic conditions. In order to examine these factors, it is important to conduct experiments, develop models, and compare them to the data. Examining the characteristics of rubber in undergraduate courses is worthwhile for assessing fundamental models for a widely used material and can facilitate the connection between theoretical principles and practical applications.

▲ **Gaining experimental independence in a lab course.**
Alemani M.
University of Potsdam, Germany
Design and building of experimental apparatus as well as data analysis methods are essential in experimental physics. I refer to these abilities as 'design' skills. Although paramount for experimental physics, these skills are typically not pursued in traditional introductory lab courses. In fact, in those settings, experimental setups, procedures, and measurement methods are pre-constructed and optimized by instructors. In this contribution, I will present how we promote experimental design skills in the introductory lab course. Students devise measurement strategies, and design and construct experimental apparatus. They optimize the apparatus and measurement procedures iteratively, based on their experimental results. I will detail the course learning goals on design and describe my experience with various lab activities developed to reach those goals. In the initial phase of the course, we modified simple, already existing experiments. Later, students design and build more complex instruments such as microscopes, spectrometers or interferometers to accomplish given goals. In the final phase, students enjoy the freedom to plan, design and implement self-determined experimental projects.

▲ **Innovazione didattica universitaria: focus sulla fisica per corsi di laurea biotecnologici.**
Michelini M.
DMIF, Università di Udine
La complessità del contesto socio culturale e lavorativo impongono modalità formative nuove per obiettivi che non possono più essere soltanto conoscenze disciplinari strutturate. Ciò

emerge da una vasta ricerca didattica a livello internazionale. La padronanza dei contenuti deve corrispondere ad una capacità di usarli in contesti differenziati per rispondere in modo flessibile a problemi sempre nuovi. La Comunità Europea ha dichiarato anno delle competenze il 2023 per sensibilizzare a questa prospettiva delineata dal quadro di riferimento delle competenze del Consiglio d'Europa. Il G7 ha dedicato la propria attenzione proprio al tema Education for All nel 2017. L'innovazione didattica universitaria è esplorata da sempre più atenei Italiani con modelli diversi. L'insegnamento della fisica è problematico soprattutto nei corsi di laurea scientifici non di fisica. A partire dai contributi di GEO con la CRUI ed alla luce di ricerche a livello internazionale, si propone la discussione di aspetti generali e specifici per il miglioramento dell'insegnamento universitario ed in particolare della fisica nei corsi di laurea in campo agro-biologico, riferendo di specifiche sperimentazioni.

▲ **Three years of projects in experimental physics at the University of Calabria.**
Pucci G. ([1])([2]), Sposato M. ([2]), Ferraro M. ([2]), Versace C. ([2]), Barberi R.C. ([2])
([1]) *CNR, Istituto di Nanotecnologia, Rende*
([2]) *Dipartimento di Fisica, Università della Calabria*
The Department of Physics at the University of Calabria has recently introduced projects in experimental physics within existing courses at both the bachelor's and master's levels. This teaching experimentation is a low-cost adaptation to the Italian university system of a class started in 1975 by Yves Couder and his colleagues at Université Paris Diderot. Groups of students design, build, and use a tabletop experimental setup, trying to answer questions issued by interesting physical phenomena. The instructors may not have any experience with the proposed topics and accompany the students in developing their projects. This method is intrinsically non-procedural and thus different from most courses in experimental physics. After giving details about the main features of the method we used, I will report what we learned from this teaching experience. Specifically, I will present some successful and unsuccessful ideas for student projects, report on students' feedback, and discuss how the method could be further implemented and improved in light of research in physics education.

Comunicazioni

● **A point-mass approach to the motion of rigid bodies down an inclined plane.**
Greco F.A. ([1]), Rizzo G.M. ([1]), Accurso G. ([1]), Frontera M. ([1]), Versace C. ([1])([2]), Pucci G. ([2])
([1]) *Dipartimento di Fisica, Università della Calabria*
([2]) *CNR, Istituto di Nanotecnologia, Rende, CS*
This work was born as a project in experimental physics in the context of the Laboratory of Mechanics and Thermodynamics course. Students were asked to study the motion of rigid bodies as if they knew the point-mass dynamics only. We propose an experiment in which students are led to discover that bodies with circular symmetry and the same shape take the same amount of time to roll down an inclined plane. Through an appropriate fit of the data, the students can find that the expression of the travel time is indeed identical to the point mass except for a multiplicative factor, which is different for each category of objects. This factor hides the geometric properties of the bodies and is thus related to the moment of inertia. In the end, we discuss how a similar result can be obtained by using dimensional analysis as a way to highlight the power of this tool to first-year students.

● **Esplorare la natura della scienza attraverso il paradosso di Zenone.**
Onorato P., Di Mauro M.
Dipartimento di Fisica, Università di Trento
Lo studio propone una sequenza di attività per discutere con gli studenti il processo di costruzione della conoscenza scientifica, in linea con i principi dell'educazione alla Natura

della Scienza (NoS). Le attività fanno parte di un corso di laboratorio fisica per studenti universitari di indirizzo didattico e si concentrano sull'esplorazione del paradosso di Achille e la tartaruga a partire dall'analisi sperimentali e teoriche di fenomeni che possono essere studiati tramite serie convergenti. La domanda se Zenone fosse uno scienziato o meno guida il percorso, facendo emergere le visioni opposte della scienza come dottrina e processo direttamente dalla discussione tra gli studenti. Queste visioni sono illustrate anche con una citazione del Paradosso di Achille ricostruita da Aristotele e un estratto da un articolo intitolato "Ombrellologia" di Somerville (1941).

Listen! It's a phase transition. The sound of a shape-memory alloy.

Rozzi C. A. ([1]), Lisotti A. ([2]), Goldoni G. ([1])([2]), De Renzi V. ([1])([2])
([1]) *CNR, Istituto Nanoscienze, Modena*
([2]) *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia*

Shape-memory alloys possess remarkable properties and find extensive technological applications owing to a solid-to-solid phase transition involving a temperature-induced rearrangement of their crystal lattice. In this study, we suggest a straightforward yet effective experiment to examine the sound emitted by a $Ni_{40}Ti_{50}Cu_{10}$ bar at various temperatures traversing the transition between martensite and austenite phases, which occurs slightly above room temperature. We explore the correlation between the sound, its perceived qualities and the material's elastic properties. Our findings demonstrate that the progress of the phase transition can be qualitatively discerned audibly, and a quantitative understanding of this phenomenon can be achieved through basic experimental setup and sound analysis tools. We argue that this approach offers a distinctive and engaging method for introducing undergraduate students to solid-to-solid phase transitions.

I fondamenti della Fisica Sperimentale: un percorso trasversale dai dottorandi alle matricole, di fisica e non solo.

Parravicini J.
Dipartimento di Fisica e Astronomia, Università di Firenze, LENS, Firenze e CNR-INO, Sezione di Firenze

Normalmente i curricula scientifico-tecnologici non presentano corsi che analizzino le basi della fisica e del metodo scientifico in generale. Perciò si è concepito un percorso didattico volto a stimolare riflessioni su quegli argomenti che in genere "si danno per scontati". Il percorso è diviso in tre branche: concetti e strumenti, struttura della conoscenza scientifica, pratica della conoscenza. Sono affrontati temi quali il rapporto tra matematica e realtà, le differenze tra osservazioni ed esperimenti, la disputa tra riduzionismo e non, l'informazione come grandezza fisica, i fondamenti della matematica, vero e falso nella fisica, buone e cattive pratiche scientifiche, i percorsi logici delle scoperte, la comunità degli scienziati, il valore sapienziale delle scienze. Tale percorso, fissato in un libro di recente pubblicazione, è proposto da ormai quattro anni a dottorandi in fisica e astronomia. Tuttavia esso è concepito perché possa essere compreso da tutti gli studenti di materie tecnico-scientifiche, a cui si auspica di estenderlo, affinché emerga una coscienza dei tanti elementi, tra loro eterogenei, che concorrono alla moderna fisica, base di tutto il sapere scientifico.

CAEN: strumenti didattici per una nuova generazione di scienziati.

Mattone C. ([1]), Maggiora A. ([2]), Mantovani F. ([3])([4]), Alberi M. ([3])([4]), Chiarelli E. ([3])([4]), Raptis K. ([3])([4]), Strati V. ([3])([4])
([1]) *CAEN S.p.A.*
([2]) *INFN, Sezione di Torino*

([3]) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara*
([4]) *INFN, Sezione di Ferrara*
Negli ultimi anni, Università e Istituti di Ricerca hanno sviluppato programmi e iniziative di divulgazione per rendere la fisica e le altre discipline scientifiche accessibili. L'obiettivo è stimolare l'interesse per la scienza, promuovere la comprensione dei principi fondamentali e ispirare le future generazioni di scienziati. CAEN, spin-off dell'INFN, ha sviluppato Kit Educativi per insegnare Statistica, Rivelazione di Particelle e Imaging Nucleare con l'obiettivo è ispirare gli studenti e guidarli nell'analisi dei fenomeni fisici con tecnologie all'avanguardia. In particolare, Cosmic Hunter, Detection System Plus e RockyRAD sono strumenti creati per applicazioni nel campo della radiazione ambientale, cosmica e terrestre. Il Cosmic Hunter e Detection System Plus sono sistemi è per la rivelazione dei raggi cosmici, basati su rivelazione di muoni su piastre scintillanti. Il RockyRAD è un geiger portatile che apre una finestra sul mondo delle radiazioni naturalmente emesse da suolo e rocce. Questi strumenti offrono agli studenti un accesso diretto alla fisica moderna tramite esperimenti pratici, facilitando l'integrazione della teoria con l'analisi critica dei risultati.

Mappatura emozionale della nascita della teoria della relatività ristretta.
Riccioni F., Levrini O.
Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna
Nel 1916 Max Wertheimer, esponente della Gestalt, intrattiene una serie di incontri con Albert Einstein a Berlino. Le conversazioni sono raccolte nel libro Il pensiero produttivo, nel capitolo Einstein: il pensiero che portò alla teoria della relatività. È un testo particolare che non esclude difficoltà e slanci emotivi dello scienziato utili a indagare il costrutto di emozione epistemica in fisica. Un primo risultato è stato estrapolare la visualizzazione della "feeling of direction" di Einstein attraverso una NLP-sentiment-analysis (positive - negative - neutral) avvenuta processando 70 espressioni stimolo estratte dal testo con la collaborazione di 7 ricercatori in didattica della fisica. È stata poi costituita una lista di 25 emozioni epistemiche per affinare la connotazione delle 70 parole stimolo e inserirle quantitativamente nel circumplex model of affect di Russel, ottenendo infine una dinamica emozionale della nascita di questa specifica teoria scientifica. Tre le metodologie in questa fase: machine learning, indagine statistica su un campione di 30 studenti del corso di didattica della fisica, valence evaluation con esperti di psicologia.

Raggi COsMICI - Un modo diverso di spiegare l'asrofisica delle alte energie a chi, giovanissimo, ha molte energie (di solito energie troppo alte per dare retta a chi spiega l'astrofisica delle alte energie).
Adamo A. ([1]), Del Santo M. ([1]), La Parola V. ([1]), Mineo T. ([1]), Sandrelli S. ([2]), Lupo A. ([3]), Argento Zangara A. ([4])
([1]) *INAF, Istituto di Astrofisica Spaziale e Fisica Cosmica, Palermo*
([2]) *INAF, Osservatorio Astronomico di Brera*
([3]) *Liceo Scientifico "G. Galilei", Palermo*
([4]) *Liceo Classico "G. Meli", Palermo*
Anni fa ho iniziato un po' per gioco a produrre fumetti incentrati su temi astrofisici che poi stampavo e lasciavo come volantini al pubblico accorso alle iniziative divulgative in cui, da assegnista INAF, venivo coinvolto. In seguito la cosa ha preso sempre più piede e si è arricchita di nuove esperienze e consapevolezze fino a diventare, oltre che una delle caratteristiche del mio lavoro di Tecnologo della Divulgazione, oggetto di una ricerca sui vantaggi offerti dall'uso del fumetto nella divulgazione del progetto ASTRI. In questo contributo illustrerò gli interessantissimi risultati di tale ricerca condotta con studenti di due licei, un classico e uno scientifico, e tesa a stabilire se vi è un effettivo vantaggio nell'adottare il fumetto

come strategia comunicativa non solo nella divulgazione, ma pure in ambito didattico. Si è trattato di un'indagine dal carattere comparativo: a valle della spiegazione di uno stesso argomento di fisica/astronomia compiuta in alcune classi con un testo, in altre con un video e in altre ancora con un fumetto, appunto, con opportuni questionari, sia quantitativi che qualitativi, ho misurato i risultati ottenuti dall'analisi delle risposte degli studenti.

Didattica e divulgazione: un connubio vincente.

Bollanti S., Murra D., Giovenale E.
ENEA, Centro Ricerche di Frascati

Sono ormai trascorsi quasi dieci anni dall'introduzione negli Istituti di istruzione secondaria superiore dei percorsi di Alternanza Scuola Lavoro (ASL), ora denominati Percorsi per le Competenze Trasversali e per l'Orientamento (PCTO). L'accoglienza di studenti presso i laboratori di ricerca fornisce loro l'opportunità di cimentarsi in attività stimolanti, tanto più quanto si riesce a realizzare in pratica esperimenti di cui essi hanno precedentemente solo studiato la teoria. Presentiamo qui alcuni percorsi di Alternanza Scuola Lavoro svolti nel Centro Ricerche ENEA di Frascati che hanno avuto una finalità molto particolare: realizzare dei dimostratori scientifici di specifici fenomeni fisici ed utilizzarli poi successivamente in occasione di eventi di divulgazione scientifica aperti al pubblico come gli Open Day della Ricerca. Il coinvolgimento in prima persona degli studenti nella presentazione e spiegazione dei dispositivi realizzati si è rivelato una carta vincente per stimolare una loro più profonda comprensione del fenomeno fisico sottostante. Un risvolto inaspettato dell'iniziativa si è inoltre avuto nella positiva interazione dei visitatori con i giovani divulgatori.

Un gioco di ruolo nell'apprendimento delle scienze dure: analisi e risultati di un approccio didattico innovativo.

Bufalino S., Galante L., Gallerati A.
Politecnico di Torino e INFN, Sezione di Torino

Il presente contributo è dedicato alla descrizione di un corso di approfondimento di fisica dedicato a studenti del primo anno del Politecnico di Torino. Il corso è stato utilizzato per sperimentare metodologie didattiche "student centred" e di "authentic learning". Nell'arco di due anni accademici, ha coinvolto 4 docenti e 500 studenti. Gli studenti sono stati coinvolti in un gioco di ruolo (GDR) che li ha visti interpretare il ruolo di fisici delle particelle e affrontare, a gruppi, sfide legate al mondo reale della ricerca in fisica. Ogni incontro è stato organizzato con mini-lecture a cui è seguito un lavoro autonomo da parte degli studenti. A tale scopo sono stati realizzati ambienti di apprendimento progettati per stimolare il ragionamento e il pensiero critico. I gruppi sono stati introdotti a dati sperimentali raccolti da un esperimento reale di fisica delle particelle e sono stati guidati all'analisi dei dati e alla loro interpretazione. Oltre alla descrizione del metodo didattico, verranno presentati i risultati dello studio dei processi di ragionamento adottati dagli studenti e l'analisi della loro risposta a stimoli di apprendimento attivo e autentico.

Aula A **ore 15:00 – 19:30**

Simposio sul Supercalcolo

Emerging data and computing technologies for frontier physics

Presiede: Baroni S. (SISSA, Trieste)

Relazioni su invito

▲ **Efficient computation of molecular and materials properties on heterogeneous HPC architectures with the Quantum ESPRESSO suite.**

Carnimeo I.
SISSA, Trieste

Heterogeneous architectures have become a de facto standard in HPC, with the majority of the world's leading exascale and pre-exascale machines being equipped with GPUs. Material science is advancing alongside developments in computer science, with scientific codes being continually refined to exploit the enhanced capabilities of HPC. Quantum ESPRESSO (QE), a suite of Open-Source computer codes for electronic-structure calculations and materials modelling, allows to compute a broad range of chemical and physical properties of molecules and condensed matter systems. Enabling quantum materials discovery and design towards exascale and extreme scaling performance on present and future HPC machines is one of the pillars of the development of the QE suite. In the last years, an extensive work has been done to enable deployment of the suite on modern HPC supercomputers, allowing to compute challenging materials properties, at higher resolution, longer time scales, and greater accuracy. In this contribution the main scientific and technical challenges encountered in this work will be presented, illustrating with example applications the potentialities of HPC for realistic simulations.

▲ **Magnetism in the flatland through the lens of high-performance computing.**

Picozzi S.
CNR-SPIN, Chieti

Magnetism and multiferroicity (i.e. the coexistence between long-range magnetic and electric dipolar or-der) constitute two related landmark phenomena in quantum physics, where profound fundamental aspects (i.e. microscopic interactions between spin and charge degrees of freedom) are intimately related to technological milestones (multifunctional devices tuned by electric/magnetic fields). In this context, the reduction of dimensionality from 3D to 2D has been boosted by the recent discoveries of multiferroicity in NiI2 layers, obtained via a joint theory-experiments approach down to the single-layer limit. I will show several examples of first-principles modelling for magnetic and multiferroic 2D-materials, highlighting the potentiality of cross-coupling phenomena in van der Waals materials. If time permits, I will also present the computational package "AMaRaNTA" (Automating MAgnetic paRAmeters iN a Tensorial Approach), offering a systematic way of automating Density Functional Theory simulations of exchange parameters for 2D magnets.

Comunicazioni

● **FFTXlib: 3D fast Fourier transforms for HPC simulations of materials.**

Ferrari Ruffino F.
CNR-IOM

Large part of modern scientific software rely on mathematical libraries, which heavily determine their overall performance on HPC systems. An important class of such libraries are

the ones performing 3D Fast Fourier Transforms (FFT). Currently, state of the art APIs can deal with grids of the order of $10k^3$ points or even more. Such APIs are internally tailored on the specific vendor technologies and are based on standard mathematical procedures and domain decompositions. On the one side they can squeeze the computational power from their own vendor HPC architectures, on the other side they may not perform at all on other architectures. Moreover, they might not be the best solution for specific problems that involve particular level of parallelism and domain features. For these reasons tailored libraries which require active development by the scientific community are often still a good choice. We bring the example of FFTXlib, an FFT library belonging to the Quantum ESPRESSO suite that has been built specifically for DFT problems in material science by exploiting features typical of such computations and with the aim to perform on a rather large variety of HPC architectures.

Democratizing quantum simulations: Materys platform makes cutting-edge science accessible.

Bertossa R.
Materys srl

Deploying cutting-edge computer simulation methods in physics, chemistry, and materials science demands advanced IT and applied math skills. This includes mastery of Unix-like systems, queuing systems, parallelisation techniques, as well as a deep understanding of algorithms and hardware architecture. This scenario presents a significant hurdle to the adoption of quantum mechanical simulation techniques, especially in industry, where they hold the promise of revolutionising R&D. The availability of on-demand computing resources in the cloud and the latest cluster and workflow management technologies are making it possible to design online platforms accessible from a browser, capable of hiding these complexities and provide advanced simulation solutions as a service. In this contribution I will present one such platform, developed by a recently established SISSA startup, called Materys. The Materys platform is expandable and organised in multiple layers. It facilitates the development of fully automated vertical applications, easily shareable with other research groups. All technical computer parameters are selected automatically, allowing users to concentrate solely on the science.

Emerging data and computing technologies for frontier physics. The OpenGADGET3 code for cosmological simulations.

Valentini M.
Università di Trieste

Cosmological simulations are powerful tools in the context of structure formation. They allow us to explore the hierarchical assembly of dark matter (DM) halos and their clustering, to validate or reject possible scenarios of structure formation, and to pose constraints on the nature of DM. I will present our ongoing work on the developer version of the OpenGADGET3 code, along with selected results from cosmological simulations that we have carried out with the aforementioned code. This Lagrangian, TreePM+SPH code can sample both collisionless (e.g., stars and DM) and collisional (gas) fluids with particles. OpenGADGET3 is fully MPI (Message Passing Interface) parallelized and highly optimized to efficiently scale up to several hundreds of cores. Besides making use of the MPI among computing cores and nodes, it benefits from the OpenMP within a single shared-memory node. The hybrid MPI/OpenMP implementation of the current branch of OpenGADGET3 also has OpenACC support for GPUs. Our computational effort fits within the framework of high-performance supercomputing and is supported by the Italian research center on high-performance computing, big data and quantum computing.

● **Uso di nodi ARM nella fisica delle alte energie.**
Noferini F. ([1]), Spiga D. ([1]), Boccali T. ([1]), Anderlini L. ([1]), Bozzi C. ([1]), Rinaldi L. ([1])([2]), Carminati L. ([1]), Veltri M. ([1])
([1]) *INFN, Sezione di Bologna*
([2]) *Università di Bologna*
Da diversi anni gli esperimenti di Fisica delle alte energie hanno iniziato a portare il codice di esperimento anche su architetture eterogenee: per esempio dotate di acceleratori grafici (GPU) e architetture ARM. Tale spinta è stata dettata dalla possibilità di trovare risorse opportunistiche disponibili nei centri di calcolo e di valutare l'acquisizione di risorse a minor impatto energetico: le architetture ARM sono un potenziale candidato nel secondo caso. La validazione del software degli esperimenti su tali architetture è un requisito fondamentale per gli esperimenti per poter passare ad un loro utilizzo in produzione. Nell'ambito dello Spoke 2 del progetto del Centro Nazionale di Supercalcolo (PNRR) è stato previsto, tra i vari obiettivi, la validazione del software per diversi esperimenti su architetture ARM. In tale ambito si discuterà lo stato di avanzamento del progetto e le sue prospettive future.

Relazioni su invito

▲ **Continuous integration of analysis workflows on a distributed analysis facility.**
Bartolini M., Lenzi P., Villani L., Lizzo M.
Università di Firenze
This contribution explores enabling Continuous Integration (CI) with CMS datasets using the XRootD IO protocol and dynamic proxy generation. This, coupled with GitLab CI/CD functionalities, allows triggering analysis executions via commits, enhancing reproducibility and workflow automation. Dynamic auth access tokens enable offloading CPU-intensive calculations to on-demand computing resources, including regional CMS Tier-2 facilities and the national-wide datalake model within the ICSC project. This integration simplifies job submission to HTCondor within GitLab CI, automating big dataset handling. In this way analysts can more easily run tests, perform parallel analyses, and track changes.

Comunicazioni

● **Ottimizzazione di una piattaforma fotonica per la generazione di qudit.**
Ciardiello A., Suprano A., Zia D., Spagnolo N., Sciarrino F., Giagu S.
Dipartimento di Fisica, Sapienza Università di Roma
In informazione quantistica, la generazione di stati ad alta dimensionalità (qudit) è di interesse per applicazioni in comunicazione, computazione e crittografia. I qudit permettono di codificare un maggiore contenuto informativo in un singolo portatore e forniscono protocolli di trasmissione più sicuri. Abbiamo realizzato un sistema software di ottimizzazione dei parametri di un circuito ottico, basato su un framework di programmazione differenziabile, per generare stati di momento angolare orbitale (OAM) fotonici ad alta efficienza e fedeltà. Questo sistema può essere interfacciato, nel setup sperimentale, con un apparato di controllo meccanico degli angoli di rotazione di una serie di lamine per generare stati arbitrari a bassa latenza. Questa soluzione migliora il protocollo di trasmissione e ne incrementa l'efficienza in termini di qualità degli stati e di velocità di generazione degli stessi. Lo sviluppo di una soluzione affidabile di generazione dell'OAM ha un potenziale impatto in diversi campi della fisica e della tecnologia, che vanno dalla comunicazione, alla sicurezza informatica, alla fisica sperimentale, alla metrologia e allo sviluppo in ottica e fotonica.

Come prepararsi all'AI act? Applicazione di un flusso di lavoro di ethics-based auditing a un progetto di ricerca applicata.

Barelli E. ([1]), Becca M. ([1]), Lanzoni M. ([2]), Manes P. ([3]), Rotolo A. ([4]), Salmi S. ([2]), Zanaroli M. ([5])

([1]) *International Foundation Big Data and Artificial Intelligence for Human Development, Bologna*

([2]) *SCS Consulting, Zola Predosa, Bologna*

([3]) *Dipartimento delle Arti, Università di Bologna*

([4]) *Dipartimento di Scienze Giuridiche, Università di Bologna*

([5]) *Fondazione ICSC Centro Nazionale di Ricerca in High Performance Computing, Big Data e Quantum Computing, Casalecchio di Reno, Bologna*

Tra le applicazioni del supercalcolo, i sistemi di Intelligenza Artificiale ricoprono un ruolo sempre più rilevante in ogni settore e filiera. Tuttavia, alla luce del nascente regolamento europeo sull'IA (AI Act), è richiesto alle organizzazioni di adottare in modo proattivo approcci che dimostrino la conformità dei propri sistemi e progetti ai principi di sicurezza, privacy, trasparenza e benessere socio-ambientale. Nella comunicazione, si presenta l'applicazione di un possibile approccio di valutazione quali-quantitativa a supporto della compliance dei progetti di ricerca e innovazione a quanto introdotto dall'AI Act. Come caso di studio, si mostra un flusso di lavoro applicato ad un progetto finanziato nell'ambito dei fondi di innovazione del Centro Nazionale di Ricerca in HPC e coordinato da IFAB (International Foundation Big Data and Artificial Intelligence for Human Development) in partnership con università, enti di ricerca ed aziende. Particolare rilievo sarà dato alla metodologia sottostante la verifica di conformità e il governo di dati e sistemi di IA in ottica risk-based, con valutazioni nelle fasi di progettazione, implementazione e successiva valorizzazione.

Aula Magna **ore 09:00 – 13:30**

Sezione I
Fisica nucleare e subnucleare
Presiede: Terrevoli C. (INFN, Sezione di Bari)

Relazioni su invito

▲ **n_TOF experiment at CERN.**
Cosentino L.
INFN, Laboratori Nazionali del Sud
The n_TOF experiment operating at CERN aims to measure high-precision cross sections in neutron-induced reactions, from thermal energy up to about 1 GeV. The availability of three experimental areas with high neutron flux and high energy resolution, makes the n_TOF facility the ideal site for challenging measurements with very low cross sections or using highly radioactive samples, as well as for experiments where resolving very narrow resonances is required. The experimental program is particularly focused on nuclear astrophysics and nuclear energy technology, although several experiments have been performed over the years for fundamental research, new cancer therapies and other applications. The availability of the recently developed irradiation area NEAR, placed just a few meters away from the spallation target, also makes possible to characterize radiation damage on materials and electronic components, as well as to perform neutron activation measurements of astrophysical interest. The presentation will present an overview of the facility and experimental activities, with a particular focus on the most significant recent results achieved by the INFN collaboration.

▲ **Nuclear structure with state-of-the-art GAMMA spectroscopy.**
Leoni S. for the GAMMA Collaboration, CNS3 INFN
Università di Milano e INFN, Sezione di Milano
Understanding the structure of atomic nuclei, across the Segrè chart, is one of the greatest challenges of modern nuclear physics, with strong connection with nuclear reactions and decays, nuclear astrophysical phenomena, as well as societal applications, including medicine and energy productions. Within the experiment GAMMA of INFN, nuclear structure properties are investigated with state-of-the-art gamma spectroscopy techniques in a series of experimental campaigns, often complementary, at international laboratories in Europe, America and Japan, exploiting stable and radioactive ion beams, and intense neutron beams. The complex experimental setups are based on large arrays of HPGe detectors, like the European gamma-tracking array AGATA (currently operational at the Legnaro National Laboratory of INFN), coupled to sophisticated ancillary detection systems for charged particles, neutrons and high-energy gamma-rays detection. The talk will present selected highlights from recent experiments aiming at shedding light on fundamental properties of the strong force.

▲ **NUMEN project: Status and perspective.**
Agodi C. for the NUMEN Collaboration
INFN, Laboratori Nazionali del Sud
NUMEN project aims to provide information on the Nuclear Matrix Elements that enter in the expression of the neutrino-less double beta ($0\nu\beta\beta$) decay half-life. The tools proposed by NUMEN project are the cross-section measurements of nuclear Double Charge Exchange (DCE) reactions. The search for $0\nu\beta\beta$ decay is currently a key topic in physics. DCE

reactions with heavy ions, whose investigation is pursued within the NUMEN project, are an exciting new frontier, also because of their possible analogy with $0\nu\beta\beta$ decay. The key aspects are that the two processes, beyond involving the same nuclear configurations, are both represented by transition operators that are a superposition of short-range isospin, spin-isospin, and rank-two tensor components with a relevant available momentum. Thus, DCE experimental cross sections can be considered as important benchmarks for theoretical models. Tuning the models on experimental data will increase their predictive power for the evaluation of $0\nu\beta\beta$ NMEs, reducing the spread presently existing among the various calculations.

▲ **Prospettive sulla fisica nucleare in plasma ai LNS: le facility PANDORA e I-LUCE.**

Santonocito D., Mascali D., Cirrone P.G.A.
INFN, Laboratori Nazionali del Sud

Nei prossimi anni, entreranno in funzione, presso i LNS, due nuove facility, PANDORA e I-LUCE che permetteranno di intraprendere nuovi studi nell'ambito della fisica dei plasmi, della fisica nucleare e della fisica atomica. Si tratta di due approcci complementari, uno basato su plasmi a confinamento magnetico e l'altro su plasmi generati da laser di alta potenza. PANDORA utilizzerà un plasma a confinamento magnetico ottenuto grazie ad una trappola magnetica per investigare, per la prima volta, possibili variazioni della vita media, indotte dall'ambiente di plasma, di alcuni radioisotopi di interesse astrofisico che decadono per emissione beta simulando così il decadimento in alcuni ambienti stellari. I-LUCE si baserà su un laser di alta potenza trasportato in due configurazioni: 50 TW (25 fs, 25-30 mJ, 10 Hz) e 350 TW (25 fs, 10 J, 2 Hz). I due laser saranno inviati in due distinte aree sperimentali utilizzate per studiare l'interazione tra plasmi generati da laser con fasci ionici prodotti dagli acceleratori LNS e per studi di accelerazione di elettroni, protoni e neutroni. Verranno presentate le caratteristiche delle due facility e la fisica che si intende affrontare.

Comunicazioni

● **Studio dello scattering coerente neutrino-nucleo con l'esperimento NuCleus.**

Giammei M. ([1])([2]), Cerulli R. ([1])([2]), Tomei C. ([1])
([1]) *INFN, Sezione di Roma Tor Vergata*
([2]) *Università di Roma Tor Vergata*

Lo scattering elastico coerente neutrino-nucleo (CENS) fu predetto nel Modello Standard (SM) già nel 1973 ma osservato per la prima volta solo nel 2017: il motivo di ciò risiede nella bassa energia di rinculo del nucleo coinvolto, il che rende necessario l'impiego di rivelatori con soglia energetica dell'ordine di 100 eV. Lo scopo dell'esperimento NUCLEUS è proprio quello di misurare la sezione d'urto del CES al livello del 5-10% di precisione. Il bersaglio di NUCLEUS è composto da matrici 3×3 di cristalli di CaWO4 e Al2O3 , per una massa totale di circa 10g; i cristalli operano ad una temperatura di circa 10 mK, sono equipaggiati da Transition Edge Sensors fatti di tungsteno (W-TES) e sono circondati da un sistema complesso di schermature attive e passive, criogeniche e non. NUCLEUS è attualmente in fase di commissioning all'Università Tecnica di Monaco e verrà installato nella centrale nucleare di Chooz nel 2025. In futuro è prevista la realizzazione di un nuovo rivelatore di circa 1 kg che potrà raggiungere una precisione stimata sulla sezione d'urto di circa l'1%.

● **Recoil-proton track reconstruction techniques for tracking fast neutrons.**

Lanzi S. ([1])([4]), Console Camprini P. ([2])([3]), Giacomini F. ([4]), Massimi C. ([1])([2]), Mengarelli A. ([2]), Musumarra A. ([5])
([1]) *Dipartimento di Fisica e Astronomia, Università di Bologna*
([2]) *INFN, Sezione di Bologna*

([3]) *ENEA, Frascati*
([4]) *INFN-CNAF, Bologna*
([5]) *Dipartimento di Fisica e Astronomia, Università di Catania*
Neutron momentum reconstruction is relevant for various scientific fields, including nuclear, particle, and astroparticle physics, radiotherapy, and radiation protection. In this context, RIPTIDE is a novel concept of recoil-proton track imaging system for fast neutrons. Based on neutron-proton (n-p) elastic scattering, it RIPTIDE aims at imaging the light output of a fast plastic scintillator, thus obtaining the spatial and temporal reconstruction of the n-p scattering event. In this context, the development of innovative track reconstruction techniques is essential. In this contribution I will present and compare various analysis techniques, starting from the well-established Hough transform, moving on to an analysis based on the moments of the photon distributions observed by the detector, and finally comparing these algorithms with deep learning algorithms based on convolutional neural networks.

Octupole collectivity in ^{96}Zr from low-energy Coulomb excitation with the AGATA+SPIDER setup.

Ercolano F. ([1]), Marchini N. ([2])
([1]) *INFN, Sezione di Napoli*
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An experiment was performed to investigate the octupole collectivity in the ^{96}Zr isotope. Previous measurements suggested that the γ-ray transition probability for the first 3^- state is one of the largest across the nuclear chart. This observation has never been reproduced by any theoretical calculations. A recent study, instead, provides a significantly reduced γ-ray transition probability for the $3_1^- \rightarrow 0_1^+$ transition, which is in better agreement with state-of-the-art shell-model calculations. Nevertheless, up to now the experimental values were obtained only via indirect methods. We performed a dedicated Coulomb-excitation study of the nucleus ^{96}Zr utilising the AGATA+SPIDER setup at INFN-LNL. This investigation is extremely timely in order to provide directly the $3_1^- \rightarrow 0_1^+$ γ-ray transition probability for the first time. In this contribution, we will present the preliminary results on the decay of this state to the ground state. The obtained B(E3) value seems to confirm how this quantity is not as large as previously thought, supporting the idea that it does not represent an outstanding value in the nuclide chart.

RIPTIDE: A detector for fast neutrons tracking.

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The determination of fast neutrons initial direction is still a challenge despite several attemps. Most of these techniques exploit single and double neutron-to-proton elastic scattering - referred to as Recoil Proton Track Imaging (RPTI) - to determine the incoming neutron energy or/and momentum, but none of them are currently operational. We propose RIPTIDE, a fast neutron detector based on RPTI. It consists of a solid plastic scintillator coupled with imaging devices. The light produced by a recoil proton inside the scintillator is focused with

a system of lenses on an high-sensitivity CMOS sensor. Two or three cameras allow us to 3D-reconstruct the proton tracks. The stereoscopic imaging of the tracks let us to obtain information on the incoming neutron energy and momentum and enables particle discrimination. Monte Carlo simulations have been built to determine the best detector setup to optimize the efficiency and the track reconstruction algorithms. We report the progresses of the RIPTIDE detector as well as the track reconstruction algorithm advances to determine the proton mometum. Some techniques used to characterize the camera specifications are also described.

Sviluppo di cristalli scintillatori di Cs_2ZrCl_6 per lo studio di processi rari negli isotopi naturali di Zr.

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Recentemente si è sviluppato un notevole interesse nello sviluppo di cristalli scintillatori della famiglia degli esacloruri metallici Cs_2MCl_6 (M = Hf o Zr) grazie alle loro eccezionali proprietà, tra cui un'elevata resa di luce (fino a 40000 fotoni/MeV), ottima linearità nella risposta energetica, eccellente risoluzione energetica ($< 3.5\%$ a 662 keV) e un'eccellente capacità di discriminazione della forma dell'impulso (PSD) tra le particelle $\gamma(\beta)$ e α. Un esperimento utilizzando due cristalli scintillatori Cs_2ZrCl_6 (CZC) è stato condotto presso il setup sperimentale a basso fondo DAMA/CRYS ai LNGS. La purezza chimica, i contaminanti radioattivi residui, le prestazioni di scintillazione, le performance della PSD sono qui presentati, insieme ai risultati sui decadimenti beta singolo e doppio beta in isotopi di ^{94,96}Zr. Un altro esperimento è stato eseguito successivamente utilizzando tre nuovi cristalli CZC, cresciuti utilizzando differenti purezze dei materiali di partenza per poterne studiare le caratteristiche e incapsulati utilizzando un sigillante a base di silicone. Sono qui presentati i risultati ottenuti.

Investigations on photoproduction off quasi-free neutron at Graal.

Riggio A.
Dipartimento MIFT, Università di Messina e INFN

An investigation on η' photoproduction on quasi-free neutron (Deuterium target) is presented, by showing a preliminary estimation of Beam Asimmetry Σ as function of polar angle in the center of mass system near the threshold by analyzing the experimental data of GRAAL experiment. The η' photoproduction channel is useful because it acts as an isospin filter, allowing to select only resonant contributions with one half isospin. The preliminary Σ measurements for the η' photoproduction off neutron was performed in the energy interval of the interacting γ photon [1447-1475] MeV for four bins in the θ. The present estimations have been compared with the data on the proton channel, published by GRAAL experiment, and they are consistent.

Studio con metodi Montecarlo di efficienza e probabilità di cross-talk per NArCoS: un nuovo correlatore per neutroni e particelle cariche.

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Il progetto NArCoS (Neutron Array for Correlation Studies) prevede lo studio e lo sviluppo di un nuovo apparato che sia in grado di rivelare, al tempo stesso, neutroni e particelle cariche con elevata risoluzione angolare ed energetica. La rivelazione di neutroni rappresenta un importante traguardo per i futuri esperimenti con fasci radioattivi (RIBs), soprattutto per quelli ricchi di neutroni, offrendo la possibilità di ampliare le nostre conoscenze relative alla struttura nucleare e alla dinamica delle reazioni fra sistemi a grande asimmetria di isospin. Il prototipo finale di NArCoS prevede l'utilizzo di 64 celle di rivelazione ciascuna costituita da uno scintillatore plastico, EJ-276, accoppiato ad una matrice di SiPM. Nel presente contributo sarà riportato il confronto fra i risultati relativi a efficienza e probabilità di cross-talk ottenuti grazie all'utilizzo di due diversi software di simulazione: GEANT4 e MCNPX. Tali studi sono finalizzati a valutare il miglior setup per lo sviluppo del modulo base (cluster) del nuovo rivelatore, minimizzando la probabilità di cross-talk e massimizzando l'efficienza di rivelazione per neutroni.

Study of light nuclei via gamma spectroscopy using the AGATA-PRISMA spectrometer.

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We present recent AGATA-PRISMA results obtained at Laboratori Nazionali di Legnaro to study the transition into the $N = 20$ Island of Inversion by multi-nucleon transfer reactions using a ^{22}Ne beam and a ^{238}U target. The experiment aims at exploring the boundaries of the Island of Inversion, following the evolution of negative parity states from the fp shell, locating excited intruder configurations and tracking the development of quadrupole and octupole collectivity toward $N = 20$. This study is primarily focused on the spectroscopy of Ne and F isotopes with neutron number $N = 10 - 16$ to benchamrk state-of-the-art nuclear structure theories. The experimental setup, comprising the AGATA γ array coupled to the PRISMA magnetic spectrometer, allowed us to detect and identify the ions of interest and measure, in coincidence, γ rays from excited states. Preliminary results and future perspectives will be discussed.

New measurements of the ^{19}F(p, α_0)^{16}O and ^{19}F(p, α_π)^{16}O* reaction cross sections close to the Coulomb barrier.

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New absolute cross section measurements of the ^{19}F(p, α_0)^{16}O and ^{19}F(p, α_π)^{16}O* reactions at energies close to the Coulomb barrier are presented. The achievement of low-noise and high-resolution energy spectra in this experiment allowed to resolve the 6.05-6.13 MeV doublet in ^{16}O. In particular, the α_π channel cross section was measured in the data-poor 1.3 MeV bombarding energy region, and the α_0 channel was investigated in the 1.6 MeV region, where a strong discrepancy is present between previous data-sets. A comprehensive R-matrix fit was performed with the inclusion of the new data, and the structure of the ^{20}Ne states ranging in the 14-15 MeV region is discussed.

Possibili stati a cluster alfa nel ^{16}O ad alta energia.

Lombardo I., Redigolo L., Dell'Aquila D., Vigilante M., per la NUCL-EX Collaboration
Università di Catania e INFN, Sezione di Catania

Vengono riportati i recenti risultati sperimentali dell'esperimento HELICA condotto all'acceleratore AN2000 dei Lab. Naz. di Legnaro, nel quale fasci di ^{3}He ad energie da 1.4 a 2.2 MeV bombardavano bersagli di ^{13}C. L'utilizzo dell'hodoscopio OSCAR ha permesso di investigare i canali di reazione in cui il nucleo composto di ^{16}O eccitato attorno a 24 MeV decadeva in $\alpha + ^{12}$C, incluso l'elusivo canale in cui il ^{12}C è eccitato nello stato di Hoyle, portando all'emissione di 4 α nel canale di uscita. L'analisi dei rapporti di diramazione dei decadimenti suggerisce la presenza di stati risonanti nel ^{16}O attorno a 24 MeV con una marcata struttura a cluster α.

ACCESS: Research program and preliminary results on the spectral shape of In-115.

Pagnanini L.

Gran Sasso Science Institute e INFN, Laboratori Nazionali del Gran Sasso

The ACCESS (Array of Cryogenic Calorimeters to Evaluate Spectral Shapes) project aims to establish a novel detector to perform a precise study of the spectral shape of forbidden β-decays. These strongly suppressed processes can help to clarify the long-standing issue of the axial coupling constant (gA) quenching. Moreover, such rare decays are also a common source of systematic uncertainty in Dark Matter and Neutrinoless Double Beta Decay experiments, where detailed knowledge of the shape of the background spectrum is required. In this contribution, we will present a brief review of the ACCESS research program, aiming to study natural (Cd-113 and In-115) and synthetic isotopes (Tc-99), which will be measured with a common experimental technique. The main focus will be on the recent results achieved for In-115.

L'esperimento CHIFAR @ LNS, primi risultati.

Zagami C. ([1])([2])([3]), Pagano E. V. ([2]), Russotto P. ([2]), De Filippo E. ([4]), Acosta L. ([5])([6]), Cap T. ([7]), Cardella G. ([4]), Fichera F. ([4]), Geraci E. ([1])([3])([4]), Gnoffo B. ([1])([4]), Guazzoni C. ([8])([9]), Lanzalone G. ([2])([10]), Maiolino C. ([2]), Martorana N. S. ([4]), Matulewicz T. ([7]), Pagano A. ([4]), Papa M. ([4]), Piasecki K. ([7]), Pirrone S. ([4]), Piscopo M. ([2]), Planeta R. ([11]), Politi G. ([1])([4]), Risitano F. ([4])([12]), Rizzo F. ([1])([2])([3]), Saccà G. ([4]), Santagati G. ([4]), Siwek-Wilczynska K. ([7]), Skwira-Chalot I. ([7]), Trimarchi M. ([4])([12])

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Tra gli obiettivi dell'esperimento CHIFAR condotto ai LNS-INFN, vi è lo studio della comprensione dell'Equazione di Stato della materia nucleare tramite l'analisi della probabilità di emissione dei Frammenti di Massa Intermedia (IMFs) e del ruolo dell'isospin dei nuclei collidenti. La collaborazione CHIMERA ha analizzato reazioni nucleari ottenute dai fasci di ^{124}Sn, ^{112}Sn e ^{124}Xe, con target di ^{64}Ni, ^{58}Ni e ^{64}Zn, ad energia incidente di 20 AMeV. Lo studio di correlazioni tra IMFs è stato possibile dall'accoppiamento di 10 telescopi del correlatore FARCOS (Femtoscope ARray for COrrelation and Spectroscopy), avente alta risoluzione energetica e angolare, con il multi-rivelatore 4π CHIMERA. Ciascun telescopio di FARCOS è costituito da 2 Double Sided Silicon Strip Detectors (DSSSD), spessore 300 μm e 1500 μm, e da 4 cristalli di CsI(Tl), spessore 6 cm. Saranno presentati risultati preliminari relativi a rapporti isotopici delle particelle e loro distribuzioni energetiche ed angolari, misurate con FARCOS.

Risultati preliminari dell'esperimento CROSSTEST ai LNL.

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Rivelare neutroni e particelle cariche leggere con alta risoluzione angolare ed energetica acquisisce una importanza strategica per i futuri studi di dinamica e struttura nucleare che saranno condotti con i fasci radioattivi prodotti nelle nuove facilities come FRAISE ai LNS, SPES ai LNL e FAIR al GSI, per fare qualche esempio europeo. La costruzione di un prototipo di correlatore, per neutroni e particelle cariche NArCoS (Neutron Array for Correlation Studies) è un obiettivo dell'esperimento CHIRONE (CNS3) e ha tratto nuova linfa dal progetto PRIN ANCHISE (2020H8YFRE), che tra i sui scopi si propone di utilizzare un materiale scintillatore di nuova generazione (EJ276) accoppiato a fotosensori compatti (SiPM) come elemento base di rivelazione. Nel presente contributo verrà presentata l'analisi preliminare dell'esperimento CROSSTEST, eseguito presso la facility CN dei LNL-INFN volto alla misura della probabilità di crosstalk tra le celle elementari del prototipo del nuovo correlatore NArCoS.

Studio sulla calibrazione e metodo di pixellizzazione di rivelatori DSSSD dell'array FARCOS preso i LNS.

Risitano F. ([1])([2]), Gnoffo B. ([1])([3]), Trimarchi M. ([1])([2]), Acosta L. ([4])([5]), Cardella G. ([1]), De Filippo E. ([1]), Dell'Aquila D. ([5])([6]), Geraci E. ([1])([3]), Lombardo I. ([1])([3]), Maiolino C. ([8]), Martorana N.S. ([1]), Pagano A. ([1]), Pagano E.V. ([8]), Papa M. ([1]), Pirrone S. ([1]), Politi G. ([1])([3]), Quattrocchi L. ([1])([2]), Rizzo F. ([3])([8])([9]), Russotto P. ([8]), Zagami C. ([3])([8])([9])

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I rivelatori DSSSD (Double Sided Silicon Strip Detector) sono ampiamente utilizzati nel contesto della fisica nucleare degli ioni pesanti grazie alle caratteristiche e prestazioni che possono offrire. Ai Laboratori Nazionali del Sud dell'INFN, nel contesto della collaborazione CHIRONE, sono stati sviluppati i moduli FARCOS (Femtoscope ARray for COrrenation and Spectroscopy), che, tramite l'uso di DSSSD, permettono di ottenere ottime risoluzioni

angolari ed energetiche. I telescopi FARCOS sono costituiti da tre stadi: due DSSSD (300 e 1500 μm di spessore), seguiti da 4 scintillatori di CsI(Tl) (6 cm di spessore). Grazie alle 32 strip sul lato frontale e 32 sul lato posteriore, ortogonali tra di loro, i DSSSD offrono una elevata accuratezza nel calcolo dell'angolo di scattering e della perdita di energia dello ione. La calibrazione energetica di ogni strip e la ricostruzione della traccia delle particelle è spesso una operazione impegnativa nell'analisi di tali rivelatori. In quest'ambito saranno mostrati i metodi di calibrazione sviluppati delle strip dei DSSSD di telescopi FARCOS, illustrando le tecniche di pixellizzazione e alcuni risultati preliminari di spettroscopia.

Deuterium-Deuterium measurement proposal.

Casaburo F. ([1])([2]), Corvisiero P. ([1])([2]), Elekes Z. ([1]), Gervino G. ([3])([4]), Gustavino C. ([5]), Mastinu P. ([6]), Musacchio Gonzalez E. ([6])
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The $\mathrm{d} + \mathrm{d} \rightarrow {}^3\mathrm{H} + \mathrm{p}$ and $\mathrm{d} + \mathrm{d} \rightarrow {}^3\mathrm{H} + \mathrm{n}$ reactions are of primary importance both in cosmology and in theoretical nuclear physics since they offer a unique opportunity to test predictions based on the description of nuclear interactions. They play a fundamental role in nuclear astrophysics in understanding stellar fusion processes and helium production in stars, but the main interest in realising a high precision measurement lies in describing the formation of the light elements during the first three minutes of the Universe life, immediately after the Big Bang. In particular, after the precise measurement S-factor of the reaction $\mathrm{p} + \mathrm{d} \rightarrow {}^3\mathrm{H} + \gamma$ achieved by the LUNA collaboration, the main the main experimental uncertainties in describing the early Universe baryon density lie in this reaction. A proposal to measure the S-factor as well as the angular distribution of both $d + d$ output channels using an intense deuterium beam impinging on a very pure deuterium gas target will be presented. The importance of a precise measurement of this reaction is not only related to cosmology: experimental results will also be used to test nuclear physics.

Aula 1D **ore 09:00 – 13:30**

Sezione II
Fisica della materia
Presiede: Cataliotti F.S. (Università di Firenze)

Relazioni su invito

▲ **Superconducting hardware of a quantum computer: Physics, implementation, operation and perspetives.**
Tafuri F. ([1]), Ahmad H.G. ([1]), Mastrovito P. ([1]), Satariano R. ([1]), Serpico G. ([1]), Cosenza C. ([1]), Stasino V. ([1]), Levochkina A. ([1]), Arzeo M. ([2]), Ausanio G. ([1]), Di Palma L. ([2]), Esposito M. ([3]), Montemurro D. ([1]), Parlato L. ([1]), Bruno A. ([4]), Arthers M. ([4]), Mukhanov O. ([5]), Pepe G.P. ([1]), Massarotti D. ([6])
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Superconducting circuits have been up to now the most successful platform to build a quantum computer, being used by major international companies since early stages. Napoli has a long-standing experience on superconducting electronics and on its key device, *i.e.*, the Josephson junction, and has been working to assemble a superconducting quantum computer, also within the framework of the High Performance Computing, Big Data and Quantum Computing Center. These efforts are being also supported by several international projects and collaborations. We are currently working on a 24-qubits processor produced by Quantware aiming at a QPU with more than 40-qubits by the end of the year, also running basic algorithms. This remarkable search in novel hardware solutions also in collaboration with leading companies like SEEQC and Quantware has promoted intensive research of novel quantum components, ranging from an innovative type of qubits based on ferromagnetic Josephson junctions to qubit readout based on a Josephson digital phase detector compatible with single-flux-quantum (SFQ) classical circuits, which are among the themes of the National Quantum Science and Technology Institute (NQSTI).

▲ **Deep learning and quantum optimal control tools to enhance NV spin qubit sensing.**
Fabbri N.
CNR-INO, Sesto Fiorentino, Firenze
Quantum sensors based on nitrogen-vacancy (NV) centers in diamond have emerged in the last years thanks to the advantages they offer in terms of precision, repeatability, operability in ambient conditions, and spatial resolution. However, the present performances of NV sensors remain far from theoretical limits. In this respect, quantum control has a great potential to enhance the NV sensor capabilities. I will show how neural networks can empower quantum control and highly increase the accuracy of the NV sensor in noise spectroscopy tasks. I will also introduce a novel optimal control method based on the mapping of the

NV-spin driving problem to the determination of the ground state of a spin chain, and I will show how it can optimize sensitivity of the NV sensor to time-varying fields in the presence of dephasing noise.

▲ **Dynamic cooling on contemporary quantum computers.**
Oftelie L.B., Campisi M.
NEST, Istituto Nanoscienze-CNR, Pisa, Italy
Quantum computers require qubits to be initialized in a pure (*i.e.*, cold) state for successful computation. Dynamic cooling offers a route to effectively lower qubit temperatures beyond what is possible with direct, physical cooling techniques via the application of certain logic gates. While it was initially dismissed as impractical for the high-temperature NMR-based quantum computers available at the time of its inception, we show how dynamic cooling is substantially more effective and efficient on the low-temperature quantum computers available today. We provide analytic expressions for how the minimum final temperature and work cost of dynamic cooling scale with system size. We discuss its implementation in terms of quantum circuits and examine the effects of hardware noise. We successfully demonstrate dynamic cooling in a 3-qubit system on a real quantum processor. Finally, we propose a sub-optimal dynamic cooling algorithm, whereby relinquishing a small amount of cooling capability results in a drastically reduced circuit complexity, greatly facilitating implementation.

Comunicazioni

● **Decoy-state quantum key distribution over long-distance optical fiber.**
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Today's society heavily relies on secure communications, which can be guaranteed by Quantum Key Distribution (QKD), the most mature quantum technology. However, achieving long-distance links without relying on trusted nodes is still challenging. An important limitation is the non-ideality of detection systems, where intrinsic dark counts can hinder key extraction. This work proposes using state-of-the-art superconducting nanowire single-photon detectors (SNSPD) with ultra-low dark count rates (< 1 Hz) to reduce the quantum bit error rate (QBER) and achieve a higher secret key rate. Together with a high-rate QKD transmitter and a self-stabilizing receiver, we enabled a key exchange over 55 dB, corresponding to 340 km over an ultra-low-loss optical fiber.

● **Quantum collective states in superconducting qubit network.**
Ruggiero B. ([1]), Bonavolontà C. ([1]), Di Meo V. ([1]), Esposito E. ([1]), Gatti C. ([2]), Brida G. ([3]), Enrico E. ([3]), Fasolo L. ([3]), Oberto L. ([3]), Mikhail Fistul M. ([4]), Oelsner G. ([5]), Ill'chev E. ([5]), Navez P. ([6]), Zagoskin A. ([6]), Romeo F. ([7]), Silvestrini P. ([1])([8]), Lisitskiy M. ([9])
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([4]) *Ruhr University Bochum, Bochum, Germany*

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We have carried out a theoretical and experimental study of quantum collective dynamics of superconducting qubit network (SQN) embedded in microwave planar resonators. An experimental realization and theoretical investigation of quantum devices with 5 and 10 flux qubits was carried out. T-type two resonators SQN with 5 and 10 flux qubits were designed, fabricated, and measured at ultra-low temperatures (15 mK) in terms of microwave measurements of scattering parameters and two-tone spectra . In case of SQN with 10 qubits there was observed a sharp shift of the position of the resonant transmission dip as a function of the amplitude of the second-tone signal. Experimental results are in a good agreement with the model based on a non-linear multiphoton interaction between pump microwave signal and a qubit system of the SQN. The frequency shift is the sum of the multiphoton AC Stark shift values of each qubit and the increase of the dip sharpness manifests the observation of quantum collective state stimulated by the second-tone microwave signal. Moreover, quantum collective states were observed without any external microwave stimulation in the case SQN with 5 flux qubits.

Investigating spurious non-linear processes in travelling wave parametric amplifiers for multiplexed qubits readout.

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Traveling Wave Parametric Amplifiers (TWPAs) are non-linear transmission line-based superconducting devices. They are widely used in quantum technologies applications, especially for the multiplexing solid-state qubits readout, thanks to their broadband and low noise amplification performance in the microwave regime. However, due to the device non-linear nature, along with the amplification process it is also possible to activate spurious non-linear processes such as generation of sidebands (combinations of pump and signal/idler tones) and harmonics, potentially degrading TWPA performance. Investigating these processes is particularly relevant in the context of multiplexed qubit readout, where multiple readout signals at different frequencies are simultaneously feed to the TWPA, in addition to the pump, facilitating the activation of spurious tones. Here we present an experimental and numerical investigation on spurious non-linear processes arising in a Josephson TWPA when one or more signal tones are applied at the input. Preliminary results on the multiplexed redout of superconducting qubits in the presence of spurious TWPA non-linear processed will be also discussed.

Hole-spin qubits in the single- and few-hole regimes for quantum technologies.

Forghieri G. ([1])([2]), Secchi A. ([2]), Bertoni A. ([2]), Bordone P. ([1])([2]), Troiani F. ([2]), Bosco S. ([3]), Loss D. ([4])
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Hole-spin qubits in semiconductors are a mature platform for quantum technologies. In particular, holes in Si and Ge present a large spin-orbit coupling, which makes the qubit amenable to all-electrical manipulation. Here we consider their use as quantum sensors, and specifically for inferring the presence and estimating the distance of a remote charge from the qubit. Accounting for the interplay between the device geometry, the spin-orbit coupling and the interband mixing through the six-band Luttinger-Kohn Hamiltonian, we identify the optimal geometry and manipulation scheme to the charge sensing, as assessed by the classical and quantum Fisher information. The final part of the contribution will be devoted to the spin qubit encoding in multihole states. These are investigated through a configuration interaction approach, and allow a closer comparison with experiments performed in devices where the single-hole regime is not achievable.

Building the practical foundations of a European quantum communication infrastructure.
Ribezzo D., Zahidy M., Antonelli C., Mecozzi A., Zavatta A., Bacco D.
Università degli Studi dell'Aquila
Today, quantum networks have made Quantum Key Distribution (QKD) the standard method for securely distributing encryption keys among multiple parties. In this study, we present an approach to implementing quantum networks, validated through on-field implementations. Utilizing a weak coherent pulse source, an optimized BB84 protocol (efficient BB84), and optical fiber channels, we took the initial steps within the European Quantum Communication Infrastructure (EuroQCI) initiative. Our method successfully established a quantum network linking the cities of Trieste (Italy), Rijeka (Croatia), and Ljubljana (Slovenia) —the first to connect three different countries. A second quantum link between Malta and Sicily (Italy) was established for technological characterization, while a multicore optical fiber in downtown L'Aquila (Italy) facilitated the first QKD process involving high-dimensional quantum states in a real-world scenario.

Optimal characterization of noisy quantum gates.
Ragazzi G. ([1]), Cavazzoni S. ([1]), Bordone P. ([1])([2]), Paris M.G.A. ([3])([4])
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We consider a quantum metrology scenario in which the parameter of interest is encoded in a quantum state through the action of a non-unitary operation. The ultimate bound on the precision attainable in the estimation of that parameter can be inferred by evaluating the Quantum Fisher information (QFI). Considering one qubit as a paradigmatic quantum state, the evolution is performed through successive applications of a quantum gate. We characterize the robustness of this procedure introducing noise in the quantum operation performed, and looking at how this affects the QFI at different steps (gate applications). The classical noise we consider is modelled by a von Mises-Fisher distribution. Compared to the noiseless case, in which the QFI grows quadratically with the number of steps, we observe a non-monotonic behaviour, and the appearance of a maximum in the QFI denoting the ideal number of steps that should be done in order to precisely characterize the action of the gate.

Towards energetic quantum advantage in trapped-ion quantum computation.
Pezzutto M. ([1])([2])([3]), Góis F. ([2]), Omar Y. ([2])([3])
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The question of the energetic efficiency of quantum computers has gained some attention only recently. A precise understanding of the resources required to operate a quantum computer with a targeted computational performance and how the energy requirements can impact the scalability is still missing. In this contribution, one implementation of the quantum Fourier transform (QFT) algorithm in a trapped ion setup was studied. The main focus was to obtain a theoretical characterization of the energetic costs of quantum computation. The energetic cost of the experiment was estimated by analyzing the components of the setup and the steps involved in a quantum computation, from the cooling and preparation of the ions to the implementation of the algorithm and readout of the result. A potential scaling of the energetic costs was argued and used to find a possible threshold for an energetic quantum advantage against state-of-the-art classical supercomputers.

All-fiber laser system for rubidium atom cooling.
Rossi L. ([1]), Marchesini M. ([2]), Dondi M. ([2]), Bolognini G. ([1]), Prevedelli M. ([2]), Minardi F. ([2])
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Cold neutral atoms are a promising foundation for applications such as gravimetry measurements, and quantum computing and simulations. To cool and manipulate atoms systems efficiently, reliable laser systems are crucial. Here, we present and characterize a simple and compact laser system for rubidium atom cooling, operating at 780 nm, based entirely on fiber components, improving reliability, versatility and complexity with respect to analogous free-space systems. We achieve this by using widely available telecom optical systems at 1560 nm, and then making use of Second Harmonic Generation (SHG) to obtain light at 780 nm. In more detail, we use two semiconductor lasers at 1560 nm (one for cooling, one for repumping) which are combined and amplified in an Erbium-Doped Fiber Amplifier (EDFA), and then frequency-doubled in a Periodically-Poled Lithium Niobate (PPLN) crystal. We characterize the output of this laser source, obtaining for example a relative rms noise amplitude of 3×10^{-4} at 1 s and linewidths well below 1 MHz, which make our system an easy-to-build suitable candidate for applications in quantum sensors and atom interferometers.

Developing an experimental setup for spin squeezing utilizing Sr atoms.
Vezio P. ([1]), Liu C. ([1])([4]), Vinelli G. ([1]), Mancini C. ([3]), Salvi L. ([1]), Rosi G. ([1]), Tino G. M. ([1])([2])
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Atom interferometry aims at unprecedented precision within the Standard Quantum Limit (SQL) of phase estimation, reducing statistical uncertainty in gravity measurements as atom numbers increase. Quantum entanglement emerges as a pivotal asset, potentially enhancing sensitivity beyond classical thresholds by reshaping scalability with atom count. Generating

squeezed states, crucial for high-precision measurements, demands stable laser frequencies, notably for the 689 nm optical source and Sr atom's level structure. To address this, we propose a novel optical scheme: a frequency shifter in a feed-forward setup, driven by the same correction signal as a reference cavity lock, allowing fine laser tuning while maintaining frequency stability. Implementing this scheme yields a remarkable linewidth reduction from 2 kHz to 100 mHz, as demonstrated by beatnote measurement and the β-line method. This advancement holds contribute to revolutionizing gravitational sensing and precision metrology.

Memory enhanced hybrid quantum reservoir computing for predicting chaotic systems.

Settino J. ([1]), Channab M. ([2]), Bozzolo L. ([2]), Policicchio A. ([2]), Mastroianni C. ([3]), Giordano A. ([3]), Lo Gullo N. ([1]), Plastina F. ([1])
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([2]) *Consiglio Nazionale delle Ricerche-ICAR*
([3]) *NTT DATA Italia*

Traditional reservoir computing (RC) is an effective method for predicting chaotic systems due to its use of a high-dimensional dynamic system called the reservoir. This system processes information through a complex network with internally fixed, random weights, but the learning phase remains linear, simplifying the training process and enhancing trainability. Quantum reservoir computing (QRC) utilizes quantum systems, whose Hilbert spaces expand exponentially with the number of qubits. The exponential dimension allows QRC to handle vastly more information, offering significant improvements in memory capacity and computational power. The original proposal of QRC by Fukii and Nakajima requires multiple copies of the reservoir system, posing challenges in practical implementation. We develop a simpler hybrid approach that leverages both quantum preprocessing and classical post-processing to solve tasks with high accuracy. Our approach is based on a classical manipulation of the output of the quantum measurements, enhancing the memory of the hybrid QRC. This helps to avoid the need for multiple system replicas while maintaining the benefits of quantum computational enhancements.

Geometry of quantum correlation and entanglement.

Franzosi R. ([1])([2]), Vesperini A. ([3])
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([2]) *INFN, Sezione di Perugia*
([3]) *INFN, Sezione di Pisa*

We show that the manifold of quantum states is endowed with a rich and nontrivial geometric structure. We derive the Fubini's Study metric of the projective Hilbert space of a multi-qubit quantum system, endowing it with a Riemannian metric structure, and investigate its deep link with the entanglement of the states of this space. As a measure, we adopt the entanglement distance E. Our analysis shows that entanglement has a geometric interpretation: $E(|\Psi\rangle)$ is the minimum value of the sum of the squared distances between $|\Psi\rangle$ and its conjugate states, namely the states $\nu\mu \cdot \sigma\mu|\Psi\rangle$, where $\nu\mu$ are unit vectors and μ runs on the number of parties.

Polarization resolved high-order harmonic generation in germanium.

Annunziata A. ([1])([2]), Bollani M. ([1]), Carpene E. ([1]), Ciriolo A.G. ([1]), Crepaldi A. ([2]), Devetta M. ([1]), Isella G. ([2]), Poletto L. ([3]), Stagira S. ([2]), Cinquanta E. ([1]), Faccialà D. ([1]), Vozzi C. ([1])
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When an intense laser pulse interacts with matter, photons with energies that are integer multiples of the original photon's energy are emitted. This process can be described in three steps. First, the interaction with the driving field promotes an electron to the conduction band, leaving a hole in the valence band. Next, the external field accelerates electrons and holes in their respective bands, emitting intra-band harmonics due to band dispersion non-linearities. Finally, electrons and holes can recombine, producing inter-band harmonics. The high non-linear nature of this phenomenon makes it a powerful tool for investigating solid-state matter in strong out-of-equilibrium conditions. By characterizing the polarization state of the harmonics emitted by bulk germanium, we disentangled two different contributions linked to a strong enhancement in the inter-band emission caused by singular points in the joint density of states. Our study paves the way for sub-cycle tracking of ultrafast electron motion in semiconductors with sub-cycle resolution as well as opening new spectroscopic frontiers for studying exotic effects in solid-state matter under strong-field excitation.

Aula 1E **ore 09:00 – 13:30**

Sezione III
Astrofisica
Presiede: Trigilio C. (INAF, Osservatorio Astrofisico di Catania)

Relazioni su invito

▲ **GINGER.**
Di Virgilio A.D.V. on behalf of the GINGER Collaboration
INFN, Sezione di Pisa
Measurements of the Earth's rotation speed made with laser gyroscopes, otherwise known as ring lasers, certainly important for the Earth sciences, are also relevant for fundamental physics tests, as they contain terms of general relativity, such as de Sitter and Lense Thirring and provide unique data to investigate Lorentz's violations. Ring lasers ensure long-term continuous operation with record sensitivity. In order to be meaningful for fundamental physics tests, it is necessary to reach the sensitivity limit of of 1 part in 10^9 of the Earth's rotation speed. The GINGER project is based on ring lasers, the apparatus will be described in detail, providing the status report of the construction inside the Gran Sasso underground laboratory.

▲ **The XENONnT Dark Matter Experiment: Status, results and prospects.**
Selvi M. on behalf of the XENON Collaboration
INFN, Sezione di Bologna
The XENONnT experiment, located deep underground at the INFN Laboratori Nazionali del Gran Sasso, is designed to search for dark matter particles with unprecedentedly low background levels. The core detector, a Dual-Phase Xenon TPC, features 5.9 t of xenon as the active target, shielded and complemented by water Cherenkov muon and neutron veto detectors. XENONnT, in operation since the end of 2020, acquired its first science data in 2021, achieving an exposure of 1 t per yr. This first dataset showed the lowest Electronic Recoil background ever reached in a dark matter detector, clarified the excess observed by its predecessor XENON1T, and set strong limits on new physics scenarios, including new limits on the interaction of WIMPs. Since then, XENONnT has completed a second Science Run with a larger exposure and an improved Radon removal system. Currently, the experiment is in its third data acquisition phase, operating with a Gd-doped neutron veto configuration to further reduce the neutron background, increasing its sensitivity in the forthcoming years. In this contribution, we will report on the performances of the detector, the achieved results, and future prospects.

Comunicazioni

● **WIMPs phenomenology using a EFT approach with XENONnT data.**
Lucchetti G.M.
Dipartimento di Fisica, Università di Bologna e INFN, Sezione di Bologna
Direct detection is a crucial probe to look for WIMP interactions with Standard Model particles, and it is achieved by searching for nuclear recoils generated by the elastic scattering of WIMPs in Earth-based underground detectors. Direct searches for WIMP induced nuclear recoil signals in xenon detectors are mostly sensitive to WIMP masses above 6 GeV,

while lighter WIMPs are probed by exploring the electron recoil channel. In this context, I will present a framework to evaluate the limits of any possible WIMP model by using a projection operator method capable of projecting the models into a finite basis of effective field theory (EFT) operators. Given the finite number of EFT operators, this approach has been implemented inside a numerical tool, named MadDM. Those limits will be evaluated using the data of the XENONnT experiment, a dual-phase time projection chamber (TPC) experiment with 5.9 tonnes of active liquid xenon, hosted at the INFN Laboratori Nazionali del Gran Sasso, which is currently one of the most sensitive direct detection experiment worldwide.

Gd-loaded neutron veto of the XENONnT dark matter experiment.

Angelino E. on behalf of XENON Collaboration
INFN, Laboratori Nazionali del Gran Sasso

The XENONnT Neutron Veto is a Gd-loaded water Cherenkov detector, designed to reduce the radiogenic neutrons background in the XENONnT experiment, which aims to directly detect WIMP dark matter via Nuclear Recoils with a liquid xenon dual-phase TPC. Radiogenic neutrons, originating from materials surrounding the xenon target, are one of the dominant backgrounds in WIMP search. The Neutron Veto, constituted by a high-reflectivity ePTFE enclosure and 120 PMTs around the TPC inside a water tank, can detect the Cherenkov photon emission which follows the capture on H or Gd atoms of neutrons that previously interacted inside the TPC. After an initial phase in which the Neutron Veto operated effectively with demineralized water, Gd was introduced into the system by using a dedicated plant capable of continuously recirculating and purifying Gd-loaded water. We present here the details of the Gd insertion and first results obtained with an AmBe neutron calibration. Due to the high cross-section of Gd for thermal neutron capture, the system shows improved performance in neutron identification with a reduction in neutron background by a factor of 2 with respect to the first scientific runs.

Monte Carlo simulation on the Gd-Water Neutron Veto of the XENONnT experiment.

Mazza V.
Università di Bologna e INFN, Sezione di Bologna

We present the comparison between data and Monte Carlo (MC) simulations of the Gd-doped Neutron Veto of the XENONnT experiment. XENONnT is the current experiment of the XENON dark matter project, at the INFN Laboratori Nazionali del Gran Sasso featuring a LXe dual-phase TPC surrounded by two water Cherenkov detectors: the Muon Veto, and a novel Neutron Veto (NV) systems. In the first two scientific runs, the NV has been operated with demineralized water. Recently, the performances are boosted by doping water with Gadolinium. The NV response is calibrated using an AmBe neutron source in various positions inside the NV. The comparison between MC simulations and calibration data is exploited to characterize both the NV performances and the AmBe source itself. We developed a dedicated signal simulator, which accurately models the PMTs' response to incident photons, supported by extensive LED calibrations and analytical studies of the single-photoelectron spectrum. We generated targeted MC simulations of AmBe calibrations with various Gd concentrations within the NV, and compared them to the NV data for a full characterisation of the detector's response.

Data-driven identification of light signals from low-energy recoils in a LAr TPC using self-supervised machine learning.

Pino N. ([1])([2]), Albergo S. ([1])([2]), Anastasi G. A. ([1])([2]), Gulino M. ([3])([4]), Pandola

L. ([3]), Puglia S. M. R. ([1])([2]), on behalf of the ReD Group
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The ReD project, within the Global Argon Dark Matter Collaboration, aims to study the response of a LAr TPC to low energy nuclear recoils (NR). Signals collected by SiPMs in the LAr TPC are the prompt scintillation light (S1) and the delayed electroluminescence (S2) due to the electrons produced by ionization in liquid and drifted by an electric field towards the gas-liquid interface. S1 is difficult to observe in NRs in the few-keV range, thus making it crucial to measure the ionization yield in Ar. A new data-driven technique involving convolutional autoencoders (CAE) has been developed to improve the background rejection in S2-only events. In this analysis, the CAE is trained on a dataset of signals produced in the ReD TPC by neutrons and gamma-rays of a ^{252}Cf source, reducing each raw waveform into a 4-dimensional vector. The features of the compressed representation have been studied, developing a method to tag traces without pulses with a sensitivity comparable to the ReD conventional reconstruction. This work has being developed in collaboration with the National Research Centre for HPC, Big Data and Quantum Computing (ICSC), specifically within the WP3 of the Spoke2.

● **Electron recoil background full simulation and reconstruction for direct dark matter search with the Darkside-20k experiment.**
Salerno C. on behalf of the Darkside-20k Collaboration
Dipartimento di Fisica, Università La Sapienza e INFN, Sezione di Roma
DarkSide-20k is an argon dual phase TPC with an active volume of 50t, currently under construction at LNGS. The aim of the experiment is the direct search for dark matter WIMPs scattering with nuclei in depleted underground argon (UAr) fill. DarkSide-20k is designed to be an "instrumental background-free" experiment, meaning that less than 0.1 background events are expected, after all selection criteria are applied, during the 200 tonne-year planned exposure. This is achievable thanks to the presence of active vetoes instrumented with SiPMs and powerful discrimination of order 109 based on signal shape, magnitude and position of the scintillation and ionization signals. To evaluate the signal efficiency and background rejection, a full background Monte Carlo simulation (GEANT4-based) is needed. In particular the MC simulation is performed in steps: energy deposits in the detector from different background sources are generated with the predicted rates and overlapped in time in order to simulate realistic pileup conditions and then detector and electronic readout responses are simulated. Finally, reconstruction algorithms are applied to produce realistic data sets.

Relazioni su invito

▲ **Preparing an orbiting observatory for the milliHertz gravitational wave sky with LISA.**
Weber W.J.
Università di Trento e INFN TIFPA
Observing the mHz gravitational wave sky requires an orbiting observatory, with a gravitationally-pure environment and long baselines that are only possible in deep space. The LISA mission, recently adopted as an ESA Cosmic Vision "Large Mission" and being developed for launch in 2035, will achieve this with a constellation of free-falling test masses inside three spacecraft in an orbiting, 2.5 million km triangular configuration. In this contribution I will introduce

the main experimental challenges needed to study the physics and astronomy of supermassive black hole mergers and other unique sources at the LISA design sensitivity: pico-meter interspacecraft interferometry and sub-femto-g free-falling reference test masses.

▲ **Sviluppi tecnologici e obiettivi scientifici di Einstein Telescope.**
Punturo M.
INFN, Sezione di Perugia
Einstein Telescope (ET), l'osservatorio europeo di onde gravitazionali di futura generazione, ha un ambizioso portafoglio di obiettivi scientifici: tramite la rivelazione del segnale di onde gravitazionali proveniente dalla coalescenza di buchi neri stellari o intermedi in pressocché tutto l'universo, ET ambisce a studiare la gravitazione in condizioni di campo molto intenso e a verificare la relatività generale di Einstein. Dall'osservazione di centinaia di migliaia di coalescenze di stelle di neutroni all'anno, ET ambisce a comprenderne la struttura interna e la fisica nucleare che la regola. Tramite l'osservazione di segnali gravitazionali a distanza cosmologica, ET contribuirà a svelare l'enigma della materia ed energia oscura. Il raggiungimento di questi obiettivi scientifici è legato allo sviluppo di nuove tecnologie rispetto ai rivelatori attuali, Virgo e LIGO, e al miglioramento di quelle esistenti. ET dovrà guadagnare un ordine di grandezza in sensibilità in un ampio spettro di frequenze e di diversi ordini a basse frequenze. Questo richiede un nuovo disegno, una nuova infrastruttura, e sviluppi nell'ottica, fotonica, meccanica, controlli, analisi dati e modelli astrofisici.

Comunicazioni

● **Aberration control in the next upgrade of advanced Virgo+: Strategies to optimize the axi-symmetric compensation of thermal lensing.**
Palma P.P. ([1])([2])([3]), Aiello L. ([1])([2]), Cesarini E. ([3]), Cifaldi M. ([3]), Ianni M. ([1])([2])([3]), Fafone V. ([2])([3]), Lorenzini M. ([2])([3]), Lumaca D. ([3]), Minenkov Y. ([3]), Nardecchia I. ([3]), Rocchi A. ([3]), Scacco V. ([2])([3])
([1]) *Dipartimento di Fisica, Università di Roma La Sapienza*
([2]) *ipartimento di Fisica, Università di Roma Tor Vergata*
([3]) *INFN, Sezione di Roma Tor Vergata*
The sensitivity and operability of advanced interferometric detectors for gravitational wave research are strongly limited by the presence of optical aberrations, which degrade their optical configuration. The thermal effects are intensified with increasing laser power entering the interferometer, as they are caused by the percentage of power absorbed by the mirrors. The Thermal Compensation System (TCS) of the Advanced Virgo interferometer is designed with several purposes: to detect, characterize and compensate for the optical aberration, both the axisymmetric and non-axisymmetric ones. In preparation for the upcoming observational run O5, the efforts to increase the efficiency of the TCS are multiple. The limiting factor for the compensation of axisymmetric thermal lensing is the presence of higher-order modes, compared to the fundamental one, in the CO_2 laser beam that is used as a TCS actuator. Development of a CO_2 mode cleaner cavity, an optical cavity capable of cleaning the beam by ensuring transmission only of the main TEM00 mode while minimizing power losses, is ongoing. Its prototype, along with preliminary characterization tests and future progress, will be presented.

● **Frost formation and electrostatic charging: One possible solution for both issues in future gravitational wave detectors.**
Spallino L., Angelucci M., Cimino R.
INFN, Laboratori Nazionali di Frascati
In the upcoming third generation of gravitational wave (GW) detectors, electrostatic charging, and the build-up of a frost layer on cryogenically cooled mirrors may represent two

potentially critical showstoppers for GW detection. We are approaching a possible mitigation solution for both such apparently uncorrelated issues, relying on irradiation with low energy electrons (few hundreds eV) of the optical elements. Low energy electrons are known to interact only with the very top layers (some nm) of any irradiated surface, are known to be very efficient in inducing gas desorption and, by properly tuning the energy of the incident electrons, can neutralize both positive and negative charges on surfaces. Therefore, low energy irradiation of mirrors' surfaces seems ideal to neutralize charge and induce frost desorption without damaging the mirror surfaces' optical properties. Here we present the status of the experimental activity carried out at LNF-INFN and some of the main results, aiming to validate the possible use of low energy electrons as a mitigation method to cure frost formation and surface charging.

Passive mitigation strategy for electrostatic charging in future gravitational wave detectors.

Angelucci M. ([1]), Chimenti P. ([1]), Liedl A. ([1]), Pietropaoli M. ([1]), Spallino L. ([1]), Viviani G. ([1]), Cimino C. ([1]), Gargiulo J. ([2]), Sentenac D. ([2]), Francescon L. ([2]), Pasqualetti A. ([2])

([1]) *INFN, Laboratori Nazionali di Frascati*

([2]) *EGO-Virgo, Cascina*

Electrostatic charging on the surfaces of the optical elements is a limiting noise source for gravitational wave detectors (GWD) already at room temperature. The charge accumulation has been already observed in Virgo. This effect cloud be amplified by the low energy electrons propagating from ion pumps (both located in the mirrors' towers and distributed along the beampipes) that will be implemented in the vacuum system. The present used mitigation method, based on N2 gas flux, would be barely implemented at cryogenic temperature due to the significantly thick condensed layer on mirrors that would affect detection operations. Some other strategies to actively remove charges from optics at cryogenic temperature are currently under study. However, the development of new technologies to passively mitigate electrostatic charging is also urgent to preserve the performances envisaged by future GWD. Here we present our collaboration R&D activity to develop a passive mitigation strategy for the electrostatic charging based on electrostatic collectors that, opportunely polarised at a given voltage, can catch electrons coming from the ion pumps.

A holy grail of pulsar astronomy lurking within a globular cluster.

Cadelano M.

Università di Bologna

Millisecond pulsars (MSPs) are rapidly spinning neutron stars formed in binary systems through mass accretion from a companion star. They are commonly found in globular clusters (GCs), where millions of stars are held together by mutual gravity within a few parsecs. In such high-density environments, 2- and 3-body gravitational interactions between stars are promoted, leading to the formation of binaries, including MSPs, and other exotic systems not predicted by standard evolution models. Among these, the long-sought MSP orbiting a black hole is considered one of the holy grails of astronomy, as its discovery would open the door to unprecedented tests of fundamental physics and general relativity. I will present the discovery of the first MSP orbiting a companion in the mass gap between neutron stars and black holes. By exploiting the synergy between radio and optical/near-UV observations, we discovered a binary system composed of a neutron star unambiguously orbiting either a low-mass black hole or a high-mass neutron star. I will discuss the possible formation mechanisms of such an exotic binary, the determinant role of the cluster environment, and follow-up developments.

Detecting relativistic Doppler in galaxy clustering via multi-tracing a single galaxy population.

Montano F., Camera S.
Università degli Studi di Torino e INFN, Sezione di Torino

The theory of general relativity plays a crucial role in our understanding of the universe. However, confirmations of the validity of this theory on cosmological scales have hitherto eluded us. In this context, the detection of relativistic Doppler via galaxy power spectrum measurements could further confirm the validity of general relativity at scales very far from the strong-gravity-field regime, where instead it has been tested with exquisite accuracy. The Doppler term acts as an imaginary correction in the relation between the galaxy density contrast and that of matter, which mostly affects the large-scales usually plagued by cosmic variance. Moreover, it is sample-dependent, so different galaxy populations display different contributions in their power spectra. In the search for the optimal galaxy samples to achieve a detection of the relativistic term, we can split a galaxy population according to luminosity, and even perform a multi-tracer analysis with auto-correlations of the two sub-samples and their cross-power spectrum. We are thus able to devise a technique enjoying multi-tracer benefits out of a single dataset and obtain a detection well above 5σ.

Magnetic fields generation over macroscopic and cosmic scale distances.

Coppi B., Basu B.
MIT, Boston, USA

The important problem of generating significant magnetic fields, in plasmas over large scale distances of relevance to astrophysics, is dealt with. A cosmic alternator process, involving extremely low frequency density fluctuations and a significant unperturbed electron temperature gradient, is introduced that produces a seed sheared magnetic field. These fluctuations are driven, for instance, by the kinetic energy of the components of a binary (e.g. with Black Hole components) immersed in a plasma circumbinary disk. When,in addition, the electon temperature becomes anisotropic, relative to the nearly stationary magnetic field, a magnetic reconnection process is shown to take place. The growth of the resulting reconnected configuration, to significant amplitudes is the driven by the combined effects of aligned electron temperature and density gradients. Thus the shortcomings of theories based on plasma modes localized or involving transients over microscopic (e.g. electron inertia) distances are avoided.

Structure of astrophysical jets: Theory and observations.

Coppi P.S. ([1]), Coppi B. ([2])
([1]) *Yale University, USA*
([2]) *MIT, Boston, USA*

The theory that identified plasma structures propagating away from circumbinary disks, in which a couple of Black Holes is immersed, has led to propose that an important class of the observed jets are the results of emission of this kind of structures. In particular,double-helix structures, propagating away from the disk, were found as a result of the non-linear interactions of modes excited in disks sustained by pairs of stellar black holes. The theory has been extended to the case of a massive BH paired with a much lighter Sheperd BH. The emitted plasma structures are associated with the modes emerging in the Swept Torus carved in the plasma disk sustained by the main BH. An independent following analysis of the observed M87 jet structure concluded that this was of a double-helix kind. A multiplicity of more recent study of jets emerging from massive BHs has identified helical or different plasma structures associated with them.

Radiation damage on SiPMs for gamma-ray detection in space missions.

Guerrisi C. [2][3][4], Ruzzarin M. [1], Acerbi F. [1], Bissaldi E. [2][3], Di Venere L. [2], Gargano F. [2], Giordano F. [2][4], Gola A. [1], Loporchio S. [2][3], Merzi S. [1]

[1] *FBK Fondazione Bruno Kessler, Trento*

[2] *INFN, Sezione di Bari*

[3] *Dipartimento Interateneo di Fisica, Politecnico di Bari*

[4] *Dipartimento Interateneo di Fisica, Università degli Studi di Bari*

Silicon Photomultipliers (SiPMs) detectors are a promising technology for space missions for their high gain, compactness, low bias operating range, insensitivity to magnetic fields and low cost. It is of general interest to study the effect of radiation damage on a SiPM. Here, we report the effect of the irradiation with protons with four fluence levels up to 1×10^{11} p/cm^2 on SiPMs NUV-HD-lowCT with poly in trench technology, with different cell pitch (40 μm and 5μm). Protons induce mainly damage in the bulk of the detector through point or cluster defects, enhancing the primary dark count rate (DCR) and this can be observed in an increase of the dark current. Functional tests on the irradiated samples (SPADs and SiPM) confirmed an exponential increment with a fluence of primary DCR and excluded significant variation in breakdown voltage. These results are in agreement with the evaluation of the effects of Ionizing and Non-Ionizing Energy Loss (NIEL and IEL) damage on SiPMs reported in literature for space application. These results provide insights for the design of future solutions aimed at mitigating SiPMs and SPADs performance degradation.

Aula F **ore 09:00 – 13:30**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Molinari I. (INGV, Sezione di Bologna)

Relazioni su invito

▲ **Modeling the 3D dynamic rupture of microearthquakes induced by fluid injection.**
Tinti E., Mosconi F., Casarotti E., Gabriel A.-A., Dal Zilio L., Rinaldi A.P., Dorozhinskii R., Cocco M.
Sapienza, Università di Roma
Understanding the dynamics of microearthquakes is a timely challenge to solve current paradoxes in earthquake mechanics and to investigate earthquake ruptures induced by fluid injection. We perform fully 3D dynamic rupture simulations caused by fluid injection on a fault and we generate $M_w \leq 1$ seismic events assuming spatially variable stress drops caused by pore pressure changes. Spontaneous arrest of a propagating rupture is possible when we consider a high fault strength parameter S, that is, high ratio between strength excess and dynamic stress drop. With high S values even minor variations in D_c have a substantial effect on the rupture propagation and on the ultimate size of the earthquakes. Modest variations of dynamic stress drop determine the rupture mode, distinguishing self-arresting from run-away ruptures. Several features inferred for accelerating dynamic ruptures differ from those observed during rupture deceleration in a self-arresting earthquake due to the spatial gradient of the effective normal stress. These results integrate those obtained with spatial variations of the initial stress, highlighting the role of the heterogeneities of stress drop and G_c.

▲ **Dynamics of the active deformation beneath the Central Mediterranean region.**
Manu-Marfo D., Aoudia A.
Earth System Physics, International Centre for Theoretical Physics, Italy
The lithospheric deformation, mantle flow, and tectonic stress in the Central Mediterranean region are influenced by the density structure and viscosity of the crust and uppermost mantle. Here, we estimate the contribution of buoyancy forces to regional dynamics by developing a 3D numerical model to compute the contemporary lithospheric flow field below the Central Mediterranean region. We use, as input, viscosity and density models derived from a well-resolved 3D shear wave velocity model. Recent ambient noise seismic tomography reveals a thick lithosphere beneath the Adriatic Sea and a broad low velocity zone beneath the Tyrrhenian Basin. We show that the slow East-West extension across central Italy and contraction in the southeastern Alps are dominated by buoyancy forces due to the density contrast between the thick lithosphere beneath the Adriatic Sea and the underlying asthenosphere. In the Tyrrhenian, the modeled flow pattern is consistent with the Northeast-oriented motion of the lithosphere. The flow pattern can explain the heat flux, regional geology, and magmatism in the Tyrrhenian Basin and provide new insights into the dynamic deformation beneath back-arc basins.

▲ **Modeling the size and recurrence of large earthquakes beneath the Himalaya in Nepal.**

Osei-Tutu D. ([1])([2]), Dal Zilio L. ([3]), Aoudia A. ([1])([2])
([1]) *University of Trieste,Trieste, Italy*
([2]) *The Abdus Salam International Center for Theoretical Physics, Trieste, Italy*
([3]) *Nanyang Technological University, Singapore*

Numerous studies have been conducted to infer the size and recurrence time of large earthquakes using empirical scaling relationships. However, these classical scaling laws prove limited in describing the entire earthquake cycle since they are derived from datasets and observations that capture just a single snapshot of the seismic sequence; the coseismic phase. In this study, we propose the interseismic phase as an alternative to the coseismic phase in assessing the expected earthquake size and recurrence time. The interseismic phase as the engine of the seismic cycle serves as a key indicator of tectonic stress accumulation and distribution along megathrust faults, ultimately impacting the scale of coseismic slips. The Main Himalayan Thrust (MHT) is a good natural laboratory for this study. Here, we use the spring-slider model and advanced numerical simulations constrained by seismo-geodetic data of the 2015 M_w 7.8 Gorkha earthquake and a recent ambient noise seismic imaging of the geometry of the MHT. We investigate the influence of the width of the creeping zone and that of the brittle creep zone of the MHT on the size of large earthquakes and their recurrence timings.

▲ **AlpArray and AdriaArray: The European telescopes to probe the Earth structure across scales.**

Piromallo C., Molinari I. per gli AlpArray Working Group e AdriaArray Working Group
Istituto Nazionale di Geofisica e Vulcanologia, Italy

The emergence of European collaborative initiatives like AlpArray and AdriaArray marks significant milestones in seismology, akin to the impactful USArray project. They serve as Earth telescopes, employing large, dense grids of seismometers to record and analyze seismic waves to enhance our comprehension of the deep Earth structure, the geodynamics and seismic hazards within Europe and the Central Mediterranean. Through state-of-the-art seismic instrumentation and innovative data analysis techniques, AlpArray and AdriaArray enable high-resolution investigations into crustal and mantle structures, earthquake mechanisms, and seismic wave propagation. These initiatives favor networking and collaboration among research institutions and observatories across Europe, fostering a cohesive research community capable of addressing geophysical challenges on a continental scale. The interconnectedness facilitated by European seismic arrays promotes data sharing, technical standardization, and the advancement of open science, thereby facilitating access to seismic data and accelerating scientific progress. An overview of the projects and main results will be provided.

Comunicazioni

● **Exploring the dynamic of earthquakes as complex fluid-related phenomena.**

Fidani C. ([1])([2]), Piscini A. ([1])([2]), Calcara M. ([1]), Cianchini G. ([1])
([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Roma*
([2]) *Central Italy Electromagnetic Network, Fermo*

The intricate interplay between CO_2 fluid and seismic activity embodies a complex relationship influenced by geological, hydrological, and geophysical factors. Understanding this dynamic coupling is essential for advancing our knowledge of earthquake processes. Both

natural and anthropogenic CO_2 injection can induce changes in chemistry and pore pressure, alter fault stability, and trigger seismic events. In terms of weakening faults, the fluid serves as a subtle energy signal capable of initiating the release of significant energy. Small energy signals that trigger substantial events are known as active information. It is a key concept for understanding complex systems and offers profound insights into the nature of interconnectedness and emergence, challenging traditional reductionist approaches and inspiring new paradigms of inquiry. Can we detect and learn to interpret these signals? As part of the FURTHER – The role of FlUids in the pReparaTory pHase of EaRthquakes in Southern Apennines project, monitoring activities conducted at the Mefite Lake site in the Ansanto Valley aim to provide some answers.

Thermo-mechanical simulations to model magma-induced seismicity at Campi Flegrei.

Nardoni C., De Siena L.
Alma Mater Studiorum Università di Bologna

The ground deformation unrest at Campi Flegrei caldera has been going on for about two decades and paired with increased seismic magnitudes and rates since 2015. While the cause of previous unrests has sparkled notable debates, current deformation and seismic signals strongly hint at magma migrating toward the surface. Here, we employ the Lithosphere and Mantle Evolution Model (LaMEM) code, a thermo-mechanical code that employs visco-elasto-plastic rheology, to model magma migration modulated by the existing structural information on the caldera, like a caprock layer and an aquifer system. The 3D thermo-mechanical numerical simulations of the magmatic system account for crustal magma migration from a ~ 7 km-deep magma sill shifted East of the centre of the caldera to a ~ 3 km magma chamber at its centre, and consider the response to stress of the seismically active caldera rim faults. The simulations aim to understand the changes in the stress field due to magma migration for future modelling of the seismic responses, thus contributing to the source and structure characterization.

Seismic data analysis in the Campi Flegrei caldera with Self-Organizing Map (SOM) and Multiscale Entropy (MSE).

Grimaldi A. ([1]), Amoroso O. ([1]), Napolitano F. ([1]), Scarpetta S. ([1]), Messuti G. ([1]), Capuano P. ([1]), Convertito V. ([2]), Galluzzo D. ([2]), Gaudiosi G. ([2]), Nardone L. ([2])
([1]) *Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, Fisciano, SA, Italy*
([2]) *Osservatorio Vesuviano, Istituto Nazionale di Geofisica e Vulcanologia, Napoli, Italy*

This communication introduces a novel approach regarding seismic signal analysis in the Campi Flegrei caldera. The main objective is to combine the Multiscale Entropy (MSE) algorithm and the Self-Organizing Map (SOM) network to tackle the challenge of small earthquake detection, which can be difficult due to the low signal-to-noise ratios and complex data volumes. By integrating these techniques, we aim to enhance seismic monitoring and dataset quality control. Our approach employs a six-month dataset from the V0102 station in the Pisciarelli area. The combination of MSE and SOM algorithms allows for effective clustering and interpretation of seismic data, reducing human bias and improving the identification of key seismic events. Results indicate that this methodology not only simplifies the categorization of seismic signals but also uncovers new patterns, particularly in response to external influences like rainfall. This analysis showcases potential advancements in seismic event detection and monitoring, contributing significantly to our understanding in the highly hazardous areas.

***P-wave picking for seismic arrays.**

Messuti G. ([1])([2]), Palo M. ([3]), Scarpetta S. ([1])([2]), Napolitano F. ([1]), Scotto di Uccio F. ([3]), Capuano P. ([1]), Amoroso O. ([1])

([1]) *University of Salerno, Department of Physics "E.R. Caianiello", Fisciano, SA, Italy*

([2]) *National Institute for Nuclear Physics INFN, Section of Naples, Salerno Collegiate Group, Naples, Italy*

([3]) *University of Naples Federico II, Department of Physics "Ettore Pancini", Naples, Italy*

We present the higher-order statistics for array algorithm (HOSA), a novel approach for *P*-phase picking. The technique comprises two stages: a single-trace stage (STS) and a multi-trace stage (MTS). STS identifies onsets on each trace and provides them with an uncertainty measure. MTS leverages the array geometry to perform a clustering analysis, ensuring consistency among the detected onsets. Tested on 226 microearthquakes recorded in Irpinia (Italy) by twenty seismic arrays within the DETECT project (September 2021–February 2022), HOSA demonstrates great reliability and inter-array consistency in its predictions. Our study highlights HOSA's ability to refine, filter, and integrate arrival times efficiently. The capability of HOSA to efficiently and robustly process large volumes of seismic data, makes it suitable for automatic workflows and real-time seismic monitoring.

Analysis of the preparation phase of the 2022 Ms6.8 Luding (China) earthquake from ground and satellite data: Application of a multiparametric and multilevel approach.

Zhang X. ([1]), De Santis A. ([2]), Liu J. ([1]), Campuzano S.A. ([2])([3]), Yang N. ([1]), Cianchini G. ([2]), Ouyang X. ([1]), D'Arcangelo S. ([2])([3]), Yang M. ([4]), De Caro M. ([2]), Li X. ([5]), Fidani C. ([2]), Liu H. ([1]), Orlando M. ([2])([6]), Nie L. ([1]), Perrone L. ([2]), Piscini A. ([2]), Dong L. ([1]), Sabbagh D. ([2]), Soldani M. ([2]), Xiong P. ([1])

([1]) *Institute of Earthquake Forecasting, Center of Earthquake Administration, Beijing, China*

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([3]) *Department of Physics of the Earth and Astrophysics, Universidad Complutense de Madrid-UCM, Madrid, Spain*

([4]) *Liaoning Earthquake Agency, Shenyang, China*

([5]) *Earthquake Agency of Ningxia Hui Autonomous Region, Yinchuan, China*

([6]) *Dipartimento di Scienze, Università Roma Tre, Rome, Italy*

Encouraged by recent results based on the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) models, we analyzed the preparation phase of a strong earthquake with a magnitude of Ms6.8 occurred on September 5, 2022, in Luding, Sichuan Province, China. This seismic event offers a good opportunity to construct the internal relationship among several parameters in different geolayers. A succession of analyses are realized: a seismological study including *b*-value and the revised accelerated moment release, Earth resistivity, ELF magnetic field emissions, atmospheric electric field, surface temperature, foF2 from ionosonde, GNSS TEC, electron density and magnetic field from CSES and Swarm satellites, etc. The results provide a chain of mixing processes, detected by various anomalies, confirming a two-way model of geolayer coupling. One kind of coupling proceeds from the ground to the above atmosphere and ionosphere, which is called "delayed-thermodynamic" coupling, probably based on a slow diffusive process; another couples lithosphere with ionosphere directly, and is called "direct" coupling, probably based on an electromagnetic interaction.

FABER, the geophysical observatory neighbor of the Italian Einstein Telescope candidate site in Sardinia.

Diaferia G. ([1]), Olivieri M. ([1]), Giunchi C. ([2]), Molinari I. ([1]), Di Felice F. ([3]), Sepede G. ([3]), Selvaggi G. ([4])

([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna*
([2]) *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa*
([3]) *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma1*
([4]) *Istituto Nazionale di Geofisica e Vulcanologia, Roma*

In the framework of the NextGeneration EU project MEET, Sardinia FABER (Far Fault Observatory) is under completion in the context of the Sos Enattos Mine (Sardinia). This site is close to the area candidate for the Einstein Telescope, the 3rd-generation gravitational wave detector. FABER is a geophysical observatory designed to operate in a low-noise environment, an essential requisite for the detection of geophysical signals, enhancing our capability to monitor and study geophysical phenomena at regional and global scale. This new laboratory includes a set of advanced instrumentation such as state-of-the-art seismometers, magnetometers, a superconducting gravimeter, and a GNSS antenna. The strategic location (one of the seismically quietest sites in the world) and technological advancements of the FABER observatory will allow geophysical studies on seismic noise, natural and anthropogenic seismic sources, contributing to the enhancement of seismic catalogs thanks to the detection of small-magnitude seismicity. This initiative will also broaden traditional geophysical research, through a multidisciplinary approach for an improved understanding of the complex dynamics of Earth processes.

Aula 1F **ore 09:00 – 13:30**

Sezione V
Biofisica e fisica medica
Presiede: Lanzanò L. (Università di Catania e Nanoscopy, IIT)

Relazioni su invito

▲ **Kelvin probe force microscopy: An ultrasensitive tool for single-molecule detection at wide biofunctionalized interfaces.**
Di Franco C. ([1]) Piscitelli M.([2]), Khaliq A. ([2]), Macchia E. ([3]), Scandurra C. ([4]), Catacchio M. ([3]), Sarcina L. ([4]), Caputo M. ([3]), Torsi L. ([4]), Scamarcio G. ([1])([2])
([1]) *CNR-Institute of Photonics and Nanotechnologies, Bari, Italy*
([2]) *Dipartimento Interateneo di Fisica "M. Merlin", Università degli Studi di Bari Aldo Moro, Bari, Italy*
([3]) *Dipartimento di Farmacia-Scienze del Farmaco, Università degli Studi di Bari Aldo Moro, Bari, Italy*
([4]) *Dipartimento di Chimica, Università degli Studi di Bari Aldo Moro, Bari, Italy*
Leveraging Kelvin Probe Force Microscopy (KPFM), we have developed an ultra-sensitive platform for the detection of diagnostic biomarkers, *i.e.*, immunoglobulins IgG, IgM, p24 antigen of the HIV-1 virus capsid, KRAS mutated gene, at large biofunctionalized interfaces with sensitivity down to the single-molecule level. Our method is based on imaging the surface potential shift occurring on a dense layer of trillions of recognition sites when assayed with increasing concentrations of the analyte. An insight into the reliability and robustness of the methodology is provided. Our findings demonstrate that a 10-minute 0.1 mL HEPES incubation, encompassing 1 ± 1 targets, triggers an extended surface potential shift that involves the whole investigated area. Such a shift quickly saturates at increasing ligand concentration, showing that the developed sensing platform works as an OFF/ON detector, capable to assess the presence of a few specific biomarkers. The reliability of the developed KPFM methodology represents an asset for single-molecule detection at wide interfaces.

▲ **Integrated multimodal imaging with 2PEF, SHG, and STED microscopy for nanoscale biophysical analysis.**
Bianchini P. ([1]), Arya G. ([1]), Scotto D'Abbusco M. ([1]), Piazza S. ([2]), Castello M. ([2]), Diaspro A. ([1])([3])
([1]) *Nanoscopy and NIC@IIT, Istituto Italiano di Tecnologia, Genoa, Italy*
([2]) *R&D Department, Genoa Instruments, Genoa, Italy*
([3]) *DIFILAB, Dipartimento di Fisica, Università degli Studi di Genova, Genoa, Italy*
Advancements in two-photon excitation fluorescence microscopy (2PEM) have revolutionised biological imaging by enhancing tissue penetration, minimising photodamage, and refining three-dimensional resolution. This research highlights the adoption of an ultrafast laser system with 15 fs pulse durations aimed at optimising two-photon excitation for improved fluorescence microscopy. Our experimental configuration integrates a single-photon avalanche diode (SPAD) array for image scanning microscopy (ISM) and a 775 nm pulsed laser for Stimulated Emission Depletion (STED) microscopy. The utilisation of ultrashort pulses facilitates the excitation of fluorophores with higher peak powers and broader bandwidths, enhancing signal-to-noise ratios and image clarity. The 7×7 SPAD array supports a descanned configuration with an open pinhole, beneficial for 2PEM applications under challenging imaging

conditions. Furthermore, our setup features a 775 nm nanosecond pulsed laser for STED microscopy, achieving nanoscale spatial resolution by depleting fluorescence outside the focal spot through stimulated emission. By merging these sophisticated imaging techniques into a unique platform, we provide a robust system for probing biological processes at the nanoscale. This integrative approach not only promises detailed insights into cellular dynamics and subcellular architectures but also opens new possibilities for exploring intricate biological interactions within their native environments. This system is poised to facilitate significant advancements in biophysics and cancer research, driving a deeper understanding of complex biological mechanisms.

▲ Leveraging the E222Q replacement to generate novel reversibly switchable fluorescent Aequorea victoria proteins for super-resolution imaging.

Bizzarri R. ([1])([5]), Storti ([1]), Lo Gerfo ([1]), Civita S. ([2])([3]), Nifosì R. ([1]), Abbruzzetti S. ([2]), Viappiani C. ([2]), Diaspro A. ([3])([4]), Bianchini P. ([3])

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([2]) *Deptartment of Mathematical, Physical and Computer Sciences, University of Parma, Parma, Italy*
([3]) *Nanoscopy and NIC@IIT, CHT Erzelli, Istituto Italiano Tecnologia, Genoa, Italy*
([4]) *DIFILAB Department of Physics, University of Genoa, Genoa, Italy*
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Reversibly photoswitchable fluorescent proteins (RSFPs) admirably combine the genetic encoding of fluorescence with the ability to repeatedly toggle between a bright and a dark state, adding a new temporal dimension to the fluorescence signal. Accordingly, in the last years RSFPs have paved the way to novel applications in cell imaging that rely on their reversible photoswitching, including many super-resolution techniques such as F-PALM, RESOLFT, and SOFI that provide nanoscale pictures of the living matter. Yet many RSFPs have been engineered by a rational approach only to a limited extent, in the absence of clear structure-property relationships that in most cases make the emergence of the photoswitching anecdotic. We have discovered that E222Q replacement is a single photoswitching mutation since it restores the intrinsic *cis-trans* photoisomerization properties of the chromophore in otherwise non-switchable Aequorea proteins of different color and mutation pattern (Q-RSFPs). Our findings link indissolubly photoswitching and Q222 presence, by a simple yet elegant scenario: largely twisted chromophore structures around the double bond (including hula-twist configurations) are uniquely stabilized by Q222 via H-bonds. Likely, these H-bonds subtly modulate the electronic properties of the chromophore, enabling the conical intersection that connects the excited *cis* to ground *trans* chromophore. Remarkably, analysis of photoswitching by fast spectroscopy revealed multiphase kinetics related to the peculiar protonation pattern of the protein. By applying E222Q to simple derivatives of the enhanced green fluorescent protein we generated a palette of green and yellow emitting Q-RSFPs that are tailored to several techniques addressing intracellular settings at nanoscale, such as photochromic FRET/anisotropy, SOFI, and F-PALM. This research has been partially funded by the project PRIN 2022RRFJC4 “Novel protein-based Genetically-Encoded Fluorescent Indicators (GEFI) for Functional Super-Resolution Imaging of Biomolecular Activities in Living Cells [GEFInder]”.

Comunicazioni

Information-theoretic approach highlights high-order behaviours in microarray data.

Lacalamita A. (1)(2), Amoroso N. (2)(3), Fania A. (1)(2), Monaco A. (1)(2), Pantaleo E. (1)(2), Pomarico D. (1)(2), Stramaglia S. (1)(2), Bellotti R. (1)(2)

(1) *Dipartimento Interateneo di Fisica, Università degli Studi di Bari, Bari, Italy*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy*
(3) *Dipartimento di Farmacia-Scienze del Farmaco, Università degli Studi di Bari, Bari, Italy*

The information-theoretic approach can help us understand the role of groups of correlated elements in a network. While there are established methods to measure new information, the definition and application of methods to measure information modification remains an open question. The information modification in a network is related to redundancy and synergy between systems that share information about a target. Redundancy refers to the presence of shared information about the target that can be accessed through the individual source systems. Synergy refers to information that is only available through the sharing of systems. A more refined approach, called partial information decomposition, separates the unique, redundant, and synergistic contributions of shared information; however these definitions are not directly derivable from the classical measures of information theory. In this contribution we report an application of this approach to publicly available microarray data on hepatocellular carcinoma. Comparing samples and genes synergy clusters with the classical correlation ones high-order behaviours, such as differential genes and enriched functions, emerge with the novel approach.

Sviluppo di un modello di intelligenza artificiale generativa per immagini di microscopia a super-risoluzione.

Lossano S. (1)(2), Arezzini S. (1), Cella Zanacchi F. (1)(2), Fantacci M. E. (1)(2), Formuso A. (1), Lizzi F. (1), Mazzoni E. (1), Noferi B. (2), Scapicchio C. (1), Retico A. (1)

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La Microscopia a Super-Risoluzione (SRM) supera il limite di diffrazione imposto dalla legge di Abbe, permettendo l'osservazione cellulare su scala nanometrica, ma è limitata da lunghi tempi di acquisizione. Per aggirare tale vincolo, si è esplorata l'applicazione all'imaging microscopico della rete neurale Enhanced Super-Resolution Generative Adversarial Network (ESRGAN), un modello generativo sviluppato per le immagini naturali. L'obiettivo è quello di generare immagini a super-risoluzione a partire da immagini di microscopia a bassa risoluzione, acquisite in un tempo significativamente più breve. Il modello è stato adattato al nuovo tipo di immagini tramite la tecnica del transfer-learning. La procedura proposta è stata implementata per l'imaging di microtubuli cellulari, ottenendo immagini che presentano strutture continue, migliorando la fedeltà della rappresentazione delle loro reali strutture filamentose. Le immagini generate, valutate attraverso metriche quali PSNR e SSIM e la validazione umana esperta, provano che un approccio di deep learning è adatto alla microscopia e ha il potenziale per accelerare l'analisi cellulare nel contesto della fisica medica.

Simulation-based analysis of type-0 non-degenerate PPKTP crystal for SPDC process.

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Spontaneous Parametric Down-Conversion is a key phenomenon in numerous quantum technologies like quantum imaging for its ability to produce entangled photon pairs. Quantum ghost imaging, quantum-enhanced imaging and quantum imaging with undetected photons have merits of reconstructing biological samples with high resolution in the presence of significant background noise, surpassing classical limits in image sensitivity and detection in visible region when sample interaction lies in infrared region. Leveraging SPDC, this work focuses on the simulation-based characterization of periodically polled Potassium Titanyl Phosphate (PPKTP) type-0 non-degenerate crystal in collinear configuration. The study of variation of signal and idler wavelengths with temperature, effect of beam-waist, spectral density of signal-idler photons and joint photon spectrum has been discussed for the customized crystal. Our findings provide crucial insights into optimizing the efficiency and spectral properties essential for quantum imaging applications, particularly in the realm of biophysics.

From 2D brightfield images to quantitative radiomics features: A non-destructive analysis of 3D spheroids.

Stellato M. ([1]), Rydzyk M.M. ([2]), Pannella M. ([3]), Rossi F. ([2]), Cappadone C. ([2]), Remondini D. ([1]), Pyun J.-C. ([4]), Castellani G. ([5]), Malucelli E. ([2]), Iotti S. ([2])([6]), Lucarelli E. ([3]), Piccinini F. ([5])([7])
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3D multicellular spheroids are structures able to mimic *in vivo* tumour conditions, providing relevant insights about tumour development and response under oncological drugs. Many of the techniques used for spheroid analysis are invasive and prevent researchers from performing further studies on the same cultures. In this contribution, 2D brightfield images of spheroids were acquired with standard microscopes and analysed to extract quantitative features without using destructive methods. This field, called radiomics, allows for the extraction of data that can be used for diagnostic, prognostic, and predictive purposes. A new release of Analysis of Spheroid, AnaSP 3.0, an open-source tool designed for segmenting and extracting radiomic features from 2D brightfield images was developed. This can assess the spheroidization of the spheroids over time, the number of cells composing a monoculture spheroid, and the extension of the necrotic core without disrupting the spheroids. Moreover, it presents other new features that extract information directly from the grey level of the images, and not only from the binary masks. AnaSP 3.0 is freely available at `https://sourceforge.net/p/anasp`.

Artificial Intelligence algorithms for the standardization of prostate cancer screening.

Lo Sasso A. ([1])([2])([3]), Bellantuono L. ([2])([4]), Facchini L. ([3]), Amato E. ([1])([2])([3]), Porcelli F. ([3]), Frascella P. ([3]), Bellotti R. ([1])([2])

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Prostate cancer stands as the most prevalent cancer among males in Italy, comprising 18.5% of all male cancer diagnoses. Nearly a quarter of men receive a prostate cancer diagnosis between ages 50 and 60. Detecting this cancer early could potentially save numerous lives. Our research endeavors to investigate cancer onset by analyzing breath samples. By examining the abundance of approximately 250 volatile organic compounds using gas spectrometry, we have studied patients afflicted with prostate cancer. Following promising results from initial pilot studies on suspected and full-blown patients, we have progressed to standardizing this procedure for screening analyses across various hospital structures. In this study, we elucidate why relying solely on classical statistics struggles to effectively discern a patient disease state. We present a clustering model based on Self-Organized Maps (SOM), which aids in data labeling and error reduction in screening. Subsequently, we explain an artificial intelligence model capable of distinguishing patients categorized into three classes: No disease, suspected and full-blown. We also discuss the algorithm's performance with these patient groups.

Enhancing thyroid cancer diagnosis with Raman spectroscopy and machine learning.

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Raman spectroscopy (RS) displays promise as a diagnostic tool for thyroid cancer due to its ability to identify biochemical changes during oncogenesis. This technique is non-invasive and does not require labels or dyes, making it a viable alternative to molecular tests. RS is more effective in distinguishing malignant features than other approaches, which can help reduce the need for unnecessary surgeries. However, the main challenge of using RS is

identifying significant patterns and peaks. To overcome this obstacle, we suggest using a machine learning algorithm to distinguish between healthy/benign and malignant nodules. We collect Raman spectra from both thyroid fine-needle aspiration specimens and surgically excised histological samples. Then, we select a set of peaks using a data-driven and label-independent approach and train the algorithm using the relative prominence of these peaks. Our models perform excellently, with an area under the Receiver Operating Characteristic curve of over 0.9. In order to make the results more understandable, we utilize eXplainable Artificial Intelligence and determine the impact of individual features on the prediction of each sample.

Studi mediante microspettroscopia FTIR dei processi coinvolti nella biogenesi di nanoparticelle di metalloidi da parte di specifici ceppi batterici.

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La spettroscopia e la microspettroscopia nel medio infrarosso, anche abbinate a tecniche di analisi statistica multivariata come l'analisi per componenti principali, rappresentano una tecnica rapida, accurata e sensibile per la caratterizzazione dei sistemi biologici e dei relativi processi biochimici. Di particolare interesse sono gli studi volti a chiarire i processi attraverso i quali alcuni ceppi batterici (quali *Stenotrophomonas maltophilia* SeITE02, *Bacillus mycoides* SeITE01, *Ochrobactrum* sp. MPV1) sono in grado, nel corso della loro crescita cellulare, di ridurre ossianioni tossici di metalloidi (quali selenio e tellurio), presenti e assorbiti dal terreno di coltura, in nanoparticelle della forma elementale non tossica rivestite di materiale organico, che vengono poi espulse nel mezzo circostante. Presenteremo alcuni significativi risultati ottenuti in questo campo all'Università di Verona nell'ambito di una collaborazione tra il Laboratorio di Spettroscopia e Micro-spettroscopia nell'Infrarosso e il Laboratorio di Biotecnologie Microbiche e Microbiologia Ambientale.

Intraday and day-to-day variability of the tear proteome.

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Tear fluid is a dynamic biological fluid, which is emerging as an attractive source of non-invasive biomarkers. Due to the minimal volume typically obtained during the collection, the in-depth study of the tear proteome presents significant challenges, particularly for personalized medical approaches. Despite the advances in high-resolution mass spectrometry, which have enabled more detailed profiling of the tear proteome, intraday and day-to-day variability of tear proteins, which could affect their utility as biomarkers, has not been well explored yet. This study aims to investigate the variations in the tear fluid proteome. Building on a foundational study that identified 890 proteins across 23 subjects, tear composition was monitored in two individuals over three weeks, collecting samples weekly both in the morning and in the afternoon. Differential analysis of ultrahigh-resolution shotgun proteomics data revealed a consistent abundance of tear proteins across the weeks, with only 25 proteins showing significant variation throughout the day. These findings enhance the understanding of tear fluid dynamics and support its potential in biomarker research.

Application of spectroscopic techniques for authenticating the origin of typical Sicilian products.

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Food quality and traceability represent important milestones in the agri-food sector. In order to detect food counterfeiting and quality, advanced quantitative techniques must be implemented. As part of the project PRIN 2022 PNRR P20223P48S entitled "Implementing advanced elemental and chemical analysis for quality, safety and traceability assessment of PGI and PDO agri-food products", funded by European Union - Next Generation EU, we propose to use Fourier-transform infrared (FT-IR), Raman and X-ray fluorescence (XRF) spectroscopic techniques for assessing the quality of three typical Sicilian products: pistacchio verde di Bronte, pomodoro di Pachino and arancia rossa di Sicilia, recognized by the European Union with the Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) labels. The possibility of authenticating the origin of these products will be evaluated comparing elemental and chemical composition of PDO and PGI products with that of samples coming from Sicilian growing areas outside PDO/PGI sites. Preliminary results obtained through FT-IR and XRF spectrometry on pistachio samples harvested from different farmlands of Sicily will be discussed.

Acrylodan-labeled bovine serum albumin as a fluorescent biosensor for evaluating the hydrolysis in phospholipid-based formulations.

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(1) *Department of Medicine and Surgery, University of Parma, Parma, Italy*
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(3) *Department of Food and Drug, University of Parma, Parma, Italy*

Phospholipids in food and pharmaceutical formulations tend to hydrolyze, forming free fatty acids and lysoforms. To monitor the degree of phospholipid hydrolysis, we conjugated bovine serum albumin (BSA), which accommodates in its multiple binding sites fatty acids with variable length, with the environment-sensitive fluorophore acrylodan, producing a biosensor we named Albuminodan. Tryptophan-to-acrylodan fluorescence resonance energy transfer (FRET) of Albuminodan was measured, as it is sensitive toward changes in protein conformation and ligation state. FRET was evaluated in the presence of two phospholipids (DPPC and POPG) and their corresponding fatty acids and lysoforms. Marked FRET changes were observed upon binding of all molecules, with KDs in the range 100–500 nM. We found that different molecules caused different effects on FRET spectra, suggesting that Albuminodan not only allows to quantify but also to discriminate among different lipids and could thus be used to characterize the stability of lipid-based formulations. The deconvolution of the spectra of phospholipid formulations was used to evaluate the degree of hydrolysis.

Characterization and diffusion study of dosimetric PVA-GTA Fricke gel functionalized with metal indicator.

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(2) *Dipartimento di Fisica ed Astronomia "Ettore Majorana", Università degli Studi di Cata-*

nia, Italy
([3]) *Fondazione IRCCS "Istituto Nazionale dei Tumori", Milano, Italy*
Fricke gel dosimeters are based on chemical dosimeters in which radiation induces the oxidation of Fe^{2+} ions which are incorporated into a hydrogel matrix, in this case composed of polyvinyl alcohol (PVA) cross-linked with glutaraldehyde (GTA). This change in concentration can be read through optical techniques, following the addition of a colorimetric metal indicator. In this way, a 3D dose map of high clinical interest can be obtained. However, one of the main limitations of this system is the diffusion of ions in the gel matrix, which causes degradation of dosimetric information in time and space. This contribution proposes a novel strategy to reduce the diffusion coefficient, which consists of covalently binding the metal indicator with the PVA gel matrix. Starting from previous studies on sulfosalicylic acid (SSA), two of its amine derivatives were proposed as chelating agent and anchored to the matrix. The data showed a good linear dose-dependent optical response for the functionalized gel matrix. However, although ion diffusion was reduced, it was not completely eliminated, suggesting that the movements of the matrix itself must be limited to effectively achieve this important goal.

Aula D **ore 09:00 – 13:30**

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiede: Boscherini F. (Università di Bologna)

Relazioni su invito

▲ **Fundamental research and applications with the EuPRAXIA facility at LNF.**

Pisano S.

Centro Fermi e INFN, Laboratori Nazionali di Frascati

In the next years, the Italian Laboratori Nazionali di Frascati of INFN will play a crucial role in the development of plasma-based acceleration techniques, being one of the major players of the EuPRAXIA initiative, that aims at realizing the first laser plasma user facility worldwide. The activity ongoing in this field is hosted at SPARC_LAB (Sources for Plasma Accelerators and Radiation Compton with Laser And Beam), that consists in a conventional high-brightness RF photo-injector and a multi-hundred terawatt laser. In parallel to the R&D program, the different radiation sources installed in the infrastructure can be exploited to carry out measurements in the nuclear physics field (from the study of reactions relevant for nuclear astrophysics to the general investigation of nuclear processes in plasma) and to develop applications in a wide range of sectors, spanning from cultural heritage to biophysics and nano-materials. In this contribution, the new facility will be presented, and a possible research program, covering both fundamental and applied fields and based on the specific aspects of the available radiation sources, will be discussed.

▲ **Recent advances and trends in nano and materials sciences at Elettra.**

Locatelli A.

Elettra-Sincrotrone Trieste S.C.p.A.

By enabling operation at 2.0 and 2.4 GeV, Elettra delivers photons across a wide energy range, which extends from the infrared to hard X-rays. Currently, there are 28 operating beamlines that utilize the radiation generated by Elettra, which provide a rich and diverse array of experimental techniques based on photoemission, absorption, diffraction, scattering, and also infrared microscopy. These beamlines enable the characterization of the structure and properties of matter with sensitivity down to the atomic level, allowing to conduct cutting-edge research in diverse fields, encompassing physics, chemistry, life and environmental sciences, cultural heritage. My contribution will provide a broad overview of the capabilities of Elettra beamlines, with a focus on recent studies conducted in nano and materials sciences. Selected studies will be presented to illustrate the strengths of the existing experimental setups. The emphasis will be placed on *in situ* and *operando* methods, which are opening up exciting pathways for studying interfaces and prototypical devices. The application of photoemission and absorption spectroscopy to emerging fields, such as energy materials, will be highlighted.

Comunicazioni

Machine learning algorithms using pca and autoencoder based on data preprocessing techniques aim to predict electron beam spot size and to perform emittance and energy virtualized measurements.

Latini G. (1), Pioli S. (1), Chiadroni E. (2), Mostacci A. (2), Martinelli V. (3), Serenellini B (1), Silvi G.J. (2), Ferrario M. (1)

(1) *INFN, Laboratori Nazionali di Frascati, Frascati Rome, Italia*

(2) *Università La Sapienza di Roma, Rome, Italy*

(3) *INFN, Laboratori Nazionali di Legnaro, Legnaro Padua, Italy*

Machine learning is an artificial intelligence subset that studies models capable of learning from data and providing predictions. The application of these systems is very vast and is useful both when it is important to save time and when the prediction is simpler to perform than the true measurement. In the development of a particle accelerator it is important to carry out real-time energy and emittance measurements which, however, by their nature lead to the destruction of the beam. For these reasons, two different machine learning algorithms were designed, exploiting two different data preprocessing techniques, to predict the spot size of the SPARC_LAB linac electron beam and virtually perform energy and emittance measurements without interrupting the beam. The results are promising using both pca and autoecoder techniques. Furthermore, a comparison with the simulator sees the algorithm being orders of magnitude faster. The goal is to lay the foundations for conducting virtualized diagnostics with an innovative approach.

Interazione onde-materia nel contesto multi-disciplinare dei sistemi meccanici nel campo della vibroacustica.

Barone F., Casazza M.

Dipartimento di Medicina, Chirurgia e Odontoiatria "Scuola Medica Salernitana", Università degli Studi di Salerno

L'interazione onde-materia nel contesto multi-disciplinare dei sistemi meccanici complessi costituisce elemento fondante della vibroacustica. Tale branca della fisica prevede lo sviluppo di modelli e metodi fisici interdisciplinari, finalizzati alla comprensione dei complessi meccanismi fisici che legano processi spesso interconnessi, quali quelli sismici e acustici, inquadrandoli globalmente come forzamenti ambientali su oggetti e/o su individui immersi in un ambiente forzante. La caratterizzazione di tali interazioni, che vanno dallo studio delle interazioni fisiche fondamentali fino alla caratterizzazione dello stato dell'ambiente nelle sue dimensioni spazio-temporali, diviene quindi direttamente finalizzabile non solo alla tutela della qualità dell'ambiente e della salute umana, ma anche a innovative interpretazioni nel contesto dei beni culturali, legate alle dimensioni di tangible e intangible heritage. Saranno presentate alcune linee di sviluppo con risultati teorico-sperimentali ottenuti nel campo della vibroacustica dal gruppo di ricerca in Fisica del Dipartimento di Medicina, Chirurgia ed Odontoiatria "Scuola Medica Salernitana" dell'Università degli Studi di Salerno.

Unraveling the interaction between nanoparticles and amyloid fibrils at the nanoscale: Insights from surface enhanced Raman spectroscopy.

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The hallmark of several degenerative and systemic diseases stems from uncontrolled protein aggregation into amyloid fibrils. Consequently, intense research efforts are directed towards the identification of the molecular mechanisms activating these phenomena and on the development of novel agents able to eliminate amyloid structures and prevent pathogenic protein aggregation. A promising approach in this direction involves the employment of biocompatible metallic nanoparticles (NPs), which can chemically interact with proteins while simultaneously serving as local spectroscopic probes due to their peculiar optical properties. We investigate the ability of gold (Au) NPs with different surface chemistry in the disassembly and breaking of amyloid fibrils formed by model proteins. Taking advantage of the remarkable sensitivity of surface enhanced Raman spectroscopy, we elucidate the molecular mechanisms driving protein-AuNP interaction at the nanoscale, identifying the amino acids directly involved. The obtained results will serve as a benchmark for developing novel diagnostic and therapeutic strategies based on the employment of AuNPs for the treatment of amyloid-related diseases.

Photoactivated nanocarriers of curcumin of fruits: Pros and cons in a mathematical model.

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The food's waste is nowadays a key problem, and the industry is in search of new methods of fresh food preservation, in particular for fruits, vegetables, milk derivatives, and meat. Curcumin is a natural substance, with antioxidant properties, that can be photoactivated by blue light, inducing the formation of Reactive Oxygen Species (ROS) with consequent reduction of a large variety of bacteria. For these reasons, it could be used to improve food's shelf life. In recent years, the use of nanocarriers in food preservation has become an important research topic, although they are not yet permitted by law. In the present work, various preparations (solution, chitosan-shelled nanobubbles, and nanocrystals of curcumin) and treatments (no illumination, photoactivation with blue and white light) at different conditions (room temperature or 4 °C) on fruits are presented. A mathematical model is developed to explain the strengths and weaknesses of each experiment and to find possible new combinations of vectors, treatments, and conditions with the best effect on shelf life. A final discussion on the model's construction and data availability is proposed.

Unveiling the mechanism of photodoping via transient light-driven photocharging of ITO/In_2O_3 core-shell nanocrystals.

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Doped metal oxide nanocrystals (MO NCs) such as indium tin oxide (ITO) are potential candidates for accumulating multiple electrons through the light-induced doping process termed "photodoping". It has been demonstrated recently that MO NCs can act as nanocapacitors when coupled with a suitable system acting as a hole acceptor, storing the charges generated upon illumination with photon energy above the MO bandgap. ITO NCs with

different In_2O_3 shell thicknesses are charged using a UV LED in a controlled and inert atmosphere, simultaneously monitoring the changes in the absorption spectra over time with a time resolution of a few seconds. In this way, we extract information on the dynamics of the light-driven charging process of a set of ITO/In_2O_3 core/shell NCs with "artificial" depletion regions. A long-term impact on the development of solar chargeable devices can be envisaged by the fruitful implementation of photodoping in solar energy storage applications which will advance the alternative sustainable solutions for energy production and storage to facilitate the carbon neutrality strategy.

Activities on X-band structures at the INFN-LNF.

Cardelli F., Alesini D., Ferrario M., Lollo V., Liedl A., Pioli S., Di Raddo G., Di Raddo R., Piersanti L.

Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati

At the Frascati National Laboratories of INFN the Eupraxia@SPARC_LAB project focuses on the development of a 1 GeV normal conducting compact Linac comprising an S-band injector followed by an X-band booster to drive an FEL radiation source. To attain the desired final energy level, the Linac booster comprises 16 traveling-wave accelerating structures operating at 11.994 GHz (X-band), with a minimum operational gradient of 60 MV/m. INFN-LNF is actively engaged in an extensive design phase, prototyping, and testing of these structures. This contribution presents a comprehensive overview of all the activities undertaken in the design and prototyping process, followed by preliminary results of the high power test of the first Eupraxia@SPARC_LAB X-band structure prototype.

Electrospun spinel-structured high-entropy oxide nanofibers as fillers for solid polymer electrolytes.

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Solid polymer electrolytes (SPEs) have great potential in enhancing the safety of lithium-ion batteries (LIBs), but suffer from low ionic conductivity and insufficient mechanical strength that limit their commercialization. These drawbacks can be overcome by incorporating inorganic fillers into the polymer matrix. High entropy oxides (HEOs) are attracting enormous scientific interest due to their enhanced properties resulting from the synergistic interaction between their multiple metallic components. In this work, electrospun HEO nanofibers (NFs) are evaluated as inorganic fillers for the preparation of composite SPEs for LIBs. For this purpose, the as-produced HEO NFs are incorporated into a polyethylene oxide (PEO) matrix and the resulting HEO@PEO composites are thoroughly characterized and tested. The obtained results demonstrate that the incorporation of HEO fillers improves the ionic conductivity and widens the anodic stability window of the pristine polymer and that HEO@PEO composites have great potential for their use with high-voltage cathodes.

Enhancing zT in solution-processable organic thermoelectric materials through lithographically controlled wetting: A leap towards high-performance flexible thermoelectric generators.

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Organic thermoelectrics (TEs) are promising for replacing inorganic compounds in near-room-temperature energy generation, but they are limited by a low figure of merit zT. We introduce lithographically controlled wetting (LCW), a technique for patterning and crystallization under confinement of solution-processable thin films, as a powerful method to enhance zT in PEDOT:PSS and, more generally, in organic TEs. LCW induces strong morphological and structural film reorganization, with elongated grains along the unconfined film direction, and the appearance of a novel PEDOT packaging with unprecedented short interchain distance in the out-of-plane direction. This results in strongly enhanced electrical conductivity and power factor. The improved PEDOT packaging and grain morphology marginally affect the in-plane thermal conductivity, but strongly reduce the dependence of thermal conductivity on electrical conductivity because of increased carrier localization length and enhanced phonon scattering. As a result, zT improves by up to 230% in LCW films compared to spin-coated films. Overall, LCW is a simple and green approach that might become a game changer in the field of organic TEs.

Nuclear magnetic resonance fingerprinting for low-field NMR applications.
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Magnetic Resonance Fingerprinting (MRF) is a novel imaging technique that offers a rapid quantitative approach for magnetic resonance imaging. We focused on adapting MRF for low-field applications to speed up NMR multiparametric analysis. By using a pseudo-random RF sequence, a unique signal, "fingerprint", is generated for different NMR parameters (*i.e.*, T_1, T_2). By matching these fingerprints against a precomputed dictionary of synthetic signals, MRF can identify the NMR parameters. To accomplish this task, and to make the data analysis robust, RF sequences and deep learning techniques were tailored on laboratory instrumentation and tested on phantom samples. A fully connected neural network was designed and trained. Experimental data showed that B_0 and B_1 inhomogeneities strongly influenced signal modulation, and a procedure to characterize B_0-B_1 correlation function was established. A good matching between T_1 and T_2 ground-truth values and the predicted ones indicated the possibility of using MRF-like sequences to speed up applications at low fields.

Ceramic Matrix Composite surface characterizations by nuclear physics techniques for space applications.
Molitierno F. (1)(2), Buompane R. (1)(3), Cantoni (2), De Stefano Fumo M. (4), Del Vecchio A. (1)(2)(3), Gialanella L. (1)(3), Mitsou M.L. (1)(3), Santonastaso (1)(3), De Cesare M. (1)(2)(3)
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The Ceramic Matrix Composite (CMC) materials are used in many aerospace fields such as Thermal Protection System (TPS) of re-entry vehicles. TPS materials are subject to

oxidation and eventually degradation, during re-entry phase in the atmosphere. Usually, such materials before flight are qualified on-ground in Plasma Wind Tunnel (PWT) facilities able to simulate the harsh environment experienced during re-entry. Nuclear physics techniques such as Ion Beam Analysis (IBA) can be applied to assess the material surface conditions. The CIRCE laboratory at the University of Campania "Luigi Vanvitelli", in collaboration with CIRA, is improving its materials analysis capabilities implementing an IBA beamline at the 3 MV tandem accelerator laboratory. This technique will be applied on ISiComp® CMC material developed by CIRA and Petroceramics for the TPS of the Space Rider, the next European Space Agency re-entry spacecraft, and qualified in the SCIROCCO PWT at CIRA. In this contribution, the state of the art of the research activity and the preliminary results are shown.

In-field Raman evaluation of plant pathogens for sustainable agriculture.

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Nowadays, sustainable crop management is mandatory to limit economical losses, tailor pesticide usage and reduce crop damages caused by plant pathogens, especially when the visual detection of symptoms occurs too late to allow a therapeutic intervention. Raman spectroscopy (RS) is a non-invasive method that can be easily accessed for in-field monitoring, via handheld portable instruments, whose benefits rely on the capability of directly monitoring molecules associated with the plant health. The aim of this work is to develop a non-destructive methodology by combining the sensing capabilities of RS with chemometric analysis, to classify the plants as healthy or infected. A proof of concept of its applicability was reported by our group, with the identification of symptomless leaves in esca disease-affected vines examining leaf samples from both symptomatic and asymptomatic shoots in infected plants. The method is currently under investigation to identify saline stress in rocket leaves and biotic infection in tomato plants. Funded by Next generation EU M4C2 1.1 within PRIN 2022JZAA9W.

Strongly coupled organic microcavities towards quantum batteries.

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Within the strong coupling regime, the confined optical modes of a microcavity undergo a coupling with the semiconductor excitons resulting in the formation of cavity-polariton states. Our microcavities are based on a double dielectric-mirror structure containing a thin film of a Lumogen-F dye suspended in a polystyrene matrix. Each molecule represents a unit that can exist in a quantum superposition state of two energy levels (fundamental and excited). By constructing the cavity in a way that units can exist in superposition, the total system can behave collectively. This behaviour, known as quantum coherence, allows the

units to act cooperatively, giving rise to a hyper-fast charge that depends on the number of molecule-units. We show by ultrafast spectroscopy that the exciton rise time decreases as $\sqrt{N}$, where N is the number of dye molecules, in agreement with theoretical predictions. This result provides the first experimental proof-of-concept for the quantum battery, opening the way for further experimental and theoretical investigations.

Effetto di forma e dimensione sulle proprietà rilassometriche e ipertermiche di nanoparticelle magnetiche.

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In nanomedicina le nanoparticelle (NP) magnetiche trovano applicazioni sia diagnostiche sia terapeutiche: come agenti di contrasto nell'imaging a risonanza magnetica e come agenti ipertermici antitumorali. Questo studio di propone di investigare come le caratteristiche morfostrutturali quali forma e dimensione possano influenzare le proprietà magnetiche e rilassometriche delle NP, al fine di ottimizzarle a seconda dell'applicazione. Sono stati esaminati 3 set di NP a base di ossidi di ferro con forma diverse (sfere e flowers) e dimensioni variabili (6–35 nm), rivestite con diverse molecole biocompatibili (DMSA, PAA e CM-Dextran). Dopo l'analisi morfostrutturale (TEM, XRD, IR, TG, DLS e VSM) sono state indagate le proprietà rilassometriche acquisendo i profili NMRD, rappresentativi della relassività nucleare longitudinale e trasversale in funzione della frequenza (campo magnetico statico). L'efficienza ipertermica è stata valutata a diverse ampiezze e frequenze del campo magnetico alternato. La forma dei profili NMRD, rappresentativa dei meccanismi di rilassamento, risulta dipendere dalla forma e dimensione delle NP, analogamente al rilascio termico.

FT-IR spectroscopy coupled with machine learning for a high sensitive detection and discrimination of gaseous volatile organic compounds.

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Volatile Organic Compounds (VOCs), such as styrene and its co-products, are organic chemical compounds able to evaporate at room temperature. They are classified as a possible human carcinogen in the short and long term and in co-exposure to other physical-chemical agent. During the last years, we systematically used Fourier Transform Infrared (FTIR) spectroscopy for quantifying VOCs in air, increasing the sensitivity of IR systems down to the parts per million (ppm) level. Here, we investigate five selected aromatic compounds, of

extreme importance in occupational safety with the aim of filling the gap in IR gas-phase database. Benzene, Toluene and Xylene (BTXs) are studied and their calibration curves are carried out. A Machine Learning (ML) algorithm is developed, providing the automatization of the single VOC detection and discrimination starting from the spectra of random mixtures. The dataset processing is optimized and different algorithms are evaluated over each single VOC recognition between styrene, ethanol, isopropanol, acetone and BTXs. This work is a very promising starting point for building a portable setup for the detection at very high sensitivity.

Investigation of silicon carbide detectors performances within the SAMOTHRACE ecosystem.

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Nowadays, the interest in SiC-based detectors is growing fast thanks to the important features of this wide band gap semiconductor. Among them, the radiation hardness and the reliability in device fabrication techniques render the use of this material a good compromise between the high performances, in terms of energy resolution and linearity, of silicon detectors and the radiation hardness of diamond ones. Moreover SiC-based detectors can be also used for fast-timing techniques. All these features are important both for the future of nuclear physics, especially with high-intensities stable and unstable beams, and of medical applications. SiC detectors are indeed used as dosimeter, micro-dosimeter as well as tagging elements in facilities delivering high-intensity Radioactive Ion Beams (RIBs), such as the FraISe one at INFN-LNS. In this framework, arrays of SiC detectors are being developed, also thanks to the SAMOTHRACE ecosystem. The contribution underlines the role of the use of such SiC detectors, especially focusing on their use for the production of high-intensity RIBs, and it presents results obtained with developed SiC detectors prototypes using both radioactive sources and beams.

3C-SiC resonators: Fabrication, modelling and characterization.

Muoio A. ([1]), Scuderi V. ([1]), Garofalo A. ([1])([3]), La Via F. ([1]), Sapienza S. ([2]), Belsito L. ([2]), Ferri M. ([2]), Roncaglia A. ([2])
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([3]) *Dipartimento di Fisica, Università di Catania*

The cubic silicon carbide (3C-SiC) layers on silicon (or silicon-based) substrates are considered interesting materials for sensors and micro- and nano-electromechanical systems (MEMS

and NEMS), due to its exceptional physical and chemical properties. Furthermore, the high Young's modulus and the relatively low mass density induce significantly higher resonant frequencies and quality factors in resonant devices at the same geometrical dimensions in comparison with Si or gallium nitride. In this contribution the stress field distribution in 3C-SiC (111) resonators with a double clamped beams structure was studied by COMSOL simulations. The 3C-SiC thin film (thickness less than 1 μm) was deposited in a previously described horizontal, low pressure, resistively heated hot wall chemical vapor deposition (CVD) system with a rotating sample holder. Hetero-epitaxial 3C-SiC growth on Si substrates was achieved using a classical two-step process with a purified hydrogen (H_2)/argon (Ar) mix as carrier gas, and silane (SiH_4) and propane (C_3H_8) as Si- and C-precursors. By COMSOL Multi-physics software different parameters like beam displacement and stress over the beam were calculated.

Sviluppo di un prototipo per la cattura di CH4 tramite strumenti di fisica delle particelle.

Angiulli F.A. ([1]), Aimè C. ([1]), Biagini D. ([2]), Braghieri A. ([1]), Brunoldi M. ([1]), Calzaferri S. ([1]), Dinuccio E. ([2]), Dondi D. ([3]), Finco L. ([4]), Giannandrea G. ([1]), Guida R. ([4]), Mandelli B. ([4]), Montagna P. ([1]), Riccardi C. ([1]), Salvini P. ([1]), Vai I. ([1]), Vadivel D. ([3]), Vitulo P. ([1])

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Il progetto mira allo sviluppo di un prototipo per la cattura del gas metano, un potente gas serra con un potenziale di riscaldamento globale pari a 28, ampiamente presente negli ambienti di allevamento bovino. Si propone l'adattamento di tecniche e strumenti impiegati nei rivelatori a gas della fisica delle particelle. Il prototipo sarà basato su un sistema preesistente di recupero gas progettato per la cattura di CF4 nell'esperimento Compact Muon Solenoid (CMS). Finanziato dall'Unione Europea - Next Generation EU, il progetto si concentra sulla cattura del metano mediante l'impiego di cristalli di zeoliti, dai quali potrebbe essere successivamente estratto. Verranno presentati i risultati della simulazione della diffusione del metano nell'ambiente della stalla, per individuare le posizioni ottimali per la cattura. Inoltre, sarà illustrata la caratterizzazione di "stazioni di monitoraggio" per rilevare la composizione dell'atmosfera della stalla nel lungo periodo. Infine, si discuterà lo stato della ricerca e sviluppo del prototipo di cattura, analizzando i risultati dei primi test in laboratorio.

Aula B **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica
Presiede: Satanassi S. (Università di Bologna)

Relazioni su invito

▲ **Design for Physics.**
Organtini G. ([1]), Del Santo M. ([1]), Bombaci G. ([2])
([1]) *Sapienza Università di Roma*
([2]) *IED, Istituto Europeo di Design, Roma*
Design for Physics è un progetto nel quale gli studenti dello IED hanno progettato e realizzato kit di strumenti per stimolare collegamenti interdisciplinari, dalle linee insolite e coloratissime, pensati per coinvolgere e stimolare l'interesse verso la fisica anche da parte degli studenti meno versati. Forme e colori richiamano lo stile radicale del design italiano degli anni '60 e '70, riproponendo una visione provocatoria e rivoluzionaria che mette in primo piano la creatività, anche sul piano scientifico. Tutti gli strumenti di Design for Physics hanno un basso costo e sono destinati alla produzione su larga scala o all'autoproduzione, grazie alla facile reperibilità dei materiali e al loro basso impatto ambientale. Le misurazioni si eseguono con l'ausilio di smartphone, promuovendo un apprendimento attivo, e favorendo l'acquisizione di competenze trasversali. 20 insegnanti hanno avuto modo di sperimentarne l'utilizzo in occasione di un corso di formazione, i cui primi risultati saranno illustrati nella relazione.

▲ **Guardare oltre i percorsi di studio universitari: la terza via per l'orientamento alle discipline scientifiche.**
Monti F.
Dipartimento di Informatica, Università di Verona
Il PLS rappresenta un'esperienza significativa di collaborazione tra scuola e università nella quale l'orientamento alla scelta degli studi universitari si realizza "sul campo" e può costituire un'occasione di formazione a tutto tondo quando si consideri il ruolo della scienza nella società e si affrontino temi di interesse generale, anche agganciati a percorsi per l'educazione civica. L'orientamento nel PLS si può realizzare secondo tre diverse prospettive: per via indiretta, mediante iniziative di aggiornamento degli insegnanti; per via diretta, attraverso attività di autovalutazione, test, corsi, laboratori, seminari, espressamente progettati e rivolti agli studenti, vuoi considerando le discipline caratterizzanti i percorsi di studio, vuoi guardando ai potenziali sbocchi lavorativi. A partire dalle esperienze del PLS di Fisica a Verona, mi propongo di mostrare come questa terza via possa e debba essere valorizzata in modo da riportare al centro dell'orientamento il lavoro, a maggior ragione ora che è stato introdotto l'albo professionale dei fisici e sono in fase di messa a punto le lauree direttamente abilitanti alla professione fisico.

Comunicazioni

● **Un percorso multidisciplinare di formazione docenti di scuola secondaria dedicato alla sostenibilità e alla cittadinanza scientifica.**
Fiorello C., Di Mauro M., Salmoiraghi A., Toffaletti S., Onorato P., Oss S.
Dipartimento di Fisica, Università degli Studi di Trento
L'Agenda 2030 enfatizza il ruolo dell'educazione "multidisciplinare" alla sostenibilità come chiave per raggiungere gli obiettivi. In questo studio, si presenta un intervento formativo

rivolto agli insegnanti, composto da una dozzina di lezioni mirate a promuovere un'efficace appropriazione dei concetti di sostenibilità attraverso l'impiego di metodologie attive e il coinvolgimento dei docenti in formazione. Il programma formativo, condotto da accademici di diversi dipartimenti, spazia su tematiche quali la psicologia del clima, gli aspetti fisici e tecnico-scientifici del clima, la produzione e il consumo di energia, le normative vigenti, nonché gli aspetti economici e socio-antropologici della sostenibilità. Ogni modulo integra metodi interattivi di insegnamento con attività di laboratorio, dibattiti e lavori di gruppo, con l'obiettivo di preparare gli insegnanti a fungere da agenti di cambiamento tra gli studenti. I risultati sono stati valutati attraverso l'analisi delle attività didattiche progettate dagli insegnanti partecipanti e l'utilizzo di questionari pre e post-corso, al fine di valutare lo sviluppo di fattori psicologici facilitatori dell'attivazione.

"Faces of Physics" - Sharing scientific culture through personal narratives.

Dryden E., Carli M., Pantano O.

Dipartimento di Fisica e Astronomia, Università di Padova

Physics research is more than just about data and publications" it's also about the people behind the discoveries. Through a series of video portraits, "Faces of Physics" showcases the careers, workplaces and daily lives of a diverse group of physicists, presenting an innovative approach to communicating scientific culture in the field of Physics. The primary aim of "Faces of Physics" is to bridge the gap between the world of physics research and society, with a particular focus on engaging young people contemplating careers in physics. Drawing from prior research on the lack of diversity in physics, "Faces of Physics" aimed to offer accessible and relatable content while showcasing the contributions and roles of physicists, highlighting the field's diversity of backgrounds and experiences. By featuring individuals from various backgrounds, the project underscores the inclusivity and accessibility of physics as a career path. Through this communication, we will outline the methodology and outcomes of the "Faces of Physics" project, highlighting its efficacy in promoting scientific culture and fostering interest in physics across diverse audiences.

Il paradosso dell'ignoranza: effetto Dunning-Kruger e apprendimento della fisica.

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([2]) *Dipartimento di Fisica e Geologia, Università di Perugia*

Saranno presentati i risultati di un'indagine svolta tra gli studenti del quarto anno di scuola superiore in alcuni istituti della fascia appenninica umbra. Lo scopo di questo esperimento sociale, condotto da una equipe mista di sociologi e fisici, è quello di mettere a tema la conoscenza della descrizione fisica della realtà, evidenziando l'eventuale presenza dell'effetto Dunning-Kruger, secondo il quale le persone con bassi livelli di competenze tendono a sovrastimare le proprie capacità. Questo effetto psicologico può portare una serie di conseguenze negative in ordine allo studio delle discipline STEM (scienza, tecnologia, ingegneria e matematica), limitando la capacità di progredire in questi campi che sono invece strategici per il nostro futuro. Infatti, queste discipline sono spesso complesse e richiedono non solo una grande quantità di conoscenze, ma anche di essere in grado di riconoscere i propri limiti. I risultati dell'indagine mostrano che in generale è presente un apprezzabile scarto tra competenze presunte e reali, con incidenza differenziata in base al sesso, all'indirizzo di studi degli studenti coinvolti e ad altri fattori come l'ambiente scolastico e familiare.

Confidence and performance of secondary school students in physics and mathematics.

Lippiello S. ([1])([2]), Carli M. ([1]), Pantano O. ([1])
([1]) *Dipartimento di Fisica e Astronomia, Università di Padova*
([2]) *Liceo Scientifico Jacopo da Ponte, Bassano del Grappa*

This contribution aims to study the relationship between students' performance and confidence when using mathematical tools such as derivatives, integrals, and vectors to solve physics problems. The research involved 260 students from four Italian secondary schools in the Licei Matematici network. We employed a modified version of the Test of Calculus and Vectors in Mathematics and Physics, initially designed in 2018 for first-year university students. We adapted it for secondary school, adding to each item a question about the student's confidence level in tackling that particular item. To examine the development of the relationship between confidence and performance over time, we administered the test both before and after a series of learning activities in the school year 2022/23, serving as a pre- and post-survey tool. The results showed an overall improvement in test and confidence scores but did not lead to a balance between over- and under-confidence. An analysis with the gender lens highlighted that males showed higher confidence than females. This research underlines the importance of working on confidence assessment practices in concert with school performance.

"A Volte Ritornano ...": dal mondo della ricerca il ritorno ai banchi di scuola.

Ercoli A. ([1]), Soffi L. ([2]), Duranti M. ([3])
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([2]) *INFN, Sezione di Roma*
([3]) *INFN, Sezione di Perugia*

Dall'a.s. 2015-2016, con cadenza annuale, il Liceo Scientifico Statale "P. Ruffini" di Viterbo organizza, per gli studenti delle classi terminali, un progetto nel quale alcuni ex studenti, già laureati in Fisica, Matematica, Chimica, Ingegneria, Geologia e Medicina, facenti anche parte di collaborazioni internazionali, presentano la loro attività di ricerca e il loro percorso professionale. Il progetto, denominato "A Volte ritornano ...", permette di favorire sia il potenziamento delle competenze scientifiche attraverso l'informazione sulle attuali attività di ricerca sia l'orientamento universitario in continuità con il percorso liceale. La partecipazione a seminari e attività di laboratorio, che spaziano dalla ricerca di base alle applicazioni in campo tecnologico, offre, ai non meno di cinquanta studenti ogni anno coinvolti, la prospettiva della ricerca scientifica come futuro sbocco professionale. Il progetto prevede, di norma, due incontri mattutini in orario curriculare per ogni giorno di un'intera settimana nel periodo di gennaio-febbraio. Dal questionario di valutazione, compilato dai ragazzi ogni volta a fine progetto, emerge l'elevato gradimento della proposta.

Potenziamento di competenze STEM in fisica con APP su mobile per esperimenti a 16 anni.

Stabon D. ([1]), Arcicasa E. ([1]), Brocato M.C. ([1]), Michelini M. ([2]), Stabon D. ([1]), Santi L. ([2])
([1]) *Liceo delle Scienze Applicate "A. Malignani", Udine*
([2]) *Unità di Ricerca in Didattica della Fisica, DMIF, PLS-Fisica, Università di Udine*

Vi è oggi la necessità di formare competenze trasversali ed autonomie progettuali ed operative fin dal biennio della scuola secondaria superiore integrando esperienze di carattere multidisciplinare. La motivazione è stimolata da compiti operativi. Nell'ambito dei progetti FUTURA, PNSD e PLS-Fisica è stata realizzata una sperimentazione didattica in fisica in tre classi seconde del Liceo delle Scienze Applicate "A. Malignani" di Udine basata sull'utilizzo

di APP del cellulare per esperimenti di meccanica. Nella sperimentazione basata sulla ricerca i ragazzi hanno effettuato uno studio di mercato delle APP disponibili, collaudandole e poi hanno realizzato progetti di esperimenti che rispondessero ai loro dubbi su concetti oggetto di studio. Le diverse fasi di presentazione e discussione dei report dei ragazzi e la raccolta di dati qualitativi e quantitativi hanno permesso l'individuazione sia di modalità con cui potenziare le competenze STEM e l'appropriazione di competenze disciplinari sia dei principali bisogni formativi di studenti, insieme alla valenza di una chiara crescita di identità fisica e di potenzialità creative e critiche in esperimenti.

Teaching physics with expressive arts.

Onate Orozco M., Bondani M., Accattato M.
Dipartimento di Scienza e Alta Tecnologia, Università degli studi dell'Insubria

My Master thesis' work comes from an academic career in physics in Università dell'Insubria and an artistic career in Scuola di Arti Circensi e Teatrali. Together with the supervisior Maria Bondani, researcher at CNR, involved in physics education and outreach for at least twenty years, and Maurizio Accattato, clown and professional scriptwriter and director, with a 40 years long career in education with expressive arts, we have produced a lesson-show about superconductors. Expressive arts, such as mime, juggling, acting, commedia dell'arte, clownerie, will be used as a tool to teach scientific concepts, because they are way more engaging than traditional methods. Every topic will be treated using a technical explanation, showing picture of scientists involved and an experimental demonstration, under the artistic direction of Maurizio Accattato. The result is a lesson that is motivating and didactical, where students learn new concepts and are engaged at the same time. The lesson has been performed in different high schools with students of different ages. Questionnaires have been used to evaluate students' motivation and comprehension of the topics treated.

Le pratiche scientifiche nel curriculum degli istituti tecnici.

Gabelli L. ([1])([2]), Carli M. ([1]), Pantano O. ([1])
([1]) *Dipartimento di Fisica e Astronomia, Università di Padova*
([2]) *Istituto Tecnico Industriale F. Severi, Padova*

Nonostante la diffusa convinzione sull'efficacia dei laboratori di fisica, recenti studi ne mettono in discussione l'impatto sull'apprendimento quando progettati con obiettivi strettamente legati alla conoscenza disciplinare. Laboratori focalizzati sulle pratiche scientifiche mostrano maggiore efficacia nel migliorare le competenze degli studenti in tali pratiche. Questa ricerca propone un rinnovamento del curriculum di fisica per gli istituti tecnici italiani, integrando le pratiche scientifiche all'interno dei laboratori. Il curriculum si sviluppa attraverso sequenze di insegnamento-apprendimento (TLS), che integrano la conoscenza disciplinare con le competenze pratiche. Il percorso didattico è strutturato per favorire lo sviluppo progressivo delle competenze nel corso di due anni. L'obiettivo è promuovere il pensiero critico e l'autonomia degli studenti, guidandoli da ricerche più strutturate a indagini via via più aperte. La sperimentazione preliminare del curriculum in tre classi ha mostrato risultati promettenti, evidenziando la potenziale efficacia del metodo nel promuovere l'autonomia degli studenti e nello sviluppo delle competenze nelle pratiche scientifiche.

Studio dell'efficacia didattica del diagramma delle forze nei libri di testo italiani.

Longo F. ([1])([2]), Ventura A.P. ([3]), Bologna V. ([1]), Levrini O. ([3])
([1]) *Dipartimento di Fisica, Università degli Studi di Trieste*
([2]) *INFN, Sezione di Trieste*
([3]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Bologna*

I libri di testo influenzano significativamente l'istruzione scolastica italiana. Essi fanno da guida nel percorso curricolare e spesso le lezioni ruotano attorno alla linea concettuale da loro tracciata. I testi di fisica hanno subito considerevoli evoluzioni negli ultimi decenni riducendosi nella loro componente verbale per lasciare maggior spazio ad una figurativa sempre più importante. Tra le rappresentazioni emerge il diagramma delle forze come una tra le più significative per il percorso liceale. Attingendo da diversi framework teorici tra cui le Rappresentazioni Multiple, l'approccio ISLE e la teoria del Carico Cognitivo si è elaborato uno strumento innovativo per analizzare il ruolo educativo e cognitivo che questi diagrammi assumono nei manuali scolastici. Lo strumento è stato applicato a tre testi tra quelli di maggior impiego nel contesto italiano, portando all'analisi di 198 diagrammi distinti. I risultati dell'analisi mostrano un quadro critico dell'utilizzo di queste rappresentazioni da parte dei libri di testo da cui partire per elaborare accorgimenti per autori e docenti che desiderano promuovere nelle nostre scuole un apprendimento profondo e più significativo.

Indagine sulle concezioni degli insegnanti di fisica: ruolo e impatto su quelle degli studenti.

Bologna V., Peressi M.
Dipartimento di Fisica, Università degli Studi di Trieste

Molte variabili influenzano il pensare e l'agire dell'insegnante di Fisica: le concezioni sulla Natura della Scienza, quelle sullo scopo, le intenzionalità e gli obettivi del suo insegnamento e infine le concezioni sull'apprendimento e sull'insegnamento stesso. Ognuna di queste è interconnessa all'esperienza soggettiva dell'insegnante, allo sviluppo professionale e all'età; tutte però concorrono a delineare quella che si può chiamare l'impronta del docente. Le concezioni possono essere etichettate come tradizionali, sperimentali, costruttiviste, pragmatiche e sociali: plasmano la conoscenza e il modo in cui questa viene costruita euristicamente nel processo di diventare ed essere un insegnante. Scopo della questa indagine, basato su una metodologia di ricerca multimodale, è stato quello di investigare le concezioni degli insegnanti attraverso un'analisi dei loro PCK (Pedagogical Content Knowledge): quello utilizzato nell'interazione tra Fisica e Matematica e a quello per il processo di argomentazione. I risultati dell'indagine sono infine stati messi a confronto con l'indagine condotta sulle concezioni degli studenti per vedere quali correlazioni potessero essere presenti.

Uno sviluppo professionale basato sulla ricerca sperimentando app per smartphone.

Moras G. ([1]), Michelini M. ([2]), Santi L. ([2])
([1]) *I.I.S. "Evangelista Torricelli", Maniago, PN*
([2]) *Unità di Ricerca in Didattica della Fisica, DMIF, Università degli Studi di Udine*

Nel contesto del Master IDIFO21 dell'Università di Udine, è stata svolta una sperimentazione di ricerca didattica con un PCTO in una classe quarta dell'I.I.S. "E. Torricelli" di Maniago (PN), utilizzando gli smartphone come laboratori portatili per esperimenti di meccanica e acustica basati sugli interessi degli studenti protagonisti. La progettazione, la realizzazione e l'analisi dei dati di apprendimento sono stati la messa in campo di competenze acquisite durante il Master: in particolare quelle relative alla progettazione didattica, alle metodologie di didattica attiva, di problem solving per l'orientamento, di proposte di didattica della fisica basate sulle tecnologie, di analisi qualitativa e quantitativa dei dati di apprendimento raccolti. Nel contesto della sperimentazione e dei relativi esiti, si discuteranno elementi, modalità e ruolo del tipo di formazione vissuta per il miglioramento delle competenze scientifiche e trasversali degli studenti. Insieme alle evidenze raccolte dai dati degli studenti verranno discusse valenze e bisogni della professionalità docente in un quadro di formazione continua.

Expanding physics teaching understanding through large-scale literature review using unsupervised natural language processing.

Caramaschi M. ([1]), Odden T.O.B. ([2]), Levrini O. ([1])
([1]) *Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna*
([2]) *Center for Computing in Science Education, University of Oslo, Norway*

All papers from "The Physics Teacher" journal from its inception in 1963 to 2020 were analysed to understand themes and interests in the history of physics teaching. The methodology combined an unsupervised machine learning method called Latent Dirichlet Allocation (LDA) into a qualitative analysis, conducted by Physics Education experts. Specifically, LDA allowed us to infer the patterns of words that represent topics that best explain the content of the documents, while researchers derived analytical process and interpretation of results. Our analysis found 13 topics displayed over time, grouped in content-focused topics, that have been consistently present over time; pedagogical, laboratory and data analysis-focused topics, emerged around 1985; and learning-theory topics, that started to trend up on late 80s, becoming the most prevalent topic in the journal. Trend of these three categories suggests a shift from practices to considering relevant learning theories. From a methodological point of view, the implemented analytical approach allowed not only to find relevant topics, but also to measure and visualize their prevalence in the journal, highlighting their rise and trend.

Comprensione concettuale delle equazioni di Maxwell e delle onde elettromagnetiche di studenti di scuola secondaria superiore.

Catena D., Michelini M., Santi L.
Università degli Studi di Udine

È stato somministrato un questionario a risposta multipla sulle equazioni di Maxwell e sulle onde elettromagnetiche a studenti dell'ultimo anno di tre diversi licei scientifici, per un campione complessivo di 261 studenti. I 12 quesiti a risposta multipla con giustificazione sono stati somministrati alla conclusione del programma curriculare di elettromagnetismo. Essi indagano i principali nodi concettuali noti in letteratura su sorgenti dei campi elettrico e magnetico, la loro propagazione (in particolare riguardo le caratteristiche della loro velocità) e le loro interazioni con le cariche (tramite la forza di Lorentz). L'analisi delle risposte è stata effettuata tramite un processo di categorizzazione iterativa, volto a verificare la coerenza delle motivazioni con le opzioni selezionate e l'emergere di nuove categorie. I risultati mostrano le difficoltà degli studenti nell'interpretare le rappresentazioni statiche (linee di campo) e della propagazione dei campi nello spazio e nel tempo, e nel distinguere tra i campi elettrici e magnetici e i loro operatori integrali (flusso e circuitazione). I risultati ottenuti permetteranno le discussione di implicazioni per l'insegnamento.

Misurare l'attitudine al problem solving in un contesto di didattica informale.

Steri A. ([1])([2]), Tuveri M. ([1])([3]), Bonivento W.M. ([1]), Gabriele F. ([1])
([1]) *INFN, Sezione di Cagliari*
([2]) *Dipartimento di Ingegneria Meccanica, Chimica e dei Materiali, Università degli Studi di Cagliari*
([3]) *Dipartimento di Fisica, Università degli Studi di Cagliari*

Motivare e coinvolgere gli studenti in merito all'applicazione dei concetti di chimica e fisica affrontati a scuola, spesso percepiti astratti e inutilizzabili nella vita reale, è uno dei compiti del mondo della ricerca. Da questa esigenza nasce la Masterclass di Aria, condotta all'interno delle attività divulgative del Progetto Aria (INFN) per la ricerca della distillazione criogenica nel campo degli isotopi stabili. Attraverso lo svolgimento di un esercizio contestualizzato e l'apprendimento cooperativo, gli studenti si immedesimano nel ruolo del

ricercatore, sfruttano le conoscenze acquisite nel proprio percorso di studi e le applicano per il dimensionamento di una colonna di distillazione. Si discuterà il ruolo e l'efficacia delle attività didattiche in un contesto informale sull'attitudine al problem solving negli studenti della scuola secondaria di secondo grado. Si mostreranno i risultati ottenuti durante la campagna sperimentale condotta tra ottobre 2023 e aprile 2024 su un campione di oltre 700 studenti, attraverso l'implementazione di un opportuno questionario di ricerca.

The role of natural language in understanding the universe: A teaching-learning sequence on cosmology for high school students.

Tuveri M.
Dipartimento di Fisica, Università degli Studi di Cagliari e INFN, Sezione di Cagliari

Introducing cosmology at high school provides educational means for bridging the gap between the image of science held by students and science itself. For example, explaining the Bang represents such an attempt. It is a metaphor to describe the initial state of the universe. However, it is taught and communicated as an explosion, leading students to misinterpret the phenomenon. Natural language (NL) is fundamental in this learning. It engages students in constructing an understanding of a concept or a notion, establishing new relations between previous and new elements of knowledge. We present a teaching-learning sequence (TLS) aimed to contextualize cosmology along the lines of the history and philosophy of science devoted to high school students (third to fifth years). We focused on the role of debates and controversy in the evolution of science, proposing science-reflexive meta-discourses to present physics as a unified knowledge textbook. We discuss our design and present results by analyzing students' semiotic registers (NL) to recap their learning during the activity. Finally, we discuss the potentiality of our TLS in orientating students towards STEM.

Rinnovamento didattico nel rientro a scuola: applicazione del framework ISLE e nuove pratiche in fisica.

Tufino E.
Liceo Scientifico "G. Gandini", Lodi

Questo intervento descrive come il rientro all'insegnamento di fisica nella scuola, dopo un periodo di ricerca in didattica, sia stato influenzato dalla padronanza del framework ISLE (Investigative Science Learning Environment), ampiamente validato dalla ricerca e condiviso dal docente nelle sue intenzionalità di promuovere un apprendimento della fisica attraverso processi simili a quelli dei fisici e sostenendo il benessere degli studenti. ISLE integra un approccio sperimentale di tipo inquiry che include esperimenti osservativi, di test e applicativi, riflettendo autentiche pratiche scientifiche. L'adozione di ISLE ha rinnovato le strategie didattiche, integrando strumenti come whiteboard per il lavoro di gruppo e rubriche per l'autovalutazione, che favoriscono l'apprendimento collaborativo e metacognitivo. È stata introdotta anche la pratica di risubmission, permettendo agli studenti di riflettere sui loro errori e migliorare le valutazioni iniziali, promuovendo una valutazione costruttiva. L'adozione di questo framework ha portato a un effettivo cambiamento nelle abitudini dell'insegnante, e si presenteranno risultati qualitativi sull'esperienza di apprendimento degli studenti.

Astrometria e caratterizzazione fisica di sistemi binari stellari: una nuova esperienza in Astrofisica per gli studenti del Piano Lauree Scientifiche - Fisica Lecce.

D'Elia M., Licchelli D., Orofino V., Nucita A., De Giorgi M.L., Ventura A.
Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Lecce

Il Gruppo di Astrofisica UniSalento ha proposto una nuova esperienza didattica laboratoriale agli studenti partecipanti al Piano Lauree Scientifiche - Fisica, incentrata sullo studio

Astrometrico e sulla caratterizzazione fisica di sistemi binari stellari. Gli studenti hanno analizzato set di immagini CCD acquisite presso l'Osservatorio Astrofisico R.P. Feynman in combinazione con dataset ottenuti dalla sonda europea GAIA e dallo United States Naval Observatory. L'obiettivo è stato quello di misurare separazione, angolo di posizione e determinazione della metrica di Hershaw al fine di migliorare la caratterizzazione fisica di sistemi binari non ancora classificati in maniera soddisfacente. I risultati ottenuti sono stati poi sottomessi alla rivista internazionale Journal of Double Star Observations.

MoCRiS: An experiment with high school students on measuring the rate of cosmic rays during the flight of a weather balloon up the stratosphere.

Liguori D. ([1])([4]), Schioppa M. ([3])([4]), Bocci V. ([2]), Iacoangeli F. ([2]), Brosio A. ([2]), Arcani M. ([5]), Passarelli D. ([3]), Procopio S. ([6]) on behalf of the OCRA Collaboration

([1]) *Liceo Scientifico "S. Patrizi", Cariati, CS*
([2]) *INFN, Sezione di Roma*
([3]) *Dipartimento di Fisica, Università della Calabria*
([4]) *INFN, Laboratori Nazionali di Frascati, Gruppo Collegato di Cosenza*
([5]) *Astroparticle Detectors Array Laboratory, GAT Astronomical Center, Tradate, VA*
([6]) *ArpaCal, Laboratorio Fisico "E. Majorana", Catanzaro*

High school students and teachers perform Victor Hesse's experiment in a modern key on the origin of the natural ionizing radiation in the air that surrounds us constantly. The "Stefano Patrizi" scientific high school of Cariati, in collaboration with the INFN-OCRA, the physics department of the University of Calabria, ADA Project and the ABProject, have trained the students to perform measurements of the natural ionizing radiation using modern particle detectors in the school laboratory. The same detectors are then put into the payload of the balloon and left to rise to stratosphere. The students follow the launch like engineers and physicists during a real space launch. They control the data flow that the GSM installed in the spacecraft transmits to the ground and checks the quality of these data. The spacecraft also carries a weather station, an ozone sensor, a UV radiation sensor, and three GPSs. This presentation describes the preparation phases and the first results of this launch, as well as the tests presented to the students to study their satisfaction.

Aula A **ore 09:00 – 13:30**

Simposio sul Supercalcolo
Emerging data and computing technologies for frontier physics

Presiede: Zanaroli M. (ICSC, Casalecchio di Reno, BO)

Comunicazioni

Il datacenter del CNAF al Tecnopolo di Bologna nel contesto dell'infrastruttura distribuita nazionale dell'INFN e del Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing.

Cesini D.
INFN-CNAF

Il CNAF di Bologna ospita il più grande centro di calcolo di cui dispone l'Istituto Nazionale di Fisica Nucleare (INFN) e fa parte di una federazione di centri simili inizialmente creati per soddisfare le esigenze degli esperimenti LHC al CERN; nella gerarchia della Worldwide LHC Computing Grid è certificato come centro Tier1. A supporto di una sempre crescente base di utenti, il centro è integrato con il resto dell'infrastruttura informatica dell'INFN, vale a dire i 9 siti Tier-2 e altre strutture importanti, come quelle di Laboratori Nazionali del Gran Sasso, utilizzando le capacità di connessione offerte da GARR. Nel corso del 2024 il CNAF ha trasferito il proprio data center presso il Tecnopolo Manifattura di Bologna, accanto ad altre grandi infrastrutture di calcolo, come ad esempio Leonardo, il supercalcolatore pre-exascale del CINECA. In questo contributo presentiamo il nuovo centro di calcolo, gli upgrade effettuati anche grazie ai recenti progetti PNRR, i nuovi servizi offerti ed il ruolo ricoperto nel contesto delle infrastrutture italiane ed europee per il calcolo scientifico, con focus sul nuovo Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing (ICSC).

L'infrastruttura HPC dei Laboratori Nazionali del Gran Sasso (INFN) per la resilienza ai disastri.

Casale A.
INFN, Laboratori Nazionali del Gran Sasso

Nel contesto del Centro Nazionale di supercalcolo ICSC, i Laboratori Nazionali del Gran Sasso dell'INFN ospitano un'infrastruttura di calcolo HPC dedicata agli studi per la riduzione del rischio di catastrofi per la resilienza. Le comunità che utilizzeranno il centro HPC saranno eterogenee: le principali università ed enti di ricerca del centro Italia coinvolti nel progetto HPC4DR (High Performance Computing for Disaster Resilience) assieme a istituti di ricerca italiani e aziende private attraverso il progetto HaMMon (Hazard mapping and Vulnerability Monitoring). Il consorzio HPC4DR ha lo scopo di creare un centro di competenza sulla prevenzione e sulla riduzione dei rischi derivati da disastri naturali e di origine umana con l'ausilio del calcolo HPC. Il progetto HaMMon si propone di sviluppare strumenti basati sull'Intelligenza Artificiale e Data Visualization per la caratterizzazione del rischio legato agli eventi climatici estremi, sia per finalità assicurative che di monitoraggio ambientale. Verranno presentati nel dettaglio lo stato attuale dei due progetti e del cluster HPC, nonché come quest'ultimo si integrerà con l'infrastruttura nazionale di calcolo distribuito di ICSC.

L'infrastruttura di calcolo distribuita dell'INFN, il progetto DataCloud e gli investimenti del PNRR.

Donvito G.
INFN

L'INFN ha una lunga storia di R&D nell'ambito del calcolo distribuito, negli ultimi 2 anni queste attività sono state riorganizzate per permettere una più sinergica collaborazione del

personale distribuito a livello geografico, e una più armoniosa implementazione di nuovi servizi e funzionalità che possano essere utilizzati non solo dalla fisica delle alte energie, ma anche da molte comunità di fisica e di altre scienze che ormai non possono eseguire analisi dati sperimentali senza l'ausilio delle più moderne tecnologie di calcolo (Big Data, AI, HPC). Per supportare la grande diversità di use case delle comunità scientifiche di riferimento è stato determinante l'investimento che con il PNRR è stato fatto sia nell'ambito del progetto ICSC sia di Terabit, tale investimento sta fornendo nuove soluzioni hw allo stato dell'arte e la possibilità di sviluppare nuovi servizi e piattaforme per la condivisione delle risorse di calcolo e di storage disponibili in più di 10 siti in tutta italia.

The TeRABIT project and the evolution of the HPC landscape.

Campanella M. ([1])([3]), Calegari E. ([7]), Carboni M. ([2])([3]), Bolzon G. ([4]), Donvito G. ([5])([1]), Salon S. ([4])([1]), Cestari M. ([8])([1]), Grandi C. ([6]), Scaini C. ([4]), Zuccolo E. ([4])

([1]) *INFN, Sezione di Milano*
([2]) *INFN, Laboratori Nazionali di Frascati*
([3]) *Consortium GARR, Roma*
([4]) *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste*
([5]) *INFN, Sezione di Bari*
([6]) *INFN, Sezione di Bologna*
([7]) *INFN-CNAF, Bologna*
([8]) *CINECA, Bologna*

TeRABIT (Terabit network for Research and Academic Big data in Italy) is an ongoing PNRR project. INFN is the applicant and OGS is the coapplicant, GARR and CINECA as unfunded partners. TeRABIT has the vision is to create a distributed, hyper-networked, hybrid Cloud-HPC computing environment offering tailored services. This will be done by strengthening and creating greater synergy between three large Italian Research Infrastructures GARR-T, PRACE-Italy and HPC-BD-AI and be integrating and complementary to the national center for High Performance Computing, Big Data and Quantum Computing (ICSC). A use case, based on existing service offered by OGS, plans to offer a near real-time earthquake physics-based ground motion simulations in northeastern Italy. The use case demonstrates the potential impact of the HPC evolution and how to tackle the ICT challenges of the HPC-Cloud distributed Federation.

Enabling the compute continuum at ICSC: A solution based on interLink.

Anderlini L., Ciangottini D., Spiga D., Boccali T., Gasparrini D., Lubrano P., Troja A., Fanzago F., Sgaravatto M., Tedeschi T., Bianchini G.
INFN

In a geo-distributed computing infrastructure with heterogeneous resources (HPC and HTC and possibly cloud), a key to unlock an efficient and user-friendly access to the resources is being able to offload each specific task to the best suited location. This presentation will initially showcase the capabilities of interLink, a virtual kubelet technology, developed at INFN in the context of ICSC and the interTwin EU funded project; the cloud resources are used as seed for orchestrating computing intensive tasks that are seamlessly brokered to any kind of remote systems, with particular focus on the HPC offload use case. Finally an overview of the co-design driven by ICSC's Spoke2, Spoke3 and Spoke0 will be presented.

Real-world data analysis on real- world infrastructure: The SOSC school case study.

Ciangottini D. ([1]), Bonacorsi D. ([2]), Spiga D. ([1]), Salomoni D. ([4]), Fanò L. ([3]), Scrucca L. ([3]), Anderlini L. ([1]), Mariotti M. ([3])

([1]) *INFN, Sezione di Perugia*
([2]) *Università degli Studi di Bologna*

([3]) *Università degli Studi di Perugia*
([4]) *ICSC, Casalecchio di Reno, Bologna*
Balancing theory and practice is a well known challenge and the physics data analysis endeavour is no exception. Scaling out from a small scale project toward a more complex workflow, possibly ending in ML training and evaluation procedures, is a usually pain point. Therefore the main risk is to train people in synthetic scenarios that might greatly differ from the ones they will be working on if in a medium to large scale project, where a declarative approach is a game-changer. On the same line, having the basic knowledge of best practices for managing science workflows in a reproducible and composable form is a crucial skill that may drastically improve the proficiency of a physicist and his/her results. The presentation will focus on the School on Open Science Cloud, filling the gap between the data analysis frameworks and their interplay with a real-world distributed cloud environment. This initiative is based on the experience of working with declarative frameworks in the context of the INFN DataCloud initiative. A general overview of the school program and its computing infrastructure will be presented along with the lessons learnt during the last 6 editions.

Relazioni su invito

▲ **The advent of Big Data in healthcare: Towards the systematic implementation of precision medicine programs.**
Cavalli A.
IIT
The burgeoning volume of big data, a relatively recent phenomenon, profoundly impacts our lives in various aspects. Data analysis represents the first step towards precision medicine, potentially one of the most significant revolutions in modern healthcare systems. Precision medicine aims to identify personalized therapeutic treatments, recognizing that each person may respond differently to a particular treatment. To effectively characterize a patient and define a customized treatment plan, a vast amount of data must be generated, suitably stored, and eventually analyzed for each person. This data can include omics data (genomic, transcriptomic, metabolomic, proteomic, lipidomic, etc.) and electronic health records. Generating and analyzing this data can provide a more specific profile for each patient, enabling improvements in diagnosis, treatment definition, prevention, and more. Among omics data, genomic data merits special attention, describing the genomic profile of each individual patient. Oncology is one field where genomics and healthcare big data analysis can significantly impact. Genomic analysis in this field already allows for identifying ad hoc therapies based on the analysis of potential target genes in both the germline genome (from blood) and the somatic genome (from tumor cells). In this contribution, we will show examples of how genomics, data analysis, and precision medicine can be applied to different types of cancer. We will explain how high-performance computing (HPC) is essential for the effective implementation of precision medicine.

▲ **Whole brain genetic correlation of brain folding: An MRI study in 60000 subjects.**
Pizzagalli F., D'Agostino C., Guiot C., Cinque M., El Hajj J., Tamba C., Liuzzi A., Noè M., Mokdad M.
Department of Neuroscience "Rita Levi Montalcini", University of Turin
Brain gyrification divides the human cortex into distinct functional regions. Differences in sulcal shapes have been associated with various diseases and may have a partly genetic basis. Here we performed an extensive genetic correlation analysis of brain folding in two large populations: ABCD (`https://abcdstudy.org`) and UKBB (`https://www.ukbiobank.ac.uk`), for a total of 60000 subjects with MRI brain scans. T1w images were processed using FastSurfer on the CINECA HPC cluster; the segmented maps were then used by the CNN-based

BrainVISA tool for sulcal-based morphometry. Quantitative genetic models were used to partition the phenotypic correlation between each pair of traits into genetic and unique environmental components. The analysis was performed using SOLAR-Eclipse. Age, sex, ICV and 5 genetic PCs (to account for ancestry differences) were added as covariates. Only Bonferroni corrected results were considered for further analyses. Our results demonstrate that 1) the harmonization algorithm, ComBat, was able to remove the variance due to different MRI scanners and scanning protocols; and 2) the genetic correlation-based network shows a modular structure.

Comunicazioni

● **Charged particle tracking with quantum graph neural networks.**

Argenton M. ([1])([2]), Cappelli L. ([2]), Amitrano V. ([2]), Schifano S.F. ([1])([2]), Calore E. ([2]), Bozzi C. ([2])
([1]) *Università di Ferrara*
([2]) *INFN, Sezione di Ferrara*

The problem of tracking charged particles in high-energy physics experiments is computationally intensive. The amount of data to be analysed will increase dramatically with the advent of the High Luminosity LHC era, which is expected to significantly increase the number of proton-proton interactions per beam collision by a factor of 3-5. Traditional algorithms suffer from scaling problems. We are investigating the possibility of combining machine learning techniques with quantum computing. In our research, we represent particle trajectories with graph data structures and train a hybrid graph neural network with classical and quantum layers. We report recent results on the application of these methods for different pile-up values, focusing on the computational aspects of code development in programming frameworks such as Jax, Pennylane and IBM Qiskit, and on the utilisation of HPC and cloud resources.

Relazioni su invito

▲ **The Spoke 2 of the National Center for Big Data, HPC and Quantum Computing (ICSC).**

Boccali T., Stamerra A., Malvezzi S., for the Spoke 2 Affiliates
INFN, INAF, Università di Milano Bicocca

Science especially fundamental research calls for computing abilities that grow alongside the succession of new generations of experiments. This is a general trend in both experimental and theoretical physics. In theoretical physics, more and more computing resources are needed to simulate at a higher level of precision systems which can vary from the innermost states of nature to complex systems and large scale astrophysics systems. In experimental physics, instruments constantly increase the amount of data to be collected, stored and analyzed, largely surpassing what ordinary computing systems can handle; extracting knowledge from this data deluge requires at the same time novel techniques. The push for a modernization of the computing approach is hence vital for the domain: the access to large-scale and efficient systems is often the limiting factor for research, more than limits in theory knowledge or in the experiments' technology. In this contribution we will present a landscape of the activities of the Spoke 2 in the National Center for Big Data, HPC and Quantum Computing, highlighting the use cases which benefit most from the availability of a modern computing infrastructure.

▲ **AI algorithms for satellite and airborne imaging reconstruction.**

Piparo G. ([1]), Anastasi G. A. ([2]), Galli G. ([3])([4]), Lopane N. ([3])([4])([5]), Strati V. ([3])([4]), Tramontana E. ([6]), Tricomi A. ([1])([2])([7])
([1]) *INFN, Sezione di Catania*
([2]) *Dipartimento di Fisica e Astronomia, Università di Catania*

([3]) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara*
([4]) *INFN, Sezione di Ferrara*
([5]) *GeoExplorer Impresa Sociale s.r.l., Arezzo*
([6]) *Dipartimento di Matematica e Informatica, Università di Catania*
([7]) *Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania*

The burgeoning space economy and the extraction of useful information from satellite and airborne data are transforming global industries and environmental monitoring. This presentation explores the use of the extensive computational resources provided by the National Research Centre for High Performance Computing, Big Data, and Quantum Computing ICSC to analyze imagery from these sources. Specifically, this project is part of Working Group 6 (WP6), "Cross-Domain Initiatives and Space Economy", under Spoke 2, "Fundamental Research and Space Economy". Our research focuses on three key methodologies: a deterministic learning algorithm for object identification, used to efficiently identify photovoltaic panels; spectral index-based image processing for precise monitoring of vineyard diseases; and advanced deep learning techniques for analyzing satellite images. These approaches exploit high-resolution RGB and multispectral images from various platforms to improve the accuracy and applicability of environmental monitoring. The presentation will illustrate these techniques, demonstrating their impact in addressing complex environmental challenges.

Comunicazioni

Data processing pipeline optimization for space and ground based experiments.

Peron R. ([1])([4]), Mazzitelli G. ([2])([4]), Fioretti V. ([3])([4])
([1]) *INAF, Istituto di Astrofisica e Planetologia Spaziali, Roma*
([2]) *INFN, Laboratori Nazionali di Frascati*
([3]) *INAF, Osservatorio di Astrofisica e Scienza dello Spazio, Bologna*
([4]) *Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing, Casalecchio di Reno, Bologna*

The rich landscape expected for the next years in astro-particles and astronomy (from experiments for neutrino physics, cosmic-ray and dark matter to innovative gamma-ray space missions to space experiments for testing the gravitational dynamics at macroscopic scales) requires large effort into the development of common tools optimizing the pipelines for data simulation and processing, based on most recent innovations in the computing fields. An opportunity in this respect is the recent establishment of the Italian Research Center on High-Performance Computing, Big Data and Quantum Computing (ICSC). After an overview of both the scientific and computational motivations, we will present an ensemble of projects (carried out in the context of ICSC Spoke 2, WP3) that share the need of an integration of common tools for analysis and simulation; involve a collaborative, open and synergistic view of the computing ecosystem (data, software, analysis, simulations); exploit recent developments on computing science in terms of safety, scalability efficiency (such as the one offered by virtualisation) and opportunistic resources (given by the cloud model and HPC architectures).

Recenti progressi nella simulazione veloce del calorimetro dell'esperimento ATLAS basata su GAN.

Corchia F.A.G., Rinaldi L.
Dipartimento di Fisica e Astronomia A. Righi, Università di Bologna e INFN Bologna

La simulazione dei rivelatori impiega un'ampia parte delle risorse computazionali utilizzate dall'esperimento ATLAS (ca. 40%), di cui la maggior parte è dedicata alla simulazione dei calorimetri. Per un uso più efficiente delle stesse si sono sviluppati sistemi di simulazione veloce con Machine Learning per simulare la risposta dei calorimetri più velocemente rispetto

a Geant4, garantendo una buona accuratezza. Per il Run-3 di LHC ATLAS ha sviluppato FastCaloGAN, basato su Generative Adversarial Network. Inoltre, un sistema basato su container, FastCaloGANtainer, facilita la distribuzione del training di FastCaloGAN su risorse aggiuntive ad alte prestazioni come cluster HPC, indipendentemente dal sistema sottostante. In questo contributo si presentano FastCaloGAN e FastCaloGANtainer e i recenti miglioramenti nelle prestazioni di fisica e computazionali: per FastCaloGAN riguardano una rappresentazione più fine della geometria del calorimetro (voxelisation) e l'estensione a più casi d'uso (altri tipi di particelle), per FastCaloGANtainer la distribuzione su una maggiore varietà di risorse e architetture con nodi multi-CPU/GPU, incluso il supercomputer Leonardo al CINECA.

● **Accelerating Geant4 simulations in medical physics with machine learning: A super-resolution approach.**

Gallo G. ([1]), Cirrone G.A.P. ([2])([4]), Fattori S. ([2]), Ientile V. ([3]), Sciuto A. ([2]), Tricomi A. ([1])([3])([4])

([1]) *Dipartimento di Fisica e Astronomia "E. Majorana", Università degli Studi di Catania*

([2]) *INFN, Laboratori Nazionali del Sud*

([3]) *INFN, Sezione di Catania*

([4]) *Centro Siciliano di Fisica Nucleare e di Struttura della Materia, Catania*

Geant4 is a widely used simulation framework in medical physics, allowing the simulation of detailed spatial interactions down to DNA size. As the complexity of the simulated system increases, the resources required by Geant4 scale linearly, limiting its effectiveness. WP6-Spoke2 of ICSC - Italian Research Center on HPC, Big Data and Quantum Computing has a use case dedicated to the integration of machine learning models to enhance Geant4. The Hadrontherapy task was recognized as an important example to start with. It provides users with a valuable tool for calculating dose and linear energy transfer distributions in water or other materials. We start by generating a high-quality dataset using a voxelized water phantom with increased density, providing "ground truth" information on primary and secondary particle properties. A generative model, such as a Variational Autoencoder or Generative Adversarial Network, is then developed to replicate the natural spatial relationships observed in the interactions of these particles. The goal is to create a super-resolution surrogate model to generate higher-resolution predictions from lower-resolution input data.

● **Le grandi idee del supercalcolo per la formazione civica e professionale**

Lodi M. ([1]), Barelli E. ([2])

([1]) *Dipartimento di Informatica, Scienza e Ingegneria, Università di Bologna*

([2]) *International Foundation Big Data and Artificial Intelligence for Human Development, Bologna*

Fornire a scienziati e professionisti che non hanno competenze tecniche specifiche in tema di supercalcolo gli strumenti intellettuali per comprenderne efficacemente i fondamenti può permettere loro di progettare e implementare soluzioni che ne fanno un uso informato ed efficace nelle loro attivitò di ricerca e innovazione. Allo stesso modo, condurre attivitò didattiche e di comunicazione scientifica per studenti di scuola primaria e secondaria o per cittadini consentirebbe loro di acquisire una comprensione più profonda dell'impatto (e quindi della rilevanza di finanziarlo) che il supercalcolo può avere nelle loro vite e nella società. Poiché il supercalcolo ha oggi un impatto determinante non solo nella ricerca scientifica, ma anche sulle imprese e sulla vita di tutti i cittadini nella società digitale, proponiamo in questa comunicazione una serie di "Grandi idee del Supercalcolo" (come ad esempio l'idea che le operazioni che dipendono dal tempo devono essere coordinate) ovvero quei principi fondamentali alla base di esso che devono essere compresi da tutti e che possono guidare, diversamente declinati, insegnamento, alta formazione, aggiornamento professionale e divulgazione.

Aula Magna **ore 14:30 – 15:10**

Sezione I
Fisica nucleare e subnucleare
Presiede: Patrizii L. (INFN, Sezione di Bologna)

Relazione Generale

Problemi aperti in fisica delle particelle.
Masiero A.
Università di Padova e INFN, Sezione di Padova
Il Modello Standard (MS) delle particelle elementari e delle loro interazioni fondamentali fornisce una descrizione del micro-cosmo di straordinario successo. Insieme alla teoria cosmologica standard del Big Bang caldo (macro-cosmo), riusciamo, per la prima volta nella storia, ad avere una conoscenza dell'universo che copre circa 60 ordini di grandezza dalle sue scale microscopiche a quelle macroscopiche. Eppure, il MS lascia ancora aperte questioni sia osservative sia teoriche di primaria rilevanza. Solo per citarne alcune, non ci fornisce un meccanismo per dare massa ai neutrini, non chiarisce quale sia la natura e composizione della maggior parte della materia e dell'energia presenti nell'universo (materia ed energia oscure) o, ancora, quali possano essere le nuove sorgenti di violazione della simmetria CP in relazione alla sopravvivenza della materia, etc. Nella presentazione mi soffermerò su due strade per esplorare nuova fisica al di là del MS in grado di dare risposta ad almeno alcune di tali questioni aperte: quella della fisica agli acceleratori ("alta energia") in cui si cercano particelle e interazioni a scale di energia più alte rispetto a quelle sinora esplorate oppure, al contrario, quella della fisica di "bassa energia" e alta precisione in cui, grazie ad apparati di media-piccola dimensione, si studiano "settori nascosti" di nuova fisica con particelle leggere che interagiscono molto debolmente con la materia ordinaria.

Aula Magna **ore 15:10 – 15:50**

Sezione V
Biofisica e fisica medica
Presiede: Diaspro A. (Università di Genova e IIT, Genova)

Relazione Generale

Deviation from Brownian diffusion in living cell compartments: Physical and biological implications.
Garcia-Parajo M.
ICFO-Institute of Photonic Sciences and ICREA-Institució Catalana de Recerca i Estudis Avançats, Mediterranean Technology Park, Castelldefels, Barcelona, Spain
Organization by compartmentalization is a general property of natural systems that efficiently facilitates and orchestrates biological events in space and time. In the last decade, compartmentalization of the plasma membrane of living cells has emerged as a dominant feature present at different spatiotemporal scales and regulating key cell functions. In parallel, recent experimental evidence points to the notion that the nucleus of living cells is highly compartmentalized. The advent of super-resolution microscopy and single particle tracking (SPT) approaches have revealed that most cell membrane receptors and/or molecules inside the cell nucleus exhibit anomalous diffusion and weak ergodicity breaking. Such behaviour is directly linked to molecular function and result from the nano- and meso-scale interaction of molecules with their surrounding environment. I will discuss evidence for anomalous diffusion on prototypical membrane receptors and in the cell nucleus and will show a direct correlation between these phenomena and biological function. Moreover, I will describe a novel methodology based on high-density single molecule imaging in living cells to map the spatial and temporal length scales of cellular compartments. We find that both molecular diffusion and dynamic re-modelling of the environment play key roles regulating biological function.

Aula Magna **ore 15:50 – 16:30**

Sezione III
Astrofisica
Presiede: Pagano I. (INAF, Osservatorio Astrofisico di Catania)

Relazione Generale

The Euclid mission —From promise to reality.
Cimatti A.
Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna
Euclid is a space mission aimed at addressing the key questions of modern cosmology. After a long process started in 2007 in the framework of the ESA Cosmic Vision 2015–2025, it was successfully launched in 2023. Euclid will shed light on the nature of dark energy, the properties of dark matter and its relations with baryonic matter, the mass of neutrino and will test modified gravity on cosmological scales. The revolutionary power of Euclid relies on the combination of different, independent and complementary probes: weak gravitational lensing, baryonic acoustic oscillations, redshift-space distorsions, galaxy clusters, strong lensing and cross-correlations with the cosmic microwave background. To achieve these ambitious goals, Euclid will collect data of huge volumes of the universe and explore their evolution as a function of the cosmic time. This will be obtained through the observations of about 15000 $\deg^2$ (Wide Survey) with visible and near-infrared imaging, plus near-infrared spectroscopy. In addition, the Deep Survey will observe selected sky fields at deeper limiting fluxes for calibration purposes and to investigate galaxy and massive black hole evolution in the early cosmic epochs during the first billion years after the Big Bang. Euclid data will include high-quality images and optical/near-IR photometry for more than 2 billion galaxies, as well as redshifts and spectra for tens of million galaxies out to redshift around 2 and beyond. The legacy value of the Euclid dataset will be immense for a wide range of science cases. The communication will focus on the scientific promise of Euclid, its first data, the synergies with other facilities and the growth of the Italian community thanks to this space mission.

Aula Magna **ore 16:30 – 17:45**

Assemblea Generale dei Soci

L'Assemblea Generale dei Soci della Società Italiana di Fisica è convocata in occasione del Congresso Nazionale SIF 2024 in prima convocazione alle ore 16.00 e in seconda convocazione alle ore 16.30 di martedì 10 settembre 2024, l'Assemblea si riunirà nell'aula Magna del Distretto Navile - Edificio UE1 dell'Università di Bologna in Via della Beverara 123/1, con il seguente ordine del giorno:

1) Approvazione dell'ordine del giorno.
2) Nomina del Segretario Verbalizzante.
3) Approvazione del verbale dell'Assemblea Generale dei Soci del 12 settembre 2023.
4) Relazione del Presidente.
5) Relazioni del Collegio dei Revisori dei Conti e approvazione dei bilanci consuntivi 2023.
6) Ratifica e nomina dei Revisori dei Conti.
7) Discussione e approvazione della Relazione del Presidente.
8) Modalità di approvazione del verbale dell'Assemblea Generale dei Soci.
9) Varie ed eventuali.

Il Presidente della SIF
Angela Bracco

Aula Magna **ore 17:45 – 19:00**

TAVOLA ROTONDA APS-SIF

Collaboration, Outreach and Engagement for the 2025 International Year of Quantum Science and Technology

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Aula Magna **ore 09:00 – 13:30**

Sezione I

Fisica nucleare e subnucleare

Presiede: Santonocito D. (INFN, Laboratori Nazionali del Sud, Catania)

Relazioni su invito

▲ **Recenti risultati e sviluppi futuri dell'esperimento BESIII.**

Scodeggio M. per la Collaborazione BESIII Italia

INFN, Sezione di Ferrara

Lo spettrometro BESIII (BEijing Spectrometer III) opera a Pechino presso il collisore simmetrico elettrone-positrone BEPCII. A partire dal 2009, l'esperimento BESIII ha raccolto dati in un intervallo di energia, nel centro di massa, compreso tra 2 GeV e 4.95 GeV. La possibilità di variare l'energia delle collisioni ha reso possibile la raccolta di numerosi campioni di dati vicino alle soglie di produzione di coppie di adroni e ha consentito di effettuare scansioni per osservare e studiare proprietà di eventuali nuovi stati. In questa presentazione verranno discussi gli ultimi risultati ottenuti dalla collaborazione BESIII nell'ambito degli stati esotici XYZ, come l'analisi della sezione d'urto del canale $e^+e^- \to D\bar{D}$ e lo studio della $\chi_{c1}(3872)$ accoppiando i decadimenti $D^0\bar{D}^0\pi^0$ e $\pi^+\pi^- J/\psi$, e dei decadimenti del charmonio, come la scoperta del canale $\psi(3770) \to K^0_S K^0_L$. Infine, verranno presentati gli sviluppi relativi al potenziamento del collisore BEPCII e alla costruzione dell'innovativo rivelatore a gas CGEM (Cylindrical Gas Electron Multiplier) per la sostituzione della camera a fili più interna.

▲ **Final results of the MEG experiment and first results of the MEGII experiment at PSI: A high sensitivity search for the $\mu^+ \to e^+\gamma$ decay.**

Cei F. for the MEG II Collaboration

Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa

The lepton flavour violating decay $\mu^+ \to e^+\gamma$ is one of the most favourite channels to search for New Physics. The MEG experiment established in 2016 the best world upper limit on this decay: $BR(\mu^+ \to e^+\gamma) \leq 4.2 \times 10^{-13}$ @ 90% C.L. based on the data collected from 2009 to 2013. The MEG collaboration designed and built an upgraded version of the experiment, MEGII, which is expected to improve significantly the MEG result by one order of magnitude. MEGII is then a potential cornerstone in the development of new theories Beyond Standard Model. In this presentation I'll summarize the main results of the MEG experiment and show the improvements of the MEGII detector with respect to the predecessor MEG, the first results of MEGII based on the analysis of the data collected in 2021 and the short and long term perspectives of the upgraded experiment.

▲ **The analysis of the last three runs at the muon $g-2$ experiment at fermilab.**

Girotti P.

INFN, Sezione di Pisa

The Muon $g-2$ Experiment at Fermilab aims to measure the muon anomalous magnetic moment with a precision of 140 parts per billion (ppb). The collaboration has published the latest measurement based on the first three Runs (collected from 2018 to 2020) in August 2023 with a precision of 200 ppb. The experiment accumulated three more years of data, from 2020 to 2023, which are currently being analyzed, with a final publication expected in

2025. The last three runs contain almost three times the statistics of the first three runs, with more than 1e11 reconstructed positrons. This talk will present the status of the analysis, discussing the challenges related to the production of the data and the collective effort to further reduce the already small systematic uncertainties.

▲ **Risultati recenti e prospettive future dell'esperimento Belle II.**
Merola M. per la Belle II Collaboration
Università degli Studi di Napoli Federico II e INFN, Sezione di Napoli
L'esperimento Belle II alla SuperB-Factory SuperKEK-B ha raccolto 424 fb^{-1} nel primo run di presa dati, dal 2019 al 2022, dimostrando eccellenti prestazioni di ricostruzione. Queste hanno permesso di produrre recentemente diverse misure significative in ricerche di fisica oltre il Modello Standard nel settore dei quarks, dei leptoni tau, e della materia oscura a bassa massa - molte delle quali unicamente accessibili a Belle II. In questa comunicazione si discuteranno i risultati più rilevanti ed il loro impatto con qualche cenno all'andamento del secondo run di presa dati, cominciato a febbraio di questo anno, e le prospettive sul potenziale futuro dell'esperimento.

Comunicazioni

● **A minimalistic perspective on neutrino CP-violation and Leptogenesis through Modular Invariance.**
Parriciatu M., Marciano S., Meloni D.
Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre e INFN, Sezione di Roma Tre
Modular Invariance is a relatively new approach to the flavor problem: in special cases, only one flavon is needed to reproduce the neutrino masses and mixing parameters, with just a small number of free parameters. By combining this framework with generalized CP-symmetry, one can determine that the flavon vacuum expectation value also dictates the CP-violation of the lepton sector. Hence, one can construct models in which it is possible to accommodate not only the recent data on CP violation but also the matter-antimatter asymmetry of the Universe through Leptogenesis. However, it is particularly challenging to build a model that is also minimalistic. Using a set of guiding principles, we demonstrate how this can be achieved by building a seesaw scenario based on the smallest modular finite group $\Gamma_2 \cong S_3$, which had never been done before this work. Both the strengths and weaknesses of this promising approach are discussed.

● **The universal behaviour at high x of the partons with the statistical parametrization.**
Buccella F.
INFN, Sezione di Roma
After many experimental confirms of the statistical parametrization, which follows logically by the validity of the conjecture by Feynman and other scientists that the isospin asymmetry of the antiquarks in the proton is a consequence of Pauli principle, more recently the parton distributions in the kaon by comparing the Drell-Yan and J/ψ production with incident kaons or pions and in the proton by analyzing HERA data . In both case and also in the analysis of the isospin asymmetry at Sea Quest the role of the main parameter $\bar{x}$ to describe the behaviour at x not small has been confirmed with the stability of that parameter around the value, 0.099, found twentytwo years ago. The statistical parametrization would allow a better precision for the distributions at large value of x, where the experimental information is scarce.

Search for nearly mass-degenerate higgsinos using low-momentum mildly-displaced tracks in *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector.

Sala A.

Dipartimento di Fisica, Università degli Studi di Milano e INFN, Sezione di Milano

Supersymmetry (SUSY) models with nearly mass-degenerate higgsinos could solve the hierarchy problem as well as offer a suitable dark matter candidate consistent with the observed thermal-relic dark matter density. However, the detection of SUSY higgsinos at the LHC remains challenging especially if their mass-splitting is $\mathcal{O}$ (1 GeV) or lower. A novel search using 140 fb^{-1} of proton-proton collision data collected by the ATLAS Detector at a center-of-mass energy $\sqrt{s} = 13$ TeV and targeting final states with an energetic jet, missing transverse momentum, and a low-momentum track with large transverse impact parameter is developed to face such challenge. Results are interpreted in terms of SUSY simplified models and, for the first time since the LEP era, a range of mass-splittings between the lightest charged and neutral higgsinos from 0.3 GeV to 0.9 GeV is excluded up to 170 GeV of higgsino mass.

Misura del processo $t\bar{t}Z$ in collisioni pp a $\sqrt{s} = 13$ TeV nell'esperimento ATLAS.

Primomo L.

Dipartimento di Scienze Matematiche, Informatiche e Fisiche, Università degli Studi di Udine

In questo contributo viene presentata l'analisi dei dati di collisione pp nell'esperimento ATLAS a $\sqrt{s} = 13$ TeV per la produzione di coppie $t\bar{t}$ in associazione a un bosone Z ($t\bar{t}Z$) con successivo decadimento $Z \to \nu\nu$. Il processo $t\bar{t}Z$ è un fondo irriducibile per molte ricerche di fenomeni BSM e fornisce un accesso diretto all'accoppiamento tra il quark top e i bosoni elettrodeboli. $Z \to \nu\nu$, in aggiunta ai canali di decadimento $Z \to \ell^+\ell^-$, permette di estendere l'accettanza della misura, specie in regioni cinematiche ad alto $p_T(Z)$. L'analisi si focalizza sul canale di decadimento di-leptonico della coppia $t\bar{t}$. L'analisi consiste in un processo di ottimizzazione dei tagli su campioni di dati simulati, svolto su osservabili rilevanti, tra i quali spiccano la significanza di energia trasversa mancante (met significance) e la cosiddetta variabile MT2. Successivamente viene effettuato un fit di massima verosimiglianza sui due osservabili principali in tre regioni di segnale ortogonali. Vengono quindi aggiunte una regione di controllo per il fondo principale (produzione $t\bar{t}$) e cinque regioni di validazione.

Measurement of integrated CP asymmetries in $\Lambda_b^0 \to pK^-$ and $\Lambda_b^0 \to p\pi^-$ decays at LHCb.

Villa A.

Dipartimento di Fisica, Università di Bologna e INFN, Sezione di Bologna

A measurement of CP asymmetries with $\Lambda_b^0 \to pK^-$ and $\Lambda_b^0 \to p\pi^-$ decays is presented in this contribution. The analysis is carried out using the full Run 1 + 2 dataset from the LHCb experiment, corresponding to an integrated luminosity of 9 fb^{-1} of *pp* collisions at $\sqrt{s} = 7, 8$, and 13 TeV. To obtain the CP asymmetries, raw asymmetries are corrected for experimental effects such as the Λ_b^0 production asymmetry, the interaction asymmetry of final-state particles, as well as asymmetries caused by particle identification and trigger requirements. Novel data-driven techniques were developed to measure part of the nuisance asymmetries, to reduce the need for simulated samples. The results represent the most precise measurements of this observables to date, and will help shed more light on the phenomenon of CP violation in baryon decays.

The resurgence of the G(2) group for the strong sector and the emergence of Dark Matter.

Masi N.
INFN, Sezione di Bologna

A new criterion to extend the Standard Model (SM) of particle physics is proposed: the symmetries of physical microscopic forces originate from the automorphism groups of main Cayley'Dickson algebras, up to the automorphism of octonions (and sedenions) i.e. the smallest exceptional group G(2). It is a viable gauge group to minimally extend the strong interaction sector including a versatile dark sector compatible with experimental observations: G(2) includes the group SU(3) of QCD as a maximal subgroup and it is equipped with six additional gluons that can acquire mass via a Higgs mechanism driven by a new Higgs particle and constitute dark matter (DM). In fact, the group G(2) manifests some complex features, not properly considered in literature, which guarantee its correct use in physics. The resulting framework can be a solid Beyond Standard Model solution for the DM problem, in the form of massive complex scalar glueballs, including proper color representations for fermions. Several QFT features are discussed, like coupling constant running and its spectrum before and after the phase transition, along with all DM astrophysical realizations, like boson stars and black holes.

BSM (Beyond Standard Model) searches with escaping invisible particles associated to a Higgs boson and protons tagged with the PPS (Precision Proton Spectrometer).

Feliziani A. for the CMS Collaboration
Università di Pisa e INFN, Sezione di Pisa

The study concerns an official analysis that is being conducted with the PPS (Precision Proton Spectrometer) detectors of CMS, in which we search for a production of a scalar particle by photon fusion. This production is possible within the Beyond Standard Model, in the extended Higgs sector, particularly in the 2HDM+s model. The scalar should be seen in association with a Higgs particle, detected in the CMS central detector, and with an additional invisible massive particle, X. The process is: $pp \to pHXp$. The protons-tagged events are recorded in the proton-proton collisions at $\sqrt{s} = 13$ TeV in the year 2018 at the LHC accelerator. The interaction is simulated by Monte Carlo methods, the analysis is developed over a range of the scalar particle masses between 800 and 1600 GeV, where the PPS detector has the maximum acceptance. For the background QCD, $t\bar{t}$ and WW interactions are chosen to be studied. In this way, the proton mass spectrum for the background and for the signal has a perfectly known shape, and strategies can be applied to select the signal against the background. At the end a bump search can be performed to highlight possible anomalies.

Interpretazione EFT dei risultati VBS su dati Run2 di LHC.

Vannucci M. per la CMS Collaboration
Università di Perugia e INFN, Sezione di Perugia

Il Run 2 di LHC è stato chiave per raggiungere risultati eccezionali nell'osservazione di scattering tra bosoni vettori (VBS). Il VBS è un processo previsto dallo Standard Model (SM), con sezioni d'urto piuttosto piccole, che permette un accesso diretto al settore di rottura spontanea di simmetria elettrodebole (EWSB), in quanto l'unitarietà dello scattering nella componente longitudinale è garantita dalla mediazione del bosone di Higgs. I risultati prodotti finora sono per lo più limitati dalla statistica, e risultano essere in accordo con le previsioni SM entro le incertezze, si rende comunque necessario costruire modelli di interpretazione di queste misure che coinvolgano eventuali contributi di nuova fisica. Vengono

usate per queste estensioni della lagrangiana SM con teorie efficaci (EFT) di dimensione 6 e dimensione 8, che fanno uso di coefficienti di Wilson sensibili a questi specifici processi. Nel contributo qui proposto si presenterà lo stato dell'arte delle misure condotte in CMS e della loro interpretazione in chiave EFT.

Approccio di Anomaly Detection per la ricerca di nuove risonanze bosoniche con stati finali completamente adronici nell'esperimento ATLAS.

Corvino A.
Università degli Studi di Napoli "Federico II" e INFN, Sezione di Napoli

Dopo la scoperta del bosone di Higgs ad LHC al CERN di Ginevra, molta attenzione è stata data alla ricerca di nuove risonanze bosoniche ad alta massa. L'uso di tecniche di Machine Learning unito a metodi di ricerca di anomalie (anomaly detection) è sicuramente un approccio innovativo che permette di cercare nuove risonanze in modo indipendente da modelli specifici. In questo contributo sono riportati i risultati di un primo studio nella ricerca di una risonanza Y che decade in un bosone di Higgs e una nuova risonanza X con stato finale puramente adronico ($Y \to XH$). Inoltre, è riportato uno studio in cui si utilizza un approccio non supervisionato con Graph Neural Networks (GNN) per ricerche di Anomaly Detection (Graph Anomaly Detection) e che da indicazioni molto promettenti. Sono quindi riportati i risultati ottenuti utilizzando il dataset pubblico LHC Olympics e prime applicazioni ai dati del Run II di ATLAS in stati finali completamente adronici.

First look into the $\Psi(2S)$ elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE.

Cerri R.
Università di Torino

Charmonium, the bound state of c and cbar quarks, is a relevant observable for quark-gluon plasma formation (QGP) in heavy-ion collisions. The modification of J/Ψ production in Pb-Pb collisions, observed by ALICE, is interpreted as a superposition of suppression and recombination mechanisms, which are at play in the QGP. The role of the recombination is confirmed by the non-zero value of the J/Ψ elliptic flow coefficient (v2). The J/Ψ v2 originates from the participation of the charm quarks to the collective flow, mainly in semicentral collisions and at intermediate J/Ψ transverse momentum. Additionally, ALICE focused also on the more loosely bound charmonium state, the $\Psi(2S)$, whose production shows a stronger modification than the J/Ψ one. Further investigation on the $\Psi(2S)$ v2 becomes crucial to complement the production studies, reaching a deeper understanding of the recombination mechanism. In this contribution first studies of $\Psi(2S)$ v2 using ALICE Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be presented. The analysis technique to evaluate the $\Psi(2S)$ v2 in the forward rapidity region ($2.5 < y < 4$) will be discussed and feasibility studies of this measurement will be addressed too.

Charmed hadron angular correlation studies in pp collisions with the ALICE experiment.

Cattaruzzi S.
Università degli Studi di Trieste e INFN, Sezione di Trieste

Fragmentation functions are one of the ingredients used for the calculation of heavy-flavour hadron production in perturbative QCD. They are typically parametrised exploiting measurements performed in e^+e^- collisions, under the assumption of their universality across collision systems. Measurements of charm baryon-to-meson production yield ratios in pp collisions at LHC have proved that the fragmentation of heavy quarks differs in hadronic and leptonic collisions. The study of angular correlations between charmed hadrons and charged

particles produced in pp collisions can provide further insights into the charm-quark fragmentation process. Moreover, these measurements offer an essential baseline for interpreting results from Pb-Pb collisions. In this contribution, the recent angular correlation studies between non-strange and strange D mesons and charged particles performed by ALICE in pp collisions will be reported, including the first results from Run 3 data. The angular correlations of charmed baryons (Λ_c^+) with charged particles in pp collisions at $\sqrt{s} = 13$ TeV will be also shown.

Misure recenti nel settore oscuro a Belle II.

Salutari L.
Università degli studi di Roma Tre e INFN, Sezione Roma Tre

L'esperimento Belle II ha raccolto un campione di dati di collisioni e^-e^+ pari a 424fb^{-1} a energie del centro di massa vicine alla risonanza $\Upsilon(4S)$. Utilizziamo questo campione di dati per la ricerca di nuove particelle nel settore oscuro. In particolare presentiamo i risultati di tre analisi in questo ambito: la ricerca di una particella S, scalare o pseudoscalare e con lunga vita media in decadimenti $B \to KS$; la ricerca una particella X, vettoriale o scalare, che decade in muoni, interpretabile come bosone di un modello $L\mu \to L\tau$ o come una particella scalare muon-filica, in grado di spiegare l'anomalia del momento magnetico del muone; la ricerca di una particella invisibile Z' nel processo $e^-e^+ \to \mu\mu Z'$ ($\to$ invisibile), anche essa bosone di un modello $L\mu \to L\tau$.

First measurement of antiproton cross section in p-He collisions at the AMBER Experiment at CERN.

Giordano D.
INFN, Sezione di Torino

One of the indirect detection method of dark matter (DM) is based on the search of the products of DM annihilation or decay. They should appear as distortions in the gamma rays spectra and in the rare Cosmic Ray (CR) components, like antiprotons, positrons and antideuterons, on top of the standard astrophysical production. In particular, the antiprotons in the Galaxy are mainly of secondary origin, produced by the scattering of cosmic proton and helium nuclei off the hydrogen and helium in the interstellar medium (ISM). In order to obtain a significant sensitivity to DM signals, accurate measurements of the production cross section in pp and pHe collisions are crucial. The AMBER experiment at CERN collected in 2023 the first data ever in pHe collisions at a center of mass energy from 10 to 21 GeV. Preliminary results will be shown in this contribution. The 2024 AMBER program with proton beam on liquid hydrogen and deuterium targets will be also presented.

Benchmarking distributed-interactive HEP analysis workflows on the new Italian National Centre analysis infrastructure.

D'Onofrio A. ([1]), Rossi E. ([1])([4]), Spisso B. ([1]), Cirotto F. ([1])([4]), Sabella G. ([1])([4]), Loffredo S. ([1])([4]), Gravili F.G. ([3])([6]), Spiga D. ([2]), Tedeschi T. ([2])([5])
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The demands of HL-LHC data processing and the challenges of future colliders are pushing to re-think High Energy Physics (HEP) computing models. This talk aims at providing transparent resources for users and experiments, with suitable tools and environment, coupled with flexible and cloud-independent deployment in the framework of the ICSC project

(Italian National Centre on HPC, Big Data and Quantum Computing). The resources will be experiment-agnostic and applicable across HEP experiments, exploited to benchmark the proposed workflows. Seamless interactive or quasi-interactive analysis are extremely promising: starting from container technology and Kubernetes, we provide analysis tools via Jupyter interface and Dask scheduling system, masking complexity for front end users and rendering cloud resources flexibly. An overview of the technologies involved and the results of a benchmark use case will be provided, with suitable metrics to evaluate preliminary performance of the workflow.

Analysis of the $W \to 3\pi$ decay as a use case for scouting–analyses on FPGA.
Brivio F.
INFN, Sezione di Milano-Bicocca
Super-computing is becoming increasingly important in High Energy Physics due to the continuous development of modern experiments and the huge amount of data that they produce. During its High-Luminosity phase, the Compact Muon Solenoid experiment is planning to exploit these upgrades to the maximum thanks to an innovative trigger program based on the 40 MHz Scouting. In this system, ultra-fast technologies will allow to record and process events at the same rate at which they are produced inside the Large Hadron Collider. One of the perfect use cases for the Scouting program is represented by the analysis of an extremely rare process predicted by the Standard Model, the $W \to 3\pi$ decay, for which collecting and processing the largest possible statistics is crucial. This analysis is being developed based on boards equipped with Field Programmable Gate Arrays (FPGA), one of the most modern technologies that guarantee extremely small and precise latency, as well as on novel packages able to translate Machine Learning algorithms into firmware.

Aula 1D **ore 09:00 – 13:30**

Sezione II
Fisica della materia
Presiede: Mauri F. (Sapienza Uninversità di Roma)

Relazioni su invito

▲ **Computational materials screening beyond high-throughput computing: Accuracy and efficiency through machine learning and post-DFT methods.**
Marrazzo A.
Scuola Internazionale Superiore di Studi Avanzati SISSA, Trieste, Italy
For more than a decade, high-throughput computing has been the workhorse driving the computational design and discovery of materials. Large databases of crystal structures have been screened for target applications, via automated simulations workflows mostly based on density-functional theory (DFT). I will start with examples of standard high-throughput workflows in the context of 2D spin-orbitronics materials, discussing success stories and challenges. Then, I will present strategies to improve the accuracy and efficiency of materials screening. First, I will argue how we can accelerate high-throughput studies through machine learning and physical descriptors of the electronic structure. Then, I will mention how beyond-DFT methods, such as many-body perturbation theory, are now being upgraded to high-throughput mode. Finally, I will present non-collinear orbital-dependent functionals that can deliver accurate spectral properties in the presence of strong spin-orbit coupling, at low computational cost and complexity. Our functionals include spin-dependent interactions and screening effects that are absent in standard diagrammatic approaches based on the random phase approximation.

▲ **Materials for (photo)electrochemical water splitting: On the role of surface charge accumulation.**
Piccinin S.
Consiglio Nazionale delle Ricerche, Istituto Officina dei Materiali, CNR-IOM, Trieste, Italy
The oxygen evolution reaction (OER) plays a crucial role in (photo)electrochemical devices that use renewable energy to produce synthetic fuels. OER is a 4-hole process leading to the oxidation of two water molecules and the release of molecular oxygen and is considered the bottleneck of water splitting. Recent measurements on semiconducting oxides have shown that the dependence of the rate of OER on the surface hole density is a power law, suggesting a multihole mechanism via surface hole accumulation. This is in stark contrast with metallic oxides like IrO_2, where the dependence is exponential. In this contribution I will discuss our recent findings where, using transient photocurrent measurements, density functional theory simulations and microkinetic modeling, we try to shed light on the origin of this behavior in hematite, Fe_2O_3. We find an approximate third-order behavior of the OER rate on the surface hole density, involving the dissociative chemisorption of a hydroxide ion via a three-hole step. We find that, at variance with the IrO_2 case, the activation energy of this step is weakly dependent on the surface hole coverage, leading to the observed power law.

▲ **Atomistic study of the configurational entropy and the fragility of supercooled liquid phase-change materials.**
Mazzarello R.
Sapienza University of Rome
Phase-change materials (PCMs) are an important family of alloys employed in non-volatile memories and neuromorphic devices. These devices exploit the ability of PCMs to undergo

rapid transitions between crystalline and amorphous phases at moderately high temperature. At ambient conditions, both phases are very stable. These properties imply a strong temperature dependence of the crystallization kinetics, which is attributed to the high fragility of the supercooled liquid phase. The exploration of the potential energy landscape (PEL) by molecular dynamics provides important information on the thermodynamics and dynamics of glass forming liquids. However, a large set of configurations in a wide range of temperatures is needed for a good sampling of the PEL, requiring long simulation times beyond the reach of *ab initio* methods. In this contribution, we use a neural network potential to investigate the PEL of liquid GeTe, a prototypical PCM. We compute the configurational entropy, the viscosity and the relaxation times as a function of temperature in the deeply supercooled regime. Finally, we use the Adam-Gibbs equation to estimate the glass transition temperature and determine the fragility.

▲ Tailorable materials for plasmonics in extreme conditions.

Calzolari A. ([1])([2])([3]), Catellani A. ([1]), Curtarolo S. ([2])([3])
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We investigate and discover refractory materials with tunable optical properties in the near-IR/vis range and high mechanical and thermal resistance for plasmonics applications in extreme and harsh conditions. By using *ab initio* simulations based on (TD)DFT, we first studied the role of composition and structural disorder of transition-metal nitrides, and we provided an efficient strategy to engineering stable, easy-to-grow hyperbolic metamaterials, with extraordinary mechanical properties. Finally, by combining computational thermodynamics and first-principles electronic structure techniques, we proposed high-entropy transition-metal carbides, which yielded plasmonic properties from room temperature to 1500 K. This new class of plasmonic materials may foster previously unexplored optical/mechanical applications (*e.g.*, aerospace and security systems) in extreme conditions.

▲ Non-adiabatic effects lead to the breakdown of the semi-classical phonon picture.

Marini A.
Istituto di Struttura della Materia e Division of Ultrafast Processes in Materials, FLASHit, of the National Research Council, Monterotondo Stazione, Italy

Despite the fact that the phonon concept is one of the most widely used, studied, reviewed concepts in modern condensed matter, some, even basic, properties are still debated. In this contribution I will discuss, trying to shed light on, some of the main open questions. Density-Functional Perturbation Theory (DFPT) is routinely used to calculate non-adiabatic properties, including phonon widths. Even if DFPT is a semi-classical theory it is widely accepted that it can provide the same kind of information of a fully quantistic theory. I will start my contribution by demonstrating that this well-known fact is, actually, based on a faulty solution of the linearized Ehrenfest dynamics. In particular I will demonstrate how a decaying semi-classical phonon oscillation corresponds to an energy violating and, thus nonphysical, solution of the linearized atomic real-time dynamics. I will, then, show that the exact time-dependent DFPT phonon energy is real and always over-estimates the real frequency, obtained as a solution of the full many-body problem. This difference induces a gap between the quantistic and classical phonon energies that increases with the energy indetermination.

Comunicazioni

Artificial photosynthesis: How can we accelerate the discover of new materials?

Salvi M., Piccioni A., Mazzaro R., Pasquini L.
Department of Physics and Astronomy, University of Bologna

Global warming necessitates a transition toward carbon-neutral alternatives across various sectors of the economy. Photosynthetic reactions harness solar energy to either store it for later use or synthesize valuable chemicals using a renewable source of energy. In artificial photosynthesis, photons are absorbed by a semiconductor electrode inserted in a solution that contains the reactants. The electron and hole that are excited are then separated and used to reduce and oxidize the reactants. The space of parameters to optimize is vast, as the field brings together aspects that are usually important in photovoltaic (absorption, charge separation) with others that are more related to electrochemistry (stability in solution, charge transfer kinetics). To accelerate this exploration, research groups have developed strategies for the combinatorial fabrication of material libraries and their high-throughput characterization. In this contribution I will show a low-cost setup developed by our group for high-throughput characterization. I will then present two examples of parameter optimizations that we performed: the doping concentration and annealing temperature of titanium-doped hematite.

Theoretical study of internal conversion: Complementary static and dynamic analysis, case of porphyrins.

Rukin P., Prezzi D., Rozzi C.A.
CNR-Istituto Nanoscienze, Modena, Italia

We investigate internal conversion (IC) within the Q band of a bare porphyrin and its functionalized modification (FP). Utilizing static time-dependent density functional theory (TDDFT), we identify the crucial molecular vibrations by referencing the calculated per-mode reorganization energies(RE) associated with the Q_x and Q_y states. Using a technique we recently introduced, we anticipate where the potential energy surfaces (PES) of the excited states might intersect. Complementarily, we conduct non-adiabatic molecular dynamics (NAMD) simulations to validate the static predictions. Through the essential dynamics analysis of a statistically significant ensemble of simulated trajectories, we validated the efficacy and reliability of the rapid static normal mode approach. This method can serve as a preliminary guide for more intricate and computationally demanding dynamical analysis of IC in the vicinity of conical intersection.

Structural phase transitions in monolayer TMDs with a neural-network interatomic potential.

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Among the wide family of layered materials, transition metal dichalcogenides (TMDs) constitute a broad class of systems exhibiting diverse properties depending on chemical composition, temperature, pressure, and dimensionality. In the single layer limit, some TMDs can exhibit different polymorphs, such as, for instance, tungsten ditelluride (WTe_2) and molybdenum ditelluride ($MoTe_2$) which showcase two dynamically stable phases characterized by a small energy difference and, indeed, both experimentally observed at ambient conditions. In this contribution, starting from density functional theory calculations and applying neural

network machine learning techniques, we developed an interatomic potential to investigate at the atomistic level the structural transition between the two polymorphs separated by a high energy barrier. By performing molecular-dynamics simulations, we examine the role of defects and interfaces in driving the structural change from the metastable to the most stable phase at high temperature.

Probing bound excitons in the *T*-phase SnS_2 monolayer: A theoretical study.

Bastos V.A. ([1]), Paleari F. ([2]), Luppi E. ([3]), Ruini A. ([1])

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([3]) *Laboratoire de Chimie Théorique, Sorbonne Université e CNRS, France*

SnS_2 is a layered material with visible spectrum absorption and energy level alignment suitable for hydrogen fuel cell electrodes. It exemplifies group IV chalcogenides, increasingly studied for second harmonic generation (SHG) response. We undertake a thorough theoretical investigation of bound excitons in the T-phase SnS_2 monolayer, employing many-body perturbation theory atop DFT-PBE electronic structure calculations. Our study reveals a more complex structure of bound excitons than previously reported, likely due to overscreening from the interlayer interaction in the previous work. The calculated first bright-exciton energy of 2.3 eV closely matches the experimental optical gap of 2.23 eV. We offer a detailed analysis of the composition and nature of the excitonic states. Future research will extend to non-centrosymmetric group IV chalcogenide systems such as H-phase SnS_2, SnS, and SnSe layered structures, exploring their SHG response. This research is performed within the PNRR MUR project ECS_00000033_ECOSISTER.

Computer modelling as a bridge across energy scales: Tritiated graphene as detector for relic neutrinos.

Tozzini V. ([1])([2]), Menichetti G. ([3])([4]), Esposito A. ([5])([6]), Casale A. ([5])([7])

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Computer modelling can act as a bridge between fields not commonly connected. For instance, multi-scale simulations are used to address the biochemical cascade occurring upon irradiation down to the cell/tissue level, or to design materials for green energy cycles. These apparently very distant applications share the use of different simulation methods (molecular dynamics, Monte Carlo) and combination of *ab initio* calculations with empirical potentials (possibly machine learning based), and typically span many orders of magnitude in time, space and energy. Here we report on the design of a detector for cosmological "relic" neutrinos, performed within the PTOLEMY Collaboration. To detect these elusive particles decoupled 1 s after the Big Bang, we are designing a graphene-based storage system for tritium (T), producing β radiation with a specific spectrum signature upon neutrino capture. We calculate the T interaction potential to precisely determine the quantum effects that may spoil the detection resolution, and design the structure of the material to optimise it as the active part of the detector, with respect to electronic properties and T concentration.

Engineering electronic and optical properties of chalcogen hyperdoped Si: A first-principles study.

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Hyperdoped Si is attracting increasing interest from materials scientists and the semiconductor industry due to its applications both in fundamental physics for studying the insulator-to-metal transition (IMT) and as a building block for innovative devices. By *ab initio* simulations and supercell methods, we investigated S hyperdoped Si by computing, for different types of S complexes, the formation energy as a function of S concentration. We enlightened the microscopic mechanisms responsible for the disappearance of electrical deactivation defects as the S population approaches the critical concentration, x_c, at which the IMT occurs. We discuss the electrical properties of S complexes in Si, identifying the optimal doping range in which the donor density can be tuned to engineer both x_c and the optical properties of the material. Our *ab initio* simulations of Si:S dielectric constant, including local field effects, show the possibility to tailor infrared absorption spectra according to industrial needs, thus paving the way for the design of materials for novel applications, ranging from long-wavelength infrared detectors to impurity band photovoltaics and nanoelectronics.

Chiral multiferroicity in two-dimensional hybrid organic-inorganic perovskites.

Stroppa A. ([1]), Zheng H. ([2]), Ghosh A. ([3]), Swamynadhan M. ([4]), Zhang Q. ([5]), Wong W. ([2]), Wu Z. ([2]), Zhang R. ([2]), Chen J. ([5]), Cimpoesu F. ([6]), Ghosh S. ([4]), Campbell B.J. ([7]), Wang K. ([8]), Mahendiran R. ([3]), Loh K.P. ([2])
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Chiral multiferroics, characterized by the coexistence of chirality and multiple ferroic orders, enable unique functionalities for multi-level control of quantum devices. Herein, we demonstrate that the ferroelectric, magnetic orders, and crystallographic chirality can coexist in hybrid organic-inorganic perovskites (HOIPs). Through Landau symmetry mode analysis, we have analyzed the cross-coupling of chirality with ferroic orders and proposed a new hybrid improper chirality transfer mechanism, for which the coupling of two non-chiral distortions enables the transfer of chirality from the organic cations to the framework. This coupling can be described by defining a new pseudo-scalar quantity, which differentiates the (R)- and (S)-chirality through its sign. Furthermore, the sign change of this descriptor is coupled to the synergetic switching of ferroelectric distortion, Jahn-Teller antiferro-distortions, as well Dzyaloshinskii-Moriya vectors, implying the pivotal role of crystallographic chirality in magnetoelectric correlation in chiral HOIP magnets.

Excitons in bilayer WTe_2.

D'Alessio M. ([1]), Molinari E. ([1])([2]), Varsano D. ([2]), Rontani M. ([2])
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Bilayer WTe_2 is a 2D metal that exhibits a macroscopic out-of-plane electric dipole. At low temperature it develops a narrow transport gap, like its monolayer counterpart where the appearance of the gap has been attributed to condensation of excitons. The similarities between transport measurements in mono and bilayer structures suggest that similar excitonic physics is at play in the bilayer. Moreover, contrary to other known bilayer excitonic insulators, in which electrons and holes are spatially separated, in WTe_2 interlayer tunneling is significant. This might impact the observable features of the putative exciton condensate, giving rise to a coherent contribution to the electric dipole, due to the interband electric polarization of excitons. In this contribution we investigate bilayer WTe_2 both from first principles and with a model built upon the symmetries of the system, focusing on the characterisation of excitons by means of the Bethe-Salpeter equation. The ultimate goal is to assess the instability against exciton condensation, as well as to predict its possible experimental fingerprint.

Excitonic instability in narrow-gap carbon nanotubes.

Sesti G. ([1]), Molinari E. ([2]), Varsano D. ([1]), Rontani M. ([1])
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Ultraclean suspended carbon nanotubes, which are predicted to be metallic by band theory, always exhibit a many-body transport gap at low temperature. Whereas the correlated ground state was early interpreted as a Mott insulator, we recently predicted that, in gapless (armchair) tubes, the gap is enforced by the permanent condensation of excitons. Here we investigate thoroughly the screening of nanotubes, developing a model fit to samples of any size and chirality, which is validated by state-of-the-art first-principles calculations. Our key result is that the long-range of Coulomb interaction, which remains largely unscreened even in the presence of Fermi points, stabilizes the excitonic insulator phase in all narrow-gap nanotubes. Furthermore, we show that the EI phase is better suited than the Mott insulator to explain available experiments, which focus on the closure of the many-body gap with the magnetic field.

Investigation of magnetic properties and spin dynamics in rare-earth–based complexes.

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Single-molecule magnets and single-ion magnets, models to study new phenomena at the nanoscale level in low-dimensional systems, have attracted the attention of the scientists for their potential technological applications. To improve their performance, researchers

devoted their efforts to increase their anisotropy barrier and minimize the relaxation mechanisms dominating at low temperature. Within the INFN NAMASSTE Project, we investigated the magnetic properties and the spin dynamics of four lanthanide-based complexes $(\mathrm{Ln(DTBSQ)(HBPz_3)_2}$, $\mathrm{(Ln(Trp)(HBPz_3)_2}$ with $\mathrm{Ln = Tb, Dy}$, Ln-SQ and Ln-Trp in short) as a function of temperature and magnetic field through ^{1}H NMR measurements and dc/ac susceptibility measurements. This study allowed us to point out: i) how the insertion of a different lanthanide could vary the spin dynamics of the system; ii) the role of the exchange interaction in the case of the compounds with the Ln bound to a paramagnetic SQ ($s = 1/2$) ligand compared to the systems where it is bound to a diamagnetic Trp ($s = 0$) radical; iii) the complementarity of NMR and ac susceptibility techniques for investigating the spin dynamics in different timescales.

Electron glass phase with resilient Zhang-Rice singlets in $\mathbf{LiCu_3O_3}$.

Consiglio A. ([1])([2])([3]), Gatti G. ([4]), Martino E. ([4]), Hofmann T. ([2])([3]), Thomale R. ([2])([3]), Sangiovanni G. ([2])([3]), Di Sante D. ([5]), Greiter M. ([2])([3]), Grioni M. ([4]), Moser S. ([4])([6])([7])

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A thorough investigation of $\mathrm{LiCu_3O_3}$, an antiferromagnetic mixed valence cuprate, reveals an intricate electronic structure and disorder-induced phenomena. The compound consists of trilayers of edge-sharing Cu(II)O, where lithium atoms stochastically substitute Cu(II) sites up to 40%, sandwiched between planes of Cu(I) ions. Using angle-resolved photoemission spectroscopy and density functional theory, we unveil distinct insulating electronic subsystems coexisting within the compound: a $\mathrm{Cu}d_{z^2}/\mathrm{O}p_z$ derived valence band (VB) on the Cu(I) planes and a $\mathrm{Cu3}d_{x^2-y^2}/\mathrm{O2}p_{x,y}$ derived Zhang-Rice singlet (ZRS) band on the Cu(II)O planes. Li atoms introduce substitutional disorder, leading to an electron glass behavior characterized by a Coulomb gap and a linear suppression of the VB at the Fermi level. The disorder minimally impacts the ZRS, suggesting a local segregation of Li and Cu atoms on separate sub-lattices. Our comprehensive experimental and theoretical work highlights the resilience of the ZRS quasiparticles against impurity scattering, despite significant Li-induced disorder.

Aula 1E **ore 09:00 – 13:30**

Sezione III
Astrofisica
Presiede: Orlando S. (INAF, Osservatorio Astronomico di Palermo)

Relazioni su invito

▲ **The intriguing life of galaxies.**
Mercurio A.
Dipartimeno di Fisica, Università degli Studi di Salerno
How, when, and where do galaxies acquire their physical properties? Observational evidence reveals that galaxies' properties and past evolution strongly depend on mass and environment. However, the evolutionary pathways of galaxy properties remain heavily debated. The critical ingredient to properly address this issue is the availability of large and homogeneous spectrophotometric data of galaxies. The advent of dedicated survey telescopes and integral-field spectrographs in synergy with space telescopes such as HST and JWST is enabling a major leap forward in the investigation of galaxy evolution. I will be presenting the most recent observational results in this research field during this contribution.

▲ **Gaia's stars as a turning point for fundamental questions of local cosmology.**
Crosta M.
INAF, Osservatorio Astrofisico di Torino
How did the Universe form and evolve? What is our place in it? Twenty-first century astrometry, thanks to the ESA Gaia satellite, can provide humanity with the answers to such key questions. The ancient branch of Astronomy dedicated to the measurement of the position of the stars and their movements in the Universe is nowadays dominated by Einstein's theory. Gaia, indeed, inaugurated a new era: we are mapping the Galaxy in which we live with unprecedented detail, we are looking for and measuring the effects of gravitational astronomy on all scales within the Milky Way to compare them with the predictions of current theories on gravity and with cosmological formation scenarios. The stellar archive produced by Gaia in this decade is already a treasure chest for revealing the Universe that surrounds us; at the end of this adventure it will constitue a fundamental legacy for the next generations of astronomers, for deep space exploration and for locating new Earths. The Gaia experience prepares us for the next technological challenges that gravitational astrometry will face to remain at the forefront of physics and astronomy research in this century and beyond.

Comunicazioni

● **Cosmology and astrophysics with upcoming dark sirens and galaxy catalogs.**
Borghi N., Moresco M., Tagliazucchi M.
Dipartimento di Fisica e Astronomia, Università di Bologna e INAF, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
Gravitational waves from compact binary coalescences are promising cosmological probes, providing direct measurement of the source luminosity distance. However, the source redshift must be obtained independently, either from an associated electromagnetic counterpart or by including a prior on the astrophysical population or host galaxy distribution. We present a

novel method enabling joint constraints on cosmological and astrophysical population parameters using galaxy data. We analyze scenarios representative of future LIGO-Virgo-KAGRA observing runs, assuming a complete catalog of massive host galaxies with either photometric or spectroscopic redshift uncertainties. We find that a percent-level Hubble constant (H0) measurement is possible with the best 100 binary black holes in O5 and a spectroscopic data. With photometric data, the precision is $\sim$10 times weaker, requiring careful modeling of the astrophysical population to avoid bias. Interestingly, the O4 configuration with spectroscopic data yields better H0 constraints than O5 with photometric data. These results highlight the importance of future galaxy surveys to maximize the scientific return of gravitational-wave science.

Sulla misura della costante di Hubble tramite la combinazione di sonde cosmologiche a basso redshift.

Cogato F. ([1])([2]), Moresco M. ([1])([2]), Amati L. ([2])
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La discrepanza tra i valori della costante di Hubble misurati tramite la scala delle distanze nell'universo locale e la radiazione cosmica di fondo, rappresenta una complessa questione a cui tutta la comunità scientifica è chiamata a rispondere. Difatti, la tensione di Hubble ha portato a riflettere sia sula nostra comprensione dell'evoluzione dell'universo, sia sulla capacità di identificare gli effetti sistematici nelle osservazioni astrofisiche. Questa comunicazione vuole presentare lo stato dell'arte dei vincoli ai parametri cosmologici ottenuti dalla combinazione statistica di diverse sonde cosmologiche, in particolare, i Cronometri Cosmici, i Gamma Ray Burst, le Oscillazioni Acustiche dei Barioni e le Supernovae Ia. Verrà dunque proposto un interessante caso studio in cui, attraverso un'analisi bayesiana, la costante di Hubble può essere inferita in maniera indipendente dai due metodi protagonisti della tensione. L'obiettivo sarà perciò quello di mostrare il potenziale di tale metolodogia di analisi, oltre a suggerire l'importanza di estendere tale approccio alle nuove sonde recentemente emerse nel panorama cosmologico, come le Onde Gravitazionali e le esplosioni di Kilonova.

The physics of fundamental astronomy in the 21st century: The Global Sphere Reconstruction (GSR) system.

Lattanzi M.G., Bertone S., Bucciarelli B., Crosta M., Vecchiato A., Buzzi R., Cesare V., Busonero D., Messineo R., De March R., Bramante L., Squillante L.A., Solitro F.
INAF, Osservatorio Astrofisico di Torino

As a spin-off of the Italian participation in the Gaia mission, GSR can model light directions to 10^9 sources (including $> 10^6$ QSOs), observed for several years, to $\leq 5 \times 10^{-12}$ accuracy. At this accuracy, the GSR mathematical and computational system is the only that rigorously follows the precepts of General Relativity, representing the observations as invariants, i.e., relativistic photon-paths intercepting at any given proper time a relativistic space observer, i.e., a space telescope operating from within the Solar System. Optimal statistical inversion of such a huge non-linear system of $>$ 100 billion equations provides researchers with absolute distances and velocities: an unprecedented observational data lake for the realization and maintenance of the Fundamental Ref. Frame to unmatched levels, and for discriminating gravity theories at all scales within our Galaxy and beyond (cosmological GWs). We illustrate today's GSR system, a unique HTC and HPC facility capable of dealing with its growing computational complexities and ready to take more space data and be exploited on a variety of outstanding problems in observational physics by our scientific communities.

Performance monitoring of the NISP instrument of the Euclid mission.

Lentini E., Testera G., Balbi E.

Università di Genova e INFN, Sezione di Genova

Euclid is an ESA mission whose launch took place in July 2023 and that is designed to explore the composition and evolution of the dark Universe. The space telescope will create a great map of the large-scale structure of the Universe across space and time by observing billions of galaxies out to 10 billion light-years, across more than a third of the sky. Regular monitoring of instrument telemetry parameters and good data quality is of fundamental importance. In this presentation, I will illustrate my activity within the Instrument Operation Team of the mission's infrared spectrophotometer (NISP): I will show the software tools developed for an easy daily verification of performances and some preliminary results.

A study of refracted gravity using galaxy clusters.

Viscusi A.

Università degli Studi di Torino

This work examines the theory of Refracted Gravity using galaxy clusters. Refracted Gravity is a classical theory of modified gravity aimed at resolving the mass discrepancy within cosmic structures without the contribution of dark matter. I implement a Monte Carlo algorithm (MCMC) to obtain the best-fit parameters of the baryonic Tully-Fisher relation, which links M_{bar} to the circular velocity V_C. I then construct density and mass profiles and by implementing the functional form of gravitational permittivity found in literature, I obtain optimal values for the three parameters of this function from the previously defined MCMC algorithm. The obtained parameters are consistent with those found in literature, and the gravitational permittivity constructed in this manner is compatible with values obtained in other studies on galaxy dynamics within Refracted Gravity.

Galaxy clusters dynamical state inference by Zernike polynomials modeling of high resolution Sunyaev-Zel'dovich effect images.

Pappalardo E. ([1]), De Petris M. ([1])([1]), Ferragamo A. ([1])([1]), Wicker R. ([1])([1]), Bartolucci I. ([3]), Benincasa A. ([1])([1]), Paliwal A. ([1])([1]), Capalbo V. ([1])([1]), Yepes G. ([2])([1]), Weiguang C. ([2])([1])

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Galaxy clusters are powerful tools for constraining cosmological parameters but an accurate knowledge of their dynamical state is required. The morphology of the clusters, inferred by several indicators applied on multi band images, allows us to investigate their dynamical state. To study the morphology of clusters,we focus on the novel approach based on Zernike Polynomials applied on maps of the signal of the Sunyaev Zel'dovich thermal effect. This analytical method is mostly implemented in adaptive optics as well as in optical metrology and medicine. After the first attempts on Planck maps, now we want to extend it to high angular resolution SZ maps, such as the mm-camera NIKA2. The procedure has been applied on mock NIKA2-like representative images generated from hydrodynamical simulated clusters present in The Three Hundred dataset to recover their morphology. We validate the capability of the ZPs by comparing them with one of the several cluster dynamical state indicators, such as the relaxation parameter. The correlation of the ZPs with other classical multi-band morphology parameters is also studied.

Relazioni su invito

▲ **SKAlow - The italian contribution.**

Monari J. ([1]), Alderighi M. ([3]), Belli C. ([2]), Bernardi G. ([1]), Bolli P. ([2]), Caito L. ([5]), Caputo F. ([1]), Chiarucci S. ([2]), Ciani L. ([8]), Comoretto G. ([2]), D'Angelo S. ([3]), Di Ninni P. ([2]), Fierro D. ([5]), Macario G. ([2]), Mattana A. ([1]), Naldi G. ([1]), Nanni J. ([7]), Perini F. ([1]), Pupillo G. ([1]), Schiaffino M. ([1]), Schillirò F. ([4]), Singuaroli R. ([8]), Tabellini A. ([1]), Tartarini G. ([7]), Paonessa F. ([6]), Virone G. ([6])

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([2]) *INAF, Osservatorio di Arcetri*

([3]) *INAF, Istituto di astrofisica spaziale e fisica cosmica di Milano*

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([6]) *CNR, IEIIT di Torino*

([7]) *DEI Università di Bologna*

([8]) *DINFO Università di Firenze*

Since 2002, INAF, collaborating with Italian industries, universities, and research institutes, has advanced a significant project. Key milestones include participation in the EC FP6 SKADS project in 2004, testing new technologies like analog RF optical fiber links and digital domain beamforming systems using the Northern Cross radiotelescope. In 2009, a national INAF group was formed, bolstered by partners from OAA, OAC, IASF-Mi, UNIBO, UNIFI, CNR-IEIIT, and industries, driving Italian technological advancement. INAF's leadership in antenna design, UAV-based test systems, digital acquisition, and beamforming firmware has been instrumental, notably applied in AAVP-2010 and AADC-2016. Post SKA Critical Design Review, INAF's contributions have largely shaped the SKAlow receiving system's "Made in Italy" baseline design. INAF's staff substantially contributed to AAVS1/2/3 prototypes' installation and participated in their observations, verification, and commissioning, advancing industrialization. Presently, INAF plays a crucial role in SKA Low's antennas, receivers, and signal processing system, deeply engaged in constructing the telescope's first release (AA0.5).

Comunicazioni

● **The northern cross fast radio burst project.**

Bernardi G.

INAF, Istituto di Radioastronomia

Fast Radio Bursts (FRBs) are short and bright extragalactic transient events, essentially visible only at radio wavelengths. Their tipical duration is a few milliseconds, and their brightness can vary by orders of magnitude, from mJy to kJy. Their origin is still fairly debated, although they are commonly associated with magnetar progenitors, although they have been found in very different environments (from nearby star forming galaxies, to high-redshift elliptical galaxies, to globular clusters). The physical mechanism that powers them is still fairly unconstrained. In this contribution I will review the observing programme that our group has started with the Northern Cross located at the MEdicina station, with the aim to characterize FRBs at 408 MHz. I will also describe complementary observations that our group routinely carry out simultanously with the MEdicina and Noto radio telescopes, at frequiencies of 1.4 GHz and 2.3 GHz respectively. I will present our latest results, in particular on our searches of FRBs in nearby galaxies, and our long-term monitoring of repeating FRB sources.

Green aware HPC and QC for radio imaging towards SKA era.
Lacopo G. ([1])([2]), Gheller C. ([3]), Tornatore L. ([2]), Taffoni G. ([2]), Varetto U. ([4]), The Pawsey Supercomputing Centre Staff ([4])
([1]) *Università degli studi di Trieste*
([2]) *INAF, Osservatorio Astronomico di Trieste*
([3]) *INAF, Istituto di Radioastronomia di Bologna*
([4]) *Pawsey Supercomputing Centre Perth, Australia*
The next generations of interferometers (e.g. LOFAR2, SKA) will produce hundreds of petabytes of data per year, requiring cutting-edge hardware technologies to analyze the data and reconstruct the brightness distribution of the sky sources. Memory and computational requirements demand for thousands of computing nodes in HPC architectures, equipped with both CPUs and GPUs. Feeding such number of devices requires tens of MW, making it hardly sustainable according to the current environmental issues, given the well-known impact of energy production on carbon footprint. The code for radio imaging which we present here is suited to different architectures thanks to its portability which makes it work on CPUs, and both NVIDIA and AMD GPUs. The work we've been focusing here is the performance portability of the code, to avoid differences in time-to-solution when running it onto different platforms. To study the energy-to-solution, we relied on the libraries and hardware counters available in the Setonix supercomputer, at the PSC in Perth. Meanwhile, we explored also the possibility to use quantum computers to perform the imaging operations in the next future thanks to quantum emulators.

Search for properties of gamma-ray bursts at high redshift.
Pizzichini G.
INAF, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
I shall report on my search for particular properties of gamma-ray bursts at high redshift.

Distributions of energy, luminosity, duration, and waiting times of gamma-ray burst pulses with known redshift detected by Fermi /GBM.
Maccary R. ([1]), Guidorzi C. ([1])([2])([3]), Amati L. ([3]), Bazzanini L. ([1])([3]), Bulla M. ([1])([2])([4]), Camisasca A.E. ([1]), Ferro L. ([1])([3]), Frontera F. ([1])([3]), Tsvetkova A. ([3])([5])
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([3]) *INAF, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna*
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([5]) *Dipartimento di Fisica, Università di Cagliari*
Long gamma-ray bursts (GRBs) are thought to be due to relativistic jets resulting from the collapse of the core of some kind of hydrogen-stripped massive stars. Despite being the first electromagnetic emission signalling the catastrophic event, the so-called prompt gamma-ray emission remains the most enigmatic aspect of GRB physics. Its irregular and complex temporal structure, consisting of a complex sequence of pulses, should provide clues on how newborn GRB engines release energy. It has been suggested that their dynamics could be ruled by self-organised criticality (SOC). This kind of dynamics is characterised by some energy input, which spontaneously drives the system to a critical state, at which a sudden release of energy through avalanches occurs. This irregular, bursty behaviour may resemble GRB prompt emission. The energy, luminosity, waiting time, and duration distributions of individual pulses of GRBs with known redshift observed by the Fermi GBM were studied in our recent paper (Maccary et al., 2024). This is the first study of this kind in which selection effects are taken into account. We discuss the compatibility of our results with SOC dynamics.

Analisi sistematica temporalmente risolta di lampi di raggi gamma rivelati da Fermi-GBM.

Depalo D. ([1])([2]), Bissaldi E. ([1])([2]), Bala S. ([3]), Goldstein A. ([3])
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([3]) *Science and Technology Institute, Universities Space Research Association, Huntsville, USA*

Il telescopio per raggi gamma Fermi è operativo da quasi 16 anni, periodo nel quale il Gamma-Ray Burst Monitor (GBM) è stato il rivelatore di lampi di raggi gamma (Gamma-Ray Burst o GRB) più prolifico di sempre, con oltre 3700 eventi osservati finora. Decine di articoli dedicati a singoli GRB e numerosi cataloghi generali hanno aiutato a far luce sulle proprietà temporali e spettrali di questi eventi affascinanti. Il lavoro che presentiamo è un'analisi sistematica di un sottogruppo di GRB brillanti, con particolare attenzione all'evoluzione temporale dei parametri dei modelli spettrali fittati. Le curve di luce sono suddivise in intervalli temporali usando il metodo dei Blocchi Bayesiani, mentre l'analisi temporalmente risolta viene fatta utilizzando i nuovi GBM Data Tools. A ogni intervallo sono applicati cinque modelli spettrali diversi, e attraverso opportuni criteri statistici viene selezionato il migliore tra essi. Le distribuzioni ottenute dei parametri dei migliori modelli confermano la predominanza del modello Comptonized. Infine, l'obiettivo del nostro lavoro è implementare questa pipeline per una futura analisi sistematica di un campione di GRB più ampio.

Archimedes experiment: The weight of quantum vacuum.

Esposito M.
Dipartimento di Fisica, Università di Napoli Federico II e INFN, Sezione di Napoli

The Archimedes experiment investigates the interaction between quantum vacuum fluctuations and gravity, placing itself into one of the most longstanding discussions in physics: the Cosmological Constant problem. Archimedes is devoted to measure the weight of zero point energy by weighing the condensation energy of a layered type II superconductor, using a balance as a small force detector. In these kind of superconductors the superconducting planes are separated by dielectric planes, forming a natural multi-layer Casimir cavity. If the vacuum energy does interact with gravity a force directed upwards acts on the cavity and can be interpreted as the lack of weight of the expelled EM modes. The expected torque generated with this modulation is of the order of 10^{-13} Nm/$\sqrt{Hz}$, therefore a very sensitive beam-balance has been suitably designed. Currently the final setup has been installed and thermal modulation tests on superconductive samples are ongoing.

Interpretation of Quantum Theory in a cosmological perspetive.

Prospèri G.M., Baldicchi M.
Università di Milano

We reconsider the problem of the interpretation of Quantum Theory (QT) in the perspective of the entire universe and of the Bphr idea that the classical language is the language of our experience and QT acquires a meaning only with a reference to it. To overcome the well known logic difficulties related to this dichotomy, we distinguish a classical or macroscopic level, directly related to our experience, and a quantum or microscopic one, that is perceived only through the modifications that it induces in the first. The macroscopic state is assumed to be specified by a set quantities, a classical energy momentum tensor and conserved currents, which are supposed to have always well-defined values independently of any observation. The microscopic dynamics is expressed by the usual QT formalism. For the macroscopic variables a basic distribution of probability is postulated in terms of quantum operators and a statistical operator, which expresses the knowledge that we have on some

part of the universe. Such postulate is intended to replace the usual probability rule of QT. Note that then the reduction of the quantum state can be simply reduced to the replacement of a joint to a conditional probability. For the Universe a variance of the ΛCDM model is assumed; with $\Omega = 1$, one inflaton with a Goldstone type potential, expectation values of all fundamental fields vanishing far in the past and consequently initial time at $t = -\infty$. The scalar fluctuation in the Cosmic Microwave Backgraound are correctly reproduced for appropriate values of the inflaton potential parameters but the present upper-bound on the tensor fluctuations is correspondingly strongly violated and their absence remains not understood. This could to suggest that Gravity is a pure classical phenomenon, what could be simply consistently accommodated in our framework.

Aula F **ore 09:00 – 11:00**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Tinti E. (Sapienza Università di Roma)

Relazioni su invito

▲ **Il potenziale della gravità terreste e il sistema di quote fisiche IHRS/IHRF.**
Barzaghi R.
DICA-Politecnico di Milano
I metodi di stima del potenziale della gravità terrestre $W(P)$ permettono oggi di ottenere valori di $W(P)$ con elevata precisione a scala globale. Queste metodologie di stima si basano su osservazioni da satellite che sono opportunamente combinate con dati di gravità misurati a terra e da aereo/nave. Come è noto poi, attraverso le differenze di potenziale della gravità terrestre si può definire la quota di punti sulla superficie terrestre. Questa quota, denominata quota ortometrica, è quella correntemente riportata in cartografia e utilizzata in tutti i problemi connessi al flusso dell'acqua. Nel 2015, la Associazione Internazionale di Geodesia (IAG) ha promosso, con una sua risoluzione, un progetto volto alla definizione dell'International Height Reference System/International Height Reference Frame (IHRS/IHRF), un sistema di quote fisiche che sia coerente a scala globale. Ciò permetterà, ad esempio, di migliorare la stima delle variazioni del livello medio del mare a scala planetaria. In questa comunicazione si illustreranno i moderni metodi di stima del potenziale della gravità terrestre e delle quote fisiche a scala globale e se ne discuteranno le possibili ricadute.

▲ **Geomagnetic paleosecular variation as a dating tool for archaeology, volcanology and stratigraphy: The Italian experience.**
Tema E.
Dipartimento di Scienze della Terra, Università degli Studi di Torino
The Earth's magnetic field continuously changes over time and space, exhibiting both long-term and short-term variations. Short-term variations, known as Secular Variation (SV), can be reconstructed for the past few centuries using direct measurements from magnetic observatories and, more recently, satellites. However, for older periods lacking direct measurements, we rely on the study of remanent magnetization preserved in well-dated rocks and archaeological artifacts. Italy's long and rich cultural heritage, coupled with its near-continuous volcanic activity, makes it an ideal location for geomagnetic field reconstructions. Recently, a comprehensive compilation of Italian paleomagnetic data from both archaeological materials and volcanic rocks was compiled. This data was used to calculate directional and intensity reference SV curves spanning the last three millennia. This contribution discusses the application of these reference curves, alongside global geomagnetic field models, as a dating tool. Particular emphasis will be placed on the use of paleosecular variation dating in archaeological, volcanological, stratigraphic, and Holocene paleoclimatic studies.

Comunicazioni

● **Nonlinear shallow water investigation of atmospheric disturbances generated by strong seismic events.**
Carbone F. ([1]), Gencarelli C.N. ([2]), Dutykh D. ([3])
([1]) *CNR, Institute of Atmospheric Pollution Research, University of Calabria, Rende, Italy*
([2]) *CNR, Institute of Environmental Geology and Geoengineering, Milan, Italy*

([3]) *Mathematics Department, Khalifa University of Science and Technology, Abu Dhabi, United Arab Emirates*

The upper portions of the Earth's atmosphere can be significantly affected by perturbations generated in the lower layers. In fact, all perturbations formed within the troposphere can easily propagate, not only horizontally within the layer but also vertically reaching regions of the atmosphere far from the Earth's surface (Wentzel-Kramers-Brillouin approximation of atmospheric waves). Because all perturbations generated in the troposphere must take into account the effects of the medium's nonlinearity or turbulence, the impact of a strong seismic event and the disturbances generated in the flow are numerically analyzed by means of a fully nonlinear model based on the classical shallow water. Two different scenarios have been investigated: a single-layer case where the fluid is approximated as a continuous system, and a multi-level case where the density stratification plays a central role in the transport/evolution of the perturbations towards the higher atmosphere. The flow perturbation presents a multiscale nature, and a strict dependence was observed between turbulence and the vertical nonvanishing modes.

Multi-instrument detection of the ionospheric response to the 6 February 2023 Turkey earthquake.

Guerra M. ([1])([2]), Haralambous H. ([3]), Chum J. ([4]), Verhulst T.G.W. ([5]), Barta V. ([6]), Altadill D. ([7]), Cesaroni C. ([1]), Galkin I. ([8]), Kiszely M. ([9]), Mielich J. ([10]), Kouba D. ([4]), Buresova D. ([4]), Segarra A. ([7]), Spogli L. ([1])([11]), Rusz J. ([4]), Zednik J. ([12])

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([7]) *Observatori de "Ebre, University Ramon Llull" CSIC, Roquetes, Spain*
([8]) *Space Science Laboratory, University of Massachusetts Lowell, Lowell, MA, USA*
([9]) *Kavesligethy Rada Seismological Observatory, Institute of Earth Physics and Space Science, Budapest, Hungary*
([10]) *Leibniz-Institute of Atmospheric Physics, Kuehlungsborn, Germany*
([11]) *SpaceEarth Technology, Rome, Italy*
([12]) *Institute of Geophysics Czech Academy of Sciences, Prague, Czech Republic*

This research explores diverse ionospheric disturbances observed across Europe following the 10:24 UT earthquake of $M_W = 7.7$ in Turkey on February 6, 2023. We can distinguish various disturbances characterised by different velocities and propagation mechanisms. Our analysis unveils co-seismic ionospheric disturbances near the epicentre and reveals ionospheric manifestations of acoustic waves resulting from seismic wave propagation. In addition, thanks to the large network of GNSS receivers available in the European and Middle-Eastern areas, it was possible to study both the near and far field response to the earthquake, allowing comparison between the TID parameters derived from different measurement techniques. Thus, our study underscores the benefits of multi-instrument investigations in discerning the propagation of earthquake-related ionospheric disturbances at various ionospheric altitudes and distances from the earthquake epicentre.

The propagation of acoustic-gravity waves in a stratified atmosphere induced by seismic events.

D'Alessi L., Lepreti F., Carbone V.

Department of Physics, Università della Calabria, Rende, Italy

The study of the energy exchange between lithosphere and atmosphere during seismic events represents an important step towards a better understanding of the excitation and propagation of acoustic-gravity waves (AGW) in the atmosphere. Several models have been proposed in the past of propagation of AGWs in a stratified atmosphere, largely based on the Wentzel-Kramers-Brillouin (WKB) analysis. Here we provide a more accurate analytical model of the propagation of the AGWs through the different atmospheric layers. The properties of the waves derived from the model, as well as the role of the seismic events in the excitation of these modes, are discussed.

The Lunar Science case for LGWA (Lunar Gravitational-Wave Antenna).

Olivieri M. per la LGWA Collaboration

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna

The Lunar Gravitational-Wave Antenna (LGWA) is a proposed experiment that uses the Moon as the response body for detecting gravitational waves in the decihertz band. The plan of the experiment is to deploy an array of next-generation seismometers in the Lunar south polar Permanently Shadowed Regions (PSRs) where instrumental thermal noise is minimized. From the geophysical perspective, this experiment, combining high-sensitivity seismometers and low-noise environment, will provide exceptional data with two complementary objectives: 1) supporting the gravitational waves detection and analysis; 2) improving the geophysical knowledge of the Moon. In detail, the array of broadband seismometers will unveil extra-lunar normal-mode excitations and record the seismic signature of events like moonquakes, thermal quakes, and meteoroid impacts. Here we discuss the impact of LGWA from a multi-disciplinary perspective, focusing on the open questions about the formation and evolution of the Moon, and about the current tectonic setting and shallow rheology.

Environmental and climatic forcing on volcanic unrest.

De Siena L. ([1]), Amoruso A. ([2]), Petrosino S. ([3]), Crescentini L. ([2])

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While volcanic eruptions are a well-know forcing on climate, there is increasing evidence that climate change and the environment affect volcanoes. However, the spatio-temporal relationship between geophysical, environmental, and geochemical responses during volcanic unrest is essentially unknown, making their joint use and interpretation for eruption forecasting challenging. Here, empirical orthogonal functions analysis applied to GPS data allows the separation of the dominant deep-sourced inflation from environmentally controlled signals associated with extension at Campi Flegrei caldera. This separation bridges the gap between deformation, seismic and geochemical responses, clarifying the processes underlying the ongoing volcanic unrest. Persistent meteoric forcing during the 2017–2018 hydrological year changed the decadal trend of seismic energy and secondary deformation components, pairing their spatial patterns. The result was a block in the carbon dioxide released in 2018 at Solfatara, the primary stress-release valve at the caldera. The subsequent overpressure weakened the fractured eastern caldera, opening pathways for deep, hot materials to reach the surface.

On the source of the 6th February 2023 tsunami in the eastern Mediterranean.
Saturnino C., Angeli C., Zanetti M., Zaniboni F., Armigliato A.
Alma Mater Studiorum-University of Bologna, Department of Physics and Astronomy "Augusto Righi", Italy
On 06/02/2023 the region between southern Turkey and northern Syria was hit by a devastating earthquake sequence, starting with a $M_w = 7.8$ event at 01:17:34 UTC on the Eastern Anatolian Fault, followed by a $M_w = 7.5$ at 10:24:29 UTC and a large number of aftershocks. Both events were accompanied by many different coseismic and secondary effects, among which, a modest tsunami following the first mainshock and recorded by a few Tide Gauges (TGs) in the eastern Mediterranean. In this work, we try to constraint the nature and location of the tsunami source by means of numerical simulations and inversion of tide gauge signals. Firstly, we consider the possible activation of some offshore faults, like the Amanos-Larnaka Fault (ALF) system. Secondly, underwater landslide sources are considered, through both simple analytical initial conditions (a combination of two Gaussian functions of opposite polarity) as well as through dynamical numerical models. The results of the simulations are compared to the few available TGs by means of both direct and inverse approaches. We discuss the results that suggest a complex generating mechanism involving at least one offshore landslide.

Real-time tsunami detection algorithm in an early warning context.
Angeli C. ([1]), Armigliato A. ([1]), Zanetti M. ([1]), Zaniboni F. ([1]), Bayraktar H. B. ([2]), Romano F. ([2]), Lorito S ([2])
([1]) *Università di Bologna, Department of Physics and Astronomy "Augusto Righi", Italy*
([2]) *Istituto Nazionale di Geofisica e Vulcanologia, INGV, Rome, Italy*
In recent decades, the attention given to different topics in tsunami research has greatly increased, particularly following very impactful events such as the 2004 Sumatra-Andaman and the 2011 Tohoku tsunamis. In particular, Tsunami Early Warning Systems (TEWS) have been empowered, as in the Pacific Ocean, or developed from scratch, as in the other main basins worldwide. In order for a TEWS to work, a key ingredient is an automatic tsunami detection algorithm, needed to identify a tsunami as soon as it reaches an instrument such as open bottom pressure gauges and/or coastal tide-gauges. In this work, three detection algorithms taken from the published literature, and a new one, based on data-driven decomposition techniques, are presented and tested against real tsunami records. The techniques are compared according to their ability to filter out disturbances of both low and high frequency. Then, criteria to select optimal thresholds for each algorithm are shown, based on simple metrics. Our technique reaches optimal detection rates for lower thresholds than the other techniques. Furthermore, it can be integrated into data assimilation strategies for real-time tsunami forecasts.

Aula F **ore 11:00 – 13:00**

SIF CPO ROUND TABLE

Actions towards the Equality Opportunities in European Physical Societies

The Round Table is devoted to exchange and debate on the activities carried out within some European Physical Societies concerning gender issues and the topics of inclusion and diversity, which are so important for a balanced and efficient development of research.

Moderator: Anna Di Ciaccio

Speakers:

Tomas Brage, Chair of the section for EDI (Equity, Diversity and Inclusion) of the Swedish Physical Society

Pas García Martínez, Chair of the group "Women in Physics" of the Royal Spanish Physics Society

Petra Rudolf, Chair of the Equal Opportunities Committee of the European Physical Society

Sara Pirrone, Chair of the CPO (Equal Opportunities Committee) of the Italian Physical Society

Aula 1F **ore 09:00 – 13:30**

Sezione V
Biofisica e fisica medica
Presiede: Vetri V. (Università di Palermo)

Relazioni su invito

▲ **Molecular biophysics of the oncogenic protein SHP2: From characterization of the conformational landscape to drug design.**
Stella L.
Department of Chemical Science and Technologies, Tor Vergata University of Rome, Rome, Italy
The Src homology-2 domain-containing phosphatase 2 (SHP2) protein is a central node in intracellular signaling and a pivotal target for anticancer therapy. The structure of SHP2 comprises three domains: one of them is responsible for the catalytic activity of the protein, while the other two (termed SH2 domains) mediate the protein-protein interactions of the enzyme. The activity, interactions, and physiological effects of SHP2 are regulated by a complex allosteric mechanism, involving modifications in the conformation of the three domains and in their relative arrangement. By a synergistic approach, combining several simulative methods, spectroscopic experiments, biochemical and cellular studies, we characterized the structural, dynamic, and functional effects of pathogenic mutations affecting SHP2, elucidated the conformational transitions modulating its activity and function, and designed a novel class of inhibitors targeting this enzyme by hampering its protein-protein interactions. Overall, our results clarify several aspects of the molecular mechanisms regulating the behavior of this crucial oncogenic enzyme and provide a novel route for SHP2-targeted therapies.

▲ **A multi-technique approach for studying biochemical and mechanical cell response to external stress.**
Delfino I.
Dipartimento di Scienze Ecologiche e Biologiche, Università degli Studi della Tuscia, Viterbo, Italia
In recent years we have witnessed extraordinary advances in understanding and describing complex biological systems, such as cells, and the processes that occur in them with ever greater detail and delving into previously inaccessible aspects. These advances have also been made thanks to the availability of new or renewed experimental techniques and the related processing of the ever-increasing size and complexity of the relevant data. The possibility of conducting studies combining different experimental and data analysis approaches has opened up new opportunities to study the effects of external stress on cells, also considering aspects related to their biochemical and mechanical properties. In this contribution, the approach based on the joint use of vibrational microspectroscopy (Raman ed FT-IR) and AFM-based measurements for the study of the effects on cells —or parts of them— induced by external stress, such as ionizing radiation, thermal stress, external pollutants/molecules, will be introduced and discussed. An overview of some significant results of particular interest in the medical and environmental fields will also be given.

▲ A twist in the cell: How to display viscosity using fluorescent molecular rotors.

Battisti A.
NEST, Nanoscience Institute-CNR and Scuola Normale Superiore Pisa, Italy

The interior of a cell is a very crowded environment where biomolecules must find their way to exert their functions. Local microviscosity emerges as a critical factor in cellular function and health, affecting microenvironment regulation, enzyme kinetics, protein-protein interactions, and molecular transport in the cytoplasm. Different cell compartments exhibit varying viscosity levels (1–400 cP), and altered viscosity is associated with diseases like cancer, neurodegeneration, and metabolic disorders. Fluorescent molecular rotors (FMRs) are powerful tools for real-time monitoring of viscosity within living cells. FMRs consist of three main components: an electron donor unit, an electron acceptor unit, and an electron-rich linker. Upon photoexcitation, FMRs undergo a twisted intramolecular charge transfer (TICT) event. The TICT dynamics are highly solvent-dependent, making the rotor emission profile sensitive to viscosity. By combining this effect with the phasor approach, which displays lifetime distributions after fluorescence lifetime imaging (FLIM) acquisitions, valuable insights into metabolic processes and diagnostic information can be obtained.

▲ Technological developments and future perspectives in particle therapy: A topical review.

Kraan A.C. ([1]), Del Guerra A. ([1])([2])
([1]) *INFN, Sezione di Pisa*
([2]) *University of Pisa*

Particle therapy is an external beam radiotherapy where the dose is delivered using beams of light ions. Over the past decades, technological advances have transformed particle therapy from a research topic into a powerful and precise treatment modality for cancer patients. Continuous improvements in dose delivery, treatment planning and verification techniques have led to higher dose conformity and better sparing of healthy tissue. At the same time, particle therapy treatments are complex and expensive, and they can be offered only by highly specialized facilities. Cost reduction is thus another strong drive behind technological developments. The number of treatment facilities has grown strongly in the last years, and the amount of research and innovations has increased likewise. In this contribution we present an overview of technological advances in particle therapy hardware (accelerators, gantries, applications of superconductivity, treatment verification techniques), software (Monte Carlo simulations, treatment planning), and studies towards clinical applications. By including a broad selection of topics, we give a unique overview of various technologies in particle therapy.

▲ Cholesterol Dynamics and Membrane Fluidity: Insights into Plasma Membrane Mimetics and Extracellular Vesicle Interactions.

Casalis L.
Elettra-Sincrotrone Trieste S.C.p.A.

Plasma membranes adapt their molecular composition and continually redistribute lipids locally, forming dynamic nano-domains known as lipid rafts. These rafts are critical for regulating intercellular communication, cell proliferation, and overall cell survival. Dysregulation of lipid composition is often associated with diseases such as cancer and neurodegenerative disorders. Cholesterol is particularly crucial for membrane function, as it regulates fluidity and maintains the structural integrity of lipid rafts. In this study, we developed multi-component plasma membrane mimics featuring lipid raft structures and investigated their biophysical properties. We employed time-resolved atomic force microscopy, fluorescence microscopy and

spectroscopy, complemented with X-ray and neutron scattering data. Our findings indicate that membrane viscoelasticity is influenced by the specific lipid species, system temperature, and cholesterol content. This viscoelasticity plays a fundamental role in determining the adsorption pathway—whether fusion or budding-fission—of bioactive molecules, whether free or carried by extracellular vesicles (EVs). In particular, we observed that cancer-derived EVs exhibit the strongest interaction with less fluid membrane regions, and that are capable of disrupting ordered domains at high cholesterol concentrations. Our versatile platform can also be applied to study the impact of fusogenic proteins on vesicle uptake pathways and to investigate the role of virus-generated EVs in regulating viral pathogenesis.

▲ **Detailed simulation and a modular tool to easily collimate small e^- field and perform their precise dosimetric characterization for the treatment of NMSC lesions.**

Tassielli G.F. ([1]), Favetta M. ([2]), Miccoli A. ([3]), M. Piombino ([4])
([1]) *Department of Medicine and Surgery, LUM University, Casamassima, Bari, Italy*
([2]) *Department of Medical Physics, University Hospital Consortium Corporation Polyclinic of Bari, Bari, Italy*
([3]) *INFN, Sezione di Lecce, Lecce, Italy*
([4]) *Department of Radiotherapy, University Hospital Consortium Corporation Polyclinic of Bari, Bari, Italy*

The treatment of non-melanoma skin cancer with RT could be a valuable alternative to surgery in some cases and it is mandatory for recurrent tumors and when the surgery it is not applicable. For these cases RT with e^- beam should be used but, especially when the area to be treated is small ($\sim$ cm), the precise beam collimation and the dosimetry process can show stoppers. To overcome these, we present a new and easy construction method of e beam collimators to build shapeable small beam that can guarantee a very precise dose delivery. Moreover, the dosimetry of small e beam requires particular attention and the common TPS algorithms could be not very precise for this task, so we developed a detailed Geant4 simulation of an Elekta LINAC for the e beam configuration. The simulation can perform the evaluation of the dose delivery inside the body, too, and can complement TPS evaluations. The simulation was validated by the measurements of the dose profiles and PDDs in water of standard beam dimensions and for the collimated beams. The measurements show a great agreement with the simulations and confirm the high, spatial and dosimetric, accuracy level that can be reached in the beam delivery.

Comunicazioni

● **High-resolution analysis of collagen in oral tongue squamous cell carcinoma: First evidence that biomolecular alterations temporally anticipate microarchitectural modifications of the stroma.**

Giuliani A. ([1]), Togni L. ([1]), Furlani M. ([1]), Belloni A. ([1]), Riberti N. ([1]), Notarstefano V. ([1]), Santoni C. ([1]), Giorgini E. ([1]), Rubini C. ([1]), Santarelli A. ([1]), Mascitti M. ([1])
([1]) *Department of Clinical Specialistic and Dental Sciences, Marche Polytechnic University, Ancona, Italy*
([2]) *Department of Life and Environmental Science, Marche Polytechnic University, Ancona, Italy*
([3]) *Department of Neuroscience, Imaging and Clinical Sciences, University "G.d'Annunzio" of Chieti-Pescara, Chieti, Italy*
([4]) *Department of Biomedical Sciences and Public Health, Marche Polytechnic University,*

Ancona, Italy
([5]) *Dentistry Clinic, National Institute of Health and Science of Aging, IRCCS INRCA, Ancona, Italy*
In recent years there has been a growing interest from the scientific community in the role of the extracellular matrix (ECM) in the biomechanics of physiological/pathological tissues. Alterations in ECM volume and distribution could modify mechanical stress on cells, leading to the activation of specific cell's signalling that contributes to tumor growth. In the light of this evidence, in this contribution we propose the characterization of the microarchitecture and biomolecular organization of collagen bundles in human oral tongue squamous cell carcinoma (OTSCC) with the aim to elucidate, for the first time to the authors' knowledge, the temporal kinetics interlacing the stroma microarchitectural modifications and biomolecular alterations. Thirty-five OTSCC biopsy samples were analyzed by synchrotron-based phase-contrast microcomputed tomography to obtain information on advanced morphometrical parameters on the collagen bundle microarchitecture. Specific parameters were calculated and statistically correlated to relevant macromolecular indices obtained by Fourier transform infrared imaging (FTIRI) spectroscopy.

Infrared vibrational spectroscopy of SARS-CoV-2 Spike protein: Open the door on the secondary structure of protein domains.

Mosetti R. ([1]), D'Arco A. ([1]), Mancini T. ([1]), Macis S. ([1]), Minicozzi V. ([2]), Della Ventura G. ([3])([4]), Marcelli A. ([4]), Luchetti N. ([5])([6]), Lupi S. ([1])([7])
([1]) *Department of Physics, University of Rome La Sapienza, Italy*
([2]) *Department of Physics, University of Rome Tor Vergata, Italy*
([3]) *Department of Science, University Rome Tre, Italy*
([4]) *Laboratori Nazionali Frascati, National Institute for Nuclear Physics INFN-LNF, Italy*
([5]) *Engineering Department, University Campus Bio-Medico of Rome, Italy*
([6]) *Centre for Life Nano- and Neuro-Science, Italian Institute of Technology, Italy*
([7]) *National Institute for Nuclear Physics Section Rome1, Italy*
Spike (S) glycoprotein is the largest membrane coronavirus protein and the first involved in the anchoring of the host receptor ACE2 through the receptor binding domain (RBD). The SARS-CoV-2 S protein is composed by two subunits: S1 (containing RBD) responsible for recognition/anchoring to ACE; S2, responsible for the membrane fusion. The protein secondary structure plays a key role in various aspects: from functionality to pathogenesis, finally to spectral fingerprint for the design of optical biosensors. Here, we characterize the whole monomeric S protein, its domains and three variants at a serological *p*H by measuring their amide I infrared absorption bands through ATR-IR spectroscopy. Experimental data in combination with MultiFOLD predictions, Define Secondary Structure of Proteins (DSSP) web server and Gravy value calculations, provide a comprehensive understanding of proteins' domains in terms of their secondary structure content, conformational order and interaction with the solvent.

Structural properties and calcium binding of differently carboxylated osteocalcin proteoforms.

Natalello A. ([1]), Ami D. ([1]), Santambrogio C. ([1]), Vertemara J. ([1]), Bovio F. ([1]), Santisteban-Veiga A. ([2])([3]), Sabín J. ([2])([3]), Zampella G. ([1]), Grandori R. ([1])([4]), Cipolla L. ([1])
([1]) *Department of Biotechnology and Biosciences, University of Milano-Bicocca, Milan, Italy*
([2]) *AFFINImeter Scientific & Development team, Software 4 Science Developments, Santiago de Compostela, Spain*

([3]) *Applied Physics Department, University of Santiago de Compostela, Santiago de Compostela, Spain*
([4]) *Institute for Advanced Simulations, Forschungszentrum Juelich, Juelich, Germany*
Osteocalcin (OC) is the main non-collagenous protein found in the bone extracellular matrix, which also acts as a bone-derived hormone. In human OC glutamic acid residues at position 17, 21, and 24 are partially or fully converted to γ-carboxyglutamic acid. In this contribution, the structural properties and the calcium binding of all the differently carboxylated OC variants will be presented. The secondary structures of unbound OC variants and the calcium induced folding were studied by circular dichroism (CD) and Fourier transform infrared (FTIR) spectroscopies. Stoichiometry and species distributions were investigated by native mass spectrometry (nMS). Finally, the thermodynamic signatures of calcium binding to the OC variants were provided by isothermal titration calorimetry (ITC). Interestingly, the global analysis of the ITC data with alternative binding models disclosed cooperative effects. In conclusion, the coupling of the above experimental data with molecular-dynamics simulations provided a structural and mechanistic insight into the peculiar features of each of the OC carboxylated proteoforms. This research was funded by Fondazione Cariplo (grant No. 2018-0458).

Guanosine hydrogels under the spotlight: An extensive analysis through mid-Infrared spectroscopy.

Notarstefano V., Pepe A., Ripanti F., Mariani P.
Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Italia
Guanosines (Gua) can self-assemble in water to form supramolecular architectures, from G-quartets, to G-quadruplexes (G4s), to hydrogels with tunable softness, self-healing, and quasi-liquid properties. Given their promising applications, a deep understanding of the chemical-physical and structural properties is needed: Infrared spectroscopy (IRS) was applied to unravel the vibrational characteristics of such structures. The spectrum of guanosine monophosphate (GMP)/K reflected its chemical composition and the formation of quartets, octamers, and quadruplexes. The comparison with the GMP/Na one confirmed that both cations induce G4 formation, with K^+ promoting a higher stabilization. IRS performed on hydrogels of Gua:GMP/K or Gua:GMP/Na revealed the same G4 structure in both mixtures, but the Gua:GMP ratio affected key features, including base stacking, sugar puckering, and guanine vibrations, reflecting the bundle formation occurring in these binary systems. We demonstrated the significant capability of IRS in offering crucial insights in the molecular mechanisms underlying G4 formation as a function of environment (K^+/Na^+) or of hydrogel composition (Gua:GMP ratio).

Modulation of albumin aggregation by quercitin and lipid bilayers.

Guzzi R., Merino Naranjo B.M., Bartucci R.
Department of Physics, Molecular Biophysics Laboratory, University of Calabria, Rende
Protein aggregation and fibril formation are among the most recurrent topics in biophysics research, as well as in biomedical and biomaterial areas. In this study the thermal aggregation of albumin was investigated in the presence of both quercitin, a bioactive molecule with antioxidant property, and bilayers of the neutral lipid DMPC. The study was performed by combining UV-Vis scattering, EPR and FTIR spectroscopies. The results indicate that quercitin binds to albumin and slows down the aggregation process while a mutual influence between albumin and DMPC is observed. In fact, native albumin alters the thermotropic phase transitions and the dynamics of DMPC that in turn affects the aggregation process of the protein acting as a crowding agent. Moreover, the aggregated protein induces a milder

perturbation to the membranes. Furthermore, albumin perturbs the hydration properties at the membrane surface in an extent depending on the conformational state of the protein. The observed effects on the aggregation of albumin are related to the intermolecular interactions favouring the stability of the protein structure.

Aula D **ore 09:00 – 13:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Lucarelli F. (Università di Firenze)
Falciano S. (GSSI, LAquila)

Relazioni su invito

▲ **Unlocking the future: Innovations in border security with neutron inspection.**
Moretto S.
Dipartimento di Fisica e Astronomia, Università degli Studi di Padova
Neutron inspection represents a cutting-edge approach to border control, offering advanced capabilities for detecting illicit materials and enhancing security measures. By harnessing the unique properties of neutron radiation, such as its ability to penetrate dense materials and provide detailed information about elemental composition, neutron inspection systems enable border control authorities to conduct thorough and precise inspections of cargo, vehicles, and other goods entering or exiting a country. These systems can identify hidden contraband, including explosives, drugs, and weapons, with a high degree of accuracy, thereby helping to prevent illegal trafficking and ensure the safety and security of borders. Additionally, neutron inspection technology is continually evolving, with ongoing research and development efforts focused on improving system performance, increasing detection sensitivity, and enhancing operational efficiency. An overview of the state of art and future perspective will be given.

▲ **Rilievi di radioattività ambientale con droni e velivoli nel contesto italiano.**
Mantovani F., Alberi M., Chiarelli E., Franceschi M., Galli G., Maino A., Raptis K.G.C., Strati V.
Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Italia e INFN, Sezione di Ferrara, Italia
Il contributo presenterà l'impiego di tecnologie nucleari airborne per la misurazione della radioattività ambientale nel territorio italiano nell'ambito del progetto ITALRAD. Utilizzando spettrometri gamma installati su velivoli e droni, sono state sorvolate estese aree del territorio nazionale (circa 10000 km^2). I rilievi aerei sono stati accompagnati dal prelievo e dalla misurazione di circa 4500 campioni di roccia e di suolo, scelti sulla base di carte geologiche. Le mappe tematiche a diverse scale di radionuclidi naturali (K, eU ed eTh), radionuclidi artificiali (^{137}Cs) e della dose efficace nell'ambiente rappresentano una risorsa conoscitiva che spazia dall'indagine mineraria e di estrazione di materiali lapidei, alla tutela di siti contaminati, allo studio dei suoli e delle formazioni rocciose. Il progetto ha avuto impatti rilevanti a livello tecnologico, scientifico e sociale, fornendo riferimenti sia per la gestione di emergenze legate a fallout di radionuclidi artificiali sia per la pianificazione di future infrastrutture nucleari.

▲ **Muography unveiled: Cosmic-ray muons as a versatile tool for applied physics and innovation.**
Frosin C. (1)(2), Bonechi L. (1)(2), Borselli D. (1)(2), Cialdai C. (2), Ciaranfi R. (2), Ciulli V. (1)(2), D'Alessandro R. (1)(2), Gonzi S. (1)(2), Paccagnella A. (1)(2),

Viliani L. ([2])
([1]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Firenze, Italia*
([2]) *INFN, Sezione di Firenze, Italia*
Muography, an emerging technique in applied physics, harnesses the power of cosmic-ray muons to peer through dense materials and unveil hidden structures with precision and non-invasiveness. We explore the advancements and diverse applications of muon radiography across various scientific disciplines, highlighting its significance in advancing our understanding of the natural world and driving innovation in applied physics. Through imaging algorithms and data analysis techniques, muon radiography enables the creation of detailed 2D and 3D images of objects, offering insights into their internal composition and structure. By imaging features such as magma chambers, fault lines, and archaeological sites, muography provides valuable information for geological exploration, hazard assessment, and cultural heritage preservation. Case studies of muographic investigations into mines, civil engineering, and archaeological ruins will be illustrated, highlighting the technique's efficacy and its benefits to various applications.

Comunicazioni

New results of an innovative biomass gasifier.
Sharma P.R., Grassmann H., Cobal M.
Università degli Studi di Udine
Traditional gasifiers are based on the engineering paradigm that gasification is linked to the lack of oxygen in the primary air flow. From a physics point of view, this paradigm cannot be understood: we therefore changed the approach, creating a gasifier that works in the presence of an abundant flow of air, which is wireable and very compact. We will describe improvements and new results of this device. With this gasifier it is possible to gasify even low-quality biofuels such as municipal green waste and even straw. The amount of unused biomass is enormous: a country like Italy typically produces 10 million tons of straw per year, and a medium-sized city produces around 20000 tons of greenery which must then be disposed of at considerable cost. The goal is to produce city gas with this device from rapidly growing "waste" biomass, to replace fossil gas in all applications. The gasifier can process biomass even partially, producing gas and bio-char. Storing this bio-char is a simple and economical way to sequester carbon.

Geocultivar discrimination and spectroscopic benchmarks of Italian EVOO through spectroscopy and machine learning.
Scatigno C., Festa G.
Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", CREF, Rome, Italy
A spectroscopic fingerprint methodology based on Fourier transform infrared and X-ray fluorescence spectroscopies coupled with Machine Learning (ML) is developed to find distinct benchmarks in the Italian Extra Virgin Olive Oil, EVOO. Cultivars discrimination, geo-traceability, adulteration, damages due to packaging or storage are investigated. The present work is carried out without reagents or esterification sample treatments and considering the entire frequency range without any spectral window selection. The recorded spectra are analysed with Soft Independent Modelling of Class Analogy, Support Vector Machine Regression and Principal Component Regression aiming to verify the geographical traceability, the cultivar, and the repeatability of the agronomical practices, till the adulterated EVOO from several seed oils such as soy, corn, sunflower and linseed. The procedure finds a distinct way to benchmark the olive variety and the agronomic practices amongst the interregional areas. This work immediately impacts the time-consuming reduction of

pre-processing data time. The developed approach opens new frontiers in the pre-processing data analyses.

ChAMBRe e Bioaerosol: risposta della vitalità batterica a diverse condizioni ambientali.

Mazzei F. ([1])([2]), Abd El E. ([1])([2]), Brunoldi M. ([1])([2]), Gatta E. ([1]), Irfan M. ([1]), Isolabella T. ([1]), Massabò D. ([1])([2]), Parodi F. ([2]), Prati P. ([1])([2]), Vernocchi V. ([2])
([1]) *Dipartimento di Fisica, Università degli Studi di Genova, Italia*
([2]) *INFN, Sezione di Genova, Italia*

Negli ultimi anni la caratterizzazione del bioaerosol è oggetto di un crescente interesse legato, in particolare, agli effetti che può avere sul clima e sulla salute umana. Una sua componente fondamentale è rappresentata dalle specie batteriche: i batteri, infatti, possono fungere da nuclei di condensazione delle nubi, influenzando i processi di precipitazione e incidendo sulla durata delle nubi, sulle proprietà ottiche e sui modelli climatici. Inoltre, costituiscono un rischio per la salute umana grazie alla loro attività biologica e alla capacità di penetrare l'apparato respiratorio. Presso ChAMBRe (Chamber for Aerosol Modelling and Bioaerosol Research) gestita congiuntamente dall'INFN e dal Dipartimento di Fisica (UniGe), studiamo come la vitalità batterica è influenzata dalla concentrazione di alcuni gas inquinanti presenti in atmosfera (NO e NO_2). Presenteremo i risultati di più di 50 esperimenti ottenuti su 4 ceppi batterici, *E. coli*, *B. subtilis*, *P. fluorescens*, *B. licheniformis*, confrontando la vitalità ottenuta in condizioni di "aria pulita" e in condizioni di esposizione a radiazione solare simulata e diverse concentrazioni di NO e NO_2.

An eXplainable Artificial Intelligence approach to the analysis of wildfire occurrences using geospatial data.

Pantaleo E. ([1])([2]), Cilli R. ([1]), Arias A.D. ([1]), Monaco A. ([1])([2]), Amoroso N. ([2])([3]), Bellotti R. ([1])([2])
([1]) *Dipartimento Interateneo di Fisica "M. Merlin", Università degli Studi di Bari Aldo Moro, Bari, Italy*
([2]) *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy*
([3]) *Dipartimento di Farmacia-Scienze del Farmaco, Università degli Studi di Bari Aldo Moro, Bari, Italy*

Wildfires have significant environmental, social and economic impacts on communities. Their occurrence, extension and severity have dramatically changed over time as a consequence of the global climate crisis. Identifying the factors that drive the dynamics of these complex phenomena is of the utmost importance. We used a public database of wildfire occurrences from 1984 to 2020 and developed a random forest classification model for their prediction using topographical, ecological, demographical and meteorological variables. The model was evaluated by repeated 5-fold cross-validation and achieved satisfying performances. With the adoption of an eXplainable Artificial Intelligence framework, we were able to assess the impact of each input in the model output and also to reveal relevant regional and temporal patterns. The designed methodology, with the joint use of machine learning and eXplainable Artificial Intelligence approaches, can effectively extract relevant information from the data and can be used to develop prevention, management and monitoring strategies for climate change induced wildfires.

Determination of the concentration of natural and anthropogenic radionuclides in milk samples in northern Italy.

Colucci M. ([1])([2]), Bassi F. ([1]), Conti E. ([3]), Manenti S. ([1])([2]), Broggi F. ([2]), Groppi F. ([1])([2])

([1]) *Department of Physics, La Statale-University of Milan, Italy*
([2]) *LASA, Laboratori Acceleratori e Superconduttività Applicata, La Statale-University of Milan e INFN Section of Milan, Italy*
([3]) *Department of Agricultural and Environmental Sciences, La Statale-University of Milan, Italy*
Following nuclear accidents, radionuclides released into the atmosphere can contaminate the environment, including soil and grass. Cows, goats, and other animals can ingest these contaminants, leading to their presence in milk. Milk and its derivatives are widely consumed in many diets, especially by children. Accurate determination of radioactive species in milk is crucial to assess the associated radiological risk. With this aim, two measurement campaigns were conducted in 2011 and 2013 following the Fukushima accident, focusing on the Rosa Mountain region and surrounding areas. In 2023–2024 a third campaign of measurements has been performed to assess the long-term impact of this and of previous accidents (*e.g.*, Chernobyl in 1986) in the above-mentioned area. Our findings revealed low to medium concentrations of long-lived anthropogenic radionuclides, such as Cs-137, in milk and cow diets. Radiation dose assessment under conservative conditions yielded values on the order of a few μSv, indicating no significant risk associated with consuming milk from this region. In our results the antagonistic effect between potassium and caesium is confirmed.

Using shearography for NDI on "green" laminates.
Pagliarulo V. ([1]), Paturzo M. ([1]), Saltarelli C. ([1]), Russo P. ([2])
([1]) *CNR, ISASI, Italy*
([2]) *CNR, IPCB, Italy*
For many years the use of advanced composite materials in aeronautical, automotive and sporting applications has been consolidated. The characteristics of composite materials in terms of weight reduction, resistance to fatigue and corrosion make them competitive in many cases compared to conventional ones (*i.e.*, metal alloys). On the other hand, the manufacturing process of the most used composites reinforced with carbon or glass fibers requires complex phases that are not always environmentally friendly. Essentially, these composite materials are not in themselves "green". For these reasons, in recent decades, the use of natural reinforcing fibers has gained increasing attention, allowing the development of new materials that share the same advantages as conventional composite systems while respecting the environment. Due to their structural complexity, these materials are not always compatible with the use of standard non-destructive evaluation methods, such as ultrasonic testing. The effective use of shearography as a non-destructive investigation method in full field and in non-contact mode is validated on "green" composite materials.

A new detector to muon tomography for glaciers melting monitoring.
Rabaglia S., Cervelli A., Sioli M.
Università di Bologna e INFN, Sezione di Bologna
We present the design of a muon tomographer intended for monitoring of glacier thickness. The process of glacier melting is not completely understood and is considered a hot topic in view of the global warming. Muon tomography is a widely used technique, employed to perform imaging of the inner structure of large objects, as volcanoes and pyramids. The goal of our project is the development of a detector able to measure the glacier thickness with a real time data taking and processing. To perform studies of the seasonal behavior and the glacier melting trend through the years, the detector should have good spatial resolution for the muon tracks and have high efficiency. The detector is operable in open-sky and cheap enough to allow for the production and use of arrays of detector. The foreseen design of the detector is based on scintillation fibers organized in layers, read by SiPMs driven by FERS

boards (A5202), developed by CAEN s.p.a. To put on solid ground the developed design, a prototype of the detector, created in collaboration with the University of Glasgow, has been constructed. Data gathered from test runs have been utilized to validate the simulation codes employed.

Preparazione per la produzione di massa e messa in funzione del modulo mPMT per l'esperimento Hyper-Kamiokande.

Di Nola A.
Diaprtimento di Fisica, Università Federico II di Napoli, Italia e INFN, Sezione di Napoli, Italia

Hyper-Kamiokande (HK) è parte della prossima generazione di rivelatori Cherenkov ad acqua a lunga baseline. Mira a ottenere risultati entusiasmanti in molti campi come lo studio della violazione della simmetria *CP*, la ricerca del decadimento del protone e lo studio dei neutrini da acceleratore, atmosferici, solari e astronomici. HK sarà caratterizzato da una configurazione ibrida che combina i PMT da $20''$ con moduli multi-PMT (mPMT), una tecnologia innovativa progettata per la prima volta per KM3NeT. Il modulo mPMT, basato su un contenitore a pressione è strumentato con 19 fotosensori da 7.7 cm di diametro, ognuno con un diverso orientamento, elettronica di readout e alimentazione. Esso offre diversi vantaggi come una maggiore granularità, un ridotto tasso di darkrate, una minore sensibilità al campo magnetico terrestre, una migliore risoluzione temporale e informazioni sulla direzionalità con un campo visivo quasi isotropo. Lo sviluppo del prototipo è quasi ultimato e sta cominciando la preparazione per la produzione di massa. In questa comunicazione verranno presentati i risultati dei test effettuati sui primi prototipi e il progetto di messa in funzione dei mPMT.

Test dei moduli per il rivelatore ETL a CMS.

Durando M. per la CMS Collaboration
INFN, Sezione di Torino e Università degli Studi di Torino

La mia presentazione riguarderà lo sviluppo e l'utilizzo del sistema di test per i moduli dell'Endcap Timing Layer (ETL) per il futuro upgrade dell'esperimento CMS per la presa dati all'High-Luminosity LHC (HL-LHC). ETL sarà composto da rivelatori al silicio Ultra-Fast Silicon Detectors (UFSD), sensori a stato solido in tecnologia Low-Gain Avalanche Diode (LGAD) che sfruttano uno strato di guadagno aggiuntivo impiantato vicino alla giunzione p-n, accoppiati all'Endcap Timing Readout Chip (ETROC). Il sistema sensore+ETROC sarà in grado di effettuare misure di tempo con risoluzione nell'ordine delle decine di picosecondi per ridurre l'effetto di pile-up dovuto all'aumento di luminosità previsto a HL-LHC.

Development of a silicon bolometer for rare event detection with LED self-calibration.

Shaikina A., Benato G.
Gran Sasso Science Institute, L'Aquila

This research introduces a novel silicon bolometer, designed to dramatically enhance sensitivity for detecting ultra-low radioactive contamination of material surfaces. Targeting a sensitivity of $1\,\mathrm{nBq/cm^2}$, the project integrates meticulous surface contamination control with advanced bolometric techniques. A central advancement is the implementation of a self-calibrating system using LED pulses, which simplifies detector operations and enhances stability, and eliminates the need for radioactive alpha sources or heater-based stabilization techniques. The calibration process involves developing an energy resolution curve from LED events, providing foundational data. LED pulses of varying amplitudes are used to linearize and calibrate the energy scale, either with a single energy line from a ^{55}Fe X-ray

source or by using the Poisson statistics of the light. The accuracy of this model is verified through simulations that assess background levels, enabling more reliable measurements. The successful development of this novel detector will enable future projects for rare events to perform high-precision screening measurements of all the components prior to the experiment construction.

Use of hydrogenated amorphous silicon pixel detectors to precisely measure ionizing radiation fluxes.

Kanxheri K. per la HASPIDE Collaboration
Dipartimento di Fisica, Università degli Studi di Perugia, Italia e Istituto Nazionale di Fisica Nucleare, Sezione di Perugia, Italia

The INFN HASPIDE research program is dedicated to developing detectors based on hydrogenated amorphous silicon (a-Si:H) designed to characterize ionizing beams, measure space radiation, and detect neutrons. Integrating hydrogen into amorphous silicon is pivotal for reducing dangling bonds, thus enhancing the quality of detector devices. These devices consist of thin layers of a-Si:H, a few micrometers thick, deposited on various substrates, including flexible materials. This contribution will explore the fabrication processes of a-Si:H devices, the characterization methods employed, and the preliminary results in measuring proton beams and synchrotron radiation. The findings demonstrate high sensitivity levels and linearity in response to beam flux, comparable to those of diamond detectors, with very low variability observed across production batches. Furthermore, the discussion will cover the diverse possible applications of these detectors, including their use in instrumented flanges for vacuum/air separation in charged particle accelerators and in transmission detectors for clinical beam dosimetry.

A novel SDD-based detector for electron spectroscopy.

Bradanini T. ([1]), Nava A. ([1])([2]), Bernardini L. ([3])([4]), Biassoni M. ([2]), Fiorini C. ([3])([4]), Brofferio C. ([1])([2]), Carminati M. ([3])([4]), De Gregorio G. ([5])([6]), Gagliardi G. ([1])([2]), Lechner P. ([10]), Mancino R. ([7])([8])([9])
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Silicon Drist Detectors (SDDs) are widely used in low-energy X-ray spectroscopy. Their application in electron spectroscopy is however rather recent, due to the complexity of modeling low-energy interactions in silicon, crucial for an accurate reconstruction of the measured spectra. We have developed a spectrometer consisting of a main SDD combined with veto detectors to reject events with only partial energy deposition in the SDD. This technique allows us to accurately measure β spectra, which can be used to test nuclear models. We use a newly implemented 1 mm thick SDD (FWHM below 200 eV at 5.9 keV when cooled at

-23^{deg}) with a custom readout electronics, in order to reach higher energies compared to traditional SDD technologies. Given the complexity of the physical case, GEANT4 simulations are used extensively to model the geometry and the spectrometer response. After a summary of the results obtained with this technique on a ^{14}C spectrum, we will present the capability of the setup to measure spectra over a wide energy range, in particular the first SDD-based measurement of the forbidden ^{99}Tc spectrum ($Q = 297\,\mathrm{keV}$).

Characterization of new generation silicon carbide for neutron diagnosic in harsh environments.

Amaducci S.
INFN, Laboratori Nazionali del Sud, Catania

The development of novel next-generation plasma diagnostics based on neutron flux monitoring is essential for nuclear fusion technologies. Because of the intense radiation present in fusion reactors, it is necessary to use neutron detectors that are highly radiation resistant and have a long operational lifespan. Silicon carbide (SiC) detectors are potential candidates that might be able to function in reactors like ITER. A new generation of SiC detectors with strong radiation resistance, quick reaction times, stability, and good energy resolution has been created at INFN-LNS in recent years. These kinds of devices hold great promise not just for plasma diagnostics in fusion reactors but also for high intensity beam nuclear physics and laser beam facilities. We will provide a more thorough description of these devices, concentrating on their ability to withstand neutron irradiation at energies ranging from thermal to tens of MeV. Specifically, we report on the irradiation campaign at the n_TOF facility, wherein an integrated neutron fluence of 10^{14} neutrons per cm^2 with a peak in the MeV was applied to SiC detectors.

The concentration effect of pyro-electrohydrodynamic jet: An innovative route towards highly sensitive detection of neurodegenerative biomarkers.

Grilli S. ([1])([2]), Di Natale C. ([1])([2]), Coppola S. ([1])([2]), Vespini V. ([2]), Tkachenko V. ([2]), Russo S. ([1]), Carbone S. ([1])([2]), Luciani G. ([1]), Vitiello G. ([1])([3]), Ferranti F. ([4]), Mari S. ([4]), Ferraro P. ([2]), Maffettone P.L. ([1])([2])
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The detection of diluted biomarkers is of great interest in biomedicine, such as for early diagnosis in neurodegenerative diseases. Here we show a new technique, that we call pyro-electrohydrodynamic jet (p-jet), for concentrating biomolecules in tiny droplets. The p-jet uses the pyroelectric effect in lithium niobate crystals and the local charge density generates a high electric field, up to a few tens of kV/mm, that we use to overcome the surface tension of the liquid sample. Tiny droplets with volumes down to tens of pL are ejected from the mother drop and are accumulated precisely in microspots on a reaction slide. We demonstrate here the possibility to use the p-jet spots for highly sensitive immunofluorescence protocols, with a limit of detection of 130 fM for Tau molecules in urine samples. The results show how this technique could open the route to the development of a highly sensitive device able to detect low abundant neurodegenerative biomarkers in small volumes of sample from peripheral body fluids for early diagnosis. Moreover, thanks to its features it could be useful also for monitoring purposes such as the case of long-term human space exploration missions.

Aula B **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica
Presiede: Robotti N. (Università di Genova)

Relazioni su invito

▲ **La scoperta della parte di Ottica nell'Enciclopedia del Cinema dell'Istituto Internazionale per la Cinematografia Educativa (1933-1936).**
Bagni E.
Dipartimento di Economia e Management, Università di Pisa
Alcuni fisici italiani tra il 1933 e il 1936 collaborarono alla stesura della prima Enciclopedia del Cinema a cura dell'Istituto Internazionale per la Cinematografia Educativa (ICE). A seguito dell'uscita dell'Italia dalla Società delle Nazioni (1937), era cessata ogni collaborazione con le organizzazioni a questa connesse, con numerose conseguenze quali, tra le altre, lo scioglimento dell'Istituto Internazionale per la Cinematografia Educativa e la mancata pubblicazione dell'Enciclopedia del Cinema. La scoperta di 150 lettere intercorse tra Vasco Ronchi, Direttore del Regio Istituto Nazionale di Ottica (RINDO), e Luciano De Feo, Direttore dell'Istituto Internazionale per la Cinematografia Educativa, unitamente al ritrovamento delle bozze della parte di Ottica della suddetta Enciclopedia, ha permesso di ricostruire per la prima volta un pezzo di storia andato perduto sia della fisica che del cinema.

▲ **Through the lens of history: A cultural framework for Quantum Mechanics a century on.**
Lovisetti L., Giliberti M.
Dipartimento di Fisica "Aldo Pontremoli", Università di Milano
A century after the birth of Quantum Mechanics (QM), in a world where the second quantum revolution acts as a driving force for the study of physics, promoting research in technological developments, there is a tendency to focus predominantly on the applied and technical aspects, rather than on the epistemological ones. This results in a widespread lack of cultural and historical aspects among students and even young physics graduates. This lack of a comprehensive cultural and historical perspective not only hinders a deeper and meaningful understanding of the intricate concepts within QM, but also provides an inconsistent epistemological framework for physics in general and risks conveying an incorrect image of the Nature of Science. This presentation will focus on the importance of contextualizing QM within its cultural and historical milieu to cultivate well-rounded physicists who are not only proficient in their field of physics research but also aware of its broader context and implications. In this contribution some examples of works made by the research group of the University of Milan aimed at a cultural and historical understanding of QM will be discussed.

▲ **La tesi di Ettore Majorana.**
Guerra F.
Dipartimento di Fisica, Sapienza Università di Roma e Centro di studi e Ricerche Enrico Fermi, Roma
Ettore Majorana conseguì la Laurea in Fisica il 6 Luglio 1929, con una Tesi dal titolo Sulla meccanica dei nuclei radioattivi. Si tratta del primo lavoro di ricerca, svolto in Italia,

sulla fisica nucleare, in cui vengono applicati i metodi della nuova meccanica quantistica, in particolare l'effetto tunnel, al decadimento nucleare α. È noto che la Tesi racchiude alcune caratteristiche sconcertanti, di cui abbiamo accennato in precedenti occasioni. Qui noi daremo un'analisi completa di tutte le anomalie presenti nella Tesi, di cui la più importante è l'argomento stesso. Fino a poche settimane prima, Ettore Majorana era intensamente impegnato nello sviluppo e applicazioni del modello statistico dell'atomo di Enrico Fermi, tanto da riferirne nell'assemblea generale della Società Italiana di Fisica, con una comunicazione pubblica, alla fine del 1928. Ci si aspetterebbe, nella forma più naturale, che l'argomento della Tesi riguardasse il modello statistico dell'atomo, nella forma data da Fermi e migliorata da Majorana. Invece si ha un cambio completo di argomento.

▲ **Tra ricerca e divulgazione, un progetto di collaborazione interdisciplinare: intorno a "Il grande Fermi - Lo scienziato come figura pubblica".**
Piazzoni I.
Università degli Studi di Milano
L'intervento intende presentare il progetto di collaborazione interdisciplinare che ha portato alla realizzazione del libro "Il grande Fermi - Lo scienziato come figura pubblica" (curato da Luisa Cifarelli e Giuseppe Pelosi, edito dalla Società Italiana di Fisica nel 2024). Oltre a indagarne aspetti poco o per nulla noti della biografia, i saggi che lo compongono si concentrano sulla dimensione pubblica di uno scienziato la cui vita e la cui attività hanno incrociato gli sviluppi politici e sociali tra anni venti e cinquanta del Novecento, consentendo di riflettere su questioni cruciali: i rapporti tra ricerca scientifica e potere politico, opinione pubblica, vita quotidiana, speranze e paure delle comunità umane; le strategie di rappresentazione e autorappresentazione degli scienziati; il ruolo, mai neutrale, dei media; l'importanza dell'intervento di eventi traumatici, come le guerre; i modelli che attengono alla proiezione mitica e simbolica, sempre in metamorfosi, da cui la scienza e gli uomini di scienza sono investiti; il ruolo della memoria e dei momenti didascalici, celebrativi e divulgativi.

Comunicazioni

● **Alle origini della teoria delle onde di de Broglie.**
Rossi P.
Dipartimento di Fisica, Università di Pisa
La teoria delle onde di materia è usualmente associata alla pubblicazione della tesi di dottorato di Louis de Broglie, discussa nel novembre 1924. In realtà tutti gli elementi essenziali della teoria erano già presenti in tre brevi comunicazioni dello stesso de Broglie, presentate tra il settembre e l'ottobre 1923 e pubblicate nei Comptes Rendus de l'Académie des Sciences, che all'epoca passarono del tutto inosservate. Si discute il contenuto delle tre comunicazioni e si commenta brevemente sulla successiva accoglienza della tesi, che ne costituisce soltanto una versione estesa.

● **Recovering the foundations: Survey of the quantum mechanics original framework as conceived in the Gottingen school.**
Picchi P. ([1])([2]), Shore S.N. ([3])([4])
([1]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze*
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([3]) *Dipartimento di Fisica "E. Fermi", Università di Pisa*
([4]) *INFN, Sezione di Pisa*
The usual approach to teach quantum mechanics barely treats the approach of the Gottingen school, where it was first conceived. Even how the quantization and evolution of

the operators is presented, is based on Weyl quantization formula, which has been recently demonstrated to be not complete. We present an alternative approach to quantum mechanics focused on methods from 1925 and 1926 that gave birth to modern quantum mechanics. We focus, in particular, on the conceptual development of fundamental aspects in quantum mechanics: non-commutativity, phase, the Born operator quantization formula and related physical meaning (which unlike Weyl's, is complete) and that, in quantum mechanics, energy conservation and the Bohr frequency laws can be directly derived from mechanical laws. Finally, we will focus on an aspect that is insufficiently emphasized in courses and books: that quantum mechanics is a kinematically different way of describing nature, but still based on the same dynamical substrate of classical mechanics.

Anamorfosi di Bohr-Rosenfeld.

Furlan S.
Max-Planck-Institut für Wissenschaftsgeschichte, Berlin e Universiteit Utrecht

Nel 1933 Niels Bohr e Léon Rosenfeld pubblicarono un celebre articolo, "Zur Frage der Messbarkeit der elektromagnetischen Feldgrössern", che a detta di molti divenne una pietra miliare. Nondimeno, la storiografia non pare averne colto interamente l'impatto. Lo scopo della presente comunicazione è duplice. Da una parte si enfatizzerà come, in quegli stessi anni, le questioni di misurabilità e di fondamenti dell'elettrodinamica quantistica è la Heisenberg-Pauli, oggetto di disaccordo tra Landau-Peierls e Bohr-Rosenfeld, ebbero - complice lo stesso Landau - un interessante "spin-off" sovietico grazie a Matvei Bronstein, che si pose domande analoghe nel caso in cui si considerasse anche la gravità. Dall'altra parte si mostrerà come le premonizioni intorno alla gravità quantistica di Bronstein, stroncate dalla tragica fine della sua vita, trovarono, com'è noto, nuova linfa nel corso degli anni '50, ma, ecco il punto, di nuovo tramite un confronto serrato, tra analogie e differenze, con l'articolo di Bohr-Rosenfeld. È in particolare il caso di John Wheeler, alla luce dei cui quaderni inediti s'illustrerà questo secondo aspetto e lo si collegherà alla sua idea di "quantum foam".

Dirac's Quantum Time.

Giannetto E.
Università di Bergamo

In 1926, Dirac had attempted to give a relativistic generalization of his mechanics of q-numbers, defining a new "quantum time" starting from the relation (P. A. M. Dirac, Relativistic quantum mechanics, Proc. Roy. Soc. of London A111 (1926) pp. 405-423): $tW - Wt = -ih$. In the 1927 article, Heisenberg will start from this relationship by Pauli and Dirac which implies this new concept of quantum (relativistic) time. All the historical formulations of quantum mechanics were time irreversible. Time was a matrix in Heisenberg matrix mechanics and all the physical variables obeyed a matrix evolution, time irreversible equation. Schrödinger equation was written as representing the propagation of an irreversible physical wave. One has been able to state that quantum mechanics is time reversible only by defining the time reversal operator in a new way, involving also complex conjugation, just to obtain reversibility. This new formal insight was obtained for the first time only in 1932, in the paper Über die Operation Zeitumkehr der in der Quantenmechanik by Eugene Wigner.

An educational discussion about the Bell's theorem.

Bonacci E.
Physics Section of the Natural Sciences Unit, ATINER, Athens, Greece

In the Italian educational system, secondary students encounter Special Relativity (SR) and Quantum Mechanics (QM) in the 5th year's physics course of Scientific High School. The foundations of SR and QM are epitomized by a powerful cross-sectional topic, the Bell's

theorem (BT), which deserves an accurate classroom explanation. In fact, the BT deals with Minkowski's spacetime and locality of interactions (SR), Schrödinger's equation and entanglement (QM), photons and polarization (Optics), as well as Probability and Statistics (Mathematics). In addition, testing Bell-type inequalities should be presented to high schoolers as a bright application of the scientific method awarded with the Nobel Prize. Motivated teachers could eventually mention the concept of retrocausality and the related hypotheses still escaping the BT.

A cultural multi-representational approach to quantum mechanics.

Giliberti M., Lovisetti L.
Dipartimento di Fisica "Aldo Pontremoli", Università di Milano

In approaching quantum mechanics education, a cultural and history-based perspective is vital for enhancing conceptual learning. To this purpose, historical offers a useful playground to conceptual understanding, while motivations for a paradigm shift must be seen by students as meaningful and well-founded. On the other hand, the mathematical aspect is also fundamental to the culturally significant approach. And for this, multi-representations play a key role in elucidating abstract mathematical facets. By integrating various representations, students can actively engage with otherwise challenging concepts. This study explores diverse methods of representing vectors in Hilbert spaces, utilizing algebraic, geometric, and web-based tools to introduce eigenvalue and eigenvector concepts. We evaluate their strengths, emphasizing the synergy of combined utilization. Results stem from experimentations with high school students, a teacher-led session, and discussions with master's students. Analysis includes surveys, classroom observations, and student interviews. Preliminary results indicate students' proficiency in mathematical tasks comparable to other physics topics.

Quando ricerca, didattica e divulgazione si incontrano: la scuola internazionale INFN-INSPYRE.

Postiglione A., Curceanu C., Arnone S., Bifaretti D., Patrignanelli E., Reda S., Santinelli E., Bertelli S.
INFN, Laboratori Nazionali di Frascati

La fisica delle particelle e la fisica moderna rappresentano un formidabile strumento per avvicinare le giovani generazioni alle STEM. Esse, infatti, permettono di trattare argomenti affascinanti che hanno numerose applicazioni nella vita quotidiana. Se poi la trattazione della fisica moderna viene fatta attraverso attività laboratoriali e nei luoghi in cui la ricerca è svolta, allora l'esperienza è ancora più preziosa: in questo caso, infatti, i giovani hanno la possibilità di conoscere il mondo della ricerca scientifica e i suoi protagonisti, e sperimentare la fisica in prima persona. È con questo spirito che, dal 2011, i Laboratori Nazionali di Frascati dell'INFN organizzano la Scuola Internazionale INSPYRE per studenti di scuola secondaria superiore da tutto il mondo. In questo contributo presenteremo l'edizione 2024 della scuola, nella quale sono confluite l'esperienza e la competenza non solo dei ricercatori INFN e di altre Università, ma anche di importanti esponenti della didattica e divulgazione di CERN e GIREP; verrà descritta la struttura della scuola sottolineando gli aspetti innovativi che hanno aperto un dialogo costruttivo tra le comunità coinvolte.

L'insegnamento della fisica quantistica nelle scuole: le opinioni degli esperti e degli insegnanti.

Di Mauro M. ([1]), Perli L. S. ([1]), Carli M. ([2]), Cogo D. ([2]), Malgieri M. ([3]), Onorato P. ([1]), Oss S. ([1])
([1]) *Dipartimento di Fisica, Università di Trento*

([2]) *Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova*
([3]) *Dipartimento di Fisica, Università di Pavia*
L'insegnamento della fisica quantistica (FQ) nelle scuole secondarie è una delle problematiche più attuali e difficili che i ricercatori e gli insegnanti si trovano ad affrontare. La FQ è ormai percepita come una materia le cui basi dovrebbero essere insegnate agli studenti in virtù del suo valore culturale e delle sue numerose applicazioni tecnologiche, sia presenti che prevedibili. Tuttavia, essa, costituendo una radicale rottura con la fisica classica, è caratterizzata da difficoltà concettuali, e dall'uso di una matematica con cui gli studenti non hanno familiarità. In questo contributo verrà descritto uno studio in corso, consistente nel sondare le opinioni su questa tematica sia di esperti ricercatori in fisica, in ambiti in cui la FQ gioca un ruolo fondamentale, sia di insegnanti, i quali hanno ben presente la situazione tipica in cui si trovano gli studenti che si intende raggiungere. Gli intervistati sono stati consultati riguardo all'opportunità e alle motivazioni dell'insegnamento della FQ a scuola, agli argomenti considerati importanti e al modo di affrontare alcuni aspetti concettualmente sottili. Le visioni degli esperti e dei docenti sono poi state confrontate.

Partecipazione del Progetto EEE all'International Cosmic Day.

La Rocca P. per la EEE Collaboration
Dipartimento di Fisica e Astronomia, Università degli Studi di Catania e INFN, Sezione di Catania
Il Progetto Extreme Energy Events (EEE) nasce nel 2004 con lo scopo di realizzare una vasta rete di rivelatori per raggi cosmici da installare nelle scuole secondarie Italiane. Dopo 20 anni, il Progetto ha completato l'installazione di circa 60 telescopi, coinvolgendo in totale un centinaio di scuole su tutto il territorio nazionale. Oltre ad ambiziosi obiettivi scientifici, l'esperimento punta a condurre un'intensa attività di outreach, coinvolgendo ogni anno migliaia di studenti in attività sperimentali e di analisi dati. Tra queste attività rientra la partecipazione all'International Cosmic Day, iniziativa organizzata annualmente dai laboratori Desy ad Amburgo, a cui la Collaborazione EEE partecipa dal 2017. Durante questa giornata dedicata ai raggi cosmici, gli studenti delle scuole aderenti al Progetto, guidati dai ricercatori, svolgono un'attività sperimentale e di analisi mirata allo studio delle proprietà della radiazione cosmica secondaria. In questa comunicazione verranno illustrate le attività svolte nell'ambito del Progetto EEE durante le recenti edizioni dell'International Cosmic Day.

Quantum mechanics through quantum cryptography: A training course for in-service teachers.

Bondani M. ([1]), Favale F. ([2])
([1]) *CNR, Istituto di fotonica e nanotecnologie, Milano*
([2]) *Liceo Scientifico "Albert Einstein", Milano*
At the heart of quantum technologies are superposition and quantum entanglement, concepts that challenge classical physics and continue to spark epistemological debates. This offers a privileged context to teach quantum physics. We set up an introductory course for in-service teachers, leveraging quantum cryptography as a focal point and using a hands-on teaching apparatus from Thorlabs. This comprehensive 14-hour course (8 hours theoretical, 6 hours experimental) approached the fundamentals of quantum mechanics, the properties of light, the description of the polarization state using vectors and matrices, and their manipulation through optical elements. In the second part, notions of classical and quantum cryptography were introduced, followed by an experimental implementation of the BB84 quantum key distribution protocol with the Thorlabs equipment. The course employed a mix of lectures, interactive sessions, group discussions, and hands-on activities, participants

deeply explored theoretical concepts and practical applications. Subsequent interviews with teachers measured their feedback on the course and assessed the feasibility of integrating such a teaching sequence.

Students hands on EEE Project muon detectors: Study of detection efficiency with eco-friendly mixture.

Ripoli C. on behalf of the EEE Collaboration
Dipartimento di Fisica "E.R. Caianiello", Università di Salerno e INFN, Gruppo Collegato di Salerno Sezione di Napoli

The Extreme Energy Events (EEE), Science inside schools, is an experiment run by CREF/Centro Fermi and INFN, it was born with the dual purpose to investigate cosmic rays and to get high schools students in touch with a real physics experiment. The EEE array of muon telescopes, based on Multigap Resistive Plate Chambers (MRPC), is designed to have local clusters and single telescope stations (GPS synchronized) distributed all over the Italian territory and installed mainly in high school buildings. This unconventional worksite offers young students the possibility to be more engaged in all aspects of the activity, from hardware to data analysis. The EEE Collaboration regularly schedules outreach and educational activities: the last in-presence meeting took place at INFN National Laboratory of Legnaro (PD) in November 2023 with a large part of the schools participating. This event gave all students the opportunity to carry out a measurement of the detection efficiency of a muon MRPC detector during the current transition phase of the EEE Project towards the use of an ecological gas mixture used in muon detectors.

Walking in the quantum world: The Italian Quantum Week exhibit 2024.

De Renzi V. ([1])([2]), Cavazzoni S. ([1]), Forghieri G. ([1]), Ragazzi G. ([1]), Paris M.G.A. ([3]), Bondani M. ([4])
([1]) *Dipartimento FIM, Università di Modena e Reggio Emilia*
([2]) *CNR, Istituto di Nanoscienze, Modena*
([3]) *Dipartimento di Fisica, Università di Milano*
([4]) *CNR, Istituto di Fotonica e Nanotecnologie e Dipartimento di Scienze e Alta Tecnologia, Università dell'Insubria, Como*

In the context of the Italian Quantum Weeks initiative, the third edition of the exhibit "Dire L'indicibile" proposed a journey through the rules and consequences of Quantum Mechanics, offering the public a glimpse at the working principles and potential applications of quantum technologies (QTs). We devised a route to introduce the key concepts of quantum superposition, quantum measure and evolution, incompatible observables , exploiting analogies based on custom-made models. Moreover, the public is invited to investigate the properties of polarized light and its measure using polaroid films and optical active materials. As examples of possible QT applications, we choose to discuss: (i) the peculiarities of quantum walks (QW), as compared to classical random walks; (ii) quantum cryptography and its applications. Two simple games - illustrating the mechanisms at the basis of QW and of the BB48 quantum key distribution protocol - were actively performed by both the general public and secondary school classes attending the exhibit. The outcome of a satisfaction survey is extremely positive, encouraging us to explore this approach in different educational contexts.

Una proposta di meccanica quantistica realizzata alla Scuola Internazionale INFN-INSPYRE.

Postiglione A. ([1]), Curceanu C. ([1]), Michelini M. ([2]), Santi L. ([2]), Bassi A. ([3]), Bertelli S. ([1])

([1]) *INFN, Laboratori Nazionali di Frascati*
([2]) *Università di Udine, Udine*
([3]) *Università di Trieste e INFN, Sezione di Trieste*
Nel programma 2024 della Scuola Internazionale INSPYRE dell'INFN è stata introdotta una proposta sulla meccanica quantistica e le tecnologie quantistiche basata sulla ricerca didattica per 40 studenti di 7 Paesi, che hanno lavorato in modo intensivo ed interattivo per un'intera giornata sul tema. INSPYRE è la scuola di eccellenza INFN realizzata ai Laboratori Nazionali di Frascati (LNF) che dal 2011 ha raggiunto più di 600 giovani di 17 Paesi del mondo. All'edizione 2024 hanno collaborato il GIREP ed il CERN ed in particolare l'Unità di ricerca didattica di Udine per una proposta didattica interattiva, comprendente esperimenti hand-on e ideali al computer, test di ingresso e di uscita e tutorial nell'ambito di una impostazione basata sulla polarizzazione ottica a cui si è integrato un seminario su tecnologie quantistiche. Un'ora di dialoghi tra ricercatori e studenti ha poi arricchito le attività. Evidenze sull'apprendimento concettuale degli studenti emergono dai dati raccolti e orientano future attività didattiche.

SIF and the birth of StatPhys: The 1949 Florence conference at the juncture of post-WWII reconstruction of national and international physics.
Lalli R. ([1]), Politi P. ([2])
([1]) *DIMEAS, Politecnico di Torino*
([2]) *CNR, Istituto dei Sistemi Complessi*
In May 1949 about 70 physicists from eight countries met in Florence to discuss recent trends in statistical mechanics. Co-organized by the Italian Physical Society (SIF) and the IUPAP Commission on Thermodynamics and Statistical Mechanics, the meeting initiated a tradition of IUPAP-sponsored international conferences on statistical mechanics that lasts to this day: the StatPhys conferences. This contribution examines the various roles of the conference, situating it in the broader contexts of the post-World War II reconstruction of Italian physics and international science. Through an analysis of IUPAP records and Italian archives, we illustrate how the event's success hinged on the aligned objectives of its organizers. Internationally, it was instrumental in defining the scientific and organizational foundations for the activities of IUPAP commissions when the Union was resurging on the international stage. Nationally, the conference served as a cornerstone in SIF's strategy to re-establish Italian physics' international stature and to aid the domestic revitalization of physics through the internationalization of its activities, notably of its flagship journal, Il Nuovo Cimento.

Aula A **ore 09:00 – 16:30**

Simposio di Optometria

Presiede: Gurioli M. (Università di Firenze)

Relazioni su invito

▲ Keratometric index obtained by the Sirius rotating Scheimpflug camera.

Calossi A., Paparusso G., Gurioli M.
Corso di Laurea in Ottica e Optometria, Università di Firenze

We report on a study to determine the keratometric index of refraction based on actual measurements of the anterior and posterior corneal surfaces using a combined Placido and Scheimpflug topography system (Sirius, CSO) and evaluate the accuracy of this keratometric index in estimating total corneal power. The random selected eye of 50 normal subjects was measured with the Sirius system. The radius of the anterior and posterior corneal surface, mean radius of simulated keratometry (simK), central corneal thickness, and ray-tracing mean pupil power (MPP) were obtained. The equivalent keratometric index was calculated in each eye from equivalent paraxial power and by ray-tracing MPP. We found that the mean calculated keratometric index was 1.3299 ± 0.0010 and 1.3332 ± 0.0010. Using the Javal indices of 1.3375, the estimated bias and 95% limits of agreement of simK vs MPP and simK vs Gaussian equivalent corneal power was 0.55 ± 0.25 diopter (D) and 0.98 ± 0.22 D, respectively; using the adjusted keratometric index, become 0.00 ± 0.25 D and 0.00 ± 0.23 D, respectively. Using the Sirius-derived keratometric index may improve the prediction accuracies of total corneal power.

Comunicazioni

● Validità e ripetibilità di tre test di bilanciamento binoculare.

Boccardo L. ([2]), Parenti L. ([1])([2])
([1]) *Corso di Laurea in Ottica e Optometria, Università di Firenze*
([2]) *Istituto di Ricerca e Studi in Ottica e Optometria, Vinci*

Obiettivo dello studio è confrontare 3 test di bilanciamento binoculare, basati sul confronto di nitidezza fra due linee di lettere, in cui lo sdoppiamento avviene con: filtri polarizzati, prisma 6D BU, filtro anaglifico. Ogni test è stato ripetuto 3 volte. Hanno partecipato allo studio 24 soggetti fra 18 e 27 anni (media 22), con equivalente sferico tra -4,87 e +1,00 D (media -0,83 D) e astigmatismo $< 2,50$ D. I risultati sono stati analizzati come differenza sferica rispetto alla refrazione monoculare e studiati tramite grafici di Bland Altman e coefficiente di correlazione intraclasse (ICC), con i seguenti risultati: polarizzato: bias 0,00 D; CI 0,1 D; ICC 0,9; prisma: bias -0,25 D; CI 0,6 D; ICC 0,4; anaglifico: bias +0,25 D; CI 0,4 D; ICC 0,6; Il test polarizzato è affidabile e ripetibile. Il test con prisma induce dispersione cromatica sull'occhio destro, rendendo difficile il confronto e migliore la visione dell'occhio sinistro, quindi non è né preciso né ripetibile. Il test con anaglifico ha una diversa focalizzazione nei due occhi e un effetto confondente dovuto al colore cangiante dello sfondo, quindi non è né preciso né ripetibile.

Children with dyslexia too show the practice effect on the Rate of Reading Test.

Zeri F. ([1])([2])([3]), Chiesa P. ([1]), Daini R. ([4]), De Luca M. ([5]), Ponzini E. ([1])([2]), Rizzo G. C. ([1])([2]), Tavazzi S. ([1])([2]), Termine C. ([6])
([1]) *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia*
([2]) *Optics and Optometry research center, COMiB, Università degli Studi di Milano-Bicocca, Italia*
([3]) *College of Health and Life Sciences, Aston University, Birmingham, UK*
([4]) *Dipartimento di Psicologia, Università degli Studi di Milano-Bicocca, Italia*
([5]) *IRCCS Fondazione Santa Lucia, Roma, Italia*
([6]) *Ospedale di Circolo e Fondazione Macchi di Varese, Italia*

The Wilkins Rate of Reading Test (WRRT) has been developed in the field of optometry to assess visual performance in a reading-like task. The test's structure, composed of sequences of unrelated words, allows for the availability of equivalent passages for serial measurement of performance under multiple different conditions. A recent study demonstrated a significant practice effect in adult readers' reading speed when consecutively reading different passages. The present study aimed to verify the presence of the practice effect in a sample of children with developmental dyslexia. Twenty-one children (aged 10–17) were recruited from the "Ospedale di Circolo e Fondazione Macchi" in Varese. Participants consecutively read 8 different passages of the standard Italian WRRT. While reading accuracy remained consistent, reading speed showed a significant difference among the passages (repeated-measure ANOVA; $p = 0.004$). This effect was due to the differences between the first readings. This finding suggests the exclusion of the first trial when assessing the effect of different experimental conditions or interventions on reading performance in this population.

Optometria al buio con mire fotoluminescenti.

Parretta A.
Dipartimento di Fisica e Scienze della Terra, Università di Ferrara e Accademia delle Scienze di Ferrara

Questo lavoro è stato ispirato dall'osservazione che adesivi fotoluminescenti (PL), al buio e con la vista adattata, possono essere facilmente oscurati alla visione diretta. Questo fenomeno ha dato l'avvio ad una sperimentazione di "Optometria al Buio", realizzabile con materiali e strumentazione relativamente economici. Il test di acuità visiva (AV) morfoscopica è stato condotto su alcuni soggetti utilizzando tavole LogMAR realizzate tracciando ottotipi con vernice PL, e confrontando i risultati con quelli dei metodi optometrici alla luce. Il test dell'angolo di vista, intrinsecamente legato alla condizione di buio, spiega il fenomeno dell'oscuramento delle mire PL, e fornisce utili informazioni sulla morfologia dell'occhio. Il test della macchia cieca di Mariotte (Mariotte's blind spot test), è stato applicato sia al buio che alla luce in funzione della distanza mira-osservatore. Quando combinato al buio con il test dell'angolo di vista, esso permette l'oscuramento simultaneo di due mire PL, da cui il nome di "Two Blind Spots Test" (TBST). Sono riportati infine i risultati di AV di risoluzione al buio e alla luce, messi a confronto con quelli di AV morfoscopica.

Selective chromatic contact lenses in sports practice: a case study in golf players.

Gheller P., Caccia C.R., Ruffato G.
Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova

The correction of ametropias and the resulting visual wellness should never be ignored, especially in sports practice, where these factors could affect the entire performance and may be crucial for an eventual victory or defeat. This work aims to investigate the improvement of

the performance in a group of golf players wearing different types of chromatic contact lenses rather than standard ones. In particular, we investigate how the performance can improve by wearing yellow or orange contact lenses, considering tests on the field, and conducting specific surveys to identify the best tint for golf practice. The procedure can be generalized to any sport, in order to identify the best colour filter depending on the field background, target colours, and typical tasks required during the game.

Quantificazione delle caratteristiche di lenti IOL attraverso misure ottiche: indicazioni per una valutazione preimpianto della visione a diverse distanze.

Giorgetti A. ([1]), Tommasi F. ([1]), Fini L. ([1]), Pelli S. ([2]), Mencucci R. ([3]), Romualdi G. ([3]), Gurioli M. ([1]), Cavalieri S. ([1])

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Questo studio riporta la misura, attraverso lo strumento Lambda PMTF, in combinazione con un modello di occhio (Model Eye ME215), delle caratteristiche ottiche di 4 tipologie di lenti intraoculari (IOL) e la successiva analisi per la valutazione e il relativo confronto. Le caratteristiche ottiche delle lenti sono valutate attraverso la MTF (Modulation Transfer Function) al variare della posizione rispetto al fuoco nominale della lente e dell'apertura del diaframma pupillare. I risultati sperimentali sono stati poi analizzati allo scopo di ricavare, attraverso calcolo numerico, ulteriori parametri di interesse, come la LSF (Line Spread Function) e la qualità di diverse possibili immagini in funzione del defocus. Tali dati permettono quindi di dare indicazioni sulla visione a diverse distanze e l'effetto delle aberrazioni per diverse aperture della pupilla. Le differenze nelle misure delle lenti si evidenziano nelle prestazioni sia per la visione da lontano che nella visione intermedia. Tali risultati sono interessanti per l'individuazione di procedure di previsione del comportamento ottico della lente in fase preimpianto.

Percezione del colore di "the dress" in soggetti non anomali e anomali per la percezione del colore.

Ducci D. ([1]), Baldanzi E. ([1])([2])([1]), Farini A. ([1])([2])([1]), Grasso P. ([1])([1]), Gurioli M. ([1])([1]), Tommasi F. ([1])([1])

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([2]) *CNR, Istituto Nazionale di Ottica*

"The Dress" indica la foto di un vestito che ha creato discussione sul web nel 2015 a causa della sua colorazione ambigua: alcune persone vedono il vestito bianco e oro, altre blu e nero, altre ancora, seppur in minoranza, riferiscono altri colori. In questo studio oltre a una risposta verbale si è chiesta l'indicazione del colore percepito in una gamma di colori presentati dal monitor del computer per capire se il vestito presenti una differenza di colore percepito o solo una differenza nel nome dato a colori visti però come identici. L'immagine del vestito è stata fatta osservare anche a soggetti anomali nella visione del colore. Preliminarmente al test relativo all'individuazione del colore del vestito tutti i soggetti sono stati sottoposti al CAD test, un test dedicato alla valutazione delle soglie di percezione cromatiche. Nei risultati sono state valutate le correlazioni tra saturazione, tinta e luminanza tra i gruppi che hanno diversa percezione e la relazione con le soglie di percezione cromatica.

Assessment of duochrome test efficacy across age groups.

Rizzo G.C. ([1])([2]), Ponzini E. ([1])([2]), Borghesi A. ([1])([2]), Rolandi R. ([1])([2]), Duse A. ([1])([2]), Zeri F. ([1])([2])([3]), Tavazzi S. ([1])([2])

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(3) *College of Health and Life Sciences, Aston University, Birmingham, UK*
The duochrome test (DT) relies on the longitudinal chromatic aberration (LCA) of the eye, so variations in LCA could affect its reliability. Additionally, previous studies have reported that, under white light conditions, an unaccommodated emmetropic eye is focused on a red focal point. The objective of this study was to assess defocus curves (DCs) at distance on green, white, and red backgrounds, while also evaluating the effectiveness of the DT across two age groups: young 21-24 years) and elderly 55-66 years). Parameters including dioptric differences between background colours, best corrected visual acuity (BCVA), and widths of the DCs for the three conditions were analysed. Results showed a significantly worse BCVA with a green background in older subjects, a slight preference for focusing on red under white light conditions for both groups and a similar LCA in both groups. However, these differences do not seem to compromise the clinical use of the DT for refraction assessment and the difference of about 0.20D between red-green DC supports the appropriateness of using a 0.25D step as the standard minimum difference in power between corrective lenses.

Presiede: Ponzini E. (Università di Milano)

Relazioni su invito

▲ **The role of neural adaptation in the perception of Haidinger's brushes.**
Ruffato G. (1), Pulcini G.G. (1), Ortolan D. (1), Battaglini L. (2)
(1) *Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova*
(2) *Dipartimento di Psicologia Generale, Università di Padova*
Haidinger's brushes are an entoptic phenomenon consisting in the perception of a yellowish bow tie when linearly polarized white light enters the eye. The pattern arises from the particular spatial distribution of dichroic carotenoid molecules in the macula, creating a sort of embedded radial polarizer for blue light. In the past years, we conducted the broadest test ever performed to identify the polarization degree threshold on healthy individuals in conditions of maximum contrast. The setup relied on the combination of two different sources, one of which was polarized using a linear polarizer, rotating to elude neural adaptation. More recently, we have further upgraded the original system by introducing an additional degree of freedom, represented by the rotational speed, and conducted for the first time psychophysical tests to investigate the correlation between polarization degree and Haidinger's brushes angular frequency.

Comunicazioni

● **Development and testing of a portable and versatile device for flickering frequency analysis.**
Ortolan D. (1), Demo A. (1), Battaglini L. (2), Ruffato G. (1)
(1) *Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova*
(2) *Dipartimento di Psicologia Generale, Università di Padova*
The critical flickering frequency (CFF) refers to the threshold frequency at which a flickering light source transitions from appearing intermittent to appearing continuous to the human

eye. It can serve as a fundamental metric in understanding the temporal properties of visual perception. Several variables can influence this threshold, including the spectral characteristics of the source, the luminance level, the age of the subject, and the overall visual health. Investigating these variables provides insight into how different factors impact the perception of flicker, offering opportunities to optimize lighting and display technologies for enhanced visual comfort and performance. In this work, we assemble and test a portable setup based on an RGB LED controlled by a programmed ARDUINO board and conduct psychophysical tests on a group of subjects to study the key parameters affecting the individual CFF.

Illusory color signals bring out large interindividual variability in color perception within the trichromats.

Grasso P.A. ([1]), Tommasi F. ([1]), Baldanzi E. ([1])([2]), Farini A. ([1])([2]), Gurioli M. ([1])
([1]) *Dipartimento di Fisica e Astronomia, Università di Firenze*
([2]) *CNR, Istituto Nazionale di Ottica, Firenze*

Color perception is an integral skill of vision aiding rapid segregation and categorization of objects in the environment. It depends on both low-level spectral analysis of the light reflected by an object and high-level interpretation of the retinal output. Although, within the trichromatic population, interindividual differences in color perception can be considered negligible, there is some indication that these differences can be quite substantial when color appearance is considered. In the current study we shed light on such variability by exploiting a series of methods that leveraged on illusory and/or ambiguous color signals. We developed a series of experiments with participants completing color matching tasks of both real and illusory colored stimuli. Our results highlight impressive and unexpected variability in color appearance suggesting that the perception of color is less universally shared than usually described. Furthermore, our data provide interesting hints for the potential use of chromatic illusions in the assessment of interindividual differences in colour processing.

Confronto tra valutazione oggettiva e soggettiva dell'abbagliamento.

Farini A. ([1]), Baldanzi E. ([1]), Giorgetti A. ([2]), Grasso P. ([2]), Lavezzi L. ([2]), Tommasi F. ([2])
([1]) *CNR, Istituto Nazionale di Ottica, Firenze*
([2]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze*

L'abbagliamento è una delle principali cause di perdita di acuità visiva e di peggioramento nella sensibilità al contrasto. Ciononostante si tratta di una grandezza che non ha ancora trovato una metodologia accettata per la sua valutazione. In questo lavoro sono messi a confronti due metodi. Il primo è legato a un anello luminoso presentato su un display che emette luce a intervalli regolari, generando una luminanza di velo su un disco posto al centro dello schermo. Il soggetto deve aumentare la luminanza del disco centrale fino ad eliminare la sensazione di sfarfallamento. Il secondo è invece basato su una maschera ricoperta internamente di led. La luminanza della maschera cresce linearmente e il soggetto deve indicare le sue soglie di fastidio. Lo studio mostra il legame tra queste due forme di misura dell'abbagliamento.

Choroidal thickness measurements: challenges in clinical practice.

Terni De Gregory B. ([1]), Rizzo G.C. ([1])([2]), Obaid A. ([1]), Ponzini E. ([1])([2]), Borghesi A. ([1])([2]), Zeri F. ([1])([2])([3]), Ferraro L. ([1]), Tavazzi S. ([1])([2])
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The increased worldwide prevalence of myopia has intensified the interest of researchers in determining causes, mechanisms, and predisposing factors that lead to its onset and pro-

gression over time. The eye growth, that is strictly linked to the refractive status and the development of myopia, is controlled by complex interactions between genetic and environmental factors. Neural mechanisms in the retina can detect the presence of defocus and generate signals that alter axial growth in a manner that eliminates optical errors. The choroidal seems to be in charge of this initial compensatory response to retinal defocus. In particular, a prolongated visual work at a near distance can induce a hyperopic defocus and the subsequent transient choroidal thinning, which, over time, would produce an irreversible ocular elongation of the scleral fibrous structures, structuring the condition of myopia. Our study is focused on finding a reliable and repeatable method to measure choroidal thickness from OCT images, and its transient response in relation to various stimuli, which could increase understanding of the relationship between the two phenomena in causing future myopization.

Le immagini ibride come test per lo screening della miopia.

Cosseddu F. ([1]) ([1]), Baldanzi E. ([1])([2])([1]), Farini A. ([1])([2])([1]), Grasso P ([1]), Gurioli M. ([1])([1]), Tommasi F. ([1])([1])

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([2]) *CNR, Istituto Nazionale di Ottica, Firenze*

Le immagini ibride sono illusioni visuali in cui due differenti interpretazioni di un'immagine possono essere percepite cambiando la distanza da cui sono viste. In questo studio, dopo aver creato nuove immagini ibride con diversi valori di taglio nelle frequenze spaziali, si sono inizialmente identificate le immagini che permettevano la migliore discriminazione delle acuità visive dei soggetti. Per farlo ad ogni soggetto sono state applicate, tramite aggiunta di lenti positive, le opportune correzioni allo scopo di indurre diversi valori di acuità visiva ottenendo così grafici della frazione di volte in cui era vista l'immagine ad alta frequenza spaziale in funzione della acuità visiva e fittando i valori con le curve psicometriche. Scelte così le immagini, esse sono state presentate ad un ampio campione di partecipanti, registrando le loro risposte insieme alla loro acuità visiva. I risultati ottenuti hanno evidenziato come le immagini ibride, utilizzate come test di screening, mostrino elevati valori di sensibilità e specificità, permettendo di ipotizzare la realizzazione di un test rapido e semplice per l'individuazione della miopia.

Evaluation of peripheral subjective refraction in relation to accommodative fluctuations and the risk of myopia progression.

Cane S., Bussa M.P., Colandrea C., Greco M., Serio M.

Dipartimento di Fisica, Università di Torino

The aim of the study was to evaluate peripheral subjective refractive responses in relation to accommodative micro-fluctuations and their possible variation between myopic and hyperopic subjects. Accommodative fluctuations were measured in each subject using an ocular aberrometer, followed by a subjective assessment of peripheral refraction. The primary aim was to determine whether subjective peripheral refraction was consistent with accommodative fluctuations and, more importantly, whether it differed between myopes and hyperopes. The ultimate goal was to determine whether different peripheral responses can influence the progression of myopia. Our results emphasize the importance of measuring peripheral refraction in addition to central measurements to provide clinicians with additional insight into refractive status that can help in assessing myopia risk. This method offers a practical approach that is accessible to all clinicians without specialized instruments and improves routine refractive examination.

Effect of instruction modulation on objective refraction in relation to accommodative micro-fluctuations.

Penna G., Bussa M.P., Colandrea C., Greco M., Serio M.
Dipartimento di Fisica, Università di Torino

In non-cycloplegic autorefraction, subjects are usually instructed to relax their vision to minimize the accommodative effects on the measurements. However, these instructions are often underestimated by operators. The aim of this study is to investigate how different methods of subject instruction can influence measurements and whether they are susceptible to individual accommodative variation. Objective refraction will be performed using autorefraction, while accommodative fluctuations will be determined using an aberrometer. The aim is to determine whether subjects in whom the measurements vary according to the instructions have similar accommodative micro-fluctuations and to distinguish between myopic and hyperopic subjects. Despite device manufacturers guidelines, users vary in their adherence to instructions and our aim is to quantify their effects. This research contributes to a better understanding by comparing these responses and their effects.

Presiede: Ortolan D. (Università di Padova)

Relazioni su invito

Laurea in Ottica e Optometria e lavoro visti da AlmaLaurea.

Bussa M.P., Botta E., Greco M., Serio M., Bellatorre A., Civiero G., Colandrea C., Di Benedetto S.
Università di Torino

Dal 1998 il Consorzio interuniversitario AlmaLaurea pubblica i risultati di una indagine sulla condizione occupazionale dei Laureati realizzata ad uno, tre e cinque anni dal titolo. I corsi di laurea in Ottica e Optometria sono stati oggetto dell'indagine fin dalla loro attivazione, tranne Milano Bicocca i cui dati sono disponibili a partire dalla XVI indagine (2014). Ad oggi i dati accessibili sono limitati ai laureati dell'anno solare precedente l'anno di svolgimento dell'indagine. I laureati sono intervistati rispetto all'ingresso nel mercato del lavoro e rispetto al lavoro attuale (sede, tipologia, retribuzione, ore lavorate). Di particolare interesse per un corso a carattere professionalizzante chiamato ad aggiornare gli obiettivi formativi con l'evoluzione del mondo del lavoro sono le valutazioni dei laureati sull'utilizzo delle competenze acquisite con la laurea e sulla sua efficacia nella attività lavorativa, nonché la soddisfazione per l'attuale lavoro. L'analisi dei dati conferma che pur con qualche differenza per genere area geografica i laureati sono rapidamente accolti nel mondo del lavoro con grande apprezzamento per la preparazione fornita dall'università.

Comunicazioni

Water kinetics coefficients to compare the dehydration properties of different CL polymers.

Galli A. ([1]), Maspero F. ([1]), Zeri F. ([1])([2])([3]), Borghesi A. ([1])([2]), Rizzo G.C. ([1])([2]), Ponzini E. ([1])([2]), Tavazzi S. ([1])([2])
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Dry eye symptoms are common among contact lens (CL) wearers, prompting this in-vitro study to explore the dehydration behavior of soft CLs. The dehydration kinetics of five CLs

was assessed by analyzing their water loss at (36°C) and (60%) relative humidity, utilizing a gravimetric approach. Dehydration kinetics coefficients were derived through a model to compare the water diffusion dynamics within the CL polymers. The findings highlight a non-Fickian dehydration behavior across all tested CLs, with notable variations in the kinetics coefficients and dehydration rate slopes. Specifically, a comparison between the investigated hydrogel (Etafilcon A and Omafilcon A) and silicone-hydrogel CLs (Senofilcon A and Delefilcon A) revealed distinct dehydration patterns. Nonetheless, the silicone-hydrogel Kalifilcon A exhibited dehydration properties more similar to hydrogel CLs. This distinctive feature is accompanied by other peculiarities of this material, such as its high equilibrium water content, similar to hydrogel values, and the recent reports concerning potential benefits in addressing the needs of CL wearers experiencing discomfort due to dry eye symptoms.

Irregular diffusion of water in worn Etafilcon A contact lenses.

Tavazzi S. ([1])([2]), Ponzini E. ([1])([2]), Rizzo G.C. ([1])([2]), Maspero F. ([1]), Galli A. ([1]), Zeri F. ([1])([2])([3]), Borghesi A. ([1])([2])

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This work concerns the modifications after wear of the mechanisms of water diffusion in contact lenses (CLs). 13 adults wore Etafilcon A CLs. After 1 hour, tear meniscus height (TMH) was measured in vivo. After 2 hours, the CL water kinetics coefficient (d) was assessed by dehydration analyses ex vivo. d was similar 1.03 ± 0.07, $p = 0.076$ to unworn CLs 0.99 ± 0.01 for 13 eyes (group A), while d was higher 1.75 ± 0.08, $p < 0.0001$ in the other 13 eyes (group B). The two groups also differed in the TMH 0.31 ± 0.06 mm and 0.25 ± 0.04 mm for A and B, respectively, $p = 0.004$. $d = 0.5$ corresponds to normal Fickian behavior. Thus, all CLs display non-Fickian behavior. When $d = 1$, water diffusion is hindered by the polymeric matrix due to rapid changes in the structure during dehydration. Conversely, when $d > 1$, diffusion is irregular due to an imbalance between water diffusion and polymer structure modification rate. The results show that wear caused changes in the water diffusion of Etafilcon A in 50% of the examined CLs. This may be linked to the tear volume measured by TMH during wear.

Assessing the impact of lysozyme adsorption on the friction coefficient in Etafilcon A contact lenses.

Ponzini E. ([1])([2]), Trabattoni S. ([1])([2]), Borghesi A. ([1])([2]), Zeri F. ([1])([2])([3]), Tavazzi S. ([1])([2])

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When a contact lens (CL) is placed in the eye, tear components begin to interact and accumulate on the lens surface. A commonly accumulated tear film protein on hydrogel CLs is lysozyme. The adsorption of proteins onto the CL can lead to discomfort, red eyes, or even inflammatory reactions. Notably, the friction coefficient of the CL has also been linked to similar symptoms. Nonetheless, few studies have explored the impact of tear protein deposition on the friction coefficient of CLs. In this context, the friction coefficient of the hydrogel CL Etafilcon A was investigated after incubation in solutions containing physiological concentrations of lysozyme, aiming to mimic a 6-hour wear period. The following measurements were conducted under conditions of reduced dehydration to closely simulate actual wear conditions. Before measuring friction, lysozyme adsorption was quantified using spectrophotometric assays. The findings indicate significant protein deposition on the CLs, while only minor changes in the friction coefficient were observed.

Ruolo della lunghezza assiale dell'occhio nella transizione emmetropia-ametropia.
Cavalieri S., Tommasi F., Grasso P.A., Fini L., Gurioli M.
Dipartimento di Fisica e Astronomia, Università di Firenze
Il ruolo decisivo della lunghezza assiale dell'occhio nelle ametropie si è affermato nelle ricerche optometriche nel corso degli ultimi decenni. In questo contributo analizziamo il ruolo di questo parametro in un campione statisticamente significativo di giovani cinesi (7600 occhi). Per ametropie importanti si evidenzia una chiara dipendenza delle stesse dalla lunghezza assiale dell'occhio. Negli altri casi si osserva un andamento medio, statisticamente rilevante, di emmetropia pur variando la lunghezza oculare, individuando quindi una transizione emmetropia-ametropia. Risulta inoltre evidente l'importanza della dispersione delle caratteristiche oculari nella ricerca delle cause dell'ametropia.

Comparison of accomodative condition between two reference distances: Average distance of smartphone use and standard proximal distance.
Pirotta A., Pelizzari S., Turcato M.
Dipartimento di Scienze dei Materiali, Università degli Studi di Milano-Bicocca, Milano, Italy
Smartphones are the electronic devices most used by young people for various types of activities: educational, work and leisure. Studies show that the distance of use of smartphones is closer than the standard optometric evaluation distance. The phoropter evaluation protocol of accommodative functions includes tests at a distance of 40 cm to verify negative and positive relative accommodation (NRA-PRA) and the accommodative response with fused cross cylinder (CCF, #14A, #14B OEP). Near phoria is quantified at the same distance to derive the AC/A ratio. The scientific bibliography reports expected data results based on age of the examined. We want to verify whether there could be a statistically significant difference in the accommodative and phoria tests at the reference distance of 33 cm, which better reflects the real use of devices, compared to the standard evaluation distance.

Valutazione delle abilità di lettura in età adulta attraverso il Radner Test.
Apiletti E., Maffioletti S., Serio M.
Dipartimento di Fisica, Università di Torino
Per decodificare un testo scritto è necessario avere abilità visive adeguate. Il Radner Test è un test di lettura che permette la misurazione di queste abilità, basato sul principio "ottotipo a frasi" e disponibile in più lingue. È stato somministrato il Radner Test ad un campione di 100 soggetti tra 20 e 60 anni divisi in quattro fasce di età con pari numerosità. È stata valutata la fluidità della lettura e il punto di soglia oltre il quale il riconoscimento dei grafemi interferisce con la corretta esecuzione della lettura. I parametri di lettura oggetto dello studio sono acuità di lettura, velocità di lettura (word/min) e dimensione critica di stampa (CPS). L'acuità di lettura corrisponde alle dimensioni dell'ultima frase letta tenendo conto degli errori commessi. La velocità di lettura è il rapporto tra il numero di parole nella frase e il tempo necessario per leggerla. La CPS è definita come la dimensione più piccola dei caratteri che il soggetto riesce a leggere alla sua massima velocità di lettura. La rappresentazione con box plot e l'analisi statistica con i test di Student e Anova hanno permesso di determinare la CPS e di confrontare i valori relativi alle fasce di età.

Questionario psicometrico per l'adattamento ad un occhiale progressivo.
Biagianti S. ([1]), Boccardo L. ([1])([2])
([1]) *Corso di Laurea in Ottica e Optometria, Università di Firenze*
([2]) *Istituto di Ricerca e Studi in Ottica e Optometria, Vinci*
Scopo dello studio è valutare validità e affidabilità di un questionario psicometrico sull'adattamento all'occhiale progressivo e individuare un punteggio di cutoff per discriminare

i soggetti sintomatici. Per valutare l'affidabilità del questionario è stato calcolato l'indice α di Cronbach. L'individuazione del punteggio di Cut-off e la valutazione della validità sono state effettuate mediante tabelle di contingenza e test Chi-quadro. Il questionario è stato proposto a 42 portatori di occhiali progressivi, da 43 a 82 anni. La media dei punteggi di Adattati (media 5, SD 4) e Non Adattati (media 21; SD 11) è significativamente diversa ($p < 0.001$). Un valore di Cut-off di 11 garantisce sensibilità 96% e specificità 83%. L'α di Cronbach (0.884) indica una buona affidabilità. Dall'analisi dei punteggi si nota una moderata correlazione con l'equivalente sferico ($R = 0,68,\ P < 0,05$) con migliore adattamento degli ipermetropi rispetto ai miopi. Il punteggio non è correlato a età e addizione. I risultati dello studio dimostrano che il questionario è in grado di identificare soggetti a rischio di non adattamento all'occhiale progressivo.

Trattamenti oftalmologici avanzati: copolimeri per il rilascio di molecole attive sulla superficie oculare.

Astolfi G. ([1]), Ponzini E. ([2])([3]), Rizzo G.C. ([2])([3]), Zeri F. ([2])([3])([4]), Borghesi A. ([2])([3]), Tavazzi S. ([2])([3]), Versura P. ([1])([5])
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([2]) *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca*
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([4]) *College of Health and Life Sciences, Aston University, Birmingham, UK*
([5]) *IRCCS Azienda Ospedaliero-Universitaria di Bologna*

I biomateriali hanno un ruolo significativo nel campo biomedico, con applicazioni promettenti anche in oftalmologia, offrendo la possibilità di modulare il rilascio di molecole bioattive e rendendo più efficace il trattamento di numerose patologie della superficie oculare. Questo studio si è concentrato sull'analisi delle capacità di carico e di rilascio di diversi copoliesteri, utilizzando come molecola modello una proteina presente nella lacrima, il lisozima. I materiali sono stati inizialmente immersi per 24h in una soluzione a concentrazione fisiologica di lisozima (3 mg/mL). La capacità di assorbimento e rilascioè stata valutata in soluzione salina, monitorando la concentrazione di lisozima nel tempo con misure di assorbanza a 280 nm. La struttura della proteinaè stata invece monitorata mediante analisi di dicroismo circolare. I risultati hanno evidenziato un rilascio graduale in funzione del tempo della proteina, che ha mantenuto la sua struttura intatta durante le analisi. I biomateriali utilizzati sono, pertanto, candidati promettenti per il rilascio controllato di molecole attive per il trattamento di malattie oculari con un approccio mirato.

Design Co-vision. The magic of light science.

Baldanzi E. ([3])([6]), Abbate V. ([2]), Amato C. ([7]), Battaglia S. ([8]), Farini A. ([3])([6]), Giusti C. ([1]), Gurioli M. ([3])([6]), Langella C. ([2]), Marino A. ([4]), Nichilò G. ([2]), Sasso C. ([5])
([1]) *Fondazione Idis - Città della Scienza di Napoli*
([2]) *DiARC - Università degli Studi di Napoli "Federico II"*
([3]) *CNR Istituto Nazionale di Ottica*
([4]) *CNR Istituto di Scienze Applicate e Sistemi Intelligenti*
([5]) *INAF Osservatorio Capodimonte*
([6]) *Dipartimento di Fisica e Astronomia Università degli Studi di Firenze*
([7]) *Università della Campania Luigi Vanvitelli*
([8]) *Museo Galielo*

In un momento di rivoluzioni scientifiche e sociali occorre ricercare nuove formule di comunicazione in grado di dialogare con la società tutta e di rendere la ricerca elemento di dibattito quotidiano. Ascoltando questi molteplici stimoli si è costituito un gruppo di lavoro trasversale per competenze e sede geografica con l'obiettivo di realizzare un progetto di outreach

che a partire dalle nozioni scientifiche sia in grado di generare oggetti realizzate da parte di giovani creativi esperti di arte e design. Le opere realizzate saranno esposte in anteprima a Futuro Remoto in collaborazione con il progetto Enlighting Mind.

Aula Magna **ore 14:30 – 15:10**

Sezione II
Fisica della materia
Presiede: Fabris S. (CNR-IOM, Trieste)

Relazione Generale

Atomistic simulations of phase change materials for electronic memories and neuromorphic devices.
Bernasconi M.
Dipartimento di Scienza dei Materiali, Università di Milano-Bicocca, Milano, Italia
Phase change materials are chalcogenide alloys suitable to undergo a fast (10–100 ns) and reversible transformation between the crystalline and amorphous phases upon heating. This feature is exploited in key enabling technologies including non-volatile electronic memories and neuromorphic computing. Readout of the memory consists of the measurement of the electrical resistance at low bias that differs by three orders of magnitude in the two phases, while the set/reset process consists of amorphization/recrystallization of the material induced by Joule heating. Partial amorphization also allows encoding an analogical information exploited to build artificial synapsis for neuromorphic computing. I will focus on the atomistic simulations of the functional properties of materials in this class, either based on electronic structure calculations or on large-scale molecular dynamics with machine-learning interatomic potentials.

Aula Magna **ore 15:10 – 15:50**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Lucarelli F. (Università di Firenze)
Villa M. (Università di Bologna e INFN, Sezione di Bologna)

Relazione Generale

Datazione con radiocarbonio: le sfide per il futuro.
Fedi M.
INFN, Sezione di Firenze
Nel 1960 W.F. Libby vinceva il premio Nobel per la chimica "for his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science". Da quel momento e da quei primi lavori pionieristici, la ricerca si è costantemente evoluta con l'obiettivo di migliorare la precisione e l'accuratezza ottenibili nelle misure di datazione e di esplorare la possibilità di applicare il metodo a sempre nuovi materiali. Ancora oggi, la comunità internazionale si trova a investigare nuove opportunità. Nella comunicazione se ne discuteranno alcune. Per esempio, la Accelerator Mass Spectrometry (AMS) vede nuovi sviluppi che si possono riassumere con la parola chiave "small": "piccoli" acceleratori per set-up di misura compatti; "piccoli" campioni, cioè campioni con masse dell'ordine addirittura di pochi microgrammi, per studiare la possibilità di sfruttare nuovi materiali o nuovi sistemi, anche inorganici, per la datazione. Il miglioramento continuo della precisione ottenibile pone inoltre nuove sfide per quanto riguarda gli studi relativi alle variazioni di concentrazione di radiocarbonio in atmosfera ed è proprio in questo campo, fra l'altro, che la ricerca nel campo del ^{14}C si intreccia con un tema di grande impatto e attualità come il cambiamento climatico.

Aula Magna **ore 15:50 – 16:30**

Sezione VII
Didattica e storia della fisica
Presiedono: Carpineti M. (Università di Milano)
Leone M. (Università di Torino)

Relazione Generale

Guglielmo Marconi and the power of communication.

Raboy M.
McGill University, Montreal, Canada

Guglielmo Marconi (1874–1937) is one of the most enigmatic figures in the history of technology. Inventor, entrepreneur, and political actor, he was the first person to imagine and develop a practical system for using the radio spectrum to communicate. Mobile, long-distance, point-to-point communication —wireless— is directly derived from Marconi's technical innovations. So are radio, television and instantaneous news broadcasting. Marconi pioneered a corporate model for exploiting his inventions that has been emulated by the founders of Microsoft, Google, Apple, and Facebook, among others. He shared the Nobel Prize for Physics in 1909 and his company was instrumental to the origin of media institutions as varied as Vatican Radio and the BBC. Historically, Marconi stood at the interface between national sovereignty, colonialism, imperialism and transnational governance mechanisms. By 1900 Marconi was involved in patent disputes in several countries as well as the diplomatic rivalries between the Great Powers of the day. Marconi and his company were also at the center of government attempts to constrain communication. The arguments we hear today about the need to rethink media regulation because of the shift from analog to digital media recall these earlier discussions. My contribution will highlight Marconi's place in the emergence and durability of a global wireless communication environment.

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Teatro Duse **ore 17:30 – 20:00**

CELEBRANDO GUGLIELMO MARCONI

L'importanza della trasmissione di segnali a distanza nella ricerca scientifica

Introducono:

Angela Bracco (Università di Milano, Presidente SIF)

Giulia Fortunato (Presidente Fondazione Guglielmo Marconi)

Modera:

Silvia Rosa-Brusin (Giornalista scientifica)

Intervengono:

Roberto Battiston (Università di Trento, già Presidente ASI – Agenzia Spaziale Italiana)

Sergio Bertolucci (Università di Bologna, già Direttore della Ricerca CERN)

Gian Francesco Giudice (CERN, Direttore del Dipartimento di Fisica Teorica)

Patrizia Tavella (BIPM – Bureau International des Poids et Mesures, Direttrice del Dipartimento Tempo)

Filippo Maria Zerbi (Direttore Scientifico INAF – Istituto Nazionale di Astrofisica)

Antonio Zoccoli (Università di Bologna, Presidente INFN – Istituto Nazionale di Fisica Nucleare)

È prevista la trasmissione in streaming a cura del Multimedia Group INFN.

Aula Magna **ore 09:00 – 13:30**

Sezione I
Fisica nucleare e subnucleare
Presiede: Cei F. (Università di Pisa e INFN, Sezionde di Pisa)

Relazioni su invito

▲ **Low-energy kaon-nuclei interaction studies at the DAFNE collider: A strangeness Odyssey.**
Sgaramella F. for the SIDDHARTA-2 Collaboration
INFN, Laboratori Nazionali di Frascati
The low-energy QCD, the theory within the Standard Model describing the strong interaction, is still missing fundamental experimental results to achieve a breakthrough in its understanding. Among these, the low-energy kaon-nucleon/nuclei interaction studies are playing a key-role. Combining the excellent quality of the low-energy kaon beam delivered by the DAΦNE collider of INFN-LNF with new experimental techniques, like high-precision spectroscopic Silicon Drift Detectors, we performed unprecedented measurements in the low-energy strangeness sector in the framework of the SIDDHARTA Collaboration and are presently running the SIDDHARTA-2 experiment for very challenging kaonic atoms measurements, such as kaonic deuterium first measurement. I shall introduce the physics of kaonic atoms, the experiment, the first exciting results, and discuss future plans. I shall also present AMADEUS collaboration results on studies of low-energy kaons interacting with various nuclei. The experiments at DAΦNE represent a unique opportunity to unlock QCD secrets in the strangeness sector and contribute to better understand the role of strangeness in the Universe, from nuclei to the stars.

▲ **Il progetto LEA: studio dell'antimateria a bassa energia.**
Venturelli L.
Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Brescia e INFN, Sezione di Pavia
Gli esperimenti con l'antimateria a basse energie possono contribuire a risolvere alcuni enigmi della fisica contemporanea, come l'esistenza della materia oscura e il predominio della materia sull'antimateria nell'Universo, e a scoprire nuove leggi fisiche oltre il Modello Standard. Il progetto LEA (Low Energy Antimatter) racchiude le attività con antimateria a bassa energia svolte dai ricercatori italiani in ambito INFN, in particolar modo per la verifica della simmetria CPT, dell'invarianza di Lorentz e del principio di equivalenza debole. L'Antiproton Decelerator (AD) al CERN è un'importante risorsa per queste indagini, mediante misurazioni delle proprietà e del comportamento di antiprotoni, dell'elio antiprotonico e dell'anti-idrogeno. L'INFN partecipa attivamente a questi esperimenti, come ATHENA, AEgIS, ASACUSA e ALPHA. Importanti risultati sono stati finora ottenuti nella spettroscopia di precisione e più recentemente sul comportamento gravitazionale dell'anti-idrogeno. Parallelamente, vengono condotti studi sulle simmetrie fondamentali nel settore leptonico con esperimenti come PsICO e QUPLAS, svolti in laboratori italiani, con l'uso di positroni e positronio.

▲ **Status of the FAMU experiment.**
Pizzolotto C. for the FAMU collaboration
INFN, Sezione di Trieste
The goal of the FAMU laser spectroscopy experiment is to measure the hyperfine splitting of muonic hydrogen in its ground state. This transition represents a situation where the precision of QED computations surpasses the precision of the established values of basic physical parameters. Therefore, its measurement offers a unique chance to measure low energy proton magnetic structure more accurately than is otherwise achievable. The Zemach radius, defined in terms of the first moment of the convolution of the charge and magnetic moment distributions, is the physical quantity related to the electromagnetic properties of the proton that can be extracted from the hfs measurements. The experimental value of the Zemach radius places significant constraints on the parametrization of proton form factors as well as the theoretical models of proton electromagnetic structure. The p's hyperfine splitting is the quantity that is most sensitive to the proton's Zemach radius. The approach for this measurement identified by the FAMU collaboration will be described as well as the present status of the experiment after the first data taking at the Rutherford Appleton Laboratory (RAL) in 2023.

▲ **The FragmentatiOn Of Target experiment: Current status and near future.**
Villa M.
Dipartimento di Fisica e Astronomia, Università di Bologna e INFN, Sezione di Bologna
FOOT (FragmentatiOn Of Target) represents an innovative experiment in applied nuclear physics, dedicated to comprehensively understanding nuclear fragmentation processes crucial in oncological treatments with hadron beams and in the field of Radiation Protection in Space. Our physics program foresees a comprehensive set of measurements conducted in both direct and inverse kinematics, employing particle beams and targets similar to the composition of human tissues from one side and spacecraft shielding materials on the other. The primary objective of this experiment is to measure double differential cross-sections as a function of scattering angle and fragment energy within the 100-800 MeV/u range, achieving a precision level exceeding 5%. Currently, the FOOT Collaboration has developed two experimental set-ups: one based on nuclear emulsions devoted to charges $Z < 4$ and another based on electronic detectors for fragments with $Z > 2$. This presentation will provide an overview of the experiment's current status, preliminary results obtained with oxygen beams, and details on the upcoming experimental campaigns.

▲ **Fission modes towards the island of stability.**
Setaro P.A., Vardaci E., Di Nitto A., La Rana G., Alifano G., Spinosa S., Banerjee T.
Università degli studi di Napoli, Federico II e INFN, Sezione Napoli
The systematics of Mass-TKE distributions in spontaneous and low energy fission of heavy and superheavy nuclei reveals several complex features of the collective nuclear degree of freedom and structural effects that are matter of intense interest. The understanding of such features is particularly important in the mass range $256 \leq A \leq 276$ and charge range from $Z = 100$(Fm) to $Z = 110$(Ds) because this region of the nuclear chart constitutes the transitional region that connects the heavy actinides with the superheavy region. The idea of my work is the study of this region, in particular, the study of potential energy surface (PES), through the different shapes of fissioning nucleus to predict the mass and total kinetic energy (TKE) distributions of primary fission fragments without the introduction of dynamical effects. I have analysed the fissioning nucleus with a scission-point model and I have analysed its configurations just-before its separation into two fragments with lemniscate coordinate

(R, x), a convenient orthogonal system to describe the shape of a fissioning nucleus close to scission. The variety of the shapes involved are expansions around basic shape (Cassini ovals).

Comunicazioni

Interpretazione della produzione doppio-Higgs nel contesto delle teorie effettive: un approccio basato sul metodo "likelihood-free inference".

Barbieri M. ([1]), De Filippis N. ([1]), Prosper H. ([2]), Johnson K. ([2]), Bhat P. ([3])
([1]) *Università di Bari e INFN, Sezione di Bari*
([2]) *Florida State University, USA*
([3]) *Fermi National Accelerator Laboratory, USA*

La produzione di coppie di bosoni di Higgs (HH) è comunemente considerato un ambito di ricerca cruciale per la misura dell'accoppiamento trilineare del bosone di Higgs. Tuttavia, essa può anche fornire informazioni preziose su altri tipi di interazione, come quelle ipotizzate nei modelli di "Nuova Fisica" noti col nome di Teorie Effettive (EFT), in cui la sezione d'urto e le proprietà cinematiche delle coppie HH dipendono dai vari coefficienti di Wilson associati agli operatori della teoria. Questa presentazione riassume gli attuali sforzi nello sviluppo degli strumenti d'indagine propri della teoria HEFT (Higgs Effective Field Theory), per la produzione di coppie HH attraverso la fusione gluone-gluone. Viene proposto, inoltre, l'utilizzo di un innovativo metodo di indagine basato sulla "likelihood-free inference" (o "simulation-based inference"), una tecnica che sta guadagnando popolarità in vari campi, quando le complessità dei modelli, degli errori sistematici, degli effetti di selezione, ecc., rendono impraticabile un approccio basato sulla funzione di verosimiglianza. L'obiettivo finale è quello di riuscire a predire con precisione gli spettri di massa invariante doppio Higgs.

Investigating the Pauli exclusion principle across the periodic table with the VIP-3 experiment.

Manti S.
INFN, Laboratori Nazionali di Frascati

The Pauli Exclusion Principle (PEP) is a fundamental principle behind the stability of matter, which finds its foundation at the core of quantum mechanics. Various experiments have been conducted to test the validity of PEP, inspired by theoretical models beyond the Standard Model of particle physics. Among these, the VIP series of experiments has consistently demonstrated improvements in measuring the limits of PEP violations through the search of PEP-forbidden X-ray transitions in copper. We discuss the status of the experiment and the latest results, also in testing quantum gravity models and showcase the latest advancements for the future: VIP-3 experiment, which expands the investigation to several elements across the periodic table, including silver, zirconium, palladium, and tin. Supported by Multi-Configuration Dirac-Fock calculations for the predicted forbidden transitions in these elements, our work not only refines our understanding of PEP but also helps establish more stringent limits on its violations across a wider array of materials.

Search for Left-Right Symmetric Model heavy neutrinos in leptonic final states using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector.

Sanzani E.
Università di Bologna e INFN, Sezione di Bologna

The discovery of neutrino oscillations implies non-null masses which are difficult to accommodate in a natural way through a pure Standard Model (SM) Yukawa coupling to the

Higgs field. An interesting Beyond the SM scenario is provided by the Left-Right Symmetric Model (LRSM). Parity is broken spontaneously and Majorana mass for the right-handed neutrino N is generated through spontaneous breaking of $SU(2)_R$. Furthermore, via the See-Saw mechanism, the lightness of left-handed neutrinos is explained. In this contribution, a new final state search performed with ATLAS Run2 data is presented. This search investigates the production of two Ns which decay in two jets and one lepton each, namely $pp \to NN \to 2\ell 4j$. The dominant mediator for this process is a Majorana Higgs Δ. In this scenario, lepton number violation is allowed, so the final state leptons signs can be equal or opposite. The displacement of the N decay vertex can provide additional discriminating power. A unexplored low N mass regime, below 80 GeV, is probed for Δ masses which span from ~ 60 GeV to ~ 180 GeV.

Intermediate mass kaonic atoms with CdZnTe detectors at the DAΦNE collider.

Artibani F. ([1])([2]), Curceanu C. ([1])
([1]) *INFN, Laboratori Nazionali di Frascati*
([2]) *Dipartimento di Matematica e Fisica, Università di Roma Tre*

The SIDDHARTA-2 collaboration at the INFN Laboratories of Frascati aims to perform precision measurement of kaonic atoms, charting the periodic table. The kaonic atoms data base contains older than 40 years data, some of which contradictory or already proved wrong, so new measurements are a must as input to theories describing the kaon-nucleon(s) interaction at low-energy. The recent improvements on CdZnTe detector technologies, in terms of energy resolution, stability and efficiency, make the use of these devices as ideal tools to measure intermediate-mass kaonic atoms transitions. The collaboration successfully installed and operated for the first time a CdZnTe based setup in a collider, the DAFNE collider at INFN-LNF. We present the very promising preliminary observations of kaonic atoms with two different targets (Al and Cu) performed in 2024 and discuss future plans.

Positronium Laser Cooling.

Caravita R. ([1]), Glöggler L. T. ([2]), Gusakova N. ([2])([3]), Rienäcker B. ([4]), Camper A. ([5]), Huck S. ([2])([6]), Volponi M. ([1])([2])([7]), Wolz T. ([2]), Penasa L. ([1])([7]), Krumins V. ([2])([8]), Gustafsson F. P. ([2]), Comparat D. ([9]), Auzins M. ([8]), Bergmann B. ([10]), Burian P. ([10]), Brusa R. S. ([1])([7]), Castelli F. ([11])([12]), Cerchiari G. ([13]), Ciuryło R. ([14]), Consolati G. ([11])([15]), Doser M. ([2]), Graczykowski Ł. ([16]), Grosbart M. ([2]), Guatieri F. ([1])([7]), Haider S. ([2]), Janik M. A. ([16]), Kasprowicz G. ([17]), Khatri G. ([2]), Kłosowski Ł. ([14]), Kornakov G. ([16]), Lappo L. ([16]), Linek A. ([14]), Malamant J. ([5]), Mariazzi S. ([1])([7]), Petracek V. ([18]), Piwiński M. ([14]), Pospisil S. ([10]), Povolo L. ([1])([7]), Prelz F. ([11]), Rangwala S. A. ([19]), Rauschendorfer T. ([2])([20])
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Experimenting with Positronium (Ps), the short-lived atom of an electron and a positron, to test bound-state QED and constraint violations to the Equivalence Principle in the lepton sector, has been limited so far by the large velocity distribution of available Ps sources. Ps laser cooling was proposed over 30 years ago as the key enabling technique to overcome such limitations. We present here the first demonstration of Ps cooling along the 13S-23P transition, achieved by developing a custom alexandrite laser, specifically designed to meet its demanding requirements: pulse energies of several mJ in the deep UV (243 nm), bandwidth of about 100 GHz, pulse duration above 100 ns with a fast falling-edge. Ps cooling was observed by measuring the Doppler broadening of its 13S-33P line with a second laser, right after cooling was completed. The equivalent temperature of the Ps atoms exiting from a porous target (at room temperature) hit by a positron beam decreased from 380 K to 170 K. Such methodology will allow the developing Ps sources below the 10 K temperature with high intensities, and it is the first milestone towards the Bose-Einstein Condensation of an antimatter system.

Searching for the microscopic origin of shape coexistence in Ca isotopes.

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Nuclear shape coexistence plays a crucial role in understanding the microscopic origin of nuclear deformation. The *Ca* isotopic chain between ^{40}Ca and ^{48}Ca is an optimal test area that can provide key information on shape coexistence when moving from the valley of stability towards the neutron-rich region of the Segrè chart. This work aims to perform complete low-spin spectroscopy of ^{42,43,44,45}Ca isotopes, complementary to the already existing data of ^{41,47,49}Ca, and to look for evidence of shape coexistence in the $A \sim 40$ region. As a first step in this direction, we focused on ^{42}Ca, where evidence for a 0^+ excitation associated with a superdeformed shape has been obtained in a Coulex experiment. The ^{42}Ca nucleus of interest was populated with a (n_{th}, γ) reaction on a ^{41}Ca radioactive target. The γ cascades emitted from the 11.480 MeV capture state were detected using the 32 HPGe crystals array FIPPS, at ILL (Grenoble). The result of this work is a complex level scheme that will be presented together with preliminary angular correlation studies made to establish spin and parities of several excited states of ^{42}Ca.

Study of J/Ψ v2 for Pb-Pb collisions at $\sqrt{NN} = 5.36$ TeV using run3 data of ALICE at the LHC.

Thakur D.
Dipartimento di Fisica, Università di Torino e INFN, Sezione di Torino

The azimuthal flow measurements of the particle provide evidence of the QGP medium and are a powerful tool for studying its evolution in heavy-ion collisions. Hence, the anisotropic flow of J/Ψ provides information primarily from the early stages of the high-energy collisions. The second-order Fourier coefficient (v2) of J/Ψ mesons is an observable sensitive to the degree of thermalization of charm quarks in the medium at low pT, as well as to the path length dependence of its energy loss. The Pb-Pb data sample collected by the ALICE experiment during LHC Run 3 is approximately twice as large as the one collected in Run 2, representing a unique opportunity to reach higher precision in statistics-hungry measurements. This talk will detail the analyses of the J/Ψ v2 via the dimuons channel to reconstruct the quarkonium states and the extraction of flow harmonics using event-plane and scalar-product methods using Run 3 Pb-Pb data at $\sqrt{NN} = 5.36$ TeV at forward rapidity ($2.5 < y < 4$).

Strange baryon enhancement with effective energy in pp collisions at the LHC.

Ercolessi F.
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The enhanced production of strange hadrons in heavy-ion collisions relative to that in pp collisions is historically considered one of the signatures of the formation of the quark-gluon plasma. At the LHC, the ALICE experiment observed that the yield ratios of strange to non-strange hadrons increase with the charged-particle multiplicity at midrapidity, evolving smoothly across all collision systems. The understanding of the origin of this effect in small systems remains unsolved. This talk presents an overview of recent results published by the ALICE Collaboration on the production of (multi-)strange hadrons in pp collisions at $\sqrt{s} = 13$ TeV. This study adopts a new multi-differential approach, introducing the concept of effective available energy to measure strangeness production at the LHC and disentangle initial and final state effects. The ALICE Zero Degree Calorimeters are used to measure the energy carried by forward emitted baryons in pp collisions, which reduces the initial energy available for particle production with respect to the nominal one. The results are presented and compared with predictions from state-of-the-art models.

The ITk detector for the ATLAS experiment, overview of the status of the construction and expected performance.

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The High Luminosity Phase of the LHC (HL-LHC) is scheduled to begin in 2029 and is expected to provide ten times more data than what will be collected at the end of Run3. The HL-LHC environment results in severe requirements in terms of occupancy, bandwidth and radiation hardness for the current ATLAS Inner Detector. The ATLAS collaboration has therefore undertaken the project of designing and building an all-silicon new Inner Tracker (ITk), which will substitute the current Inner Detector for operation at the HL-LHC. The new pixel detector will cover a sensitive area of 13 square meters, made of planar and 3D silicon sensors bump bonded to readout with new Front-End ASIC, developed by the RD53 Collaboration. This talk will provide a snapshot of the ongoing efforts in the construction of the pixel detector, focusing in particular on the status of the Innermost layer, which is equipped with 3D sensors in order to be more compliant to the extreme conditions of the

HL-LHC environment. Moreover expected performance of the new tracker will be briefly reported.

Analysis of nuclear clustering at intermediate energies with the FOOT experiment.

Caglioni A., Battistoni G., Muraro S., Dong Y., per la FOOT Collaboration
INFN, Sezione di Milano

The interaction between nucleons promotes the tendency of the constituents of a system to congregate in clusters. The highest correlated system within nuclei is the α particle which generates the α-clustering phenomenon. Clustering phenomena in light nuclei can be probed by investigating the characteristics of their excited states obtained by means of experiments involving nucleus-nucleus collisions. This phenomenology has been studied up to the Fermi energies. The FOOT (FragmentatiOn Of Target) experiment has been designed to measure fragmentation cross sections of interest for hadrontherapy and it can study the α clustering at high energies (> 150 MeV/u). Monte Carlo simulations have been used to evaluate the possibilities of this experiment to measure multiple α production in the fragmentation of Carbon (C) projectiles on a C target. Insights on the intermediate states produced in C ion fragmentation, such as the case of 8Be, whether in the ground or in the excited state, can be obtained from the distribution of the angular separation between pairs of α particles. Results from this study will be presented together with the preliminary analysis of 16O fragmentation data analysis.

γ decay from near-threshold states in ^{11}B and ^{14}C.

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We discuss recent results on the γ decay from near-threshold states in light nuclei, in particular concerning ^{11}B and ^{14}C. Such narrow resonances, lying within few-hundred keV from particle-decay thresholds, are expected to provide relevant information about rare decay processes (e.g. β-delayed proton emission of ^{11}Be) and microscopic mechanism involved in collectivization and clusterization phenomena. In the context of the Shell Model Embedded in the Continuum (SMEC), the appearance of near-threshold state emerges as a universal phenomenon, resulting from the coupling of a core with the closest particle decay channel. Our goal was to study the γ-decay branch of these states, which is an extremely sensitive probe of their wavefunction, expected to be of the order of 10^{-3}-10^{-5}. Two experiment were made, employing the GALILEO-TRACE setup at LNL for ^{11}B and the GRETINA-ORRUBA setup at ANL for ^{14}C. Fusion-evaporation reactions were employed to populate these resonances and measure their γ-decay branch. The obtained results and their implications on the open-quantum system picture of light nuclei will be discussed.

Metastable positronium clouds production for fundamental experiments.

Mariazzi S., Caravita R., Sennen Brusa R.
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A new bunched positron beam is currently under final development at the Antimatter Laboratory (AML) of the University of Trento. The beam, called PsICO (Positronium Interferometry and Correlation Observation), will be dedicated to the production of clouds of positronium and its excitation to a metastable state for fundamental experiments. In particular, two experiments are planned on this purely leptonic matter-antimatter system: i) measurements of the entanglement in the polarization degree of the three gamma rays generated by the self-annihilation of positronium in selected quantum states and ii) force-sensitive inertial measurements (including gravity) on metastable positronium. In this contribution, the characteristics of the new positron beam will be presented. Moreover, the concept and methodology of the two planned experiments will be described.

Theoretical modelling of ^{7}Be decay rates in compact magnetoplasma.

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Phase-two of PANDORA (Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry) project aims to study the orbital electron capture decay rate of the radionuclide ^{7}Be in a 16O ECR (Electron Cyclotron Resonance) plasma, resembling a stellar environment. Initially, a theoretical study of the starting conditions effects of neutral ^{7}Be on the simulation results is performed, as the ion PIC-MC (Particle In Cell-Monte Carlo) code is highly sensitive to the initial conditions of ^{7}Be. This allows to understand how the final results change. The second part is about in-plasma atomic processes: an in-depth study on the coronal model is carried out. This allows to compute the LPD (Level Population Distribution) of ^{7}Be ions, which strongly influences the in-plasma decay rate. Till now, only the effects of the CSD (Charge State Distribution) were taken into account. The novelty of this thesis is that, for the first time ever, a model is developed to study also the influence of

the LPD on the decay properties of ^{7}Be, extending the ion PIC-MC code to radioisotopes for PANDORA, making this code more complete and appropriate for the ECR plasma trap.

Two-phonon octupole excitation in ^{96}Zr.

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In this work we present the preliminary analysis of an experiment performed at INFN LNL in November 2023 aimed at studying the two-octupole phonon collectivity in ^{96}Zr. The goal of the experiment was to perform a γ-decay branching ratio measurement from the 6^+ to the 3^- state, so as to extract the B(E3; $6^+ \rightarrow 3^-$) value. If large, this parameter would indicate for the 6^+ level to be a member of the $3^- \times 3^-$ multiplet. The 6^+ state was populated via the ^{96}Zr(p, p$'$)^{96}Zr proton inelastic scattering and the scattered protons were measured in the SAURON Double-Sided Silicon Strip detector. These were used to select the reaction channel of interest, in coincidence with the γ rays in the AGATA array.

Aula 1D **ore 09:00 – 13:30**

Sezione II
Fisica della materia
Presiede: Panaccione G. (CNR)

Relazioni su invito

▲ **Investigation of attosecond dynamics in semiconductors based on table top laser sources.**
Vozzi C.
Consiglio Nazionale delle Ricerche - Istituto di Fotonica e Nanotecnologie
Tabletop XUV sources based on high-order harmonic generation (HHG) allow ultrafast spectroscopy to achieve extreme time resolutions, and site and chemical selectivity. These features make it possible to investigate fundamental aspects of how light interacts with matter. I will discuss efficient XUV generation inside a microfluidic device made by femtosecond laser exposure followed by chemical etching, which allows controlling and manipulating the harmonic-generation conditions in gas at the micro-metre scale with great flexibility, enabling a high photon-flux and phase matching on broadband harmonics up to 200 eV. This XUV source is coupled with a beamline for transient absorption and reflectivity measurements in molecules and solids recently built at CNR-IFN. Furthermore, I will discuss how HHG can be used as a spectroscopic tool in solids, showing how polarization and time-resolved HHG can be used to investigate ultrafast processes in condensed media. Because the process is highly nonlinear, this could enable us to study properties of solids far from equilibrium with higher sensitivity than typical femtosecond pump-probe techniques.

▲ **Ultrafast dynamics of photoinduced polaron formation in cerium oxide investigated by pump-probe XAS at the EuXFEL.**
Luches P. ([1]), Pelatti S. ([1])([2]), Spurio E. ([1])([2]), Pelli Cresi J.S. ([3]), Benedetti S. ([1]), di Bona A. ([1]), D'Addato S. ([1])([2]), Zalden P. ([4]), Jiang Y. ([4]), Uemura Y. ([4]), Wang H. ([4]), Vinci D. ([4]), Huang X. ([4]), Lima F. ([4]), Biednov M. ([4]), Khakhulin D. ([4]), Milne C. ([4]), Turchini S. ([5]), Ammirati G. ([5]), O'Keeffe P. ([6]), Catone D. ([5]), Boscherini F. ([7])
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An accurate description of the processes occurring after photoexcitation in photocatalysts is a key issue to understand and possibly optimize the light-induced functionality of such materials. The European X-ray free electron laser (EuXFEL) facility provides ultra-short and ultra-intense X-ray pulses, suitable to follow the dynamics of photoexcited charges and the consequent modifications that occur in photocatalysts upon photoexcitation providing also element sensitivity and a time resolution below 100 fs. We will discuss the results of recent Ce L_3-edge pump-probe X-ray absorption spectroscopy experiments performed at the

FXE instrument of the EuXFEL on cerium oxide, a material with relevant redox properties that can be enhanced by photoexcitation. The analysis of the pump-probe spectra in the near edge (XANES) and in the extended energy (EXAFS) range, combined with the time correlation observed in the dynamics of electronic and local atomic structure rearrangements, have allowed us to gain previously unavailable details on the formation of photoinduced small-polaron states, that possibly determine a long-living transient increase of the redox functionality of the material.

▲ **Magnetic microscopy at the nanoscale.**

Locatelli A.
Elettra - Sincrotrone Trieste S.C.p.A.

Photoemission electron microscopy (PEEM) is a powerful and versatile full-field imaging method, capable of lateral resolution well into the nanoscale. PEEM has flourished at third-generation synchrotrons, following the development of powerful sources of linearly or circularly polarized radiation in the soft X-ray spectral range, resulting in tremendous progress in the field of surface and thin-film magnetism. Thanks to elemental sensitivity, synchrotron-based PEEM has opened the possibility to monitor spin reorientation transitions and image the magnetic state in complex systems comprising ferromagnetic and antiferromagnetic layers. Most recently, PEEM has tackled the challenge of studying non-trivial magnetic structures such as skyrmions. In my contribution, I will focus on work conducted with the PEEM microscope at the Nanospectroscopy beamline of Elettra, highlighting the power and versatility of the set-up. A variety of studies will be presented and discussed, each illustrating key aspects of magnetism in thin films and nanostructures, particularly nanowires. The emphasis will be placed on systems exhibiting enhanced perpendicular magnetization and in magnetically coupled bilayers.

Comunicazioni

● **Potassium-based perovskites: The key role of polar nanoregions in their cubic-to-tetragonal phase transition.**

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An experimental study on different disordered potassium-based perovskite compounds is carried out, a class of single crystals hosting nanometric-sized polarized regions (PNRs). By combining different techniques such as Raman spectroscopy, dielectric response, and dielectric calorimetry (Froehlich entropy estimation), we investigate the specific behavior straddling the nominal cubic-to-tetragonal long-range phase transition. Our results demonstrate that the arising of phase transition is driven by the temperature evolution of polar nanoregions (PNRs), whose behavior is correlated with several macroscopic features of the samples. In particular, the onset of the phase transition occurs when PNRs display a percolation process, which is highlighted by the sudden arising of a specific Raman mode.

How does structural disorder impact heterogeneous catalysts? Ammonia decomposition on non-stoichiometric lithium imide.

Mambretti F., Raucci R., Yang M., Parrinello M.
Istituto Italiano di Tecnologia, Genova

Ammonia has recently attracted attention due to its potential as a hydrogen vector in a low-carbon economy. The feasibility of H_2 production from NH_3 crucially hinges on the development of efficient catalysts. To this end, experiments on lithium imide (Li_2NH) and, later, on the imide-amide non stoichiometric compounds $Li_{2-x}(NH_2)_x(NH)_{1-x}$ have evidenced highly promising catalytic properties. Progress in building machine learning-based reactive potentials with near-quantum accuracy and the use of enhanced sampling techniques to accelerate the occurrence of reactive events have recently enabled the simulation of the NH_3 decomposition on Li_2NH. Here, we extend our recent work, studying the imide-amide mixture with molecular dynamics to elucidate the origin of the reported enhanced catalytic efficiency, providing atomic-scale insights into the mechanism and an estimate of the free energy for the rate limiting step (*i.e.*, the formation of an N-N bond). We highlight the role played by enhanced fluctuations of the surface layers, with NH_2 groups featuring a larger mobility: catalytic reactions are favored, making the system flexible enough to accommodate and stabilize reactive intermediates.

Physical synthesis and characterization of Cu@CaF_2 core@shell nanoclusters.

D'Addato S. (1)(2), Spurio E. (1)(2), Pelatti S. (1)(2), Gazzadi G. C. (2), Rosi P. (2), Rotunno E. (2), Paolicelli G. (2), Luches P. (2)
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The use of physical synthesis of nanoparticles (NPs) offers advantages, as it is single-step and ligand-free. These characteristics enhance the precision of NP structure analysis and elucidate their properties more accurately. Recently, various types of NPs have been prepared and studied. Techniques like co-deposition and sequential layer deposition have been exploited in fabricating core@shell NPs. These methodologies have enabled the creation of non-native oxide shells, easing the exploration of metal@metal oxide core@shell NPs by independently varying core diameter and shell thickness. This contribution presents findings on physically synthesized Cu@CaF_2 NPs, which can be significant due to their potential for enhancing power cell efficiency in photovoltaic devices through surface plasmon resonance (SPR). The characterization of NP assembly involved techniques such as SEM, TEM, AFM, *in situ* XPS and UV-VIS absorption spectroscopies. These analyses establish correlations among SPR behavior, film morphology, and core/shell interface properties, stressing the crucial role of precise synthesis procedures in tailoring the optical properties of these systems.

Morphological, plasmonic and electronic properties at the different stages of Cu NPs oxidation.

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Nanostructures of Cu and corresponding oxides are promising candidates for photocatalytic applications. The oxidation of Cu nanoparticles (NPs) influences position and shape of their plasmonic resonance. We investigated morphology and composition evolution of Cu NPs as a function of exposure to air plasma, and their spectral response in the UV-Vis region through the shift of the plasmonic resonance. The Cu NPs, after 30 s exposure to plasma are characterized by a Cu(0) core and a thin CuO shell, while the NPs dimensions and the

substrate coverage is unmodified. The optical spectra still show the plasmonic excitation of the NPs, red-shifted with respect to the initial situation, compatibly with a core@shell Cu@CuO system. After 90 s of plasma, no more Cu(0) is observed: the core turns into Cu_2O, while the CuO shell thickens. Some NPs start to exhibit internal voids typical of the nano-Kinkerdall effect, the surface coverage by CuO is enhanced and the NPs become closer, while the optical absorptance shows a faint plasmonic peak. After 120 s of plasma, almost all NPs present a hollow structure surrounded by a CuO shell, and the plasmon-related absorptance feature disappears.

Phosphorus on Cu(110) as decoupling buffer layer for organic molecules.

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Organic materials have shown potential applications in catalysis, electronics and photovoltaics. Among these, porphyrinoid compounds stand out in surface science due to their high thermal stability, enabling the deposition of molecular films via vacuum physical vapor deposition without damage. On the other hand, when these films are deposited onto a metal surface, the interaction between the porphyrins' macrocycle and the metal atom can deeply influence the molecular and electronic structure. Thus, in order to mitigate this interaction, one strategy involves the growth of a thin decoupling buffer layer between the substrate and the organic film. In our investigations, we have employed phosphorus for this purpose due to its capacity to form several 2D structures with predicted promising electronic properties. The results obtained by different complementary techniques, *i.e.*, Low-Energy Electron Diffraction (LEED), X-ray Photoelectron Spectroscopy (XPS) and Near Edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy, show that in the case of Zn-tetraphenylporphyrin (ZnTPP), the P layer is effective in decoupling the molecules from the Cu(110) substrate.

Metal functionalization of epitaxial graphene grown on porous 4H-SiC: Toward hydrogen storage and sensing applications.

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Porous carbon materials are currently employed in many applications. We have recently demonstrated the growth of epitaxial graphene on a porous 4H-SiC backbone, creating a three-dimensional graphene (3DG) which combines the properties of graphene with a porous structure. We have already employed pristine 3DG for hydrogen storage and sensing applications. Here, we present the first successful functionalization of 3DG with metal nanoparticles (NPs). We have utilized Au, Pd, and Ni, but the method can be easily extended to other metals. Scanning electron microscopy demonstrates the penetration of the NPs down to the bottom of the porous layer, creating a functionalized surface which is around 200 times larger than the sample top surface. In the case of Pd NPs, we measure a density of about 100 NPs/micron^2 at 1.5 micron below the surface. The samples are stable up to a temperature of 530 °C, above which a Pd silicide forms, which represents the limit of thermal

stability. Our results open the perspective to the use of 3DG as a versatile platform for catalytic applications, sensors, and energy storage and conversion.

Facile and fast synthesis of highly ordered $L1_0$-FeNi nanoparticles.

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The chemically ordered $L1_0$-FeNi alloy is a promising candidate for next-generation rare-earth–free permanent magnets, which can revolutionize the high-performance magnets market currently dominate by Nd-Fe-B. Despite many efforts, the experimental results fall short of theoretical predictions, and current approaches are not suitable for industrial implementation. In this contribution, we propose an innovative and efficient synthesis method that exploits the natural order of a crystalline Ni/Fe complex, which closely mimics the atomic organization in the $L1_0$ structure, to drive the formation of the ordered phase. By low-temperature reduction of the complex salt, carbon-coated aggregates of FeNi alloy nanoparticles (20–120 nm) with a $> 55\%$ of $L1_0$ phase, high coercivity (up to 65 mT) and large saturation magnetization ($\sim 140\,\mathrm{Am^2/kg}$) were obtained. The results pave the way for the development of a novel and sustainable route to produce high-anisotropy FeNi nanoparticles of potential interest for next-generation critical-element–free permanent magnets.

Synthesis and characterization of MoS_2 ultra-thin films.

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([1]) *Department of Mathematics and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, Italy*

([2]) *Nuclear Physics Institute, NPI, of CAS, Rez, Czech Republic*

Innovative materials such as ultra-thin films are extremely interesting and are being studied especially for possible applications in new-generation energy devices such as solar cells and batteries. Here we present a study in which we firstly synthesized MoS_2 few-layers samples by means of the Ion Beam Sputtering technique and we characterized them to collect a variety of fundamental information. In fact, a fine control over structural characteristics of materials, such as crystalline quality (structure and imperfections of crystals), thickness of grown films and density is extremely important for the realization of devices with targeted performances. After a brief introduction on the synthesis procedure and the techniques used, we will show some measurements, performed to identify some physical properties mentioned above.

Exploring nanostructures with scanning near-field optical microscopy.

Becerril Rodriguez D., Luce M., Cricenti A.

Institute of Structure of Matter-CNR

Scanning near-field optical microscopy (SNOM) stands as an important tool in nanotechnology research, offering unparalleled insights into the intricate world of nanostructures and nanomaterials. This contribution highlights recent advancements in SNOM setups in the CNR-Institute of Structure of Matter. We showcase the capabilities of these techniques

in imaging and probing of the optical response with nanometric resolution and sensitivity. Moreover, we delve into some challenges and common artefacts when using these setups, as well as their identification and possible solutions. Through the synergy of optics and nanoscience, optical scanning probe microscopy (SPM) emerges as a versatile platform for interdisciplinary research, facilitating breakthroughs in fields ranging from materials science to biophysics. This presentation serves to inspire collaboration and foster discussions among researchers aiming to push the boundaries of optical SPM for diverse applications in fundamental science and technology.

Hydrides of multicomponent Zr-based C14 Laves-type intermetallic compound containing Nb, V, Fe, Mn, Ni, Cr for hydrogen storage at variable pressure-temperature conditions.

Verna D. ([1]), Yartys V. ([2]), Pasquini L. ([1])
([1]) *University of Bologna, Italy*
([2]) *Institute for Energy Technology, Norway*

Among various types of intermetallic compounds Laves-type AB_2 alloys form the largest group containing more than 1000 representatives. The majority of Laves phases crystallize in either hexagonal (C14) or FCC (C15) structures. The ideal ratio of the atomic radii is $r_A/r_B = 1.225$, even if a wide range of ratios has been reported. The capability to form solid solutions for both A and B sites further extends the list of possible compositions. Some of these alloys find application in various hydrogen-related technologies, depending on the conditions at which they can absorb and desorb hydrogen. These applications include hydrogen getters, battery anodes, ambient condition hydrogen storage, thermally driven hydrogen compression. We present a detailed study of the Laves-type compound formed by Zr, V and Nb that crystallizes with a hexagonal C14 structure, in which the Zr occupies the A site, while V and Nb occupy the B sites. Its hydride has a high volumetric hydrogen density and is very stable. Different substituents like Ni, Mn and Fe are employed to tailor the desorption temperature, with the aim to achieve reversible hydrogen storage close to ambient temperature.

Addressing the moiré exciton thermal stability and local atomic registry in two-dimensional $WSe_2/MoSe_2$ heterostructures by magneto-optical spectroscopy measurements.

Tuzi F. ([1]), Blundo E. ([1]), Cianci S. ([1]), Cuccu M. ([1]), Olkowska-Pucko K. ([2]), Kipczak Ł. ([2]), Contestabile G. ([1]), Miriametro A. ([1])([1]), Felici M. ([1]), Pettinari G. ([3]), Taniguchi T. ([4]), Watanabe K. ([5]), Babiński A. ([2]), Molas M. R. ([2]), Polimeni A. ([1])
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Moiré excitons (MXs) are electron-hole pairs confined in the minima of the moiré potential that is formed when monolayers with differing lattice orientations are stacked to form two-dimensional heterostructures (HSs). MXs can act as nanoscale-ordered quantum sources and allow the observation of Bose-Einstein condensates at relatively high temperatures. In

this contribution, we address the thermal stability and the electronic properties of MXs in a $WSe_2/MoSe_2$ HS by time-resolved and continuous-wave micro-photoluminescence (μ-PL) and magneto-μ-PL. By studying the exciton emission lineshape, temporal dynamics, and magnetic moment as a function of temperature and photo-generated carrier density, we first show that MXs turn into free interlayer excitons above 100 K. In addition, we unveil that the MX emission spectrum is composed of multiple contributions with distinct Zeeman splitting values. We demonstrate that those contributions map on the minima of the moiré potential corresponding to different local atomic registries. Thus, our work provides a thorough picture of the MX electronic properties and their evolution with increasing temperatures.

Ultrafast broadband optical spectroscopy of a layered metal phosphorus trichalcogenide.

Baserga A. ([1]), Bertolotti M. ([1]), Grandi F. ([1])([2]), Jadrisko V. ([1]), Cinquanta E. ([2]), Sofer Z. ([3]), Cerullo G. ([1]), Gadermaier C. ([1]), Dal Conte S. ([1])

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([3]) *Institute of Chemical Technology, Technická, Czech Republic*

Two-dimensional van der Waals materials have attracted great attention because of their peculiar properties like strong light-matter interactions and pronounced excitonic effects. Metal phosphorus trichalcogenides (MPX_3) are a family of perovskites of these materials which shows unique magnetic and optoelectronic. $HgPSe_3$ is a semiconductor of this species with an optical gap around 2 eV that shows remarkable absorption properties making it a great candidate for broadband light detection. Although the static optical response has been already investigated, its non-equilibrium optical response is still totally unexplored. We exploited broadband optical pump-probe spectroscopy to probe the transient optical response of bulk $HgPSe_3$ down to cryogenic temperatures over a wide energy range in the visible to the near-infrared spectral window. The transient reflectivity signal at 78 K above 2.1 eV is dominated by strong interband transitions at 2.15 eV, 2.3 eV and 2.44 eV. The dynamics of the low energy peak is characterized by two exponential dynamics of time constants of about 3 ps and 180 ps, hinting at photogenerated long-lived mobile carriers.

Long -range signal recording in perovskite materials.

Margotti L., Fabbri L., Ciavatti A., Cramer T., Fraboni B.

Dipartimento di Fisica e Astronomia, Università di Bologna

The past decade has been dominated by the outstanding growth of lead-halide perovskites in the field of photovoltaics, reaching up to 25.6% efficiency. These semiconducting structures have also garnered significant interest for radiation detection applications for their exceptional intrinsic properties —high atomic number, low dark current, high S/N ratio— leading them among the most studied classes of materials. Nevertheless, a lot is yet to be discovered in matter of charge transport and opto-electronic mechanisms. We here report a fascinating photo-induced phenomenon wherein 2D hybrid perovskites exhibit electrical signal recording even at illumination far from the applied electric field. Investigations are performed with focalised light and Atomic Force Microscopy: this non-local photoresponse is proven both in photovoltage and photocurrent to be on a centimetre-scale, thus outcasting conventional interpretation of photon recycling and charge diffusion dynamics. Therefore, a deep understanding of the mechanism that drives far-field electrical response generation in perovskites promises efficiency enhancement and advancements in optoelectronic devices and photovoltaics.

Dependence of built-in tensile strain on lateral size of monolayer MoS_2 grown by liquid precursor chemical vapor deposition.

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Strain engineering is an efficient tool to tune and tailor the electrical and optical properties of 2D materials. The built-in strain can be tuned during the synthesis process of a two-dimensional semiconductor, as molybdenum disulfide, by employing different growth substrate with peculiar thermal properties. In this contribution we demonstrate that the built-in strain of MoS_2 monolayers, grown on SiO_2/Si substrate using liquid precursors chemical vapor deposition, is mainly dominated by the lateral size of the monolayer. In fact, we identify a critical size equal to 20 μm, from which the built-in strain increases drastically. The built-in strain is maximized for 60 μm sized monolayer, leading to 1.2% tensile strain with a partial release of strain close to the monolayer triangular vertexes due to formation of nanocracks. These findings also imply that the standard method for evaluation of the number of layers based on the Raman modes separation can become unreliable for highly strained monolayer with a lateral size above 20 μm.

Optimizing gold-assisted exfoliation of layered materials using (3-aminopropyl)triethoxysilane (APTES) to achieve large-area monolayers.

Curreli N., Petrini N., Kriegel I.
Functional Nanosystems, Italian Institute of Technology, Italy

Gold-assisted exfoliation is a promising technique for obtaining large-area, high-quality monolayers from layered materials. However, it often suffers from low yield due to poor adhesion between the gold foil and the substrate. In this study, we address this issue by using (3-aminopropyl)triethoxysilane (APTES), a silane compound known to enhance adhesion on hydrophilic surfaces. By applying APTES to the substrate, we observed a significant improvement in adhesion, resulting in reduced delamination and an increased yield during the exfoliation process. We compared the performance of APTES-treated gold-assisted exfoliation with conventional scotch tape exfoliation through comprehensive characterization techniques. Additionally, this approach allows for the efficient transfer of exfoliated monolayers onto a variety of rigid substrates, such as Si/SiO_2, ITO, and Al_2O_3, as well as flexible substrates like PET and Kapton. Using APTES in gold-assisted exfoliation provides a robust method for producing large-area monolayers, opening new pathways for integrating 2D materials into a wide range of applications, from electronic devices to photonic systems.

Charged- and multi-exciton dynamics in colloidal quantum dot molecules.

Florio D. ([1])([2]), Levi A. ([3]), Hou B. ([4]), Hörmann M. ([1]), Rabani E. ([4])([5])([6]), Cerullo G. ([1])([2]), Banin U. ([3]), Camargo F.V.A. ([2])
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([6]) *The Raymond and Beverly Sackler Center of Computational Molecular and Materials Science, Tel Aviv University, Israel*

Colloidal quantum dot molecules (CQDMs) are artificial nanocrystal structures resulting from the fusion of two core-shell quantum dots, exhibiting both structural and electronic coupling. Previous studies employing single-particle spectroscopy have demonstrated significant disparities in the emissive behavior of CQDMs compared to their constituent quantum dots, implying the formation of novel charged- and multi-excitonic species. To interpret the different emissive properties, it is anticipated how these new excitonic species in the CQDMs participate in non-radiative Auger processes distinct from those in the constituent quantum dots. To elucidate these differences, we employ femtosecond transient absorption (TA) spectroscopy. Through this method, we conduct a comparative analysis of the relaxation dynamics of the 1S exciton in a homodimer composed of two CdSe/CdS core-shell quantum dots and that of the constituent monomer. This analysis spans a range of excitation conditions, gradually progressing from the single-exciton regime to the multi-exciton regime.

Aula 1E **ore 09:00 – 13:30**

Sezione III
Astrofisica
Presiede: Mercurio A. (Università di Salerno)

Relazioni su invito

▲ **Galaxy evolution through the archaeological treasure of deep spectroscopic surveys.**
Gallazzi A.R.
INAF, Osservatorio Astrofisico di Arcetri
The physical properties, such as age and chemical abundances, of different generations of stars in galaxies constitute a fossil record of their past star formation histories. They can thus provide important constraints on the evolutionary paths of massive quiescent galaxies. Decoding stellar population physical parameters from high-quality galaxy spectra is the so-called archaeological approach, extensively adopted in the present-day Universe. Only recent deep spectroscopic surveys at intermediate redshifts have opened the possibility to perform archaeological studies at earlier cosmological epochs, complementing studies on the evolution of the number density of different galaxy types. In this contribution I will give an overview of the main results from our efforts to constrain stellar population properties from low-redshift spectroscopic surveys and their dependence on mass, star formation activity, and environment. I will then present the evolution of these stellar population scaling relations in the last 6 billion years, from the LEGA-C survey. I will then highlight prospects from the upcoming WEAVE-StePS and 4MOST-StePS surveys.

▲ **Progenitors of relativistic supernovae.**
Izzo L.
INAF, Osservatorio Astronomico di Capodimonte
Type Ic broad-lined supernovae (SNe) are core-collapse stripped-envelope supernovae showing high-velocity broad absorption lines, which suggest the presence of a central engine in addition to the neutrino heating mechanism. Ic-BL SNe are also associated with gamma-ray bursts (GRBs), but only a small fraction of these explosions produce a GRB. Factors like Fe-core rotation and metallicity may affect the jet's ability to penetrate, influencing GRB production. In this contribution, I will present and discuss the observational evidence that led us to propose the presence of choked jets even in core-collapse events without GRBs. Multi-messenger probes can further constrain this model in the next years.

▲ **Probing the life and death of massive stars through supernova remnants.**
Orlando S.
INAF, Osservatorio Astronomico di Palermo
The remnants of core-collapse supernovae (SNe) exhibit intricate morphologies and a highly non-uniform distribution of stellar debris. In the case of young remnants (less than 5000 years old), their properties encode valuable insights into the inner processes of the SN engine, including nucleosynthetic yields and large-scale asymmetries originating from the early stages of the explosion. Additional characteristics of the remnants can reflect the nature of the progenitor stars and the interactions between the remnants and the circumstellar medium (CSM), shaped by the progenitor's mass-loss history. Hence, investigating the connection

between young SNRs, parent SNe, and progenitor massive stars can be of paramount importance to delve into the physics of SN engines, and to investigate the final stages of massive star evolution and the elusive mechanisms governing their mass loss. In this contribution, I will review recent advances in modeling young to middle-aged SNRs, focusing on investigations aimed at linking the observed physical and chemical properties of SNRs to their progenitor stars and SN explosions, thus telling us about life and death of massive stars.

Comunicazioni

The TeV blazar sequence: Towards a physical understanding.

Bovolon F. ([1]), Righi C. ([2]), Prandini E. ([1])([3]), Viale I. ([1])([3])
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([2]) *INAF, Osservatorio Astronomico di Merate*
([3]) *INFN, Sezione di Padova*

Blazars, a class of jetted active galactic nuclei, are the most numerous permanent extragalactic gamma-ray sources. Their peculiar double-bumped spectral energy distributions (SEDs) are usually interpreted as non-thermal emission from a relativistic jet of particles closely aligned with the line of sight. Population studies have highlighted a "blazar sequence", i.e. an anticorrelation between the frequency of the low-energy peak and its bolometric luminosity. Its existence and origin are still unclear, despite the influx of new data, including in the TeV band. This work thus aims at building a sequence that finally includes very high-energy gamma-ray spectra. A sample of TeV-detected blazars was extracted from the 4LAC-DR2 catalog, and their average broadband SEDs were binned according to their low-energy peak frequencies. BL Lac-type only sources were chosen, allowing for use of the same emission model (one-zone Synchrotron Self-Compton) for all. The SED of one representative blazar per bin was modeled with different techniques, including machine learning: best-fit parameters were compared to search for trends hinting at the physical mechanisms underlying the sequence.

X-ray view of dual AGN candidates.

Battistini L.
Dipartimento di Matematica e Fisica, Università di Roma Tre

Dual Active Galactic Nuclei (DAGN, projected spatial separation rp $<$ 100 kpc) are sources of great interest in Astrophysics, since they can help to understand how AGN are triggered. However, either identify and characterize such sources is challenging (multi-waveband observations and analysis are needed), and lots of them have been detected serendipitously so far. X-rays are a very great method we can exploit to characterize these systems, since they allow us to define some important DAGN properties, such as the absorption ones, but at the closest separations rp $<$ 30 kpc) most of the sources are not resolved in the X-ray band. So, we must exploit other DAGN features to identify them, such as a Double- Peaked OIII line profile, which however is not uniquely attributed to a DAGN, since several mechanisms in a single AGN instead can produce the same OIII line feature. Here, we present a first characterization of an X-ray selected sample of $\sim$ 360 DAGN candidates obtained with XMM-Newton and Chandra observations, up to rp $\sim$ 100 kpc, and the analysis of a sample of 22 optically selected Double- Peaked AGN (DPAGN), from which we derive the absorption properties of these systems.

Long term multi-wavelength analysis of the flat spectrum radio quasar OP 313.

Bartolini C. ([1])([2]), Bissaldi E. ([2])([3]), Cerasole D. ([2])([3]), D'Ammando F. ([4]), Di

Venere L. ([2])([3]), Giordano F. ([2])([3]), Giroletti M. ([4]), Lindfors E. ([5]), Loporchio S. ([2])([3])
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([5]) *Tuorla Observatory, University of Turku, Finland*
The flat spectrum radio quasar OP 313 showed extremely intense γ-ray activity from November 2023 to March 2024, as observed by the Large Area Telescope on board the Fermi Gamma-ray Space Telescope. This initiated a wast follow-up campaign at all wavelengths, resulting in a confirmation of the increase of the source activity from the radio to very high energy (VHE) bands. Remarkably, it also led to the first VHE detection of the emission from OP 313 by the Large-Sized Telescope (LST-1). Here we present a complete multi-wavelength analysis of OP 313, covering 15 years of LAT observations (2008-2024). In our study, we include X-ray, optical and radio data collected by Swift, the Nordic Optical Telescope, and the Medicina radio telescope, respectively. We aim to compare the Spectral Energy Distribution of the various active periods and to find a theoretical model able to explain the source's behavior, in order to understand the mechanisms involved in particle acceleration inside the jet and how radiation in different wavelengths is connected.

● **Plasma wave-particle interactions as sources of galactic gamma-ray bubbles.**
Cardinali A. ([1])([2]), Coppi B. ([3]), Tavani M. ([1]), Vittorini V. ([1])
([1]) *INAF IAPS, Roma*
([2]) *CNR-ISC, Politecnico di Torino*
([3]) *MIT, Boston, USA*
The Fermi Bubbles are two giant g-rays bubbles extending above and below the Galactic plane characterized by a smooth surface, sharp edges, and almost flat intensity distribution. They were discovered in 2010 by the Fermi Gamma Ray Telescope and detected in the energy range 1-100 GeV. In order to explain the observed phenomenology we have developed a model based on the in situ generation of an energetic electron population powered by unstable electromagnetic waves triggered by a non-relativistic outflow of hadronic/leptonic matter escaping from the Galactic center. A hadronic outflow crossing the large-scale magnetic field can induce a micro-em-instability in the lower hybrid frequency domain . These waves propagate along the magnetic field lines in the galaxy halo and can accelerate, via resonant Landau damping, the thermal electrons of the background plasma up to hundreds of GeV. This energetic electron population, localized in a thin coronal layer of the halo up to 8 kpc radiates by synchrotron emission and by Inverse Compton scattering. An evaluation of the emission and comparison with spectral data is presented.

Relazioni su invito

▲ **The connection between the inflow and outflow around accreting compact objects.**
Del Santo M.
INAF/IASF, Palermo
X-ray binaries are composed of a stellar-mass black hole or neutron star in orbit with and accreting matter from a nearby companion star. These objects exist in large numbers in our Galaxy, having a profound impact on their surroundings. Most impoirtantly, these objects cycle through their full range of accretion phases in days to years, as opposed to the millions of years required for the supermassive black holes at the centres of galaxies. This rapid

evolution makes X-ray binaries ideal observational laboratories to study how matter behaves in extreme gravity, from how material accretes onto to the compact object to how some of that material is expelled out in winds or even launched in the form of fast, focused 'jets' that can be shot out at close to the speed of light. However, while there is an observed connection between the accretion inflow and outlfow, currently the precise and causal connection is not well understood, hampering our understanding of the accretion and ejection processes on all physical scales. In this contribution, I will briefly review the state of the art and recent results in the field.

▲ **(New) Athena and its transformative high-resolution X-ray spectroscopy capability.**

Piro L.

INAF, Istituto Astrofisica e Planetologia Spaziali, Roma

I will review some key aspects of (New)-Athena, including its programmatic status, the mission and instrument profile after the successful reformulation phase and outline the primary scientific objectives. New Athena capabilities, in particular high-resolution spectroscopy, will break new ground in many fields, here I will focus on multimessenger and explosive events, such as GRBs and GW counterparts.

Comunicazioni

● **Study of quasi-periodic oscillations from black hole X-ray binaries with IXPE.**

Tugliani S. ([1])([2]), Bonino R. ([1])([2]), Negro M. ([3]), Cibrario N. ([1])([2]), Latronico L. ([1]), Maldera S. ([1]), Frassà A. ([2])

([1]) *INFN, Sezione di Torino*

([2]) *Dipartimento di Fisica, Università di Torino*

([3]) *Department of Physics and Astronomy, Louisiana State University, Baton Rouge, USA*

Mass accretion is a fundamental process of energy extraction that powers some of the brightest X-ray sources. It operates very efficiently for X-ray Binaries (XRB), which are some of the astrophysical sources that can be studied by the Imaging X-ray Polarimetry Explorer (IXPE). IXPE represents the current state-of-the-art of astrophysical X-ray polarimetry, measuring the linear polarization over the photon energy range 2-8 keV. Polarization can provide a new observable to understand the geometry of the XRB emission region, which conventional spectroscopy and timing observables haven't fully explained yet. Swift J1727.8-1613 is a Black Hole XRB that underwent a bright outburst that on Aug 24, 2023. With IXPE we measured its polarization and found an evident strong quasi periodic oscillation (QPO). QPOs can be caused by possible misalignments between the black hole spin and the binary orbital axis. In this study we present an analysis technique to investigate the polarization properties of such objects, searching for statistically significant differences between the events that show a QPO feature (signal) and events that don't show it.

● **The THESEUS mission concept.**

Mattioli G. ([1])([2]), Amati L. ([2]), Labanti C. ([2]), Virgilli E. ([2])

([1]) *Dipartimento di Fisica e Astronomia, Università di Bologna*

([2]) *INAF, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna*

The Transient High–Energy Sky and Early Universe Surveyor (THESEUS) is a mission concept developed by a large European collaboration, under study by ESA since 2018 and currently one of the three candidate M7 mission for a launch in mid 2030s. THESEUS aims at fully exploiting Gamma–Ray Bursts for investigating the early Universe and for advancing multi-messenger astrophysics. By providing an unprecedented combination of

X-/Gamma-ray monitors, on-board IR telescope and spacecraft autonomous fast slewing capabilities, THESEUS would be a wonderful machine for the detection, multi-wavelength characterization and redshift measurement of many classes of X-ray transients and any kind of GRBs. Italy has the leadership of THESEUS, with the coordination of the whole project, the responsibility of the GRB monitor and of the IR telescope optical system, thus exploiting its great technological and scientific heritage in these research fields. Moreover, THESEUS would provide a great synergy with the astronomical facilities of the future working in the e.m. (e.g., ELT, CTA, SKA, Athena) and multi-messenger (e.g., Einstein Telescope, Cosmic Explorer, km3NET), in which Italy plays a key role too.

The LARIX facility: An X-ray facility for high energy astrophysics.

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The LARge Italian X-ray (LARIX) facility is a multidisciplinary laboratory at the University of Ferrara, Dept. of Physics and Earth Science. It was built to be a multipurpose hard X-/soft gamma-ray facility that caters to the needs of the high energy astrophysics community. It consists of two beamlines: LARIX-A (15-200 keV), equipped with a Bragg-Bragg fixed exit monochromator, and LARIX-T (20-300 keV), a 26m long beamline installed in a 100m tunnel. A portable betatron (maximum voltage 2.5 MV) is also available. The LARIX facility has already been used for ground calibration of hard X-ray telescopes aboard satellites and is currently dedicated to developing Laue lens optics. As part of the AHEAD2020 transnational access programme, the LARIX is a unique facility available to the European community. It is of key importance for developing new technologies such as soft gamma-ray focusing telescopes and for the accurate testing and calibration of high energy, position-sensitive detectors. The goal is to satisfy the requirements of the most advanced needs of soft gamma-ray astronomy and its science goals. Here, I will illustrate the status of the facility and its development prospects

Il Progetto Extreme Energy Events espande le sue frontiere.

Pinazza O. per la EEE Collaboration
CREF/CentroFermi e INFN, Sezione di Bologna

Dal 2018 il progetto EEE ha allargato le sue frontiere geografiche e scientifiche, prima con la spedizione Polarquest che misurò muoni secondari a livello del mare dall'Islanda alla banchisa, e poi con un'installazione permanente alla base scientifica di Ny Alesund a 79°N, dove tre rivelatori di muoni funzionano ininterrottamente dal 2019. A più di 5 anni dall'inizio della presa dati, la collaborazione EEE ha a disposizione un dataset unico e un sistema di ricostruzione ben collaudato, che hanno consentito studi originali sulle caratteristiche del flusso e sulle coincidenze a latitudini polari. Dopo aver studiato la dipendenza dalla latitudine, la sensibilità ad effetti Forbush e la stagionalità del rate di muoni, il progetto ambisce ora ad ampliare anche l'orizzonte temporale, continuando la presa dati per studiare la possibile dipendenza dal ciclo solare. L'installazione ina un sito ricco di infrastrutture scientifiche permette inoltre di ricercare eventuali correlazioni fra il flusso di muoni ed altri parametri, solari, planetari e atmosferici, aprendo le porte a collaborazioni multidisciplinari, un'opportunità di grande valore per gli studenti e i ricercatori di EEE.

Detection and study of medium-low energy gamma-rays with novel spaceborn detectors.

Smirnov A.
Gran Sasso Science Institute

Recent observations have shown that gamma-rays with medium-low energy levels (approximately keV to MeV) serve as powerful tools for exploring the extremes of the Universe. Despite their potential, this energy range remains largely untapped. Consequently, it is imperative to develop new detectors specifically tailored for this medium-low energy spectrum. A promising approach is utilized by Crystal Eye, an innovative all-sky monitor leveraging cutting-edge technology. This technology encompasses a broad field of view, precise sky localization capabilities, and a substantial effective area. Currently, the research team is engaged in multiple aspects of this initiative: developing a Crystal Eye prototype for the Space Rider mission, designing a full-scale Crystal Eye detector, and integrating the Crystal Eye detection technique into the calorimeter for the Zirè payload on the NUSES mission. In this presentation, I will discuss the characterization and testing of various scintillators. These tests help refine certain parameters of the Crystal Eye to enhance its design. Additionally, I will share some simulation results related to both the prototype and the entire detector.

Caratterizzazione dell'elettronica di readout per l'esperimento Antartic Demonstrator for APT (ADAPT).

De Palma G. ([1])([2]), Bissaldi E. ([1])([2]), Di Venere L. ([1])([2]), Gargano F. ([2]), Giordano F. ([1])([2]), Licciulli F. ([2]), Loizzo P. ([2])([3]), Mazziotta M.N. ([2]), Serini D. ([2]), for the APT Collaboration
([1]) *Dipartimento Interateneo di Fisica dell'Università e del Politecnico di Bari*
([2]) *INFN, Sezione di Bari*
([3]) *Università di Trento*

Il progetto Advanced Particle astrophysics Telescope (APT) rappresenta una proposta di missione per un futuro osservatorio spaziale per l'astronomia gamma tra MeV e TeV, il cui prototipo per volo su pallone, l'Antarctic Demonstrator for APT (ADAPT), è attualmente in via di sviluppo. Il lavoro da noi presentato consiste nella caratterizzazione e sviluppo dell'elettronica multicanale necessaria per potere leggere i fotomoltiplicatori a silicio (SiPM) per la rivelazione dei segnali; in particolare, stiamo studiando la risposta di due specifici chip, caratterizzati da alta compattezza e basso costo, insieme a un ottimo livello di integrazione dell'elettronica: lo SMART (SiPM Multichannel ASIC for high Resolution Cherenkov Telescopes) e il TARGET (TeV Array Readout Electronics with GSa/s sampling and Event Trigger) rispettivamente per l'amplificazione e la digitalizzazione del segnale. In questo contributo presenteremo i risultati di caratterizzazione dell'elettronica in particolar modo in termini di guadagno e rapporto segnale rumore, ottenuti con misure in laboratorio e nel corso di test beam presso il CNAO di Pavia.

A regular black hole from gravitational collapse in asymptotic safety.

Panassiti A. ([1])([2])([3])([4]), Bonanno A. ([1])([2]), Malafarina D. ([5])
([1]) *INAF, Osservatorio Astrofisico di Catania*
([2]) *INFN, Sezione di Catania*
([3]) *Dipartimento di Fisica e Astronomia, Università di Catania*
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([5]) *Department of Physics, Nazarbayev University, Kazakhstan*

A model where a regular black hole spacetime is obtained from an effective Lagrangian for quantum Einstein gravity is presented. The collapsing matter is modeled as a dust fluid,

which interacts with the geometry through a multiplicative coupling function. The specific form of this function is deduced from asymptotically safe gravity. As a consequence the gravitational coupling vanishes at high energies, and the formation of the singularity is avoided, replaced by a matter core which collapses for eternity. The static exterior geometry of the black hole is entirely determined by the junction conditions at the boundary surface of the star. Consequently, the global spacetime geometry remains geodesically complete. This outcome offers a new perspective on how regular black holes are formed via gravitational collapse.

Aula F **ore 09:00 – 13:30**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Di Sabatino S. (Università di Bologna)

Relazioni su invito

▲ **L'atmosfera: un laboratorio a cielo aperto di tutta la fisica.**
Zardi D.
Universià di Trento
La fisica nasce, come l'etimo suggerisce, in quanto scienza che studia i fenomeni della natura. Molti di questi si verificano nell'ambiente naturale in cui trascorriamo tutta la nostra esistenza: l'atmosfera. In effetti, si può dire che non vi sia argomento della fisica che non trovi riscontro in uno o più fenomeni dell'atmosfera terrestre: dalla meccanica, all'ottica, all'acustica, alla termodinamica, all'elettromagnetismo, ai fenomeni nucleari e subnucleari. Si potrebbe scrivere un intero trattato di fisica generale basato su esempi tratti dall'atmosfera. Molti ci sono familiari dall'esperienza, alcuni sono particolarmente affascinanti. Anche per questo si prestano come richiamo per stimolare i giovani a scoprire i meccanismi fisici che li governano, e utili esempi per una didattica che aiuti lo studente a passare dall'osservazione del fenomeno, all'analisi delle variabili coinvolte e delle condizioni che lo caratterizzano, alla scoperta degli strumenti sviluppati per misurarlo. Ciò contribuirebbe anche a sostanziare la crescente attenzione della società per il fenomeno del cambiamento climatico, delle sue cause e dei suoi effetti, con solide basi scientifiche.

▲ **Processi di scambio di energia e materia tra biosfera e atmosfera.**
Cava D. ([1]), Brondani D. ([1]), Mortarini L. ([1])([2]), Landi C.T. ([1]), Giostra U. ([3])
([1]) *CNR-Istituto di Scienze dell'Atmosfera e del Clima*
([2]) *Università degli Studi di Milano, Dipartimento di Scienze della Terra, "Ardito Desio", Milano, Italy*
([3]) *Dipartimento di Scienze Pure e Applicate (^{DiSPeA}) , Università degli Studi di Urbino "Carlo Bo", Urbino, Italy*
I processi che regolano il mescolamento e il trasporto di energia e scalari al di sopra e all'interno di una canopy vegetale sono di grande complessità e di grande rilevanza ambientale. Sebbene negli ultimi vent'anni l'approccio a mixing-layer sia stato confermato in condizioni semplificate di vegetazione e stabilità termica, la necessità di descrivere casi reali più complessi ha portato a notevoli progressi nella descrizione teorica, numerica e sperimentale. L'utilizzo di modelli LES ha permesso di studiare condizioni di densità variabile delle chiome, di disomogeneità dell'orografia, di interazione con lo strato limite atmosferico. Sono state allestite torri micrometeorologiche con numerosi livelli di misura, dal suolo fino a quote superiori al canopy sublayer, per monitorare dettagliatamente i processi di scambio attraverso lo sviluppo di specifiche tecniche di analisi dei dati. Sono state prodotte parametrizzazioni per modelli meteorologici e climatologici. In questo contesto teorico le sfide più ambiziose sono forse l'abbandono del paradigma dell'omogeneità orizzontale e la comprensione della struttura della turbolenza in presenza di canopy vegetale ed orografia complessa.

▲ **Interannual variability of ozone deposition, drivers, and risks for a lowland broadleaf deciduous forest.**

Gerosa G.A., Marzuoli R., Finco A.
Catholic University of the Sacred Heart, Department of Mathematics and Physics, Brescia, Italy

Ten years measurements of ozone deposition were performed in an Italian broadleaf forest with the aim of identifying the sources of interannual variability and drivers of ozone fluxes in that ecosystem. Ozone fluxes were measured every half an hour from 2012 to 2023 with the eddy covariance technique on a 41 m high tower, 15 m above the forest canopy. The measurements captured a marked variability of O_3 fluxes that was explained by the stomatal activity, with soil water content and air dryness being the main responsible for the day-to-day and interannual variability of ozone deposition. Instead, the non-stomatal deposition showed a lower interannual variability but a large seasonal variation, with air humidity, surface wetness and chemical sinks by soil emitted NO being the main drivers of this component. During the years of measurements, the forest experienced on average an annual phytotoxic O_3 dose of $10.55\,\mathrm{mmol O_3\,m^{-2}}$, corresponding to an estimated reduction of the forest growth around 3% $\mathrm{yr^{-1}}$ according to the dose-effect relationships of the UNECE for broadleaf deciduous forests. The high interannual variability of POD1 highlighted the need for multiannual measurements.

▲ **Passive mitigation of vehicular pollution in urban street canyons: The influence of in-street obstacles.**

Buccolieri R., Carlo O.S.
Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali, University of Salento, Laboratory of Micrometeorology, Lecce, Italy

Urban street canyons worsen vehicular pollution due to their shape, which traps pollutants. Research shows that in-street obstacles, like parked cars, boundary walls, hedges and trees can alter air pollutant dispersion patterns, affecting the local air quality for pedestrians. Our recent wind tunnel (WT) studies show that low-level obstacles like parked cars, boundary walls and hedges can have a significant reduction on pedestrian pollutant exposure along sidewalks. Porosity, obstacle height and surface roughness of obstacles appear to be potential indicators of their influence on pollutant dispersion. For instance, boundary walls being non-porous and possessing the largest height show the best reductions in pollutant levels. While WT experiments have provided valuable groundwork, our forthcoming computational fluid dynamics (CFD) investigations promise to enrich our understanding further. We are exploring various combinations of obstacles, using CFD simulations to enhance the insights gained from WT studies. General optimization frameworks will be investigated to iterate through various simulation parameters and obstacle design criteria to find an optimal solution.

Comunicazioni

● **Warmest extremes and land-sea breeze regime in the Mediterranean Basin.**

Cosimato G. ([1]), Gandolfi I. ([1]), Rosoldi M. ([1]), Madonna F ([1])([2])
([1]) *Consiglio Nazionale delle Ricerche-Istituto di Metodologie per l'Analisi Ambientale, CNR-IMAA*
([2]) *Università degli Studi di Salerno, Dipartimento di Fisica*

Recent heatwaves in the Mediterranean Basin have impacted health and ecosystems, leading to wildfires, heat-related illnesses, and challenges to infrastructure such as electricity grids and water resources. These heatwaves result from a quasi-stationary anticyclone, impeding

the swift movement of air masses and allowing heat to accumulate for extended periods, resulting in extreme and persistent temperatures. This study examines the frequency of warmest temperatures per year over the past decade using ERA5 reanalysis data and the land-sea breeze regime outlined during the Mediterranean Sea Salt And Dust Ice Nuclei (MESSA-DIN) campaign, held from June to November 2021, at the Soverato site (38° 41′16″ N 16° 33′00″ E) using Doppler wind lidar data. The discussion includes contrasting effects of the land-sea breeze regime and heatwaves in Soverato. Utilizing the approach developed for the MESSA-DIN campaign, this study also investigates the warmest extremes in the central-western Mediterranean basin to validate the representativeness of single-site analysis and to explore, on a larger scale, the relationship between changes in temperature and in land-sea breeze over the last decade.

Air temperature sensors calibration in the Arctic, and its impact for climate measurements.

Coppa G. ([1]), Becherini F. ([2]), Musacchio C. ([1]), Mazzola M. ([2]), Merlone A. ([1])
([1]) *Istituto Nazionale di Ricerca Metrologica, INRiM, Italia*
([2]) *Consiglio Nazionale delle Ricerche-Istituto di Scienze Polari, CNR-ISP, Italia*

The Arctic is an important place for environmental data due to its sensitivity to climate change and its remoteness. The research center of Ny-Ålesund, in the Norwegian Svalbard Archipelago, is a key place to perform such measurements given the infrastructures already available and the relative ease of access. The harsh environment of the polar regions can degrade the performance of sensors, which are not designed to be run in these environments: maintenance of these sensors must be frequent and made with metrological rigour, in order to provide traceability and comparability in time and space with other sensors. This communication reports on the calibration campaign INRiM set out on the air temperature sensors installed on the Ny-Ålesund Climate Change Tower (CCT), managed by CNR-ISP. This campaign was able to correct the temperature measurements of the atmospheric vertical profile from ground to 34 m, and found errors up to 1 °C; moreover it was able to reduce the absolute measurement uncertainty with respect to the one stated by the manufacturer, and the relative uncertainty on the profile to few hundredths of a degree Celsius. Future development will also be illustrated.

Una valutazione critica delle tendenze degli eventi estremi in tempi di riscaldamento globale.

Alimonti G. ([1]), Mariani L. ([2]), Prodi F. ([3]), Ricci R. A. ([4])
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([2]) *Università degli Studi di Brescia, Dicatam, Italy*
([3]) *Accademia Nazionale delle Scienze, Verona, Italy*
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L'articolo passa in rassegna la bibliografia recente sulle serie temporali di alcuni eventi meteoclimatici estremi e di alcuni indicatori di risposta ad essi relativi, al fine di comprendere se sia rilevabile un aumento in termini di intensità e/o frequenza. I più significativi cambiamenti globali negli estremi climatici si riscontrano nei valori annuali delle ondate di calore; l'intensità giornaliera e la frequenza delle precipitazioni estreme sono stazionarie nella maggior parte delle stazioni meteorologiche e una sostanziale stazionarietà mostrano le serie storiche dei cicloni tropicali e dei tornado negli USA. L'analisi viene poi estesa ad alcuni indicatori di risposta globale agli eventi meteorologici estremi ovvero disastri naturali, inondazioni, siccità, produttività dell'ecosistema e rese delle quattro colture principali (mais, riso, soia e grano). Nessuno di tali indicatori manifesta tracce evidenti di eventuali trend positivi degli eventi estremi. In conclusione, è opinione degli autori che la crisi climatica, paventata

da diverse fonti mediatiche, non sia ancora evidente e di questo dovrebbero tenere conto le strategie di adattamento e mitigazione.

A study on rainfall intermittency using disdrometers in Italy.

Pandey R.S., Carrassi N.A., Porcù F.
Dipartimento di Fisica e Astronomia "Augusto Righi", Alma Mater Studiorum-Università di Bologna, Italy

At current almost 50% of the global population lives in cities, where cities generate around 80% of GDP alone. The frequency of intense rainfall events increases worldwide due to climate change. Rapidly increasing ecohydrological urban crisis like urban flooding, landslides, etc., causes huge economic losses. Mostly the rainfall data are averaged hourly making it unrealistic. Moreover, rainfall intermittency which refers to breaks during a rainfall is a vital aspect associated with rainfall intensity. Thus, an unbiased acquisition of high temporal resolution data is vital for proper city infrastructure updation. Disdrometers are the most advanced laser-based rainfall measuring instruments with a 1-minute resolution and have the capability of measuring raindrop diameter, terminal velocity, and kind of precipitation. We further calculated various aspects including rainfall rate and mass-weighted mean diameter, etc., using various moments and other equations. All data is taken from the GID network of Italy. Detailed statistical analysis is done along with a detailed comparison with conventional rain gauge data to provide a crucial advancement.

Studio della composizione elementale e della sorgente di mineral dust in aree polari.

Calzolai G. ([1]), Chiari M. ([1]), Fratticioli C. ([1])([2]), Giardi F. ([1]), Nava S. ([1])([2]), Lucarelli F. ([1])([2])
([1]) *Istituto Nazionale di Fisica Nucleare, INFN, Sezione di Firenze, Sesto Fiorentino, FI, Italia*
([2]) *Dipartimento di Fisica e Astronomia, Università di Firenze, Sesto Fiorentino, FI, Italia*

La componente minerale del particolato atmosferico ha una notevole importanza a livello globale, ad esempio per i suoi effetti climatici e di fertilizzazione degli oceani. La PIXE (Particle Induced X-ray Emission) è una tecnica nucleare molto sensibile, che non richiede pre-trattamento del campione (minimizzando il rischio di contaminazioni) e particolarmente efficace nella caratterizzazione delle polveri minerali, dato che è sensibile a tutti gli elementi crostali (eccetto l'ossigeno), incluso il silicio. Il laboratorio LABEC è coinvolto in diversi progetti di studio della composizione elementale (e in particolare crostale) del particolato atmosferico in Artide, Antartide e recentemente anche in campagne oceanografiche artiche. Saranno mostrati i vantaggi dell'ottimizzazione delle tecniche di campionamento in sinergia con le tecniche analitiche usate (fondamentale per gli studi in aree quali quelle polari, caratterizzate da scarsi quantitativi di particolato) e alcuni risultati dalle campagne svolte.
Attività finanziata dai progetti PRA2021_0020 BETHA-NyA, PNRA16_00252 SIDDARTA e dall'Unione Europea - Next Generation EU, PRIN 20229JLCRZ.

FROG: An unmanned aerial system for measuring solar-induced chlorophyll fluorescence and hyperspectral reflectance.

Tagliabue G. ([1]), Rossini M. ([1]), Garzonio R. ([1]), Vignali L. ([1]), Panigada C. ([1]), Cogliati S. ([1]), Marras P. ([2]), Tattarletti B. ([2]), Julitta T. ([3]), Burkart A. ([3]), Colombo R. ([1])
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([3]) *JB Hyperspectral Devices GmbH, Düsseldorf, Germany*

The upcoming Fluorescence Explorer (FLEX) mission developed by the European Space Agency as part of the Earth Explorer programme will provide global maps of vegetation Sun-Induced Fluorescence (SIF). The Calibration and Validation (Cal/Val) of such products are key to ensure high-quality SIF estimates for environmental monitoring. In this context, Unmanned Aerial Systems (UAS) hold the potential to bridge the gap between field and satellite due to their high spatio-temporal resolution. In this contribution we present the FROG, a novel spectroscopy system composed of 2 point spectrometers (Ocean Insight, USA) connected to bifurcated fibre optics switching between the downwelling irradiance and the upwelling radiance. The two spectrometers complement each other having different spectral range and resolution for measuring both SIF and reflectance. The payload (4 kg) is mounted on a commercial hexacopter (Matrice 600 Pro, DJI, China). To test the reliability of the FROG we flew it above an agricultural area in Italy contemporary to an airborne campaign. The flights were designed to assess the spatial heterogeneity of SIF and the effectiveness of different sampling schemes for Cal/Val.

A simple "device" for three quantum mechanics experiments.

Valli F.
ISPRA, Roma

Three "simple" experiments are proposed to verify a) the impulse and thrust of photons —towards "photon propulsion"; b) the Casimir effect; c) entanglement "with a designed Radar Entangled System".

Lo Specchio Lineare e il Parco dell'Energia di Udine.

Cobal M., Grassmann H., Sharma P.R.
DPIA, Università degli Studi di Udine

Molti processi industriali richiedono temperature operative superiori a 100 °C, limite oltre il quale l'efficienza dei collettori solari tradizionali cala significativamente. Lo Specchio Lineare è un concentratore termico solare che offre diversi vantaggi se confrontato con sistemi analoghi, in quanto la luce concentrata viene riflessa sempre sulla stessa superficie fissa durante tutto il giorno (e tutto l'anno) in vicinanza del suolo. Questo offre per esempio l'opportunità di usare l'aria come termovettore, raggiungendo anche temperature elevate, sopra i 200 °C, senza il bisogno di avere una alta pressione (come quando si usa l'acqua). Per consentire la raccolta e la gestione dei dati generati dal sistema, è stato realizzato un sistema IoT, basato su sensori e dispositivi di acquisizione dati, per monitorare in tempo reale i parametri operativi dei vari componenti. Il sistema IoT consente anche la visualizzazione dei dati sia in locale sia da remoto, attraverso un webserver. Lo Specchio Lineare fa ora parte del progetto Energy Park per la realizzazione di un parco-museo dell'"energia pulita" alla Università di Udine, nella Azienza Agraria Servadei, dove viene utilizzato per essiccare le biomasse di scarto della Azienda stessa e produrre poi "carbone solare" gassificando le biomasse stesse, in un ciclo virtuoso green.

Aula 1F **ore 09:00 – 13:30**

Sezione V
Biofisica e fisica medica
Presiede: Bianchini P. (Nanoscopy and NIC@IIT, Genova)

Relazioni su invito

▲ **Innovative light sources for phototherapy.**
Fusi F., Romano G., Insero G.
Dipartimento di Scienze Biomediche Sperimentali e Cliniche, Fisica Medica, Università di Firenze, Italy
The use of light for therapeutic purposes dates back to ancient Egypt, where the Sun was the primary source used to treat skin diseases. Since then, technical innovation and advancement in medical sciences have produced newer and more sophisticated solutions for light-emitting sources and their applications in medicine. Starting from a brief historical introduction, the concept of innovation in light sources is discussed and analysed, first from a technical point of view and then in the light of their fitness to improve existing therapeutic protocols or propose new ones. If it is true that a "pure" technical advancement is a good reason for innovation, only a sub-system of those advancements is innovative for phototherapy. To illustrate this concept, the most representative examples of innovative light sources are presented and discussed, both from a technical point of view and from the perspective of their diffusion and applications in the clinical field.

▲ **Targeting bacteria with PDI.**
Abbruzzetti S. ([1]), Viappiani C. ([1]), Delcanale P. ([1]), Mussini A. ([1]), Diaspro A. ([2])([3]), Bianchini P. ([3]), Nonell S. ([4])
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Photosensitizers (PSs) are one of the three main components of photodynamic inactivation (PDI), in addition to visible light and molecular oxygen. The therapy is an innovative methodology based on the administration of the PS to "undesidered" cells: when irradiated with visible light of appropriate wavelength, the photo-activated molecule starts a cascade of molecular transitions leading to cytotoxic effects promoted by the formation of singlet oxygen in proximity of targeted cells. The features of this approach make it interesting in fighting not only cancer cells but also bacteria, providing a possible alternative strategy against a relevant health emergency, the antibiotic resistance. Therefore, it is crucial to develop supramolecular constructs as modular platforms, not only able to carry the pro-drug (PS), increasing its bio-availability, but also endowed with selectivity capabilities. Hence, the aim of the herein research project is to create all-in-one multi-functional bio-molecules to be used in PDI treatments against bacteria, with targeting, imaging and photosensitizing features.
This research was funded by the National Recovery and Resilience Plan (NRRP), Mission 04 Component 2 Investment 1.5 NextGenerationEU, Call for tender n. 3277 dated 30 December 2021, Award Number: 0001052 dated 23/06/2022.

▲ **A photoactive decoy for targeted antiviral photodynamic inactivation.**
Viappiani C. ([1]), Viappiani C. ([1]), Abbruzzetti S. ([1]), Delcanale P. ([1]), Mussini A. ([1]), Diaspro A. ([2])([3]), Bianchini P. ([3]), Mariangeli M. ([1])([3]), Moreno A. ([4])
([1]) *Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università di Parma, Italia*
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([4]) *Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, Brescia, Italia*
The recent COVID-19 pandemic has highlighted the need for effective antimicrobial treatments that could be rapidly deployed with minimal selective pressure. Antiviral Photodynamic Inactivation (PDI) has been recently proposed as one such strategy. In this contribution, ACE2, the natural receptor for the SARS-CoV-2 spike protein, is exploited to devise a supramolecular construct, able to deliver photoactive molecules to the viral surface. In particular, we elaborate on a previously proposed versatile molecular platform, where a biotinylated human recombinant water soluble ACE2 provides the targeting property to a photoactive streptavidin, covalently labelled with either a fluorophore or a photosensitizer. Using Fluorescence Correlation Spectroscopy (FCS) and direct STocastic Optical Reconstruction Microscopy (dSTORM), we show that the construct is indeed driving the photoactive molecules to the viral surface. We also report a preliminary evaluation of the antiviral activity of the construct that demonstrates photodynamic potentiation of the viral inhibitory effect of ACE2. Funded by the European Union-Next Generation EU.

▲ **Investigating molecular mechanisms in protein self-assemblies using fluorescence lifetime imaging.**
Vetri V.
Dipartimento di Fisica e Chimica-Emilio Segrè, Università degli Studi di Palermo
Protein supramolecular assembly is an intricate phenomenon which leads the formation of functional structures with unique properties. The concept of emulating these processes to design nature-inspired biomaterials, for applications like drug delivery or sensors, is now gaining attention. The deep comprehension of the molecular mechanisms and fundamental laws underlying protein condensation and aggregation is essential to grasp the fundamentals of their biological function and to rationalize the design of biomimetic materials. Fluorescence lifetime imaging has emerged as a powerful method for monitoring protein aggregation and liquid-liquid phase separation processes. Its remarkable sensitivity allows for the detection of early-stage aggregation events, providing molecular insights that are often elusive with bulk methods. By combining this technique with classical biophysical approaches, we can dynamically map occurring events and correlate the molecular structure of aggregates with the overall morphology of protein assemblies. This experimental approach, with a focus on the selection of appropriate dyes, provides a new easily adaptable highly versatile screening method for the characterization of self-assembled structures.

Comunicazioni

● **Application of the gamma-index analysis to in-beam PET images to identify interfractional morphological changes in proton therapy.**
Moglioni M. ([1])([2]), Kraan A.C. ([1]), Bersani D. ([1]), Carra P. ([1])([2]), Cerello P. ([3]), Ciocca M. ([4]), Ferrero V. ([3]), Fiorina E. ([3]), Morrocchi M. ([1])([2]), Orlandi E. ([4]), Pennazio P. ([3]), Retico A. ([1]), Rosso V. ([1])([2]), Sarti A. ([5])([6]), Sportelli G. ([1])([2]), Traini G. ([5]), Vischioni B. ([4]), Vitolo V. ([4]), Bisogni M.G. ([1])([2])
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([4]) *Centro Nazionale di Adroterapia Oncologica, Pavia*
([5]) *Istituto Nazionale di Fisica Nucleare, Sezione di Roma I*
([6]) *Dipartimento di Scienze di Base e Applicate all'Ingegneria, Università di Roma La Sapienza*

Proton therapy offers precise and targeted radiation doses to tumor volumes, yet it faces challenges from anatomical changes that can lead to significant deviations in dose range. In-beam Positron Emission Tomography (PET) provides a non-invasive technique for *in vivo* range monitoring. This study focuses on a patient with SCC, simulating a gradual emptying of the sinonasal cavity alongside treatment and in-beam PET activity distributions from three irradiation fields. We aim to determine whether the gamma-index map, typically used for dose comparison, and the passing rate can effectively detect progressive anatomical changes. Our results indicate that gamma-index analysis proves to be a valuable tool for comparing simulated in-beam PET images, particularly sensitive to sinonasal cavity emptying. Monitoring the gamma passing rate throughout the treatment course proves useful in identifying anatomical changes. Moreover, we test the gamma index analysis on real clinical data, yielding consistent results.

Advancements in lung cancer diagnosis and treatment: Integrating radiomics and high-resolution micro-CT imaging for enhanced analysis.

Megalizzi S. ([1]), Bortolotto C. ([1])([2]), Brero F. ([3])([4]), Cabini R. ([4])([5])([6]), Filibian M. ([4])([7]), Gioia R. ([7]), Lascialfari A. ([3])([4]), Preda L. ([1])([2])
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([6]) *Euler Institute, Università della Svizzera Italiana, Switzerland*
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Lung cancer is one of the most prevalent and lethal forms of cancer worldwide, with its incidence steadily rising. Recent advancements in treatment, particularly in Non-Small-Cell Lung Cancer (NSCLC) variants like Adenocarcinoma (ADC), Squamous Cell Carcinoma (SCC), and Large Cell Carcinoma (LCC), have notably improved patient survival rates. This study, with a dataset comprising 30 cases each of ADC and SCC, aims to refine lung tumor analysis by extracting radiomic features from both micro-CT and conventional CT tomographic images. The use of micro-CT, with its very high resolution of 10 microns, enables the generation of ultra-thin, high-resolution images, facilitating in-depth tumor analysis. Furthermore, radiomics, a rapidly evolving research field, allows to extract quantitative metrics for predictive (radiomic) biomarkers and differential diagnoses, possibly providing a virtual biopsy. The combination of micro-CT and radiomics could allow to face the multifaceted nature of lung cancer research, in particular for improved diagnostic accuracy and treatment outcomes.

PHYSICAL characterization of a cone-beam CT scanner dedicated to intra-surgical imaging of the head.

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This contribution aims at characterizing a cone-beam CT scanner dedicated to image guided maxillo-facial surgery for defining the first QA routine protocol for this type of scanner. We evaluated the detector response curve and we measured the dose level by using the weighted cone-beam dose index ($CBDI_w$) in a 16 cm in diameter PMMA cylindrical phantom. The 3D image quality was then evaluated in terms of spatial resolution, noise power spectrum and by means of tests on dedicated phantoms. These last were used for assessing the contrast-to-noise ratio (CNR) and the accuracy in the evaluation of distances and Hounsfield Units (HU). All examinations were performed for head scanning protocols and 120 kV, as automatically set by the scanner. The $CBDI_w$ for head examination of an adult patient resulted 2.5 ± 0.1 mGy. The 10% frequency modulation transfer function resulted 0.77 1/mm. The HUs were assessed in a phantom simulating different materials: Air $= -836 \pm 10$ HU, expected value-ep[−1046:−986]; Bone20% $= 111 \pm 14$ HU, ep[211:263]; Bone50% $= 450 \pm 16$ HU, ep[667:783]; Teflon $= 646 \pm 17$ HU, ep[941:1060]. Furthermore, the CNR evaluated between Teflon and PMMA resulted 43.

Novel magnetically drivable theranostic nanobubbles for local iron chelation in neurodegenerative disease models.

Rizzo S.A. ([1]), Ficiarà E. ([2]), Molinar C. ([3]), D'Agata F. ([1]), Rabbito R. ([1]), Cavalli R. ([3]), Guiot C. ([1])
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Alzheimer's and Parkinson's diseases, amongst many other neurodegenerative diseases, have a multifactorial nature, and assessing the trigger of the pathology is still challenging. Recently, findings suggest that brain iron dysregulation may be implied. In particular, iron accumulation has been linked to oxidative stress and the aberrant protein aggregation typical of these diseases, for which current therapies show scarce benefits, thus urgently requiring alternatives. Here, we propose a novel theranostic approach based on nanobubbles (NB) for local iron chelation, while using superparamagnetic iron oxide nanoparticles (SPIONs) as magnetic guidance and imaging agent. By conjugating deferoxamine (DFO) to glycol chitosan (GC), it was possible to formulate GC-DFO NB (166.6 ± 23.2 nm) able to chelate Fe^{3+} up to 640 μM in the presence of 50 μM SPIONs (18.6 ± 2.3 nm). *In vitro* studies also showed GC-DFO NB's ability to prevent amyloid β misfolding in the presence of Fe^{3+} ($p < 0.001$) and ROS production. Future work will comprise novel GC conjugates to maximise both iron chelation and SPIONs reversible conjugation.

Readout characterization of homemade polymer gels dosimeter with X-ray computed tomography.

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The aim of this work is the readout characterization of an eco-friendly, low-toxicity homemade polymer gel for dosimetry in Computed Tomography (CT). This gel known as PAGBIT,

operating as a tissue-equivalent material, has the capability to reconstruct 3D dose map following the polymerization process induced by ionizing radiation. It was made by mixing 89% high-purity water (HPLC), 5% type-A gelatine, 3% of acid ammonium salt, 3% N methylene bis acrylamide (Bis 99%), and 10 mM of THPC. Once the gel was obtained, it was placed in sterile centrifuge tubes and sealed with rubber caps to prevent oxygen ingress. Then, it was irradiated and characterized at "ICC Humanitas" using a 6 MV clinical photon beam. For the irradiation setup, PLA printed phantom was made. The response in Hounsfield Units (HU) from CT and the dose delivered with LinAc was studied as the HVL reading beam varied. The results show good dose linearity in the range between 0 and 10 Gy and good performance using CT as reading technique. This approach enables the accurate acquisition of dose distributions, partially mitigating the lengthy application times associated with conventional MRI-based polymer gel dosimetry.

Multicomponent nanoscintillators in radiotherapy and Alzheimer's disease treatment.

Villa I., Secchi V., Campione M., Rahimipour S., Monguzzi A.
Department of Materials Science, University of Milano-Bicocca, Milano, Italy

Multicomponent nanomaterials (MNs) consist of dense scintillating nanoparticles grafted by photosensitizers (PSs), generating cytotoxic singlet oxygen (SO) species and acting as sensitizers in radiotherapy (RT) protocols. Fascinating MNs are chrysotile nanotubes (NTs) grafted by porphyrins. They show biocompatibility and blood-brain barrier-permeability. Their efficiency as sensitizers has been tested *in vitro*, showing an enhancement of both prompt cytotoxicity and long-term radiation-activated apoptosis. Another outstanding result comes from the functionalization of NT surface by chlorin e6 for the cure of Alzheimer's disease. Upon X-rays, the MNs inhibit the formation of Aβ oligomers, the neurotoxic species in Alzheimer's disease. Moreover, we investigate the radiation-induced SO enhancement in MNs by exploring the energy transfer/deposition processes in a series of PS functionalized NT with diverse NT-PS intermolecular distances. Our findings clarify the crucial mechanism of matter-ionizing radiation interaction in MNs, triggering the SO production. These findings will enable to design novel architectures for innovative RT coadjuvants.

A combined radiomics and machine learning approach to magnetic resonance imaging for a quantification of PD-L1 expression in lung cancer.

Robustelli Test A. ([1])([2]), Bortolotto C. ([5]), Pinto A. ([5]), Messana G. ([5]), Pairazzi C. ([5]), Seetha S.T. ([6]), Brero F. ([1])([2]), Cabini R.F. ([2])([4]), Mariani M. ([1])([3]), Preda L. ([5]), Lascialfari A. ([1])([2])
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Nowadays lung cancer is the leading cause of cancer-related death worldwide. The expression of PD-L1 biomarker, commonly assessed via biopsy, is used to predict immunotherapy response. In this contribution, we aimed to classify patients as PD-L1 expressive or not, combining radiomics and Machine Learning (ML) applied to MRI data. We analysed 43 lung cancer patients, considering DWI maps and pre-contrast T1 VIBE images. Segmentation was semi-supervised, images were preprocessed, and 102 IBSI-compliant features were extracted through pyradiomics. The ML models were built dividing patients between PD-L1 expressive (PD-L1 $\geq 1\%$) or not (PD-L1 $< 1\%$). We chose 3 classification models, built

considering 4 data analyses: single sequences, optimal subset, 4 folders, and segmentation split. We observed that DWI maps showed the finest discriminative power, logistic regression yielded the optimal results, and the split approach provided the best performance. The highest AUC score was 0.768, in line with literature values for a rigorous analysis of relatively small datasets. IVIM maps investigation provided information on PD-L1. Despite so, further studies with a wider cohort are strictly needed.

Caratterizzazione fisico-chimica-tecnologica di una crema radioprotettiva per la chirurgia radioguidata.

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I danni biologici dovuti alle radiazioni X utilizzate nella chirurgia radioguidata possono interessare vari componenti della cellula e in particolare del DNA con possibile cancerogenesi. Numerosi sono i dispositivi di protezione individuale adottati in tale contesto, tra cui teli monouso, grembiuli, occhiali protettivi e guanti protettivi i quali però riducono notevolmente la destrezza e la sensazione tattile dell'operatore. In questo lavoro sono state analizzate le prestazioni di una crema radioprotettiva composta da un agente organico a base acquosa e da una percentuale variabile di ossido di bismuto che protegge le mani mantenendo inalterata la sensibilità e il tatto, aderendo direttamente alla pelle, senza però essere assorbita e potendo essere facilmente rimossa. Dalle analisi effettuate si sono ottenute dettagliate informazioni sulla composizione della formulazione, sul tipo di comportamento a diverse temperature, sulle caratteristiche reologiche e quindi sulla facilità di applicazione, e infine sulla capacità di attenuazione della radiazione X a diversi spessori.

Significant behaviour of vibrio samples on PFOA grounds.

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Currently a major problem plaguing humanity is the extensive use of PFOA, perfluorooctanoic acid, used as a non-stick for cookware and anti-wettability for many different clothes. The consequences of the PFOA presence can be anticipated by studying the behaviour of bioluminescent vibrions during their growth on normal medium and on PFOA doping medium. The advantage of the use of bioluminescent vibrions lies in the fact that the monitoring of the emitted light is indicative of the microbial physiology of the species and the activation of quorum sensing circuits. The measurements were carried out by monitoring the light emitted from different samples during their growth on control agar medium and on PFOA-doped agar medium. Two very sensitive photomultipliers (PMT 1P28) capable of recording low-intensity light were used to measure light intensity. The gain factor of the PMT is 5E6, and its sensitivity range is 185-700 nm. Measurements of wettability of the mediums were performed. A data acquisition system was used to record the output signals every 30 min. The acquisitions were performed for more than 20 days. The first observations showed that the kinetics of light emission were.

Aula D **ore 09:00 – 13:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Finocchiaro P. (INFN, Laboratori Nazionali del Sud, Catania)
Monti S. (Associazione italiana Nucleare e Europe Nuclear Society)

Relazioni su invito

▲ **Optical quantum sensors.**
Genovese M.
INRIM, Turin
Among quantum technologies one of the most promising for a rapid real application is quantum sensing. This technology exploits specific properties of quantum systems to beat the classical limits in measurements or overcome their limitations. In this contribution, after a general presentation of quantum sensing in the optical domain, I will describe the development of temperature and electromagnetic field sensors based on ODMR techniques with NV colour centers in diamond that we are developing in INRIM, describing in some detail some biological applications.

▲ **ASIX: An Analog Spectral Imager for X-rays.**
Baldini L.
Università di Pisa e INFN, Sezione di Pisa
Funded by the Italian ministry for university and research through a dedicated call targeted to applied science, and carried out by INFN and the University of Pisa, the ASIX project aims at delivering a new class of hybrid X-ray detectors for single-photon, event-driven, spectral imaging, with excellent spatial and spectral resolution, and suitable for relatively large data throughput applications. This will be achieved by coupling custom, pixelated, large area front-end ASICs, equipped with analog readout and smart self-triggering logic, to finely segmented solid-state sensors with similar patterns, both down to a 50 μm hexagonal pitch. In this contribution we shall describe the basic goals of the project, the preliminary design of the readout ASIC and will present results from the initial detector simulation. We expect to have a functional, full-scale demonstrator within a year from the start of the activities and the final, engineered product within three years.

▲ **Development and characterization of high- and low-efficiency GEM-based neutron detectors optimised for measurements at spallation sources: 10 years of experience in Milano.**
Croci G. ([1]), Caruggi F. ([1]), Muraro A. ([2]), Putignano O. ([2]), Perelli Cippo E. ([2]), Celora A. ([1]), Grosso G. ([2]), Cancelli S. ([1]), Tardocchi M. ([2]), Gorini G. ([1])
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Experiments at future spallation sources constantly require the development of new detectors capable to sustain the high neutron flux without event losses and with high detection efficiency to perform measurements in a short time. The GEM (Gas Electron Multiplier) technology, invented in 1997 by F. Sauli and developed for high-energy physics applications thanks to its capability to stand very high rates, shows excellent performances for thermal neutron detection when coupled with proper converters like B4C. In the last 10 years in

Milano (within a collaboration among University of Milano-Bicocca, INFN and CNR) we have developed several gas detectors based on the GEM technology coupled with 2D and 3D B4C based converters. The structure of the converter depends on the application the detector is suited for. The performance of beam monitors (bGEM), small angle neutron scattering detectors (BANDGEM) and transmission detectors (MB-GEM) will be described in terms of efficiency, time resolution and spatial resolution. Finally the physics applications for the different detectors at spallation sources will be described and future perspective will be described.

▲ Rivelatori 4D per fluenze estreme - Sensori al silicio sottili LGAD con compensazione dei droganti.

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I futuri collisori adronici ad altissima energia e altissima intensità avranno bisogno di tracciatori in grado di operare in ambienti con altissima radiazione, dove la fluenza di particelle supererà $10^{17}/\mathrm{cm}^2$. I rivelatori LGAD con spessore attivo di circa 50 μm e moltiplicazione dei portatori di carica di un fattore tra 10 e 30 hanno dimostrato ottime capicità di tracciamento 4D, combinando la risoluzione spaziale dei rivelatori al silicio con un'eccellente risoluzione temporale. Al momento, negli LGAD il meccanismo di moltiplicazione è preservato fino a una fluenza di $3 \cdot 10^{15}/\mathrm{cm}^2$. Per utilizzare i rivelatori LGAD come tracciatori 4D a fluenze estreme è necessario sfruttare la saturazione del danno da radiazione, particolarmente efficace in substrati sottili 20–40 μm, e un disegno innovativo dello strato di guadagno dei sensori LGAD basato sulla compensazione di atomi droganti di tipo p e n. I primi LGAD compensati sono stati prodotti a FBK a fine 2022. Si presenteranno i test sui sensori prima e dopo l'irraggiamento con neutroni e si discuterano i possibili sviluppi degli LGAD compensati per i futuri tracciatori 4D.

▲ Silicon carbide detectors for ultra-high dose rate particle beams.

Milluzzo G.

Istituto Nazionale di Fisica Nucleare, Sezione di Catania

Implementing FLASH radiotherapy which implies the use of ultra-high dose rate (UHDR) particle beams ($> 40\,\mathrm{Gy/s}$) requires reliable and innovative dosimeters capable of measuring the delivered dose per pulse (DPP) and the instantaneous dose rate with high accuracy as the conventional dosimeters saturate at these extreme conditions. In this contest, p-i-N junction silicon carbide detectors (0.2–20 μm thick, 1–10 mm^2 area) have been realized at the ST-Lab start-up and characterized at the INFN-CT, including a unique configuration where the thick bulk substrate is electrochemically removed. Such devices have been fully characterized with the UHDR low-energy electron beams available at the CPFR in Pisa, where an optimal linearity of the SiC response in charge with the DPP, up to about 22 Gy/pulse and an instantaneous dose rate of 5.5 MGy/s, was clearly observed. Following such excellent results and in the contest of the INFN-CNTT financed R4I project "DREAM" recently started at INFN-CT, a linear array of multiple small-size SiC detectors will be also developed with the aim of measuring the spatial dose distribution of UHDR electron beams.

Comunicazioni

Rivelatori di numero di fotoni basati su nanostrisce superconduttive.
Ercolano P. ([1])([2]), Bruscino C. ([1]), Salvoni D. ([3]), Zhang C. ([3]), Ejrnaes M. ([4]), Huang J. ([5]), Li H. ([5]), You L. ([5]), Parlato L. ([1]), Pepe G.P. ([1])
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I rivelatori in grado di risolvere il numero di fotoni sono fondamentali in diversi ambiti, come l'ottica e la comunicazione quantistica. Questi dispositivi consentono infatti di ricostruire la distribuzione del numero di fotoni emessi da una sorgente a partire dai conteggi osservati. Tuttavia, diverse applicazioni richiedono fotoni a lunghezze d'onda delle telecomunicazioni, a cui i rivelatori convenzionali basati sul silicio non sono sensibili. Una valida alternativa a queste lunghezze d'onda sono i rivelatori di fotoni basati su nanostrisce superconduttive, le quali possono essere disposte in un array in grado di risolvere il numero di fotoni incidenti. In questo lavoro, discutiamo le prestazioni di un rivelatore basato su 8 nanostrisce in NbN nel ricostruire la statistica del numero di fotoni. Caratterizziamo il rivelatore e descriviamo la sua risposta per mezzo di una matrice, tenendo conto dell'efficienza di rivelazione e delle prestazioni temporali del dispositivo.

Rivelazione di elettroni di bassa energia con Transition Edge Sensors.
Corcione B.
Sapienza Università di Roma e Istituto Nazionale di Ricerca Metrologica, Torino
I TES (Transition Edge Sensors) sono rivelatori criogenici che sfruttano la forte dipendenza della resistenza dalla temperatura in corrispondenza di una transizione superconduttiva. Tradizionalmente usati per misurare singoli fotoni, i TES possono raggiungere altissime efficienze di rivelazione con conteggi di buio molto bassi. All'Istituto Nazionale di Ricerca Metrologica di Torino è stato fabbricato e studiato un TES costituito da un bilayer quadrato di titanio e oro, di lato 100 micrometri e temperatura critica di 83 mK. Una transizione superconduttiva a temperatura così bassa garantisce una buona risoluzione energetica abbinata ad una superficie attiva 100 volte superiore ai tradizionali TES per applicazioni ottiche. Usando un laser impulsato da 406 nm (3 eV) in fibra ottica è stato possibile caratterizzare il TES e discriminare fino a cinquanta fotoni, raggiungendo energie degli impulsi superiori a 100 eV, con risoluzione energetica migliore di 1 eV. L'obiettivo principale di questo studio è approfondire le performance del rivelatore osservandone la risposta a elettroni di bassa energia (< 150 eV) —una sfida del tutto nuova.

Characterisation of the degree of damage by neutrons and optical probes in SiC MOSFET power devices.
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Silicon Carbide (SiC) has become an attractive material lately as a power device for avionic and space applications thanks to its excellent electric properties, such as high breakdown field

and thermal conductivity. In this contribution we describe results from several characterisations of SiC MOSFET power devices using optical and neutron probes and complementary and multilevel techniques. Experiments were performed using both XRD tomography, SEM, X-rays diffraction, profilometry MRFs of the ISIS@MACH ITALIA's suite of instrumentation, as well as ChipIr neutron beamline of ISIS Facility (UK). In the neutron tests the failure-in-time monitoring, visible in the form of micro-burnings, showed the occurrence of Single Event Burnouts (SEBs) caused by the MeV neutrons. The optical tests provided 2D and 3D reconstructions of the burned devices and detailed overview of the positioning, size and shape of the micro-burnings caused by SEBs inside SiC MOSFETs. The authors gratefully acknowledge the support of the ISIS@MACH ITALIA Research Infrastructure, the hub of ISIS Neutron and Muon Source (UK), [MUR official registry U. 0008642.28-05-2020 – 16th April 2020].

Detection of single protons by fluorescent nuclear track detectors based on color centers in lithium fluoride crystals.

Piccinini M. ([1]), Nichelatti E. ([2]), Esposito G. ([3]), Cisbani E. ([3]), Nigro V. ([1]), Buratti E. ([5]), Limosani F. ([2]), Colantonio C. ([4]), Ampollini A. ([1]), Nenzi P. ([1]), Santavenere F. ([3]), Anello P. ([3]), Vincenti M.A. ([1]), De Angelis C. ([3]), Ronsivalle C. ([1]), Ruzicka B. ([4]), Montereali R.M. ([1])

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Visible photoluminescence in lithium fluoride (LiF) crystals, due to local aggregate color centers produced by ionizing radiation in the crystal lattice, is exploited for fluorescent imaging of single tracks of low-energy protons. LiF crystals were irradiated with proton beams produced by the vertical extraction beamline of the TOP-IMPLART linear accelerator, in operation at ENEA C.R. Frascati, at the energies of about 1 MeV in the fluence range from 6×10^5 to 3×10^7 p/cm^2 and of about 2.6 MeV in the fluence range from 9×10^5 to 5×10^6 p/cm^2. The fluence values were estimated by detecting and automatically counting the tracks on the images acquired with a fluorescence microscope at high magnification and they were found to be in agreement with those obtained using CR-39 plastic detectors irradiated under the same conditions. Within the framework of the BIOTRACK project, thin films of poly(*N*-isopropylacrylamide) microgels were deposited on the LiF crystals surface and characterized, with the aim of making the LiF-based fluorescent nuclear track detectors biocompatible for ion radiobiology experiments.

Sensitized triplet-triplet annihilation in nanostructured polymeric scintillators allows for pulse shape discrimination.

Pollice L. ([1]), Hu X. ([2]), Rigamonti D. ([3]), Villa I. ([1]), Mauri M. ([1]), Tardocchi M. ([3]), Meinardi F. ([1]), Weder C. ([2]), Monguzzi A. ([1])

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Plastic scintillators capable of generating delayed fluorescence by triplet-triplet annihilation (TTA) are used to discriminate neutrons and charged particles from γ-rays by applying the

pulse shape discrimination (PSD). This is a time-gated technique that exploits the difference in the kinetics of the scintillation pulse intensity decay, which depends on the energy density released in the material, and thus on the type of the incident radiation. Nowadays, it is difficult to realize efficient PSD with plastics, which have several advantages over liquid or crystalline scintillators such as mechanical robustness and shapeability, but strong limitations on the composition tuning. Here we demonstrate that sensitive and fast PSD detection is achieved in nanostructured polymeric scintillators. These latter consist of a solid polymer matrix, to have structural stability, embedding liquid nanodomains containing a high concentration of TTA dyes and a triplet sensitizer, so that the delayed fluorescence occurs at ultra-low energy densities. Thanks to the sensitizer, the material shows an enhanced sensitivity and discrimination ability with respect to the non-sensitized counterpart.

Characterization of a hybrid photon-counting detector based on Timepix4 for spectral X-ray imaging applications.

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Photon-counting technology represents a significant advancement in clinical applications, offering the potential for substantial transformations in the field of X-ray medical imaging by the implementation of spectral techniques. The international Medipix4 Collaboration aims to develop two application specific integrated circuits (ASICs): Medipix4 for medical imaging applications and Timepix4 for particle tracking. Hybrid photon-counting detectors, based on a Timepix4 ASIC coupled with a silicon sensor, were characterized by studying the response to X-rays and gamma radiation. The characterization was performed by using several radioactive sources, an X-ray tube, and a quasi-monochromatic X-ray irradiation setup. The quasi-monochromatic system is based on Bragg diffraction by a mosaic crystal and is capable of providing X-rays with an average energy that is tunable between 10 keV and 35 keV. In this contribution, the irradiation tests aimed at studying the response of the detector to radiation and evaluating the energy resolution are presented.

CMOS cameras: A low-cost alternative for X-rays detection.

Frassá A. ([1]), Aglietta M. ([2]), Bonino R. ([1]), Gorgi A. ([2])([3]), Latronico L. ([2]), Maldera S. ([2]), Tugliani S. ([1])

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The X-ray Calibration Facility is a specialized lab hosted at the University of Turin for the calibration and characterization of X-ray detectors, sensitive to position, energy and polarization. The facility encompasses two X-ray tubes providing 2 distinct beams, one polarized via Bragg's diffraction, with energy ranging from 2 to 8 keV. The beams are monitored by two sensors: a Silicon Drift Detector (SDD) and a CMOS camera with IMX294 sensor. Notably, this camera, originally designed for astrophotography, has been adapted for this purpose through the removal of its glass protection layer. With an energy resolution of $\approx 1\%$ at 6 keV, its performance is comparable to SDD, thus making the CMOS camera a cost-effective and efficient detector.

Radiation damage assessment of SiPMs for the ZIRÈ space-based experiment.

Fontanella G. per la NUSES Collaboration
Gran Sasso Science Institute, L'Aquila, Italy

NUSES is a space mission proposed and coordinated by the Gran Sasso Science Institute (GSSI), in collaboration with INFN, academic institutions and Thales Alenia Space Italy (TAS-I). The core experiment, ZIRÈ, is designed to measure the energy spectra of charged particles up to 300 MeV to study low-energy cosmic rays, the Van Allen belts and space weather phenomena and analyze magnetosphere-ionosphere-lithosphere coupling (MILC) systems. ZIRÈ relies on a detection system of four primary sub-detectors: 1) a precision tracker made of scintillating fibers 2) an array of plastic X-Y scintillation bars 3) a calorimeter utilizing LYSO crystals as detection target and 4) an anti-coincidence system to tag background induced events. All sub-detectors use SiPMs to read out the scintillation light. This contribution presents the results of simulations of the radiative environment expected during the NUSES mission, focusing on TID (Total Ionising Dose) and TNID (Total Non-Ionizing Dose) damage. In addition, attention is given to the strategy employed to mitigate the radiation dose on SiPMs, to minimize the effects of the dark current to meet the satellite's power consumption constraints.

Enhanced photo response from MoS_2-InAs/ZnSe heterostructure.

Kuriyil S. ([1])([2]), Thakur M.K. ([1]), Asaithambi A. ([1]), Petrini N. ([1])([2]), Rebecchi L. ([1])([2]), Curelli N. ([1]), Krigel I. ([1])
([1]) *Department of Applied Science, Politecnico Di Torino, Italy*
([2]) *Functional Nanosystems, Italian Institute of Technology, Genova, Italy*

Transition metal dichalcogenide monolayers are two-dimensional (2D) direct bandgap semiconductors with improved light-matter interactions and carrier mobility, making them an excellent component in optoelectronic devices. However, the atomically thin nature of these materials results in a weak ($< 1\%$) light absorption and low photocurrents. Poor response times, and bandgap energy limitations in the case of MoS_2 make it difficult to realize optoelectronic devices. Integration with strong light-absorbing nanomaterials, such as zero-dimensional (0D) nanocrystals (InAs NCs), can enhance their interaction with light and improve optoelectronic device performance. We report an efficient charge transfer in a 0D-2D heterostructure of InAs/ZnSe core-shell nanocrystal and MoS_2 monolayer, forming a type-II heterostructure (with InAs/ZnSe being the lower bandgap material). We use steady-state, time-resolved μ-PL spectroscopy and photocurrent measurement techniques to probe the photo-induced charge transfer. Upon excitation of both materials, efficient hole transfer to InAs is observed, with selective excitation of InAs resulting in electron transfer from InAs to the MoS_2 monolayer.

Elemental and angular fragmentation cross-section measurements with the FOOT experiment.

Dondi M., Ridolfi R.
Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna, Italy e INFN, Section of Bologna, Italy

Different fields can profit by nuclear fragmentation cross-section measurements: among them hadrontherapy and space radioprotection are of particular interest. Hadrontherapy employs high-energy beams of charged particles (protons and heavier ions) to treat deep tumours. In these treatments beam particles can fragment in the human body releasing a non-zero dose beyond the tumour while fragments of human body nuclei can modify the dose released in healthy tissues. On the radioprotection side, the interest in long-term manned space missions beyond low Earth orbit is growing but it has to cope with huge health concerns from radiation

in space, requiring an accurate cross section data description. The FOOT (FragmentatiOn Of Target) experiment was proposed to detect, track and identify nuclear fragments measuring double differential cross-sections in angle and kinetic energy, the most complete information to address existing questions. The FOOT experimental setups, the experimental program and a first cross-section analysis of 400 MeV/u ^{16}O beam on carbon and polyethylene target data acquired at GSI (Darmstadt, Germany) beam accelerator facility will be presented.

Aula B **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica
Presiede: Leone M. (Università di Torino)

Relazioni su invito

▲ **Building for science: The contribution of Italian physicists in the first half of the 19th Century.**
Mantovani R.
Dipartimento di Scienze Pure e Applicate, Gabinetto di Fisica, Museo urbinate della Scienza e della Tecnica, Università di Urbino Carlo Bo, Collegio Raffaello, Urbin
The 19th century began with the spectacular construction of Volta's electric pile, leading to Electrochemistry and Electrodynamic's birth. This invention inspired Giuseppe Zamboni to propose a pile that did not require liquids to function. Italian scientists continued to make significant contributions to science in the first half of the 19th century with the invention of new scientific apparatuses. Leopoldo Nobili's astatic galvanometer was significant for developing Electrodynamics, while Macedonio Melloni's thermoelectric pile and optical bench were notable for studying Thermal Phenomena. In the first two decades of the century, Giovanni Battista Amici's catadioptric microscope gained international prominence for being free of chromatic aberration. Other contributions were made by Italian scientists and instrument makers who were dedicated not only to inventing but also to critically evaluating and improving existing apparatus. This contribution will provide an overview of the primary inventions and technical solutions produced by the Italian geniuses of that period.

▲ **Italian physics between the end of the Risorgimento and the start of the new unified state.**
Fregonese L.
Dipartimento di Fisica, Università di Pavia e Museo per la Storia, Università di Pavia
The contribution focuses on Italian physics during the important initial decade (1860-1870) of the national unification. The birth of the new unified state put the problem of how to organize and direct the discipline on a national scale, as opposed to its previous more local setting in the various states which had existed on the peninsula. The recent deaths of various relevant figures of the older generation (Amedeo Avogadro in 1856, Giuseppe Belli in 1860, Ottaviano Fabrizio Mossotti in 1863) and of Carlo Matteucci (1869) among the recent key protagonists was also an occasion to reflect and set renewed goals. The younger successors became particularly aware that the new national physics was to be aligned to the advanced international trends. The analysis will concentrate on major themes which emerged in this context, among which especially a redefinition of the grounds and activities of meteorology and joint efforts towards a physics of the future finally based on the dynamical theory of heat and on the correlation of physical forces.

▲ **Il caso storico del "terremoto elettrico": fondamentali contributi italiani.**
Esposito S.
Università di Napoli "Federico II", INFN, Sezione di Napoli e SISFA
L'ipotesi su una origine elettrica dei terremoti nasce nella seconda metà del XVIII secolo, in un periodo fortemente caratterizzato dagli studi sui fenomeni elettrici. Essa si basava

su evidenze empiriche considerate solide, apparentemente confermate anche da esperimenti modello. Pur sviluppandosi principalmente in una teoria esplicativa di natura fortemente empirica, essa presentava tuttavia un ragionamento scientifico "pulito", ricollegandosi agli studi di Franklin sull'elettricismo atmosferico. Essa venne particolarmente sostenuta dagli studiosi italiani, che potevano beneficiare di molte osservazioni dirette di eventi sismici. Tra questi studiosi, il franklinista Giuseppe Saverio Poli seppe fornire una spiegazione accurata ed esauriente sia del disastroso sisma calabrese del 1783 che dell'altrettanto rovinoso "terremoto di Sant'Anna" del 1805, facendo ricorso a tutta la fenomenologia pertinente disponibile, non limitata a quella elettrica. Nel presente contributo ricostruiamo la nascita, lo sviluppo e la successiva evoluzione, fino all'inizio del XIX secolo, del paradigma del "terremoto elettrico", concentrandoci particolarmente su alcune opere (anche inedite) del Poli.

▲ **Augusto Righi, Guglielmo Marconi e l'UK patent 12039/96.**

Robotti N.

Dipartimento di Fisica, Università di Genova, INFN, Sezione di Genova e Centro Studi e Ricerche Enrico Fermi, Roma

Una delle maggiori conquiste della fisica applicata di fine Ottocento fu, come è noto, lo sviluppo della telegrafia senza fili da parte di Guglielmo Marconi, futuro premio Nobel, di cui quest'anno ricorre il cinquantesimo della nascita. In questo lavoro analizziamo il debito scientifico, se mai c'è stato, di Marconi verso un altro fisico italiano, famoso a livello internazionale per le sue ricerche sulle onde elettromagnetiche, Augusto Righi. Questa questione verrà affrontata sia attraverso uno studio dettagliato del primo brevetto depositato da Marconi in Inghilterra nel 1896 (UK patent 12039/96) sia attraverso un'analisi della corrispondenza scientifica di Righi con alcuni dei più importanti scienziati coinvolti in questo settore, oltre che di quanto riportato dalla stampa popolare del tempo. Da un'analisi di questo tipo, che comprende anche uno studio delle attività svolte da Righi e Marconi, quando erano entrambi senatori del Regno d'Italia, è possibile evidenziare quanto Marconi deve agli scienziati suoi contemporanei, di quali contributi specifici fu l'ideatore e infine che cosa Marconi e Righi pensavano l'uno dell'altro.

Comunicazioni

● **Costruire lenti e telescopi nel seicento: la dioptrica pratica di Carlo Antonio Manzini.**

Burani B.

I.S.S. "Galileo Galilei", Mirandola, MO

La presentazione riporta un lavoro di tesi svolto al Dipartimento di Fisica e Astronomia dell'Università di Bologna. L'obiettivo è stato quello di dare nuova luce e analizzare sia la figura del conte Carlo Antonio Manzini come esempio di intellettuale seicentesco, sia la sua opera principale, "L'Occhiale all'Occhio", la quale risulta essere una piccola enciclopedia della "dioptrica pratica", l'arte seicentesca di costruzione di lenti e telescopi. Essa descrive i prodotti di quest'arte, oltre alle tecniche e agli strumenti utilizzati al tempo con l'esplicito intento di conservare il tutto e renderlo accessibile agli artigiani, destinatari principali dell'opera, o a chiunque potesse essere interessato all'argomento. L'analisi originale è ulteriormente arricchita dalla presenza di tabelle ideate e inserite da Manzini stesso, oltre a vari consigli per raggiungere la perfezione in quest'arte. A questo si aggiunge uno studio di raccolta di informazioni dalle iscrizioni delle lenti, in primis quelle di Giuseppe Campani, conservate al Museo di Palazzo Poggi e della Specola, osservate in maniera più consapevole poiché note le caratteristiche dell'arte della "dioptrica pratica".

Verso i confini disciplinari: esperimenti di "matematica mista" all'Accademia del Cimento (1657-1667).

Rossi E.
Università degli Studi di Milano

La Fiorentina Accademia del Cimento (1657-1667), di ispirazione galileiana e patrocinata dalla famiglia de' Medici, condusse oltre un migliaio di esperimenti durante il suo decennio di attività. Le principali linee di ricerca sperimentale riguardavano la pneumatica (lo studio del vuoto e della pressione dell'aria) e la termologia (gli effetti del caldo e del freddo, e i fenomeni di agghiacciamento). L'agenda dell'Accademia includeva anche esperimenti di ottica, acustica e meccanica, spesso riuniti sotto il concetto di "matematica mista" è il termine, divenuto comune intorno al 1660, riguardava lo studio di numeri e grandezze non astratti, ma in relazione a oggetti e fenomeni fisici. Oscillazioni di pendoli e i relativi punti di equilibrio, la caduta e il rimbalzo dei corpi pesanti, le traiettorie dei proiettili, la propagazione del suono e della luce attraverso diversi mezzi sono solo alcuni esempi di esperimenti in questi campi. Il contributo offre una panoramica di tali osservazioni, condotte in un'epoca precedente alla specializzazione delle discipline scientifiche, quando i confini tra i vari ambiti della fisica non erano ancora ben definiti.

L'opera di Paolo Anania De Luca tra arte e scienza.

Del Monte R., Auteri A.
Museo di Fisica del Centro Musei delle Scienze Naturali e Fisiche, Università di Napoli Federico II

In occasione del 160° anniversario dalla sua scomparsa, si vuole ricordare la figura di Paolo Anania De Luca (1778-1864), patriota e scienziato, le cui invenzioni sono in parte conservate nel Museo di Fisica del Centro Musei delle Scienze Naturali e Fisiche dell'Università di Napoli Federico II. Nato a Montefusco irpino, si trasferì a Napoli dove, grazie agli insegnamenti di Mario Pagano e Gaetano Filangieri, si distinse per il suo impegno politico a favore della libertà, opponendosi alla Monarchia Borbonica. La vita di De Luca non si limitò alla politica, durante il suo soggiorno a Napoli, si dedicò infatti anche alla sua grande passione: la fisica. I suoi studi evidenziano un'attenzione minuziosa ai dettagli e le sue invenzioni, realizzate personalmente, spaziano dalla meccanica all'ottica e all'acustica, rivelando una notevole abilità manuale e una mente capace di coniugare arte e scienza. Nominato nel 1860 "professore onorario" da Francesco De Sanctis, direttore del Ministero della Istruzione Pubblica, De Luca, ormai anziano e quasi completamente cieco, donò le sue invenzioni all'Università di Napoli, declinando l'incarico con gratitudine.

Armi e innovazioni: il genio della famiglia Nobel.

Franchini L.
Associazione Amici di Città della Scienza

Alla famiglia Nobel si devono importanti invenzioni ed innovazioni, utilizzate sia per scopi bellici che in ambito civile. Il capostipite Immanuel, architetto svedese geniale, per meglio sviluppare la sua invenzione delle mine sottomarine mandò il figlio Alfred, a Parigi nei laboratori di Sobrero, un italiano che stava sperimentando un nuovo esplosivo, la nitroglicerina. Da ciò nacque l'invenzione della dinamite e del detonatore. Al secondo figlio Ludwig, geniale ingegnere ed grande capitano d'industria, si deve la costruzione della prima petroliera e di nuovi mezzi di trasporto del petrolio. Fu invece del primogenito Robert l'idea acquistare una raffineria di petrolio in Azerbaijan dove poi si sviluppò una grande industria petrolifera. Il primogenito di Ludwig, Emanuel, fece costruire a San Pietroburgo la prima fabbrica di motori Diesel del mondo e fu l'unico della famiglia a sostenere la volontà di Alfred di creare un premio con il suo capitale.

Marconi e Bologna: ricostruzione preliminare di un rapporto complesso.
Buccilli B., Pipi F.
Dipartimento di Fisica e Astronomia, Università di Bologna
Questo intervento si colloca nell'ambito delle iniziative per le celebrazioni per i 150 anni dalla nascita di Guglielmo Marconi. In particolare, verrà descritto un lavoro di studio e approfondimento del rapporto tra Marconi e la città di Bologna che verrà utilizzato per la realizzazione di un percorso rivolto a visitatori e promosso dal Comune. La ricostruzione del rapporto tra Marconi e Bologna risulta piuttosto complesso e diversificato. Il lavoro svolto ha individuato alcune macro-aree di analisi che comprendono la figura di Marconi in relazione ad alcuni luoghi significativi della città, in relazione ai suoi cittadini, alle istituzioni accademiche e allo sviluppo industriale del territorio. In conclusione, si riscontra un profondo legame tra Marconi, Bologna e i suoi cittadini; una spinta entusiastica nell'industria bolognese soprattutto in relazione alla figura dei fratelli Ducati insieme ad un rapporto controverso con le istituzioni accademiche. Quest'ultimo si concretizza da una parte in un legame incerto e storicamente dibattuto con Righi, dall'altra in una valorizzazione della figura di Marconi testimoniata da diverse onorificenze a lauree ad honorem conferitegli.

I rapporti tra Augusto Righi e il giovane Guglielmo Marconi raccontati da un testimone di eccezione: Bernardo Dessau.
Carlotti G.
Dipartimento di Fisica e Geologia, Università di Perugia
Mentre si festeggiano i centocinquant'anni dalla nascita di Guglielmo Marconi, rimane ancora piuttosto controversa la questione dei rapporti tra lui e il prof. Augusto Righi. Da un lato, infatti, è certo che il giovane Marconi, nei primi anni novanta dell'ottocento, trasse vantaggio dai colloqui e dalle visite al laboratorio di Righi presso l'Istituto di Fisica dell'Università di Bologna. D'altra parte è chiaro a tutti come Marconi sia stato capace di osare e arrivare a risultati eccezionali e originali, laddove "da altri non erano state fatte che delle timide proposte, e di aver trasportato nel campo pratico ciò che altri avevano soltanto intravveduto o realizzato in scala minore" (B. Dessau). Con questo breve contenuto intendiamo analizzare la questione attraverso alcune testimonianze dirette di Bernardo Dessau, assistente di Righi a Bologna dal 1890 al 1904, che fu testimone oculare delle visite del giovane Marconi all'Istituto di Fisica di Via Zamboni.

Dal Regio Museo di Fisica dell'Università alla telegrafia senza filo: l'esposizione di strumenti storici presso il Dipartimento di Fisica e Astronomia "A. Righi" di Bologna.
Bertozzi E., Rigotti L.
Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna
Il 12 Aprile del 1907 Augusto Righi fondava l'Istituto di Fisica di Bologna insieme al Regio Museo di Fisica ivi annesso. Negli spazi del museo, teche di legno e vetro ospitavano il vasto patrimonio di apparati utilizzati per l'insegnamento della fisica ottocentesca. La presentazione illustrerà il recente allestimento realizzato presso il DIFA di Bologna volto a ricreare, tramite teche e apparati originali, l'ambiente del Regio Museo; obiettivo del riallestimento è quello di mostrare tramite pannelli, didascalie e libri di testo dell'epoca, i caratteri principali e la logica seguita nell'insegnamento della fisica ottocentesca. La relazione mostrerà inoltre come Righi arricchisse l'insegnamento con lezioni speciali sulle onde hertziane. Ricorrendo quest'anno i 150 anni dalla nascita di Guglielmo Marconi, tali lezioni risultano particolarmente interessanti sia perché, a volte, lo stesso Marconi vi fa riferimento, sia perché, come si mostrerà, esse tracciano "un filo" diretto tra Galvani, Righi e Marconi stesso.

Corbino, Marconi e la nascita dell'Istituto Nazionale di Elettroacustica del CNR.

Focaccia M.
Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Roma

Con Decreto del 10 luglio 1936 del Presidente, veniva costituito l'Istituto Nazionale di Elettroacustica del CNR, con sede in via Panisperna, nei locali lasciati liberi dopo il trasloco del Regio Istituto di Fisica. Ideatore ne fu Orso Mario Corbino, con il decisivo appoggio dell'allora presidente del CNR, Guglielmo Marconi. Fu proprio lo stretto sodalizio scientifico e istituzionale tra i due, che permise la promozione e la fondazione del nuovo istituto. Un sodalizio che aveva origini lontane, a partire dal loro condiviso impegno di attenti promotori della politica della ricerca dei primi decenni del Novecento e dal loro comune coinvolgimento in alcuni dei maggiori istituti scientifici dell'Italia del tempo. La presente comunicazione intende ripercorrere la fondazione di questo Istituto, a partire dal legame scientifico e istituzionale e dal comune interesse nel campo dell'elettrotecnica che legò i due scienziati. L'Istituto di Elettroacustica, che restò a via Panisperna fino al 1943, allorquando i tedeschi invasero Roma, potè godere brevemente tanto della direzione di Corbino che della supervisione di Marconi, entrambi scomparsi prematuramente nel 1937, a pochi mesi di distanza.

Dalla storia chimica di una candela di Faraday alcuni suggerimenti per la didattica delle odierne discipline STEM.

Cerreta P.
Associazione ScienzaViva, Calitri

Non c'è nulla di più istruttivo di una candela che arde lasciava intendere Faraday e ciò ci invita, oggi, ad attualizzare i fenomeni che lo scienziato inglese mise in scena oltre centocinquant'anni fa. Esporre la fiamma di una candela ai raggi del sole e osservarne l'ombra su un foglio bianco, come lui raccomandava, consente di scoprire non solo la traccia dei moti convettivi dell'aria riscaldata da essa, ma anche la presenza di qualcosa di curiosamente opaco in corrispondenza della punta della fiamma stessa: il nerofumo che irraggia la luce. E inoltre, tagliare a diversi livelli la fiamma con una reticella sottile mostra che essa è cava e che durante la combustione dal suo interno fuoriesce il vapore bianco della cera fusa che, più in alto, diventa nerofumo. Altri spunti sperimentali interessanti sono il raffreddamento automatico dei bordi esterni della candela, la separazione della cera fusa dalla fiamma, la necessità di uno stoppino intrecciato che la alimenti per capillarità pescando dalla ciotola sottostante, il vapor d'acqua e l'anidride carbonica come prodotti della combustione e la similitudine di questa con la respirazione umana. Tutti argomenti STEM.

c dalla storia della scienza al laboratorio scolastico: da impossibile problema a risorsa concreta.

Varagnolo A. ([1]), Carli M. ([2]), Pantano O. ([2])
([1]) *Istituto di Istruzione Superiore "Giordano Bruno - Raimondo Franchetti", Venezia*
([2]) *Dipartimento di Fisica e Astronomia "Galileo Galilei", Università degli Studi di Padova*

La velocità della luce, nel vuoto o in un mezzo, è spesso nel corso di Fisica della scuola secondaria un oggetto/concetto tanto affascinante quanto intangibile, confinato a descrizioni teoriche e situazioni astratte. Si vuole dimostrare la possibilità di un percorso innovativo che, a partire da una base storica non limitata all'aneddotica ma concretizzata in momenti di ricerca e analisi attiva (ricalcando l'approccio di Roemer con dati odierni, ottenibili tramite software), arriva a sfruttare le opportunità offerte da elettronica e digitale per effettuare misure dirette (cinematiche, a echeggiare la preveggente idea di Galilei) e affidabili, conducendo infine gli studenti a indagare le proprietà dei mezzi trasparenti e degli stessi strumenti di misura; tale percorso può essere adattato al contesto scolastico. Le attività sperimentali relative alla misura cinematica di c in aria sono state proposte in classi di terzo, quarto e quinto

anno di Scientifico e Scienze Applicate (modulando contenuti e richieste sulle conoscenze a disposizione), consentendo di valutarne i punti di forza e le criticità, nonché di suggerire agli studenti appassionati la meraviglia del possibile.

Laboratorio didattico e museo di fisica al Polo Umanistico delle Arti per un nuovo Rinascimento nel CLXX anniversario del Liceo Ginnasio Dante.
Sottili L., Busato P.
I.I.S. Alberti-Dante, Firenze
Il Liceo Ginnasio Dante di Firenze, dal 2018 confluito nell'IIS Alberti-Dante, ha una lunga tradizione di didattica della fisica, testimoniata dal museo che contiene numerosi strumenti scientifici, e dalla documentazione presente nell'archivio d'istituto. A centosettanta anni dalla nascita del Liceo, il gruppo dei docenti del settore scientifico è impegnato nella didattica laboratoriale della fisica, anche grazie alla presenza del laboratorio di scienze naturali e fisica, ed alla partecipazione a progetti PON e PNRR. In questo contributo verranno presentate alcune esperienze didattiche eseguite durante il corrente anno scolastico.

Il Booklet del Museo Enrico Fermi di Roma.
Verduci D.
Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Roma
I musei non sono un fine in se stessi, ma un mezzo al servizio dell'umanità. Ne consegue che la funzione comunicativa del museo è intrisa nella sua stessa natura. Tra le varie tipologie di comunicazione museale, quella testuale è tanto interessante, quanto poco conosciuta e studiata. In questo contesto, è stata ideata, progettata e realizzata una guida scritta del Museo Storico della Fisica "Enrico Fermi". Si tratta di uno strumento pensato per un target specifico: le scuole secondarie di primo e secondo grado. La scrittura del booklet, scaricabile gratuitamente sul sito web del Museo, si è articolata in varie fasi successive: l'analisi preliminare, la raccolta di informazioni e materiale ed infine la revisione della forma e del contenuto. A tale scopo, sono stati coinvolti esperti afferenti a molteplici settori, oltre che alcuni archivi storici e musei scientifici presenti sul territorio italiano.

Le attività di outreach del Centro Fermi.
Garbini M., Focaccia M.
Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Roma
Il Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi" è un ente pubblico di ricerca con sede nella storica palazzina di via Panisperna a Roma, un tempo "Regio Istituto Fisico", dove Enrico Fermi, coadiuvato da un gruppo di giovani, condusse negli anni Trenta del Novecento gli esperimenti sulla radioattività indotta da neutroni. L'Ente è per natura contraddistinto da una duplice missione: sviluppare linee di ricerca originali e interdisciplinari ed offrire un'ampia diffusione e comunicazione della Scienza e della vita e delle scoperte di Enrico Fermi. Il Museo dedicato a Fermi, ospitato nella sede dell'Ente, ripercorre le tappe della sua vita e delle sue scoperte, combinando in maniera innovativa oggetti e pannelli tradizionali con moderne tecnologie multimediali. Le attività di outreach comprendono le visite ai laboratori ospitati all'interno del complesso monumentale di via Panisperna, naturale completamento della visita museale, l'organizzazione di cicli di conferenze su tematiche di storia della scienza ma non solo, la partecipazione ad eventi quali la Notte Europea della Ricerca e molte attività legate al Progetto Extreme Energy Events - La Scienza nelle Scuole.

Aula A **ore 09:00 – 13:30**

Sezione Giovani
Da Marconi al Cloud

Presiedono: Terranova A. (AISF)
Romano P.F. (Young Minds, EPS)

La Società Italiana di Fisica, in collaborazione con il network di giovani ricercatori della European Physical Society (EPS) Young Minds e l'Associazione Italiana Studenti di Fisica (AISF), organizzano dal 2015 la Sezione Giovani, un momento del Congresso SIF espressamente dedicato ad un pubblico giovane, con relazioni che possano favorirne lo sviluppo scientifico e professionale su uno specifico campo della fisica, ogni anno differente.

Quest'anno, per unirci alle celebrazioni dei 150 anni dalla nascita di Guglielmo Marconi e approfittando della collocazione del Congresso SIF proprio a Bologna, sua città natale, la Sezione Giovani intitolata "Da Marconi al Cloud" sarà dedicata proprio all'inventore della Radio. Si parlerà della figura di Marconi, calata nel suo contesto storico, e della sua eredità, declinata nello sviluppo di quelle tecnologie di telecomunicazione senza fili che trovano origine proprio nella radio da lui creata, da internet fino alle ultime frontiere della comunicazione ottica free space.

Relazioni su invito

Moderatore: Alessandro Terranova (Università di Pisa)

▲ **Il ragazzo del wireless: Guglielmo Marconi 1874/2024.**
Valotti B.
Museo Marconi, Fondazione Guglielmo Marconi, Sasso Marconi, Bologna
Guglielmo Marconi intuì la possibilità della comunicazione senza fili mediante onde elettromagnetiche a 20 anni, l'anno successivo - grazie a una intensa attività sperimentale svolta nella residenza di famiglia, la Villa Griffone situata sulle prime colline bolognesi - inventò la radiotelegrafia, a 23 anni fondò a Londra la prima azienda nel settore del wireless e a 27 anni realizzò un'impresa ritenuta impossibile, ossia la trasmissione di un segnale radio attraverso l'Atlantico e a 35 anni fu il primo italiano a vincere il Premio Nobel per la Fisica. Nella presentazione saranno presentati il contesto e il percorso che portarono un "giovane dilettante appassionato di elettricità" (così si definì Marconi nella prima intervista che rilasciò alla stampa britannica) ad agire da vero e proprio pioniere della comunicazione wireless prima dei trent'anni e a divenire il simbolo delle radiocomunicazioni nel corso di una lunga carriera in cui fu inventore, sperimentatore e imprenditore globale imponendosi come figura-chiave della modernità. Eppure, non sempre è riconosciuto come tale e nell'anno in cui ricorre il 150° della nascita questo contributo ne delinea un ritratto a tutto tondo.

▲ **Marconi, Corbino e l'Istituto di Fisica di via Panisperna.**
Focaccia M.
Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Roma
Nel 1929, in un'intervista a un'agenzia americana, Marconi affermava che tra gli sviluppi più interessanti e promettenti della fisica erano senz'altro la fisica del nucleo atomico e la televisione. Nel 1931, all'Istituto di Fisica dell'Università di Roma, venne organizzato il primo

congresso internazionale di fisica nucleare. L'idea fu di Enrico Fermi, Segretario generale, mentre Orso Mario Corbino, direttore dell'Istituto di Fisica, era il Presidente effettivo, con Guglielmo Marconi Presidente onorario. Nel luglio del 1936, dopo che l'Istituto di Fisica venne traslocato nella nuova città universitaria, a Panisperna venne costituito l'Istituto di Elettroacustica del Consiglio Nazionale delle Ricerche diretto da Corbino. Se l'ideatore fu Corbino, decisivo fu appoggio dell'allora presidente del CNR, Marconi. Partendo da queste tappe storiche e scientifiche, si tenta di ripercorrere il rapporto e il sostegno dati da Marconi all'Istituto di Fisica romano e ai suoi protagonisti; un rapporto e un sostegno stretti e proficui, a partire dai comuni interessi scientifici, e rafforzati dalle diverse posizioni istituzionali occupate da queste personalità all'interno del Consiglio Nazionale delle Ricerche, dell'Accademia d'Italia e dell'Università.

▲ Comunicazioni ottiche wireless.

Ciaramella E.
Scuola Superiore Sant'Anna, Pisa

L'intervento presenta le principali caratteristiche scientifiche e le molteplici prospettive delle comunicazioni ottiche wireless, nella regione della luce visibile e infrarossa. Si illustrano alcune realizzazioni sperimentali di sistemi wireless ottici, effettuate presso i laboratori della Scuola Superiore Sant'Anna. Sono descritte anche alcune recenti linee di ricerca nel campo delle comunicazioni per lo spazio: comunicazioni a bordo di satelliti a breve distanza e comunicazioni su grandi distanze, come collegamenti tra satelliti diversi e tra satellite e Terra.

▲ Connessioni (ottiche) tra Ricerca di base e Industria.

Potenza M.
Università di Milano

Il termine "trasferimento tecnologico" viene spesso interpretato a senso unico, dalla Ricerca alle applicazioni, ma rappresenta una realtà più complessa fatta di un dialogo continuo tra lo scienziato, il tecnologo e la Natura, tra la Ricerca e le sue applicazioni, che può generare in sé la Conoscenza necessaria all'Industria. Se un asserto scientifico è tale solo se falsificabile, come può questo essere utile all'Industria, dove sono essenziali ripetibilità e previsione? Questi temi verranno sviluppati prendendo spunto dallo sviluppo di una tecnologia per telecomunicazioni mediante interconnessioni ottiche, brevettata dall'Università di Milano e portata alla creazione di impresa. Lo studio dei fronti d'onda svolto negli anni scorsi, dall'astronomia ai fasci emessi dagli acceleratori di particelle, e lo sviluppo di strumenti per lo Spazio e gli ambienti estremi, hanno fatto emergere un metodo robusto per il riconoscimento di particolari fasci di luce: è possibile generare diversi fasci, modularli, sovrapporli, trasmetterli e quindi distinguere le informazioni su ciascuno di essi. La tecnica ha subito destato l'interesse del mondo imprenditoriale per lo sviluppo in ambito spaziale.

▲ Da zero al Tbit/s: l'evoluzione del calcolo distribuito nell'INFN sull'onda della crescita delle reti.

Pardi S.
INFN Sezione di Napoli

A paritre dagli anni '70 gli istituti di ricerca italiani iniziarono a implementare le prime reti di calcolatori. L'INFN fu pioniera, creando INFN Net e lavorando ai primi collegamenti internazionali con CERN, Fermilab e KEK per gli esperimenti HEP. La nascita del web negli anni '90 e la creazione di grandi Data Centers spinsero l'avanzamento delle reti. Nello stesso decennio, lo sviluppo del Grid Computing diede inizio alle grandi infrastrutture mondiali di calcolo distribuito, essenziali per il calcolo degli esperimenti LHC che confermarono

l'esistenza dell'Higgs nel 2012. Con l'introduzione del Cloud Computing, si ottenne una maggiore personalizzazione degli ambienti di calcolo,in parallelo, i modelli di Big Data e Data Lake definirono nuovi modi per la condivisione dei dati su reti sempre più veloci. L'INFN è stata leader in questa evoluzione, dalla nascita delle prime reti alla creazione del Centro Nazionale di Ricerca in High Performance Computing, Big Data e Quantum Computing (ICSC). Questa presentazione descrive l'evoluzione di queste tecnologie e come è cambiato l'uso delle risorse di calcolo grazie alla crescita delle reti.

PANEL DISCUSSION

Pubblico e relatori avranno modo di discutere e approfondire insieme i temi legati a Marconi, dalla fisica su cui si lavorava al suo tempo fino alle tecnologie di telecomunicazione attuali, in un ambiente aperto e di confronto.

Moderatore: Pasquale Francesco Romano (Università di Napoli "Federico II")

Intervengono:

Barbara Valotti, Museo Marconi, Fondazione Guglielmo Marconi, Sasso Marconi, Bologna

Miriam Focaccia, Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Roma

Ernesto Ciaramella, Scuola Superiore Sant'Anna, Pisa

Marco Potenza, Università di Milano

Silvio Pardi, INFN Sezione di Napoli

Aula 1C **ore 09:00 – 13:30**

Sezione II
Simposio di Fisica Statistica e Sistemi Complessi
Presiedono: Spagnolo B. (Università di Palermo)
Corberi F. (Università di Salerno)

Relazioni su invito

▲ **Out-of-equilibrium response, dissipation, and control in flocking systems.**
Giardina I.
Dipartimento di Fisica, Sapienza Università di Roma
Flocking systems are known to be strongly out of equilibrium. Energy input occurs at the individual level to ensure self-propulsion, and the motility in turn contributes to ordering, strengthening collective motion. However, even beyond ordering, a crucial feature of natural aggregations is response. How, then, off-equilibrium features affect response behavior? I will address this issue both from an empirical and a theoretical perspective. I will first summarize what we know from experiments on natural swarms and flocks and show that out-of-equilibrium effects are stronger in one case than in the other. Then I will consider a minimal model of flocking and investigate theoretically and numerically the response behavior. Violations of equilibrium fluctuation-dissipation relations occur both at the local and at the global level and their amount peaks at the ordering transition. Entropy is always produced locally. However, cooperative mechanisms close to the transition spread off equilibrium effects on the whole system, producing an out-of-equilibrium response on the global scale. This picture reconciles nicely with the data, providing an explanatory framework for natural systems.

▲ **Fast Rare events in exit time distributions.**
Burioni R.
Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università degli Studi di Parma e INFN, Sezione di Milano Bicocca - Gruppo Collegato di Parma
A stochastic process that reaches a certain threshold for the first time can trigger many events: a chemical reaction occurs, a target is reached, biological and ecological processes take place. The study of these triggering events and the probability of their occurrence is based on the knowledge of first-passage probabilities. Because of their "triggering" property, the tails of these distributions are particularly important as they allow the probability of rare anomalous events to be estimated, such as leaving an interval in a very short time. A few results are available for the first-pass probabilities of jump processes, which are stochastic processes that involve random jumps between different states or positions, occurring at random times and with random magnitudes. When jump distributions are heavy-tailed, the mechanism that leads to rare events is peculiar. Instead of being caused by a set of many small deviations all in the same direction, one jump, the largest of the lot, provides the main contribution to the rare large fluctuation. We will review some recent results obtained using this big jump approach in a wide class of Lévy processes.

▲ Data mining of biological and material systems: How complex systems and networks can help.

Gili T.
IMT School for Advanced Studies, Lucca

The spatial and temporal complexity of real-world data offers everyday challenges to their analysis and interpretation that grow progressively together with their amount and our need for natural phenomena forecasting. This is even more difficult considering the variability of biological systems and the disordered nature of many materials. In this contribution, we show how the methods developed in the context of complex systems, especially those regarding complex networks theory, can help to describe the many-body interactions typical of such systems at the mesoscopic scale, joining the microscopic with the macroscopic regimes.

▲ Solvable models of energy transport: From micro to macro.

Giardinà C.
Dipartimento di Fisica, Informatica e Matematica, Università degli Studi di Modena e Reggio Emilia

We consider exactly solvable models of energy transport, i.e. the so-called harmonic processes, associated with the open integrable XXX chain with non-compact spins. We show that it is possible to explicitly compute the non-equilibrium steady state, which turns out to be a mixture of equilibrium product measures. We identify the law of the mixture in terms of the Dirichlet process. Next, by using the explicit knowledge of the non-equilibrium steady state, we establish rigorously formulas predicted by the Macroscopic Fluctuation Theory for several quantities of interest, in particular the density large deviation function.

▲ Measuerement indiced phase transitions, multipartite entanglement and chaos.

Silva A.
SISSA

The combination of many-body quantum dynamics and monitoring through measurements gives rise to peculiar phenomena when one retains the result of measurement and looks at time evolutions trajectory by trajectory. In this case non trivial phase transitions can be observed as a function of the measurement rate, for example separating regimes with different scaling of the entanglement entropy. In this contribution I will discuss a different point of view on these phenomena focusing on either different characterizations of the transition (i.e. multipartite entanglement) or on the degree of sensitivity of the latter to postselection.

▲ Statistical physics tools to characterize the geometry of high-dimensional, non-convex random landscapes.

Ros V.
LPTMS Orsay, CNRS and Université Paris Saclay

Random landscapes have been introduced long ago as models of the potential energy landscapes of complex systems, such as glasses; understanding their structure has been (and is) instrumental for determining the evolution of local dynamics of the associated glassy systems. In more recent years, these landscapes made their appearance as generalized cost functions in a variety of high-dimensional optimization, inference and control problems. I will comment on the analytical methods available to characterize the geometrical properties of random non-convex landscapes in high dimension, such as the distribution and connectivity of its stationary points, and the energy profile along paths interpolating between them. I will discuss applications to problems related to (1) metastability and barrier crossing in high-dimensional optimization, (2) inference and denoising in high dimensions and (3) modeling of complex dynamical systems with plenty of randomly interacting agents.

Comunicazioni

On probability theory and quantum mechanics.

Rocchi P.
Istituto di Economia, Università LUISS, Roma

Researchers have progressively discovered the multifaceted nature of probability (P) and developed irreconcilable theories that negatively affects quantum physics studies. Each author postulates that P has only one meaning, or two at most, whereas P proves to be objective and subjective, empirical and logical, epistemic and ontological, practical and abstract, and so on. Each probabilists selects the meaning of P that he deems to be the best according to personal criteria. E.g., frequentists concentrate on the experimental control of probability and overlooks whether the collective is a special kind of happening. Bayesians mean to calculate the probability of any event, no matter if probability cannot be tested. In short, what is important for former is negligible for the latter and vice versa.
Quantum physics is intrinsically probabilistic, in accordance with Popper I've made an attempt to integrate the various standpoints. In particular I prove fifteen theorems to address the single case problem which emerges both in classical and quantum contexts.

Reversal-time criticality in Ising models with defects.

Ettori F. ([1]), Sluckin T.J. ([1])([2]), Biscari P. ([1])
([1]) *Politecnico di Milano*
([2]) *University of Southampton, UK*

In a magnetization reversal process, a magnetic system exhibits collective rearrangements of magnetic moments, which give raise to magnetic avalanches. Understanding these phenomena holds significant promise for advancing spintronics, magnetic recording technology, and the study of phase transitions. By employing Monte Carlo simulations with Glauber dynamics, we explore the dynamics of a magnetic system under an oscillating magnetic field using the Ising model. We analyze the individual spin reversal time quantified as the number of half periods before the average spin direction undergoes a sign change (spin reversal event). For homogeneous systems, the spin reversal event follows a Poissonian distribution, and the average reversal time has an exponential temperature dependence below the dynamical critical temperature. By contrast, the spin reversal event in systems with impurities -spins with fixed orientation throughout the experiment- displays a power-law distribution. Two regimes emerge above and below the dynamical critical temperature, characterized by distinct critical exponents. Finally, we propose a theoretical framework to explain the empirical findings.

Aula Magna **ore 14:30 – 15:10**

Sezione I
Fisica nucleare e subnucleare
Presiede: Patrizii L. (INFN, Sezione di Bologna)

Relazione Generale

Frontiere della fisica nucleare sperimentale.
Giubellino P.
GSI, Darmstadt, Germany
La Fisica Nucleare attraversa un momento di straordinaria vitalità. Lo sviluppo della nostra capacità di osservare l'Universo negli ultimi anni, con nuove "finestre" sull'Universo che si sono aperte grazie a nuovi strumenti, come l'astronomia delle onde gravitazionali, ha portato con se la necessità di un salto di qualità nella comprensione dei processi nucleari alla base di molti aspetti essenziali della evoluzione e della struttura dell'Universo. Nello stesso tempo, nuove infrastrutture permettono ai fisici nucleari di realizzare esperimenti impensabili anche solo qualche tempo fa. Nuovi acceleratori hanno appena aperto o stanno aprendo un po' in tutto il mondo, e altri sono prossimi ad essere completati. Anche in Italia, si aprono nuove possibilità per la sperimentazione. Allo stesso tempo, si sta sviluppando nella società una nuova coscienza del ruolo che la fisica nucleare svolge e degli sviluppi che potrebbe avere nel futuro: la necessità di produrre energia minimizzando le emissioni di CO_2 ha riportato attenzione sull'energia nuleare, sia fissione che fusione, l'uso di tecniche nucleari in medicina non cessa di espandersi con una necessita continua di innovazione, dalla produzione di radioisotopi alla terapia dei tumori. Anche l'esplorazione dello spazio è tornata alla ribalta: sognamo viaggi su Marte, basi spaziali ... E di nuovo, la necessità della protezione degli astronauti dalle radiazione è diventata un tema centrale. La Fisica Nucleare è fondamentale per la nostra comprensione dell'Universo e per la nostra qualità della vita, e le nuove opportunità sperimentali che stanno aprendo in tutto il mondo ci permettono di essere ottimisti sulla possibilità di rispondere a queste esigenze. Si apre un periodo entusiasmante.

Aula Magna **ore 15:10 – 15:50**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Lucarelli F. (Università Firenze)
Villa M. (Università di Bologna e INFN, Sezione di Bologna)

Relazione Generale

Potenzialità delle tecnologie nucleari nel processo di decarbonizzazione.
Dodaro A.
ENEA, Dipartimento Nucleare, NUC
La domanda di energia sempre più elevata e la consapevolezza delle conseguenze di una politica mondiale, per troppo tempo miope sui cambiamenti climatici, impongono di minimizzare l'emissione di gas serra ed il ricorso a fonti energetiche che garantiscano la neutralità climatica. La fusione nucleare è la speranza per un futuro verde che minimizzi la produzione di rifiuti radioattivi. Essa implica sfide scientifiche e tecnologiche che presuppongono enormi sforzi economici e intellettuali verso un futuro che veda l'energia delle stelle come fonte energetica verde, virtualmente illimitata ed economicamente sostenibile. Oggi, però, è necessario intervenire con soluzioni implementabili nel breve periodo che supportino la decarbonizzazione (rinnovabili, efficienza energetica, idrogeno, sistemi di cattura della CO_2, nucleare). Ipotizzare una produzione 100% RES è un sogno irrealizzabile, non tanto per i tempi e i costi, quanto per gli evidenti limiti di continuità di produzione e per le problematiche relative ai sistemi di accumulo: per una quota non trascurabile del fabbisogno nazionale, occorre una fonte che sia disponibile 24 ore al giorno per 365 giorni l'anno: appare, quindi, evidente che le fonti rinnovabili e il nucleare debbano avere un ruolo complementare in un mix energetico equilibrato che riduca gli sprechi e risponda alle esigenze del Paese.

Aula Magna **ore 15:50 – 19:00**

Sezione I
Fisica nucleare e subnucleare
Presiede: Pirrone S. (INFN, Sezione di Catania)

Relazioni su invito

▲ **Searching for the X17 with the PADME experiment.**
Gianotti P. ([1]), Bertelli S. ([1]), Bossi F. ([1]), De Sangro R. ([1]), Di Giulio C. ([1]), Di Meco E. ([1])([2]), Dimitrova K. ([3]), Domenici D. ([1]), Ferrarotto F. ([4]), Finocchiaro G. ([1]), Foggetta L.G. ([1]), Frankenthal A. ([5]), Garattini M. ([1]), Georgiev G. ([3])([6]), Gianotti P. ([1]), Ivanov S. ([3]), Ivanov Sv. ([3]), Kozhuharov V ([1])([3]), Leonardi E. ([4]), Long E. ([4])([7]), Mancini M. ([1])([2]), Organtini G.C. ([4])([7]), Raggi M. ([4])([7]), Sarra I. ([1]), Simeonov R. ([3]), Spadaro T. ([1]), Spiriti E ([1]), Valente P. ([4]), Variola A. ([4]), Vilucchi E. ([1])
([1]) *INFN, Laboratori Nazionali di Frascati*
([2]) *Dipartimento di Fisica, "Tor Vergata" Università di Roma*
([3]) *Facoltà di Fisica, Università di Sofia "St. Kl. Ohridski", Sofia, Bulgaria*
([4]) *INFN, Sezione di Roma*
([5]) *Dipartimento di Fisica, Università di Princeton, USA*
([6]) *INRNE, Accademia delle Scienza Bulgara*
([7]) *Dipartimento di Fisica, "Sapienza" Università di Roma*
The Positron Annihilation into Dark Matter Experiment (PADME) has been designed with the primary goal to look for a signal of a dark photon. PADME can investigate the existence of different feeblyinteracting particles (FIPs) produced in the interaction of a positron beam with a thin diamond target. These particles are predicted by theories beyond the Standard Model developed to solve the dark-matter problem in scenarios alternative to the WIMP paradigm. In 2016, an experiment at the ATOMKI of Debrecen studying the de-excitation of ^{8}Be via Internal Pair Creation, reported an anomaly that might represents the first evidence of a FIP of mass ~ 17 MeV (X17). PADME is in the unique position of verifying the existence of this particle, by trying to produce resonantly the X17 via the annihilation of its positron beam with the electrons of the target. The data taking performed by PADME in winter 2022 (Run III) was thus designed with this goal. This paper presents the experimental technique used by the experiment and the preliminary results of the ongoing analysis.

▲ **The FCC project.**
Giacomelli P.
INFN, Sezione di Bologna
The Future Circular Colliders (FCC) project is centered on the construction of a large circular tunnel of 91 km in circumference, located around the Geneva area. The project foresees two distinct phases of operation. In the first one, denominated FCC-ee, the tunnel will house an electron positron collider. FCC-ee will be operated at several center-of-mass energies, ranging from the Z peak to the Higgs boson production peak (~ 250 GeV), and then to just above the ttbar production threshold (~ 365 GeV). FCC-ee promises exceptionally high luminosities and will allow to explore with unprecedented precision the electroweak sector while also producing more than a million Higgs boson events in very clean experimental conditions. One detector concept was designed by several INFN sections and will be briefly

presented. In a second phase, denominated FCC-hh, the tunnel will house a proton-proton collider producing the highest possible collision energies, up to more than 100 TeV in the cms. The combination of FCC-ee and FCC-hh will provide the best possible infrastructure for the future of particle physics for the next 60-70 years.

▲ **JLab e l'Electron Ion Collider: due "microscopi" per comprendere la struttura del nucleone.**

Antonioli P.
INFN, Sezione di Bologna

La Continuous Electron Beam Accelerator Facility (CEBAF) al JLab offre un fascio di elettroni a 12 GeV di energia, ad altissima intensità (10^{38} cm^2s^{-1}), sviluppato per sondare la struttura più interna dei nucleoni, e i suoi costituenti elementari quark e gluoni. CEBAF in questa decade è il più potente "microscopio" a disposizione della comunità scientifica per investigare la struttura adronica via DIS e studi di spettroscopia adronica (esperimenti CLAS12 e GlueX). Saranno presentati i più importanti risultati recentemente ottenuti. Come al Jlab, l'impegno italiano è elevato anche nel nuovo acceleratore l'Electron Ion Collider (EIC). EIC - unica nuova macchina acceleratrice a entrare in funzione nella prossima decade è il primo collider elettrone-ione, con energia variabile dei fasci (elettroni fino a 18 GeV, protoni da 41 a 275 GeV), alta luminosità (10^{34} cm^2s^{-1}) e con elevata polarizzazione (fino al 70%). Sarà delineato l'impegno italiano nell'esperimento ePIC a EIC, l'ampio programma scientifico e il dominio cinematico esplorato, più ampio di quello attualmente a disposizione al Jlab e in esperimenti a bersaglio fisso al CERN.

Comunicazioni

● **Beamtest characterization of the ENUBET Demonstrator.**

Saibene G.
Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como e INFN, Sezione di Milano Bicocca

The goal of ENUBET (Enhanced NeUtrino BEams from Kaon Tagging) is to develop the first monitored neutrino beam for high precision cross section measurements, in which the neutrino flux in the HK and DUNE energy range is inferred from the measurement of charged leptons in an instrumented decay tunnel. Based on the obtained successful results, ENUBET is now studying for a site dependent implementation at CERN, using the SPS as proton driver and the two protoDUNEs as neutrino detectors. This talk will describe the Demonstrator, a large scale prototype of the instrumented decay tunnel (1.65 m long), consisting of a sampling calorimeter with longitudinal, azimuthal and radial segmentation and composed of iron and plastic scintillators, whose light is collected by WLS fibers and readout by SiPMs. The first implementation, with 400 channels, has been tested at the T9 CERN-PS beamline in 2022. An upgraded prototype with 1200 readout channels has been tested on the same beamline in 2023. The results in terms of linearity and energy resolution will be described, together with the study of possible crosstalk effects and of its PID capability.

● **MPGD-based hadronic calorimeter full simulation studies for a Muon Collider Experiment.**

Generoso L. on behalf of the IMCC Collaboration
Università degli Studi di Bari Aldo Moro e INFN, Sezione di Bari

The European Particle Physics strategy and the US P5 call for a multi-TeV muon collider to study the Standard Model with unprecedented precision post-HL-LHC. A challenge in the design of the experiment is the background induced by muon beams (BIB), placing limits on

the performance of the apparatus and stringent requirements on radiation hardness. In this environment, studying the Higgs boson's properties with sub-percent precision in its hadronic decay channels demands a 3-4% jet energy resolution. It can be reached through a hadronic calorimeter performing 5D particle reconstruction with a position measurement precision of ~ 1 squared cm, precise energy deposit matching with tracker tracks, few ns time resolution for BIB rejection, and a $60\%\sqrt{E}$ energy measurement. The innovative proposal for the hadronic calorimeter explored in this contribution employs a sampling of absorber material and resistive MPGD as active layers, meeting all requirements. Performance optimization of the prototype involves full simulations of the experimental set-up at the Muon Collider, adapting the Particle Flow algorithm to the proposed layout and using simulated hadron beams for characterization.

Characterization and Irradiation study for the Crilin Electromagnetic Calorimeter.

Ciccarella V.L. ([1]), Sarra I. ([1]), Di Meco E. ([1]), Diociaiuti E. ([1]), Ceravolo S. ([1]), Saputi A. ([1]), Pastrone N. ([2]), Lucchesi D. ([3]), Sestini L. ([3]), Zuliani D. ([3]), Giraldin C. ([3]), Gargiulio R. ([4]), Scifo J. ([5]), Verna A. ([5]), Disarcina I. ([5]), Cemmi A. ([5])
([1]) *INFN, Laboratori Nazionali di Frascati*
([2]) *INFN, Sezione di Torino*
([3]) *INFN, Sezione di Padova*
([4]) *Sapienza Università di Roma*
([5]) *ENEA, C.R. Casaccia, Dipartimento Fusione e Techologie per la Sicurezza Nucleare, Roma*

A muon collider is being proposed as a next generation facility. The incredible physics potential comes at the cost of technological challenges due to the short muon lifetime. From the detector side, the beam-induced background, produced by the muon decays in the beams and subsequent interactions, may potentially limit the physics performance. As an example, a diffused flux of photons and neutrons passes through the calorimeter system, which thus requires a design to avoid this substantial background. The Crilin calorimeter is being studied as a valuable option for the muon collider electromagnetic calorimeter: it is a semi-homogeneous calorimetric system with Lead Fluoride (PbF2) crystals interfaced with Silicon Photomultipliers (SiPMs). In this contribution, the latest experimental test on one layer of the Crilin prototype, consisting of 3×3 PbF2 crystals, is presented. This test, performed using 450 MeV electrons at the LNF Beam Test Facility, explores the prototype's light yield before and after being irradiated by a gamma ray source. This test is fundamental to demonstrate that the requirements established with the muon collider simulation are achieved by the Crilin technology.

LHCspin: a polarized fixed-target experiment at the LHC.

Pappalardo L.L. ([1]), Ciullo G. ([1]), Di Nezza P. ([2]), Lenisa P. ([1]), Santimaria M. ([2])
([1]) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara*
([2]) *INFN, Laboratori Nazionali di Frascati*

A polarized gaseous target, operated in combination with the high-energy and high-intensity LHC beams, has the potential to open new physics frontiers and to deepen our understanding of the strong interaction in the non-perturbative regime of QCD. Specifically, the LHCspin project aims to perform spin-physics studies in high-energy polarized fixed-target collisions using the LHCb detector. Being designed and optimized for the detection of heavy hadrons, LHCb will allow to probe the nucleon structure through, e.g., the inclusive production of c- and b-hadrons, and ideal tool to access the essentially unexplored spin-dependent gluon

TMDs. This configuration will allow to explore the nucleon internal dynamics at unique kinematic conditions, including the poorly explored high x-Bjorken and high x-Feynman regimes. With the installation of the proposed setup, LHCb will become the first experiment delivering simultaneously unpolarized beam-beam collisions at 14 TeV and both polarized and unpolarized beam-target collisions at center-of-mass energies of the order of 100 GeV. The status of the LHCspin project is presented along with a selection of physics opportunities.

Simulation and test of the new PADME micromegas detector.

Quaranta D. ([1]), Mancini G. ([2])
([1]) *Dipartimento di Fisica, Università di Roma La Sapienza*
([2]) *INFN, Laboratori Nazionali di Frascati*

Starting from Run III the PADME experiment, originally conceived to search for a dark photon signal, turned its attention to the resonant production of the X17, a 17 MeV mass particle theorised to explain a series of anomalies observed by the ATOMKI collaboration. In view of Run IV, foreseen for the end of the 2024, a new gas-based tracker has been built and tested, and will be placed in front of the BGO calorimeter to detect charged particles. It is a resistive Micromega detector filled with a fast ArCF4Iso gas mixture (88:10:2) and it features a small material budget making it well-suited for low-energy track reconstruction. Two different schemes have been proposed for the readout planes: the first using 400 μm strips with 450 μm pitch both for the x and y direction; the second using pads with an area of few mm^2 and a distance of 1.1 mm. In parallel, a full GEANT4 simulation of the tracker has been developed and implemented in the PADME MonteCarlo framework. The simulation accounts for both layouts to estimate the performance of the two options and has served as a support for the detector design process. The talk will give the details of the developed simulation code.

Performance of 65 nm CMOS monolithic sensors with Operational Amplifier output buffer for the ALICE ITS3 upgrade.

Colelli A.,
Università degli Studi di Bari e INFN, Sezione di Bari e CERN

During the 3rd LHC Long Shutdown the three innermost layers of the ALICE Inner Tracking System will be replaced by a truly cylindrical tracker (ITS3) consisting of Monolithic Active Pixel Silicon sensors. The improvements in tracking capability and efficiency at low transverse momentum have guided the concept of the ITS3. To realize a half barrel layer from a single wafer-scale sensor, the 65 nm CMOS process of Tower Semiconductor has been proposed as the new technology. An Analog Pixel Test Structure (APTS) is one of the prototypes developed to validate the technology. It consists of a 6 x 6 pixel matrix with a low dose n-implant in the epitaxial layer near the collection diode. They are equipped with an output buffer based on the high-speed individual operational amplifier (APTS-OA) that allows to explore timing performance. In this contribution, a focus on the APTS-OA laboratory results in terms of the timing performance and signal chain response will be given. Moreover, the pixels characterization using ^{55}Fe as source and the analysis of test beam data indicating a time resolution of 63 ps with a detection efficiency exceeding 99% for that APTS-OA prototypes will be presented.

Studio delle performance di rivelatori Micromegas resistivi ad alte prestazioni con piano di lettura a pad attraverso accoppiamento capacitivo.

Chmiel K.
Università degli Studi Roma Tre

RHUM - Resistive High-granUlarity Micromegas è un progetto di R&D di nuovi rivelatori di particelle con lo scopo di consolidare la tecnologia MPGD per misure di particelle a flussi

dell'ordine di 10 MHz/cm^2 con una lettura a bassa occupancy ad alta granularità su pad di dimensioni dell'ordine del mm^2, in grado di resistere a radiazioni elevate, e dimostrarne la scalabilità su grandi superfici per futuri esperimenti di Fisica delle Alte Energie. Per ampliare la versatilità di questi rivelatori e permettere il funzionamento anche a flussi di particelle non estremi, si è implementato per la prima volta su rivelatori Micromegas un sistema di lettura basato sull'accoppiamento capacitivo. Questo sistema coinvolge diversi strati consecutivi del piano di lettura, ognuno con pad di dimensioni crescenti, consentendo contemporaneamente una riduzione del numero di canali di lettura e il mantenimento di un'eccellente risoluzione spaziale. Verranno presentati i risultati in termini di risoluzione spaziale, efficienza e stabilità di questo rivelatore ottenuti dalla campagna di raccolta dati effettuata in aprile 2024 al CERN con fasci di muoni e pioni di media/alta intensità.

The calibration of the FOOT calorimeter.

Spadavecchia B. on behalf of the FOOT Collaboration
INFN, Sezione di Torino

The FOOT Experiment aims at improving the precision of clinical treatment planning systems in tumor hadrontherapy, by measuring double differential cross sections for nuclear fragmentation of light nuclei with a precision better than 5%. The experimental setup includes a calorimeter made of 320 BGO crystals to measure the kinetic energy of fragments produced in beam-target interactions: in order to properly reconstruct the mass of fragments, its resolution must be kept under 2%. In October 2023, this detector was used in its almost final configuration in a data taking campaign carried out at CNAO. This work describes the hardware characteristics of the calorimeter, as well as its construction. Successively, the detector was calibrated by irradiating the crystals with 12-C ions at different energies, in dedicated runs. The amplitude-energy response was studied, by taking into account the Birks effect, temperature corrections and possible anomalous energy spectra. The final results successfully meet the experimental requirements.

Real-time compression of high-speed streaming readout signals with artificial intelligence algorithms.

Rossi F. ([1]), Battaglieri M. ([1]), Ragusa E. ([2]), Gastaldo P. ([2]), Gavalian G. ([3])
([1]) *INFN, Sezione di Genova*
([2]) *Dipartimento di Ingegneria Navale, Elettrica, Elettronica e delle Telecomunicazioni, Università di Genova*
([3]) *Jefferson Lab*

The new generation of high-energy physics experiments plans to acquire data in streaming mode. With this approach, it is possible to access the information of the whole detector for optimal and lossless triggering of data acquisition. The drawback of this approach is a very high data rate that requires a data reduction strategy to avoid bottlenecks in the communication network. This contribution describes the compression algorithm and the Streaming Readout DAQ (SRO) system prototype developed to test it. The SRO prototype is designed with three separate nodes connected to the same network. We use a PC as a proxy of the final high-level analysis node and different hardware as compression node. Consideration concerning the compression algorithm complexity, loss during compression, and execution time are considered to achieve the best tradeoff. Results of autoencoder training and timing of some implemented configurations are reported.

Micromegas resistive a small-pad di grande area per rivelazione di alti flussi di particelle ai futuri esperimenti di High Energy Physics.

Perna S.

Università degli Studi di Napoli Federico II e Università degli Studi Roma Tre
Nel 2024 gli studi del progetto RHUM, Resistive High-granUlarity Micromegas, per lo sviluppo di rivelatori Micromegas (MM) resistivi ad alte prestazioni, hanno portato alla realizzazione di un primo prototipo di MM a pad di grande area in grado di operare in condizioni di alti flussi di particelle, fino a decine di MHz/cm^2, rappresentando un passo significativo verso la costruzione modulare di grandi apparati per futuri esperimenti di fisica delle particelle. Il rivelatore, delle dimensioni di 50×40 cm^2, implementa uno schema resistivo innovativo, composto da un doppio strato di fogli in DLC (Diamond Like Carbon). Il piano di lettura è costituito da pad di piccola area (pochi mm^2) per mantenere i tassi di conteggio sui singoli canali sufficientemente bassi, compatibili con i tempi di risposta del rivelatore e del sistema di readout. Nell'aprile 2024, questo rivelatore è stato sottoposto a fasci di muoni e pioni ad alta energia presso il CERN. In questa presentazione verrà descritta la struttura del rivelatore e saranno presentati i risultati di efficienza e risoluzione spaziale e temporale in funzione dei parametri operativi del rivelatore analizzando i dati raccolti al test-beam.

The IDEA detector concept for FCC-ee.

Ali M.
Alma Mater Studiorum Università di Bologna e INFN, Sezione di Bologna
The future circular electron-positron collider (FCC-ee) is receiving much attention in the context of the FCC Feasibility Study currently in advanced progress described in the mid-term report, in preparation for the next EU strategy update. We present IDEA, a detector concept optimized for FCC-ee and composed of a vertex detector based on DMAPS, a very light drift chamber, a silicon wrapper, a dual readout calorimeter outside a thin 2 Tesla solenoid and muon chambers inside the magnet yoke. In particular we discuss the physics requirements and the technical solutions chosen to address them. We also present some possible upgrades that are studied in order to further extend and improve the physics capabilities of IDEA. We then describe the detector R&D currently in progress and show the expected performance on some key physics benchmarks.

Tracking electron-positron pairs: A study of the X17 anomaly at n_TOF.

Pieretti N. ([1]), Massimi C. ([1])([2])on behalf of rhe n_TOF Collaboration
([1]) *Dipartimento di Fisica e Astronomia, Università di Bologna*
([2]) *INFN, Sezione di Bologna*
A significant anomaly in the emission of electron-positron pairs has recently been observed in two different nuclear reactions: ^{7}Li(p, e$^-$e$^+$), ^{8}Be and ^{3}H(p, e$^-$e$^+$)^{4}He, at ATOMKI. While the origin of this anomaly remains unexplained, among other hypotheses it can be interpreted as the signature of the existence of a new particle beyond the standard model: a boson called X17. To further investigate this phenomenon, the n_TOF Collaboration is evaluating different detection setups to investigate the conjugate neutron-induced reaction ^{3}He(n, e$^-$e$^+$)^{4}He. Here, we present an assessment of the performance of the detection setup currently undergoing testing and calibration. This setup consists of two μ-RWELLs gas detectors and a configuration of crossed scintillator bars surrounding the target, designed to track electrons and positrons and therefore deduce the position of their origin.

Study of the electrical couplings among the conductive strips of the BIL-RPC of ATLAS Phase-2 Muon Spectrometer upgrade.

Passarelli D., Schioppa M.
Università della Calabria
ATLAS's major Phase-2 upgrade of the Muon Spectrometer includes the addition of a new trigger layer coupled to the barrel inner layer (BIL) of the tracking chambers consisting of

thin gas gap resistive plate chambers (RPC) with a unique type of strip to read both the eta and phi coordinates of the point where the charged particle passes through the detector. To make the most of the performance of this new detector it is necessary to know how the signal on the system of conductive strips propagates. It is of great importance to understand the different couplings between the strips of the two panels that enclose the gas volume itself, and consequently the crosstalk between strips. In this communication, the full simulation of this multi conductors system is compared to the measurements of an assembled detector to better understand the readout system of an RPC.

Ricostruzione degli elettroni in un detector prototipo al Muon Collider a $\sqrt{s} = 10$ TeV e valutazione delle prestazioni nei decadimenti del bosone di Higgs.

Palombini L.
Università di Padova e INFN, Sezione di Padova

Nel panorama dei collisori futuri, il Muon Collider si distingue per essere l'unica opzione in grado di sondare la frontiera dell'energia, raggiungendo energie nel centro di massa di 10 TeV o superiori e garantendo la possibilità di misure di alta precisione. Lo sviluppo di un apparato sperimentale adeguato a rilevare particelle tanto di bassa energia, nell'ordine dei GeV, quanto di alta energia, nell'ordine dei TeV, è una delle sfide prioritarie. In questo contesto, la capacità di ricostruzione degli elettroni nel difficile ambiente del Muon Collider risulta essere uno dei punti fondamentali di un esperimento competitivo. Infatti, gli stati finali con elettroni figurano spesso come i canali con maggior potenziale nello studio di nuova fisica oltre il modello standard, con ricerca di risonanze e^+e^-, e nella caratterizzazione dei decadimenti del bosone di Higgs. In questo lavoro è stata studiata la ricostruzione di elettroni con impulso tra 1 e 1000 GeV/c in presenza di fondo indotto dai decadimenti del fascio. Inoltre, le prestazioni del rivelatore sono state studiate valutando la precisione sulle sezioni d'urto di processi fisici, come $h \to ZZ^* \to 4e$.

Aula 1D **ore 15:50 – 19:00**

Sezione II
Fisica della materia
Presiede: Luches P. (CNR)

Relazioni su invito

▲ **Signatures of a surface spin-orbital chiral metal.**
Mazzola F.
University of Venice, Ca' Foscari e IOM-CNR
Surface experimental probes, such as angle-resolved photoelectron spectroscopy provide researchers access to the electronic structure of solids. Despite the advances in the field, often, forms of surface local magnetism different from standard descriptions have been proven challenging to be detected. One example of such forms of magnetism is the one generated by the so-called loop currents, quantities created by the collective motion of electrons in solids. Such currents are of paramount importance, and their manifestation is tightly connected to the symmetries of a material. For example, if they involve the orbital and angular momentum, then there will be asymmetries upon mirror operator which will affect the orbital-and-angular momentum conservation. While this phenomenology can be often grasped by muon spectroscopy in bulk systems, surface and interface effects remain elusive. Here, I aim to give an overview of a new powerful methodology, based on the combination of circular dichroism and spin-resolved photoelectron spectroscopy, to uncover such elusive phases.

▲ **High-resolution X-ray spectroscopy on oxide 2D electron gas.**
Salluzzo M.
CNR-SPIN
X-ray spectroscopy methods have been widely employed to understand the physics of transition metal oxides. X-ray absorption spectroscopy, using linear and circular polarization, can be used to study the orbital splitting, occupancy and the magnetism in engineered oxide two-dimensional electron gas (2DEG). High-resolution resonant inelastic X-ray scattering (RIXS) can be used to study elementary excitation, including magnons, phonons and d-d excitations, with momentum resolution. As a first example, I will provide evidences of large polaron quasiparticles in the $LaAlO_3//SrTiO_3$ 2DEG by high-resolution RIXS. As a second example, I will show how XAS can be used to determine the interfacial orbital splitting, occupancy and the magnetism in engineered oxide 2DEGs, namely $LaAlO_3//SrTiO_3$, $LaAlO_3/EuTiO_3//SrTiO_3$. Finally I will show the use of XAS *in operando* conditions, in particular with application of gate voltages, to ferroelectric and multiferroic 2DEGs, namely $LaAlO_3$//Ca-doped-$SrTiO_3$ and $LaAlO_3/EuTiO_3$//Ca-doped-$SrTiO_3$.

▲ **Polariton Bose-Einstein condensate from a bound state in the continuum.**
Ballarini D.
Istituto di Nanotecnologia, CNR-NANOTEC
Polaritons, hybrid quasiparticles arising from the strong interaction between photons and electronic excited states in materials, have become a focal point of research for both fundamental studies and nanophotonic applications. Here, we will explore recent advances in polariton waveguides, emphasizing the realization of topologically protected bound states in

the continuum (BICs) and their potential for ultra-low threshold Bose-Einstein condensation. We will discuss the advantages of using 2D planar waveguides to tailor band topologies, offering ease of growth and external control. Additionally, we will delve into the effective attractive potential stemming from the negative mass of these states, allowing evanescent coupling between optically created polariton condensates. Finally, we will highlight the recent fabrication of polariton BICs working at room temperature using different materials, such as 2D semiconductor monolayers of transition metal dichalcogenides and perovskites.

Comunicazioni

Connecting structure and optical properties of soft plasmonic complexes.
Brasili F.
Istituto dei Sistemi Complessi, Consiglio Nazionale delle Ricerche
The integration of thermoresponsive microgels and metallic nanoparticles (NPs) yields versatile complexes, ideal for applications. However, the assembly process between these microscale networks and the NPs remains unexplored, hindering the ability of designing such hybrid complexes *a priori*. Combining numerical simulations and experiments, we unveil the microscopic mechanisms governing microgel-NPs assembly under electrostatic interactions. Our study investigates the effects of NPs adsorption on the polymer network, as well as those of the volume phase transition (VPT) —the microgel collapse when temperature exceeds 32 °C— on the arrangement of incorporated NPs, that plays a crucial role in plasmon coupling. First, we address the microgel shrinking upon NPs adsorption, commonly observed in experiments. Subsequently, the structure factors of NPs reveal that, across VPT, they maximize their distance and adopt a more ordered arrangement. We thus establish a link between the structural modifications and those of the optical properties of the system, providing a basis for the rational design of thermoresponsive plasmonic systems with properties tailored for specific applications.

Evidence of molecular hydrogen in the N-doped LuH_3 system: A possible path to superconductivity?
Tresca C. ([1]), Forcella P. M. ([2]), Angeletti A. ([3])([4]), Ranalli L. ([3])([4]), Franchini C. ([4])([5]), Reticcioli M. ([4]), Profeta G. ([1])([2])
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([4]) *University of Vienna, Faculty of Physics and Center for Computational Materials Science, Vienna, Austria*
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The discovery of ambient superconductivity would mark an epochal breakthrough long-awaited for over a century, potentially ushering in unprecedented scientific and technological advancements. The recent findings on high-temperature superconducting phases in various hydrides under high pressure have ignited optimism, suggesting that the realization of near-ambient superconductivity might be on the horizon. However, the preparation of hydride samples tends to promote the emergence of various metastable phases, marked by a low level of experimental reproducibility. Identifying these phases through theoretical and computational methods poses a considerable challenge, often resulting in contentious outcomes. In this contribution, we consider N-doped LuH_3 as a prototypical complex hydride: By means of machine-learning-accelerated force-field molecular dynamics, we have identified the formation of H_2 molecules stabilized at ambient pressure by nitrogen impurities. Importantly, we

demonstrate that this molecular phase plays a pivotal role in the emergence of a dynamically stable, low-temperature, ambient-pressure superconductivity.

Tunable Dirac cones and flat bands in mesoscale ordered two-dimensional semiconductor polymers.

Contini G.

Istituto di Struttura della Materia-CNR, ISM-CNR, Roma, Italy e Department of Physics, University Tor Vergata, Roma, Italy

Dirac cones are responsible of the charge-transport properties of graphene. However, they are not exclusive to graphene but require that the material presents specific symmetry and delocalized electrons. Efforts have been devoted to identifying 2D materials beyond graphene that offer a degree of tunability and a non-zero band gap while retaining high carrier mobility. On-surface synthesis represents an opportunity to manipulate the electronic band structure by varying the molecular building blocks. By using a class of heteroatom substituted triangulene monomers we synthesized mesoscale ordered 2D π-conjugated polymers on Au(111) with semiconducting properties arranged in a kagome lattice showing Dirac cone structures and flat bands. We demonstrate that it is possible to tune the Dirac cone structures and flat bands energy positions by changing the bridging atoms in the triangulene monomers. These results overcome the major barriers to the application of 2D π-conjugated polymers due small domain size and high defect density attained so far. Although the 2D polymers have been obtained on a metal surface, they can be detached and transferred to other substrates to be used in devices.

Carrier density and carrier-phonon coupling in tin-based halide perovskites by time-resolved THz spectroscopy.

Grandi F. ([1])([2]), Gatto L. ([2]), Poli I. ([3]), Treglia A. ([3]), Meggiolaro D. ([4]), Folpini G. ([2])([3]), Devetta M. ([2]), De Angelis F. ([4])([5]), Petrozza A. ([3]), Vozzi C. ([2]), Cinquanta E. ([2])

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Tin-based halide perovskites (THPs) emerge as promising candidates for solar energy harvesting. Nevertheless, the defect chemistry in THPs results in self-doping of the material. This aspect becomes detrimental to device performances if not managed. To do so, SnF_2 has been proposed as an additive in the fabrication process to control the formation of defect states. We exploited terahertz (THz) spectroscopy to assess the charge transport properties of THPs. In particular, THz radiation is sensitive to the presence of mobile charge carriers together with their interaction with the surrounding lattice and thus is a powerful tool for the investigation of the effect of SnF_2 in the conductive properties of THPs. Specifically, THz spectroscopy can lead to an estimate of the charge carriers' concentration by fitting the conductivities with a Drude-Smith model. Performing pump-probe measurements it is possible also to follow the recombination dynamics of photogenerated carriers investigating charge-phonon coupling. This study has been performed on $FACSnI_3$ thin film and the obtained results are supported by DFT calculation.

Thin-film heterostructures based on Co/Ni synthetic antiferromagnets on polymer tapes: Toward sustainable flexible spintronics.

Varvaro G. ([1]), Hassan M. ([1])([2]), Laureti S. ([1]), Peddis D. ([1])([3]), Rinaldi C. ([4]), Fagiani F. ([4]), Barucca G. ([5]), Casoli F. ([6]), Mezzi A. ([7]), Bolli E. ([7]), Kaciulis S. ([7]), Fix M. ([2]), Ullrich A. ([2]), Albrecht M ([2])

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([5]) *Dipartimento SIMAU, Università Politecnica delle Marche, Ancona, Italy*
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([7]) *ISMN-CNR, Monterotondo Scalo, Roma, Italy*

Synthetic antiferromagnets with perpendicular magnetic anisotropy (PMA-SAFs) have attracted great interest for both conventional and advanced spin-based applications. Although great progress of PMA-SAF spintronic devices on rigid substrates has been achieved, only few examples on flexible thin-film heterostructures, all containing critical platinum group metals (PGMs) are reported in the literature. In this contribution, Co/Ni-based flexible PMA-SAFs and MR spin-valves (SVs) containing a SAF reference with reduced content of PGMs were deposited on flexible tapes with different combinations of buffer (BL) and capping (CL) layers (*i.e.*, Pt, Pd and Cu/Ta). High-quality SAFs and SVs were obtained in all cases. However, due to the different interdiffusion mechanisms occurring at the interface between the metallic layers, we demonstrated that while PGMs allow to obtain the best results when used as BL, Cu is the best choice as CL to optimize the properties of the stacks. The results thus indicate that complex Co/Ni-based heterostructures with reduced content of PGMs can be deposited on flexible tapes, allowing the development of novel shapeable and sustainable spintronic devices.

Magnetic transparent conductors for spintronics.

D'Amico P. ([1]), Catellani A. ([1]), Ruini A. ([2]), Curtarolo S. ([3]), Fornari M. ([4]), Buongiorno Nardelli M. ([5]), Calzolari A. ([1])

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Transparent Conductors (TCs) exhibit optical transparency and electron conductivity, and are essential for many opto-electronic and photo-voltaic devices. The commonest TCs are electron-doped oxides, which have few limitations when transition metals are used as dopants. Non-oxides TCs have the potential of extending the class of materials to the magnetic realm, bypass technological bottlenecks, and bring TCs to the field of spintronics. In this contribution we propose new functional materials that combine transparency and conductivity with magnetic spin polarization that can be used for spintronic applications, such as spin filters. By using high-throughput first-principles techniques, we identified a large number of potential TCs, including non-oxides materials. Our results indicate that proper doping with transition metals introduces a finite magnetization that can provide spin filtering up to 90% in the electrical conductivity, still maintaining a transparency greater than 90%.

Transport properties of crystalline topological insulators of Bi_2Se_3 and Bi_2Te_3.
Qadri M.W.R. ([1]), Guarino A. ([1]), Lettieri M. ([1]), Balakrishnan G. ([2]), Fittipaldi R. ([1]), Vecchione A. ([1])
([1]) *CNR/SPIN c/o Physics Department, University of Salerno, Italy*
([2]) *Department of Physics, University of Warwick, Coventry, UK*
Topological insulators (TI) are of great interest in condensed-matter physics because of their applications in quantum computing and spintronics. TI are different from conventional insulators, as they are insulating in bulk, but their surfaces and edges are conductive. The conductive surface state is topologically protected having a single Dirac cone in contrast to the graphene's surface which has two Dirac cones and spin degeneracy. Bi_2Se_3 and Bi_2Te_3 are two important materials to understand the underlying physics in TI. We have studied the structural, morphological and transport properties of Bi_2Se_3 and Bi_2Te_3 single crystals. We have carried out the transport measurements (voltage *vs.* current-VI) at room temperature with the help of micromanipulators installed in FESEM on different regions of the samples' surfaces. Temperature-dependent transport measurements were carried out by using a liquid-nitrogen cryogenic system. Resistance *vs.* temperature measurements confirmed the metallic surface state of these TI, but non-linear resistance was observed from the VI measurements at the mesoscopic level.

Electron-irradiated graphene —Properties and applications.
Bianco F. ([1]), Melchioni N. ([1])([2]), Bellucci L. ([1]), Fabbri F. ([1]), Basta L. ([2]), Moscardini A. ([2]), Tozzini V. ([1]), Heun S. ([1]), Veronesi S. ([1]), Tredicucci A. ([1])([3])
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([3]) *Dipartimento di Fisica, Università di Pisa, Italia*
2D materials are an optimal platform for applications in electronics, optoelectronics and optics both in classical and quantum regime. Materials with perfect crystal are typically preferred, as lattice defects are generally considered as detrimental. However, when deterministically created, chemical, thermal, optical, and electronic properties are tuned or even newly created if not naturally present, unlocking the development of devices with novel functionalities. Here, we present an excursus on our studies on the physical and chemical properties of electron-irradiated graphene in the realm of defective graphene applications. We describe the temporal stability of the defect sites, that defines the operability timescale when dealing with device physics. We explain the role of the supporting substrate and the cross-talk among defective nanostripes on the lateral resolution of defective patterns. Indeed, periodically irradiated graphene can find applications in plasmonics, coherent charge carrier transport or in thermal transport. Finally, we present our results on the chemical functionalization of patterned defective graphene, opening the route for producing complex sensing circuits.

Generatore di numeri casuali basato su dark count intrinseci di nanofili superconduttivi.
Bruscino C. ([1]), Raj V. ([2]), Kuznesof D. ([2]), Morozov D. ([2]), Pepe G.P. ([1]), Hadfield R. ([2])
([1]) *Dipartimento di Fisica "E. Pancini", Università degli Studi di Napoli Federico II, Napoli, Italia*
([2]) *James Watt School of Engineering, University of Glasgow, Glasgow, UK*
I generatori di numeri casuali sono ampiamente usati in molte applicazioni che vanno dalla simulazione al gioco d'azzardo alla crittografia. Fin'ora sono stati proposti diversi metodi per generare numeri casuali usando sorgenti di luce e fotorivelatori, come lasers e rivelatori

superconduttivi di singolo fotone a nanofili, sfruttando le leggi della meccanica quantistica. D'altro canto, i conteggi di buio intrinseci dei rivelatori superconduttivi a nanofili esibiscono una natura randomica nel numero di eventi per intervallo di tempo e di differenza di tempo tra due eventi consecutivi a causa di fluttuazioni termiche e quantistiche. In questo contributo, proponiamo una tecnica di estrazione di numeri casuali da un rivelatore superconduttivo polarizzato in corrente vicino al suo valore di corrente critica analizzando sia la differenza di tempi di arrivo tra due conteggi consecutivi, sia la distribuzione del numero di eventi ogni fissato intervallo temporale.

Aula A **ore 15:50 – 19:00**

Sezione II
Fisica della materia
Presiede: Mazzola F. (Università di Venezia)

Relazioni su invito

▲ **van der Waals BP/(MoS_2) heterostructures: Electrical and optoelectronic characterization.**
Durante O. ([1]), Viscardi L. ([1]), De Stefano S. ([1]), Intonti K. ([1]), Kumar A. ([1]), Pelella A. ([2]), Giubileo F. ([3]), Kharsah O. ([4]), Daniel L. ([4]), Sleziona S. ([4]), Schleberger M. ([4]), Di Bartolomeo A. ([1])
([1]) *Department of Physics "E.R. Caianiello", University of Salerno, Fisciano, SA, Italy*
([2]) *Department of Physics, University of Roma Tor Vergata, Rome, Italy*
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In recent years, heterojunctions formed by stacking two-dimensional (2D) materials have attracted considerable interest because of their outstanding electronic and optoelectronic characteristics. The combination of black phosphorus (BP) and molybdenum disulfide (MoS_2) is particularly noteworthy for its potential in creating state-of-the-art optoelectronic devices. This research explores the dynamics between BP, (MoS_2), and chromium (Cr) contacts, shedding light on the electrical characteristics of a BP/(MoS_2) heterojunction that exhibits rectifying behavior, mainly n-type conduction, and a significant ON/OFF current ratio. The higher unexpected current observed in the presence of a negative bias applied to both the (MoS_2) and BP sides is clarified through an energy band model that includes a type-II heterojunction at the BP/(MoS_2) interface. The BP/(MoS_2) heterojunction also shows a remarkable photoresponse, which increases linearly with the incident light power, reaching a responsivity of 100 μA/W to white light with an incident power of 50 μW. Time-resolved photocurrent experiments show a fast response, with rise times of less than 200 milliseconds.

▲ **Second-order nonlinear photonic disorder: An easy platform for deep computing.**
Savo R.
Centro Ricerche Enrico Fermi, CREF, Roma, Italia
Photonic systems offer a promising platform for analog neuromorphic computing and machine learning acceleration, boasting advantages such as massive parallelism, low latency, and energy efficiency. Disordered photonic media have been utilized for implementing neural networks (NNs) architectures with simultaneous coding and processing of information, overcoming digital NNs' bottleneck of data transfer between memory and processor. This paper explores second-order nonlinear disordered photonic media assembled from oxide nanoparticles, particularly barium titanate and lithium niobate nanocrystals. Thanks to the simultaneous linear scattering and second-harmonic generation, these media enable multiple implementation of the activation function in the neural network, facilitating deep multi-layer operation. Experimental demonstrations showcase the potential of these media, particularly a deep two-layer optical neural network based on a nonlinear disordered multiple-scattering slab of lithium niobate nanocrystals, enhancing computing performance for various machine learning tasks including image classification and regression.

Comunicazioni

Energy storage in a quantum battery.

Downing C.A.
Department of Physics, University of Exeter, UK

We consider some simple theoretical models for quantum batteries, which are energy storage devices constructed using inherently quantum-mechanical objects. We discuss the optimal ways to charge the battery, store energy in the battery and extract useful work from it. In particular, we show how quantum batteries display some nice non-Hermitian physics effects, in which so-called exceptional points govern the performance of the battery. We conclude by proposing some experimental platforms which could verify our theoretical predictions.

Frustration-driven Josephson phase dynamics.

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Josephson equations predict remarkable effects concerning the phase state of a junction with an oscillating current induced by a static voltage. Whether the paradigm can be twisted by yielding an oscillating voltage without using harmonic drives is a problem yet not fully settled. We show that a dynamical regime with an oscillating phase evolution is a hallmark of driven Josephson systems exhibiting sign competition in the Josephson couplings. We show that in frustrated Josephson systems an oscillating phase dynamic gets switched on by driving the changeover among diverse ground states. The character of the transitions allows different types of dynamics, with few or several harmonics. This result sets out a characteristic mark of any superconducting system with frustrated Josephson couplings and can be used to disentangle the complexity of underlying phases. Beyond superconductivity, our results extend to frustrated spin systems, suggesting universal dynamics in systems characterised by frustration. Practical implementations in multi-terminal junctions offer an avenue for experimental validation, leading up to deeper insights into dynamic phase transitions.

Contact lens-TiO_2 nanocomposites for a sustainable wastewater remediation.

Lufrano E., Curcuruto G., Zimbone M., Strano V., Leonardi A.A., Sfuncia G., Nicotra G., Buccheri M.A., Carroccio S.C., Impellizzeri G
CNR-IMM, Catania, Italy

Growing concerns about plastic waste and microplastic pollution from products like contact lenses determine the need for innovative environmental solutions. This study, performed in the framework of the PNRR project SAMOTHRACE, originally introduces a sustainable method for creating photocatalytic nanocomposites for wastewater treatment. TiO_2 nanoparticles were integrated into waste contact lenses via controlled spray deposition. The nanocomposites were thoroughly characterized using a range of techniques: TGA to evaluate the thermal stability and the TiO_2 content, SEM/TEM for the morphological analyses, Raman spectroscopy to assess the structural properties, and Z-potential analysis to determine the surface charge. The photocatalytic performance of the nanocomposites was tested by measuring the photodegradation under UV light of two common pollutants: methylene blue dye and sodium dodecyl sulfate surfactant. Additionally, the antibacterial properties were performed using *Escherichia coli* as a model organism. This work offers a new, economic,

and easy way to prepare photocatalytic nanocomposites from waste contact lenses for a sustainable wastewater treatment.

Investigation of amorphous semiconductors with electrostatic atomic force microscopy.

Fabbri L. ([1]), Bordoni C. ([1]), Barquinha P. ([2]), Crocco J. ([3]), Migliaccio L. ([4]), Sirvinskyte A. ([1]), Rizzi G. ([1]), Bondi L. ([1]), Tamarozzi C. ([1]), Weber A.L.S. ([5]), Glowacki E.D. ([4]), Fraboni B. ([1]), Cramer T. ([1])

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In contrast to crystalline materials, amorphous semiconductors possess a disordered atomic arrangement at the microscopic level which significantly impacts their optoelectronic properties. A deep understanding of these effects is fundamental for material optimization, with huge relevance for technological applications such as large-area and biological electronics. Kelvin Probe Force Microscopy (KPFM) is exceptional as it enables a precise local electronic investigation combined with *in operando* imaging. Here, we present our progress in using KPFM to determine crucial optoelectronic properties of amorphous semiconductors. As a first example, we demonstrate how spectroscopic measurements enable the quantification of local band-tail broadening in amorphous IGZO thin-film transistors. We exploit the technique to understand charge trapping occurring as a consequence of ionizing radiation exposure. A second example, illustrates how KPFM provides access to the local exciton diffusion length in organic p-n heterojunctions. In the context of the investigated material, such property is crucial to understand limitations on the spatial resolution in organic optobioelectronic devices.

Bandgap tuning and single-photon emitters in 3-5 dilute nitrides nanowires through hydrogenation.

De Vincenzi P. ([1]), Denis N. ([2]), Santangeli F. ([1]), Cianci S. ([1]), Polimeni A. ([1]), Yukimune M. ([3]), Ishikawa F. ([3]), De Luca M. ([1])

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Semiconductor nanowires (NWs) are structures with new optical and electronic properties due to their peculiar morphology. In this contribution, we demonstrated bandgap tuning on GaAs/GaAsN core/shell nanowires by post-growth hydrogenation. The passivating effect of hydrogen on nitrogen results in the restoration of the emission at the gap energy of GaAs. Subsequently, we subjected the wires to thermal annealing procedures to remove the hydrogen and thus restore the effect of nitrogen on the bandgap: a huge red-shift is observed, up to 200 meV, depending on the initial N concentration, leading to a degree of reversibility of the process. We achieved fine-tuning of the emission energy between hydrogenated and pristine NW states by controlling annealing parameters, such as temperature and duration. In addition, we observed single-photon light emission from single NWs. Optical measurements at 5 K showed excitonic lines, arising from the non-hydrogenated N clusters with a $g(2)(0) = 0.32$. These results are the basis for combining post-growth energy gap fine-tuning with single-photon emission in NWs, to create an energy-controlled and site-controlled single-photon emitter.

Nanoscale investigation of mixed ionic-electronic transport in conductive polymers with modulated-electrochemical atomic force microscopy.

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Organic mixed ionic-electronic conductors (OMIECs) are in the focus of material research for bioelectronic interfaces, energy storage devices, and soft actuators due to their combination of efficient transport phenomena, high charge storage capacity, facile processing, and electrochemical stability. Progress on all fronts is predicated on an advance in understanding fundamental material processes, but the mixed conductivity renders the characterization of individual carrier transport difficult. To address this issue, we introduce here the modulated electrochemical atomic force microscopy (mEC-AFM). The technique reveals reversible, local ion accumulation by measuring the related volumetric changes in the material with nanoscale resolution. We demonstrate microscopic imaging of the electroactuation effect and its relation to the materials nanoscale morphology. With multidimensional mEC-AFM spectroscopies we inquire on the kinetics of ion and water transport in OMIECs, achieving depth sensitive profiling of ion migration and accumulation. The resulting knowledge offers a novel insight on mixed transport and serves as a guideline for the development of enhanced OMIEC-based devices.

Plasmonic SERS substrates for Shiga toxins detection.

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Shiga toxin-producing *Escherichia coli* (STEC) are zoonotic pathogens causing severe diseases, such as the hemolytic uremic syndrome (HUS) which represents the most important cause of acute renal failure in children, in some cases lethal. The main virulence factors of STEC responsible for the onset of the HUS are two main types of cytotoxins, Shiga toxins 1 (Stx1) and 2 (Stx2). To date, there are no effective therapies for STEC infection and the diagnostic methods available are complex and sometimes inconclusive. Plasmonic biosensors are powerful platforms for detecting various types of analytes. Specifically, surface enhanced Raman spectroscopy (SERS) allows a label-free, sensitive and selective detection. In this activity, developed in the framework of the PRIN Project "'Development of a plasmonic nanobiosensor for the rapid diagnosis of Shiga toxin producing *E. coli* human infections at the point of care - SENSOSTEC", SERS substrates based on novel nanopattern fabricated by both top-down and bottom-up approaches, are designed, characterized and tested for the Stx1 and Stx2 analysis. Our preliminary results open up specific detection of the two analytes and their discrimination.

Charge transport properties of 2D perovskite thin films for photodetectors.
Cepić S., Bordoni C., Margotti L., Fratelli I., Ciavatti A., Basiricò L., Fraboni B.
Department of Physics and Astronomy, University of Bologna
Perovskite-based photodetectors have attracted attention due to their exceptional optoelectronic properties, especially 2D perovskites which crystallize in a natural self-assembled quantum well-like structure. Their stability, high-performance for both visible and ionizing radiation with low dark current, high responsivity, and rapid response time have been reported in the literature in the last few years. However, achieving high performance requires depositing high-quality thin films, where morphology and crystalline quality significantly influence transport properties and detecting capabilities. This study investigates the impact of different PEA_2PbBr_4 perovskite film morphologies on device properties by controlling deposition conditions. Varying spin-coating speed and solution concentration enabled full control over morphology, revealing a correlation between grain size and electrical mobility. Two device architectures, co-planar and vertical, were explored to understand charge transport mechanisms and directional dependence of charge transport within the perovskite layer.

Electronic properties and charge density distribution in cesium-doped black phosphorus.
Tonelli A. ([1]), Cavani N. ([1]), Biagi R. ([1])([2]), De Renzi V. ([1])([2])
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Black phosphorus (BP) is a narrow-gapped and slightly p-type semiconductor, consisting of stacked layers of phosphorene and characterized by strongly anisotropic electronic and optical properties. The BP energy gap (EG) can be tuned by applying an external electric field due to the giant Stark effect, which affects both the energy and the spatial localization of the conduction and valence bands (CB and VB). An alternative strategy to establish an electric field inside BP is to adsorb alkali metals on its surface. In this contribution, we provide a comprehensive description of the electronic and dielectric properties of Cs-doped BP by combining ultraviolet photoelectron spectroscopy (UPS) and high-resolution electron energy-loss spectroscopy (HREELS). Besides monitoring the VB downward shift and the EG reduction, UPS provides an estimate of the CB electron density. Analysis of the HREEL spectra —based on a multilayer dielectric model— allows to determine the plasmon frequency and the step-like profile of the Cs-induced free-carrier density along the surface normal. These results are discussed and compared with the charge profile obtained using the non-linear Thomas-Fermi screening model.

Enhanced actuation and energy generation using a photomobile polymer-piezoelectric composite.
Sagnelli D. ([1]), D'Avino A. ([1]), Guilcapi B. ([1]), Marchesano V. ([1]), Piccolo A. ([1]), Villani F. ([2]), Loffredo F. ([2]), De Girolamo del Mauro A. ([2]), Nenna G. ([2]), Petti L. ([1])
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This study presents a method to improve the quantum yield and wavelength sensitivity of photomobile polymer (PMP) films containing azobenzene by incorporating noble metal nanoparticles into the polymer matrix. The doped films show enhanced and accelerated

bending when exposed to UV, visible, and near-infrared light, thereby broadening the possibilities for PMP-based actuators. A prototype model was developed to demonstrate practical applications, combining power generation with flexible piezoelectric materials in a simulated sunlight environment. The model has been tested in real operating conditions, demonstrating the potential to produce electricity with varying light exposure levels. The synthetic protocol is free of solvents, reducing environmental impact. The research lays the foundation for creating devices responsive to sunlight, such as photomechanical actuators and advanced photovoltaic modules, which could significantly advance smart materials.

Study of conductivity and persistent photocurrent in ITO films.

Petrini N. ([1])([2]), Muraleedharan A.P. ([2])([3]), Kuriyil S. ([1])([2]), Rebecchi L. ([1])([2]), Rubino A. ([2]), Curreli N. ([2])([4]), Kriegel I. ([2])

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The use of nanocrystals (NCs) has emerged as promising for next-generation electronics due to their tunable optoelectronic properties and cost-effective, solution-based production methods. This study focuses on the manufacturing of conductive devices based on thin films of indium tin oxide NCs, widely used as transparent conductive oxide. Various deposition techniques, including spincoating, dipcoating, and self-assembly were investigated to determine the optimal parameters yielding to compact and connected monolayers. Various geometries were employed to electrically characterize the obtained films, indicating an insulative behavior at room temperature. Post-annealing improved conductivity significantly, determining also changes in the plasmonic peak, thanks to the effective ligand removal. Additionally, UV-light–induced photodoping was examined, revealing a persistent photocurrent (PPC) dynamic. A model combining variable range hopping and surface kinetics was proposed to explain these dynamics. This model underscores the role of surface adsorbates in modulating the depletion layer present on the NCs surface, providing a new perspective on conductivity in disordered NC films.

Analisi della crescita del radicchio in serre agrivoltaiche con tetto in perovskite di composizione $CsPbI_3$.

Spampinato C. ([1])([2]), Valastro S. ([1]), Calogero G. ([1]), Smecca E. ([1]), Mannino G. ([1]), Arena V. ([1]), Balestrini R. ([3])([4]), Sillo F. ([3]), De Jong B. ([5]), Cina L. ([5]), La Magna A. ([1]), Alberti A. ([1])

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L'agrivoltaico, combinando agricoltura ed energia solare,rappresenta una metodologia sostenibile volta ad un uso razionale del suolo agricolo. Il nostro studio evidenzia i benefici nell'utilizzo di nuove tecnologie fotovoltaiche basate su perovskiti (PSK) semitrasparenti,in grado di raggiungere pari performances delle celle in silicio.Il lavoro multidisciplinare del

progetto CNR Vertigrow tratta la crescita del radicchio sotto luce solare simulata con LED e filtrata da PSK di composizione $CsPbI_3$. Il radicchio è stato scelto come coltura sperimentale per la sua adattabilità alle condizioni di scarsa illuminazione. Sono state condotte misurazioni per valutare l'intensità e la distribuzione spettrale della radiazione solare filtrata da PSK, e pertanto disponibile per la crescita delle piante. A questo studio sono state correlate analisi di trascrittomica che hanno evidenziato come il radicchio coltivato sotto PSK si sviluppa in modo simile e, per alcuni aspetti, migliore rispetto al sistema di piante di riferimento. Simulazioni opto-elettroniche hanno infine indicato come serre fotovoltaiche in PSK possano soddisfare il fabbisogno energetico per climatizzazione, illuminazione e irrigazione.

$TiO_2 : Ta_2O_5$ coatings for gravitational wave detectors, a study of TiO_2 content and substrate.

Granata V. ([1])([2]), Durante O. ([1]), Magnozzi M. ([4])([5]), Amato A. ([6]), Michel C. ([7]), Pinard L. ([7]), Granata M. ([7]), Canepa M. ([4])([5]), Carapella G. ([1])([2]), Chiadini F. ([2])([8]), De Simone R. ([2])([8]), Fittipaldi R. ([2])([3]), Fiumara V. ([2])([9]), Pierro V. ([2])([10]), Pinto I.M. ([2]), Vecchione A. ([3]), Bobba F. ([1])([2]), Di Giorgio C. ([11])

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Gravitational wave detectors (GWDs) are designed to detect the elusive signals produced by the ripples in spacetime, the gravitational waves. The key to improving GWDs sensitivity lies in reducing the thermal noise introduced by the coatings of the mirrors. The high-refractive-index component of the mirrors installed in the current generation of GWDs, such as Advanced LIGO and Advanced Virgo, consists of a mixture of $\sim 27\%$ TiO_2 and $\sim 73\%$ Ta_2O_5. Such a coating plays a fundamental role in GWD performance. The $27 : 73$ $TiO_2 : Ta_2O_5$ ratio ensures high structural, optical, and mechanical performance, which enabled the first detection of GWs, but may not be sufficient for new-generation GWDs. In this contribution, the potential of $TiO_2 : Ta_2O_5$ coatings in a wider range of $Ti/(Ta + Ti)$ cation ratio has been investigated. This investigation covers the morphological and structural properties of the coatings and their correlation with optical and mechanical properties. The TiO_2 content influences the structural properties of the coating, as increasing TiO_2 content leads to a lower-temperature amorphous-to-crystalline transition.

Aula 1E **ore 15:50 – 19:00**

Sezione III
Astrofisica
Presiede: Pareschi G. (INAF, Osservatorio Astronomico di Brera)

Relazioni su invito

▲ **The search for PeVatrons, current status and future prospects.**
Giuliani A.
INAF-IASF Milano
The cosmic-ray spectrum suggests that there are galactic sources capable of accelerating particles to energies up to 1 PeV. Several classes of sources have been proposed as possible PeVatrons, including supernova remnants, young stellar clusters, microquasars, and the massive black hole in Sag A*. PeVatrons are expected to be visible in the gamma-ray sky at ultra-high energies ($E > 100$ TeV). The LHAASO shower detector has recently detected many sources with a spectrum reaching these energies, however most of them are still unidentified. The advent of the next generation of Cherenkov arrays, such as CTAO and ASTRI Mini-Array, will permit a more detailed characterisation of the sources and a more comprehensive understanding of the physical processes underlying the generation of these extreme energies due to their high angular and energetic resolution.

Comunicazioni

● **INAF and Italian High-energy Astrophysics: current and future opportunities.**
Cappi M.
INAF-OAS
I will review current and future high energy facilities/observatories accessible to INAF and Italian researchers from the ground and from space, and the opportunities they offer.

● **Gamma rays studies at Fermi-Large Area Telescope (Fermi-LAT).**
Casaburo F., Ciprini S.
INFN, Sezione di Roma Tor Vergata e ASI, Space Science Data Center
The Fermi-Large Area Telescope (Fermi-LAT) onboard the Fermi satellite is a γ-ray detector covering energies from 20 MeV to over 300 GeV. Launched in 2008, its primary goal is to investigate the origin and nature of high-energy γ-rays in the universe. The experiment explores various phenomena including particle acceleration mechanisms and electromagnetic radiation from sources like Active Galactic Nuclei (AGN), pulsars, and supernova remnants. It studies galactic and extragalactic diffuse γ-ray emission, searches for unidentified γ-ray sources, and seeks indirect detection of dark matter through decay or annihilation into photons. Additionally, the Fermi-LAT examines high-energy emissions from transient sources like solar flares and Gamma Ray Burstss (GRBs). Recent scientific results from the Fermi-LAT have significantly advanced our understanding of these cosmic processes. We present the contributions of the INFN- Roma Tor Vergata and Space Science Data Center - Agenzia Spaziale Italiana (SSDC-ASI) to the experiment.

● **Clustering analysis of Fermi-LAT unidentified gamma-ray point sources.**
Cozzolongo G., Mitchell A., Malyshev D., Spencer S., Wach T., Unbehaun T.
Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
This work is motivated by prior observations of extended TeV gamma-ray sources, such as HESS J1813-178, and their GeV counterparts. In this example case, two unidentified Fermi-LAT point sources, 3FGL J1814.0-1757c and 3FGL J1814.1-1734c, were found in the region. Subsequent multiwavelength (MWL) analysis combining TeV and GeV data found a single extended source to be a better description of the emission in this region. HESS J1813-178 is currently classified as a PWN candidate and exemplifies the challenges posed by extended sources, where intricate morphology can lead to the misidentification of multiple point-like sources instead of a single entity. Our study utilizes clustering techniques in the spatial domain and conducts a spectral analysis of the cluster candidates to address these challenges by refining methods for source identification, particularly focusing on the potential extension of sources within the galactic plane. We present our results in a MWL context and aim to enhance the accuracy and reliability of source characterization in astrophysical observations.

Relazioni su invito

▲ **Direct measurements of cosmic rays: A status report.**
Sparvoli R. ([1]), Ricci M. ([2])
([1]) *Università di Roma Tor Vergata e INFN, Sezione di Roma Tor Vergata*
([2]) *INFN, Laboratori Nazionali di Frascati*
Direct measurements of cosmic rays in the energy region between tens of MeV/n up to few TeV/n have been extensively performed since the sixties by experiments on board stratospheric balloons, satellites and Space Stations. The main science goals of the missions have been the search for primordial antimatter, the detection of dark matter or exotic particles and the study of the mechanisms of production, acceleration and propagation of cosmic rays. In this contribution I will present a short review of the major results obtained by previous and current experiments, with a view to the future.

Comunicazioni

● **Antideuteron source with AMS-02 on the ISS.**
D'Angelo F. ([1])([2]), Masi N. ([1])([2]), Oliva A. ([2])
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Most of the antimatter in cosmic rays is produced by collisions of high energy particles with the interstellar medium while they propagate through it. The detection of an antimatter component over the collisional background can be used to investigate new sources, as the presence of dark matter annihilations in the halo. A possible smoking gun for dark matter is given by the detection of antideuterons below the GeV/n scale, where the secondary production is forbidden by kinematics and the presence of anti-deuterons can be associated only with exotic processes. The Alpha Magnetic Spectrometer (AMS) installed in 2011 on the International Space Station, is a large field of view high-energy particle detector able to measure rare antimatter components. In this contribution we will review the physics of antideuterons in cosmic rays, and we will discuss the experimental methods that AMS is using to detect them in cosmic rays.

Modelling antideuteron production by coalescence from high-energy hadronic collisions to cosmic rays.

Jacazio N., Bellini F., Agrawal N., Ercolessi F., Khuntia A., Malfattore G.
Università di Bologna e INFN, Sezione di Bologna

The formation mechanism of light nuclei in high-energy processes is a subject of great interest in high-energy physics and astrophysics. In recent years, high-precision measurements of deuteron (d) and helium (He) production in pp and nuclear collisions at the LHC have provided new significant constraints to models. These gave input to searches for $\bar{d}$ and $\bar{H}e$ in cosmic rays, the "smoking gun" channels for indirect dark matter searches for which the modelling of light nuclei production plays a fundamental role. We present predictions of $\bar{d}$ production in pp collisions that could be used from SPS to LHC energies and for the secondary cosmic ray $\bar{d}$ spectra. PYTHIA8 simulated events tuned to describe $\bar{p}$ yields and energy distributions as measured in pp collisions from SPS to LHC energies are used as input. Antideuterons are formed on an event-by-event basis using a coalescence afterburner, depending on the nucleon momentum distribution, the nucleus wavefunction, and the size of the nucleon emitting source. After discussing the results compared with existing data, we present prospects for future developments and applications.

Spectra of He isotopes and their ratio anomaly.

Masi N. ([6])([7]), Boschini M.J. ([1])([2]), Della Torre S. ([1]), Gervasi M. ([1])([3]), Grandi D. ([1])([3]), Jóhannesson G. ([4])([5]), La Vacca G. ([1])([3]), Moskalenko I.V. ([8])([9]), Pensotti S. ([1])([3]), Porter T.A. ([8])([9]), Quadrani L. ([6])([7]), Rancoita P.G. ([1]), Rozza D. ([1])([3]), Tacconi M. ([1])([3])
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Since its launch, the Alpha Magnetic Spectrometer-02 (AMS-02) has delivered outstanding quality measurements of the cosmic-ray (CR) spectra for fundamental particles and nuclei (H-Si, S, Fe), which resulted in a number of breakthroughs. AMS-02 can also discriminate the spectra of light isotopes albeit in a smaller rigidity range. We used precise measurements of He isotopes and the ^{3}He/^{4}He ratio by AMS-02, together with Voyager 1 data, to test their origin. An excess in ^{3}He at higher energies may indicate the presence of primary ^{3}He or signify a change in the propagation parameters in the large Galactic volume probed by the ^{3}He/^{4}He ratio. The updated local interstellar spectra (LIS) of ^{3}He and ^{4}He are provided. The calculations employ the self-consistent GALPROP-HELMOD framework that has proved to be a reliable tool in deriving the LIS of CR with Z28 and trace fine anomalies.

Analysis of cosmic neon, magnesium, and silicon nuclei with DAMPE.

Casilli E. on behalf of the DAMPE Collaboration
Dipartimento di Matematica e Fisica, Università del Salento e INFN, Sezione di Lecce

The Dark Matter Particle Explorer (DAMPE) is a satellite-based detector optimized for precise Galactic cosmic ray studies up to hundreds of TeV. Since its launch on December 17th, 2015, DAMPE has been continuously collecting data on high-energy cosmic particles with excellent statistics and particle identification capabilities, thanks to a large geometric factor

and a good energy resolution. In this contribution, we discuss the latest advancements in the direct measurement of cosmic ray neon, magnesium, and silicon. Precise knowledge of their energy spectra provides important insights into the origin, acceleration, and propagation processes of cosmic rays in the Galaxy.

Studio della variazioni stagionali e pluriennali del flusso dei muoni atmosferici.

Ghezzer L.E. on behalf of the EEE Collaboration
Università di Trento

I muoni atmosferici, prodotti nelle interazioni adroniche dei raggi cosmici primari con la stratosfera, sono la componente più abbondante di raggi cosmici secondari al suolo. Il flusso di muoni al suolo presenta una modulazione annuale, imputabile alle variazioni stagionali dello spessore e densità dell'atmosfera, e una variazione su scala undecennale, legata alla modulazione solare dei raggi cosmici primari indotta dalle variazioni del campo magnetico solare. In questo contributo, sono presentate le misure del flusso di muoni di tre telescopi a scintillazione costruiti dalla collaborazione EEE (Extreme Energy Events) ed installati dal 2019 presso la base artica di Ny Alesund (isole Svalbard). L'ampiezza della modulazione annuale e solare osservata per il flusso di muoni alle isole Svalbard (79°N, $RC < 0.1$ GV) è confrontata con le osservazioni di rivelatori di muoni e/o neutroni posti a diverse latitudini e soggetti a diverse condizioni di cutoff geomagnetico. La particolare locazione geografica delle isole Svalbard fornisce dati molto utili per la modellizzazione della complessa fenomenologia descrittiva delle variazioni del flusso di muoni al suolo.

The performance of the High Energy Particle Detector (HEPD-02) on board the second China Seismo-Electromagnetic Satellite (CSES-02).

Sorbara M. on behalf of the CSES-Limadou Collaboration
Università degli Studi di Roma Tor Vergata e INFN, Sezione di Roma Tor Vergata

The High-Energy Particle Detector (HEPD-02) on board of the second China Seismo-Electromagnetic Satellite (CSES-02) is a particle detector that is designed to measure the fluctuation of electron and proton fluxes in the energy range 3-100 MeV for electrons and 30-200 MeV for protons, caused by short time perturbations of the radiation belts induced by solar, terrestrial or anthropic phenomena. This is the second mission of the China-Italy CSES-Limadou collaboration aimed at investigating perturbations in the plasma, electromagnetic field and particles in the ionosphere. The HEPD-02 detector comprises a double layer of plastic scintillator bars used as a trigger, a three-layer tracker made of CMOS Monolithic Active Pixel Sensors (MAPS), a tower of 12 plastic scintillator planes and two segmented layers of LYSO crystals. The calorimeter is surrounded by plastic scintillator planes used as a veto system. This work will present the characteristics of the HEPD-02 detector, the energy reconstruction procedure and its performances measured with proton beams.

The design and validation of the HEPD-02 scintillator counters.

Sahnoun Z. ([1])([2]), Contin A. ([1])([2]), Lega A. ([3])([4]), Lolli M. ([2]), Nozzoli F. ([4]), Oliva A. ([2]), Palmonari F. ([1])([2]), Pozzato M. ([2])
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([3]) *Dipartimento di Fisica, Università di Trento*
([4]) *INFN-TIFPA, Trento*

The High Energy Particle Detector-02 (HEPD-02) is one of the scientific payloads onboard the second China Seismo-Electromagnetic Satellite (CSES-02). Among others, it is aimed at characterizing the cosmic-ray environment in the Earth's vicinity and identifying sudden

changes in the particle fluxes correlated to solar and terrestrial phenomena. The core of HEPD-02 - completely designed and integrated in Italy - consists in two trigger planes, a tracker system and a tower of scintillation counters made of plastic and LYSO crystals, that is able to recognize electrons in the range between 3 and 100 MeV, and protons and nuclei between 30 to 200 MeV/n. The LYSO crystals are the largest crystals (15 cm $\times$ 5 cm $\times$ 2.5 cm) ever used in space. They allow both excellent energy measurements and capabilities in Gamma Ray Bursts detection. The light yield and efficiency of all scintillator counters were studied to ensure their suitability to fulfill the experiment scientific requirements. In this contribution, we present the design, validation, and integration of the HEPD-02 scintillator counters, highlighting their performances as compared with simulations.

Performance study of a small-scale prototype of the Zirè detector.

Liguori A. on behalf of the NUSES Collaboration
Dipartimento di Fisica M. Merlin, Università e Politecnico di Bari e INFN, Sezione di Bari

Zirè is a cosmic-ray detector that will be installed onboard the NUSES satellite. Its scientific goals include the measurements of low-energy cosmic electron, proton and light nuclei energy spectra (up to 300 MeV), the detection of transient gamma signals (0.1-10 MeV), space weather monitoring, and the search for anomalies in cosmic-ray fluxes in connection to terrestrial phenomena (e.g., earthquakes, eruptions). Importantly, Zirè will act as a technological pathfinder for future space-borne detectors. Its design features a fiber tracker, a plastic scintillator tower, a LYSO calorimeter, and an anticoincidence system. All its scintillator sub-systems will be read out using silicon photomultipliers (SiPMs). For the development of Zirè, a beam test campaign was conducted at CERN PS/SPS and at BTF-Frascati with a small-scale prototype of the detector, Zirettino. In this contribution, the evaluation of the detector's performance through the analysis of beam test data will be presented, with a particular focus on its fiber tracker.

The Low-Energy Module (LEM) of the Zirè instrument onboard the NUSES space mission.

Nicolaidis R.
Dipartimento di Fisica, Università di Trento e INFN-TIFPA, Trento

NUSES is a new space mission aimed at testing innovative approaches for studying low-energy cosmic and gamma rays, astrophysical neutrinos, space weather, and magnetosphere-ionosphere lithosphere coupling models. The NUSES platform will host two scientific payloads: Terzina and Zirè. Zirè will measure protons and electrons up to a few hundred MeV and includes the Low Energy Module (LEM). The LEM will be a particle spectrometer devoted to observing fluxes of low-energy electrons in the 0.1-7 MeV range and protons in the 3-50 MeV range along the Low Earth Orbit followed by the satellite. With its compact size and limited acceptance, the LEM will allow the exploration of hostile environments such as the South Atlantic Anomaly and the inner van Allen belt, in which are expected electron fluxes of the order of 10^6 cm^{-2}s^{-1}sr^{-1}. The innovative aspects of the LEM reside in its compactness, within $10 \times 10 \times 10$ cm^{-3}, and in its active collimation approach dealing with the problem of multiple scattering at these low energies. In this presentation, I will present the detection concept of the LEM, its geometry, the status of the project, and future activities.

Aula F **ore 15:50 – 19:00**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Zardi D. (Università di Trento)

Relazioni su invito

▲ **Exploring noise-induced and CO_2-driven collapses of the Atlantic meridional overturning circulation.**
Corti S. ([1]), Cini M. ([1])([2]), Zappa G. ([1]), Ragone F. ([3])([4])
([1]) *National Research Council of Italy, Institute of Atmospheric Sciences and Climate, CNR-ISAC, Bologna, Italy*
([2]) *Department of Physics, Università degli Studi di Torino, Turin, Italy*
([3]) *Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, Belgium*
([4]) *Royal Meteorological Institute of Belgium, Brussels, Belgium*
Understanding the stability of the Atlantic Meridional Overturning Circulation (AMOC) and its response to human-induced changes is crucial for advancing climate science. The concept of a "safe-operating space" has been introduced to establish a limit on human impact within which the AMOC remains stable. This necessitates grasping the interplay between CO_2-driven and noise-induced processes in climate tipping events. Using the coupled atmosphere-ocean PlaSIM-LSG model, we investigate the potential for spontaneous AMOC collapses and how they are influenced by external human-induced factors. We address the occurrence of AMOC collapses triggered by chaotic internal climate variability without external influences using a rare event algorithm. The algorithm samples several abrupt shifts. The primary driver of the initial slowdown of AMOC is zonal wind stress across the North Atlantic, while the subsequent collapse is likely caused by the suppression of surface convection in the Labrador Sea. Higher CO_2 levels escalate the likelihood of encountering abrupt noise-induced transitions.

▲ **Climate change impact on agriculture: Harvest time forecast of olive oil and wine grape based on machine learning approach.**
Di Carlo P., Aruffo E., Mascitelli A., Chiacchiaretta P.
University "G. d'Annunzio" of Chieti-Pescara, Center for Advanced Studies and Technology-CAST e University "G. d'Annunzio" of Chieti-Pescara, Department of Advanced Technologies in Medicine and Dentistry, Chieti, Italy
Changes in regional climate are causing disruptions in global agriculture, including wine and olive oil production. Temperature is the key factor influencing the growth stages of wine grapes and olive oil and its recent increase is causing early harvests, affecting the quality and quantity of wine and oil. Water availability is the other important element: during the growing season the crop yield benefits of constant moderate rains, whereas this positive effect would be reversed if the same precipitation amounts fell in short periods of time. Using the harvest dates of the last 100 years (1920–2020) of a grape wine and olive oil, made by a farm that has kept the cultivation methods and practices unchanged since 1650, and the local and global meteorological data as input for a machine learning model, we found the parameters that impact the olive and grape growing and how those parameters can be used to forecast the harvest timing.

▲ **Merging data assimilation and machine learning: The new frontiers of nonlinear inference of complex physical systems. The cases of the Arctic sea-ice and ocean biogeochemistry.**

Carrassi A., Driscoll S., Durand C., Porro F., Chen Y., Pasmans I., Finn T., Farchi A., Brajard J., Bocquet M., Bertino L., Jones C., Vittorioso F., Ying Y., Olason E., Dansereau V., Aydogdu A., Rampal P.
University of Bologna, Italy e University of Reading, UK

We shall present an overview of the recent research effort at the crossroad of modern machine learning (ML) techniques and data assimilation (DA) approach for state estimate and model identification. We shall show how the two approaches can be merged so that the respective strengths are magnified, and the weaknesses mutually coped. The DA-ML framework offers unique opportunities to handle strong nonlinearity, non-Gaussianity, discontinues anisotropy, multifractality and generally non-regular physical phenomena that are also poorly observed. The climate system or some of its components are exemplar of this scenario. We shall illustrate several ways how the merge of DA and ML can be undergone and will show numerical results from two contexts: the prediction of the Arctic sea-ice and of the ocean biogeochemistry.

▲ **Evidence of scale-free clusters of vegetation in tropical rainforests.**

Gabrielli A. ([1])([2]), Villegas P. ([2]), Gili T. ([3]), Caldarelli G. ([4])([5])
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([5]) *Istituto dei Sistemi Complessi, ISC-CNR, Rome, Italy*

In this contribution we show that tropical rainforests exhibit a rich repertoire of spatial patterns emerging from the intricate relationship between the microscopic interaction between species. In particular, the distribution of vegetation clusters can shed much light on the underlying process that regulates the ecosystem. Analyzing the distribution of vegetation clusters at different resolution scales, we show the first robust evidence of scale-invariant clusters of vegetation, suggesting the coexistence of multiple intertwined scales in the collective dynamics of tropical rainforests. We use field data and computational simulations to confirm our hypothesis, proposing a predictor that could be particularly interesting to monitor the ecological resilience of the world's green lungs.

Comunicazioni

● **A feasibility study of LSTID events forecasting with a machine learning model.**

Ventriglia V. ([1]), Guerra M. ([1])([2]), Cesaroni C. ([1]), Spogli L. ([1])([4]), Altadill D. ([3]), Segarra A. ([3]), Belehaki A. ([5])
([1]) *Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*
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([5]) *National Observatory of Athens, IAASARS, Athens, Greece*

Travelling Ionospheric Disturbances (TIDs) are wave-like plasma density fluctuations that ripple through the ionosphere. Large-Scale TIDs (LSTIDs) typically originate from energy injection in polar regions due to geospace forcing. They affect global navigation satellite systems and radio communications, especially at mid-latitudes; hence forecasting their occurrence is crucial. Since there are no physical or empirical models to forecast LSTIDs, the

EU-funded T-FORS project (GA-101081835) aims to develop a machine learning model to forecast an occurrence 1 to 3 hours before its onset. The model leverages a catalogue of manually inspected HF-based LSTID detections along with various external drivers, spanning 9 years (2014–2022) and including auroral electrojet, solar wind and ring current data, as well as ionosonde data from the European network. Despite the imbalanced nature of the problem and the complex coupling triggering the phenomenon, our time-series classification approach demonstrates promising performance. To the best of our knowledge, there are no consolidated LSTIDs forecasting models available. Our investigation reports a cross-validated F1-score of 0.54 ± 0.03.

Characterisation of Xact625i elemental analysis by intercomparison with PIXE.

Frattticioli C. ([1])([2]), Calzolai G. ([2]), Giardi F. ([2]), Lucarelli F. ([1])([2]), Chiari M. ([2])

([1]) *Dipartimento di Fisica e Astronomia, Università di Firenze, Sesto Fiorentino, Italy*

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Measurement of the elemental composition of Particulate Matter (PM) is of paramount importance when studying PM sources. In the last decade, the use of state-of-the-art instrumentation like Xact625i, which can measure elemental composition in near-real-time by means of X-ray fluorescence spectrometry, rapidly increased. Nevertheless, Xact625i showed over/underestimation of the concentration of different elements compared to reference methods. Despite these observed discrepancies, a robust calibration approach based on a reference technique is still lacking. With the aim of overcoming this limitation, aerosol samples collected on 25 mm PTFE filters were measured by both Xact625i and Particle Induced X-ray Emission (PIXE) at the INFN-LABEC laboratory in Florence. Then, orthogonal regressions were performed for each analysed element. Good linearity (correlation coefficient > 0.95) and intercept consistent with zero were observed, but an over/underestimation in range 0–50% was observed for several elements. Thus, the use of 25 mm PTFE aerosol filters analysed by PIXE could represent a new, valuable and low-cost way for calibrating the XRF analytical module of Xact625i instrument.

Simultaneous detection of multi-scale ionospheric irregularities detected by LOFAR and GNSS.

Ghidoni R. ([1])([2]), Spogli L. ([2])([3]), Mevius M. ([4]), Cesaroni C. ([2]), Alfonsi L. ([2]), Beser K. ([5]), Guerra M. ([2])([6]), Maestri T. ([1])

([1]) *Physics and Astronomy Department, University of Bologna, Bologna, Italy*

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([6]) *University "La Sapienza", Rome, Italy*

This research aims to understand the dynamic of the multi-scale processes involved in the ionospheric response to a minor geomagnetic storm occurred on January 14–15, 2022. To do that we analyzed the data from both the LOw Frequency ARray (LOFAR), a distributed radio telescope array, and the Global Navigation Satellite System (GNSS). The data used from the LOFAR telescope are at a frequency of tens of MHz with a 1 s resolution and are distributed between 47° and 63° in latitude. On the other hand, the GNSS data comes from signals at the order of the GHz with a time resolution of 30 seconds and are present over all the European continent. The combined use of data from the two instrument gave

us the opportunity to observe three distinct phenomena: the increment of direct particles precipitation in the auroral oval, the steepening of the edge of the equator-ward ionospheric trough and the propagation towards lower latitudes of wave-like structures having scale size of less than 30 km and velocity of hundreds of meters per seconds. This was the most intriguing region, in which we had the presence of irregularities measured by LOFAR, but not by GNSS.

Realizzazione di uno spettrofotometro UV-VIS di nuova concezione per il monitoraggio delle acque.

Persiani R. ([1]), Albergo S. ([1])([2])([3]), Di Bari I. ([4]), Millesoli S. ([1])([2]), Saccà G. ([1])([2]), Sciuto A. ([4]), Tricomi A. ([1])([2])([3])

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([4]) *CNR-IMM, Consiglio Nazionale delle Ricerche, Istituto per la Microelettronica e Microsistemi, Italia*

Nell'ambito del monitoraggio ambientale e in particolare in quello delle acque, una tecnica molto importante è rappresentata dalla spettrofotometria UV-VIS. Questa tecnica permette di rivelare la presenza di piccole concentrazioni di sostanze inquinanti in acqua, misurandone l'assorbanza. All'interno dell'ecosistema SAMOTHRACE è stata studiata la possibilità di costruire uno spettrofotometro di nuova concezione. Particolare attenzione è stata dedicata all'ottimizzazione di un portacampione in teflon (PTFE) attraverso una simulazione MC in Geant4. Questo portacampione, costruito presso l'officina meccanica dell'INFN-Catania, è simile a una sfera integratrice e apporta diversi benefici rispetto alle normali cuvette usualmente adottate. Il nuovo spettrofotometro utilizza delle fibre ottiche solarizzate ed è corredato da una lampada allo xenon come sorgente, da un monocromatore e da un sistema di SiPM per la rivelazione della luce al livello del singolo fotone. Test preliminari hanno permesso di rivelare la presenza di nitrati in acqua fino a concentrazioni di 50 mg/l.

PRISMA hyperspectral satellite data for the retrieval of biophisical environmental parameters.

Panigada C., Tagliabue G., Rossini M., Colombo R.

Università degli Studi di Milano-Bicocca

The Earth Observation community is approaching a new era with the recently launched and upcoming hyperspectral satellite missions, such as the PRecursore IperSpettrale della Missione Applicativa (PRISMA) by ASI. Hyperspectral sensors, featuring contiguous visible-to-shortwave infrared spectral data, open opportunities for the accurate retrieval of biophysical parameters that are useful for a more sustainable management of forest and agriculture resources, addressing still challenging environmental issues. We will present a workflow that combine vegetation radiative transfer models and machine learning algorithms for mapping biophysical variables by exploiting a unique PRISMA dataset. PRISMA images were acquired on a large agricultural and forested area between 2020 and 2022. Field activities were conducted to acquire spectral measurements contemporary to PRISMA overpasses for bottom of atmosphere L2D product validation and to measure vegetation biophysical parameters (*i.e.*, plant structural and biochemical parameters) for model calibration and validation. The quality of the validated maps and their use demonstrates the importance of space spectroscopy for environmental applications.

On the tidal and loading Love numbers of a planet with Andrade rheology.

Consorzi A. ([1]), Melini D. ([2]), Gonzalez-Santander J. L. ([3]), Spada G. ([1])
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([3]) *Departamento de Matematicas, Universidad de Oviedo, Spain*

The Andrade rheological model is often employed to describe the response of planets to tidal perturbations, especially when their properties are still poorly constrained. While for uniform planets characterized by a steady-state Maxwell rheology the analytical form of the time-dependent Love numbers (LNs) was established long ago, in the case of the transient Andrade model no closed-form solutions have been so far determined, and the planetary response is usually studied in the frequency domain (FD) or by numerical methods in the time domain (TD). First, we focus on the Andrade rheological law in 1D and we obtain a previously unknown explicit form, in the TD, for the relaxation modulus in terms of the higher Mittag-Leffler function. Second, we consider the general response of an incompressible planetary model studying the Laplace transformed, the FD and the TD LNs by analytical methods. Through numerical methods, we assess the effect of compressibility on the Laplace transformed LNs. By exploiting the results obtained in the 1D case, we establish analytical expressions of the TD LNs and we discuss the FD response with Andrade rheology analytically.

Aula 1F **ore 15:50 – 19:00**

Sezione V
Biofisica e fisica medica
Presiede: Delfino I. (Università della Tuscia, Viterbo)

Relazioni su invito

▲ **A geometrical framework for thinking about proteins.**
Skrbic T. ([1])([2]), Banavar J.R. ([2]), Giacometti A. ([1]), Hoang T.X. ([3]), Maritan A. ([4])
([1]) *Dipartimento di Scienze Molecolari e Nanosistemi, Università Ca' Foscari, Venezia, Italia*
([2]) *Department of Physics, University of Oregon, Eugene, OR, USA*
([3]) *Institute of Physics, Vietnam Academy of Science and Technology, Hanoi, Vietnam*
([4]) *Dipartimento di Fisica e Astronomia, Università di Padova, Padova, Italia*
We present a model, based on symmetry and geometry, for proteins. Using elementary ideas from mathematics and physics, we derive the geometries of discrete helices and sheets. We postulate a compatible solvent-mediated emergent pairwise attraction that assembles these building blocks, while respecting their individual symmetries. Instead of seeking to mimic the complexity of proteins, we look for a simple abstraction of reality that yet captures the essence of proteins. We employ analytic calculations and detailed Monte Carlo simulations to explore some consequences of our theory. The predictions of our approach are in accord with experimental data. Our framework provides a rationalization for understanding the common characteristics of proteins. Our results show that the free energy landscape of a globular protein is pre-sculpted at the backbone level, sequences and functionalities evolve in the fixed backdrop of the folds determined by geometry and symmetry, and that protein structures are unique in being simultaneously characterized by stability, diversity, and sensitivity.

▲ **Nanomechanics of negatively supercoiled diaminopurine-DNA.**
Cassina V. ([1]), Salerno D. ([1]), Mantegazza F. ([1]), Marrano C. ([1]), Cristofalo M. ([1]), Shao Q. ([2]), Finzi L. ([2]), Dunlap D. ([2])
([1]) *School of Medicine and Surgery, BioNanoMedicine Center NANOMIB, Università di Milano-Bicocca, Italia*
([2]) *Department of Physics, Emory University, Atlanta, GA USA*
Single-molecule experiments have demonstrated a progressive transition from a B- to an L-form helix as DNA is gently stretched and progressively unwound. Since the particular sequence of a DNA segment influences both base stacking and hydrogen bonding, the conformational dynamics of B-to-L transitions should be tunable. To test this idea, diaminopurine (DAP) was substituted for adenine in PCR reaction to produce linear DNA with triply hydrogen-bonded DAP:T base pairs. Triple hydrogen bonding stiffened the DNA. In addition, DAP-substituted DNA formed plectonemes with larger gyres for both B- and L-form helices. Both unmodified and DAP-substituted DNA transitioned from a B- to an L-helix under physiological conditions of mild tension and unwinding. L-form DNA displayed about tenfold lower persistence length than B-form DNA. However, left-handed DAP DNA was twice as stiff as unmodified L-form DNA. Significantly doubly and triply hydrogen bonded segments have very distinct mechanical characteristics at physiological levels of negative supercoiling and tension.

▲ **Development of high-resolution imaging methods for the study of DNA damage formation.**

Lanzanò L. ([1])([2]), Longo E. ([1]), Di Franco E. ([1]), Paternò G. ([1]), Scalisi S. ([1])
([1]) *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Italia*
([2]) *Nanoscopy, Istituto Italiano di Tecnologia, Italia*

The development of advanced optical microscopy techniques has opened the way for studying biological processes at the nanoscale and at high temporal resolution. Here we show recent improvements in the field of confocal and superresolution microscopy that find application to the study of chromatin organization in intact cells. We apply confocal and superresolution microscopy in combination with image cross-correlation spectroscopy (ICCS) to an *in vitro* model that allows us to activate the expression of the PML-RARα oncogene and analyze its effects on the spatiotemporal organization of nuclear processes and on the generation of DNA damage. Quantitative features of oncogene-induced DNA damage are compared with DNA damage induced by other sources (*e.g.*, chemical or ionizing radiation agents). We also describe a method for performing segmented fluorescence correlation spectroscopy (FCS) in a commercial confocal microscope. The segmentation of FCS data provides an efficient way to measure the diffusion of molecules in specific regions of the subcellular environment. We apply this method to investigate the dynamics of the repair protein PARP1 at sites of laser-induced DNA damage.

▲ **Investigation of protein-protein interactions by phasor-FLIM-FRET measurements.**

Angeli E. ([1]), Gatta E. ([1]), Bazzurro V. ([1]), Diaspro A. ([1])([2])([3])
([1]) *SEELIFE, Dipartimento di Fisica, Università di Genova, Italia*
([2]) *Nanoscopy, CHT-Istituto Italiano Tecnologia, Genova, Italia*
([3]) *Istituto di Biofisica, Consiglio Nazionale delle Ricerche, Genova, Italia*

Förster resonance energy transfer (FRET) is a well-established method for studying molecular interactions. At the same time, fluorescence lifetime microscopy (FLIM) is a powerful technique to enhance the information stored in fluorescence images by adding the lifetime on a pixel-by-pixel scale. Using FLIM to measure FRET, such as in FLIM-FRET measurements, is a valuable technique for investigating molecular dynamics in fixed and live cells with high spatial and temporal resolution. Here, we show examples of how FLIM-FRET measurements can be exploited to study crucial biophysical questions such as protein-protein interactions in live cells. In particular, we describe the advantages of a fit-free approach based on data analysis using the phasor plot representation, which simplifies and speeds up data comparison and interpretation. In this approach, only changes in the donor's lifetime are monitored, as they are considered consequences of the FRET process. The research project was funded by the European Union-Next Generation EU PNRR MUR Infrastructure - SEELIFE "StrEngthEning the ItaLIan InFrastructure of Euro-bioimaging"(B53C22001810006, IR0000023).

Comunicazioni

● **Understanding the antiviral effects of hypericin through a combined and correlative approach with advanced AFM and fluorescence microscopy.**

Mariangeli M. ([1])([2]), Dante S. ([3]), Pedraz P. ([4]), Delcanale P. ([2]), Abbruzzetti S. ([2]), Diaspro A. ([1])([5]), Flors C. ([4]), Viappiani C. ([2]), Bianchini P. ([1])([2])([5])
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([5]) *DIFILAB, Department of Physics, University of Genoa, Genoa, Italy*
Hypericin (Hyp) is a lipophilic compound known for its fluorescent and photosensitizing properties; it can effectively inactivate enveloped viruses, either with or without light exposure. We aimed to uncover the mechanisms underlying Hyp's virucidal ability by fluorescence microscopy and atomic force microscopy (AFM) for a comprehensive understanding of the nanoscale structure, mechanics, and chemical properties. For this purpose, supported lipid bilayers (SLBs) simulating the lipid composition of enveloped viruses were used as a model. AFM topography showed morphological changes in Hyp-loaded SLBs, under light exposure, which are a result of Hyp's photodynamic activity. The rapid occurrence of these changes was studied by FastScan AFM to gain a detailed vision of the processes involved. Furthermore, by correlating confocal imaging to AFM, we determined Hyp binding affinity to distinct lipid phases. Beyond the effects induced by light, spectroscopic measurements by AFM has revealed that Hyp alters the nanomechanical properties of SLBs, leading to increased stiffness. As a result, Hyp could prevent viral entry providing a reasonable explanation for its antiviral action in the dark.

Bio-hybrid atomic force microscope as weapon against cancer: A dive into the future.

Leporatti S.
CNR Nanotec-Istituto di Nanotecnologia, Lecce, Italy
Atomic force microscopy has been employed worldwide as standard tool for investigating biological samples in fluid environment, but recent integration with always more sophisticated optical modules like fluorescence microscopy, laser scanning confocal, super-resolution microscopy and others has paved the way towards a better comprehension of hidden pathways and mechanisms in the cellular nanoworld to develop an effective nano-weapon against the evil of the Century. In this contribution I will overview recent development of atomic force microscopy with integrated optical microscopy tools for enhancing the investigation of morpho-mechanical features in cancer cells. Super-resolution microscopy and a perspective outlook in the future of cancer research will be further discussed.

Optical label-free DNA-based biosensor for Sars-CoV2 sequence detection.

Rotondi S.M.C. ([1]), Dante S. ([2]), Bisio F. ([1])([3]), Canepa M. ([1]), Cavalleri O. ([1])
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Coupling different methods like spectroscopic ellipsometry (SE), quartz crystal microbalance with dissipation (QCM-D), atomic force microscopy (AFM), and X-ray photoemission spectroscopy (XPS), we comprehensively characterized a label-free DNA-based sensing platform designed for detecting specific oligonucleotide sequences. The platform was specifically designed for targeting the RdRp-Helicase of Sars-CoV2. We immobilized on a gold surface thiolated DNA single-strands, whose sequence is complementary to the target one. Through dynamic measurements (SE and QCM), we monitored the single-strand deposition and the subsequent hybridization with the target sequence. By combining these two methods and examining the UV region in detail, we also observed hypochromism. Although this phenomenon is well documented in solution, to our knowledge, our study represents the first attempt to characterize this effect for DNA monolayers immobilized on a surface. Optical measurements also demonstrated the selectivity and recovery properties of the sensing platform. Furthermore, we coupled SE and SPR, obtaining surface plasmon-enhanced ellipsometry (SPEE), which increased the platform sensitivity.

Combination of Monte Carlo and reactive molecular dynamics to model the early steps of the radiobiological cascade within cells.

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([4]) *ICCOM-CNR, Pisa*

In the recent past, a substantial effort has been spent to understand how radiation damage is created and evolves in biological material as the latter is invested with different types of ionizing radiation. Combining Monte Carlo (MC) and molecular dynamics (MD) techniques offers a promising strategy for modeling radiation interaction and evolution. In this work, the combination between MC and MD is realized using the state-of-the-art implementation of the two methods. Concerning MC, we studied the impact of different physical parameters, like radiation quality and fluence, affecting the inter-track distance for different spatiotemporal configurations of irradiation, on chemical evolution. For MD, the most advanced version of the atomistic reactive force field is used and tested *vs.* their capability of reproducing reactions involving hydroxyl radicals. This work also aims at laying the foundations for a future extension capable of describing the cascade of physicochemical processes occurring, from the interaction of radiation to DNA damage and beyond.

Clinical missense mutations in MMACHC gene affect its conformational stability and vitamin B12-binding activity: The example of R161Q mutation.

Vilasi S. ([1]), Longo L. ([1])([3]), Randazzo L. ([1]), Bollati M. ([1]), Velazquez Campoy A. ([4]), Carrotta R. ([1]), Costa M.A. ([1]), De Rosa M. ([1]), Ortore M.G. ([2]), Mangione M.R. ([1]), Martorana V. ([1]), Milani M. ([1]), Passantino R. ([1]), Tutone M. ([1])

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([2]) *Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona, Italy*
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MMACHC is a crucial protein in the metabolism of vitamin B12 (cobalamin, Cbl) chemically transforming it into its active forms (AdoCbl and MeCbl), which are cofactors in important cellular reactions. Mutations in the gene encoding MMACHC are responsible for the metabolic disorder CblC methylmalonic aciduria and homocystinuria, cblC type (cblC), which, in most cases, affects children, causing neurocognitive and cardiovascular dysfunctions. Here, through the combined use of circular dichroism and differential scanning calorimetry, we demonstrate how a pathological mutation, R161Q, occurring far from the Cbl-binding pocket, affects the MMACHC thermal unfolding pathway and the populations of conformational intermediates. The binding properties to Cbl and the ability to form homodimers, triggered by the presence of the ligand, and assessed by native electrophoresis, light and small-angle X-ray scattering, were also impaired. Our study confirms a correlation between the energetics of thermal unfolding of MMACHC and its Cbl-binding properties, gaining knowledge into the molecular mechanisms underlying the function of MMACHC and providing insights for potential therapeutic interventions.

Unraveling Cryo-EM structures of complexes between hemoglobin and the *S. aureus* hemophore IsdH for modeling novel protein-protein interaction inhibitors.

Marchetti M. ([1]), Buoli Comani V. ([2]), De Bei O. ([1]), Paris G. ([3]), Luisi B. F. ([3]), Marchesani F. ([1]), Faggiano S. ([2])([4]), Ronda L. ([1])([4]), Campanini B. ([2]), Bettati S. ([1])([4])

([1]) *Department of Medicine and Surgery, University of Parma, Parma, Italy*
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Staphylococcus aureus relies on iron to infect the host, and hemoglobin (Hb) is its primary source. Indeed, it captures heme via a nine-protein machinery, overexpressed under iron-restricted conditions. The process is initiated by two surface receptors, IsdB and IsdH, which bind Hb and extract heme. Through Cryo-EM single-particle analysis, we determined the structures of two different IsdH constructs in complex with carboxyHb (HbCO), capturing snapshots of protein-protein interactions (PPI) before heme extraction occurs. The analysis of the minimal functional construct of IsdH (containing two out of the three domains of the native protein, the only form for which structural data were available so far) led to the reconstruction of multiple maps at a resolution close to 3 ångström, revealing the presence of different oligomeric states and stoichiometries. Our investigations also extended to full-length IsdH:HbCO complex, for which no structural data are available so far. These results could pave the way for the design of PPI inhibitors able to block IsdH-mediated iron acquisition. Impairing *S. aureus* iron uptake represents an appealing strategy to develop new antimicrobial agents.

Multi-scale modeling of interactions between green fluorescent proteins and bio-functionalized nanoparticles.

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The interaction between bio-functionalized Nanoparticles (NPs) and proteins has gained attention in theranostics. For instance, the GFP can be engineered to carry a negative charge, allowing it to form a stable complex with the highly positively charged NP, acting as a biosensor. Various factors like size, charge and hydrophobicity of both proteins and NPs influence aggregation, requiring optimization. MD simulations allow studying these properties, with coarse-grained models necessary for reducing computational costs. We have tested with GFPs several force fields of the minimalist C_α based models for proteins, differing by parameterization strategy and input dataset, leading to variations in interaction representation, especially in the hydrophobic part. We have then developed a coarse-grained model for the NP using a multi-scale approach based on atomistic data, and ensuring the compatibility with the GFP models. These models were utilized to explore protein aggregation with diverse sequences, altering charge and hydrophobicity, interacting with NPs. This exploration aimed to identify the conditions that would result in the most effective theranostic outcomes.

Mapping FUNctional connectivity in the motor and somatosensory areas: FUN-mTMS.

Pieramico G. ([1]), Guidotti R. ([1]), Souza V.H. ([3])([4]), Mutanen T.P. ([3]), Voso D. ([1]), Ilmoniemi R.J. ([3])([4]), Romani G.L. ([2]), Pizzella V. ([1])([2]), Marzetti L. ([1])([2])

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([4]) *BioMag Laboratory, HUS Medical Imaging Center, Aalto University, University of Helsinki e Helsinki University Hospital, Helsinki, Finland*

Multi-locus Transcranial Magnetic Stimulation (mTMS) is an innovative and non-invasive technique that influences brain networks by applying a focused electric field (*E*-field) through a set of coils placed over the scalp. The advantage of mTMS is that it enables precise *E*-field adjustment by tuning the currents that flow in the coils thus facilitating parameter-based network studies. In this study, we investigated how mTMS *E*-field position affects electroencephalography (EEG) functional connectivity. Eight participants underwent 5-coil mTMS experiment targeting left motor cortex (M1) and somatosensory cortex (S1) at different sites $5\,mm$ apart. The EEG signal was recorded concurrently to capture connectivity changes modulated by mTMS pulses. The main goal was to predict stimulation origin by classifying post-stimulus functional connectivity across sites, utilizing six phase coupling metrics. Support vector machine (SVM) and random forest algorithms were used for classification. Results underscore the predictive potential of post-stimulus connectivity modulation in discerning various stimulated positions during mTMS.

Aula D **ore 15:50 – 19:00**

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiedono: Croci G. (Università di Milano Bicocca)

Badini L. (Università di Pisa)

Relazioni su invito

▲ **Low-cost radiation detectors for safety and security applications developed at INFN.**

Finocchiaro P.

INFN, Laboratori Nazionali del Sud

In the framework of the H2020 Euratom projects MICADO, PREDIS, CLEANDEM, and of the PI3SO project supported by INFN-Energy, several low-cost sensors for gamma and neutron detection were developed. These sensors can be exploited as building blocks for monitoring systems in nuclear safety and security applications. In particular, compact detectors were developed which can be installed around radioactive waste packages for a medium-to-long term monitoring. The same detectors can be arranged in a portal fashion, to check people and prevent the illicit carrying of hidden radioactive materials, or they can be exploited to equip a room or a field tent in order to monitor and/or locate possible radioactive sources inside. Miniature detectors were also developed which can be installed on unmanned vehicles or drones, remotely operated, to be employed during the preliminary phases of nuclear plants decommissioning and/or for accident remediation. The same kind of miniature detectors were assembled in linear arrays thus obtaining a gamma-ray scanner table with hot-spot finding and spectroscopic features, to be employed for radwaste (re)conditioning.

▲ **Unlock the potential of nuclear energy: Challenges and opportunities for a new nuclear renaissance.**

Monti S.

Associazione Italiana Nucleare, AIN e European Nuclear Society, ENS

The need to find suitable and reliable solutions to the very challenging trilemma —decarbonization of the whole energy sector, security of energy supply, availability of large amount of energy at affordable and stable prices— has triggered a renewed interest in nuclear energy, not only in the regions of the world where nuclear power has been always part of a consistent energy mix, but now also in newcomer countries in Europe, Asia and Africa. Of all the low carbon energy sources, nuclear power is one of the few, if not the only one, that can generate at scale all the main energy carriers: electricity, heat and hydrogen. It can produce a large amount of base load and dispatchable carbon-free electricity, but also supply other clean energy products needed to decarbonize energy intensive sectors such as the transport sector, the building sector, industrial heat applications and desalination. This contribution provides a brief overview of the current status of nuclear power and of the new constructions worldwide, and highlights the new trends, including the R&D&I efforts to address the remaining challenges to make advanced and innovative nuclear systems an industrial reality.

▲ **UHDR VHEE beams for FLASH RT: Challenges and opportunities.**

Bisogni M.G.
Università di Pisa, Dipartimento di Fisica "E. Fermi" e INFN, Sezione di Pisa

The FLASH effect is a radiobiological effect that consists in a substantial spare of healthy tissues, while maintaining unaltered the efficacy on tumors. It has been experimentally verified delivering a therapeutical dose in less than 200 ms with a dose rate greater than 40 Gy/s. Ultra High Dose Rate (UHDR) low energy electrons (4–15 MeV) are already produced in FLASH mode but they are limited to superficial tumors and intra operative radiotherapy (RT). To treat deep-seated tumors, the research efforts are concentrated on Very High Energy Electron (VHEE) FLASH beams produced by compact LINAC in the range 50–200 MeV. Dosimetry and beam monitoring of UHDR VHEE beams are also challenging. Since an active scanning of the tumor with pencil beams must be used, standard equipment shows saturation, dynamic range and timing issues. Additionally, the extremely hypofractionated regime envisaged for FLASH RT requires control imaging systems, currently not available, able to check the compliance of the treatment plan *in vivo* with high accuracy and during the very short irradiation time. In this contribution, the latest advances and recent results in UHDR VHEE technology for FALSH RT will be reviewed.

Comunicazioni

● **AI algorithms for plasma characterization by X imaging in the framework of the PANDORA project.**

Peri B. ([1])([2]), Naselli E. ([1]), Finocchiaro G. ([1]), Mishra B. ([1]), Pidatella A ([1]), Mascali D. ([1])
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PANDORA is a multidisciplinary project aiming at investigating β decays in plasmas; it is based on a new facility able to create some stellar-like plasma properties, thus representing a breakthrough for fundamental studies about weak interactions in astrophysical contexts; it will also enable a wide range of applications including materials science, physics and technology of accelerators and ion sources, etc. In this framework, an innovative algorithm for X-ray imaging in SPhC mode with multiple exposures in High Dynamic Range (HDR) was developed, enabling powerful space-resolved plasma spectroscopy in the soft X-ray domain. In this contribution we will be presenting the results of the further development and optimization of the algorithm by implementing an AI-based machine learning model encoded in MatLab. Moreover, emphasis will be placed also on the experimental aspects, such as energy calibration, quantum efficiency and energy resolution evaluation, presenting the characterization results obtained by systematic measurements on the new advanced X-ray diagnostic testbed named PYN-HO.

● **Single-pass absorption simulations in Divertor Tokamak Test scenarios.**

Salvia C. ([1]), Cardinali A. ([2])([3])([4]), Castaldo C. ([5]), Ceccuzzi S. ([5])([6]), Van Eester D. ([7])
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([2]) *INFN, Laboratori Nazionali del Sud, Catania, Italy*
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([5]) *ENEA, Frascati,Italy*
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(7) *LPP-ERM/KMS, Association EUROFUSION-Belgian State, TEC partner, Brussels, Belgium*

An analysis of the Ion Cyclotron Resonance Heating (ICRH) propagation and single-pass absorption in DTT (Divertor Tokamak Test) facility heating scenarios has been performed by means of the numerical tool TOMCAT. It allows to study wave propagation and damping as well as mode conversion for a 1D plasma of Maxwellian species and it is based on solving a twelfth-order differential system using the finite-element formalism. This analysis aimed to explore a wider parameter space compared to previous results obtained using TORIC, with the goal of enhancing the understanding of DTT scenarios and confirming the physics inputs to system design. Scenarios of minority heating at 3 T and 6 T were analysed, simulating with different plasma species, including varying concentrations of D, ^{3}He and H, across the frequency range from 45 MHz to 90 MHz. Three-ion scenarios for full-field scenarios have been analysed, too, indicating the need for further exploration to determine the plasma and radio frequency (RF) parameters required to achieve significant power absorption by the third ion species. Finally, an approximative evaluation of the ICRH contribution to heat load has been also performed.

Conceptual study for tritium production by using fusion-fission hybrid systems.

Panza F. (1)(2), Bustreo C. (3), Cappelli M. (1), Ciotti M. (1), Claps G. (1)(4), Cordella F. (1)(4), De Leo V. (1)(4), Lomonaco G. (1)(5), Orsitto F.P. (1), Pacella D. (1)(4), Piovan R. (3)(6), Pompeo N. (7), Ripani M. (2), Murgo S. (2)(7)
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(2) *INFN, Sezione di Genova, Genova*
(3) *Consorzio RFX, Padova*
(4) *INFN, Laboratori Nazionali di Frascati*
(5) *Università degli Studi di Genova*
(6) *CNR-ISTP, Padova*
(7) *Università degli Studi Roma Tre*

Tritium demanding will increase when the first fusion reactors (ITER, DEMO, CFETR, etc.) will be operating. The current tritium production is performed by using CANDU reactor, but the actual tritium amount will be not sufficient for the future. Even if the future machines will be equipped with tritium blanket modules, the tritium production amount seems to be not sufficient, so, a complementary approach based on fusion fission hybrid reactor (FFHR) seems to be very promising. In fact, FFHRs are based on a fusion neutron source (Tokamak, RFP, etc.) driving a subcritical fission complex, able to obtain a high neutrons multiplication. A dedicated breeding area composed by materials containing lithium and surrounded by moderators (like graphite or beryllium oxide) keeping the neutron energies until the thermal region, where the tritium production cross-section is higher has been designed and investigated. This approach, based on FFHRs (currently not in operation but only studied for conceptual designs) could, in principle, guarantee a high TBR value with a good net tritium production (considering more production modules surrounding the available space around the neutron source).

Intelligent ports and nuclear safety: Innovations from the RAISE and ROSSINI projects.

Grazzi S., Battaglieri M., Vittorini T.
INFN, Sezione di Genova

The RAISE project, funded by Italy's Ministry of University and Research under Investment 1.5 (M4C2) of the National Recovery and Resilience Plan (PNRR), aims to develop

and strengthen innovation ecosystems aligned with regional industrial and research interests. The project, coordinated by the University of Genoa, has INFN, CNR, and the IIT has partners. Within RAISE, SPOKE4 is focused in updating port's infrastructures using robotic technologies and artificial intelligence systems by developing autonomous systems for critical operations, real-time data and machine learning technologies for monitoring and safety, models for optimizing logistics and transport networks, and pollution reduction tools for small to medium-sized ports. As part of it, the ROSSINI project (Remotely-operated Onboard Inspections for Special Nuclear material) aims to develop a new approach to container inspection in maritime transportation. INFN-Genova is currently developing a new approach to security using radiation detectors mounted on flaying drones and terrestrial robots to perform container inspections minimizing the time and human exposure to radiations. Status of the ROSSINI project will be reported.

Fusione con Combustibile Polarizzato: a che punto siamo?

Ciullo G.

Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara e INFN, Sezione di Ferrara

Dal punto di vista della fisica le verifiche sperimentali sulle reazioni nucleari dipendenti da spin, dagli anni '70, e le proposte conseguenti, dagli anni '80, per il loro utilizzo nella fusione nucleare, hanno oggi la possibilità di essere risolutive per la produzione di energia grazie alla maturità tecnologica, ottenuta nell'ambito di bersagli nucleari polarizzati solidi e gassosi. Le comunità scientifiche competenti hanno orientato attenzione e impegno in R&D per il loro sfruttamento a vantaggio della fusione nucleare. In tale contributo si presenteranno i vantaggi dell'utilizzo di combustibile polarizzato nuclearmente e le problematiche, che ne limitano l'applicazione in ambienti di fusione. Sarà fornito il panorama internazionale e le attività satelliti, che orbitano nell'ambito della ricerca su bersagli nucleari polarizzati, che hanno di recente proposte in atto per prove su facility di fusione.

Optimization of the production of the theranostic ^{155}Tb using alpha induced reactions on ^{nat}Gd targets.

Marrella M. ([2]), Colucci M. ([1])([3]), Cardani I. ([1])([3]), Nigron E. ([4]), Haddad F. ([4])([5]), Groppi F. ([1])([3]), Manenti S. ([1])([3])

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([5]) *GIP Arronax, Saint-Herblain, France*

Radionuclides have considerable relevance in medical applications and their production represents a notable resource for guaranteeing and improving the diagnostic and therapeutic techniques known today and those under development. The present contribution focuses on a set of four terbium radionuclides, whose decay characteristics lend themselves well to theranostics, a concept aimed at indicating the combination of therapy and diagnostics. In particular, the cross-section of production of ^{155}Tb ($T_{1/2} = 5.32$ d) starting from the ^{nat}Gd(α, x) nuclear reaction will be discussed. The irradiations were conducted at the GIP Arronax cyclotron in St. Herblain (France) with alpha-particle beams in the 25–65 MeV energy range using the stacked-foil activation technique while the gamma spectrometry measurements were performed both at GIP Arronax and at the LASA laboratories in Milan (Italy). Furthermore, an indirect production method via the formation of ^{155}Dy ($T_{1/2} = 9.9$ h) is proposed. All the results obtained were compared with the experimental data present in the literature and with TALYS 1.9 nuclear simulation code.

The role of methylthymol blue and sulfuric acid in the dosimetric response of PVA-GTA-based Fricke gel dosimeters.

Gallo S. ([3]), Locarno S. ([1]), Franco E. ([1]), Lenardi C. ([1]), Pignoli E. ([2]), Veronese I. ([1])

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In this contribution, the results of optical absorbance measurements on Fricke gel dosimeters made with synthetic matrices of Polyvinyl Alcohol and Glutaraldehyde (PVA-GTA-FG) varying the concentration of Sulfuric Acid (SA) and Methylthymol Blue (MTB) are presented. The design idea of this work arises from the observation that there is no standardized preparation protocol. The PVA-GTA-FG dosimeters were prepared using MTB concentrations in the range of 0.03–0.80 mM and SA in the range of 15–100 mM. The optical absorbance properties and the response to FG were studied in the range of 0–42 Gy with particular attention to doses below 6 Gy. The results demonstrate that the amount of SA and MTB determines both the sensitivity to absorbed dose and the linearity range of the dose-response curve. The study also suggests that an appropriate choice of wavelength for optical acquisitions allows the detection of doses even lower than 1 Gy. Optimization of the PVA-GTA-FG manufacturing recipe, combined with improvements made by the synthetic matrix, has maximized the sensitivity of the optical response, and minimized the loss of spatial and temporal dosimetric information.

Single wall carbon nanotubes-polymer composite materials and their biomedical applications.

Priori ello A. ([1])([2]), Fazi L. ([2])([3]), Romanelli G. ([1])([2]), Morales P. ([2]), Andreani C. ([1])([2]), Senesi R. ([1])([2])

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Combining the electrical conductivity and the robustness of single wall carbon nanotubes (SWCNT) bundles, with the viscoelastic properties of polymer films (*e.g.*, stretchability and mouldability), promising conductive stretchable Composite materials (CM), useful in the biomedical field, have been obtained. By self-grafting SWCNT bundles onto the plastic poly-ethylene (PE), we obtained microelectrodes to monitor the cortical brain activity of laboratory rats; while using the more elastic poly-dimethyl-siloxane (PDMS), the realization of an artificial bladder prototype is allowed. The interface properties of the composites have been investigated, since they depend on the CNT grafting into the polymeric matrices. The CM morphology has been investigated by scanning electron microscopy and micro-Raman spectroscopy; while the CM electro-mechanical properties have been studied by measurements of stress and resistance *vs.* strain and of current *vs.* voltage applied to thin CM stripes. Our studies reveal a deeper penetration of SWCNT into the polymer bulk of thermosetting elastomer substrates (PDMS), showing mechanical and electrical responses suitable to repeated deformation of the polymer.

The unexpected diagnostic potential of 3D nano-disorder: Development of an innovative Raman platform to explore biomechanical properties of genomic DNA.

Mussi V. ([1]), Convertino A. ([1]), Lisi A. ([2]), Ledda M. ([2]), Cirillo E.M. ([3]), Durastanti C. ([3])

([1]) *Istituto di Microelettronica e Microsistemi del CNR, IMM-CNR*
([2]) *Istituto di Farmacologia Traslazionale, IFT-CNR*
([3]) *Dipartimento di Scienze di Base e Applicate per l'Ingegneria, SBAI, Sapienza Università di Roma*

While many efforts have been devoted to detect mutations in the sequence of DNA basis related to cancer disease, it is now clear that physical properties, like structural conformation, stiffness and shape, can play an important role to recognize DNA modifications. Here, Ag-coated silicon nanowires (Ag/SiNWs) are exploited as Raman platform to fast discriminate sane and cancer DNA, extracted from human normal skin and malignant melanoma cells. Aqueous DNA drops are deposited onto a forest of Ag/SiNWs and Raman maps are acquired after dehydration. Principal component analysis of the maps allows to distinguish healthy and cancer DNA without false negative outcomes and with few false positive results. The discrimination occurs through Raman bands strictly related to the interfacing of the DNA and the NWs. The diagnostic result is ascribed to conformational differences and diverse charge properties determining a diverse arrangement of the molecules adsorbed on the NWs. The unique interaction with DNA and facile fabrication technology make Ag/SiNWs an effective platform for a robust, rapid and label-free cancer diagnosis, and a potential tool to investigate physical properties of DNA.

An overview of the SECURE project in Horizon 2021.

Capogni M. ([1]), Lepore L. ([1]), Cozzella M.L. ([1]), Cherubini N. ([1]), Falconi L. ([1]), Croia M. ([1]), Spagnuolo L. ([1]), Guarcini T. ([1]), Placidi S. ([1]), Limosani F. ([1]), Pagano A. ([1]), Pietropaolo A. ([2]), Colangeli A. ([2]), Rizzo A. ([3]), Ottaviano G. ([3]), Ubaldini A. ([3])
([1]) *ENEA Nuclear Department, Casaccia Research Center*
([2]) *ENEA Nuclear Department, Frascati Research Center*
([3]) *ENEA Nuclear Department, Bologna and Brasimone Research Centers*

The SECURE project is funded by the EU Horizon 2021 program and focuses on the development of secure and reliable supply chains for theragnostic radiopharmaceuticals, which are a key tool in modern medicine. The ambition of the SECURE consortium, made by 17 European partners coordinated by POLATOM (Poland), is to identify and efficiently use the current resources for new medical radionuclides, which would create new opportunities for society, healthcare and economics. The project is structured in 4 technical work packages which are focused on designing new irradiation targets, developing production routes for emerging theragnostic radioisotopes, developing a framework of guidance and recommendations that enables exploring the full clinical potential of alpha and beta particle therapy and its safe application throughout the supply chain from the production centre to the clinic, addressing issues in upscaling and sustaining isotope production. ENEA is involved in the project with its main facilities and expertise of the own Nuclear Department, such as radionuclides measurements, nuclear research reactors, accelerator-driven 14 MeV neutron fusion source and radiochemical resources.

Aula B **ore 15:50 – 19:00**

Sezione VII
Didattica e storia della fisica
Presiede: Lovisetti L. (Università di Milano)

Relazioni su invito

▲ **IA nella didattica della fisica. Ignoranza o intelligenza artificiale? Pochi dubbi oggi, ma il fenomeno è in rapida evoluzione.**
Oss S.
Dipartimento di Fisica, Università di Trento
L'accelerazione delle interfacce dei "grandi modelli linguistici" (ChatGPT per esempio) è inquietante ed è molto difficile fare previsioni sul loro impatto sia a breve che a medio termine, soprattutto perché riguarda questioni metodologiche, di contenuto, pedagogiche, comportamentali, docimologiche e molto altro. La didattica della fisica non fa eccezione: è un territorio particolarmente sensibile alle influenze "artificiali", basate sul supporto informatico, multimediale e computazionale. Quindi la tentazione di gettarsi a capofitto nel parco giochi della cosiddetta intelligenza artificiale è grande, con i corrispondentemente grandi rischi connessi al coinvolgimento della popolazione scolastica, molto esposta e fragile. Cosa si intende per "intelligenza" in questo contesto? La risposta può iniziare dal fatto spesso sottovalutato che la "intelligence" anglosassone è qualcosa di differente dalla traduzione in lingua italiana che abbiamo automaticamente adottato.

▲ **Paradigmi digitali per l'apprendimento della fisica: ruolo della computazione e digressioni sul futuro (im)prevedibile.**
Sapia P., Bozzo G.
Dipartimento di Matematica e Informatica, Università della Calabria, Rende
Le discipline scientifico-tecniche (e i loro processi didattici) tradizionalmente si basano su due pilastri: teoria ed esperimento. Negli ultimi decenni, ubiquità dei computer e larga disponibilità di strumenti digitali hanno reso sfumata la dicotomia teoria/esperimento, con l'irruzione sulla scena di un vero terzo pilastro del processo di acquisizione della conoscenza, la computazione, che ha progressivamente assunto importanza anche nei percorsi formativi scolastici e universitari, dato che il pensiero algoritmico è uno strumento intellettuale potente che può essere favorito da attività di risoluzione di problemi che fanno uso di computazione. A sua volta, la programmazione (nella sua dimensione concettuale) ha un profondo impatto sulle abilità di ragionamento e assume quindi grande importanza per i processi T/L delle discipline STEM. Questo contributo esamina il ruolo delle risorse digitali nell'istruzione STEM, con particolar riferimento alla computazione, inclusi alcuni strumenti computazionali alla base dei moderni sistemi di IA. Verranno inoltre offerte delle riflessioni critiche sulle possibili linee evolutive di tali risorse e sul loro impatto nei processi didattici.

▲ **Investigating how the new technological landscape is re-shaping science and science education.**
Satanassi S. ([1]), Erduran S. ([2]), Levrini O. ([1])
([1]) *Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna*
([2]) *Department of Education, St Cross College, University of Oxford*
We are living in a revolutionary time. The new technological landscape, like artificial intelligence (AI) and quantum technologies (QTs) has become the main driver of societal changes.

New technologies are reshaping the knowledge structures and requiring new competencies for current and future scientists to keep pace with these changes. Erduran and Levrini (2024) called for reflections on how AI is changing the ways in which science is done. While there is growing interest in AI's role in teaching and learning, authors shed light on the need to delve deeper into the new aims and values, practices, methods, and knowledge of STEM research for informing STEM education. Similarly, QTs are becoming one of the pillars of research and development in several countries. Many efforts have been made to incorporate QTs at different university levels and to expand the workforce. The present contribution paves the way for research to investigate how the new technological landscape can impact physics and how it can fruitfully inform science education. It illustrates examples of how AI and QT are being infused into science and provides examples of potential integration in science education.

Comunicazioni

Didattica della fisica ai tempi di ChatGPT: l'arte di fare domande.

Torre M.

Liceo "G. Peano", Tortona, AL

L'intelligenza artificiale generativa conversazionale potrà avere davvero un impatto nella didattica della fisica? La discussione è aperta. Per far fronte al quesito, nell'a.s. 23-24 ho sperimentato un percorso didattico su ChatGPT che ha visto coinvolti circa 100 studenti di 3 e 4 Liceo per un totale di 8 ore curriculari. L'obiettivo era integrare ChatGPT nella tradizionale didattica e pensarlo come strumento per lo sviluppo di competenze. Gli studenti hanno proposto a ChatGPT problemi verbali e un questionario preparato per valutare le misconoscenze in fisica, validi esempi per far sviluppare loro domande metacognitive (i perché), per interpretare le risposte date da ChatGPT e per condurre il bot a formulare la risposta corretta dopo i suoi errori. Questi dialoghi metacognitivi hanno spostato l'attenzione degli studenti verso la riflessione sui significati dei termini fisici proposti da ChatGPT e sulla conquista dell'esigenza di spiegare i perché e non accontentarsi dei come. Vista l'ampia disponibilità di chatbot, in futuro sarà interessante implementare la sperimentazione usando altri chatbot (Claude2, Bard e Mistral) per confrontare le risposte fornite su specifici item.

Analisi di come un osservatore meccanicistico privo di coscienza percepisce eventi reali e quelli simulati da un computer.

Sisini F.

Liceo Artistico Dosso Dossi, Ferrara

L'ipotesi della simulazione solleva un dilemma cruciale sulla credibilità della fisica nota: la possibilità che gli eventi percepiti siano simulati, non reali. Per analizzare questa ipotesi in termini deterministici e meccanicistici, si sviluppa concettualmente un osservatore la cui condizione interna dipende dagli eventi esterni. Si dimostra che tale osservatore non può distinguere tra eventi simulati e reali. Si argomenta che, se l'osservatore potesse osservare la sua dinamica interna, potrebbe formulare i principi necessari della relatività per distinguere i movimenti fisici reali da quelli non reali. Infine, si tenta di applicare le stesse considerazioni sviluppate per l'osservatore meccanicistico all'essere umano, esplorando il modo in cui potremmo percepire e interpretare la realtà. Questo studio getta luce su questioni filosofiche profonde riguardanti la natura della realtà e l'esperienza soggettiva, e suggerisce che la nostra comprensione della fisica potrebbe essere influenzata dalla nostra percezione di ciò che è reale.

Le strutture temporali della scienza dei sistemi complessi e la formazione di competenze di sostenibilità.

Ilari V., Levrini O., De Zuani Cassina F., Fantini P.
Dipartimento di Fisica e Astronomia "A. Righi", Università di Bologna

Nel contributo, sarà presentato uno studio realizzato all'interno del progetto FEDORA (Horizon 2020) che ha, tra i suoi obiettivi, l'elaborazione di modelli educativi nelle discipline STEM che favoriscano lo sviluppo di competenze di sostenibilità, come la gestione della complessità e l'immaginazione del futuro, previste dal GreenComp. Lo studio riguarda l'esplorazione e l'analisi delle strutture temporali caratteristiche dell'evoluzione dei sistemi complessi. Ispirandosi alle definizioni di Ilya Prigogine di tempo interno e tempo esterno, si sono elaborati criteri per confrontare le strutture temporali della scienza dei sistemi complessi con quelle della fisica classica. Questi criteri hanno guidato la progettazione di attività di laboratorio incentrate su due fenomeni di auto-organizzazione, proposti in una classe seconda di scuola superiore. Gli esperimenti sono stati realizzati nell'ambito di un modulo interdisciplinare finalizzato a far riflettere gli studenti su come diverse discipline (fisica, chimica, letteratura) concettualizzano e trattano i diversi "volti" del tempo.

Using uncertainties in physics to develop sustainability competencies for climate change.

De Zuani F., Miani L., Levrini O.
Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna

Climate change represents a complex global challenge requiring specific competencies to effectively interpret and respond to its uncertainties. In addressing this challenge, the multifaceted nature of uncertainties in physics - specifically epistemic, aleatoric, ontological and reflexive uncertainties - can provide a framework for developing such competencies. Therefore, we designed and implemented a 20-hour course for upper secondary students focusing on these uncertainties, employing diverse teaching methodologies such as lectures, workgroups, and individual creative tasks. Furthermore, we designed and engaged students in a gameboard enclosing the key concepts introduced in the course as uncertainties, climate models and future scenarios. In the contribution, we discuss specifically how we embedded uncertainties within the course and the game, to allow students to explore climate-related decision-making processes and develop a comprehensive view of the impacts and management strategies related to climate phenomena. Preliminary outcomes show that students broadened their perspectives of the climate problem and the role that physics can have in addressing crucial societal issues.

Advanced data analytics techniques in physics education: A critical and methodological study.

Peruzzi O., Barelli E., Levrini O.
Dipartimento di Fisica e Astronomia, Università di Bologna

This study focuses on a critical and methodological analysis of artificial intelligence techniques applied to a composite dataset derived from the European project FEDORA, which includes both textual and quantitative data related to the field of Physics Education and History. Employing a dual analytical approach, the work utilizes (i) prompt engineering for text classification and generation using the GPT-4 model, and (ii) the application of machine learning (ML) and deep learning (DL) techniques, including neural networks (NN) and transformers, as well as lexicometry to develop quantitative metrics. The goal is to evaluate texts and numerical features through a rigorous quantitative evaluation framework, originally developed by Barelli et al. for similar texts. Furthermore, a critical epistemological inquiry is conducted to validate the methodologies used. This work seeks to contribute

to methodological research in the field of physics education, proposing advanced analytical tools for a deeper understanding of data.

Modello pedagogico per la formazione insegnanti sul tema del cambiamento climatico.

Rossi C., Levrini O., Tasquier G.
Dipartimento di Fisica e Astronomia, Univeristà di Bologna

Il presente lavoro si colloca nel progetto europeo CLIMADEMY (Climate Change Teachers' Academy), un progetto Erasmus+ coordinato dall'Università di Creta. Il progetto CLIMADEMY ha l'obiettivo di sviluppare un quadro di riferimento per la formazione insegnanti sul tema dei cambiamenti climatici, per dare un supporto agli insegnanti nella comprensione dei fattori e degli impatti dei cambiamenti climatici, delle possibili azioni di mitigazione e adattamento, e promuovere un processo di insegnamento-apprendimento che sia efficace. La domanda di ricerca è la seguente: Quali sono le esigenze degli insegnanti nel processo di insegnamento dei cambiamenti climatici e come queste possono essere affrontate attraverso la formazione insegnanti? Un'indagine qualitativa, che ha coinvolto 41 insegnanti, ha permesso di individuare le esigenze degli insegnanti e confrontarle con i risultati della letteratura di ricerca. Le esigenze emerse sono state raggruppate in quattro macro-categorie (disciplinari, pratiche educative, orientamento e supporto istituzionale) e utilizzate nella progettazione di un modello pedagogico per la formazione insegnante.

Orienting the young in the complexity of climate change to foster in societally relevant choices: Overview of the ENCOMPASS project.

Tasquier G. ([1]), Pongiglione F. ([2]), Ricci E.C. ([3])
([1]) *Dipartimento di Fisica e Astronomia, Università di Bologna*
([2]) *Dipartimento di Filosofia, Università San Raffaele Vita-Salute, Milano*
([3]) *Dipartimento di Management, Università di Verona*

Recent reports highlight that general population seems increasingly aware of climate change. However, forms of radical activism are showing a lack of orientation among young people, who have trouble understanding deeply the complexity of the issue and how to become agents of change. There is a lively research debate, across several disciplines, about how to conceive agency in the field of climate change. The overarching goal of ENCOMPASS, a national project financed within the PRIN PNRR2022 programme, is to respond to these phenomena by unpacking the concept of agency from three disciplinary perspectives, including both individual action and political participation, and incorporate it in science education programs.

Concetti chiave per l'educazione alla sostenibilità nelle scuole secondarie: uno studio Delphi.

Salmoiraghi A., Di Mauro M., Toffaletti S., Fiorello C., Onorato P., Oss S.
Dipartimento di Fisica, Università di Trento

L'educazione alla sostenibilità nella scuola secondaria di secondo grado rappresenta una sfida per la sua complessità e la sua natura multidisciplinare. Per identificare quali sono i concetti chiave, i contributi delle varie discipline e gli obiettivi specifici, abbiamo condotto uno studio utilizzando il metodo Delphi. Questo metodo propone un approccio strutturato e iterativo di comunicazione di gruppo, volto a mettere a confronto le visioni di esperti per raggiungere un consenso su questioni complesse. Il nostro studio prevede tre round di questionari volti a identificare i concetti fondamentali da includere in un programma didattico efficace sulla sostenibilità rivolto a studenti della scuola secondaria. I risultati anonimi e aggregati di ogni questionario sono stati sottoposti ai partecipanti allo studio prima del round successivo. Con

l'obiettivo di far emergere la natura multi disciplinare dell'argomento, è stato selezionato un panel composto da esperti di area scientifico-tecnologica, economica e delle scienze sociali, insegnanti della scuola secondaria e operatori del settore.

La sfida di educare gli studenti alla sostenibilità: progettazione e risultati preliminari di una sequenza didattica.

Toffaletti S., Di Mauro M., Salmoiraghi A., Fiorello C., Onorato P., Oss S.
Dipartimento di Fisica, Università di Trento

L'alfabetizzazione scientifica e in particolare l'educazione civica scientifica hanno un ruolo chiave nella sensibilizzazione della popolazione studentesca verso le tematiche della sostenibilità e gli obiettivi dell'Agenda 2030. Nell'ambito di un progetto sul tema della sostenibilità rivolto agli studenti delle scuole secondarie di secondo grado della provincia di Trento abbiamo sviluppato un intervento didattico focalizzato sull'effetto serra e i cambiamenti climatici ampliato alle problematiche legate alla produzione e al consumo di energia, alle scelte individuali e sociali, al coinvolgimento e alla partecipazione degli studenti come futuri cittadini. Siamo partiti dalle sequenze didattiche rivolte a studenti universitari da noi sviluppate nel decennio trascorso e abbiamo operato una trasposizione didattica dei contenuti, del linguaggio e della struttura per venire incontro alle differenti esigenze di apprendimento degli studenti della scuola secondaria. Nel corso della comunicazione verranno presentate le modifiche apportate con la nuova progettazione e alcuni risultati preliminari di una sperimentazione condotta in tre classi di scuola secondaria di secondo grado.

Il ruolo della narrazione nell'educazione alla gestione dell'incertezza per il cambiamento climatico.

D'Orto E., Tasquier G.
Dipartimento di Fisica e Astronomia, Università di Bologna

Il cambiamento climatico (CC) sta avendo un impatto profondo sulla nostra cultura, mettendo in discussione il nostro modo di relazionarci col pianeta. A livello educativo assume un ruolo particolare l'effetto che il CC sta avendo sul nostro modo di concepire il rischio e la nostra abilità di gestire l'incertezza. Un corpus letterario emergente, sia all'interno che all'esterno dell'ambito della science education, suggerisce di porre l'attenzione al ruolo delle narrazioni per la loro capacità di dare un senso all'esperienza, di essere una bussola nel cambiamento e di stimolare l'immaginazione di futuri possibili. Nella comunicazione si presenterà il design di un approccio narrativo al CC (e nello specifico un'attività basata su di esso e focalizzata sull'analisi di scenari climatici di tipo SSP), ovvero un approccio che adotta una prospettiva narrativa con l'obiettivo di indagare quale ruolo specifico possono svolgere i vari elementi della narrazione per educare all'incertezza e come questi possano bilanciare o essere bilanciati dal linguaggio scientifico/argomentativo.

Cilindri che oscillano come pendoli composti reversi: stima dell'accelerazione di gravità.

Fiore O. ([1]), Adesso M. G ([2]), Iannuzzi S. ([3])
([1]) *Liceo Statale "P.E. Imbriani", Avellino*
([2]) *Liceo Scientifico "G. Da Procida", Salerno*
([3]) *Dipartimento di Fisica, Università degli Studi di Salerno*

In questo lavoro, è mostrata una attività di ricerca progettata nell'ambito di un percorso di tirocinio del corso di laurea triennale in Fisica. L'attività è stata sperimentata in due licei scientifici delle provincie di Salerno ed Avellino, con circa 60 studenti, di età compresa tra i 15 e i 17 anni. Il focus dell'attività è stato la misura dell'accelerazione di gravità attraverso la realizzazione di un sistema composto da un cilindro cavo, con incollato al suo interno,

parallelamente all'asse, un cilindro pieno della stessa lunghezza del guscio cilindrico e con diametro un ordine di grandezza inferiore. Il cilindro cavo è stato fatto oscillare intorno al punto di contatto con un piano orizzontale, rimanendo nell'approssimazione di "piccole oscillazioni". La misura del periodo del sistema e il calcolo del momento d'inerzia dello stesso, hanno consentito di ottenere una stima dell'accelerazione di gravità. La metodologia didattica utilizzata è quella del problem solving con attività hands-on. Gli studenti hanno realizzato gli artefatti, diventati poi strumenti con opportuni schemi d'uso suggeriti dai referenti, secondo il modello teorico del *Documental Approach to Didactics*.

Aula 1C **ore 15:50 – 19:00**

Sezione II
Simposio di Fisica Statistica e Sistemi Complessi
Presiedono: Spagnolo B. (Università di Palermo)
Corberi F. (Università di Salerno)

Relazioni su invito

▲ **Scenarios and models for the post-generative phase of AI.**
Zecchina R.
Department of Computing Sciences, Bocconi University, Milano
This talk will explore potential scenarios emerging from the continued development of artificial intelligence (AI) technologies. We will begin with an overview of the fundamentals of generative AI, analyzing the technical and conceptual limitations of the current state of the art and highlighting the main challenges that remain. Next, we will delve into alternative models that are currently being researched and aim to overcome these limitations. Particular attention will be paid to the physical aspect of such models.

▲ **Exploring nonequilibrium phenomena in the sine-Gordon model: From high-Tc cuprates to ultracold atoms.**
De Santis D. ([1]), Guarcello C. ([2]), Spagnolo B. ([1]), Carollo A. ([1]), Valenti D. ([1])
([1]) *Università degli Studi di Palermo*
([2]) *Università degli Studi di Salerno*
The sine-Gordon model, both classical and quantum, is among the most celebrated nonlinear theories, with diverse applications spanning high-energy physics, geology, biology, and condensed matter physics. In this talk, we will explore how nonequilibrium sine-Gordon physics can elucidate complex phenomena, such as the superconducting-like behaviors observed in recent experiments involving optically driven cuprates. Additionally, we will discuss the application of these concepts to other experimental platforms, particularly ultracold atomic systems.

▲ **Large-deviations approach to thermalization: The case of harmonic chains with conservative noise.**
Lepri S.
CNR, Istituto dei Sistemi Complessi, Sesto Fiorentino, Firenze
We investigate the possibility of characterizing the different thermalization pathways through a large-deviation approach. Specifically, we consider clean, disordered and quasi-periodic harmonic chains under energy and momentum-conserving noise. For their associated master equations, describing the dynamics of normal modes energies, we compute the fluctuations of activity and dynamical entropy in the corresponding biased ensembles. First-order dynamical phase transition are found that originates from different activity regions in action space. At the transitions, the steady-state in the biased ensembles changes from extended to localized, yielding a kind of condensation in normal-modes space. For the disordered and quasi-periodic models, we argue that the phase-diagram has a critical point at a finite value of the disorder or potential strength.

▲ **Shaping topological patterns in liquid crystal shells.**
Orlandini E. ([1]), Negro G. ([2]), Carenza L. ([3]), Gonnella G. ([2]), Marenduzzo D. ([4])
([1]) *Dipartimento di Fisica e Astronomia, Università degli Studi di Padova e INFN, Sezione di Padova*
([2]) *Dipartimento di Fisica, Università degli Studi di Bari e INFN, Sezione di Bari*
([3]) *Department of Physics, Kos University, Istanbul, Turkey*
([4]) *SUPA, School of Physics and Astronomy, University of Edinburgh, UK*
Liquid crystals (LC) shells are fascinating soft materials that naturally exibith a rich variety of topological phases and singularities known as topological defects. Since they provide a fertile ground in different areas of physics and a wealth of potential applications in optical devices and nanotechnology it is important to study how these topological phases and spatial organisation of the network of defects depends on the shape (mainly curvature) of the confining boundaries and the underlying flow field. After a brief introduction of the physics of LC shells we present recent results mainly based on numerical simulations on the effects that shell curvature and externally imposed (shear) flow can have on the formation and evolution of topological phases at the transient and stationary states. A comparison with the physics of defect formation in active turbulence is provided too.

▲ **Metastability of negative-temperature states in systems with two conserved quantities.**
Politi A. ([1])([2]), Iubini S. ([1])
([1]) *CNR, Istituto dei Sistemi Complessi, Firenze*
([2]) *Aberdeen University, UK*
More and less recent simulations of the discrete nonlinear Schroedinger equation strongly suggest that this model exhibits stationary extended states in the (absolute) negative temperature region. This is in contrast with the expected condensation of a finite fraction of energy on a single site, predicted by entropic arguments. With the help of a simplified model and by developing effective grand-canonical thermal baths, it is shown that, in the negative-temperature region, the condensation of energy on a single site progresses (on average) only above a temperature-dependent critical threshold. This argument allows determining the lifetime of extended states, an estimate confirmed by direct numerical simulations.

Comunicazioni

● **Laplacian Renormalization Group resolves the multi-scale organization of complex networks.**
Villegas P. ([1])([2]), Gili T. ([3]), Poggialini A. ([1])([4]), Gabrielli A. ([1])([5])
([1]) *Centro Ricerche Enrico Fermi, Roma*
([2]) *Instituto Carlos I de Fisica Teorica y Computacional, Granada, Spain*
([3]) *Networks Unit, IMT Scuola Alti Studi Lucca*
([4]) *Dipartimento di Fisica Università "Sapienza", Roma*
([5]) *Dipartimento di Ingegneria Civile, Informatica e delle Tcnologie Aeronautiche, Università di Roma Tre*
Heterogeneous and complex networks represent the intertwined interactions between real-world elements or agents. One of the fundamental problems of complex network theory is identifying inherent partitions or clusters. By taking advantage of the recent Laplacian Renormalization Group approach, we scrutinize information diffusion pathways throughout networks to shed further light on this issue. Based on inter-node communicability, our definition provides a unifying framework for multiple partitioning measures: the multi-scale Laplacian (MSL) community detection framework. Moreover, we solve one of the central

conundrums in the community detection field: we propose a method that lacks any null-model assumption and can unravel the network mesoscopic structures at different resolution scales. Therefore, this new framework enables us to introduce a scale-dependent optimal partition in communities, shedding to light a particular class of nodes, called metastable nodes, that switching communities at different scales are expected to play a central role in the communication between different communities and, therefore, in the managing of any dynamics on top of the whole network.

Grand canonical ensemble of networks and systemic risk assessment.

Cimini G. ([1])([2])([3]), Caldarelli G. ([3])([4]), Ferracci A. ([5]), Gabrielli A. ([2])([6]), Mastrandrea R. ([7])

([1]) *Dipartimento di Fisica, Università di Roma Tor Vergata e INFN, Sezione di Roma Tor Vergata*

([2]) *Centro Ricerche Enrico Fermi, Roma*

([3]) *CNR, Istituto dei Sistemi Complessi, Roma*

([4]) *Dipartimento di Scienze Molecolari e Nanosistemi, Università Ca' Foscari, Venezia*

([5]) *Dipartimento di Economia, Sapienza Università di Roma*

([6]) *Dipartimento di Ingegneria Civile, Informatica e delle Tecnologie Aeronautiche, Università Roma Tre*

([7]) *IMT Scuola Alti Studi, Lucca*

We present a statistical mechanics model for heterogeneous weighted networks based on mesoscopic (local) constraints, which reproduces the number and total weight of connections for each node. The model builds on a mapping with lattice gasses and allows defining a Grand Canonical ensemble where each link is characterized as a Fermi-level system with local values of Temperature and Chemical Potential. We apply this framework to model an ensemble of synthetic interbank networks with a given balance sheet composition of the participating banks. We then study the difference between the level of systemic risk that is empirically measured on an real interbank network and that of the model arising solely from such balance sheets composition. We show that the aggregate levels of observed and expected systemic risks are usually compatible (but during turbulent times). The implication for regulators is that our model can provide good estimates of overall systemic risk. However, for conducting precise stress tests on individual banks, knowing the empirical details of the network remains of paramount importance.

Aula Magna **ore 09:00 – 13:30**

Sezione I
Fisica nucleare e subnucleare
Presiede: Antonioli P. (INFN, Sezione di Bologna)

Relazioni su invito

▲ **The new era of collider neutrinos: The Scattering and Neutrino Detector at the LHC.**
De Lellis G.
Università degli studi di Napoli Federico II e INFN, Sezione di Napoli
SND@LHC is a compact and stand-alone experiment to perform measurements with neutrinos produced at the LHC in a hitherto unexplored pseudo-rapidity region of $7.2 < \eta < 8.4$, complementary to all the other experiments at the LHC. The experiment is located 480 m downstream of IP1 and the detector is composed of a hybrid system based on an 800 kg target mass of tungsten plates, interleaved with emulsion and electronic trackers, followed downstream by a calorimeter and a muon system. The configuration allows efficiently distinguishing between all three neutrino flavours, opening a unique opportunity to probe physics of heavy flavour production at the LHC in the region inaccessible otherwise. This is of particular interest for future circular colliders and for predictions of very high-energy atmospheric neutrinos. The first phase aims at operating the detector throughout LHC Run 3. The experiment has taken data since 2022 and has recently reported the first observation of collider neutrinos. We shall review the first experimental results and the plans for the upgrade to operate at the high-luminosity LHC. A new era of collider neutrino physics has just started.

▲ **ICARUS at the Short-Baseline Neutrino program: First results.**
Menegolli A. for the ICARUS Collaboration
Università di Pavia e INFN, Sezione di Pavia
The ICARUS collaboration employed the 760-ton T600 detector in a successful three-year physics run at the underground LNGS laboratory, performing a sensitive search for LSND-like anomalous appearance in the CNGS beam. After a significant overhaul at CERN, the T600 detector has been installed at Fermilab where, in June 2022, the data taking for neutrino oscillation physics began collecting events from the Booster Neutrino Beam (BNB) and the Neutrinos at the Main Injector (NuMI) off-axis beams. ICARUS successfully completed its commissioning phase in June 2022, moving then to data taking for neutrino oscillation physics, aiming at first to either confirm or refute the claim by Neutrino-4 short-baseline reactor experiment. It will also perform measurements of neutrino cross sections in liquid Argon with the NuMI beam and several BSM searches. ICARUS will soon jointly search for evidence of sterile neutrinos with the Short-Baseline Near Detector (SBND). In this presentation, preliminary results from the ICARUS data with the BNB and NuMI beams are shown both in terms of performance of all ICARUS subsystems and of capability to select and reconstruct neutrino events.

▲ **DUNE experiment at FermiLab.**
Surdo A. for the DUNE Collaboration
INFN, Sezione di Lecce
DUNE (Deep Underground Neutrino Experiment) is a leading-edge international experiment for the study of the intimate neutrino properties, like oscillations, mass ordering and CP symmetry violation. The detailed insight of such properties will contribute to answer several fundamental questions about the nature of matter and the evolution of the universe. Exploiting a high intensity Long Baseline (LBL) neutrino beam, DUNE will include two detectors: one (Near Detector, ND) will be placed near the beam source at Fermi Accelerator Laboratory, the other one (Far Detector, FD) will be installed more than 1 km underground at the Sanford Underground Laboratory in South Dakota, 1300 km downstream of the source, and will consist of four 17-kton liquid argon TPC modules. The role of the Near Detector will be to reduce the systematics in the LBL oscillation analysis, by constraining the uncertainties in neutrino flux and cross section in liquid argon. The main features of DUNE will be outlined, together with the contribution of the Italian component of the Collaboration: the System for on-Axis Neutrino Detection (SAND) as a part of the ND complex and the photodetection system for the FD.

▲ **The Mu2e experiment.**
Di Falco S.
INFN, Sezione di Pisa
L'esperimento Mu2e, in costruzione a Fermilab, investigherà la conversione $\mu \to e$ senza neutrini nel campo di un atomo di alluminio. Un chiaro segnale di questo processo a due corpi che viola la conservazione del sapore leptonico è la presenza di un elettrone monocromatico di 104.97 MeV nello stato finale. Un fascio impulsato di 8 GeV/c viene mandato su un bersaglio di tungsteno per produrre i pioni che decadono in muoni; un sistema di magneti superconduttori guida il fascio di muoni negativi verso il bersaglio di alluminio dove i muoni fermati possono convertire in elettroni; un insieme di rivelatori viene usato per identificare gli elettroni da conversione e sopprimere il fondo cosmico. L'esperimento prenderà dati per 3-5 anni per migliorare di un fattore 10^4 l'attuale sensibilità. Dopo un'introduzione sulla fisica di Mu2e, si riferirà sullo stato delle diverse componenti dell'apparato sperimentale. Verrà anche presentata una stima aggiornata della sensibilità dell'esperimento.

Comunicazioni

● **A large-area SiPM readout plane for the ePIC-dRICH detector at the EIC: Realisation and beam test results.**
Preghenella R., Rubini N., Rignanese L.P.
INFN, Sezione di Bologna
The ePIC experiment at the Electron-Ion Collider (EIC) includes a dual-radiator RICH (dRICH) detector for PID in the forward region. The dRICH will be equipped with 3×3 mm^2 silicon photomultipliers (SiPM) for Cherenkov light detection over a surface of ~ 3 m^2 ($\sim$ 300k readout channels), representing the first HEP application of SiPMs for single-photon detection. In this contribution we present the current status of the R&D performed for the ePIC-dRICH detector at the EIC. A special focus will be given to the beam test results obtained with the dRICH prototype SiPM optical readout. A large-area readout plane consisting of a total of 1280 3×3 mm^2 SiPM sensors was built and tested with particle beams at CERN-PS in October 2023. The data have been collected with a complete chain of front-end and readout electronics based on the ALCOR chip, developed by INFN Torino. This presentation will highlight the features of the PDU and the performance of the full dRICH SiPM prototype system that successfully recorded Cherenkov photon rings.

Studies of radiation damage and mitigation strategies for the SiPM of the ePIC-dRICH detector at the EIC.

De Gruttola D. ([1])([2]), Preghenella R. ([4]), Rignanese L. ([4]), Rubini N. ([3])([4])
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The dual-radiator (dRICH) detector of the ePIC experiment at the Electron-Ion Collider (EIC) will be equipped with silicon photomultipliers (SiPM) sensors. SiPMs have excellent performance for efficient photodetection in high-magnetic field environments, but they are very sensitive to radiation damage. Rigorous testing is needed to ensure that their dark count rates (DCR) are kept under control over the years of running. The DCR can be maintained to an acceptable rate by reducing the SiPM operating temperature and by recovering the radiation damage with high-temperature annealing cycles. We present an overview of the current status of the R&D performed on significant samples of SiPM sensors. The devices have undergone proton and neutron irradiations aimed at studying their performance with increasing non-ionising energy loss (NIEL) doses up to 10^{11} MeV *neq* / cm^2, the device recovery with long high-temperature annealing cycles and the reproducibility of the performance in repeated irradiation-annealing cycles. We also studied the use of the self-heating capabilities of the SiPM to exploit the Joule effect as an effective way to perform the high-temperature annealing in-situ.

The DUNE photon detection system.

Galizzi F.
Dipartimento di Fisica, Università degli Studi Milano-Bicocca

The Deep Underground Neutrino Experiment (DUNE) aims to answer the remaining open questions in the neutrino oscillation field. It will probe the CP violation in the lepton sector and determine the neutrino mass hierarchy employing Liquid-Argon TPCs to the tenths-of-kiloton scale and the well-established baseline scheme. A capable Photon Detection System (PDS) will allow to use of the Far Detector for astroparticle purposes and Beyond Standard Model research offering the trigger for non-beam events, such as Supernova Neutrino Bursts and proton decay. In addition, it will also enhance the TPC performance by detecting the liquid argon scintillation light to estimate the absolute time of neutrino interactions, indispensable to reconstructing the drift coordinate of the charged particle tracks. In this presentation, I describe the light trap technology, the X-ARAPUCA, and the whole readout chain of the PDS. In particular, I will detail the expected performance of the system in terms of light collection efficiency, time and energy resolution and the impact on the DUNE physics programme.

Commissioning of the mu2e data acquisition system and the vertical slice test of the straw tracker.

Gamba S. ([1]), Murat P. ([2]), Donati S. ([1])([3])
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Mu2e will search for the charged-lepton-flavor-violating neutrino-less conversion, which would reveal physics beyond the Standard Model. Mu2e uses a tracker and an electromagnetic calorimeter to detect 105 MeV/c e^-'s and to reject backgrounds. The tracker, consisting of 18 stations, will measure the e^- momentum using drift tubes (straws). Signals from both ends of a straw provide position information. I will discuss the Vertical Slice Test (VST) of

the tracker: the complete testing chain from straws to readout to processed data on disk. I will use the VST to monitor data quality from pulsed preamps and test software performance under high-rate input data. The next step will be the time calibration of the first station using cosmic rays without a magnetic field. The time calibration of signals from the straws is crucial to optimize the momentum resolution of the tracker. We will use the simulation to determine the optimal station orientation for the VST, identifying biases between the reconstructed and the true hit coordinates. Our goal is to find the drift velocity in the straws and the timing offsets between channels, aiming for a longitudinal resolution of less than 4 cm.

Improving multi-track reconstruction algorithms in the Mu2e Experiment.

Ricci A.M. on behalf of the Mu2e Collaboration
INFN, Sezione di Pisa

Mu2e will search for the neutrinoless coherent $\mu^- \to e^-$ conversion in the field of an Al nucleus, a Charged Lepton Flavor Violation (CLFV) process. The experiment is expected to start in 2026 and will improve the current limit by 4 orders of magnitude. Mu2e consists of a straw-tube tracker and crystal calorimeter in a 1T B field complemented by a plastic scintillation counter veto to suppress cosmic ray backgrounds. The tracker geometry, composed of 36 tracking planes equally spaced with straws transverse to the beamline, makes track reconstruction a quite unique problem. The first step of track reconstruction is hit clustering, in space and time. Pattern recognition is performed for each time cluster to identity hit combinations compatible with a 3D helix and remove background hits. Track fitting acts on the hit combinations to determine precision track parameters. The existing algorithms are robust and efficient for the topologies of interest for the principal physics analyses. However, we developed pattern recognition algorithms to improve track reconstruction of multi-particle events which are important for background estimates through data-driven procedures.

ALICE ITS3 test device characterization.

Sturniolo A. on behalf of the ALICE collaboration
Dipartimento di Scienze Matematiche, Informatiche, Fisiche e Scienze della Terra MIFT, Università di Messina e INFN, Sezione di Catania

The state-of-the-art ALICE Inner Tracking System, ITS2, is currently structured in 7 silicon CMOS Monolithic Active Pixel Sensor (MAPS) layers. Thanks to the MAPS integrated readout circuitry, each ITS2 layer is only $0.35\%X_0$ thick, and could be further thinned down to $0.07\%X_0$ (X_0 is the radiation length) by removing the detectors' non-silicon material, to boost detection efficiency and track resolution at lower momenta. The aim is to upgrade the existing ITS2 with ITS3 during the upcoming Long Shutdown 3 (2026-2028). The 3 innermost ITS2 layers (Inner Barrel, IB) will be replaced by 3 flexible, truly cylindrical layers of stitched MAPS chips. The ITS3 is also foreseen to reduce power consumption to below 40 mW/cm^2 and employ an air cooling system with low material budget. In this contribution, we will show the results of detection efficiency, spatial resolution and charge collection efficiency measurements on ITS3 small test devices such as Analog and Digital Pixel Test Structures (APTS and DPTS), both in a laboratory and a test beam setup. In particular, up to $\sim 99\%$ efficiency and a resolution finer than 5 μm have been achieved, in line with ITS3 plans.

Commissioning of the Mu2e crystal calorimeter.

Fedeli P., Giovannella S.
INFN, Laboratori Nazionali di Frascati

The calorimeter of the Mu2e experiment is composed of two disks of pure CsI crystals, readout by two custom arrays of large area UV-extended Silicon Photo-Multipliers (SiPMs).

The experiment is currently in the construction phase, with the calorimeter assembly of the first disk expected to be completed by summer 2024. The commissioning and calibration phase foresees the readout of half calorimeter disk at a time, corresponding to about 340-2 channels, on a Vertical Slice Test with final detector components and electronics. A laser is used to monitor and calibrate the gain of the SiPMs, and to measure the time resolution of the readout channels. Validation and calibration of the calorimeter response is carried out with Cosmic Ray data and laser runs. Event selection and calibration algorithms have been tuned on simulated data. Selected events provide calibration of the energy response below $< 1\%$ and a time offset alignment better than 50 ps. The status of construction will be summarised, along with plans for commissioning the disks fully assembled with final electronics, achieving the first calibration dataset and studying response stability.

Cosmic background rejection in the ICARUS experiment at Fermilab.
Pasqualini L., Poppi F.
Università di Bologna e INFN, Sezione di Bologna
The Short Baseline Neutrino program at Fermilab aims to explore significant regions of parameter space, applicable to sterile neutrinos at the eV mass scale, as suggested by existing experimental anomalies. To this purpose it exploits Liquid Argon Time Projection Chamber detectors located along the Booster Neutrino Beamline to measure νe appearance and $\nu\mu$ disappearance: the Short Baseline Neutrino Detector and the ICARUS-T600 detector at 110 and 600 m from the neutrino source, respectively. The ICARUS T-600 Far Detector, located at shallow depth, is surrounded by a Cosmic Ray Tagger system to mitigate the cosmic ray background. The cosmic ray tagger is composed of plastic scintillator bars, aiming at tagging cosmic muons and thus reject γs produced by muon interactions in the surrounding materials that can generate an electromagnetic showers mimicking a νe signal. The system allows to disentangle cosmic rays from particles originated in a neutrino interaction inside the detector by measuring their position and crossing time. An overview of the cosmic ray tagger system as well as its role in the neutrino events identification and cosmic background rejection will be presented.

First tests of TIGER ASIC for the readout of the drift chamber of SAND.
Chiapponi F.
Dipartimento di Fisica e Astronomia, Università di Bologna e INFN, Sezione di Bologna
The SAND (System for On-Axis Neutrino Detection) apparatus is part of the DUNE Near Detector complex. It will be composed of a superconducting magnet, an electromagnetic calorimeter, an active Liquid Argon target (GRAIN) and a low mass tracker equipped with targets of different materials. SAND is expected to significantly constrain systematic errors, such as those related to neutrino flux, cross sections, and nuclear effects. Moreover, it will monitor the beam stability. Two alternative options for the tracker are currently under study: a straw tube- and a drift chamber-based trackers. Small scale prototypes of both options are being built, and larger ones are planned. The TIGER ASIC is a possible candidate for the drift chamber readout. In this contribution I will present the results of the tests performed so far on the ASIC to define its requirements.

A drift chamber tracking system for SAND.
Ruggeri A.
Dipartimento di Fisica e Astronomia, Università di Bologna e INFN, Sezione di Bologna
The Near-Detector complex of the DUNE next-generation neutrino oscillation experiment will have the key roles of constraining systematic uncertainties in the oscillation measurements and carrying out an extensive program of precision searches. The SAND apparatus

is one of the components of the Near Detector, tasked with monitoring the neutrino beam from an on-axis position and performing novel cross section measurements on different target nuclei. The magnetized volume of SAND will host a low-density gas-detector tracker with thin (1-2% X_0) passive target layers of several materials, combining the large target mass (about 5 t) and high spatial and momentum resolution optimal for performing neutrino interaction studies. A backup tracker design based on large-area drift chambers is currently being developed. In this contribution, the role of this detector in SAND is presented, and the present status of the design, from the ongoing R&D activities on small-scale prototypes to its full integration in SAND, is discussed.

Caratterizzazione e validazione di SiPMs per il sistema di fotorivelazione del DUNE Far Detector.

Montagna E.

INFN, Sezione di Bologna

Il Deep Underground Neutrino Experiment (DUNE) sarà un esperimento di nuova generazione, con lo scopo di studiare l'oscillazione di neutrini, determinare un ordinamento di massa e una possibile violazione della simmetria di CP nel settore leptonico. DUNE si compone di un Near Detector e di un Far Detector posti ad una distanza di $\sim$ 1300 km. Il complesso del Far Detector prevede quattro moduli di rivelatore a camere a proiezione temporale ad Argon Liquido e dotati di un sistema per rivelare la luce di scintillazione prodotta nel volume attivo. Tale sistema di fotorivelazione si basa su collettori di luce accoppiati a fotomoltiplicatori al Silicio (SiPMs), immersi in Argon Liquido. Questo contributo è incentrato sulla selezione e validazione dei fotosensori per l'esperimento. I risultati ottenuti sono qui riportati, insieme alla descrizione del sistema semi-automatico utilizzato per testare i sensori sia a temperatura ambiente che criogenica (77 K). È in corso una campagna di validazione che coinvolge l'intera produzione di SiPMs ($\sim$ 300000) che verranno installati nel primo modulo del Far Detector di DUNE. I risultati relativi ai campioni finora testati sono presentati.

Development of pattern recognition algorithm for reconstructing multi-particle events in the Mu2e experiment.

Kitagawa H. ([1]), Donati S. ([1]), Murat P. ([2]), Ricci A.M. ([1])

([1]) *Università di Pisa*

([2]) *Fermi National Accelerator Laboratory, USA*

The Mu2e experiment at Fermilab will search for Charged Lepton Flavor Violation (CLFV) through neutrinoless coherent $\mu^- \to e^-$ conversion in the field of an Al nucleus. Mu2e intends to probe 4 orders of magnitude beyond the current limit, and the first data-taking will take place in 2026. The Mu2e detector comprises a straw-tube tracker and electromagnetic calorimeter under a 1T magnetic field. The tracking planes with straw-tubes are installed vertically to the beamline and measure the trajectory and momentum of the charged particle. The current algorithms are robust and efficient for the principal physics analyses. However, we are improving the reconstruction efficiency for multiple-particle events, which are generated mainly by antiproton annihilations in the stopping target. We designed a pattern recognition algorithm to find hit combinations compatible with the trajectories of different particles, and this leads to track fitting acting on different combinations separately. This is expected to improve the robustness and time performance for reconstructing multi-particle events, which are essential for background estimates through data-driven procedures.

Overview, recent results and future plans of the KATRIN experiment.
Gagliardi G.
Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca
The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to measure a high-precision integral spectrum of the endpoint region of beta decay of molecular tritium, with the primary goal of probing the absolute mass scale of the neutrino. After the decay of molecular tritium, electrons are adiabatically guided using magnetic fields through a MAC-E spectrometer, which acts as an energy high pass filter, and toward a Si detector. From the integral spectrum of the endpoint, it is possible to extract the electron antineutrino effective mass with a sensitivity of 0.2 eV at 90% C.L. The KATRIN beamline will also be used to reconstruct the whole beta spectrum and search for kink-like signatures associated with keV sterile neutrinos. To do so it will be upgraded with the TRISTAN detector, consisting of nine modules of 166 SDD pixel matrices, to improve energy resolution and withstand higher rates. In my contribution, I will present an overview of KATRIN and TRISTAN, including their latest results and future plans.

Muon momentum reconstruction in ICARUS-T600 LArTPC via multiple scattering.
Chiello G.
Università di Pisa
The ICARUS T600 detector is a large-scale LArTPC operating as the far detector in the SBN program at Fermilab. Inside a LArTPC photons and electrons energy is reconstructed by calorimetric measurements of the electromagnetic shower, as well as hadrons energy can be reconstructed from the related hadronic shower, but this method is not suitable for muons that escape the active volume: Multiple Coulomb Scattering serves then as the only alternative for estimating the momentum. MCS momentum measurement is particularly useful in those neutrino interactions in the few GeV energy range: in such cases, most of the muons generated in the neutrino CC interactions are emitted at large angles and escape the detector, preventing a calorimetric energy measurement. Two algorithms able of inferring momentum from MCS angle have been developed. I study how these algorithms perform, focusing first on stopping muons (an excellent sample as they allow to ascertain if the algorithms are performing well, comparing MCS momentum with range-based momentum) and secondly on non-contained muons (the most interesting physics case, a similar study would in fact lead to a future reconstruction of numu CC energy).

Imaging di interazioni di neutrino con maschere ad apertura codificata.
Mei F. on behalf of the DUNE Collaboration
Alma Mater Studiorum, Universitá di Bologna e INFN, Sezione di Bologna
L'obiettivo principale dell'esperimento DUNE è la determinazione dell'ordinamento di massa dei neutrini e della violazione della simmetria CP nel settore leptonico. Un componente del Near Detector Complex di DUNE è l'apparato sperimentale denominato SAND, che avrá tra i suoi obiettivi il controllo della stabilità del fascio di neutrini LBNF oltre a un ampio programma di fisica. Un componente di SAND è il sotto-rivelatore GRAIN (GRanular Argon for Interactions of Neutrinos), un nuovo rivelatore ad Argon liquido che ha lo scopo di eseguire imaging delle interazioni dei neutrini utilizzando la luce di scintillazione. In questa presentazione viene descritto un innovativo sistema di lettura della luce basato su maschere ad apertura codificata, e l'algoritmo di ricostruzione basato sulla Maximum Likelihood Expectation-Maximization volto a fornire una mappa tridimensionale dell'energia depositata dalle particelle cariche. Questo approccio rappresenta una notevole sfida computazionale poiché richiede l'utilizzo ottimizzato su un sistema di calcolo con GPU multiple.

Characterization of the drift chamber's gas mixture in MEG II experiment.

Gabbrielli E. on behalf of the MEG II Collaboration
Dipartimento di Fisica, Università di Roma La Sapienza e INFN, Sezione di Roma

The aim of the MEG II experiment, which will collect data until 2026, is to search for the cLFV decay $\mu^+ \to e^+ + \gamma$, with a sensitivity expected at 6×10^{-14}, which would be a signal for new physics beyond the Standard Model. Combining MEG II data collected until 2021 with the final MEG results, it was possible to set the most stringent upper limit for the branching ratio: $\mathrm{BR}(\mu^+ \to e^+ + \gamma) < 3.1 \times 10^{-13}$ (90% C.L.). One component of the spectrometer that reconstructs the positron trajectory is a gaseous cylindrical drift chamber filled with a He-isobutane gas mixture with the addition of a small percentage of O_2 and isopropyl alcohol. During these last three years of data taking, this innovative mixture has shown some behaviours that are worth to be studied, such as an anomalous attachment effect and a lower than expected ageing rate. We will go through some of the results of the characterization of the gas mixture that has been performed this year. These results are in the interest not only of the MEG II experiment but also of other future muon experiments that might need a mixture with similar characteristics.

Aula 1D **ore 09:00 – 13:30**

Sezione II
Fisica della materia
Presiede: Zito G. (CNR)

Relazioni su invito

▲ **Josephson nanocircuits-based quantum heat engines.**
Giazotto F.
NEST, Istituto Nanoscienze-CNR e Scuola Normale Superiore, Pisa, Italy
Thermoelectric effects in metals are typically minor due to the nearly perfect particle-hole symmetry around their Fermi surface. Furthermore, thermo-phase effects and linear thermoelectricity in superconducting systems have been identified only when particle-hole symmetry is explicitly broken since thermoelectric effects were considered impossible in pristine superconductors. Here, we experimentally demonstrate that superconducting tunnel junctions develop a very large bipolar thermoelectricity in the presence of a sizable thermal gradient thanks to spontaneous particle-hole symmetry breaking. Our junctions show Seebeck coefficients of up to $\pm 300\ \mu$V/K, comparable with quantum dots and roughly 10^5 times larger than the value expected for normal metals at sub-kelvin temperatures. Moreover, by integrating our junctions into a Josephson interferometer, we realize a bipolar thermoelectric Josephson engine generating phase-tunable electric powers of up to ~ 140 nW/mm^2. Our device also implements the prototype for a persistent thermoelectric memory cell, written or erased by current injection.

▲ **Photodoping of doped metal oxide nanocrystals for the accumulation of multiple charges.**
Kriegel I.
Functional Nanosystems, Istituto Italiano di Tecnologia, Torino, Italy
Photodoping in doped metal oxide nanocrystals, such as indium tin oxide, combines light absorption, charge separation, and accumulation in the same set of materials. In the underlying physical process, photons with light beyond the bandgap are absorbed and an electron hole pair is created. The charges are separated at the electronic interface with their surroundings. If the photo-generated holes react with sacrificial hole scavengers, such as ethanol, the extra electrons remain stored within the nanocrystal. Hundreds of electrons per nanocrystal can be stored in this way. In this contribution I will give a fundamental insight into the mechanism of charge storage within metal oxide nanocrystals and an outlook towards its implementation within the next generation of solar energy devices.

Comunicazioni

● **Superconducting diode effect in asymmetric Al Dayem bridge weak links.**
De Simoni G., Antola F., Battisti S., Giazotto F.
NEST Istituto Nanoscienze-CNR e Scuola Normale Superiore, Pisa, Italy
Diodes, such as pn or Schottky junctions, are devices that allow an electric current to flow in one direction only, due to the lack of spatial symmetry. These ubiquitous semiconductor devices have a wide range of applications, from detecting and generating photons to signal

rectification. Due to its superior energy efficiency and larger operation frequency, superconducting electronics has also undergone significant development: indeed, many superconducting equivalents of semiconducting devices have been demonstrated, including supercurrent diodes (SDs) featuring non-reciprocal dissipationless Cooper pair transport. The latter leads to different values of their positive and negative switching currents. Despite an intense research effort, a platform of choice to realize SDs has not been identified yet. Here we discuss a SD based on Dayem bridge Josephson junctions, in which the combined action of supercurrent crowding and of the pinning of the Abrikosov vortices is exploited to engineer and control the superconducting diode effect. Experimental prototypes based on this concept are presented with the support of time-dependent Ginzburg-Landau modeling to interpret the data.

n-type GaSe thin flake for optoelectronic devices.

Kumar A. ([1]), Palella A. ([2]), Intonti K. ([1])([3]), Viscardi L. ([1])([3]), Durante O. ([1]), Giubileo F. ([3]), Romano P. ([4]), Neill H. ([5]), Patil V. ([5]), Ansari L. ([5]), Hurley P.K. ([5]), Gity F. ([5]), Di Bartolomeo A. ([1])([3])

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2D chalcogenide semiconductor materials have gained a significant attention, and the new class of materials is being investigated. Herein, we will be presenting the latest results obtained on the fabricated device utilizing a thin GaSe flake channel. The fabricated device exhibits n-type conduction and wider hysteresis at ambient conditions. The device shows a high mobility and an on-off current ratio of three orders of magnitude. The device shows a high photo response and detectivity under the illumination of maximum laser power. Further, it has been observed that the time-resolved photocurrent exhibits a fast rise and decay time, followed by a slow rise and decay time of several seconds, respectively. Notably, the device exhibits memory behaviour maintaining stability for over an hour with repeatable cycles and sensitivity to light stimuli. This confirms its potential as a non-volatile optoelectronic memory, offering an enhanced programming window spanning two orders of magnitude. The results provide fundamental understanding of n-type conduction of GaSe thin flake and demonstrate that the investigated material could be suitable for future optoelectronic devices.

Generation of two interferometrically stable UV pulses with controlled relative delay by resonant dispersive wave emission in hollow capillary fibre.

Cappenberg F. ([1]), Manzoni C. ([2]), Lucchini M. ([1])([2]), Borrego-Varillas R. ([2]), Nisoli M. ([1])([2]), Reduzzi M. ([1])

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Resonant dispersive wave emission (RDW) in hollow capillary fibres (HCF) allows for the generation of μJ-level, widely tuneable, few-cycle pulses in the deep ultraviolet spectral range. These combined features have recently grown the interest in the ultrafast community. Here, we investigate the extension of this technique to the generation of a pair of UV pulses in the same HCF with controlled relative delay. A 75 cm long, 150 μm core diameter HCF filled with neon was seeded with two delayed replicas of a 9 fs pulse (800 nm) exploiting an ultrastable inline interferometer (TWINS). The output spectrum was measured in the UV range as a function of the group delay between the two IR pulses. At delays longer than

20 fs a RDW spectrum centered around 310 nm is generated, and the good contrast of the fringes demonstrates the coexistence of two UV pulses. A Fourier analysis reveals that the delay between the two IR pulses is maintained between the UV pulses, except for a small modulation whose period is equal to the IR cycle. The couple of UV pulses with controlled relative delay here demonstrated is exploitable in various spectroscopic and interferometric applications.

Nature-mimicking intelligent micro/nanorobots.

Urso M., Mirabella S.

Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Italia e CNR-IMM Catania Unit, Italia

Nature provides a plethora of self-organization phenomena, where biological systems manifest global patterns resulting from the interactions between their constituents. These intricate behaviors serve as a source of inspiration for the development of nature-mimicking micro/nanorobot swarms to solve specific challenges beyond individuals' capabilities. Micro/nanorobots are obtained starting from micro/nanomaterials by introducing the motion feature and increasing intelligence in terms of programmable functions and collective behaviors. Inspired by the cooperative actions of fire ants, active self-assemblies of photocatalytic magnetic microrobots have been developed. Breaking the symmetry of hematite microparticles with different shapes by metal layer asymmetric deposition, the resulting microrobots manifest self-propulsion under visible light irradiation, sense other microrobots in their surroundings, communicate on a long-range by phoretic interactions and finally assemble by exploiting magnetic dipole-dipole interactions. The mutual communication between microrobots and micro/nanoplastic pollutants has been carefully investigated, opening new possibilities in water purification.

Sub-THz detection through nanomechanical membranes.

Zanotto S. ([1]), Bertoni B. ([1]), Alborghetti L. ([2]), Vicarelli L. ([2]), Tredicucci A. ([2]), Roddaro S. ([2]), Pitanti A. ([2])

([1]) *CNR-NANO, Laboratorio NEST-SNS, Pisa*

([2]) *Dipartimento di Fisica, Università di Pisa*

Imaging in the THz and sub-THz frequency range has emerged as technology impacting to several fields as security, quality control, *in vivo* diagnostics and astrophysics. Here, constraints for field applications and integration with existing platforms favour the use of uncooled, fast detectors arranged in focal-plane arrays. A promising technology in this direction is that of thermomechanical bolometers (TMB). The basic concept of TMBs relies on the eigenfrequency shift of a mechanical resonator upon irradiation-induced heating. Our careful design and device fabrication have led to significant performances, summarized by a noise equivalent power as low as 80 pW/sqrt(Hz) and almost 20 Hz operating speed. The aforementioned values have been measured in trampoline resonators based on silicon nitride-gold bilayer with interferometric detection, while more recently we have devised an effective Lorentz-force–based electrical readout scheme. What is more, the TMB platform naturally lends to the integration of 2d materials and of metamaterials able to augment the detector functionality in the directions of polarization sensitivity and multispectrality.

The use of MTJs for sensing, reservoir computing and Ising machines.

Grimaldi A. ([1]), Raimondo E. ([2]), Meo A. ([3]), Garescì F. ([1]), Giordano A. ([1]), Carpentieri M. ([3]), Finocchio G. ([4])

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The development of new applications based on magnetic tunnel junctions (MTJs) is a heated research topic due to their nanoscale size, low energy consumption, and high tunability. Apart from their already established use in MRAMs, MTJs can be used for sensing, energy harvesting, and unconventional computing. We have proposed an MTJ-based accelerometer consisting of two coupled MTJs, the acceleration being proportional to the voltage across one of them. We use the same device design to simulate a reservoir computing application and use it to classify spoken digits. We have also implemented two emerging Ising machines (IMs) paradigms using MTJs, oscillatory IMs (OIMs), and probabilistic IMs (PIMs). OIMs are implemented by generating in-plane self-oscillations using a dc STT current combined with ac STT current at double the oscillation frequency. PIMs are here implemented using out-of-plane MTJs with unperturbed stable energy minima along the z-axis. An SOT current pulse can be used to temporarily bring the magnetization in-plane, and an STT current can be used to tune which states it relaxes to after the pulse. This work was supported by the PRIN_20225YF2S4 MMAGYC.

Filamentary cation-based resistive memory devices for neuromorphic computing.

Spiga S., Dutta M., Brivio S.
CNR-IMM,Unit of Agrate Brianza, Agrate Brianza, MB, Italy
Cation-based resistance switching memories (RRAMs), exploiting redox reactions and electrochemical phenomena in oxides, are gaining increasing interest in neuromorphic computing due to their capability to emulate the dynamic behavior of biological neurons and synapses. The working principle of two terminals metal/oxide/metal cation-RRAMs is based on the formation and dissolution of nanoscale conductive filaments (CFs) due to the cation diffusion of the metal electrode (Ag or Cu) into the dielectric. In the so-named volatile RRAMs, the formed CF self-dissolves over a certain relation time due to surface diffusion effects. In this contribution, we study the Ag/SiO_x/Pt device response to single voltage pulses or train of identical pulses at various applied voltages and frequencies. Based on the experimental results, we provide a comprehensive physical understanding of how the interplay between the switching time (CF formation) and the short-term memory effects (CF dissolution) controls the dynamical features of the devices. The dynamic behavior is finally linked to short-term plasticity, paired pulse facilitation and inhibition of biological synapses, and integrative function of neurons.

Blueprint of diode and anomalous Josephson effects in kinked nanowire junction.

Maiellaro A. ([1])([2]), Trama M. ([1]), Settino J. ([3]), Guarcello C. ([1])([2]), Rome F. ([1])([2]), Citro R. ([1])([2])
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We explore the emergence of a diode-like effect in short Josephson junctions achieved by constraining a two-dimensional Rashba-like system into a curved nanostrip geometry. We provide a comprehensive characterization of the diode efficiency by systematically tuning the geometric mismatch and the external magnetic field oriented perpendicular to the system plane. Our analysis uncovers a meaningful phase diagram showcasing a geometric-field controlled diode effect and an anomalous Josephson effect at the crossover of a topological phase

transition. The phase diagram also reveals the emergence of Majorana bound states (MBSs), trivial Andreev bound states (ABSs) and zero-energy Andreev bound states (ZABSs) at the Fermi level. Our study paves the way for the design and optimization of novel nanoscale devices with tailored transport properties.

Investigation of spin effects in Ge-based devices.

Gherardi M. ([1])([2]), Scali F. ([1]), Zucchetti C. ([1]), Bottegoni F. ([1]), Isella G. ([1]), Ciccacci F. ([1]), Finazzi M. ([1]), Bollani M. ([2])
([1]) *Department of Physics, Politecnico di Milano, Milano, Italy*
([2]) *CNR-IFN, LNESS Laboratory, Como, Italy*

Spintronics is an emerging field of physics that aims at the active control and manipulation of the spin degree of freedom in solid-state systems. In this contribution we present the fabrication of a spintronic device on a lightly n-doped Ge (As, $\sim 5 \times 10^{15}\,\mathrm{cm}^{-3}$) substrate, for the study of spin currents generation, transport, and detection. Spins are locally generated at the indirect gap of bulk Ge by means of circularly polarized light and then detected by exploiting the inverse spin-Hall effect (ISHE) occurring inside two different spin detectors, namely a thin Pt and Ti pad deposited at the top of the Ge substrate. This allows us investigating the spin-to-charge conversion as a function of the atomic number. A metallic AgSb stripe is also realized in contact with the Ge substrate, to directly acquire the spin-related signal coming from the diffusion of the spin-polarized electrons. Specific nanofabrication details such as the realization of rectifying metal-semiconductor junction to have a Schottky barrier or non-rectifying metal-semiconductor junction on the Ge mesa for the Ohmic contact, and, finally, the electrical characterizations to validate the novel design will be presented.

Dielectric multilayers impact on radiation-induced charge accumulation in highly sensitive oxide field effect transistors.

Bordoni C. ([1]), Ciavatti A. ([1]), Cortinhal M. ([2]), Pereira M. ([2]), Luca F. ([1]), Cramer T. ([1]), Barquinha P. ([2]), Fraboni B. ([1])
([1]) *Department of Physics and Astronomy, University of Bologna, Bologna, Italy*
([2]) *CENIMAT|i3N, Department of Materials Science, NOVA University Lisbon e CEMOP/UNINOVA, Campus da Caparica, Caparica, Portugal*

Radiation dosimetry is crucial in many fields, where the exposure to ionizing radiation must be precisely controlled to monitor health and environmental safety. Among solid-state detectors, we recently demonstrated that Radiation sensitive Oxide Field Effect Transistors (ROXFETs) are excellent candidates for personal dosimetry due to their fast response and high sensitivity to X-rays. ROXFETs use indium-gallium-zinc-oxide as a semiconductor, and a dielectric based on high-permittivity and high-atomic number materials. Here, we study ROXFETs with gate dielectric fabricated by atomic layer deposition, and we compare single- and multi-layer structures to determine the best performing configuration. We identify an optimised bi-layer dielectric structure made of tantalum oxide and aluminium oxide, which demonstrates a sensitivity of $(63 \pm 2)\,\mathrm{V/Gy}$, an order of magnitude larger than previously reported values. To explain our findings, we propose a physical model identifying the relevant charge accumulation and recombination processes leading to the transistor threshold voltage shift under ionizing radiation, *i.e.*, of the parameter that defines the sensitivity of the device.

Defect engineering in graphene for optoelectronic applications.

Thakur M.K. ([1]), Asaithambi A. ([1]), Kalbac M. ([2]), Kriegel I. ([1])
([1]) *Functional Nanosystems, Istituto Italiano di Tecnologia, Genova, Italy*

(2) *J. Heyrovsky Institute of Physical Chemistry of the Czech Academy of Sciences, Prague, Czech Republic*

After the discovery of graphene, the era of 2D materials research began, ushering in a new platform for advancing semiconductor technology. Despite the growing prominence of these materials, graphene remains a focal point due to its remarkable optoelectronic properties. However, graphene faces challenges, including its Dirac-like band dispersion at the Fermi level, lack of a band gap, and ultra-fast carrier recombination time. These characteristics contribute to a low on/off current ratio and responsivity (mA/W) for graphene-based transistors and photodetectors, limiting their practical application in electronic circuits. Modulating the carrier recombination rate and opening the band gap through various graphene functionalization techniques are crucial to overcome this limitation. With this motivation, we explore defect creation through graphene functionalizations through fluorination. Following defect creation, ensuring stability becomes a critical focus. We highlight the importance of stable graphene functionalization, especially through fluorination. This method enables tuning electronic properties and unlocks possibilities for next-generation ultrafast optoelectronics devices.

Strong chirality-induced spin polarization in twisted transition metal dichalcogenides.

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(1) *Dipartimento di Fisica dell'Università di Pisa, Pisa, Italy*
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(3) *Dipartimento di Ingegneria dell'Informazione dell'Università di Pisa, Pisa, Italy*
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(6) *Max Planck Institute for Chemical Physics of Solids, Dresden, Germany*
(7) *ICFO-Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Castelldefels, Barcelona, Spain*
(8) *ICREA-Instituciò Catalana de Recerca i studis Avançats, Barcelona, Spain*

In 1999, R. Naaman's team noted a significant discovery: films composed of chiral organic molecules exhibit an asymmetrical scattering of polarized electrons. This phenomenon is now widely known as the chirality-induced spin selectivity (CISS) effect. Despite its complexity, it has drawn attention in chiral chemistry. The CISS effect involves electrons gaining spin polarization when passing through chiral molecules. Our study explores atomically thin chiral crystals made by twisting van der Waals heterostructures. Even in systems with just two monolayers, especially those with strong spin-orbit coupling, this effect is significant due to structural chirality and spin-flipping spin-orbit coupling. Calculations on twisted homo-bilayer transition metal dichalcogenides show the chirality-induced spin polarization exceeding 50% for materials like $MoTe_2$. We also introduce a theoretical framework based on the microscopic Hamiltonian and a spin-resolved scattering matrix approach. These findings suggest that twisted quantum materials offer a versatile platform for studying and manipulating the CISS effect in condensed-matter physics and chiral chemistry.

Non-local architecture for spin current manipulation in silicon platforms.

Bottegoni F. (1), Zucchetti C. (1), Scali F. (1), Grassi P. (1), Bollani M. (2), Anzi L. (1), Isella G. (1), Bussetti G. (1), Finazzi M. (2)
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(2) *CNR-IFN, LNESS Laboratory, Como, Italy*

A fundamental aim of spintronics is the development of spin-based devices in Si to enhance the functionalities of CMOS-compatible circuits. However, due to the weak spin-orbit cou-

pling, the manipulation of the spin degree of freedom of carriers in Si is a difficult task if one excludes the application of magnetic fields. Here, we present an alternative method that takes advantage of the Si spin-transport features to accomplish electrical control of spin-dependent output signals by modulating the spin current rather than the spin itself. We realized a non-local architecture for spin current generation, modulation and detection in lightly n-doped bulk Si at room temperature. Spin-polarized electrons are injected by means of optical orientation technique and then detected by means of the Inverse Spin Hall Effect inside a Pt stripe that is electrically contacted, by measuring the voltage drop across Pt under open circuit condition. We demonstrate that spin-polarized electrons can be driven by an in-plane electric field that fosters or hinders spin diffusion. As a result, we verify that the ISHE voltage drop can be electrically manipulated to have high or low output values.

Aula 1E **ore 09:00 – 13:30**

Sezione III

Astrofisica

Presiede: Pagano I. (INAF, Osservatorio Astrofisico di Catania)

Relazioni su invito

▲ **The present and future of European exoplanetary research with the space missions CHEOPS, PLATO, Ariel.**

Nascimbeni V.

INAF, Osservatorio Astronomico di Padova

Exoplanets in transiting configurations, i.e., eclipsing their host stars at a regular cadence, provide a unique opportunity for both detection and characterization, allowing us to gather information about their atmospheres, internal structure and formation/migration history. Research interest in the field of exoplanets is moving towards planets of increasingly smaller size and cooler temperatures, slowly approaching the discovery of Earth's first "twin". In this context, Europe is playing a crucial role through three ESA space missions focused on transiting exoplanets. CHEOPS, launched in 2019 and currently undergoing its first extension, is a high-precision photometric telescope designed to follow-up individual planets. PLATO, to be launched in late 2026, will monitor a large number of solar-like stars for > 2 years over a very wide field of view, with the ambitious goal of detecting transits of Earth twins hosted by bright and nearby stars, also amenable to asteroseismic analysis. Finally, Ariel is a NIR space telescope scheduled for launch in 2029. It will observe transits in spectroscopic mode to detect chemical species in their atmospheres.

Comunicazioni

● **CHEOPS-TESS reveals the colors of ultra-hot Jupiter exoplanets.**

Singh V. on behalf of the CHEOPS Consortium

INAF, Osservatorio Astrofisico di Catania

Ultra-Hot Jupiters (UHJs) are Jupiter-sized exoplanets with temperatures exceeding 2000 K due to their close proximity to their host stars. Their brightness varies based on their physical and chemical conditions within their atmospheres. In hotter regimes, the optical brightness is primarily due to radiative emission from the dayside atmosphere (as in the case of WASP-12 b), while cooler UHJs have significant contamination from reflection of the stellar light. ES'As CHEOPS space mission that is specifically designed to study transiting exoplanets using using high precision photometryhas recently discovered reflective atmospheres in a couple of UHJs (KELT-20 b and WASP-76 b). In one instance, we observed time-variability in the planetary brightness, while in another, we detected asymmetries in the dayside brightness distribution. The latter hints at a Glory-like strong scattering feature on the eastern limb of the day-night terminator. As a result of these observations, we have estimated the reflective color of these three Ultra-Hot Jupiters which further helps in characterizing their atmospheres.

Relazioni su invito

▲ **The on-ground characterisation of the CAMERA system for the ESA PLATO mission.**

Nicolini G.
INAF-Osservatorio Astrofisico di Trieste

PLATO (PLAnetary Transits and Oscillations of stars) is the M3 class ESA mission dedicated to the discovery and study of extrasolar planetary systems by means of planetary transits detection. More than a dozen of flight cameras were TVAC tested for acceptance and performance verification between June 2023 and May 2024 at 3 different test facilities (SRON, IAS and INTA), with the remaining units to be tested by the end of the year. In this contribution, we provide an overview of our serial testing approach, some of the associated challenges, and key performance results, including comparison between models and with subsystem results. An up-to-date overview on the remaining planned activities will also be discussed.

Comunicazioni

● **Stato dell'arte della missione spaziale Ariel.**

Guerriero E. per il Telescope Assembly Team Italiano e il Gruppo Esopianeti Palermo EXOPA
INAF, Osservatorio Astronomico di Palermo

Ariel sarà una missione VIS/IR finanziata da ESA e sarà lanciata nel 2029 e avrà come obiettivo lo studio di un target di circa 1000 esopianeti per studiarne le atmosfere sia in composizione chimica che in efemeridi. Questa sarà la prima missione spaziale progettata appositamente per tale scopo. L'intervento vuole dare una panoramica dello stato dell'arte del progetto spaziale, in particolare, verrà enfatizzato il contributo italiano alla scienza ed alla realizzazione del telescopio. L'Italia negli hanno si è guadagnata un posto rilevante nelle missioni spaziali e si punta, anche con Ariel, a consolidare sempre più tale posizione. In particolare, si parlerà degli studi preparatori che si stanno eseguendo per la selezione degli esopianeti target, e della R&D e tecniche di trattamento innovativo per la realizzazione di ottiche in alluminio per il telescopio di Ariel che si stanno svolgendo in Italia.

Relazioni su invito

▲ **SHARK-NIR, a caccia di pianeti nel cielo di LBT.**

Farinato J. ([1]), Barbato D. ([1]), Baruffolo A. ([1]), Bergomi M. ([1]), Carolo E. ([1]), Cerpelloni P. ([1]), Chinellato S. ([1]), Di Filippo S. ([1]), Dima M. ([1]), D'Orazi V. ([1]), Greggio D. ([1]), Laudisio F. ([1]), Lessio L. ([1])([1]), Lorenzetto A. ([1]), Magrin D. ([1]), Marafatto L. ([1]), Mesa D. ([1]), Radhakrishnan K. ([1]), Ragazzoni R. ([1]), Ricci D. ([1]), Umbriaco G. ([2]), Vassallo D. ([1]), Viotto V. ([1]), Antoniucci S. ([3]), Pedichini F. ([3]), Piazzesi R. ([3]), Esposito S. ([4]), Pinna E. ([4]), Agapito G. ([4]), Puglisi A. ([4])
([1]) *INAF, Osservatorio Astronomico di Padova*
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SHARK-NIR is an instrument which provides direct and coronagraphic imaging, with the possibility to perform also dual-band imaging and low-resolution spectroscopy in Y, J and H bands. Its main scientific goal is the detection of exoplanets, and the characterization of already known planets, young stellar systems, jets and disks. SHARK-NIR is installed at the Large Binocular Telescope in Arizona, had a very successful first light in January 2023, and we will report of the main results obtained during the instrument commissioning phase.

Comunicazioni

● **ANDES, the high resolution spectrograph for the ELT: Project overview, future developments and science goals.**

Marconi A.
Dipartimento di Fisica e Astronomia, Università di Firenze e INAF, Osservatorio Astrofisico di Arcetri

ANDES, the ArmazoNes high Dispersion Echelle Spectrograph, will be the high-resolution spectrograph of the European Extremely Large Telescope and is being developed thanks to the efforts of a large, international consortium composed of more than 220 scientists and engineers from 33 institutes in 13 countries. ANDES will consist of three fibre-fed spectrographs providing a spectral resolution of 100,000 with simultaneous coverage of 0.4-1.8 μm (goal of 0.35-2.4 μm). It will be able to operate in seeing limited conditions but will also include a unique integral field unit which, coupled with a SCAO module, will provide diffraction-limited observations. ANDES has a wide range of science cases spanning nearly all areas of research in astrophysics and even fundamental physics. Some of the top science cases will be the detection of biosignatures from exoplanet atmospheres, finding the fingerprints of the first generation of stars, tests on the stability of Nature's fundamental couplings, and the direct detection of the cosmic acceleration. I will provide a general overview of the ANDES project, including its main science cases and its current status.

Relazioni su invito

▲ **Origins of exoplanetary systems: Our Solar System in context.**

Testi L.
Uninversità di Bologna

Planetary systems are expected to form as a byproduct of the star formation process from the material that cannot accrete directly onto the central star and is accumulated in the circumstellar disk. While most of the early development of the planet formation theories was based on the attempt to explain the present day Solar System, the last few decades have seen a transformation of our views following the discovery of the variety of exoplanetary architectures and the detailed analysis of protoplanetary disks around young stars in the solar neighbourhood. Our observational knowledge of the populations of exoplanets and protoplanetary disks are now reaching a stage in which we can start to draw meaningful comparisons with what we know of our Solar System and we can start to derive common traits in the formation processes and the probability of producing different exoplanetary system architectures. In this talk I will review our recent progress in understanding the planet formation process, highlighting what we think are the key important processes that shape the formation of the bulk of planetary systems. In this context I will try to highlight which processes may have shaped the formation and early evolution of the Solar System.

▲ **Unveiling cosmic cradles: The physics of star formation investigated with a multi-faceted approach.**

Bacciotti F.
INAF, Osservatorio Astrofisico di Arcetri

Understanding the intricate pathways governing the formation of stars and planets represents one of the most compelling frontiers in contemporary astrophysics. Star formation regions are fascinating cosmic laboratories where an extremely rich ensemble of physical and chemical processes shape the evolution of molecular clouds down to the birth of stellar objects and planetary systems. Recent observations at high spectral and angular resolution

and advanced theoretical models testify the complexity involved in the process and tell us about the interplay of the various elements of the young systems in their first 10 Myr. The investigations cover the study of multiple and diverse components, such as prestellar cores, young star clusters, accreting stellar objects, protoplanetary disks, powerful jets and winds, newly born planets. In this review I will outline the most recent developments in this field of research as well as the promising perspectives for future studies.

Comunicazioni

Searching for the building blocks of our Galaxy through the kinematics and metallicity distributions of halo stars.

Mori A. ([1]), Di Matteo P. ([2]), Salvadori S. ([1])([3]), Khoperskov S. ([4]), Pagnini G. ([2]), Haywood M. ([2])

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([4]) *Leibniz-Institut für Astrophysik Potsdam, Germany*

The standard cosmological scenario predicts a hierarchical formation for galaxies. Many substructures were found in the Galactic halo, identified as clumps in kinematic spaces. If they also feature different chemical properties, they are then associated to independent merger debris. Our aim is to explore to what extent different clumps in the energy-angular momentum space (E-Lz) with different metallicity distribution functions (MDFs) in the Galactic halo trace the accretion history of the Milky Way (MW). We analysed N-body simulations of a MW accreting a satellite with mass ratio 1:10, with different orbital parameters and metallicity gradients. We confirm that accreted stars from a 1:10 mass ratio merger event redistribute in a wide range of E and Lz, due to the dynamical friction, thus not being associated to a single clump. Because satellite stars with different metallicities can be deposited in different regions of the E-Lz space, this implies that a single accretion can manifest with different MDFs. This method can bias the reconstructed merger tree of the Galaxy towards increasing the number of past accretions and decreasing the masses of the progenitor galaxies.

Fast rotating blue straggler stars in galactic globular clusters.

Billi A.

Dipartimento di Fisica e Astronomia, Università di Bologna

Blue Straggler Stars (BSSs) are an exotic stellar population that, in the color-magnitude diagram, lies on a bluer and brighter extension of the main sequence. Large rotational velocities are expected in recently formed BSSs for both formation scenarios (mass transfer and collisional), but braking mechanisms should then intervene and slow down these stars. Thanks to an extensive high-resolution spectroscopic survey performed at large ground-based telescopes, we have measured the rotational velocities of a representative sample of BSSs in eight Galactic globular clusters with different structural parameters. In this contribution I will present the distribution of the BSS rotational velocities observed in NGC 3201 and M55 and discuss the main findings of the entire survey. While most of BSSs are slow rotators, some have large rotational velocities, up to 200 km/s, and the percentage of fast rotating BSSs (with $vsin(i) > 40$ km/s) increases for decreasing central density of the host cluster. The collected evidence suggests that recent BSS formation is occurring in low-density environments and preferentially involves massive primordial binaries.

Exploring the size-age conundrum: a study of the globular cluster NGC1835 in the large magellanic cloud.

Giusti C.
Dipartimento di Fisica e Astronomia, Università di Bologna

The distribution of core radius (rc) versus age for globular clusters in the Large Magellanic Cloud (LMC) is very peculiar: all young clusters have small rc, while the older ones display a wide range of values. The variety of rc in the oldest clusters has been attributed to different levels of dynamical evolution, with systems with large rc being dynamically younger than the others. In this context we studied the old cluster NGC 1835. Using optical and near-uv HST images we constructed the star density profile from resolved star counts, determining core, half-mass and tidal radii. The same data also allowed us to evaluate the dynamical age through the A+ parameter. It is defined as the area between the cumulative radial distribution of BSSs and that of a lighter population and it strongly correlates with the dynamical age of clusters. Results confirm that NGC 1835 is a very compact cluster (rc = 0.84 pc) and with an A+ of 0.30, the largest value measured so far in the LMC. NGC 1835 fits well in the correlation between A+ and the central relaxation time and in the anti-correlation between A+ and the core radius defined by the Galactic and the LMC clusters investigated to date.

Searching for variability and transients in DECam images.

Franco A., Nucita A.A., De Paolis F., Strafella F., Sacquegna S.
Dipartimento di Matematica e Fisica "E. De Giorgi", Università del Salento e INFN, Sezione di Lecce e INAF, Sezione di Lecce

The study of variable sources and transient phenomena makes it possible to observe astrophysical systems that would otherwise be much more complex to analyse. A striking example of variability phenomena is given by pulsating variables that, in the specific case of RR Lyrae and Cepheids, are now conventionally used as standard candles, and gravitational microlensing, allowing astronomers for testing Einstein's General Relativity and the indirect detection of compact, faintly shining objects. In this contribution will be described the implemented techniques for the variability search in optical and near-infrared images toward the Large Magellanic Cloud acquired by DECam between 2018 and 2020 with the main purpose of detecting microlensing events induced by Intermediate Mass Black Holes (IMBHs) in the Galactic Halo. A pipeline for the data reduction has been developed. A catalogue of variable sources has been carried out, containing 1262 new variables, thereafter classified thanks to a neural network. A microlensing-like variable has been analysed allowing us to estimate the lens mass, of 0.2 Solar Masses, and distance of 750 pc, making it one of the closest lenses ever detected.

On the Hertzsprung progression of Classical Cepheids.

Marconi M., De Somma G., Molinaro R., Musella I., Ripepi V., Leccia S., Sicignano T., Bhardwaj A., Trentin E.
INAF, Osservatorio Astronomico di Capodimonte

The Hertzprung progression (HP) is a phenomenon shown by Classical Cepheids light and radial velocity curves for pulsation periods ranging from about 9 d to about 12 d and consisting in a relationship between the position of the secondary maximum, called bump, and the pulsation period. A new fine grid of pulsation models representative of these bump Cepheids has been developed to investigate this phenomenon and to search for a dependence of this observed feature on physical and/or chemical properties of the host stellar populations. The period corresponding to the centre of the HP is investigated as a function of various model assumptions, such as the efficiency of superadiabatic convection, the mass-luminosity relation,

and the metal and helium abundances. The predictive capability of the presented theoretical scenario is tested against observed light curves of bump Cepheids in the ESA Gaia data base, also considering the variation of the pulsation amplitudes and Fourier parameters with the pulsation period.

Synthetic Cepheid period-luminosity relations as a tool to investigate the Hubble tension.

Musella I., Marconi M., De Somma G.
INAF, Osservatorio Astronomico di Capodimonte

In this work, I will present an updated set of synthetic Period-Luminosity (PL) relations, based on recently published non-linear and convective pulsating models for Classical Cepheids able to predict all the relevant observables (mean magnitude, period, amplitude, and light curves) in any bands we are interested in also at varying the chemical composition. These synthetic relations can be applied to observational Cepheid samples (both space and ground-based) present in literature to obtain fundamental constraints on their distances and stellar properties. In particular, they can be used to point out the possible existence of systematic errors possibly affecting the local determination of the Hubble constant giving hints for the comprehension of the well-known tension existent with the H0 determination based on the cosmic microwave background measurements in a standard cosmological model framework. As an example of the power of this tool, I will show the application of the synthetic PL, transformed in the HST filters to the Cepheid samples of the SH0ES project.

Aula F **ore 09:00 – 13:30**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Gerosa G. (Università Cattolica del Sacro Cuore, Brescia)

Relazioni su invito

▲ **Conceptual models for the development of tornadoes in Italy.**
Miglietta M.M.
Department of Earth and Geoenvironmental Sciences, University of Bari, Bari e CNR-ISAC, Padua
Although rare, intense tornadoes can occasionally affect the Italian territory. In recent years, some initial steps have been taken toward the identification of possible risk scenarios, studying the conditions associated with tornadoes in some Italian regions. Considering the morphology of the Italian territory, complex circulations induced and/or modulated by the presence of the sea and of the orography may affect the meso-gamma scale; hence, the conceptual models developed for the U.S. Midwest should be modified or adapted to the peculiar Mediterranean environment. In the Ionian regions, the warm Mediterranean Sea surface and the orography of Calabria appear fundamental to explain the genesis of intense tornadoes occasionally affecting the region. More recently, a conceptual model for the development of tornadoes in the Po Valley was proposed, in which two surface boundaries created a triple point: an outflow boundary generated by convection triggered in the Alpine foothills, and a dryline generated by downslope winds from the Apennines, while warm and moist air was advected westward from the Adriatic Sea east of the boundaries.

▲ **An overview of the CALIGOLA Mission: Present status and the future steps.**
Di Girolamo P. ([1]), Dionisi D. ([2]), Franco N. ([1]), Di Paolantonio M. ([1])([2]), Summa D. ([3]), Lolli S. ([3]), Mona L. ([3]), Santoleri R. ([2]), Zoffoli S. ([4]), Tataranni F. ([4]), Venafra S. ([4]), Scopa T. ([4]), Longo F. ([4]), Votta R. ([4]), Sacchieri V. ([5]), Coppola F. ([5]), Perna A. ([5]), Cosentino A. ([5]), Hu Y. ([6]), Hostetler C.A. ([6]), Thorsen T. ([6]), Smith J. ([6]), Behrenfeld M.J. ([7]), Braun S. ([8]), Holz B. ([9]), Mace G. "Jay" ([10]), Maring H. ([11]), Lorenzoni L. ([11]), Hall S.R. ([6]), Trepte C.R. ([6])
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([10]) *University of Utah, Salt Lake City, UT, USA*
([11]) *NASA Head Quarters, DK000, Washington, DC, USA*
The Cloud and Aerosol Lidar for Global Scale Observations of the Ocean-Land-Atmosphere System (CALIGOLA) is an advanced multi-purpose space lidar mission with a focus on

observations of the atmosphere and oceans and aimed at characterizing the Ocean-Earth-Atmosphere system and mutual interactions within it. This mission has been conceived by the Italian Space Agency (ASI) with the aim to provide the international atmospheric and ocean science communities with an unprecedented dataset of geophysical parameters, with the ultimate purpose of generating increasing scientific knowledge in the areas of atmospheric, aquatic, terrestrial, cryospheric and hydrological sciences. ASI is partnering with NASA on this exciting new space lidar mission. The mission is planned to be launched in the time frame 2030–2031, with an expected lifetime of 3–5 years, thus allowing data collection over a time period presently not covered by other space lidar missions. CALIGOLA is baselined to fly in an orbit compatible with other NASA missions seeking to advance an understanding of aerosols, clouds and convection for possible formation flight during a portion of CALIGOLA's duration.

▲ **Thirty years of spectrally resolved observations from far to near infrared.**
Masiello G. ([1]), Serio C. ([1]), Liuzzi G. ([1]), Maestri T. ([2]), Martinazzo M. ([2]), Cassini L. ([1])([3]), Donat F. ([1])([2]), Giosa R. ([1]), Masin F. ([2]), Pasquariello P. ([1]), Proietti Pelliccia G. ([2]), Venafra S. ([4])
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Over the past thirty years, spectrally resolved infrared observations have made significant contributions to climate modeling, weather forecasting, disaster management, and agriculture. During this time, we have developed methods and models for analyzing data from past, present, and future instruments, including the upcoming 9th ESA Earth Explorer mission FORUM. Among these instruments, the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp platform since 2006 has played a pivotal role. IASI measurements greatly enhance weather forecast accuracy and are vital for refining meteorological models. For IASI we developed methods based on the forward model σ-IASI that enable the simultaneous retrieval of thermodynamical parameters, gas constituent and surface properties. The latest version, σ-IASI-f2n, spans the entire infrared emission spectrum and employs a novel scaling approach to address multiple scattering from clouds and aerosols. Applied to IASI spectra over Antarctica, these methods yield valuable insights into cloud and atmospheric parameters, aiding in the evaluation of ozone depletion in this crucial region.

Comunicazioni

● **Influences of urban areas on severe storm dynamics.**
De Martin F. ([1]), Zonato A. ([2]), Di Sabatino S. ([1])
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It is well known that cities can modify the rainfall distributions, while the effect of urban areas on the most extreme convective events is poorly studied. This topic needs further investigation since exposure and vulnerability to severe storm risk is larger in cities than in the surrounding rural area. Our analysis began with a detailed investigation, by means of observations and high-resolution numerical simulations with the WRF model, of a case study that occurred on 25 July 2023 in Milan, when a nocturnal windstorm affected the city centre, downing many trees. The analysis pointed out that Milan influenced the severe storm development, causing a shift on the severe storm track westward to the city, a stronger updraft over the city, and more intense precipitations downstream. However, it is challenging

to disentangle the physical processes that cause those alterations in the storm from a specific case study, especially in a region with such complex topography. For that reason, idealized simulations are being performed to investigate the sensitivity of severe storms to the urban land use, exploring different types of cities and atmospheric environments.

Raman Lidar observations of the vertical profiles of aerosol optical properties and water vapour within ultra-high energy cosmic-rays Observatory Pierre Auger.

Rizi V.

DSFC/CETEMPS, Università degli Studi dell'Aquila e INFN, LNGS

The observations of a Raman Lidar at Pierre Auger Observatory in the Argentinian Pampa are reported. The Raman Lidar is utilized for real-time atmospheric monitoring along the detection of cosmic-ray air showers. The vertical profiles of water vapor mixing ratio, aerosol optical depth, and aerosol backscatter are presented and discussed, along 7 years (2016–2022). The results could give insights into regional climate dynamics over the Argentinian Pampa.

Nuove misure di assorbimento ottico di aerosol atmosferici.

Isolabella T. ([1])([2]), Bernardoni V. ([3]), Brunoldi M. ([1])([2]), Mazzei F. ([1])([2]), Parodi F. ([2]), Prati P. ([1])([2]), Vernocchi V. ([2]), Massabè D. ([1])([2])

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Il particolato (PM) ha un impatto dannoso sulla salute, sulla qualità dell'aria e sui cambiamenti climatici. Molti dei composti che compongono il PM svolgono un ruolo importante nel bilancio energetico della Terra assorbendo e disperdendo la radiazione solare. Tra questi, gli aerosol carboniosi rappresentano la classe di particolato che assorbe maggiormente la luce. La polvere minerale presenta caratteristiche selettive di assorbimento della luce in alcune bande dello spettro della radiazione solare. Diventa quindi necessario comprendere l'assorbimento di ciascuna delle diverse componenti del PM. L'analisi ottica del PM è il punto di partenza per la ripartizione dei componenti e della fonte dell'aerosol atmosferico. Sfruttando il diverso comportamento spettrale delle componenti del PM, è possibile dedurre la composizione dell'aerosol e le sue sorgenti. Un nuovo strumento per la misurazione dell'assorbimento della luce bianca degli aerosol è stato assemblato e validato presso l'Università di Genova. In questo contributo verrà fornita una panoramica dello strumento, insieme a una presentazione dei risultati delle analisi di diversi ambientali.

Artificial intelligence models to estimate daily ground level air pollution in Italy using Sentinel-5P and ERA5 data.

Fania A. ([1])([2]), Monaco A. ([1])([2]), Pantaleo E. ([1])([2]), Maggipinto T. ([1])([2]), Bellantuono L. ([2])([3]), Cilli R. ([1])([2]), Lacalamita A. ([1])([2]), La Rocca M. ([1])([2]), Tangaro S. ([2])([4]), Amoroso N. ([2])([5]), Bellotti R. ([1])([2])

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Recently, there has been growing concern about air pollutants and their impact on human health. It is becoming increasingly clear that human, animal and environmental health are closely linked as part of the One Health approach. However, there are few ground-based air monitoring stations as they are very expensive and therefore offer limited coverage. As an alternative, satellite and reanalysis data offer high spatial and temporal resolution. The aim of this work is to develop artificial intelligence models to predict daily air pollutant concentrations in Italy using satellite, climate reanalysis, geographic and social data. In particular, we developed and compared two models with different spatial resolutions: a model with a fixed grid of 5 km × 5 km and a municipal model with a variable spatial resolution. We used the data from the monitoring stations of the Regional Environmental Protection Agency (ARPA) from 2019 to 2022 as a basis. The analysis involves comparing the performance of 3 learning methods (Linear Model, Random Forest, XGBoost) and applying an explainable artificial intelligence (XAI) approach to evaluate the role of each feature in the model.

● **A machine learning forecasting model for vertical total electron content.**

Asamoah E.N. ([1])([2]), Cafaro M. ([1])([2]), Epicoco I. ([1])([2]), De Franceschi G. ([1])([2]), Cesaroni C. ([1])([2])
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Vertical Total Electron Content (vTEC) is one of the most important parameters to study the impact of space weather on the ionosphere. vTEC is used to quantify the level of ionisation of the upper atmosphere, and its variability depends on latitude, time space weather on the ionosphere of day, season, and solar cycle phase, which is exacerbated especially under severe space weather events. As a contribution to countermeasures for mitigating the impact introduced by ionospheric threats on communication and navigation systems, several vTEC forecasting models have been developed using different approaches. In our research study, we leverage machine learning techniques to build a multivariate predictive model and design physics-informed loss functions to improve the training process specifically to cope with the associated events of space weather.

● **Towards the assimilation of MTG-IRS and all-sky microwave radiances in the convection-permitting ICON model.**

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The new ICOsahedral Non-hydrostatic (ICON) model represents a powerful tool for investigating the atmospheric dynamics at convection-permitting scale. Together with this modeling facility, the new geostationary platform Meteosat Third Generation Infrared Sounder (MTG-IRS) will soon provide high-resolution radiances in the long- and mid-wave infrared. The purpose of this work is to set up an Observing System Simulation Experiment (OSSE) to investigate the contribution of specific water vapour-sensitive MTG-IRS channels to the representation of the physical properties of convective systems. This study is conducted in parallel with another experiment involving synthetic microwave all-sky radiances in water vapour channels from polar satellites, that are expected to give important complementary information to IRS in the study of convective systems. ICON is run at 2.2 km resolution

and the data assimilation is performed employing a state-of-the-art ensemble method, the LETKF, together with the fast radiative transfer model RTTOV used as observation operator. We present here the outline of the OSSEs configuration with an overview on the possible future applications on real case studies.

● **Validating the amplitude scintillation index from Swarm satellites faceplate measurements against the GNSS scintillation receiver measurements in Malindi.**
Imam R. ([1]), Abu Elezz O. ([2]), Yassen A. ([3]), Spogli L. ([1])([4]), Alfonsi L. ([1]), Cesaroni C. ([1]), Zheng Y. ([5]), Xiong C. ([5])([6]), Jin Y. ([7]), Clausen L.B.N. ([7]), Wood A. ([8]), Miloch W.J. ([7])
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Recently, we developed a model that relies on *in situ* electron density measurements from the Swarm satellites constellation for estimating the amplitude scintillation index ($S4$). Such an index from Swarm has the potential to provide global space weather service for critical infrastructures that rely on Global Navigation Satellite Systems (GNSS) for their operation. The model leverages Rino's well-known formula for weak scattering to estimate $S4$ from the Swarm mission's faceplate measurements. We present the evaluation of the model outputs and compare them to the ground-based GNSS scintillation monitoring using various measures of accuracy, bias, association and precision. We sort the analysis according to the space weather conditions. For this, we consider conjunctions of Swarm measurements over the ionospheric scintillation monitoring receiver in Malindi, Kenya. This location is chosen because it includes also an ionosonde, which allows evaluating the inputs to the model and the ionospheric environment conditions during the Swarm overfly. Finally, we compare the climatology of scintillation in Malindi obtainable from Swarm and the GNSS receivers, independently.

● **Towards ensemble-based data assimilation on a Discontinuous Galerkin (DG) sea ice model with solid-like rheology.**
Vittorioso F. ([1]), Carrassi A. ([1]), Aydogdu A. ([2]), Ying Y. ([3]), Bertino L. ([3]), Chen Y. ([4])
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The Scale-Aware Sea-Ice Project (SASIP) aims to develop an innovative sea-ice model for climate research and, more specifically, for the better understanding and predicting the rapid changes caused by the warming of the polar regions (`https://sasip-climate.github.io`). This is done through the development of the neXt-generation Sea Ice Model (neXtSIM), which is constantly being updated with the implementation of advanced techniques, novel numerical approximation for its numerical core and optimization of its parameters, and via modern Data Assimilation (DA) and machine learning techniques. In particular, neXtSIM is being equipped by an advanced Discontinuous Galerkin (DG) method, preserved with very

anisotropic and non-local sea ice physical features. This is done in conjunction with the novel Brittle Bingham-Maxwell (BBM) rheology, which looks at the ice as a solid subject to mechanical stresses rather than a fluid. The core of the present work is to couple neXtSIM-DG to an ensemble Kalman filter for state and parameter estimation. Preliminary results will be illustrated in the communication.

Scientific objectives and expected performance of the EFD-02 instrument of the future CSES-02 satellite mission.

Rebustini G. ([1]), Diego P. ([2]), Parmentier A. ([2]), Badoni D. ([1]), De Santis C. ([1]), Sparvoli R. ([1])([3]), Ricci M. ([1]) per la CSES-Limadou Collaboration

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The new Electric Field Detector (EFD-02), designed to measure the ionospheric electric field components in Low Earth Orbit (LEO), will be launched in December 2024 on board the China Seismo-Electromagnetic Satellite (CSES-02). The EFD-02 concept is the well-known "dual probe technique" already used for DEMETER and CSES-01. The EFD-02 instrument has been improved in various aspect ranging from the full redundancy and configurability of the subsystems, up to the scientific information computed by the electronics. In this study, we describe the calibration and test procedure used to optimize the performance of the EFD-02 detector, a crucial step in preparing for data analysis in the subsequent instrument commissioning phase on CSES-02. This detector not only contributes to the understanding of ionospheric phenomena, but also provides a solid foundation to future studies in the fields of space physics and geophysics. Indeed, the innovative features of both analog and digital units will allow the detection of a set of previously unmonitored parameters able to increase the scientific information and the spatial resolution of plasma structure in the ionospheric space.

Added value of a multi-model ensemble of convection-permitting rainfall re-forecasts over Italy.

Giordani A., Ruggieri P., Di Sabatino S.

Università degli Studi di Bologna, Dipartimento di Fisica e Astronomia, Gruppo di Fisica dell'Atmosfera

The interest in developing high-resolution atmospheric re-forecasts has been growing, with convection-permitting (CP) datasets showing improved rainfall representation compared to convection-parameterized counterparts. However, the simulation of convective-related events is highly model-dependent, which limits to capture the full range of natural variability with single-model experiments. Multi-model ensembles (MMEs) offer a way to tackle this issue, which, in case of CP regional climate models, have shown added value over Europe. This contribution presents the first MME of CP re-forecasts over Italy formed by four dynamical downscalings of the global reanalysis ERA5 with different numerical models. The pluviometer-based analysis GRIPHO serves as the reference. The investigation over a decade includes various aspects: annual/seasonal dependence of daily/hourly rainfall intensity and frequency, heavy precipitation occurrences, and their summer diurnal cycles. The ensemble systematically improves rainfall estimates over single datasets producing more realistic spatial patterns and reducing biases with observations, at the expense of a reduction in the spatial variability of the distributions.

Covariant Lyapunov vectors for determining abrupt regime changes in intermittent chaotic systems.

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Intermittency is a very peculiar phenomenon of many chaotic systems present in Nature and in engineering or laboratory phenomenon. These include precipitation patterns, climate oscillations or electric power networks. The abrupt changes in the system's behavior may have downstream impacts on humans or infrastructures, or even lead to the system's collapse. Understanding the fundamental mechanisms driving these changes, what characterizes an intermittent system and ultimately developing theoretical and practical tools to predict the regime changes is thus of paramount importance in many areas of science and engineering. Our focus is on the atmospheric dynamic, where intermittency is found in several cases such as convection, heatwaves or precipitation. We use tools from dynamical systems theory to discover the precursors of the change of regime typical of the intermittent behavior, in particular the Lyapunov analysis and bifurcation theory to isolate and predict transitions between the intermittent states emerging in these systems. These precursors are then used to train a neural network for predicting the regime changes.

Aula 1F **ore 09:00 – 13:30**

Sezione V
Biofisica e fisica medica
Presiede: Spighi R. (INFN, Sezione di Bologna)

Relazioni su invito

▲ **Unsupervised and supervised semantic segmentation for early detection of metabolic anomalies.**
De Spirito M. ([1])([2]), Maulucci G. ([1]), Bianchetti G. ([1]), Abeltino A. ([1]), Serantoni C. ([1]), Riente A. ([1])
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This contribution explores innovative techniques in semantic segmentation for the early detection of metabolic anomalies using both supervised and unsupervised learning methods. A first study introduces a novel approach to semantic segmentation using unsupervised learning algorithms to analyze metabolic clustering in live cell imaging. By classifying metabolic clusters in breast cancer cell lines, the study reveals insights into cellular metabolism at a microscale, enhancing understanding of mitochondrial dynamics and metabolic reprogramming in cancer cells. A second study extends these results by employing a supervised learning approach combined with PET imaging. This approach allows for precise localization and quantification of metabolic activity, useful for early disease detection and monitoring. The combined approaches offer a comprehensive set of tools to improve diagnostic accuracy and enhance patient outcomes in oncology and beyond. This integration holds significant promise for the development of targeted therapeutic strategies and the advancement of personalized medicine.

▲ **X-ray absorption spectroscopy and simulations to investigate copper redox chemistry in neurodegenerative disorders.**
Minicozzi V.
Dipartimento di Fisica, Università di Roma Tor Vergata, Italia e INFN, Sezione di Roma Tor Vergata, Italia
The aetiology of the so-called protein conformational disorders is in general related to an unfolded protein that loses its functionality and can also become toxic. One of the many factors influencing the process is metal ions presence. In particular, Cu ions bound to the Amyloid-β (Aβ) peptide represent a source of oxidative stress in the context of Alzheimer's disease because of their redox activity. In order to explain the efficient redox cycling between Cu(II)-Aβ and Cu(I)-Aβ resting states, the existence of a low-populated in-between state, prone to bind Cu in both oxidation states, has been postulated. Here, we describe a multiscale computational pipeline aimed at reproducing the resting and the in-between states of Cu-Aβ and at better interpreting X-ray absorption (XAS) spectra. We start by performing classical Molecular Dynamics (MD) simulations of both Cu(I)- and Cu(II)-Aβ complexes. The configurations coming out from MD will then be validated with deep-learning methods and quantum-mechanical calculations. Finally, theoretical X-ray absorption spectra will be calculated to compare our numerical results with experimental observables.

▲ **Physics investigation of the vasculature network in human jawbones.**

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Compact bone model is represented by a system of Haversian canals connected by Volkmann's canals. Models are mainly based on either histology or microcomputed tomography, but the microstructure, especially that of the canal networks and their spatial relationships, deserves further quantitative investigation to understand the consequence of pathological modification. We present a study whose aim is to provide the 3D representation, and quantitative characterization of the human jawbone Haversian system. By using high-resolution X-ray microtomography based on synchrotron radiation (SRmCT), and a quantitative image and network analysis, we obtained the 3D reconstruction of different segments of the human jawbone, and studied them as complex networks. We performed X-ray SRmCT experiments on two different pools of autopsy specimens: crestal bone in heavily resorbed mandibular jawbones, and crestal bone containing tooth. The first set of samples represents a typical situation of edentulous jaw, while the second set includes the healthy control sites. Comparison of the bone samples obtained by SRmCT provides unexpected outcomes, as well as the density of canals and network degree exponent.

Comunicazioni

● **Metabolic response in deactivated areas using fMRS at 3 T.**

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Functional Magnetic Resonance Spectroscopy (fMRS) allows quantifying dynamic changes in metabolite concentration within activated brain areas. A focalized increase of glutamate and lactate has been reported upon stimuli eliciting a positive BOLD response, and it has been shown to be uncoupled from BOLD magnitude according to involved neural mechanisms. Comparatively less is known about metabolic dynamics in areas of Negative BOLD Response (NBR), due to the difficulty in inducing it reliably in an extended area, compatible with MRS. The origin of NBR is still debated, but it is hypothesized that it originates from deactivation. Metabolic measures during deactivation can help elucidating the neural origin of NBR, offering information of brain metabolic diseases trough the assessment of dissociation between neurovascular and neurometabolic coupling. Purpose of this study is to explore the metabolic response to deactivation induced by a visual stimulus. Data were acquired at 3 T

with a semiLASER sequence. A functional localizer was used to place the MRS VOI within NBR area. Results are consistent with values reported for higher field strengths supporting a decrease in neuronal activity.

Patch-based V-Net for malignant breast lesion segmentation in 3 T DCE-MRI.
Fedon Vocaturo M. (1), Altabella L. (1), Esposito P. (1), Cardano G. (2), Cardobi N. (2), Montemezzi S. (2), Cavedon C. (1)
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In medical imaging, accurately segmenting lesions is vital for further analysis, such as monitoring tumor progression and extracting radiomic features. This study aims to overcome human variability by creating an automated deep learning model for segmenting malignant breast lesions based on V-Net architecture. The retrospective analysis involved 131 women who underwent DCE-MRI before neoadjuvant chemotherapy on a 3 T MRI scanner. Manual segmentation of the second subtracted post-contrast images was used to train the V-Net algorithm. A two-stage process was adopted, initially segmenting the whole breast, then focusing on lesions using smaller 3D patches to capture fine-grained features. The best model, utilizing all image information, achieved a median accuracy of 0.9998 (IQR: 0.9995–0.9999) for both training and testing. Median Dice scores, comparing human and automated segmentation tasks, were 0.77 (IQR: 0.66–0.83) and 0.71 (IQR: 0.51–0.82), respectively for train and test. While significantly reducing operator variability and improving segmentation speed (5 times faster), human supervision remains necessary to address false positives and fine-tune binarisation thresholds.

Predicting neoadjuvant chemotherapy response in breast cancer patients with 3 T DCE MRI: Developing a robust radiomic and clinical model.
Altabella L. (1), Fedon Vocaturo M. (1), Esposito P. (1), Cardano G. (2), Cardobi N. (2), Montemezzi S. (2), Cavedon C. (1)
(1) *Medical Physics Unit, Azienda Ospedaliera Universitaria Integrata, Verona, Italy*
(2) *Radiology Unit, Azienda Ospedaliera Universitaria Integrata Verona, Italy*
This study built a pipeline to predict response to neoadjuvant chemotherapy in breast cancer by combining 3 T DCE MRI radiomic features with clinical and histological data from 127 women. Radiomic analysis of both third dynamic and second subtracted images, utilizing 18 filters, yielded over 3472 extracted features. Dimensionality reduction entailed progressively filtering out non-useful information and employing mRMR, LASSO, and UDFS techniques for feature selection. Radiomic data was enriched with patient age, tumor grade, margins and type information. Feature selection and logistic regression classification were evaluated via repeated nested cross-validation and AUC metrics. Most parsimonious models were favored in each case, with mean AUC of 0.83 ± 0.01 (CI = 0.81–0.85) for mRMR with one radiomic feature, 0.78 ± 0.01 (CI = 0.75–0.80) for LASSO with 2 features, and 0.85 ± 0.01 (CI = 0.83–0.87) for UDFS with 4 features. Comparable results were achieved when applying the models to various segmentations (median Dice score 0.71, IQR 0.51–0.82), indicating strong predictive performance and robustness to segmentation variations, suggesting potential clinical application.

Study and characterization of zeolites for the removal of artificial radionuclides in wastewater samples from nuclear power plants.
Ambrosino F. (1), Pisciotta F. (2)(1), Gravino C. (3), La Verde G. (1), Gargiulo N. (3), Caputo D. (3), Pugliese M. (1), Gagliardo G. (1), Della Peruta G. (1)
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Being the most important inorganic adsorbents and cation exchangers, zeolites were proposed and successfully used for decontamination of artificial radionuclides-containing wastewaters. In this work, water solutions from the processes of cooling and storing the irradiated fuel elements of the former nuclear power plant of Garigliano are considered. Samples of the wastewater are characterized radiologically by performing γ-spectrometry using HpGe detector: ^{137}Cs and ^{60}Co are main sources. This work falls within the decommissioning of the above-cited facility and aims to provide an alternative solution for correctly managing the problem of radioactive wastewaters. In-batch experiments —by using simulated solution containing Cs and Co not radioactive isotopes and two synthetic zeolites (4A, 13X) together with one natural term (philipsite-rich tuff)— have been performed to obtain the kinetic characterization of the exchange process. By inductively coupled plasma spectrometry the Cs and Co concentrations have been monitored over time. The results demonstrate the high efficacy of zeolite 13X having almost 100% of adsorption of both elements, in a short time in the order of 20 minutes.

Multi-organ X-ray imaging approach to assess damage progression in neurodegenerative diseases.

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X-ray phase-contrast tomography (XPCT) provides a highly sensitive 3D imaging approach to study different disease-relevant networks at the level of single cells up to whole organs. We present here a concomitant study of the evolution of tissue damage and inflammation in potential target organs of the disease in the mouse model of multiple sclerosis. XPCT identifies and monitors structural and cellular changes throughout the central nervous system, but also in the gut and eye, of mice induced to develop multiple sclerosis-like disease and sacrificed at different stages. This approach relies on multi-scale analysis to detect the early appearance of imaging indicators that may act as biomarkers predictive of disease. The longitudinal data allow an original evaluation of the sequential development of multi-organ damage in the animal model, shedding light on the role of the gut-brain axis in the initiation and progression of the disease, relevant to the human case. The same approach, focusing on the gut in addition to the central nervous system, holds promise for the preclinical study of other neurodegenerative diseases, such as Alzheimer's.

Proprietà rilassometriche di nanoparticelle magnetiche a base Fe_3O_4: effetto del doping con Zn^{2+} e Mn^{2+}.

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Le nanoparticelle (NP) magnetiche sono studiate in nanomedicina come agenti di contrasto (CA) per l'imaging con risonanza magnetica (MRI). La loro natura magnetica perturba la dinamica degli spin dei nuclei ^{1}H circostanti, riducendo i tempi di rilassamento nucleare $T_{1,2}$ e aumentando il contrasto nelle immagini MRI. Questo studio mira a comprendere l'effetto del drogaggio del core di NP Fe_3O_4 con Zn e Mn sulle proprietà rilassometriche al variare della dimensione per ottimizzare il contrasto MRI. Abbiamo studiato 2 set di NP sferiche a base Fe_3O_4, di formula $Mn_xZn_yFe_{3-x-y}O_4$ e core di circa 4 nm e 15 nm. Set i): 6 campioni di cui 1 non drogato, 3 a diversa concentrazione di Zn^{2+} (0.1, 0.7, 0.9) e 2 con zinco costante (0.5) e Mn^{2+} variabile (0.2, 0.4). Set ii): 7 campioni di cui 1 non drogato, 3 con Zn^{2+} variabile (0.1, 0.3, 0.5) e 3 con zinco costante (0.3) e Mn^{2+} variabile (0.1, 0.2, 0.3). La caratterizzazione morfo-strutturale e magnetica è stata fatta con ICP-OES, TEM, XRD, IR, TG, DLS e VSM. Le proprietà rilassometriche sono state indagate acquisendo i profili NMRD, *i.e.*, rilassività nucleari *vs.* frequenza (0.01–64 MHz).

Preliminary studies of barley seed samples stressed by magnetic fields.

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Several magnetic fields have been used to study the behaviour of barley seeds, *Hordeum vulgare*. The idea of carrying out such experiments was stimulated by the fact that several fields are active on the Earth's crust since its formation. We have chosen to apply a magnetic field larger than the Earth's one; it was fixed to 470 mT. The frequencies utilised were 0 Hz, 25 Hz, 2.5 kHz, 250 kHz and 22.5 MHz which have an increase of a factor 100. Several current generators fed the coils which had an active area of $2 \times 2\,\mathrm{cm}^2$ and a height of 4 cm. For treatment, the seeds were placed inside the coils. The irradiation lasted 48 h. The seeds treated and the one used as control, after 1 week from treatment were soaked in water at 8 °C for 48 h. Next the samples were placed in pots containing soil at 24 °C, 16 h with light for 7 days for germination. Several parameters were measured: germination, cotyledon length, roots, etc. The frequency of 22.5 MHz did not show differences in germination, but it proved to be the best, compared to the control. The cotyledon increased of 27%, and the fresh and dry weight of 40% and 37%, respectively, compared to the control.

The thermal neutron cross-sections of air: The contribution of molecular rotations.

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The accurate knowledge of thermal neutron transport in air is particularly relevant for radioprotection, both in research and medical facilities, because of the possibility to activate 40-Ar. One of the most popular tools to estimate dose are Monte Carlo transport simulations, which often rely on thermal neutron scattering cross-sections, approximated using the free gas model which, however, does not take into consideration neutron excitation of molecular vibrations and rotations, nor the magnetic interaction with electrons. To simulate the transport of thermal neutrons in air, we implemented the Young and Koppel model to

describe homonuclear diatomic molecules, such as N_2 and O_2, that are abundant in air. Moreover, the paramagnetic behaviour of O_2 was taken into account. The model is being tested in Geant4 simulations using the NCrystal module, which provides a computational environment to implement new neutron cross-section libraries. Transport simulations performed using the free gas model and Young and Koppel model will be compared to discuss the impact of a simplified model on the calculation of dose delivered by argon activation.

Valutazione delle prestazioni di un sistema di imaging Timepix4 con radiazione monocromatica di sincrotrone.

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Il Timepix4 è un chip di lettura sviluppato dalla Collaborazione Medipix4. Tramite bump-bonding il chip può essere connesso a sensori pixellati (passo 55 μm) di diverso materiale e spessore, realizzando sistemi di rivelazione ottimizzati per specifiche applicazioni. Tra le diverse modalità di acquisizione, la Time over Threshold-Time of Arrival data-driven è indicata per applicazioni di imaging spettrale. I pacchetti di dati sono prodotti solo quando la carica depositata nel pixel supera una soglia preimpostata, permettendo di contare i fotoni incidenti e misurarne l'energia. A differenza dei rivelatori generalmente impiegati in imaging spettrale, il Timepix4 è quindi in grado di acquisire immagini in uno spettro continuo di energia. Per caratterizzare un sistema di rivelazione Timepix4 equipaggiato con un sensore in Si da 300 μm di spessore, il fascio di fotoni monocromatico della linea SYRMEP del sincrotrone Elettra è stato impiegato come sorgente. La risoluzione energetica e spaziale del rivelatore e il tempo morto dei singoli pixel sono stati stimati. I risultati dimostrano l'applicabilità del sistema di rivelazione nel campo dell'imaging spettrale ad alti flussi.

Synchrotron phase-contrast x-ray imaging for systemic sclerosis evaluation in humanized murine model.

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Systemic Sclerosis (SSc) is an autoimmune pathology, characterized by an increased fibrosis activity. It can arise in dermal tissue as well as in internal organs, in severe cases. Human transgenic mice were generated using Platelet Derived Growth Factor Receptor α (PDGFRα), which is one of the known autoimmunity targets for antibodies. HuPDGFRα

mAbs were administered and the response in skin and lungs evaluated. Soft tissues require experimental setups that do not rely solely on x-ray absorption, as this cannot discriminate among soft tissues compositions. Synchrotron radiation was employed to produce phase-contrast 3D images (SYRMEP, Elettra, Trieste). In order to assess if a fibrotic response occurred, 3D imaging provided valuable insight on both the distribution and the severity of the fibrosis, on both skin and alveoli samples. In particular, for the first set of samples we have been able to evaluate the thickness and the physical density of the dermal layer. In the latter, beyond these measurements, we also determined whether a change in the overall morphology had occurred. This result validated an animal model useful to identify and corroborate new therapeutic strategies for SSc.

Development of quantitative magnetic resonance imaging methods of the spinal cord.

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Quantitative MRI (qMRI) is crucial for assessing the central nervous system integrity by providing objective continuous metrics that are important for the comprehension of pathophysiological processes. Despite the success of qMRI techniques in brain imaging, their application in spinal cord (SC) imaging is uncommon due to technical and methodological limitations that are related to SC physiological noise and poor spatial resolution. We developed a SC scanning and data analysis protocol derived from the spine generic protocol in order to obtain images for the study of SC traumatic and inflammatory injuries at either cervical or thoracic level. We applied the optimized protocol to a group of healthy subjects ($N = 6$) and to a group of patients ($N = 6$) with cervical or dorsal SC lesions. The cross-sectional area (CSA) of the SC was evaluated as a biomarker of spinal cord atrophy. Despite the small sample size and the heterogeneity of the patient group, preliminary results show that the SC CSA along vertebral level in patients is characterized by a higher variability and a tendency to smaller CSA. This finding may give information about the distal effects of the lesion on SC integrity.

Feasibility study of a wearable sensing device for activity monitoring in patients treated with ^{131}I.

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In nuclear medicine therapy, personalized treatments would increase the effectiveness of the treatment and reduce induced toxicity. The knowledge of the biokinetics of the administered

radiopharmaceutical is fundamental for an accurate dose estimation and the Time Activity Curve (TAC) is obtained by multiple-time scintigraphic imaging implying an additional obligation for patients to provide time-limited information. Properly designed wearable radiation sensors could —in principle— provide the TAC with the desired acquisition time granularity. In the hypothesis of a patient undergoing to ^{131}I treatment of thyroid cancer, MC simulations were carried out simulating ICRP110 male phantom for the estimate of the response of a sensor placed at the thyroid level. The initial biodistribution was set according to the indications of ICRP for ^{131}I biokinetics. The contribution from other uptaking organs, such liver, spleen, kidneys, urinary bladder to the sensor response was also computed. TAC of thyroid was successfully reconstructed by a proper deconvolution method thus encouraging the experimental study and consequent optimization of wearable sensors for this purpose.

Radiomic features characterization of CT images using the RadiomiK phantom.

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The extraction of radiomic features from CT images is an analysis tool that allows the identification of quantitative information not perceptible to the human eye. Unfortunately, its potential is limited by the dependence of the features on the image acquisition parameters. Doing an upstream harmonization based on image quality, we characterized the features extracted from the RadiomiK phantom, an in-house developed geometric phantom containing inserts with different materials and textures. Thirty CT images of RadiomiK were acquired with ten protocols using two scanners, three dose values and four levels of iterative reconstruction algorithms. The repeatability on three repetitions of the same protocol and on ROIs placements and volumes was assessed by calculating the coefficient of variation; the robustness by computing the intraclass correlation coefficient among different protocols. The harmonization improved the robustness of the features, especially for more homogeneous inserts. A standardized feature extraction process should be used as the ROI placement and volume strongly influenced the repeatability.

Aula D **ore 09:00 – 13:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Lo Giudice A. (Università di Torino)
Morigi M.P. (Università di Bologna)

Relazioni su invito

▲ **Digital innovation: When cultural heritage meets the technology.**
Costantini A. ([1]), Bombini A. ([1]), Dell'Agnello L. ([1]), Di Giulio R. ([2]), Felicetti A. ([3]), Medici M. ([2]), Niccolucci F. ([3]), Ronchieri E. ([1]), Taccetti F. ([1])
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Cultural heritage, as well as many sectors ranging from economy to social, has been affected by the rise of Information and Communication Technologies (ICTs), which radically changed the paradigms of organizations, forcing them to rebalance their strategic vision and operations. Digital transformation, in fact, can help cultural institutions to further valorise their heritage and enhance the generated value. This is also the intention of the European Commission which is promoting heritage valorisation together with conservation and preservation. In such respect, the European Competence Centre for the Conservation of Cultural Heritage has the mandate to promote and harmonize the technologies that can be used for the conservation and the preservation of the cultural heritage and how it may be valorised. In particular, the adoption of state-of-the-art computer-based approach for accessing a knowledge base and delivering digital technologies, including 3D and semantic technologies as well as AI techniques to be applied to monuments and sites, represent a fundamental pillar in the preservation and valorisation of the heritage.

▲ **Strengthening resilience of cultural heritage from climate change induced hazards: Methods and approaches of safeguarding in facing gradual and extreme variations.**
Bonazza A. ([1])([2]), Sardella A. ([1])([3]), Cacciotti R. ([4]), Drdácký M. ([4])
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The risks on cultural heritage caused by climate change have gained increasing attention during the last 20 years and significant progress has been made concerning the analysis of the projected impacts on cultural assets, such as archeological sites, historic centers, cultural landscape. This contribution addresses approaches for the development of projections of the impacts of climate change on cultural heritage, in relation to gradual and extreme variations of climate/pollution parameters. State of advancement and still existing gaps are discussed with a focus on approaches attempting a quantification of the damage, vulnerability ranking and risk assessment of cultural heritage categories. Exemplificative results based on the

exploitation and analysis of data from climate modelling, Earth observation domain and environmental monitoring will be illustrated, as well as on participatory approaches with local stakeholders. The discussion will be centered on the driving role of research in supporting the definition of priorities for heritage managers and the development of strategies by decision and policy makers for the prevention and safeguarding of cultural heritage at risk.

▲ **Non-invasive stratigraphy of painted surfaces: From traditional to advanced techniques.**

Fontana R., Dal Fovo A.

CNR-INO, Istituto Nazionale di Ottica

From the stratigraphic analysis, it is possible to learn about the different decorative steps, transformations and remodelling that have affected the artwork over time and, consequently, to identify the most appropriate aesthetic and conservative restoration intervention. Typically based on sampling, in the early 2000s stratigraphic analysis was realized non-invasively through Optical Coherent Tomography (OCT), an interferometric technique that uses visible or infrared light to provide cross-sections of partially transparent or scattering media. Since then, other techniques based on Non-Linear Optics (NLO) have been successfully applied especially in those cases where OCT is not effective. Innovative processing of spectral data has been recently proposed to extend the stratigraphic analysis to entire painted surfaces. In this contribution, an overview of the results obtained by OCT, NLO and spectral imaging on paintings is presented.

Comunicazioni

● **Data cube segmentation via Deep Spectral Clustering.**

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Nuclear methods are widely used for Cultural Heritage Imaging. However, the data cubes steaming from such analysis often pose a challenge in their interpretation, due to the intrinsic difficulty in discerning the relevant information from the spectra composing the data cube. Furthermore, the huge dimensionality of data cube spectra poses a complex task in its statistical interpretation; nevertheless, this complexity contains a massive amount of statistical information that can be exploited in an unsupervised manner to outline some essential properties of the case study at hand, *e.g.*, it is possible to obtain an image segmentation via (deep) clustering of data cube's spectra, performed in a suitably defined low-dimensional embedding space. To tackle this topic, we perform deep clustering on the spectral properties of data cube pixels. A statistical dimensional reduction is performed by an *ad hoc* trained (Variational) AutoEncoder, to map spectra to lower dimensions, while the clustering is performed by a (learnable) iterative K-means algorithm. We apply this technique to an *ad hoc* use case: a set of Macro mapping X-Ray Fluorescence (MA-XRF) synthetic data on pictorial artworks.

Research opportunities for Cultural Heritage investigations using the ISIS@MACH ITALIA research infrastructure.

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The Cultural Heritage community can largely benefit from multi-disciplinary and multi-scale characterization analyses. When little information is known of an artifact or finding, a variety of techniques should be applied to gather as much information as possible. The ISIS@MACH ITALIA Research Infrastructure provides the possibility to apply for access to a number of characterization techniques via a single point of access and periodic calls for proposals. Here we will present some recent case studies of Cultural Heritage investigations performed, *inter alia*, at the Unit of the Tor Vergata University, where microscopy and spectroscopy techniques can be used in a non-destructive and non-invasive way, including scanning electron microscopy with concurrent energy-dispersive X-ray spectroscopy, and micro-Raman microscopy also operable in the AFM-configuration. Complementary experiments at the ISIS Neutron and Muon Source will also be discussed. The authors gratefully acknowledge the support of the ISIS@MACH ITALIA Research Infrastructure, the hub of ISIS Neutron and Muon Source (UK), [MUR official registry U. 0008642.28-05-2020 – 16th April 2020].

Super-resolved far-field terahertz imaging.

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Spatial resolution, the ability to distinguish details in an image, is limited by diffraction. The Point Spread Function (PSF) describes image blurring caused by the optical system's response to a point source. Super-resolution methods mitigate PSF effects, especially in terahertz (THz) imaging, where diffraction degrades resolution to about 1 mm, according to the Abbe limit. Various optical techniques, including structured illumination, have been developed to overcome this problem. This contribution focuses on a far-field THz imaging system using a freestanding knife-edge in a confocal setup, targeting small-scale details in planar samples. Implemented on a THz time-domain spectrometer (Menlo Systems TERA K15), the technique involves placing one or two blades near the object plane to enhance spatial resolution by reconstructing super-resolved images in the far-field. The improvement is demonstrated in slit diffraction, edge imaging, and reflection imaging of structures made on a paper substrate using graphite, carbon black, and inorganic pigments. Additionally, super-resolved images of an ancient document on parchment further demonstrate the effectiveness of the proposed method.

First-principles methods to evaluate and prevent the degradation of cadmium pigments in paintings.

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Several of the historical coloured pigments belonging to the paintings of the late 1800 and early 1900, are undergoing an irreversible degradation process. In the specific case of the cadmium pigments, which derive their yellow/red colouration from cadmium sulfide (CdS) and cadmium sulphoselenide ($CdS_{1-x}Se_x$), research is being conducted to understand the relationship between their electronic structure and the degradation mechanism. The study employs a first-principles approach based on the density functional theory along with various analytical techniques such as photoluminescence, FT-IR, Raman and syncrothron based X-ray spectroscopies on both historical and commercial pigments. As opposite to the investigations on novel materials, in the field of Cultural Heritage —where pigments already possess their long history— a theoretical method becomes secondary to the experimental analysis. Yet, it represents an excellent complementary tool useful in the interpretation of complex mechanisms not easily accessible by experiments. The interdisciplinary work takes advantage of various chemical and physical skills, both experimental and theoretical.

Modelli fisici dinamici di interazione applicati all'ambiente e ai beni culturali.
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Il concetto di interazione, fondamentale nello studio della fisica, occupa un grande rilievo anche per la comprensione delle dinamiche ambientali. Infatti, le strutture delle interazioni, descrivibili attraverso la quantificazione sperimentale dei flussi di materia e/o energia a diverse scale spazio-temporali, caratterizzano la forme dinamiche dei sistemi, dei quali si voglia studiare la stabilità e l'evoluzione. Lo studio di tali forme dinamiche, attraverso l'accoppiamento tra modelli e dati sperimentali, consente di rappresentare, attraverso un processo di mutua ottimizzazione, differenti fenomeni naturali. In tal senso, saranno presentate alcune linee di sviluppo e risultati teorico-sperimentali ottenuti dal gruppo di ricerca in Fisica del Dipartimento di Medicina, Chirurgia e Odontoiatria "Scuola Medica Salernitana" dell'Università degli Studi di Salerno.

Characterization of an AlN-based MEMS device for microclimate monitoring in preventive conservation of cultural heritage.
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This research aims to characterize a Micro Electro Mechanical System (MEMS) based on an AlN layer as the active material, focusing on radiation within the visible spectrum, whose intensity measurement is crucial in preventive conservation (PC) of cultural heritage (CH). The proposed micromachined sensor has the potential to convert other physical quantities of interest in the CH field by exploiting a generating material, which could reduce the occupied area and electrical power consumption. The methodology included measuring the junction voltage variation of the device to assess the effects of different light sources, integrating the use of a thermo-camera to evaluate thermal variation on the AlN layer. A computational model was developed in MATLAB to simulate variation in temperature and radiation power, contributing to the interpretation of the results. This approach provides a comprehensive understanding of the device response and the interactions between light and thermal factors

and their influence on MEMS functionality. The results are crucial to developing innovative devices and targeted microclimate monitoring strategies, opening new perspectives in the field of PC in CH.

"Living sensor" mimetici e rispettosi dell'ambiente.

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Le proprietà intrinseche e specifiche delle piante sono riconosciute come fondamentali per il benessere. Uno studio sui "living sensors", precedentemente presentato, è stato esteso con altre campagne di misurazione sulla *S. cylindrica* della temperatura e dell'umidità relativa controllate in una camera climatica al fine di comprendere possibili influenze. Il meccanismo di trasduzione per il sensing di grandezze fisiche di interesse nel contesto dei beni culturali è stato indagato tramite l'approccio dell'equivalente elettrico e attraverso la caratterizzazione in laboratorio. Tali attività sono state supportate da campagne di misurazione in siti di interesse storico-artistico, come il Castello Ursino di Catania, il Museo Nunzio Bruno di Siracusa e il Santuario della Beata Vergine dei Miracoli a Saronno. Il monitoraggio del microclima, avviato in alcuni casi più di un anno fa, ha restituito risultati promettenti, sottolineando i vantaggi dell'approccio di misurazione "green" proposto. Questa soluzione è vantaggiosa per la sua natura mimetica, il basso costo, l'ecocompatibilità e la biodegradabilità, suscitando interesse anche per applicazioni in ambienti outdoor come giardini storici.

Dispositivi innovativi per il monitoraggio microclimatico: il caso studio della Chiesa di San Biagio a Catania.

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La Chiesa di San Biagio, una delle tre legate al culto della Santa Patrona di Catania, è oggetto di una campagna di monitoraggio microclimatico che ha importanza sia dal punto di vista applicativo che metodologico. Le misure dei principali parametri fisici oggetti del monitoraggio, temperatura, umidità relativa e illuminamento, hanno infatti l'obiettivo di registrarne l'andamento su base annua per osservarne le variazioni, soprattutto in concomitanza con le diverse ricorrenze legate alla Santa. L'impatto metodologico dello studio risiede nel fatto che alle misure, realizzate con dispositivi commerciali, sono state affiancate quelle effettuate con sistemi di misura autonomi in grado di autosostenersi dal punto di vista energetico. In tale ambito la caratteristica ritenuta di maggiore impatto è infatti quella dell'energy *harvesting*, ossia del recupero di energia da fonti quali le vibrazioni, la luce e i gradienti termici e, quindi, dell'assenza di alimentazione da rete elettrica e di sostituzione delle batterie. Lo sviluppo di tali sensori è un obiettivo del progetto PNRR PE5 CHANGES: *Cultural Heritage Active Innovation for Sustainable Society.*

In situ diagnosis and monitoring of cultural heritage using NMR techniques.

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Non-destructive techniques are key to assessing the effectiveness of treatments and the state of conservation of cultural heritage. Nuclear magnetic resonance (NMR) relaxometric profiling is an innovative, non-invasive, and non-destructive candidate to address these issues directly *in situ* using single-sided portable devices. Two applications are presented: a) Conservation methods for natural stone on buildings and monuments, such as consolidation and hydrophobisation treatments to improve their long-term durability. NMR can localize the consolidation agent and the water uptake of the stone. b) Investigations of the structure of paintings providing essential information on their physical condition and pictorial technique to plan appropriate conservation measures. NMR could avoid the sampling of painting fragments for stratigraphic analysis. We present diagnostic and monitoring results from two sites in Germany: The Hoppenlau Friedhof in Stuttgart for stone monument conservation and the Gründonnerstagsretabel in the sacristy of Freising Cathedral for painting restoration. This work was supported by the Deutsche Forschungsgemeinschaft, grants FR 2912/2-1 and AN 984/24-1.

Liquid anode source for Cultural Heritage applications and development of a phase-contrast X-ray imaging setup with a Talbot interferometer.

Lo Giudice A. ([1])([2]), Guidorzi L. ([1])([2]), Boano R. ([3]), Giustetto R. ([4]), Ricchiardi G. ([5]), Trocino D. ([2]), Cerello P. ([2]), Ramello L. ([2])([6]), Di Martino D. ([7]), Vigorelli L. ([7]), Marcucci G. ([7])([8]), Pozzi F. ([2])([9]), Ricci C. ([2])([9]), Re A. ([1])([2])
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The High-Brilliance X-ray laboratory (HiBriX Lab) is under development in Torino. It is based on the use of a liquid anode X-ray source that achieves a maximum brilliance by at least one order of magnitude compared to conventional microfocus sources. HiBriX Lab was designed by integrating different detectors and focusing optics to create a unique laboratory in Italy. In particular, μXRF maps and X-ray imaging (radiography and tomography) were implemented. Recently, in the framework of the PITCH and Vi-Hi projects, Phase-Contrast (PC) X-ray imaging have also been taken into account. PC X-ray imaging shows great potential for Cultural Heritage (CH) applications, as it can provide high-quality information on micro-structural features. The use of a liquid-metal-jet source in a small laboratory will open extremely interesting prospects, with numerous potential applications in conservation, archaeology, archaeometry, anthropology, paleopathology, etc. This work is funded by SAX project (Regione Piemonte), SAXSAB and HiBriX Lab (University of Torino and Fondazione Compagnia di San Paolo), PLaMeRaX (Fondazione CRT), PITCH (PRIN2022) and Vi-Hi (INFN-CSN5).

Muonic atom X-ray Emission Spectroscopy (μXES) e X-Ray Fluorescence (XRF): confronto per l'applicazione a campioni metallici archeologici.

Monza P. ([1])([2]), Cataldo M. ([4]), Clemenza M. ([3])([4]), Di Martino ([3])([4]), Hillier A.D. ([5]), Marcucci G. ([3])([4])([5]), Oliva P. ([1])([2]), Sipala V. ([1])([2])
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Il recente sviluppo di nuove tecniche non distruttive include l'utilizzo di sorgenti di muoni per lo studio composizionale di campioni archeologici. Il progetto CHNET-Maxi, finanziato dall'INFN, intende sviluppare e implementare una tecnica innovativa basata sull'utilizzo di muoni negativi, detta μXES (Muonic atom X-ray Emission Spectroscopy), presso ISIS Neutron and Muon Source. Presentiamo i risultati ottenuti mediante μXES fornendo un confronto con una tecnica già consolidata in abito archeologico e basata sempre sull'emissione di raggi X caratteristici, ovvero l'XRF, per analisi di composizione qualitativa e quantitativa. Con la tecnica μXES è possibile fare un depth profile di tutti gli elementi degli strati superficiali fino ad 1 cm all'interno del campione mentre con l'XRF si caratterizzano gli strati superficiali fornendo una quantitativa di riferimento utile per la validazione e il calcolo delle sistematiche di misura per μXES. Pertanto, il confronto tra XRF e μXES è stato effettuato utilizzando i dati superficiali analizzando dei frammenti di navicelle votive nuragiche dell'età del Bronzo e una moneta portoghese risalente al tardo XVIII secolo.

Sviluppo di un sistema di monitoraggio dello stato di conservazione dei monumenti storici mediante analisi con fasci di neutroni.

Agugliaro A. ([1]), Tricomi A. ([1])([2]), Barone G. ([3]), Mazzoleni P. ([3])
([1]) *INFN, Sezione di Catania, Italia*
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([3]) *Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Catania, Italia*

L'utilizzo dei neutroni in tomografia consente, oltre alla ricostruzione 3D dell'oggetto, anche di identificare gli elementi presenti in tracce nel materiale, sfruttando il processo di attivazione neutronica. Tomografi a neutroni sono stati realizzati per applicazioni in ambito pittorico e scultoreo. Tuttavia, la necessità di un acceleratore che produca il fascio di neutroni non consente un'agevole acquisizione dei dati *in situ*. Per il progetto Data-Highway è in fase di sviluppo, presso l'INFN di Catania, un prototipo di tomografo a neutroni trasportabile basato su un generatore compatto deuterio-deuterio. Associandolo a un rivelatore al germanio iperpuro, sarà possibile identificare i gamma provenienti dall'attivazione neutronica. Lo strumento sarà adoperato per indagare lo stato di conservazione di beni di interesse culturale. Grazie alla sua trasportabilità, si potranno effettuare misure su elementi architettonici non amovibili (*e.g.*, colonne e pareti), al fine di valutare eventuali infiltrazioni di umidità nel materiale, favorendo gli interventi di recupero. In questo contributo verranno presentate le analisi delle simulazioni effettuate con il toolkit Geant4.

Calibrating neutron techniques for the characterisation of historical bronzes: Bragg-edge neutron transmission analysis approach.

Marabotto M. ([1])([2]), Re A. ([2])([3]), Busi M. ([4]), Grassini S. ([2])([5]), Grazzi F. ([6]), Guidorzi L. ([2])([3]), Lo Giudice A. ([2])([3]), Marcucci G. ([7])([8]), Scherillo A. ([8]), Di Martino D. ([7])
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Ancient metallurgy is crucial for understanding the artistic and technological evolution of various civilisations. Neutron-based techniques offer a non-destructive means to determine alloy and phase composition of ancient artefacts. The work here presented is part of the INFN CHNet_BRONZE project, aiming to quantitatively calibrate neutron techniques for the analysis of Cu-based archaeological items. Three methods are employed: Time-of-Flight Neutron Diffraction (ToF-ND), Neutron Resonance Transmission Imaging (NRTI) and Bragg-Edge Neutron Transmission imaging (BENT). Initially, a reference set of samples with known structure and composition is analysed to optimise the experimental parameters for the analysis of historical artefacts and help with data interpretation. The work will focus on the measurements carried out with the BENT technique, a non-destructive method that reveals composition, texture and microstructure of materials. Exploiting a 2D imaging detector, position-dependent Bragg-edge transmission spectra are acquired, enabling reconstruction of phase spatial distribution. These characteristics make this technique appealing also for cultural heritage applications.

Study of corroded archaeological bronzes through macro-XRF and reflectance spectrometry mapping.

Caglio S., Orsilli J., Galli A.
Department of Materials Science, University of Milano-Bicocca, Italy
Bronze, an alloy of copper and tin, holds an important historical presence throughout the world discovered by archaeological sites. Examination of bronze artifacts offers insights into production techniques and trade routes, but these objects are susceptible to corrosion, with copper mineral layers darkening or damaging them, as is the case with "bronze disease". Preserving this type of artwork is vital for safeguarding cultural heritage. This study investigates corroded bronze objects from different burial conditions using non-invasive mapping techniques: macro XRF and VIS-NIR-SWIR reflectance. These methods provide important information for understanding the composition of the patina and the distribution of materials, both from the elemental point of view and the compounds and minerals that are produced on the surface. Understanding corrosion in relation to burial conditions and alloy composition is critical to effective conservation and understanding alteration processes of artifacts at archaeological sites.

Comparative analysis of contact and non-contact color specification measurements.

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([1]) *Department of Electrical Electronic and Computer Engineering, University of Catania*
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This study focuses on the comparative analysis of two colorimetric specification methodologies: contact spectrophotometry (CS), with Konica Minolta CM-2600d, and remote spectroradiometry (No contact - NC) with Konica Minolta CS-1000 A. Through the use of Spectralon® reference samples, the correlation between measurements made with these two

techniques was analyzed. The black Spectralon® reference shows anomalous behavior above 70 cm. A critical range between 50–100 cm was identified, with ΔE^*ab values consistently below two for all references, indicating optimal performance. Differences emerged between achromatic and chromatic references, with optimal distances at 60 cm and between 40 cm and 100 cm, respectively. Although there are slight variations in L^* measurements, the correlation between contact and non-contact measurements remained strong. The importance of optimizing the distance to ensure reliable colorimetric measurements, especially for achromatic references, was emphasized. In conclusion, this research highlights the potential of non-contact colorimetric measurements, while emphasizing the importance of identifying the optimal experimental configurations.

Ancient handwriting attribution via spectroscopic benchmarks and machine learning: "*Clavis Prophetarum*" by Antonio Vieira.

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([1]) *Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Rome, Italy*
([2]) *Historical Archives of Pontifical Gregorian University, Rome, Italy*

Book writing is a multi-phase process spanning from initial drafting to more advanced proofing stages, which include corrections, revisions, and annotations, which ultimately refine a draft up to the final text that must be published. Here is presented a novel approach that combines X-ray fluorescence and Fourier transform infrared spectroscopies as well as machine learning to provide insights into the genesis of an ancient manuscript by recognising different iron gall inks used for author attribution. The procedure was successfully applied to "*Clavis Prophetarum*", a manuscript authored by Antonio Vieira (1608–1697) and revised by different authors. Vieira is considered one of the "fathers" of the Portuguese language. This study is expected to have an impact in the field of authentication, with potential applications to ancient and modern manuscripts and handwriting analysis.

Aula B **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica
Presiede: Guerra F. (Sapienza Università di Roma)

Relazioni su invito

▲ **Quarant'anni dal manifesto di Erice: il ruolo degli scienziati per la riduzione del rischio nucleare.**
Forti F.
Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa e Unione Scienziati Per Il Disarmo
Nel 1982 il manifesto di Erice, firmato da 100000 scienziati, sottolineava il ruolo della scienza e degli scienziati nella riduzione del rischio nucleare e come veicolo di pace. Oggi il sistema dei trattati per il controllo degli armamenti è in profonda crisi e assistiamo ad un nuovo sviluppo delle armi nucleari. In questa presentazione, stimolata dall'addendum al manifesto di Erice del 2023 e da una iniziativa dell'American Physical Society per coinvolgere maggiormente i fisici nelle iniziative volte a ridurre il rischio nucleare, saranno discussi gli aspetti di base delle armi nucleari dal punto di vista tecnico e l'evoluzione storica dei trattati di controllo degli armamenti fino alla situazione attuale, sottolineando il ruolo degli scienziati nella riduzione del rischio nucleare.

▲ **Shedding light on a rising star: A preliminary survey on the history of controlled thermonuclear fusion in Europe.**
La Rana A.
Dipartimento di Scienze della Formazione, dei Beni Culturali e del Turismo, Università di Macerata e INFN, Sezione di Roma
The present contribution will attempt to make a general survey of the main phases of the European thermonuclear fusion program, starting from the early work of the group de liaison lead by Donato Palumbo up to the establishment of the global project ITER. Spanning over five decades since the late 1950s, the survey will aim at identifying the different stages of the development of controlled nuclear fusion research in Europe through its main scientific targets, its technological hurdles and the possible solutions, analyzed in the international scientific context of plasma physics investigations. This historical-scientific review will trace a framework for a future more detailed analysis on how scientific requirements interfaced political constraints, and what were the outcomes in terms of techno-scientific decisions and solutions. The present research is carried out in the framework of the PRIN "FusEUrope - European cooperation in nuclear fusion research: from history to future policy design".

▲ **From students to professors: The road to gender equality at the Physics Institute of Milan.**
Gariboldi L.
Dipartimento di Fisica "Aldo Pontremoli", Università degli Studi di Milano
The 100th anniversary of the first Institute of Physics of the University of Milan is an opportunity to examine the role played by women, at different levels, in the foundation and training of a community of physicists. Female students, assistants and lecturers contributed

to the development of physics education and research, during the directions of Aldo Pontremoli and Giovanni Polvani, within different legislative contexts during the fascist regime and in the subsequent republican democracy. Their role in keeping the Milan Institute of Physics active was particularly crucial in the years of the Second World War. Although the percentages of female students and graduates were never small, even after the war, social habits unfavorable to an equal relationship between men and women continued to hinder the undertaking of comparable academic paths after graduation. Only in 1964, the long process of integrating graduates into the teaching staff, after a period as assistants, finally led to the assignment of the first professorship to a female professor, Constance Dilworth.

▲ **Sulla sphairopoiia. Una nuova lettura della Macchina di Anticitera.**
Amabile A.
Università degli Studi di Napoli Federico II
La Macchina di Anticitera, calcolatore meccanico-astronomico risalente al II secolo a.C., è l'unico esemplare parzialmente sopravvissuto dell'antica arte greca della sphairopoiia. In questa relazione discuterò alcuni problemi sollevati dall'esistenza di tale congegno, soffermandomi in particolare sul ruolo svolto dalla sphairopoiia nel quadro teorico dell'astronomia greca. La mia tesi è che con lo sviluppo della meccanica tra IV e II secolo a.C. divenne possibile tradurre problemi astronomici (relativi ai moti celesti) in problemi meccanici (relativi al moto delle parti di un meccanismo), dando luogo a una vera e propria "astronomia meccanica". Alla luce di tale lettura, illustrerò una possibile interpretazione del significato dei diagrammi a eccentrici/epicicli, che risulta coerente con recenti scoperte relative ai metodi utilizzati per il calcolo delle posizioni planetarie dagli astronomi babilonesi del periodo ellenistico.

Comunicazioni

● **Collazione e aggiornamento di materiali inerenti alla proliferazione nucleare e al disarmo per la formazione di cittadinanza attiva.**
Teruzzi P., Ludwig N.
Dipartimento di Fisica "A. Pontremoli", Università degli Studi di Milano
Il Dipartimento di Fisica dell'Università degli Studi di Milano dal 2014 al 2024 ha attivato - unico ateneo in Italia - il corso Armi nucleari, disarmo e proliferazione nucleare tenuto dal Prof. Paolo Cotta Ramusino. Gli obiettivi principali del corso riguardavano l'insegnamento dei fondamenti fisici degli ordigni nucleari, l'analisi del contesto geopolitico dal dopoguerra a oggi e la disamina dei trattati internazionali per il disarmo. Nell'ambito di un dottorato di ricerca in didattica della fisica i materiali del corso sono stati aggiornati e resi fruibili in una pagina web pubblica (disnuc.fisica.unimi.it), con lo scopo di fornire un supporto alla scuola secondaria di secondo grado per ampliamenti dei percorsi didattici di fisica nucleare. Nella collazione e nell'aggiornamento dei materiali, si è operato in modo da approfondire la dimensione storico-scientifica, per favorire attività pluridisciplinari di Educazione civica e nell'ottica di consolidare il profilo di cittadinanza attiva al termine del ciclo di studi. In questo lavoro si riportano infine i risultati delle prime esperienze di disseminazione realizzati in diversi istituti del territorio e in assemblee pubbliche.

● **Manhattan Project. Quando la storia è attuale.**
Lo Piano A.
Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma
Suscitare passione per la storia della fisica può sembrare un'operazione difficile. In questa comunicazione vogliamo raccontare come abbiamo ideato e realizzato un programma di conferenze sul Progetto Manhattan che ha riscosso un grande successo per un pubblico anche di

adolescenti, combinando l'uscita di un film, il racconto di storie personali, e l'identificazione personale con questioni che mostrano la loro attualità malgrado lo scorrere del tempo.

The rise of electron positron physics: Raul Gatto and Bruno Touschek's joint legacy.

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([4]) *INFN, Sezione di Roma*

Raoul Gatto's contribution to the establishment of electron-positron colliders as a fundamental discovery tool in particle physics is illustrated. His collaboration with Bruno Touschek both in the construction of AdA, the first ever electron-positron collider, and in the proposal for building a more powerful electron-positron collider, called ADONE, is highlighted, through unpublished photographs and documents. We shall recount the little-known story of Gatto and Touschek's collaboration in providing AdA's theoretical grounds, and their friendship with Wolfgang Pauli and Gerhard Lüders, crucial to their understanding of the CPT theorem as the basis for Ad'As success. We shall see how these two exceptional scientists shaped physics between Rome and Frascati, starting from their first discussions about the interest and feasibility of electron-positron collisions in 1959 up to the discovery of the J/Ψ in 1974. Gatto and Touschek's contribution to mentoring an exceptional roster of pupils and collaborators whose work contributed to the renaissance of Italian theoretical physics after the Second World War, will be highlighted.

Per una storia filosofica della cosmologia moderna: Jacques Merleau-Ponty.

Macchia G.
Dipartimento di Scienze Pure e Applicate, Università di Urbino

J. Merleau-Ponty (1916-2002) è stato un filosofo e storico francese della fisica, astronomia e cosmologia, professore di epistemologia all'Université de Paris X-Nanterre dal 1967, per anni presidente della Società Filosofica Francese, e grande sostenitore del dialogo fra filosofia, storia e scienza. Nel suo capolavoro del 1965, Cosmologie du XXe siècle. Ètude épistemologique et historique des théories de la cosmologie contemporaine, testo di rara elegante competenza storico-scientifico-filosofica, egli fa magistralmente dialogare, nel loro divenire storico, le ipotesi cosmologiche, a partire da quella di Einstein del 1917, con il pensiero filosofico, in uno scambio autentico che s'interroga sullo statuto epistemologico di questa scienza peculiare, sulle metodologie adottate dai suoi protagonisti, sui risvolti ontologici della sottostante fisica. In occasione della recente (2023) ristampa anastatica della versione italiana del 1974, credo sia fecondo tornare alla sua opera, purtroppo rimasta essenzialmente confinata all'ambito francese, che meriterebbe un respiro più internazionale e un'attenzione di quegli storici più sensibili alle radici filosofiche della fisica.

Theromathematics.

Zangari del Balzo G.
Università di Roma La Sapienza

A new exegesis of the scientific method spanning two thousand years of history, from Lucretius to Dirac, Russell and Feyerabend, can help us to trace, through the means of category theory, new logical and mathematical tools for the scientific method, making it more suitable to face the new science challenges, from climate change to pandemics. A first result of this effort is Theromathematics (from the Greek thér, wild), which allows us to understand the non- anthropomorphic laws of nature.

Nascita morte e "resurrezione" dell'effetto Piccardi.

Artemi C.

Ministero dell'Istruzione e del Merito, Viterbo

Nella storia della Fisica, e non solo, può accadere che modelli, teorie, idee vengano presentate o ritenute valide per poi essere abbandonate e in seguito ripresentate magari in forma modificate per essere accettate dalla comunità scientifica. Nella seguente comu8nicazione la storia dell effetto Piccardi viene presentata fono alla dimostrazione del suo essere un effetto di autoillusione. Poi si richiamano le molte analogie tra l'idea dell effetto Piccardi e le conclusioni a cui si è arrivati nel campo della chimica dello spin.

Relazione tra accuratezza dell'autovalutazione e performance in fisica al primo anno di università.

Testa I., Cioffi A., Galano S.

Dipartimento di Fisica "E. Pancini", Università Federico II, Napoli

La ricerca in didattica ha mostrato che l'accuratezza dell'autovalutazione, definita come la differenza tra la confidenza nella propria performance e la performance stessa, ha una relazione significativa con la motivazione, l'interesse, e i risultati di apprendimento in diversi contesti. In questa comunicazione riportiamo i risultati di una indagine sull'accuratezza dell'autovalutazione di studenti del primo anno di università in un corso di laurea di ingegneria. Il campione era composto da N=134 studenti (88 M, 46 F). Come strumento di misura sono state adattate venti domande tratte dal Force Concept Inventory. I risultati mostrano che il campione in grande maggioranza fornisce risposte sbagliate con poca confidenza ed è quindi in media sostanzialmente calibrato. Tuttavia, le studentesse si mostrano significativamente meno fiduciose nelle risposte date rispetto ai colleghi maschi sebbene il loro punteggio non sia statisticamente differente da quello degli studenti. Implicazioni per l'insegnamento della fisica al primo anno di università saranno brevemente discusse.

Studio dei fattori alla base del drop-out degli studenti del primo anno dei corsi di laurea di area STEM.

Passeggia R. ([1]), Esposito G. ([1]), Palazzo L. ([2]), Testa I. ([3])

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Il drop-out accademico, cioè l'abbandono precoce della formazione universitaria è un fenomeno che ha implicazioni negative sia sul piano individuale che sul piano strutturale dell'educazione terziaria in Italia. Nella comunicazione verrà presentato il progetto Orientation (drOpout pReventIon and EngagemeNT At The unIversity Of Naples), che studia una delle variabili psicologiche che influenza maggiormente l'abbandono universitario, l'engagement accademico (EA), inteso come il livello di investimento e affiliazione alla vita universitaria da parte degli studenti universitari. Il progetto mira inoltre ad analizzare le relazioni dell'EA con altre variabili, come la motivazione accademica, il distress, l'intenzione di abbandonare l'università, l'effettivo abbandono e la performance accademica. Il progetto seguirà longitudinalmente 2500 studenti iscritti ai corsi di laurea triennale di area STEM dell'Università Federico II. Sulla base dei risultati ottenuti si metteranno a punto interventi di prevenzione del drop-out per gli studenti ai primi anni dei corsi di area STEM e di orientamento per studenti della scuola secondaria al fine di compiere una scelta universitaria più informata.

Studio della relazione tra identità disciplinare in fisica e visione stereotipata della fisica.

Liccardo A., Galano S., Testa I.
Dipartimento di Fisica "E. Pancini", Università degli Studi Federico II, Napoli

Una delle priorità dell'UE per una crescita inclusiva è superare le disuguaglianze di genere in materia di istruzione e occupazione incoraggiando un maggior numero di studentesse verso le discipline STEM. Tuttavia, la ricerca mostra che le studentesse hanno una identità in ambito STEM minore di quella degli studenti. Nella comunicazione si presenterà uno studio che mira a indagare la relazione tra l'identità in fisica e le opinioni stereotipate sulla fisica in un campione di N = 432 studenti iscritti a tre corsi di laurea - fisica (N=141), biologia/biotecnologia (N=210), informatica (N=81). Attraverso un'analisi gerarchica dei cluster e un'analisi della varianza a due vie, emerge che gli studenti con un'identità fisica più elevata hanno una visione della fisica significativamente più stereotipata. Emerge inoltre che le studentesse con un'identità fisica più alta hanno una visione della fisica significativamente più stereotipata rispetto alle studentesse con un'identità fisica più bassa. Il nostro studio suggerisce che l'identificazione con la fisica può essere influenzata dall'adozione di una visione stereotipata della fisica diventando pertanto più debole e instabile.

Studio della percezione delle materie STEM di studenti di scuola secondaria superiore.

Fantacone F., Cimino R., Galano S., Fantozzi A., Nespolino A., Testa I.
Dipartimento di Fisica, Università Federico II, Napoli

Recentemente nella scuola secondaria di secondo grado sono stati finanziati numerosi progetti finalizzati ad avvicinare gli studenti allo studio delle cosiddette discipline STEM (Science-Technology- Engineering - Mathematics). Tuttavia, in Italia, sono pochi gli studi che indagano le percezioni e gli atteggiamenti degli studenti verso queste materie. In questa studio pertanto, abbiamo analizzato come gli studenti percepiscono un insieme di professioni e di discipline STEM o non e se questa percezione sia legata alla loro attitudine verso le STEM in generale. A tal fine è stato coinvolto un campione di N=187 studenti partecipanti al Piano Lauree Scientifiche (PLS) Fisica e si è validato uno strumento che presentava item in forma sia testuale che grafica. I risultati mostrano che, come atteso, gli studenti del PLS hanno una attitudine positiva verso le STEM ma la percezione è più informata verso le discipline che verso le professioni. Inoltre, non sono percepite del tutto come materie STEM discipline quali Geologia, Statistica e Informatica. Il nostro studio suggerisce che le percezioni degli studenti verso le STEM siano influenzate dal curriculum scolastico e dai media.

Studio della relazione tra percezione del futuro e intenzione di iscriversi all'università.

Nespolino A., Cimino R., Fantacone F., Fantozzi A., Galano S., Testa I.
Dipartimento di Fisica "E. Pancini", Università Federico II, Napoli

Recentemente, sono finanziati numerosi progetti di orientamento rivolti a studenti di scuola secondaria di secondo grado al fine di migliore di aiutare gli studenti a compiere una scelta post-diploma informata. Tali progetti mirano ad affrontare problematiche emerse a causa della pandemia e della conseguente didattica a distanza. Tra queste problematiche, la ricerca in didattica si sta sempre più interessando della percezione del tempo e del futuro da parte degli studenti di scuola secondaria in quanto si ritiene che possa avere un ruolo nelle scelte che andranno a fare gli studenti al termine della scuola. In questo studio, si è analizzato come le dimensioni della percezione del futuro siano legate all'intenzione di iscriversi all'università ed in particolare ad un percorso scientifico o STEM. A tal fine sono stati coinvolti N=4000+

studenti delle scuole secondarie superiori partecipanti ad attività di orientamento a cui è stata somministrata la scala della Prospettive Future e a cui è stato chiesto in maniera anonima di indicare l'eventuale intenzione di iscriversi ad un corso universitario. Nella comunicazione saranno presentati i dettagli dell'analisi dati tuttora in corso.

Studio dell'autoefficacia nelle materie STEM di studenti di scuola secondaria superiore.

Fantozzi A., Cimino R., Fantacone F., Galano S., Nespolino A., Testa I.
Dipartimento di Fisica "E. Pancini", Università Federico II, Napoli

L'autoefficacia è considerata uno dei costrutti più importanti per predire il successo e la performance accademica degli studenti. In questo studio ci si è focalizzati sull'autoefficacia nelle STEM. La ragione è che nella scuola secondaria di secondo grado sono stati finanziati numerosi progetti finalizzati ad avvicinare gli studenti allo studio di queste discipline ed inoltre la letteratura didattica suggerisce un effetto di genere significativo. Inoltre, in Italia, esistono pochi studi sulla percezione di autoefficacia nelle materia STEM e spesso sono limitati a piccoli campioni. A tal fine si sono coinvolti N=4000+ studenti delle scuole secondarie superiori partecipanti ad attività di orientamento a cui è stata somministrata la scala di 10 item dell'Autoefficacia Generalizzata. Dopo averne verificata l'unidimensionalità mediante analisi fattoriale, sono state condotte analisi statistiche per indagare la relazione tra l'autoefficacia percepita e il genere, il tipo di scuola frequentato, il rendimento scolastico e l'età. Sono state indagate le relazioni con l'attitudine verso le STEM. Nella comunicazione saranno presentati i dettagli dell'analisi dati tuttora in corso.

Aula Magna **ore 14:30 – 15:10**

Sezione IV
Geofisica e fisica dell'ambiente
Presiedono: Di Sabatino S. (Università di Bologna)
Todesco M. (INGV, Sezione di Bologna)

Relazione Generale

Progress and challenges to earthquake predictability.

Marzocchi W.
University of Naples Federico II

Earthquake predictability is the essential scientific ingredient for any sound seismic risk mitigation planning. But what do we really know about earthquake predictability? Since the optimistic approach to deterministic earthquake prediction in the seventies, the seismological community is moving towards probabilistic forecasts, in which seismologists can estimate probabilities for the earthquake occurrence in any specific space-time-magnitude windows. Here I describe the principles of the most reliable earthquake forecasting models in the short (days to months; Operational Earthquake Forecasting) and long (decades; seismic hazard for building code purposes) time windows, and their main physical assumptions and limitations. I also discuss the challenges that these models bring to the earthquake predictability problem, and possible future developments in this field.

Aula Magna **ore 15:10 – 15:50**

Relazione Generale

Presiede: Cifarelli L. (Università di Bologna)

Relazione Generale

Un inaspettato legame tra Galilei e Bologna —storia e prova sperimentale.

Bettini A.
Università di Padova, Dipartimento di Fisica e Astronomia "Galileo Galilei" e INFN, Sezione di Padova

Galilei, prigioniero ad Arcetri, lavora a sviluppi teorici e a nuove osservazioni, e cura l'orto e il vigneto, un "passatempo e occasione di filosofare". Il Gran Duca gli fa avere vini pregiati e Suor Maria Celeste squisiti dolci preparati dalle Monache del Convento, ma alle mortadelle ci vuol pensare di persona, da quando, appena dopo la condanna, ha appreso del loro profumo. Gliele manda, dai migliori "salaroli" di Bologna, B. Cavalieri, che ivi copre la Cattedra di Matematica. Ne discutono epistolarmente assieme agli sviluppi del metodo degli indivisibili. Alla morte di Galilei, Viviani raccoglie quanto lasciato dal Maestro, ma, preoccupato che la diffusione delle lettere possa fornire occasione alla "vile ed ignorante turba dei maligni peripatetici" di infangarne l'immagine, anche dopo la morte, ma ancora senza degna sepoltura, nasconde documenti ed oggetti in una "buca da grano" nel suo "Palazzo dei cartelloni" a Firenze. Cosa accadrà del prezioso materiale dopo la sua morte (1703) non poteva prevederlo, ed ancor meno immaginare l'importanza storica che avrebbero avuto fette di mortadella. Lo scopriamo nelle *Notizie aneddote* pubblicate da Targioni Tozzetti nel 1780.

Aula Magna **ore 15:50 – 19:30**

Sezione I
Fisica nucleare e subnucleare
Presiede: Surdo A. (INFN, Sezione di Lecce)

Relazioni su invito

▲ **L'ammodernamento dell'esperimento CMS per la fase di alta luminosità di LHC.**
Siviero F. per la CMS Collaboration
INFN, Sezione di Torino
Il Large Hadron Collider (LHC) è in corso di aggiornamento per raggiungere la nuova fase ad alta luminosità (High-Luminosity LHC o HL-LHC), con inizio della presa dati previsto nel 2029. La maggior luminosità permetterà all'esperimento CMS di studiare il modello standard con una precisione mai raggiunta prima, aumentando allo stesso tempo le possibilità di scoprire fisica oltre il modello standard. L'aumento di luminosità porterà però anche nuove sfide al rivelatore di CMS: HL-LHC sarà un ambiente sperimentale difficile, con livelli di radiazione e numero di collisioni per bunch crossing senza precedenti. La collaborazione CMS è quindi impegnata in un ambizioso progetto di ammodernamento del rivelatore (Fase 2) con l'obiettivo di mantenere le ottime prestazioni attuali, ma nel nuovo ed impegnativo ambiente di HL-LHC. In questo contributo verrà presentata una panoramica dell'upgrade del rivelatore di Fase 2, evidenziando sia i miglioramenti tecnologici che l'impatto sulla fisica di CMS, per poi passare allo stato dell'arte dei singoli sotto-sistemi e alle prospettive future.

▲ **ATLAS upgrade and perspective for HL-LHC.**
Boscherini D.
INFN, Sezione di Bologna
Per utilizzare al meglio le collisioni che LHC sarà in grado di produrre durante la fase di alta luminosità, ATLAS sta portando avanti un ambizioso programma di aggiornamento del rivelatore. La presentazione descriverà lo stato di avanzamento dei lavori, nonché i principali risultati ottenuti con prototipi, fornendo una visione dell'intero progetto di aggiornamento.

▲ **Status of the FCC feasibility study.**
Boscolo M.
INFN, Laboratori Nazionali di Frascati
This seminar will give an overview of the Future Circular Collider Feasibility Study. The luminosity-frontier electron-positron collider (FCC-ee) is part of the proposed Future Circular Collider (FCC) programme which consists of FCC-ee followed by an energy-frontier hadron collider (FCC-hh). This study is well aligned with the 2020 Update of the European Strategy for Particle Physics that requested a global feasibility study of a future 100 TeV hadron collider at CERN, with an electron-positron Higgs and electroweak factory as a possible first stage. The latest accelerator design for FCC-ee and FCC-hh with the R&D for key technologies will be presented.

Comunicazioni

The OREO (ORiEnted calOrimeter) project.

Selmi A.
Università degli Studi dell'Insubria

In recent years, several studies have been performed on the fact the crystalline nature of inorganic scintillator can heavily affect the Bremsstrahlung and Pair Production mechanisms. In fact, experimental tests have shown that when the incident beam is aligned with the crystal axes within some tenths of a degree, the electromagnetic shower development is accelerated. The OREO (ORiEnted calOrimeter) project intends to assemble and test an electromagnetic calorimeter prototype based on oriented crystals. The calorimeter will consist of a 3×3 matrix of 5 radiation length oriented PWO-UF (Ultra-Fast) crystals readout by SiPMs, followed by non oriented crystals. This contribution will present the status of the OREO project and the results of the beamtests performed at the CERN PS and SPS with a 3×1 and a 2×2 matrix of oriented PWO crystals. We will also discuss the potential application of such a detector in fixed target experiments and γ-ray telescopes.

A novel simulation approach for full-carbon 3D diamond sensors.

Buti C. ([1]), Anderlini L. ([1]), Bombini A. ([1]), Passaleva G. ([1]), Janssens D. ([2])
([1]) *INFN, Sezione di Firenze*
([2]) *CERN, Geneva, Switzerland*

Diamond is a high band-gap semiconductor widely studied for fabricating highly radiation-tolerant and fast particle detectors. 3D diamond detectors, obtained via laser graphitization of the electrodes, are studied for applications for particle detectors with timing capabilities, for dosimetry, and as beam monitors. Timing performance of 3D diamond detectors has always been limited by the high resistance of the graphite electrodes, but recently-improved fabrication technology is making this contribution to the time resolution comparable to that of detector geometry. Design optimisation thus requires novel simulation techniques properly describing the effects of resistive electrodes and detector geometry. In this work, we discuss the application of an extended version of the Ramo-Shockley theorem to the simulation of 3D diamond detectors with graphitic electrodes. The results are validated with data from a beam test at CERN and used to disentangle the various contributions to the time resolution. This work provides a sound method to optimise 3D diamond detectors' design and paves the way towards promising developments on their design and fabrication.

Caratterizzazione e risultati preliminari su sensori 3D a trincea altamente irraggiati a fluenze fino a 10^{17} 1Mev neq/cm^2.

Verdoglia M.
Università di Padova e INFN, Sezione di Cagliari

L'esperimento LHCb, al CERN, sta progettando un aggiornamento del detector (UPG2) previsto per il 2033, per far fronte all'incremento di luminosità. Per ricostruire correttamente i vertici primari e secondari, nello scenario di più elevata luminosità, è necessario sviluppare sensori ed elettronica capaci di risoluzioni temporali dell'ordine dei 50 ps e risoluzioni spaziali di 10 μm, al fine di mantenere le attuali prestazioni del rivelatore in tutta la fase di presa dati. La collaborazione TimeSPOT dell'INFN ha sviluppato dei sensori di silicio a pixel 3D a trincea capaci di soddisfare i requisiti citati. Tali sensori hanno già dato prova di raggiungere risoluzioni spaziali di 10 μm, risoluzioni temporali di 10ps con elevata efficienza di rivelazione per particelle minimo ionizzanti. Con l'obiettivo di studiare la resistenza alla radiazione dei sensori, è stata condotta una campagna di irraggiamento fino a fluenze di 10^{17} 1MeV neq/cm^2. I risultati della caratterizzazioni di queste strutture di test in laboratorio

ed al test beam sarnno presentati alla conferenza ed indicano che questi sensori sono degli ottimi candidati per l'utilizzo nei tracciatori di prossima generazione.

Certification tests of the BIL-RPC chambers of the ATLAS Muon Spectrometer Phase-2 upgrade.

Tassone G., Schioppa M.
Università della Calabria

The trigger chambers of the central region of the ATLAS Muon Spectrometer are made of resistive plate chambers (RPC). To make the most of the high luminosity upgrade of LHC, the ATLAS experiment will be equipped with an additional trigger plane in the innermost region of the spectrometer (hereinafter called BIL-RPC). This layer of trigger chambers will considerably increase the acceptance and triggering efficiency of the Muon Spectrometer, as well as the identification of muons in windows of momentum. The assembly and testing of the 112 BIL-RPC chambers under the responsibility of the INFN groups will be carried out at CERN. This communication covers the complete sequence of quality assurance and quality control tests that individual detectors and chambers must pass to be certified as "ready to install". The emphasis is on tests to be carried out with cosmic rays within a test bench specially designed for this purpose.

Timing performance comparison of SiPMs after irradiation for ALICE 3 experiment at LHC.

Maestrelli M., Carnesecchi F., Sabiu B., Strazzi S., Agrawal N., Alici A., Antonioli P., Arcelli S., Bellini F., Cavazza D., Cifarelli L., Colocci M., Durando S., Ercolessi F., Falchieri D., Ficorella A., Garbini M., Giacalone M., Gola A., Hatzifotiadou D., Jacazio N., Margotti A., Malfattore G., Nania R., Noferini F., Paternoster G., Pinazza O., Preghenella R., Rath R., Ricci R., Riganese L., Romanenko G., Rubini N., Scapparone E., Scioli G., Zichichi A.
Dipartimento di Fisica e Astronomia, Università di Bologna

ALICE 3 is the next-generation multipurpose detector, designed as an upgrade of the present ALICE experiment for the LHC Runs 5-6. One of the main goals is to build a detector for time measurements with 20 ps resolution. Silicon PhotoMultipliers (SiPMs) are among the possible candidates for the ALICE-TOF silicon based detector, due to their high efficiency and their capability to directly detect charged particles thanks to the Cherenkov light produced through the protection layer of the SiPM. Few sensors of 1×1 mm^2 area with 1 mm and 1.5 mm silicone resin, whose performances was previously studied with a beam test at CERN-PS, have been irradiated with 10^{10} 1 MeV n_{eq}/cm^{-2} and changes in performances have been studied for different overvoltages. Beam test results on SiPMs before and after the irradiation are reported for a comparison, and it is shown that, thanks to the very high signal detected on the SiPM at the passage of a charged particle, the sensors maintain an excellent time response. Besides, the Dark Count Rate (DCR) even if it gets worse after irradiation, it can be maintained at low level once an appropriate threshold is applied.

Investigating the energy resolution of LGAD sensors for the ALICE 3 experiment.

Rovati E., Carnesecchi F., Sabiu S., Strazzi S., Agrawal N., Alici A., Antonioli P., Arcelli S., Bellini F., Cavazza D., Cifarelli L., Colocci M., Durando S., Ercolessi F., Falchieri D., Ficorella A., Garbini M., Giacalone M., Gola A., Hatzifotiadou D., Jacazio N., Maestrelli M., Margotti A., Malfattore G., Nania R., Noferini

F., Paternoster G., Pinazza O., Preghenella R., Rath R., Ricci R., Riganese L., Romanenko G., Rubini N., Scapparone E., Scioli G., Zichichi A.
Dipartimento di Fisica e Astronomia, Università di Bologna
ALICE 3 is a new generation experiment in heavy-ion collision physics, scheduled to commence data-taking operations for LHC Run 5 in 2035. It aims to a significant advancement in our efforts to comprehend the challenging physics of ultrarelativistic heavy-ion experiments. The proposed experimental apparatus will be constructed entirely using state-of-the-art silicon technologies, with the aim of delivering exceptional spatial and temporal resolution. In this context, Low Gain Avalanche Diode (LGAD) sensors are being evaluated as a potential technology for the Time-Of-Flight (TOF) layer of ALICE 3's detector. Their high radiation tolerance and the time resolution near 20 ps make this sensor a optimal candidate. The primary objective of this study is to assess the energy resolution of sensors with varying thicknesses. To this goal, an ^{55}Fe source emitting beta particles and X-rays below 6 keV was employed to measure the charge profile deposited by the source, with a view to determining the energy resolution. The comparative analysis was conducted looking for significant performance differences among the sensors, particular focus on their energy resolution.

Direct experimental determination of the ^{22}Ne$(\alpha, n)^{25}$Mg cross-section with SHADES.

Mercogliano D., Best A., Rapagnani D.
Dipartimento di Fisica E. Pancini, Università di Napoli Federico II e INFN, Sezione di Napoli
The reaction ^{22}Ne$(\alpha, n)^{25}$Mg is the main neutron source in massive stars, providing the neutron flux for the weak component of s-process. Due to very low stellar energies and therefore very low cross section, direct experiments have been only able to provide upper limits below a strong resonance at 832 keV. The large uncertainties on the low energy states strongly impact the reaction rate and the nucleosynthesis predictions. The purpose of SHADES is to directly measure the ^{22}Ne$(\alpha, n)^{25}$Mg in the range of astrophysical interest between the neutron threshold and the 832 keV resonance. he measurement is performed at Laboratori Nazionali del Gran Sasso and is currently carried out using a high and stable α particle current delivered by the newly commissioned LUNA MV accelerator. To withstand such high current, a 99% enriched ^{22}Ne gas target is used. To improve the neutron detection, a suitable hybrid detector array has been built which guarantees high detection efficiency and beam-induced and external background identification. We will present the current status of the project and the preliminary results of the first experimental campaign.

Development of a new large area Micromegas detector and its readout electronics for AMBER experiment at CERN.

Alice C.
Università degli Studi di Torino e INFN, Sezione di Torino
In the context of the AMBER (NA66) experiment, various upgrades of the spectrometer are planned for the medium and long-term AMBER program. As part of this Research and Development (R&D) initiative, plans include replacing a portion of the Multi-Wire Proportional Chambers (MWPCs), previously used in COMPASS, to address their structural aging. The chosen technology for substituting the most aged MWPCs is the Micro-Pattern Gaseous Detectors (MPGD), specifically a resistive bulk MICRO-MEsh-GAseous Structure (Micromegas) detector. Currently, both the mechanical structure and the readout planes of the Micromegas detector have been designed, and the production of the first module is underway. The first test with TIGER-based front-end electronics is foreseen within 2024. Leveraging results gained from prior tests, with TIGER based FEs, and relying on the expected

signal properties for both Micromegas and Wire chambers, a new 64-channel mixed-signal front-end Application Specific Integrated Circuit (ASIC) for time and energy measurements is under development. The ongoing work on the detector and the front-end electronics will be presented.

MUSIC: proposta di detector per il Muon Collider a $\sqrt{s} = 10$ TeV.

Giraldin C. ([1]), Lucchesi D. ([1])([2]), Casarsa M. ([3]), Sestini L. ([2]), Gianelle A. ([1]), Andreetto P. ([1]), Palombini L. ([1])([2]), Zuliani D. ([1])([2])
([1]) *Università degli Studi di Padova*
([2]) *INFN, Sezione di Padova*
([3]) *INFN, Sezione di Trieste*

Tra i futuri esperimenti a collider, il Muon Collider rappresenta una alternativa per proseguire l'indagine del modello Standard alla frontiera dell'energia attraverso un vasto programma di fisica. La possibilità di ottenere interazioni pulite e di raggiungere elevate energie del centro di massa, con perdite trascurabili per radiazione da sincrotrone, consente di combinare i vantaggi tipici dei collider e^+e^- con quelli dei collider adronici. Le prestazioni del rivelatore sono influenzate dalla presenza del fondo di particelle indotte dal decadimento dei muoni lungo l'anello. Sebbene questo possa essere ridotto posizionando degli assorbitori in prossimità della regione di interazione, una componente irriducibile entra nel rivelatore complicando la ricostruzione degli eventi. Risulta fondamentale studiare in modo accurato lo sviluppo del rivelatore, considerando nuove tecnologie per migliorare la reiezione del fondo. In questo contributo verrà descritta una configurazione per collisioni di muoni a $\sqrt{s} = 10$ TeV, discutendo le prestazioni attese e ottenute per gli oggetti fisici più importanti.

Study of sidis processes at the electron-ion collider.

Polizzi L., Bellini F.
Dipartimento di Fisica, Università di Bologna

The Electron-Ion Collider (EIC), set to be located at the Brookhaven National Laboratory (USA), promises unprecedented accuracy in providing insights into the quark and gluon structure of protons and nuclei. Polarized beams will be exploited for spin-dependent measurements and to investigate how parton distributions are distorted due to the quark orbital angular momenta. In particular, the study of Semi-Inclusive Deep Inelastic Scattering (SIDIS) processes, could provide a three-dimensional characterization of the nucleon internal structure through transverse momentum-dependent (TMDs) parton distribution functions (PDFs), thus improving our current knowledge based on collinear PDFs. In this analysis, we present a simulation study of polarized SIDIS processes at the EIC involving polarized electron and proton beams. This study addresses the identification of final-state charged hadrons to reconstruct the dynamics of the process and analyze the fragmentation behaviour over various kinematic ranges.

Characterization of Time Projection Chambers (TPCs) with μRWell readout for experiments at the intensity frontier.

Scarpellini S.
Dipartimento di Fisica, Università di Roma La Sapienza e INFN, Sezione di Roma

In high precision experiments in particle physics the detectors must work properly at high rates, due to the high beam intensity. A device that reconstructs tracks made of Resistive Micro-Well (μRWell) with strip readout is at the moment under study. The μRWells are micro pattern gaseous detectors, characterized by a resistive layer between the amplification and the readout regions, that allows to reach high rates without going in the streamer regime. These detectors could be used in future $\mu \to e\gamma$ experiments; when an high intensity beam

of μ is used, it may be more convenient to reconstruct the photons by pair conversion, using a TPC with μRWell readout to track the produced e^+e^-. They are also under consideration by the nTOF collaboration, which is working on an experiment that aims to probe the existence of a new boson, named X17, that could explain the anomalies observed for the first time at ATOMKI lab. Four μRWells will be used to track the e^+e^- ejected from the performed nuclear reactions. Several prototypes of μRWells are under analysis and results of characterization studies using cosmic rays and particle beams will be presented.

ATLAS Open Data: Public access and use for education and research in high energy physics.

Van Wijk D.

Radboud University, Nijmegen, The Netherlands e Università degli Studi di Udine

The ATLAS Open Data project represents a lasting success, driven by CERN's Open Data policy. Its main goal is to provide public access to data, simulation, documentation and other resources for educational purposes, as well as, for the first time, also for research in high energy physics. This project provides data collected during proton-proton collisions at centre-of-mass energies of 8 and 13 TeV by the ATLAS Experiment during Run-1 and Run-2 of the LHC at CERN. The resources provided by the ATLAS Open Data project are accessible across various platforms and are available both online and via physical storage devices, such as USB drives. They can be used to promote the study of particle physics through Summer Schools, High School Masterclasses, engaging young students, university projects and various activities within the ATLAS Collaboration. This contribution provides an overview of the materials available within the scope of the ATLAS Open Data project and explains how they can be used for educational and research purposes. Information on the provided resources is available on a new dedicated website, developed at the end of 2023 and still under improvement.

L'attività outreach della Collaborazione ATLAS.

Di Luca A.

Fondazione Bruno Kessler e TIFPA, Trento Institute for Fundamental Physics and Applications

La Collaborazione ATLAS si dedica da diversi anni alla divulgazione scientifica, impegnandosi nel comunicare la scienza e i suoi risultati a un vasto pubblico. Queste iniziative rivestono un ruolo cruciale nell'ispirare le generazioni future e nel coinvolgere le persone, promuovendo la fiducia nella ricerca di base. Nell'era digitale, la comunicazione attraverso i social media e la realtà virtuale è diventata parte integrante della nostra quotidianità. La Collaborazione ATLAS utilizza questi strumenti per mantenere un legame con il pubblico, spesso estraneo al mondo della scienza. Attraverso i suoi canali sui social media, YouTube e le visite virtuali, infatti, la Collaborazione offre al pubblico la possibilità di immergersi direttamente nella caverna dell'esperimento. In questa presentazione, verrà offerta una panoramica delle attività svolte dalla Collaborazione ATLAS, evidenziandone l'importanza nel favorire il dialogo tra la comunità scientifica e il pubblico generale.

Study of the gas target density profile for the reaction ^{22}Ne$(\alpha,\mathrm{n})^{25}$Mg.

Vagnoni M. ([1])([2]), Best A. ([3])([4]), Rapagnani D. ([3])([4]), for the LUNA Collaboration

([1]) *Dipartimento di Fisica, Università La Sapienza, Roma*

([2]) *INFN, Sezione di Roma*

([3]) *Dipartimento di Fisica, Università Federico II, Napoli*
([4]) *INFN, Sezione di Napoli*

^{22}Ne$(\alpha, \mathrm{n})^{25}$Mg is one of the main neutron source for the creation of the heavy elements, and, due to the high uncertainty of its low energy cross section, considered an important reaction to be investigated for nuclear astrophysics. The LUNA Collaboration with the Bellotti Ion Beam Facility at the LNGS, is studying this reaction in the framework of ERC-Srating Grant SHADES. The main goals are the measurement of the cross section in the low-energy range 600-800 keV and the redetermination of the 702 keV resonance energy and strength. The accelerator at the IBF provides a high-intensity alpha beam, which impinges on a ^{22}Ne gas target, consisting of the three differential pumping stages. For a precise evaluation of the cross section, knowledge of the density inside the target chamber is required, and beam heating effects need to be taken into account. In this contribution I will present the measurements of the gas target density profile through the ^{20}Ne$(\mathrm{p}, \gamma)^{21}$Na reaction.

Aula 1D **ore 15:50 – 19:30**

Sezione II
Fisica della materia
Presiede: De Pascale O. (CNR)

Relazioni su invito

▲ **The emerging phase-space complexity of nearly reversible turbulent plasmas.**
Pezzi O.
Institute for Plasma Science and Technology, National Research Council of Italy, CNR/ISTP
Understanding the kinetic-scale dynamics of turbulent weakly collisional plasmas is decisive for tackling the fundamental issues of energy dissipation and plasma heating in space and astrophysical systems. As a result of the weak collisionality, kinetic-scale plasma turbulence naturally generates a large variety of non-equilibrium velocity-space structures in the plasma distribution function. Such an emerging complexity has been recently envisioned as a turbulent cascade occurring in the entire six-dimensional phase space. In this contribution, I will review some recent results on this topic, mainly obtained by employing Eulerian Vlasov-Maxwell numerical simulations.

▲ **Stabilità magnetoidrodinamica di plasmi di fusione confinati magneticamente: problemi aperti.**
Porcelli F.
Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino
Negli esperimenti di fusione tokamak, si ritiene che il divertore giochi un ruolo fondamentale per il controllo del flusso termico del plasma verso la parete della camera di confinamento. Tuttavia, manca ancora una comprensione a livello fondamentale di alcune instabilità MHD che dipendono in modo essenziale dalla presenza dei punti a X magnetici del divertore, dove la componente del campo magnetico poloidale si annulla. Tra queste, instabilità di modi a simmetria toroidale sembrano giocare un ruolo molto importante, poiché tali modi tendono a sviluppare singolarità nel limite MHD ideale. Queste instabilità sono scarsamente studiate, probabilmente perché il loro studio analitico e numerico è relativamente difficoltoso. In questa comunicazione, discuteremo la natura di queste singolarità e recenti progressi nello studio analitico di questi modi.

▲ **Free normal flow boundary conditions are fundamental for MHD modelling.**
Spinicci L. ([1]), Bonfiglio D. ([1])([2]), Cappello S. ([1])([2]), Chacon L. ([3]), Veranda M. ([1])([2])
([1]) *Consorzio RFX, CNR, ENEA, INFN, Università di Padova, Acciaierie Venete S.p.a., Padova*
([2]) *Istituto per la Scienza e la Tecnologia dei Plasmi, CNR, Padova*
([3]) *Los Alamos National Laboratory, Los Alamos, NM, USA*
Resistive wall boundary conditions with a free normal flow (FNF) formulation in three-dimensional magneto-hydrodynamic (3D MHD) codes have raised some interest recently. A FNF is deemed mandatory to effectively describe the fluid-magnetic coupling at the edge of a magnetically confined burning plasma. We first describe the nonlinear verification study of boundary modules between the SPECYL and PIXIE3D nonlinear MHD codes. Remarkable codes agreement is achieved on several case studies, both in reversed-field pinch (RFP) and

in tokamak configurations. We further illustrate the capital impact that FNF conditions bear on the modelling of MHD instabilities that develop at plasma edge. A comparative study, performed by SPECYL against fixed flow conditions, shows that FNF is essential for 3D MHD simulations to agree with tokamak linear stability theory. Relevant physical applications are being investigated, mainly concerning RFP quasi-laminar regimes for RFX-mod2 (PNRR project: NEFERTARI) and ITER-relevant studies of tokamak disruptions and the resulting electromechanical loads on the vessel walls. In both cases, FNF is expected to play a crucial role.

Comunicazioni

Revamping of a diagnostic neutral beam injector for a reversed field pinch experiment.

Barbisan M. ([1]), Boldrin M. ([2]), Cinnirella L. ([3]), Fasolo D. ([2]), Laterza B. ([2]), Maistrello A. ([2]), Marrelli L. ([1])([2]), Peruzzo S. ([1]), Taliercio C. ([2]), Valisa M. ([1])([2]), Zampiva E. ([1])([2]), Zerbetto E. ([2])

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The injection of a neutral beam in toroidal magnetic confined plasmas is a well-established method to measure ion flow, impurity content, ion temperature, besides intensity and direction of the magnetic field. While this diagnostic method was extensively explored in Tokamak plasmas, only little experimentation has been carried out in reversed field pinch (RFP) plasmas so far. Characterizing the magnetic field in the center of the plasma is especially relevant for RFPs, in order to properly reconstruct the magnetic configuration. For this reason the diagnostic neutral beam injector (DNBI) of the RXF-mod2 experiment in Consorzio RFX, Padua, is object of deep maintenance and upgrade. Several DNBI plants (electrical, control and data acquisition, vacuum pumping, etc.) will be renovated for improved performances and reliability. Numerical simulations are ongoing in order to properly design the duct connecting the DNBI to the toroidal chamber, so as to minimize the beam reionization losses inside the duct. This contribution discusses the technical improvements and the physics studies which led to the final design of the entire DNBI diagnostic system.

Design of diagnostic system with high temporal and spatial resolution for the electronic temperature measurement in RFX-mod2.

Milazzo R. ([1]), Franz P. ([2]), Fassina A. ([3]), Carraro L. ([1])

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The Reversed Field eXperiment (RFX), latest upgrade to RFX-mod2, is currently under construction and it will be the largest machine in the world (major and minor radii respectively of 2.0 m and 0.5 m) for plasma studies in Reversed Field Pinch (RFP) configuration. The new device has significant improvement of the diagnostic performance. Among them, a particular effort has been dedicated to increasing the experimental capability of providing more detailed information (in space and time) on the electron temperature (T_e) both in the core and in the edge region of the plasma. In this way, better understanding of the Te dynamics, such as thermal barriers which are crucial features for the confinement, will be possible. In particular, the measurements by Thomson Scattering (TS) are improved thanks

to the supplement of a new NdYAG laser, emitting 4 J energy at high Repetition Rate (RR), namely in the kHz regime. The new laser will support the existing one having RR = 100 Hz. Simultaneously, the soft X-ray (SXR) tomography system is strengthened on account of the double filter technique and it aims to a better reconstruction of the plasma topology and of the core thermal structure behavior.

Predictive plasma modelling of the new linear plasma device BiGyM using the SOLPS-ITER code.

Casiraghi I. ([1]), Scionti J. ([1]), Bin W. ([1]), Ricci D. ([1]), Furno I. ([2]), Guittienne Ph. ([2]), Uccello A. ([1])

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For future nuclear fusion reactors, a critical issue is plasma-material interactions, investigated in linear plasma devices (LPDs) as GyM, a EUROfusion facility. GyM ion flux of $< 10^{21}\,\mathrm{m^{-2}s^{-1}}$ allows to study plasma-wall interactions of tokamak main chambers, outside the divertor. To achieve divertor-relevant ion fluxes of $10^{23}\,\mathrm{m^{-2}s^{-1}}$, GyM is being upgraded to BiGyM within the NEFERTARI project funded by NextGenerationEU. In BiGyM, helicon plasmas will be generated by two 10 kW birdcage resonant antennas at 13.56 MHz, as in RAID LPD. This contribution is focused on the predictive modelling of BiGyM plasmas using SOLPS-ITER, a code package for tokamak plasma edge simulations, recently adapted to the LPD geometry. To set proper constraints for BiGyM simulations, the expected power density distribution absorbed by electrons and the radial anomalous transport coefficients are assessed through RAID plasma simulations matching experimental data from diagnostics, *e.g.*, Langmuir probes. SOLPS-ITER modelling allows to study the plasma parameter dependence on main experimental conditions, such as input power and pressure.

Boundary turbulence simulations of RFX-mod discharges.

Giacomin M. ([1]), Vianello N. ([2])([3]), Zuin M. ([2])([3]), Abate D. ([2])([3]), Barbisan M. ([2])([3]), Molisani S. ([2]), Momo B. ([2])([3]), Spolaore M. ([2])([3]), Veranda M. ([2])([3])

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One the greatest uncertainties in the success of magnetically confinement fusion is related to turbulent transport in the boundary region of fusion devices, which controls the heat flux to the wall and the access to high confinement regimes that allow high performance operation. Achieving a deep understanding of turbulent transport in this region is therefore of fundamental importance in the way to magnetic confinement fusion energy. We will show here the results of global three-dimensional boundary turbulence simulations of RFX-mod, which is a magnetic confinement fusion device located at Consorzio RFX in Padua. These simulations, carried out with the GBS code, are leveraged to characterize the main turbulent transport regimes in the boundary of RFX-mod with the aim of providing some guidance in the design of new boundary turbulence diagnostics founded by the PNRR NEFERTARI project, which will be installed in RFX-mod2. Along with RFX-mod turbulence simulations in tokamak configuration, the preliminary results of the first-of-their-kind boundary turbulence simulations in reversed field pinch will be presented.

Semi-analytical formulation of the propagation and absorption of the ion cyclotron wave in the context of DTT tokamak plasma scenario and realistic field pattern radiated by the antenna.

Francalanza V. (1), Salvia C. (2), Cardinali A. (1)(5), Ceccuzzi S. (3)(4), Mauro G.S. (1), Mishra B. (1), Pidatella A. (1), Torrisi G. (1), Mascali D. (1)
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(4) *ENEA, Frascati, Italy*
(5) *CNR-ISC, Turin, Italy*

Minority heating scenario in the ion cyclotron resonant heating context of tokamak plasma (in particular DTT tokamak under construction in the CR Frascati ENEA) has been studied by obtaining a simplified wave equation of the second order for the electromagnetic fast mode in a straight Cartesian geometry in the complex domain of the coefficients. The relevant equation which takes into account also the wave damping via the anti-Hermitian part of the relevant component of the dielectric tensor is brought back to a harmonic oscillator, Airy- or Weber-type of equation depending on the spatial variation of the coefficient, which can be in turns constant (harmonic Oscillator), linear (Airy) or parabolic (Weber). The solution in turn can be expressed in terms of the trigonometric, Airy or parabolic cylinder functions. A comparison with the full numerical integration obtained by considering the realistic kinetic profiles, and in the full spatial domain is also presented and discussed.

Advanced energetic particle transport models.

Falessi M.V. (1), Chen L. (1)(3)(4), Lauber Ph. (2), Qiu Z. (1)(5), Zonca F. (1)(3)
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(5) *Key Laboratory of Frontier Physics in Controlled Nuclear Fusion and Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China*

The ATEP EUROfusion project focuses on developing advanced transport models for Energetics Particles in reactor-relevant fusion plasmas. Within this project, a theoretical framework has been established to study gyrokinetic transport in the phase space. The main differences with usual thermal plasma transport analysis have been discussed, with a special emphasis on the assumption of scale separations between fluctuations and equilibrium meso-scale corrugations and non-Maxwellian features. This theory relies on a re-definition of plasma equilibrium in the presence of a finite level of electromagnetic fluctuations known as the Zonal State. A set of equations describing its evolution have been integrated into the ITER Integrated Modelling & Analysis Suite (IMAS), supported by stability analyses conducted using local gyrokinetic codes like DAEPS and LIGKA. Its accuracy is ensured through a validation against global gyrokinetic simulations codes like ORB5. Here, the physics foundations of the theoretical framework are presented along with applications to cases of practical interest, adopting numerical simulation tools that have been developed within the ATEP project.

Aula 1E **ore 15:50 – 19:30**

Sezione III
Astrofisica
Presiede: Nicolini G. (INAF, Osservatorio Astrofisico di Torino)

Relazioni su invito

▲ **Probing particle acceleration and transport through gamma-ray Solar flare observations.**
Pesce Rollins M. ([1]), Omodei N ([2]), Krucker S. ([3]), Klein L. ([4]), Warmuth ([5]), Veronig A. ([6]), Di Lalla N. ([2])
([1]) *INFN, Sezione di Pisa*
([2]) *Stanford University, USA*
([3]) *University of Applied Sciences and Arts Northwestern Switzerland*
([4]) *Observatoire de Paris, LESIA and Observatoire Radio Astronomique de Nancy, France*
([5]) *Leibniz-Institut für Astrophysik Potsdam, Germany*
([6]) *University of Graz, Austria*
Observations of greater than 100 MeV gamma-ray emission from solar flares with hour long duration or from active regions located behind the visible solar disk pose interesting questions regarding the acceleration sites and mechanism, the transport and interaction points of the accelerated particles during these events. Two of the most popular scenarios to explain these observations are (a) acceleration at the coronal mass ejection (CME)-driven shock with back precipitation to the solar atmosphere and (b) trapping of flare-accelerated ions in extended coronal loops or additional acceleration and release into the loop. In this contribution I will discuss the most recent results from the Fermi Large Area Telescope that help to answer some of the outstanding questions regarding ion acceleration and transport during solar flares.

▲ **The Solar Orbiter mission, a breakthrough in the exploration of the Sun and the heliopshere.**
Romoli M.
Dipartimento di Fisica e Astronomia, Università di Firenze
This running decade represents a major breakthrough in the study of the Sun and the heliosphere from space. A fleet of space solar observatories has been implemented in the last years by two Sun orbiting spacecrafts: Parker Solar Probe and Solar Orbiter. In particular, the Solar Orbiter mission, launched on February 10th, 2020, and travelling in a very elliptical orbit between 0.29 ua and 1 ua, has been designed to explore how the Sun shapes and modifies the heliosphere. The payload consists of remote sensing telescopes and in-situ instruments. Starting from February 2025, after a series of Venus gravity assist manoeuvres, the orbit will be tilted with respect to the ecliptic providing an unprecedented view of the solar poles. The main achievements will be presented with particular focus on the coronagraphic observations performed by the Metis instrument on board Solar Orbiter, designed and built by Italy.

Comunicazioni

● **Small-scale interplay between plasma and magnetic field in the solar atmosphere observed with IRIS satellite and ground-based telescopes.**
Guglielmino S.L. ([1]), Murabito M. ([2]), Ferrente F. ([1])([3]), Lezzi S.M. ([4]), Andretta V. ([4]), Ermolli I. ([2]), Romano P. ([1]), Spadaro D. ([1])
([1]) *INAF, Osservatorio Astrofisico di Catania*
([2]) *INAF, Osservatorio Astronomico di Roma*

([3]) *Università degli Studi di Catania*
([4]) *INAF, Osservatorio Astronomico di Capodimonte*
Multiwavelength, coordinated high-resolution observations of the solar atmosphere allow us to investigate the dynamic interplay between plasma and magnetic field in the solar atmosphere. Ultraviolet (UV) observations, taken simultaneously with photospheric measurements conveying information about the magnetic configuration of the region of interest, have shed light on various small-scale processes that drive coronal heating and energy release phenomena in the transition region. We report on recent results obtained using UV observations by the IRIS satellite and ground-based high-resolution telescopes that illustrate how magnetic reconnection can explain the occurrence of small-scale energetic events and their physical implications, paving the way for advancements which will be available with the future MUSE and SOLAR-C missions.

Joint investigation of the September 5, 2022, coronal mass ejection event with remote observations, numerical simulations, and in situ measurements.
Zimbardo G. ([1]), Bemporad A. ([2]), Biondo R. ([2]), Mancuso S. ([2]), Mesoraca A. ([1])([3]), Nisticò G. ([1]), Pagano P. ([3]), Perri S. ([1]), Prete G. ([1]), Reale F. ([3]), Susino R. ([2])
([1]) *Università della Calabria, Rende*
([2]) *INAF, Osservatorio Astrofisico di Torino*
([3]) *Università di Palermo*
Outstanding questions in astro- and space physics are (i) how charged particles are accelerated up to high energies and (ii) how they are transported in magnetized environments. Among candidates for particle acceleration in the heliosphere there are shocks driven by eruptive phenomena in the solar corona, such as coronal mass ejections (CMEs). We started a new research project whose main methods are (i) studying coronal shocks with both white light and UV coronagraphs, (ii) running magnetohydrodynamics simulations of CME-driven shocks using a new version of the PLUTO code, thus being able to study particle energisation, too, and (iii) analysing energetic particles observed in situ, also considering the observed magnetic turbulence levels in association with both diffusive and superdiffusive transport. Here, we show the results of applying these approaches to the fast CME event of September 5, 2022, which was observed in situ by Parker Solar Probe and Solar Orbiter, and remotely by Stereo-A, SOHO and PSP. Project "Heliospheric shocks and space weather: From multispacecraft observations to numerical modeling", funded by the Italian MUR within Next Generation EU.

Comprehensive analysis of CME-driven shocks as an input for a data-based model of solar energetic particle arrival to the Earth.
Perri S. ([1]), Pucci F. ([2]), Chiappetta F. ([1]), Nisticò G. ([1]), Malara F. ([1]), Sorriso-Valvo L. ([2])([3]), Zimbardo G. ([1])
([1]) *Dipartimento di Fisica, Università della Calabria, Rende*
([2]) *CNR, Institute for Plasma Science and Technology, Bari*
([3]) *KTH, Division of Space and Plasma Physics, Stockholm, Sweden*
Energetic particles are ubiquitous in the interplanetary space (IS) and the Sun is a powerful accelerator of particles with energies up to 1 GeV. Those particles represent a natural hazard for the functioning of commercial and scientific satellites. In addition, shock waves driven by coronal mass ejections (CMEs) are the most relevant particle accelerators in the IS. In this study, we aim at analyzing CME-driven shocks observed by multiple satellites at the solar source and in the IS. Thanks to remote observations, it is possible to reconstruct shocks in 2D and 3D and to derive their parameters at the source. The analysis is supported by in-situ observations at different radial distances and longitudes. Turbulence properties

of interplanetary CMEs are also studied, jointly with transport properties of high-energy protons accelerated at CME shocks. The parameters obtained from observations will be used as input for a test-particle model, where energetic particles interact with a 3D turbulence. This study is achieved in the context of the project Data-based predictions of solar energetic particle arrival to the Earth (PRIN-PNRR-2022).

Relazioni su invito

▲ **Sun-planet interactions in the solar system: Mercury, a paramount.**
Milillo A.
INAF/IAPS, Roma
The bodies in a planetary system are embedded into their parent star corona, thus interacting with the stellar wind and the transported magnetic field. These interactions are crucial for defining the planet present conditions and its evolution. Detailed studies of different interactions with the parent star can be done by observing the environments of the planets in our solar system. In fact, there is a variety of conditions, depending on the presence of an internal magnetic field or of an atmosphere, and on the distance from the Sun. In the solar system, the most relevant example of planet interacting with the Sun is the innermost planet, Mercury. Mercury has not a dense atmosphere but only a surface bounded exosphere, while it has a weak internal dipolar magnetic field, slightly shifted northward. The interaction of the IMF and the internal field forms a highly dynamics and quite open magnetosphere. The solar wind, the solar radiation and the interplanetary dust interact directly with the exposed surface, producing a release of material that constitute the Hermean exosphere. BepiColombo mission will allow studying Mercury's environment with a comprehensive suite of instruments.

▲ **Venus: The hellish twin sister of the Earth and a suitable analog for studying terrestrial exoplanets.**
D'Incecco P. ([1]), Filiberto J. ([2]), Di Achille G. ([1])
([1]) *INAF, Osservatorio Astronomico d'Abruzzo, Teramo*
([2]) *ARES Division, XI NASA JSC, Houston, TX, USA*
Venus is considered the most similar planet to our Earth, in terms of size and composition. Both planets share the presence of an atmosphere and active volcanism on the surface. However, unlike the Earth, Venus is characterized by a caustic surface environment with 475 Celsius degrees temperature and 90 bars pressure on its surface, which make it unfavorable for life as we know it and difficult to explore. Several missions have been selected that will investigate the interior, the surface, and the atmosphere of Venus during the next decade. One key science question for these future missions to Venus is to better understand the past and present-day volcanic activity. Venus may have hosted life on its surface in the past so, unveiling its geologic history can provide clues on how this planet developed the runaway greenhouse effect, which created such an hostile surface environment. Similarly, Venus also is a very suitable analog for the study of terrestrial exoplanets, as it has been recently proposed that some of these exoplanets may develop thick (CO_2-like) atmospheres during their geologic evolution.

Comunicazioni

● **Early-stopping SOMs as a tool to classify SSOs in space surveys.**
Sacquegna S., Nucita A.A., Franco A.
Dipartimento di Matematica e Fisica "E. De Giorgi", Università del Salento e INFN, Sezione di Lecce e INAF, Sezione di Lecce
Self-organizing maps (SOMs) are unsupervised machine learning techniques that reduce the dimensionality of a dataset while preserving its topological structure. Their implementation

corresponds to a transformation of n data points each with p variables as clusters on a two-dimensional map. This approach is widely used in astronomy due to the simplicity of the algorithm and its ability to identify unknown features emerging from the variable space. In particular, we present its use as a classifier of stars, Solar System Objects (SSOs) and galaxies in large space surveys, such as TESS. The innovation in this approach is the inclusion of an early-stopping method: by training the neural network on an input data set and, at the same time, testing its performance on an independent randomly chosen control set, it is possible to minimize the risk of over-fitting and losing the genericity of the algorithm. With the great number of important space surveys in the coming decade, an algorithm capable of swiftly handling large amounts of data and discerning SSOs from galactic or extragalactic sources will be enormously valuable.

Hazardous asteroids forecast via Markov Random Fields: A case study for Explainable Artificial Intelligence (XAI).

De Corato M. ([1]), Ferrara A. ([1]), Salini S. ([2]), Vello C. ([3])
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([2]) *Dipartimento di Economia, Management e Metodi Quantitativi, Università degli Studi di Milano*
([3]) *Dipartimento Di Fisica, Università degli Studi di Milano*

The recent interest in machine learning (ML) techniques has raised concerns about their interpretability, especially if they are to be used in physics. In physics, a good prediction should be justified by a model that connects it to fundamental principles. Graphical methods (i.e. Markov Random Field) are a good compromise between interpretability and accurate forecasting. Our study used the asteroid's hazardousness data provided by CNEOS as a dataset since the underlying physics is well-known. Therefore, we can evaluate how well these methods capture physical laws. In addition, we considered other ML algorithms like Random Forest and Support Vector Machines to have a baseline for accuracy and interpretability. Our findings suggest that graphical methods are a viable choice, as they provide a highly interpretable model with sufficient accuracy.

Advancements in relative gravimeter design for high-precision celestial event monitoring and validation.

Campion M.G. ([1]), Oliva F. ([2]), Fidani C. ([3])
([1]) *Gruppo Astrofili Polesani*
([2]) *Technion, Israel Institute of Technology*
([3]) *INGV*

Precise monitoring of the local gravitational field on Earth provides a continuous record of Earth's internal dynamic behaviors and interactions with celestial bodies; its usage extends to observing tides, planetary conjunctions, and eclipses, but also volcanic eruptions and seismic activities. This work focuses on a relative gravimeter's design process and its usage in observing planetary conjunctions. We propose a relative gravimeter based on a damped pendulum, achieving a period precision to the seventh decimal, yielding a relative gravity resolution on the order of tenths of a milliGal, obtaining an almost continuous measurement. The instrument's reliability was validated through a ten-day measurement campaign, and the results were compared with Earth tides predicted by the TSOFT program. A verification of the instrument's stability was also performed. Finally, we focus on observing the two Earth-Venus-Jupiter conjunctions in February 2021 and 2023 and the Earth-Saturn conjunction in February 2023 and 2024. The comparison of the predicted events with the gravimeter's measurements shows how the local gravitational field accurately highlights these phenomena.

Irraggiamenti con radiazione ultravioletta per applicazioni spaziali.

Murra D. ([1]), Bollanti S. ([1]), Di Lazzaro P. ([1]), Aquilini M. ([1]), Alpat B. ([2]), Bartolini G. ([3])

([1]) *ENEA, Centro Ricerche di Frascati*

([2]) *INFN, Sezione di Perugia*

([3]) *BEAMIDE S.r.l., Perugia*

Nelle missioni spaziali è di fondamentale importanza utilizzare materiali in grado di sopportare quelle emissioni solari che sulla Terra vengono schermate dall'atmosfera, quali particelle elementari e radiazioni dagli ultravioletti ai raggi gamma. Nel Centro Ricerche Frascati dell'ENEA, negli ultimi anni abbiamo messo a punto un apparato per eseguire test di resistenza per esposizioni all'ultravioletto. Tale apparato sfrutta una lampada a mercurio che emette radiazione nell'intervallo compreso tra 250 e 400 nm, con alcune righe spettrali anche nel visibile e vicino infrarosso. I materiali da sottoporre a test sono irraggiati per centinaia o migliaia di ore solari equivalenti, in una camera con elio a pressione atmosferica per evitare reazioni con l'ossigeno e favorire lo smaltimento di calore. Per garantire una più accurata riproduzione dello spettro solare UV fuori dall'atmosfera ed evitare il surriscaldamento dovuto alle componenti di luce visibile e infrarossa, ENEA sta inoltre mettendo a punto una lampada basata su emettitori a LED, bilanciando opportunamente i contributi delle varie lunghezze d'onda, con un'intensità totale variabile tra una e cinque volte quella del Sole.

Aula 1F **ore 15:50 – 19:30**

Sezione V

Biofisica e fisica medica

Presiede: De Spirito M. (Università Cattolica del Sacro Cuore, Roma e Fondazione Policlinico Universitario A. Gemelli, Roma)

Relazioni su invito

▲ **Un'analisi statistica degli eccessi di morte in Italia negli anni 2021–2022.**

Spighi R.

INFN, Sezione di Bologna

Negli ultimi anni, il mondo è stato teatro di un nuovo virus (COVID-19) che ha seminato morte in ogni luogo. Adesso che la pandemia sembra finita, è utile quantificare il numero di decessi diretti o indiretti che questo ha causato e fornire uno strumento che in futuro possa evidenziare un eccesso di morti fin dai primi giorni in cui si manifesta. L'analisi è stata effettuata sui dati provenienti dall'ISTAT, dall'Istituto Superiore di Sanità e dalla Protezione Civile, attraverso un fit cinematico con oltre 180 parametri liberi e oltre 4000 gradi di libertà: il fit è molto robusto ed essendo fatto su un periodo piuttosto lungo (dal 2011 al 2022) permette di determinare con grande precisione il numero di decessi attesi per ogni giorno e di conseguenza ogni eccesso dovuto a qualsiasi causa. L'analisi è ad ampio spettro, quindi, oltre ai dati del COVID, presenta anche gli eccessi di morte dovuti a influenze, ondate di calore o di freddo, alle differenze stagionali, annuali, di genere e di età. Di particolare interesse sono i risultati sull'aumento dei decessi nelle sempre più frequenti ondate di calore estive che potrebbero essere un segnale di cambiamento climatico.

▲ **Algorithmic biomarkers for early diagnosis of Alzheimer's disease.**

Testa C. ([2]), Pizzagalli F. ([1]), Landi G. ([3]), Tesi M.C. ([3]), D'Agostino C. ([1]), Silvagno F. ([4]), Vernone A. ([1]), Guiot C. ([1])

([1]) *Department of Neuroscience "Rita Levi Montalcini", University of Turin*

([2]) *Department of Physics and Astronomy, University of Bologna*

([3]) *Department of Mathematics, University of Bologna*

([4]) *Department of Oncology, University of Turin*

Alzheimer's disease (AD), a very common form of dementia, is characterized by progressive cognitive decline and memory loss, presenting marked and progressive brain structural abnormalities including severe brain tissue loss. Neuroimaging is a powerful tool to investigate brain structure and functionality in order to map out the course of cognitive decline toward dementia. Several studies suggest that the deposition of amyloid β protein extracellularly, the presence of aberrant tau proteins intracellularly and the dysregulation of iron homeostasis may play a significant role in the pathogenesis of AD. In this study we will present some tools for monitoring the AD trajectories, combining multimodal neuroimaging biomarkers to hallmarks of AD associated with proteins and iron accumulation. The analyses include a preliminary investigation performed on large databases, such as ADNI ($N = 1000$) (`https://adni.loni.usc.edu`), UK Biobank ($N = 50000$) (`https://www.ukbiobank.ac.uk`), OASIS ($N = 450$) (`https://www.oasis-brains.org`) and AIBL ($N = 800$) (`https://aibl.csiro.au/adni/index.html`). The results are used to propose algorithmic biomarkers to produce a tool for the early detection of AD.

Comunicazioni

Symmetry-breaking supports functional transitions in a brain network engaged in language.

Gili T. ([1])([2]), Avila B. ([3]), Pasquini L. ([4]), Holodny A. ([4]), Phillips D. ([5]), Boldi P. ([6]), Gabrielli A. ([7])([8]), Caldarelli G. ([9]), Zimmer M. ([1]), Makse H.A. ([3])
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([4]) *Memorial Sloan Kettering Cancer Center, NY, USA*
([5]) *University of New Mexico, Albuquerque, NM, USA*
([6]) *Università di Milano, Italia*
([7]) *Enrico Fermi Research Center, CREF, Italia*
([8]) *Università degli Studi "Roma Tre", Italia*
([9]) *Vienna Biocenter, VBC, Austria*

Symmetry is a cornerstone of physics, that has not yet found widespread applicability to describe living systems, even though life emerges from physics through chemistry. In this context, we focus on the human brain network engaged in language and explore the relationship between the structural connectivity (connectome or structural network) and the emergent synchronization of the mesoscopic regions of interest engaged in language (functional network). This relationship is explained by a different kind of symmetry with respect to physical symmetry derived from the categorical notion of Grothendieck fibrations. This introduces a new level of understanding of the human brain by proposing a symmetry theory of the connectome, which accounts for how the symmetry structure of the brain's network determines its coherent activity. We show that the resting state is a particular realization of the cerebral synchronization pattern characterized by a fibration symmetry that is broken in the rest-to-task transition to language. Our findings suggest that the brain's symmetry at a mesoscopic level determines its coherent function, and we can understand this relationship from theoretical principles.

Recurrence quantification analysis within rupture repair episodes in psychotherapy.

Zimatore G. ([1])([2]), Hogenhaug S.S. ([3])([4]), Orsucci F. ([5])([6]), De Spirito M. ([7])([8])
([1]) *Department of Theoretical and Applied Sciences, eCampus University, Novedrate, Italy*
([2]) *CNR Institute for Microelectronics and Microsystems IMM, Bologna, Italy*
([3]) *Clinic North, Psychiatric Hospital, Bronderslev, Denmark*
([4]) *Department of Clinical Medicine, Faculty of Medicine, Aalborg University, Aalborg, Denmark*
([5]) *Norfolk and Suffolk NHS Foundation Trust, Research and Development Hub, Norwich, UK*
([6]) *CEMHS-Centre for Excellence in Mental Health Sciences, University of Amsterdam, The Netherlands*
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Studying human change mechanisms within complex dyadic interactions involves delving into the intricate dynamics contributing to therapeutic outcomes. This work expands a novel approach to the study of human change processes, leveraging the Recurrence Quantification Analysis (RQA) method within the realm of psychotherapy. This potentially highlights how all human dyads might interact in conversational settings. In our pilot study, we analyzed a single case in detail. This study significantly enhanced our understanding of the underlying

mechanisms of collaboration rupture and repair processes within and across the psychotherapeutic treatment process. RQA is a method for analyzing time series data, particularly in nonlinear dynamics and chaos theory. It focuses on identifying patterns of recurrence in a time series. RQA is particularly useful for detecting hidden patterns and phase transitions in complex systems that may not be apparent with traditional linear methods. More recently, four subjects were evaluated to realize an idiographic comparison of multimodal management of rupture and repair segments in two good *vs.* two poor outcome sessions from four different treatment cases.

Classificazione automatica di immagini da esami in *Digital Breast Tomosynthesis* tramite algoritmi di deep learning.

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Dipartimento di Fisica, Università di Ferrara, Italia

L'avvento della *Digital Breast Tomosynthesis* (DBT) ha permesso passi in avanti nel campo della mammografia, migliorando la rivelabilità delle lesioni. Ogni esame contiene, però, un gran numero di immagini, e il processo di analisi è pi'u lungo e complicato rispetto a esami tradizionali. Sistemi CAD basati su CNN possono alleviare la mole di lavoro dei professionisti sanitari. Scopo di questo lavoro è la validazione di una rete Deep CNN che possa classificare immagini DBT tra tumorali e sane. Sono stati apportati diversi accorgimenti atti ad evitare l'*overfitting* ed il *data leakage* tra training e test set. È stato inoltre implementato un algoritmo per la mappatura dell'attivazione delle classi pesate sul gradiente che fornisca un certo livello di spiegabilità dei risultati. Durante l'intervento mostrerò i risultati ottenuti con l'architettura proposta sia nella classificazione binaria, tra immagini contenenti lesioni e sane, sia usando tre classi (immagine di organo sano, presenza di tumori benigni e maligni), usando diversi dataset e confrontando le performance con quelle di altre architetture note.

A post-processing pipeline for ^{23}Na-MRI of the brain: Preliminary applications for Alzheimer disease.

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^{23}Na-MRI is an interesting quantitative technique sensitive to tissues sodium levels. It can be a promising method for clinical applications because of the key role of sodium in physiology and in the development of many neurodegenerative disorders such as Alzheimer disease (AD). However, sodium has non-ideal NMR characteristics hampering the application of the technique: one of the challenging problems for ^{23}Na-MRI is the low signal-to-noise ratio (SNR), because of the low sodium concentration in tissues and its low gyromagnetic ratio. Moreover, sodium images analysis requires different steps that can be influenced by inter-operator variability. In this study, we developed a post-processing pipeline for sodium images analysis. The pipeline takes into account the low SNR, the B_1 inhomogeneity and the different relaxation times between calibration phantoms used to weight images and human brain tissue, and gives in output the sodium maps of the total brain and the three different brain tissues (wm, gm and csf). We applied this pipeline for both healthy controls and AD patients in order to assess correlations between standard AD metrics and sodium levels in the different brain regions.

Study of edge-preserving denoising filters for digital subtraction angiography in a clinical setting.

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Medical imaging plays a crucial role in accurately diagnosing pathologies. Digital Subtraction Angiography (DSA) is a vital technique in interventional radiology as it provides clear visualization of blood vessel morphology. However, the digital subtraction process introduces noise that needs to be promptly reduced to preserve image quality. This project aims to study and optimize two denoising filters for DSA acquisitions; these filters must be able to reduce the noise print of the image while preserving the quality of the vessels edges. The use of hospital equipment and evaluation of clinical images allows for obtaining concrete and immediately applicable results. Two edge-preserving filters for noise reduction are presented, applied to DSA images acquired with iodinated contrast medium. Subsequently, a parameter optimization process is developed for one of these filters, through the study of merit figures in phantom acquisitions and clinical images. The results demonstrate the effectiveness of the parameter optimization process based on the knowledge of the anatomical district characteristics under analysis.

High-Z plastic scintillators for an innovative SPECT detection system: The reSPECT project.

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Single Photon Emission Computed Tomography (SPECT) is a nuclear imaging technique that allows diagnosing cancer and other pathologies by investigating the physiological processes that take place inside the body. Conventional SPECT detection systems consist of a monolithic inorganic scintillation crystal coupled to an array of photomultiplier tubes. The reSPECT detection system, instead, relies on a tungsten metal frame that serves both as a collimator and as a container for the scintillator segments. The reSPECT project involves the development of innovative organic scintillators doped with high-Z impurities, to profit from the extremely fast scintillation process, while maintaining a remarkable photoelectric effect probability (despite the plastic substrate) and a low cost. Moreover, the process of polymerization used to produce such scintillator segments permits to give them any desired

size and geometrical shape. The silicon-based readout system, tuned for fast scintillation events and high rates, will have an independent channel for each scintillator segment to improve the spatial resolution. The detector will be compliant with MRI and theranostic studies.

Evaluation of denoising methods in ultra-high field fMRI data and their impact on distinct human brain regions.

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One major challenge in functional magnetic resonance imaging (fMRI) is minimizing the impact of signal noise. Ultra-high magnetic field (UHF; 7 T and above) allows for higher spatial resolutions compared to conventional field strengths, but at the cost of increased thermal and physiological noise. We tested novel denoising pipelines on 7 T fMRI data acquired from ten healthy subjects, which included motion correction, thermal denoising and physiological denoising. The pipelines were compared using two quality metrics: temporal signal-to-noise ratio and delta-variation signal. Additionally, we assessed the spatial distribution of physiological noise throughout the brain and its reproducibility across fMRI runs. We found that the pipeline including aCompCor algorithm yielded the greatest improvement in fMRI signals across all brain tissues. Specifically, we observed that cerebrospinal fluid was the brain tissue most impacted by physiological noise, with a high level of reproducibility. These findings could contribute to the optimization of region-of-interest–based denoising algorithms, enabling the selection of the most reliable source of noise to be removed from the UHF-fMRI signal.

Effect of denoising on laminar connectivity in fMRI.

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Functional connectivity (FC) between cortical layers can evaluate the directionality of the connections, but high-resolution fMRI data are affected by noise which can confound connectivity results. This study investigated how denoising impacts the strength of FC between layers of the primary motor cortex (M1) and two other regions (primary somatosensory cortex (S1) and premotor region (PM)). To this aim, datasets from 7 healthy participants were analyzed. Each participant underwent a MRI session on a Siemens 7 T including resting-state BOLD with in-plane spatial resolution of 0.8 mm, TR = 0.994 s, 540 volumes/run. All datasets were motion-corrected and denoised for thermal and physiological noise. A region of interest (ROI) containing 20 laminae was taken within M1. Two seeds from each participant's M1 were extracted: one from deeper laminae and one from upper laminae, and Pearson's r correlation coefficient was evaluated with voxels in S1 and PM. A significant reduction of FC was found for the seed-to-ROI connectivity between upper M1 laminae and PM. This result is in line with a previous study and might indicate a beneficial effect of denoising in eliminating spurious connectivity.

Materiali da costruzione e radon secondo il nuovo piano nazionale d'azione radon.

La Verde G., Ambrosino F., Gagliardo G., Imparato C., Mottareale R., Pugliese M.

Dipartimento di Fisica "E. Pancini", Università degli Studi di Napoli Federico II, Napoli

L'esposizione alle radiazioni ionizzanti di origine naturale e la conseguente radioprotezione è una tematica sempre più rilevante sia in campo scientifico che normativo. Per quest'ultimo aspetto, il riferimento è il D.Lgs. 101/2020. Inoltre, relativamente all'esposizione al gas radon, di recente pubblicazione è il Piano Nazionale d'Azione Radon (PNAR), uno strumento che ha lo scopo di determinare le azioni per gestire i rischi a lungo termine, in ambiente di vita e di lavoro. Il tema dei materiali da costruzione viene affrontato all'interno dell'Asse 2, in particolare dell'Azione 2.3 che rappresenta l'obiettivo di questo lavoro. Sono stati condotti studi su un particolare tufo grigio della zona nord-est della Campania, prodotto dall'eruzione dell'ignimbrite circa 39.395 anni fa e utilizzato per la costruzione di gran parte del borgo. Attraverso misure con spettrometria gamma per Ra-226, Th-232, K-40 e con camera a raccolta elettrostatica per la discendenza del radon, sono stati ottenuti i valori del coefficiente di emanazione, e del rateo di esalazione sia per il Rn-222 sia per Rn-220.

Aula D **ore 15:50 – 19:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiedono: Galli A. (Università di Milano Bicocca)
Mandò P. (Università di Firenze)

Relazioni su invito

▲ **Characterization of inhomogeneous samples in the CH field: From AR-XRF to XAS, how far X-ray spectroscopies techniques can go.**
Orsilli J.
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The variety and history of cultural heritage objects pose a challenge to the analysts due to the numerous parameters involved: raw materials, technology, and deterioration phenomena. Many of these materials are thus inhomogeneous, due to the nature of the object; or due to the aging process that causes the formation of corrosion layers. Analysis of cross-sections immediately gives information on the layered structure; however, it is not always possible to collect them, especially for extremely precious or rare samples. In this contribution, we will discuss how emission and absorption X-ray spectroscopy, which are both considered non-invasive bulk techniques, can be employed to analyze a selected volume of the sample, like in the case of luster renaissance ceramics. We will focus on the application of angle-resolved XRF to characterize the distribution of the elements inside the sample, whose concentration depends on the composition and thickness of each layer observed; and the combined application of total electron yield and fluorescence yield XAS, which allows us to distinguish not only the presence of the elements but also their oxidation state in the surface and the bulk.

▲ **La spettroscopia Raman per la caratterizzazione e l'autenticazione di ceramiche archeologiche.**
Sodo A., Privitera A.
Dipartimento di Scienze, Università degli Studi Roma Tre, Roma, Italia
La spettroscopia Raman è una fra le tecniche più utilizzate per la caratterizzazione dei materiali e per l'identificazione dei prodotti di degrado, e può fornire un importante contributo all'autenticazione delle opere d'arte. In questo contributo, verranno illustrati tre casi studio, investigati nel laboratorio SpectraLab, su manufatti ceramici pseudo-archeologici in deposito permanente presso il Laboratorio del Falso, un centro di studi per il contrasto alla falsificazione dell'opera d'arte, presso il Dipartimento di Studi Umanistici di Roma Tre. In particolare, verranno presentati e discussi i dati raccolti da due unguentari ad imitazione dello stile etrusco-corinzio del VII–VI sec. a.C., da due vasi decorati a figure rosse ad imitazione della ceramica italiota (stile incerto) e da un'anfora decorata a figure rosse ad imitazione dello stile apulo del IV sec. a.C. Le opere analizzate mostrano un diverso grado di abilità dei falsari, che si è tradotto in una gradualità nella complessità interpretativa dei dati acquisiti. Per ciascun caso, verrà messo in evidenza lo specifico contributo della spettroscopia Raman, che ha fornito importanti indizi sul modus operandi dei falsari.

▲ **Scientific methods applied to cultural heritage analysis: The study of Kha's grave goods by means of X-ray Computed Tomography.**
Morigi M.P. ([1])([2]), Bettuzzi M. ([1])([2]), Brancaccio R. ([1])([2]), Riccardizi C. ([1]), Amjad N. ([1])
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Nowadays, the study of cultural heritage is increasingly based on a scientific multidisciplinary approach, in which the synergy of various analytical techniques plays a key role to address inquiries concerning the composition, dating, manufacturing technique and state of conservation of an ancient object or work of art. The research activity of our group fits into this context and is focused on the development of innovative systems for X-ray Computed Tomography (CT), a powerful non-destructive technique able to give morphological and physical information on the inner structure of the objects. Our CT systems can perform the analysis of artifacts of various types and size both in the laboratory and on-site. In June 2023 we transferred one of our systems to the Egyptian Museum in Turin for the investigation of several items from Kha's grave goods, still regarded nowadays as the richest non-royal burial assemblage ever found in Egypt. In particular, this contribution will illustrate some interesting results from the CT analysis of six wooden boxes and five terracotta amphoras, also focusing attention on the difficulties that need to be faced when carrying out CT investigations on site.

Comunicazioni

● **Transportable x-ray CT systems for Cultural Heritage diagnostics: Development, operation and case studies.**
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X-ray Computed Tomography (CT) is a pivotal non-destructive technique in Cultural Heritage diagnostics, offering 3D insights into object structures. Our X-ray imaging group has developed two compact and transportable systems for on-site and laboratory analysis of artworks and archaeological artifacts, at different resolutions. Both systems feature a VARIAN PS2520D flat panel detector, with a pixel size of 127 μm ensuring high-resolution imaging. The first, employing a KEVEX PXS10 microfocus X-ray tube, excels in medium-size object analysis, providing a voxel size of 50–100 μm. Conversely, the second system, featuring a YXLON SMART EVO 200D 1 mm focal spot X-ray tube, is intended for large-size objects with a typical resolution of 200–300 μm. These systems have been instrumental in the investigation of a wide range of objects different in nature, shape and size, showcasing their versatility and efficacy in Cultural Heritage preservation and restoration endeavours. In this study, we provide details about the development of these CT devices, outlining their functionality, technical specifications, and demonstrating their application through real case studies with specific examples.

● **Non-invasive physical analyses on painted wall plasters from the church in the summa cavea of the Greek Theatre in Agrigento.**
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This work aims to present an archaeometric research conducted through non-invasive physical analyses on some fragments of painted wall plasters from the Greek theatre of Agrigento, in the Valle dei Templi Archaeological Park. This site is related to the multidisciplinary research PNRR project SAMOTHRACE. The fragments were found in the summa cavea of the theatre, where a large building belonging to a church seems to have been constructed around the 7th century a.D. The research is part of a broader multidisciplinary project, which aims to cross archaeological and scientific data, in order to completely focus on the context under analysis and, in particular, on the relationship between the construction of the church and the ancient use of the theatre. Among all the available fragments, eight monochromatic wall plasters were selected, red, white and blue in colour, which —on the pigments and also on the preparatory layers— were subjected to investigations using Raman spectrometry, spectrophotometry and XRF. The analyses led to the preliminary conclusion that the painted wall plasters were made by pigments of hematite, calcite and Egyptian blue.

Characterization of seals from the Santi Quattro Coronati complex (Rome, Italy): A multi-analytical techniques approach.

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This study employed a multi-analytical approach to investigate and characterize seals found at the Santi Quattro Coronati complex in Rome. These seals were discovered during the excavation of a section of the tower, which had served as a disposal pit in the Early Modern Age. In the archeological context, alongside the seals, fragments of paper and parchment manuscripts were also recovered during the excavation. Non-destructive analytical methods such as Fourier Transform Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray Spectroscopy (EDS) were utilized in this work, followed by a statistical analysis. Our goal was to characterize the artifacts and gain insights into the evolution, production and manufacture of seals by combining multiple techniques for analytical examination.

The stable isotope analysis to investigate the "way of life" of ancient community of Pompei.

Lubritto C.
Dipartimento Scienze e Tecnologie Ambientali, Biologiche e Farmaceutiche Università della Campania "Luigi Vanvitelli" e Marea Centre

Recent excavations at the World Heritage Site of Pompeii have led to an increasing interest in this Roman town, with a growth of research project and scientific publications. In this contribution we present the results of a multidisciplinary research, in which, using different innovative methodology of isotopic mass spectrometry, the "way of life" of people of the ancient community of Pompei is analyzed. In detail we present stable C and N isotope results from faunal and botanical remains from Pompei, with the aim to provide new

direct evidence for the local production or importation of food sources, reflecting on the management strategies of crops and animals adopted by the Romans in a time and location of rapid economic growth. Moreover we investigated infant feeding practices at the core of the Roman Empire through high-resolution Bayesian modeled stable isotope measurements from incremental dentine, in order to infer how socio-economic and cultural contexts heavily influenced the duration of breastfeeding. Finally a systematic study of human paleodiet, by using compound-specific isotope analysis of amino acids, gives us a clear picture of "way of life in Pompei site" by common person.

Multi-technique characterization and provenance determination of white marbles from the site of the Roman villa in Fiumana (Forlì-Cesena, Emilia-Romagna, Italy).

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Several white marbles have been uncovered during the most recent archaeological excavations at the site of the Roman villa in Fiumana (Forlì-Cesena, Emilia Romagna, Italy). They are decorative elements: fragments of reliefs and slabs for floors and walls. Samples were investigated by means of a multi-method approach using micro-Raman spectroscopy, optical microscopy (OM), X-ray powder diffraction (XRPD) and stable isotope ratio analysis (δ^{18}O and δ^{13}C). OM on thin sections and XRPD revealed the mineralogical-petrographic features, in terms of microstructure and mineral phases, respectively. Interestingly, micro-Raman analyses highlighted these peculiar features through the use of a single technique. The main and accessory mineral phases were identified and related to the crystal morphology. The combination of these data with the determination of the O and C stable isotopic ratio suggested the possible provenance of white marbles of Fiumana. Through the comparison of these results with international databases and available studies about Mediterranean white marble quarries used in antiquity, decisive information to archaeologic investigation were revealed.

Combined use of 3D X-ray microscopy and correlative microscopy for chemical-physical investigation of bronze Phoenician coins.

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High-resolution and non-destructive 3D imaging and tomography offer multi-length scale visualization of archaeological artifacts and provide as much physical and microstructural information about the objects as possible. This research presents a correlative microscopy workflow, encompassing X-ray Microscopy (XRM), μ-Raman spectroscopy and Correlative

Light and Electron Microscopy (CLEM), to investigate Phoenician-Punic bronze coins dating back to the 5th–4th century BC. In this context, XRM revealed internal features and hidden sample details, enabling us to estimate and analyze irregularities such as cracks and pits inside the coins, as well as to examine the phase composition. CLEM analysis, conducted via cross-section preparation of the coins, provided details about corrosive phases, and exhibited notable differences in terms of their elemental composition and microstructures, resulting from physical stresses and exposure to environmental conditions. This research presents broader applications of interest in the field of materials science technology, as it not only enhances our understanding of ancient coins, but also accelerates and improves data acquisition and processing.

Exploring Tumshukayko: A monumental site in Peru investigated through OSL analysis.

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Tumshukayko is an ancient, monumental site in the north-central Andes of Peru, specifically in Caraz, Ancash. Built around 3500 BC, it has been rebuilt at least twice. Preliminary studies suggest that some remodeling phases may be associated with catastrophic floods. The exploration of Tumshukayko began in 2021 with a topographic survey that included the collection of a terrain sample for Optically Stimulated Luminescence (OSL) dating analysis. The first phase concentrated on exploring an open gallery known as Galleria Raimondi. The following years, 2022 and 2023, saw an expanded exploration effort: various test pits were excavated to investigate the site's morphology, chart its chronological evolution, and delineate its construction chronology. This involves determining the age of the buried sediments and rocks (in the latter case using surface dating technique) by OSL. The multigrain sand-sized quartz method was applied for the dating of sediments, while the fine-grain technique was employed for rock surface dating.

The archaeological mission to the Erbil plain (Iraqi Kurdistan) project: Unveiling the ancient history of a tell.

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The Italian Archaeological Mission to the Erbil Plain (Iraqi Kurdistan), conducted by the University of Milan, has shed light on the region's ancient history, spanning from the Neolithic to the Medieval period. Excavations have revealed a multi-layered settlement, known as a tell, rising over 20 meters above the surrounding plain. The site of Hellawa exhibits a continuous occupation sequence from the Halaf and Ubaid periods through the Late Chalcolithic and Early Bronze Ages, culminating in the Islamic era. To establish an absolute chronology, 25 samples were collected for ^{14}C-AMS analysis in collaboration with the Lambda laboratory at the University of Milan-Bicocca. A targeted sampling of short-lived materials (seeds, charcoals) associated with stylistically well-dated objects (ceramics, tools) has enabled the reconstruction of the tell's occupation with continuity, highlighting the areas occupied during different historical periods and the phases of abandonment of the site. The application of Bayesian statistics, combining phases, stratigraphic sequences, and stylistic elements, has significantly refined the definition of the site's occupational phases.

Tracing lapis lazuli provenance with ion beam analysis: The case of Egyptian amulets from Heliopolis.

Magalini M. ([1]), Guidorzi L. ([1]), Re A. ([1]), Lo Giudice A. ([1]), Terzoli M. ([2]), Turina V. ([2]), Lemasson Q. ([3]), Pacheco C. ([3]), Pichon L. ([3]), Moignard B. ([3])
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Lapis lazuli has been used since the VII mill. BCE to craft precious objects in ancient Middle East, Egypt, and Asia. The Badakhshan area (Afghanistan) is believed to be its primary source in antiquity, although other possible quarries have been debated by scholars. Analyzing the physical-chemical properties of the minerals in the rock is an effective way to differentiate between various provenances. Since 2007, our group is using Ion Beam Analysis (IBA) for this purpose. IBA are highly suitable for analysing valuable artifacts due to their non-invasive approach. Using proton-induced X-ray emission and ion-beam–induced luminescence on reference rocks from Afghanistan, Tajikistan, Siberia, Chile and Myanmar, markers were identified to establish a provenance protocol. Exploiting the in-air beam of the NewAGLAE accelerator (C2RMF, France), this protocol was recently applied to 7 lapis lazuli amulets from the Late Period (722–332 BCE) discovered in Heliopolis by Ernesto Schiaparelli and now part of the Museo Egizio (Turin) collection. This research will enhance our knowledge of the raw material sources for these amulets, also providing insights into the trade routes of the time.

Active thermography for structural and technical analysis of the cultural heritage of the Naples area.

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Imaging techniques represent non-invasive analyses today commonly used for the study and investigation of works of art in the cultural heritage field. They can provide structural and technical information useful for its conservation or for planning the most appropriate intervention strategy for a restoration work. Among imaging techniques Active Thermography (AT) is a reliable, non-invasive and non-contact method for providing *in situ* analysis of a work of art. We apply AT analysis using different methods for thermal stimulation. The acquired infrared images are analyzed in both the spatial and temporal dimension by combining the results achieved from various post-processing analysis including: Principal Component Thermography (PCT), Absolute Thermal Contrast (ATC) and Thermal Recovery Time (TRT) method. In this communication, different applications of AT for pre-restoration analysis of paintings, artefacts, historical buildings and archeological sites belonging to the cultural heritage of the Naples area are shown and discussed.

Aula B **ore 15:50 – 19:30**

Sezione VII
Didattica e storia della fisica
Presiede: Carpineti M. (Università di Milano)

Relazioni su invito

▲ **Facilitating the adoption of investigative learning environments through technologies: Insights from the ADELANTE project.**
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The ADELANTE (Adopting Digitally Enhanced Laboratories in a Network of Teachers) project, funded within the PRIN 2022 funding scheme, aims to facilitate the adoption of investigative learning environments in high schools by leveraging technologies such as Arduino microcontrollers and smartphones. The project embraces a paradigm of "authentic collaboration" between teachers and researchers. In the initial phase, a national network of 15 "teacher leaders" was established to develop laboratory-based teaching-learning sequences, which will be shared and piloted within a wider teacher community in the second year. The research questions focus on (1) the learning outcomes that can be enhanced by using digital technologies in instructional laboratories, and (2) how teachers' competences regarding the use of technology-enhanced laboratories develop across different professional development opportunities. In this contribution, I will describe the project structure and outline its findings after the first year.

▲ **Sperimentare a scuola: il progetto LSOSA per promuovere la didattica laboratoriale nelle scuole.**
De Angelis I. ([1])([2]), Mobilio S. ([1]), Meneghini C. ([1]), Brancaccio A. ([3]), Cifelli F. ([1]), Rampioni G. ([1]), Venditti I. ([1]), Conte A. ([4]), Mancinelli C. ([4]), Borgi E. ([4]), De Paolis P. ([5]), Casini G. ([5])
([1]) *Università degli Studi Roma Tre*
([2]) *INFN, Sezione di Roma Tre*
([3]) *Ministero dell'Istruzione e del Merito*
([4]) *Accademia delle Scienze di Torino*
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Le attività sperimentali sono essenziali per stimolare il ragionamento scientifico, ma sono spesso trascurate nella formazione STEM. Il progetto LSOSA (Laboratorio di Scienze Obiettivi Specifici di Apprendimento) nasce nel 2013 per promuovere la pratica laboratoriale nelle scuole e supportare gli insegnanti nella progettazione e nella realizzazione di attività sperimentali. Sul sito del progetto è pubblicato un archivio di oltre 200 attività di laboratorio realizzate in collaborazione con i docenti di scuola superiore, ognuna accompagnata da una scheda dettagliata che comprende la raccolta e l'analisi dei dati. Le attività si basano sull'idea di laboratorio inteso non solo come luogo fisico, ma anche e soprattutto come attitudine a osservare i fenomeni, a collegare le quantità osservate in relazioni causali e modelli matematici, a raccogliere e analizzare i dati. Esse traggono spunto dalla realtà quotidiana e usano materiali e strumenti facili da reperire. Dal 2023 il progetto è stato esteso anche alla scuola media coinvolgendo docenti della scuola secondaria di primo grado.

Comunicazioni

Misconoscenze di fisica nella scuola del I ciclo: una prima sperimentazione.
Torre M. ([1]), Calvani A. ([2]), Leone M. ([3])
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([2]) *Associazione SApIE, Italia*
([3]) *Università di Torino*
Il conseguimento di un adeguato livello nelle conoscenze scientifiche è riconosciuto come un importante traguardo non solo per formare futuri scienziati ma soprattutto per consentire alle nuove generazioni il possesso di competenze per una cittadinanza responsabile e criticamente informata. Per ciò che riguarda l'Italia le comparazioni internazionali evidenziano l'accentuarsi di particolari criticità in questo ambito. Per ciò che riguarda la ricerca delle azioni didattiche volte a migliorare la comprensione dei fenomeni fisici rimane fondamentale comprendere le preconoscenze da cui muovono gli alunni con gli ostacoli cognitivi che queste comportano. Abbiamo allestito e validato un questionario per mettere in evidenza gli elementi di criticità più diffusi nella spiegazione di fenomeni fisici da parte di alunni di età 11-14. I dati raccolti confermano la presenza di diffuse misconoscenze già segnalate in letteratura che è opportuno mettere al centro dell'attenzione dei docenti. Il questionario si completa con un feed formativo che intende fornire prime indicazioni per una loro revisione.

Scienza per Gioco: un'esperienza di apprendimento non-formale per la scuola primaria.
Bozzo G., Sapia P.
Dipartimento di Matematica e Informatica, Università della Calabria e Agorà LAB, Università della Calabria
L'integrazione di esperienze di apprendimento non-formali nei percorsi formali in ambito STEM è elemento motivante e in grado di promuovere la corretta percezione delle scienze, contribuendo all'educazione civica scientifica. In Calabria si registra una grande richiesta, da parte delle scuole primarie, di occasioni e ambienti di apprendimento non-formali da integrare nella progettazione curriculare in ambito STEM. Perciò, il laboratorio Agorà LAB dell'UniCal propone al territorio un'annuale iniziativa di apprendimento non-formale denominata Scienza per Gioco, che consente a bambini/e della scuola primaria di vivere la scienza attraverso una serie di attività laboratoriali progettate, allestite e condotte da studenti/esse del CdLM in Scienze della Formazione Primaria. L'evento offre, inoltre, ai docenti un'esperienza dalla quale trarre stimoli e spunti innovativi per la didattica curriculare basata su attività laboratoriali e per la sua integrazione con i contesti non-formali. Viene qui presentato l'evento e descritta l'azione di follow-up che permetterà di valutarne l'impatto sulla percezione della scienza che i partecipanti continueranno a sviluppare nel percorso curriculare.

Le esercitazioni del corso di Fisica e Didattica della Fisica a Scienze della Formazione Primaria: spazi di apprendimento per formare gli insegnanti di oggi e domani.
Albani G. ([1]), Cancelli S. ([1]), Marcucci G. ([1]), Musa M. ([2]), Onida M. ([1]), Rozza D. ([1]), Testa M. ([1]), Di Martino D. ([1])
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Il corso di Fisica e Didattica della Fisica con Laboratorio del Corso di Laurea Magistrale a ciclo unico in Scienze della Formazione Primaria dell'Università Milano-Bicocca si rivolge a circa 500 iscritti spesso poco interessati alle materie scientifiche ed in particolare alla fisica,

percepita dai più come difficile, astratta e lontana dalla quotidianità: uno degli obiettivi dei docenti è quindi quello non solo di fornire contenuti disciplinari, ma anche quello di (ri)svegliare la curiosità e l'interesse verso lo studio dei fenomeni naturali. Per questo motivo, oltre alle lezioni e al laboratorio, da molti anni agli studenti è offerta possibilità di frequentare delle ore di esercitazioni. Descriveremo in particolare questi momenti e spazi di apprendimento durante i quali poter sperimentare ed esplorare, in piccoli gruppi, diversi fenomeni, utilizzando un approccio laboratoriale che parta dall'osservazione e dalle domande e che conduca alla formulazione di ipotesi, attraverso un percorso di ricerca. Nella maggior parte delle esperienze si utilizzano materiali di uso comune, perché siano un modello concretamente trasferibile nelle realtà scolastiche di infanzia e primaria.

Un percorso didattico sul concetto di energia nella scuola primaria: benessere cognitivo e autoefficacia in base al genere.

Giarratano G. ([1]), Battaglia O. R. ([2]), Termini G. ([2]), Fazio F. ([2])

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Nonostante negli ultimi anni il divario di genere in ambito educativo e lavorativo si sia notevolmente ridotto, le recenti ricerche dimostrano che i percorsi di istruzione non sono ancora paritari. Molti studenti optano per scelte formative stereotipate per genere, con le studentesse sovrarappresentate in alcuni ambiti e sottorappresentate in altri. In particolare, alcune discipline STEM, come fisica, ingegneria e informatica, continuano ad essere appannaggio dei maschi. Le disparità di genere trovano il loro fondamento negli stereotipi, i quali influenzano i valori dei contesti culturali e il percorso educativo degli studenti. Quest'ultimi iniziano ad essere condizionati dai pregiudizi fin dalla scuola primaria e, soprattutto nelle studentesse, ciò influenza negativamente il senso di autoefficacia e di appartenenza verso alcune discipline STEM. Viene presentata la nostra ricerca volta allo studio della promozione del benessere e dell'autoefficacia da parte degli alunni delle scuole primarie nelle discipline scientifiche, con particolare attenzione alle differenze di genere, attraverso un percorso didattico di tipo Inquiry-Based sul concetto di energia.

Geometry week for kids: Science adventures for primary school students.

Stroppa A.

CNR-SPIN, L'Aquila

We strongly believe that "Nothing in science has any value to society if it is not communicated, and scientists are beginning to learn their social obligations" (A. Roe). Geometry Week for Kids (GWKs) is a week designed for implementing significant cross-disciplinary STEM learning activities for primary school students to strongly favour positive attitudes towards science. Indeed, in the new era of an information-based and highly technological society, students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past, starting right from the beginning of their school career. Our aim is to bring very young students closer to the world of science by playing and having fun with mathematics and science in general, starting from geometry, which is inevitably linked to awareness that the child has of the world, of life, of time and of the space that surrounds him. In this way, they will be provided with an unsual and captivating point of view on Geometry, Physics and Chemistry, from an interdisciplinary perspective, with operational discovery paths, interactive activities and augmented reality experiences.

Imaging nei processi di insegnamento/apprendimento della fisica e nella comunicazione della scienza.

Sapia P., Bozzo G.
Dipartimento di Matematica e Informatica, Università della Calabria e Agorà LAB, Università della Calabria

Gli strumenti di visualizzazione (di fenomeni reali, di esperimenti mentali, di modelli analogici) sono riconosciuti come una risorsa fondamentale a servizio sia dei processi di apprendimento che di comunicazione della scienza. I supporti visuali a integrazione di varie metodologie didattiche sono indicati come fattori "che possono facilitare la costruzione da parte degli studenti di modelli mentali per la conoscenza scientifica" (Piyatissa et al. 2018). Nel vasto campo delle tecniche e metodologie di visualizzazione, un ruolo speciale è giocato da quelle volte a produrre immagini di oggetti e fenomeni reali (imaging). Queste possono essere eseguite nella banda visibile o nell'infrarosso; possono consistere in immagini statiche o in filmati, sia a velocità normale che ad alta velocità, così come in time-lapse. In questo contributo viene offerta una panoramica delle tecniche di imaging implementabili in contesto didattico, con specifico riferimento ad alcuni aspetti originali sviluppati dagli autori. Verranno inoltre discussi esempi di utilizzo, inclusa la realizzazione di attività di tipo Interactive Lecture Demonstrations basate su video e immagini.

Percezione della scienza nella scuola primaria e questione di genere: esiti di un'indagine nazionale.

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L'alfabetizzazione scientifica è cruciale per costruire nel nuovo millennio una società moderna capace di affrontare consapevolmente le opportunità e le sfide indotte dai progressi tecnologici, di vivere responsabilmente e costruire un futuro sostenibile, di prendere consapevolmente decisioni partecipando attivamente e criticamente ai dibattiti pubblici. In questo quadro emerge il ruolo dell'Educazione Civica Scientifica e la necessità di curarla sin dai primi anni della scuola primaria. D'altra parte, la percezione della scienza influenza gli atteggiamenti sociali nei suoi confronti, specialmente tra le giovani generazioni, condizionandone le scelte future. Per elaborare strategie atte a contrastare il declino dell'interesse per le carriere scientifiche è necessario comprendere come bambini e bambine in età scolare percepiscono la scienza, in particolare la fisica, e chi la pratica. Il laboratorio Agorà LAB, in collaborazione con il centro di ricerca GEO, ha condotto su scala nazionale lo studio "Disegna una Persona che Fa Scienza" per esplorare tali percezioni. In questo contributo vengono presentati e discussi gli aspetti di genere emergenti dall'analisi di circa 1700 disegni.

Il progetto Ambasciatrici di Scienza dell'Università Milano Bicocca.

Di Martino D.
Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano Bicocca

PISA (acronimo di Programme for the International Student Assessment) è un'indagine che valuta gli studenti quindicenni principalmente nelle loro capacità di lettura, matematica e

scienze. Per quanto riguarda i risultati italiani del 2022, si è delineato un record negativo: il maggior divario di genere in matematica. Il divario di genere (o gender gap) è un problema ben noto, che è emerso anche da altre indagini (come TIMSS) e riguarda anche altri Paesi. Il progetto Ambasciatrici di Scienza si propone di offrire alle classi delle scuole superiori l'opportunità di incontrare le dottorande dell'Università Milano Bicocca in ambito STEM, in una serie di sessioni in cui giovani scienziate raccontano la loro esperienza, le loro ricerche e le loro prospettive di carriera. Il coinvolgimento delle sole scienziate è motivato dall'idea di aumentare l'interesse per le STEM anche tra le studentesse, decostruendo gli stereotipi e fornendo modelli di ruolo che possano ispirare le scelte universitarie delle studentesse. Saranno presentati i risultati dei primi due anni di attività, partendo da un approccio STEM multidisciplinare, con azioni formali e non formali.

inVISIBILI outreach project.

Jiménez D., Merkel E., Bellini F., Fabbri L., Pascoli S.

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inVISIBILI is a collaborative outreach and research initiative targeting children aged 5-10 led by the University of Bologna, in partnership with the EU-funded HIDDeN and CosmicAntiNuclei projects. The objectives of inVISIBILI are to spark curiosity about the nature's marvels, particularly focusing on the invisible Universe, like Dark Matter and Neutrinos, as well as to mitigate the development of gender stereotypes and their impact on the learning mindset of young children by creating an inclusive and gender-neutral learning environment. To accomplish these objectives, two outreach classroom events comprising a sequence of interactive activities are designed. These events are facilitated by gender-balanced teams of physics researchers and students who received training on gender issues, children-focused science communication, and pedagogy. Concurrently, a research study investigating gender stereotypes in young children is conducted. Around 1700 children as well as 80 researchers and students are involved in the project. In this contribution we outline the design of the outreach events, discuss the feedback received, and share the first findings from the conducted research study.

Progettazione e sperimentazione di un percorso didattico sui fenomeni di superficie per studenti universitari.

Grazia I., Battaglia O.R., Termini G., Fazio C.

Dipartimento di Fisica e Chimica "Emilio Segré, Università degli Studi di Palermo

In questo lavoro proponiamo la progettazione, la validazione e l'implementazione di una sequenza di insegnamento-apprendimento (TLS) per studenti universitari sui fenomeni di superficie nei liquidi. La TLS è finalizzata a favorire nello studente un processo graduale di costruzione attiva delle proprie conoscenze. Il quadro teorico scelto si basa su risultati di ricerca in psicologia cognitiva, didattica della fisica ed epistemologia. Il modello adoperato, basato sul pensiero costruttivista, è quello dell'Educational Reconstruction. Gli studenti utilizzano metodologie basate sull'indagine e la scoperta per identificare ipotesi, esercitarsi nell'uso del pensiero critico e fornire spiegazioni alternative per interpretare le situazioni fisiche proposte. Gli aspetti che caratterizzano l'apprendimento dello studente sono spesso stati studiati singolarmente, senza individuare correlazioni tra essi. Nella ricerca che descriveremo, sarà, tra l'altro, discussa una mappa concettuale sulle "dimensioni" dell'"Apprendimento delle Scienze". Tale mappa facilita la costruzione delle TLS e la verifica della loro efficacia nel favorire l'apprendimento degli studenti nell'ambito della fisica.

Analisi qualitativa dei processi di apprendimento degli studenti emersi durante la sperimentazione di una sequenza insegnamento/apprendimento sui fenomeni di superficie nei liquidi.

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In questo contributo presentiamo alcuni aspetti generali di due sequenze insegnamento/apprendimento (TLSs) sui fenomeni di superficie nei liquidi sperimentate con studenti della scuola secondaria di secondo grado durante l'anno scolastico 2021/22. Dopo aver introdotto il quadro teorico delle TLSs, gli approcci didattici e le tecniche utilizzate per analizzare i dati, esploriamo alcune specifiche sottodimensioni dell'apprendimento che consideriamo rilevanti per la nostra ricerca e mostriamo i risultati di un'analisi di tipo tematico condotta su dati qualitativi raccolti in fase di sperimentazione. Attraverso questo tipo di analisi, miriamo a ottenere informazioni sui processi di apprendimento che gli studenti mettono in atto durante la sperimentazione di approcci didattici allo studio della fisica alternativi a quelli tradizionali. La scelta del contenuto da trattare è legata al ruolo significativo che ricopre in vari ambiti scientifici, e al fatto che in letteratura emerge la necessità di approcci didattici innovativi che possano coinvolgere gli studenti e migliorare la loro comprensione di questo argomento sia a livello scolastico che universitario.

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