PASSION FOR PHYSICS

International School of Physics Enrico Fermi

23 June 2023 Villa Monastero, Varenna (Lake Como)

70th Anniversary

Seventy years of breakthroughs in atomic physics reported at the Enrico Fermi School

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The Enrico Fermi School courses have reported the tremendous progresses made in all domains of physics over the last seventy years. In atomic physics and quantum optics many impressive breakthroughs have occurred, most notably due to the invention and development of lasers. In the 1950s, experiments involved large samples containing billions of particles. We can now observe and manipulate atoms individually with laser beams and realize in the laboratory the thought experiments which the founding fathers of quantum physics could only dream about. The possibility to control single particles has led to the new field of quantum information which promises to exploit the strange quantum logic for measuring, communicating and calculating more efficiently than can be done with classical machines. While the lowest temperature achievable before lasers were of the order of milli-Kelvins, we can now cool atoms at sub-nanokelvin temperatures and study new phases of condensed matter having surprising properties. The precision of spectroscopic measurements has also made tremendous improvements. This has led to a revolution in the precision of atomic clocks, opening fascinating perspectives for fundamental physics and practical applications. I have been lucky to participate to some of these developments and to witness the advances made by friends and colleagues coming from all over the world, who have reported their results at the Fermi School. I will recall my memories about the sessions I have attended to in Varenna. It will also give me the opportunity to share my reflections about the challenges that science is facing today.

Ultracold quantum matter in Varenna: Counting on the future

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The investigation of matter at the atomic and molecular level has led to the invention of instruments and techniques, such as the laser, that have then revolutionized science, allowing for more and more accurate studies of Nature, in a virtuous circle where science produces technology and technology enables new science. Atomic physics has been a constant presence in Varenna, starting from the early Schools in the 1950s before the invention of the laser: from the applications of laser spectroscopy to metrology and fundamental tests of physics, the field was then revolutionized by groundbreaking techniques to use lasers to manipulate the atomic motion, leading to the discovery of new phases of matter down to almost absolute zero and new approaches to utilize quantum physics for technology. Decades of progress in ultracold atomic physics have been witnessed by hundreds of motivated students (several of them then becoming Lecturers, Directors and even Nobel Prizes), who attended Schools that always marked the topical moments in the evolution of the field: a path full of passion and surprises, which constantly led to new directions of research and new dreams for the future. This tradition will continue, with a new Varenna School on quantum computing, 70 years after the famous Varenna school where a farsighted Enrico Fermi proposed the construction of the first Italian computer.

Unveiling the invisible: Applications of spectroscopic methods for studying the intangible value of cultural heritage materials

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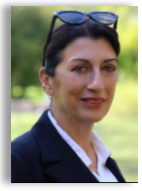
Tangible cultural heritage poses interesting challenges to the field of spectroscopy because of the need to develop methods to discriminate compounds that are often mixed, layered, and altered over time, but at the same time contained in valuable and unique samples. Much work has been done in recent decades to develop non-invasive methods that can work directly on artworks, based on elemental and molecular spectroscopy, in point mode, thus contributing fundamentally to the development of research in conservation, art history, and archaeology. The next stage of advancement was to push toward hyperspectral applications in the macro mode, with the goal of combining the potential of chemical information obtainable from point techniques with the spatial information provided by imaging techniques. The state-of-the-art applications of macroscale hyperspectral imaging/scanning methods will be presented by discussing cases of particular importance for their added value to the solution of challenging problems in the art-historical, codicological, and archaeological fields. Case studies will be chosen as part of the international activities of MOLAB access platform of E-RIHS, the European Research Infrastructure for Heritage Science, also to present the potential and challenges of multimodal applications. Recent developments to move macro-hyperspectral application from near to mid-infrared will also be discussed, in order to exploit the strong specificity and sensitivity of this spectral range in the recognition of compounds of great importance for understanding the conservation status of artworks. Finally, the potential of artificial intelligence algorithms to assist the interpretation of multimodal data and improve the capacity for knowledge extraction will also be given.



High energy physics between past and future

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Particle physics has achieved, from the early years of its birth until nowadays, extraordinary results which helped us in understanding the fundamental components of matter and their interactions. And some of the most renewed protagonists of this history were lecturing at the International School of Physics "Enrico Fermi" of the Italian Physical Society. The School in Varenna celebrates its 70th anniversary this year, and the most recent discovery – the identification of the

Higgs boson, which completed the Standard Model picture – dates back to ten years ago. Yet, there are still many unanswered questions and we are hoping to make soon another significant step beyond in the knowledge and understanding of our Universe. The next big collider machines can help us to get closer to this goal: a short introduction of the high luminosity LHC and Future Circular Collider machines is given, and their potential is reviewed.

Inspiration for students and teachers on photonic materials, atomic physics, energy, and metrology

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European Laboratory for Nonlinear Spectroscopy (LENS) and INRiM, Torino, Italy

The Enrico Fermi School of Physics in Varenna provides a unique environment for science in my opinion, both for the students attending the schools as well as for the teachers. The discussions that take place here at the shore of the Lake Como are usually remembered for years to come and in many cases provide a source of inspiration for new research projects and scientific collaborations. I will talk about some scientific ideas that came out of the Varenna schools in which I was involved either as student, teacher, or course director, and how they led to new scientific projects and collaborations.

Slow but sure. The pace of scientific progress in neutrino physics

Francesco Vissani
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Since their appearance in science (1930), neutrinos have aroused mixed feelings. Neutrinos gave rise to remarkable ideas since immediately, but they were not taken entirely seriously until the mid-1950s, when they proved to be the Rosetta Stone for understanding weak interactions. In later years, the idea of using them to explore the Sun's interior was considered with some timidity, and the first observational results (in the late 1960s) created discussion and controversy that lasted about 20 years. However, this perception changed substantially since the end of the last century. It is amusing to note that those once controversial results 1) have turned into a gateway to a physics that goes beyond the accepted model of particles (the only one with an observational basis), 2) increase the opportunities for using neutrinos in astrophysical exploration, and 3) suggest that we should continue to investigate the processes of creation of matter particles. I will conclude by listing some remarkable results obtained with neutrinos and the prospects for development that they indicate.

70 years of Varenna International Schools: History and role of nuclear physics in modern knowledge

Fabiana Gramegna
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Speaking of 70 years of Varenna, going through the development of nuclear physics is a beautiful challenge: many important physicists and teachers have been involved in this historical and long journey. Nuclei are quantum complex systems that still hide a lot of new properties which have to be discovered. Nevertheless, many important aspects were present since the very beginning and the pioneers of the discoveries were able to stress the importance of looking at nuclei both from the point of view of single particle properties, but also from that of collective aspects of the sea of nucleons which remember always to behave in a complex nuclear field. Decay studies together with the properties derived by those related to the interaction between particles and nuclei gave up to a huge and still mysterious quantity of information, which have been, from time to time, correlated to get a validated information and to proceed in the knowledge of this fascinating world of nuclei and nuclear matter. Nuclear physics is an important pillar for itself, since it is regulating the world we all see around us, but it is also a very important tool which can be widely used in very different application needed by the society: nuclear techniques can be applied either to perform material studies or to build up tools and products which are useful for diagnostics and therapy in nuclear medicine.

The Laser: Past, Present and Future

Orazio Svelto
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After more than 60 years since its invention, the laser continues to create around itself a mixed atmosphere of curiosity and wonder. Curiosity mostly comes from the fact that new lasers are still being invented and new, quite fascinating, applications are continuously developed. Wonder essentially comes from the pervasive character of the laser: there is in fact no field in science and technology which has not been influenced, often fundamentally, by this revolutionary invention. In this talk, we will illustrate a few peculiar aspects about this invention also in relation to the Italian research. In particular, we will first consider the early beginning of the research activity at the international level. On the Italian side, the role of Giovanni Polvani, the founder of Varenna School and, at that time, the President of the Italian National Research Council, in promoting laser research in Italy will be considered. A few remarks about the first two Varenna Courses on Lasers, held in 1963 and 1967, respectively, will also be made. Lastly, the present situation in laser activity both internationally and in Italy will also be presented together with a short discussion about future prospective activities.

Statistical physics of biopolymers throughout the Enrico Fermi Schools

Guido Tiana
Università di Milano, Italy

The study of biopolymers with the tools of statistical mechanics took off in the eighties of last century and is still bearing important fruits. The history of the physics of proteins and DNA chains is punctuated by several Enrico Fermi Schools, which had the virtue of making a synthesis of this highly interdisciplinary field and triggering the development of new ideas and new methods. I will summarise the main steps of this development, from the early studies of “lattice model” proteins to the recent breakthroughs obtained with machine-learning techniques and with the application to drug design. A key aspect that determined the success of this evolution has been the continuous interaction between theory and experiments; Enrico Fermi Schools had an important role in this, as they prepared students (who are now top researchers) with a very wide background in all aspects of the physics of biopolymers.

Bridging condensed matter physics and quantum optics in Varenna

Cristiano Ciuti
Laboratoire Matériaux et Phénomènes Quantiques, Université Paris Cité, France

Over the years, several key meetings at the International School of Physics "Enrico Fermi" have brought together the quantum optics and condensed matter physics community, creating new synergies and exciting research directions. After a brief historic review of these events, I will present some recent advances at the crossroad: electron quantum Hall effect modified by cavity vacuum fluctuations and unprecedented quantum many-body effects in circuit Quantum Electrodynamics (QED) with quantum superconducting circuits.

The Empire of Lights

Alberto Diaspro
Università di Genova and Nanoscopy IIT, Erzelli Labs, Genova, Italy

The International School of Physics “Enrico Fermi” of the Italian Physical Society in Varenna is a kind of “magic” place where science meets arts, the right place for “The Empire of Lights” from Rene Magritte to the advanced optical microscopes enabling the exploration of the NanoWorld. Their developments are positioned at the interface between biology and physics, and today they offer an unprecedented insight into the molecular mechanisms that govern and determine the fate of living cells. The “occhialino per vedere cose minime” by Galileo Galilei, named microscope, is today an optical nanoscope boosted by artificial intelligence. Today, exploiting light matter interactions from super resolved fluorescence to label free imaging, we will consider the ambitious target to create a robust virtual environment "to see “what we could not perceive before” by means of the realization of the artificial microscope.