107° CONGRESSO NAZIONALE della SOCIETÀ ITALIANA DI FISICA

Indirect methods and innovative techniques for Nuclear Astrophysics

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on behalf of AsFiN and PANDORA collaborations

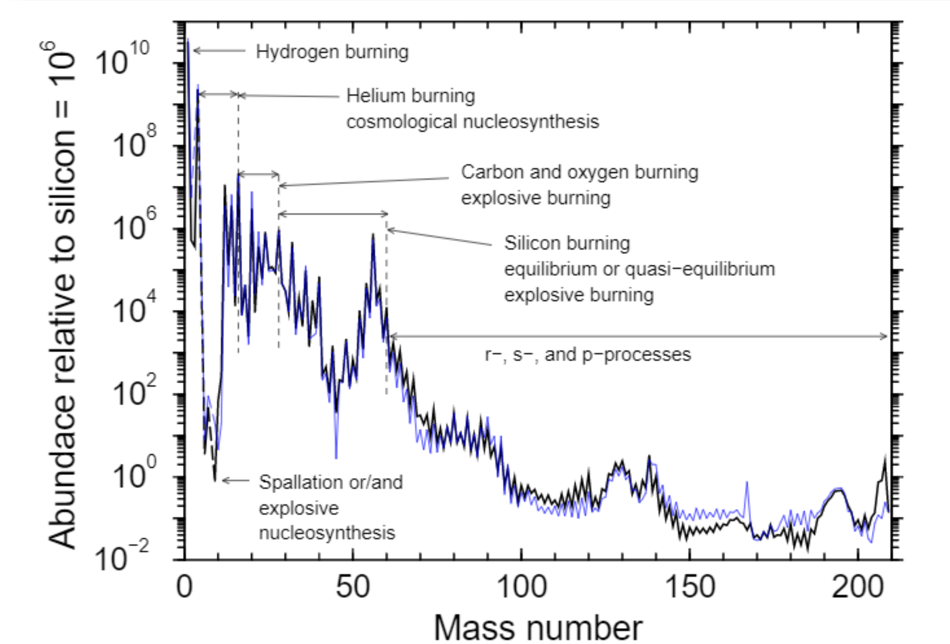
AsFiN

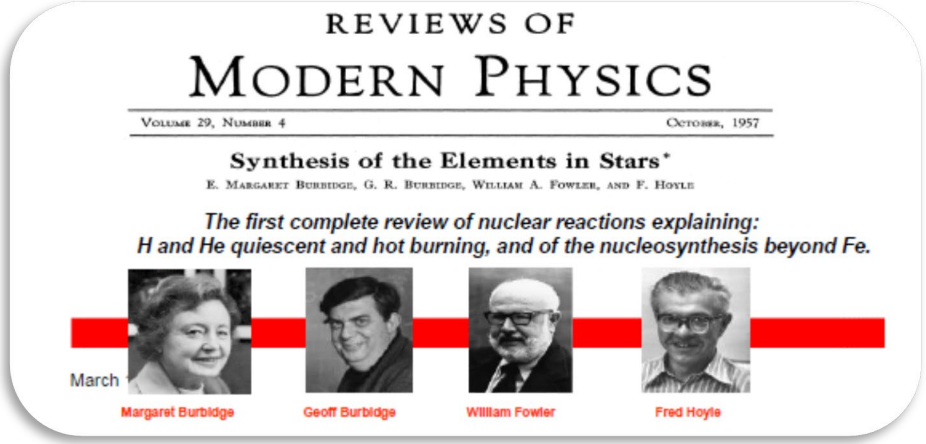
INFN LNS

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

Experimental Nuclear Astrophysics

Everything starts from the **B²FH** **review paper of 1957,**
<u>the basis of the modern nuclear astrophysics.</u>

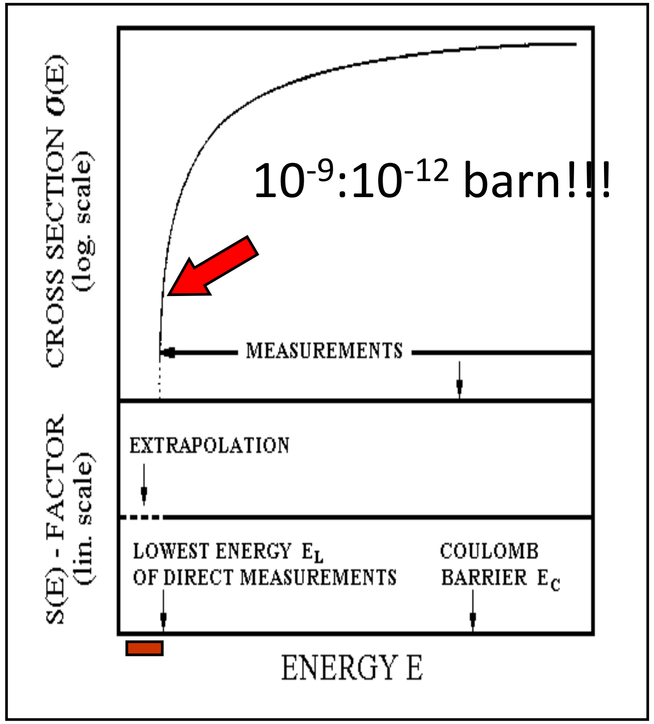


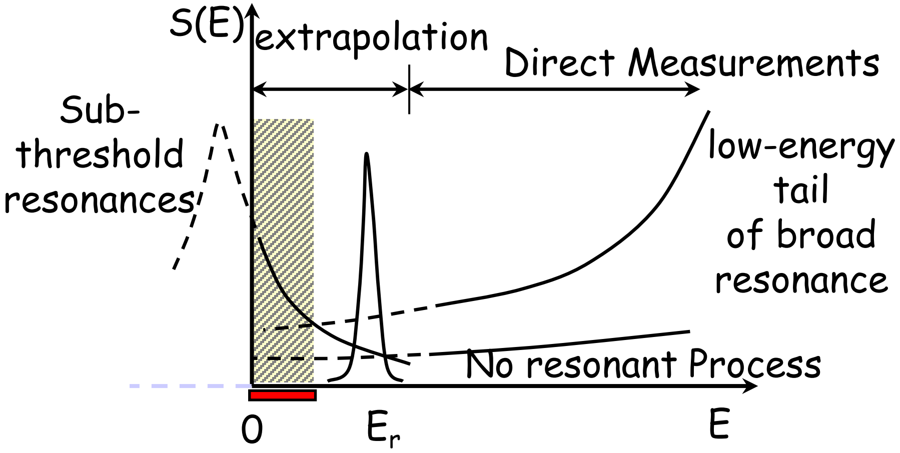


The elements composing everything from planets to life were forged inside earlier generations of stars!
Nuclear reactions responsible for both <u>ENERGY PRODUCTION</u> and <u>SYNTHESIS OF ELEMENTS</u>

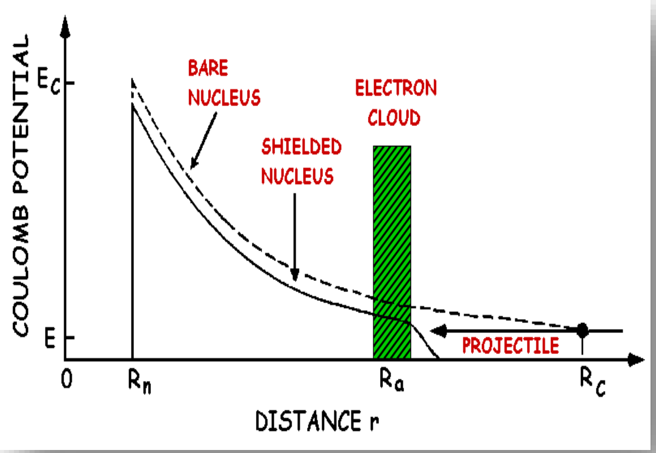
Direct Measurements

- Very small cross section values reflect in a faint statistic;
- Very low signal-to-noise ratio makes hard the investigation at astrophysical energies;
- Instead of the cross section, the S(E)-factor is introduced

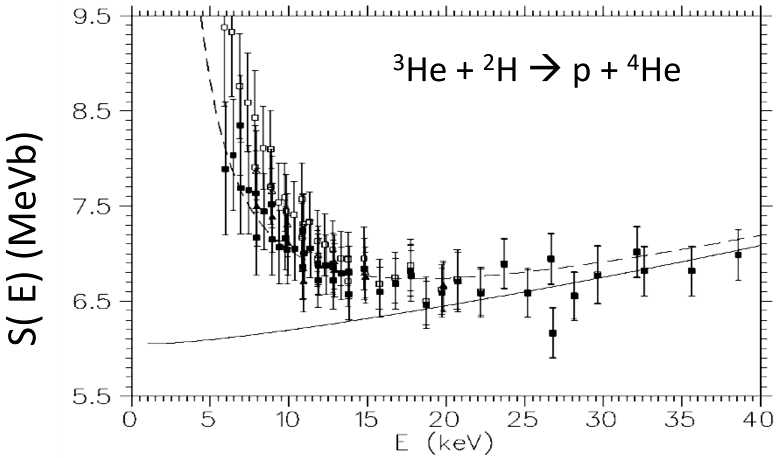




Electron Screening

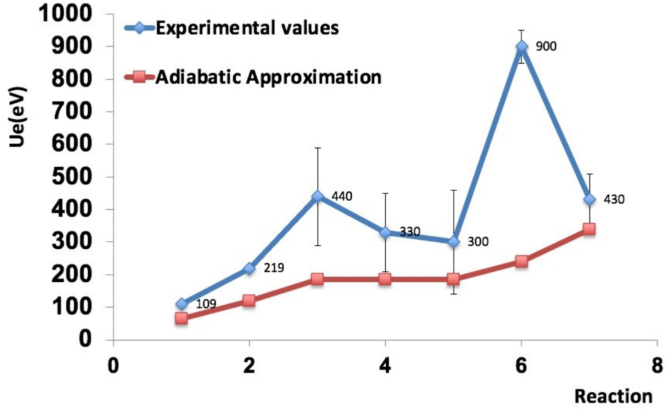


Due to the electron cloud surrounding the interacting ions the projectile feels a reduced barrier

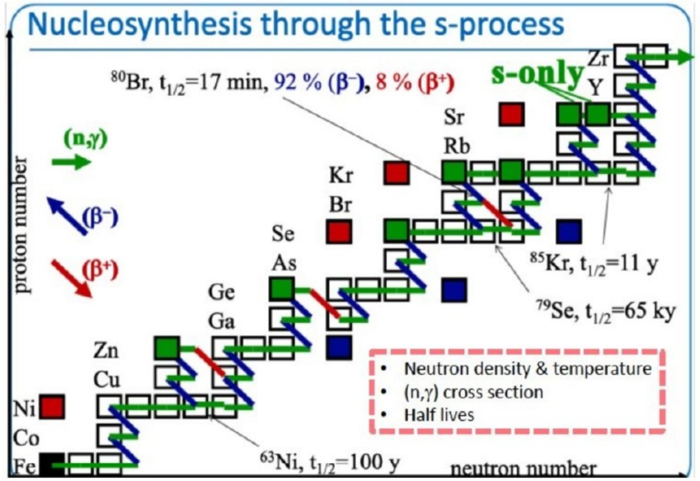


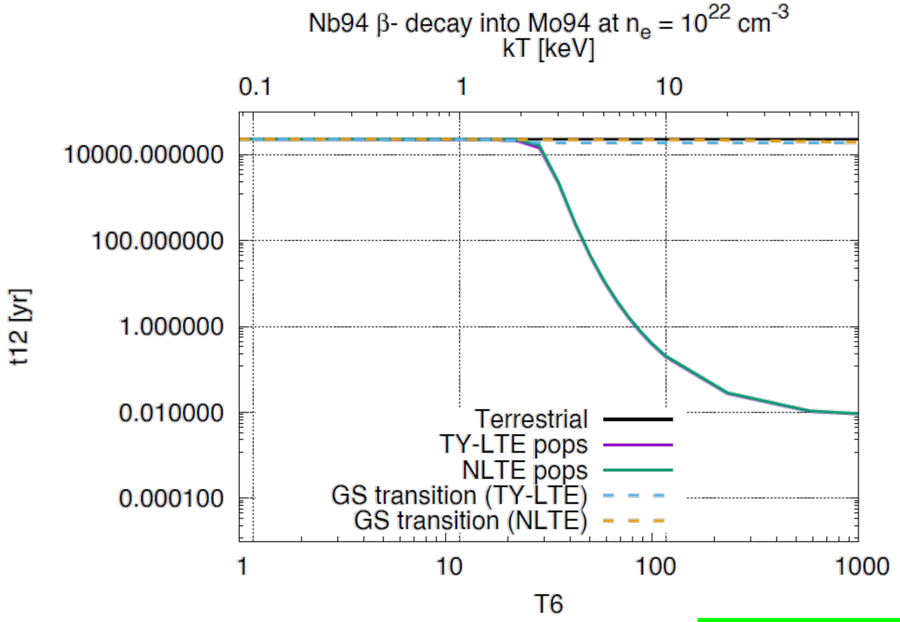
Reaction	U_{ad} (eV)	U_{exp} (eV)	Reference
$^6Li(p,\alpha)^3He$	186	440±150	[Engstler et al.(1992)]
$^6Li(d,\alpha)^4He$	186	330±120	[Engstler et al.(1992)]
$H(^7Li,\alpha)^4He$	186	300±160	[Engstler et al.(1992)]
$^2H(^3He,p)^4He$	65	109±9	[Aliotta et al.(2004)]
$^3He(^2H,p)^4He$	120	219±7	[Aliotta et al.(2004)]
$H(^9Be,\alpha)^6Li$	240	900±50	[Zahnow et al.(1997)]
$H(^{11}B,\alpha)^8Be$	340	430±80	[Angulo et al. (1993)]

Theory vs. Experiment→ Stellar plasma…far to be understood



β decay Branching Point





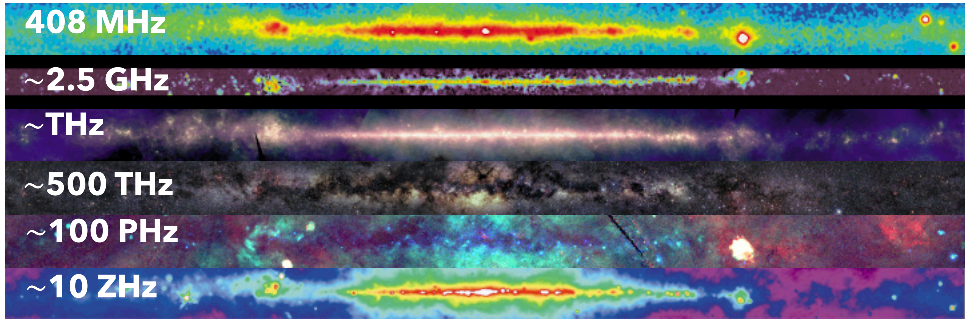
Busso M., et al, Ann. Rev. Astr. Astrophysics, 37 239, (1999)
Cristallo S., et al., APJ Suppl. 197, 17 (2011)

- **s-process branching → neutron capture vs. nuclear β decays. Unknown radionuclides lifetime in strongly ionized stellar environment**

- **Abundances search for elements heavier than iron through r-process nucleosynthesis in neutron-rich compact binary objects**

A Way To Face These Problems

AS SIMILAR AS TO Multi-wavelength astronomy : many information on the Galaxy composition, dynamics, structure from variety of telescopes and detectors within a broad range of EM spectrum → **COMPLEMENTARY PICTURE OF GALAXY**



https://asd.gsfc.nasa.gov/archive/mwmw/mmw_sci.html

- **Radio**: SN shocked electrons moving at v~c thorugh interstellar B field
- **Radio**: hot, ionized gas and high-energy electrons
- **IR**: thermal, dust warmed by absorbed starlight, star-forming regions embedded in interstellar clouds
- **Optical**: low-density gas, light from stars at few thousand LY from the Sun
- **Composte X-Ray**: hot, shocked gas (~keV), cold clouds of interstellar gas absorbers
- **γ-Ray**: high-energy photons (≥300 MeV), collisions of cosmic rays with hydrogen nuclei in interstellar clouds

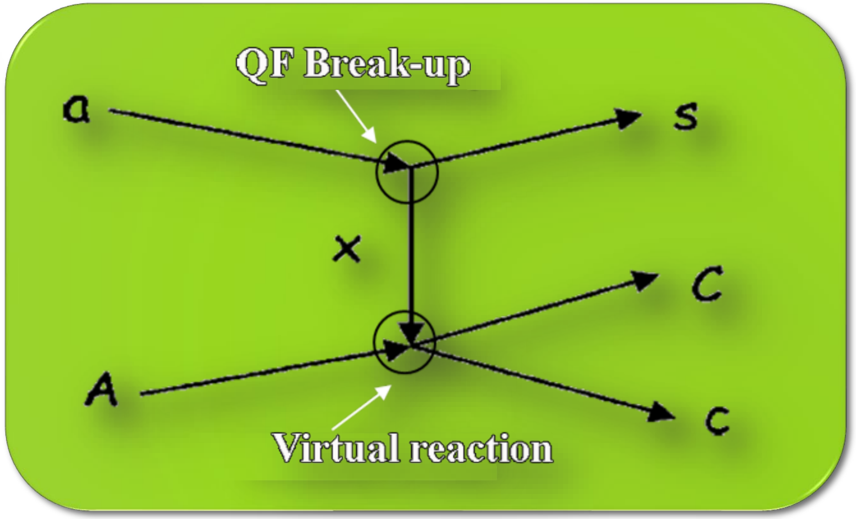
Beyond the extrapolation procedure, indirect and innovative experimental methods are highly demanded to address missing or incomplete aspects led by the complexity of nuclear reactions in stars

Multi-diagnostic experiments for **Multi-messenger Astronomy (MMA)**: several methods, detectors, instruments to investigate single processes relevant for Nuclear Physics and Astrophysics, under extreme conditions of ionized stellar environments

→ COMPLEMENTARY PICTURE OF NUCLEAR PHYSICS AND NUCLEAR ASTROPHYSICS PHENOMENA

The Trojan Horse Method

The idea of the **THM** is to extract the cross section of an astrophysically relevant two-body reaction **A+x→c+C** at low energies from a suitable three-body reaction **a+A→c+C+s**



Quasi free kinematics is selected

✓ **only *x* - A interaction**

✓ ***s* = spectator (p_s~0)**

$E_A > E_{Coul}$ →

- **NO coulomb suppression**
- **NO electron screening**
- **NO centrifugal barrier**

- ***THM Review paper* → *Spitaleri C. et al., EpJ A, 2019***

Theorethical Approach

The TH-nucleus is chosen because of:

- **its large amplitude in the *a*=*x*⊕*s* cluster configuration;**
- **its relatively low-binding energy;**
- **Its known *x*-*s* momentum distribution $|\Phi(p_s)|^2$ in *a*.**

$$E_{Ax} = \frac{m_x}{m_x + m_A} E_A - B_{xs}$$

$B_{x\text{-}s}$ plays a key role in compensating for the beam energy thanks to the *x-s intercluster motion* inside a, it is possible to span an energy range of several hundreds of keV with <u>only one beam energy</u>

In the <u>Plane Wave Impulse Approximation</u> (PWIA) the cross section of the 3-body reaction can be factorized as:

$$\frac{d^3\sigma}{d\Omega_c d\Omega_C dE_c} \propto KF \cdot |\Phi(p_s)|^2 \cdot \frac{d\sigma_{Ax}}{d\Omega}$$

Three body measured cross section

Calculated kinematical factor

Fourier trasform for the x-s intercluster motion

Astrophysically relevant two body cross section

- *THM Talk@Sif2021 → A. Oliva "La reazione di fusione $^{12}C+^{16}O$ nel carbon burning "*

Applications of THM

	Binary reaction	Indirect reaction	Beam energy (MeV)	Q_3 (MeV)	TH nucleus
1	$^7Li(p,\alpha)^4He$	$^2H(^7Li,\alpha\alpha)n$	19–22, 28–48	15.122	$d=(p\oplus n)$
2	$^7Li(p,\alpha)^4He$	$^7Li(^3He,\alpha\alpha)^2H$	33	11.853	$^3He=(d\oplus p)$
3	$^6Li(d,\alpha)^4He$	$^6Li(^6Li,\alpha\alpha)^4He$	5	22.372	$^6Li=(\alpha\oplus d)$
4	$^6Li(d,\alpha)^4He$	$^6Li(^3He,\alpha\alpha)^1H$	17.5	16.879	$^3He=(d\oplus p)$
5	$^6Li(p,\alpha)^3He$	$^2H(^6Li,\alpha^3He)n$	14–25, 21–36.6, 25	1.795	$d=(p\oplus n)$
6	$^{11}B(p,\alpha)^8Be$	$^2H(^{11}B,^8Be\alpha)n$	27	6.366	$d=(p\oplus n)$
7	$^{10}B(p,\alpha)^7Be$	$^2H(^{10}B,^7Be\alpha)n$	27, 28	−1.079	$d=(p\oplus n)$
8	$^9Be(p,\alpha)^6Li$	$^2H(^9Be,^6Li\alpha)n$	22.25	−0.099	$d=(p\oplus n)$
11	$^{18}F(p,\alpha)^{15}O$	$^2H(^{18}F,\alpha^{15}O)n$	52	0.66	$d=(p\oplus n)$
12	$^{15}N(p,\alpha)^{12}C$	$^2H(^{15}N,\alpha^{12}C)n$	60	2.741	$d=(p\oplus n)$
13	$^{18}O(p,\alpha)^{15}N$	$^2H(^{18}O,\alpha^{15}N)n$	54	1.755	$d=(p\oplus n)$
14	$^{19}F(p,\alpha)^{16}O$	$^2H(^{19}F,\alpha^{16}O)n$	50	5.889	$d=(p\oplus n)$
15	$^{19}F(\alpha,p)^{22}Ne$	$^{19}F(^6Li,p^{22}Ne)^2H$	6	0.199	$^6Li=(\alpha\oplus d)$
16	$^{12}C(^{12}C,\alpha)^{20}Ne$	$^{12}C(^{14}N,\alpha^{20}Ne)^2H$	30	−5.655	$^{14}N=(^{12}C\oplus d)$
17	$^{17}O(p,\alpha)^{14}N$	$^2H(^{17}O,\alpha^{14}N)n$	45	−1.033	$d=(p\oplus n)$
18	$^{17}O(n,\alpha)^{14}C$	$^2H(^{17}O,\alpha^{14}C)^1H$	41, 43.5	−9.407	$d=(p\oplus n)$
19	$^{12}C(\alpha,\alpha)^{12}C$	$^6Li(^{12}C,d^{12}C)^4He$	18	−1.474	$^6Li=(\alpha\oplus d)$
20	$^{13}C(\alpha,n)^{16}O$	$^{13}C(^6Li,nd)^{16}O$	7.82	0.742	$^6Li=(\alpha\oplus d)$
21	$^{12}C(^{12}C,p)^{23}Na$	$^{12}C(^{14}N,p^{23}Na)^2H$	30	−7.28	$^{14}N=(^{12}C\oplus d)$

- Various astrophysical scenarios
- Different TH-nucleus
- One beam energy for a wide E_{cm} range
- «simple» experimental setup

Recent Results of THM

nature
International journal of science

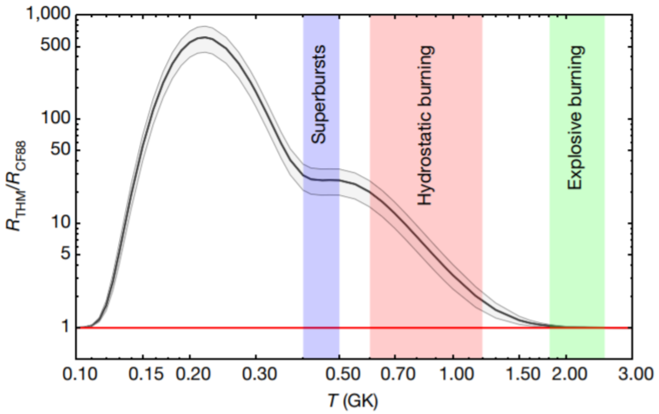
Letter | Published: 23 May 2018

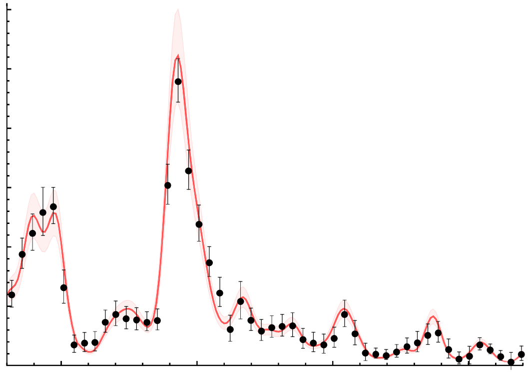
An increase in the $^{12}C + ^{12}C$ fusion rate from resonances at astrophysical energies

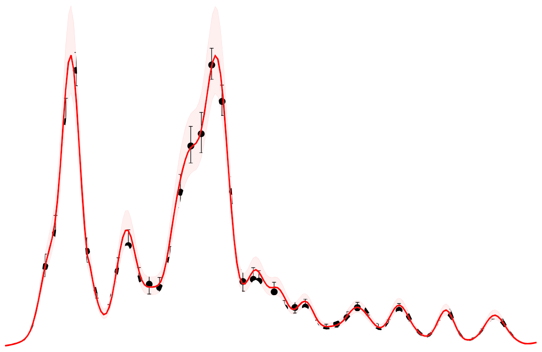
A. Tumino, C. Spitaleri, M. La Cognata, S. Cherubini, G. L. Guardo, M. Gulino, S. Hayakawa, I. Indelicato, L. Lamia, H. Petrascu, R. G. Pizzone, S. M. R. Puglia, G. G. Rapisarda, S. Romano, M. L. Sergi, R. Spartá & L. Trache

Nature **557**, 687–690 (2018) | Download Citation

Experiment performed @ INFN-LNS







Recent Results of THM

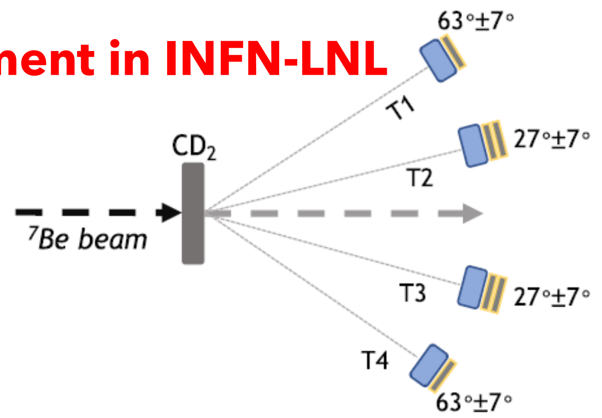
THE ASTROPHYSICAL JOURNAL, 850:175 (5pp), 2017 December 1
https://doi.org/10.3847/1538-4357/aa965c

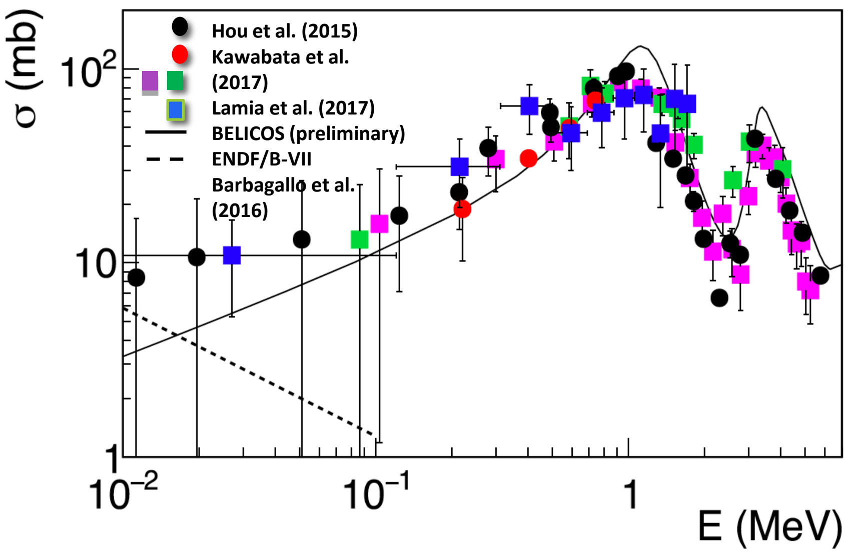
CrossMark

On the Determination of the ^{7}Be(n, α)^{4}He Reaction Cross Section at BBN Energies

L. Lamia[1,2], C. Spitaleri[1,2], C. A. Bertulani[3], S. Q. Hou[3,4], M. La Cognata[2], R. G. Pizzone[2], S. Romano[1,2], M. L. Sergi[2], and A. Tumino[2,5]
[1] Dipartimento di Fisica e Astronomia, Università degli Studi di Catania, Catania, Italy
[2] INFN—Laboratori Nazionali del Sud, Catania, Italy
[3] Department of Physics and Astronomy, Texas A&M University-Commerce, Commerce, TX 75428, USA
[4] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[5] Facoltà di Ingegneria e Architettura, Università degli Studi di Enna "Kore", Enna, Italy
Received 2017 September 12; revised 2017 October 20; accepted 2017 October 24; published 2017 November 30

Experiment in INFN-LNL





Application of THM with RIBs and neutron induced reactions

THE ASTROPHYSICAL JOURNAL, 879:23 (8pp), 2019 July 1
https://doi.org/10.3847/1538-4357/ab2234

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Cross-section Measurement of the Cosmologically Relevant ^{7}Be(n, α)^{4}He Reaction over a Broad Energy Range in a Single Experiment

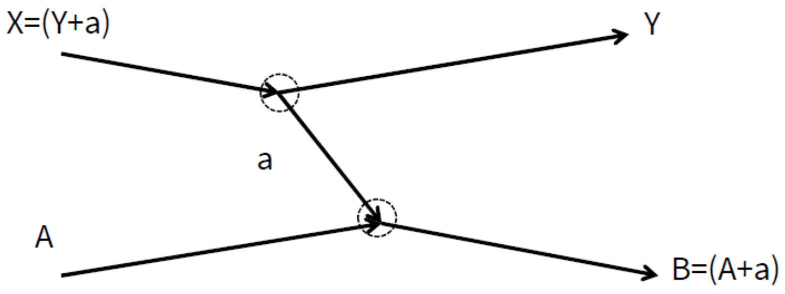
L. Lamia[1,2], M. Mazzocco[3,4], R. G. Pizzone[2], S. Hayakawa[5], M. La Cognata[2], C. Spitaleri[1,2], C. A. Bertulani[6], A. Boiano[7], C. Boiano[8], C. Broggini[4], A. Caciolli[3,4], S. Cherubini[1,2], G. D'Agata[1,2,13], H. da Silva[9], R. Depalo[3,4], F. Galtarossa[10], G. L. Guardo[1,2], M. Gulino[2,11], I. Indelicato[1,2], M. La Commara[7,12], G. La Rana[7,12], R. Menegazzo[4], J. Mrazek[13], A. Pakou[14], C. Parascandolo[7], D. Piatti[3,4], D. Pierroutsakou[7], S. M. R. Puglia[2], S. Romano[1,2], G. G. Rapisarda[2], A. M. Sánchez-Benítez[15], M. L. Sergi[2], O. Sgouros[2,14], F. Soramel[3,4], V. Soukeras[2,14], R. Spartá[1,2], E. Strano[3,4], D. Torresi[2], A. Tumino[2,11], H. Yamaguchi[5], and G. L. Zhang[16]

- *LNS perspectives Talk@Sif2021 → D. Carbone "Nuclear physics perspectives at LNS"*

Asymptotic Normalization Coefficient

Widely used to gain informations about **DIRECT RADIATIVE CAPTURE**

Studies performed by means of «simple» transfer reactions



In Distorted Wave Born Approximation, the transition amplitude between the states before and after the reactions can be written as:

$$M(E_i, \vartheta_{c.m.}) = \sum_{M_a} \left\langle \chi_f^{(-)} \, \boldsymbol{I}_{Aa}^{B} \left| \Delta V \right| \boldsymbol{I}_{Ya}^{X} \, \chi_i^{(+)} \right\rangle$$

Using DWBA we were able to find the ANC's coefficients from the spettroscopic factors. This gives us some advantages:

- For perihperal reactions, ANCs have small dependance from the potential
- R_{l_B, j_B, l_x, j_x} is nearly indipendent from b^2
- ANCs are defined in the nuclear «exterior», so are «observable»

$$\frac{d\sigma}{d\Omega} = \sum_{j_B, j_x} \left(C_{Aa, l_B, j_B}^{B}\right)^2 \left(C_{Ya, l_x, j_x}^{X}\right)^2 \frac{\sigma_{l_B, j_B, l_x, j_x}^{DWBA}}{b_{Aa, l_B, j_b}^2 \, b_{Ya, j_x, j_x}^2} = \sum_{j_B, j_x} \left(C_{Aa, l_B, j_B}^{B}\right)^2 \left(C_{Ya, l_x, j_x}^{X}\right)^2 R_{l_B, j_B, l_x, j_x}$$

- *ANC Review paper →* *Tribble R. et al., Rep. Prog. Phys. 2014*

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

Recent results of ANC

Physics Letters B 807 (2020) 135606

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Astrophysical S-factor for the ^{3}He(α,γ)^{7}Be reaction via the asymptotic normalization coefficient (ANC) method

G.G. Kiss [a], M. La Cognata [b,*], C. Spitaleri [b,c], R. Yarmukhamedov [d], I. Wiedenhöver [e], L.T. Baby [e], S. Cherubini [b,c], A. Cvetinović [b], G. D'Agata [b,c,f], P. Figuera [b], G.L. Guardo [b,c], M. Gulino [b,g], S. Hayakawa [b,h], I. Indelicato [b,c], L. Lamia [b,c,i], M. Lattuada [b,c], F. Mudò [b,c], S. Palmerini [j,k], R.G. Pizzone [b], G.G. Rapisarda [b,c], S. Romano [b,c,i], M.L. Sergi [b,c], R. Spartà [b,c], O. Trippella [j,k], A. Tumino [b,g], M. Anastasiou [e], S.A. Kuvin [e], N. Rijal [e], B. Schmidt [e],

Astrophysical factor at Gamow energies for the Sun was extracted via the ANC method. For the ^{3}He(^{4}He,γ)^{7}Be case, in good agreement with previous experiments

Experiment in ATOMKI

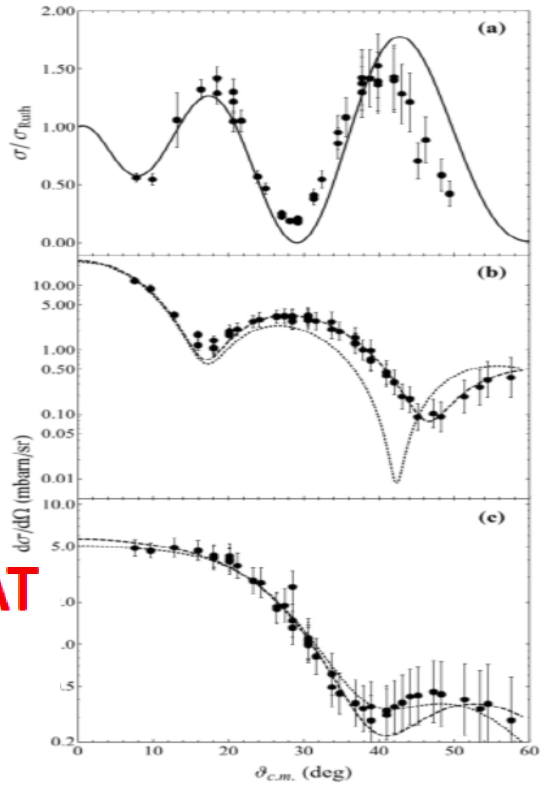
PHYSICAL REVIEW C 103, 015806 (2021)

^{26}Si(p,γ)^{27}P direct proton capture by means of the asymptotic normalization coefficients method for mirror nuclei

G. D'Agata,[1,*] A. I. Kilic,[1] V. Burjan,[1] J. Mrazek,[1] V. Glagolev,[1] V. Kroha,[1] G. L. Guardo,[2] M. La Cognata,[2] L. Lamia,[2,3,4] S. Palmerini,[5,6] R. G. Pizzone,[2] G. G. Rapisarda,[2] S. Romano,[2,3,4] M. L. Sergi,[2,3] R. Spartà,[2,3] C. Spitaleri,[2] I. Siváček,[1,7] and A. Tumino[2,8]

Experiment in Rez, Prague

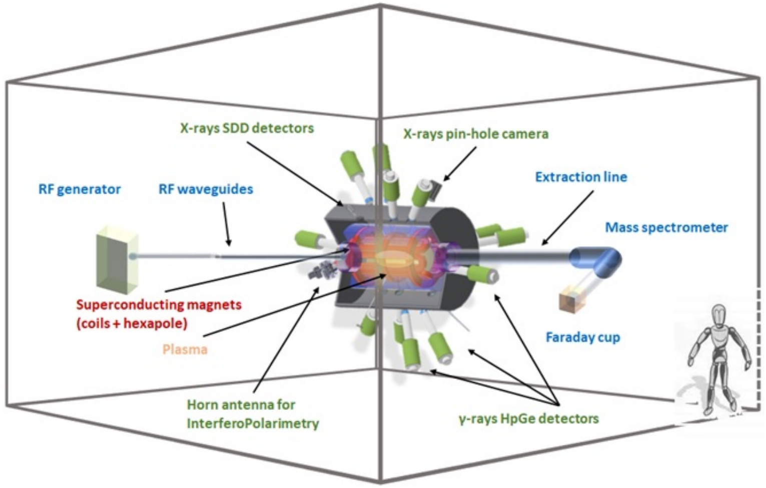
REACTION RATE CALCULATED AT GAMOW ENERGIES!!!



THM Talk@Sif2021 → G. D'Agata "ANC: The ^{26}Si(p, γ)^{27}P case "

The PANDORA Project

- **PANDORA concept**: compact plasma **trap** to magnetically confine **ions of radioisotopes** in a microwave-sustained **plasma**
- **Main Goal:** nuclear decay measurements in a plasma resembling **astrophysical conditions** (temperature, ion charge state distribution)
- **Multi-diagnostic setup**: **monitoring diagnostics** + **detectors array**



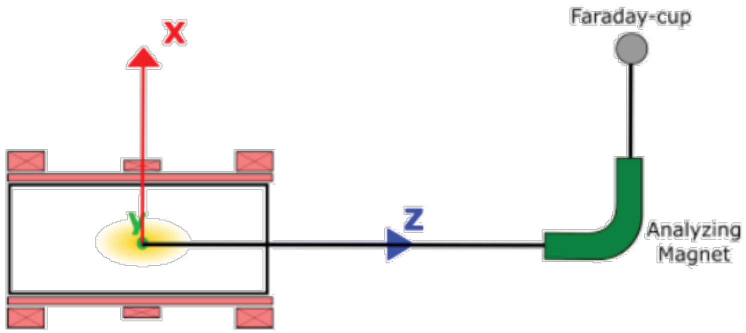
- Assembling multi-diagnostic setup: simultaneously monitor plasma parameters and carry measurements under stable conditions

- **Electron dens:** $10^{12} - 10^{14}$ **cm**$^{-3}$
- **Electron Energy:** $\sim$ **eV - 100 keV**
- **Ion dens:** 10^{11} **cm**$^{-3}$

PHYSICS OF INTEREST FOR MMA AND NUCLEAR ASTROPHYSICS

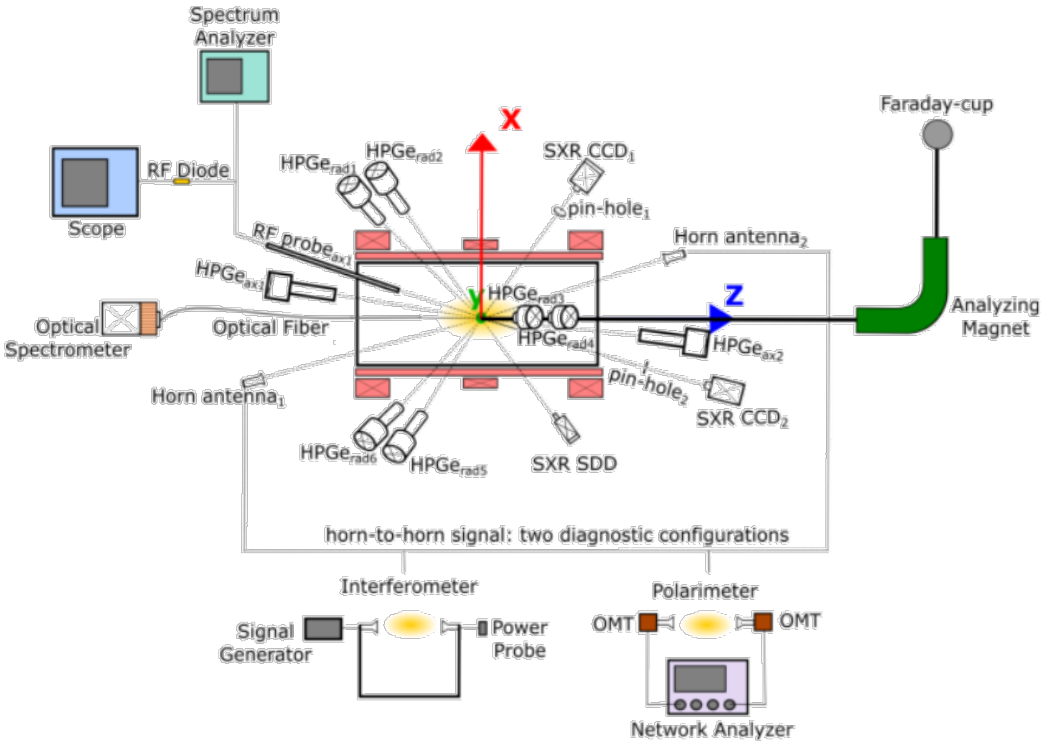
- s-process nucleosynthesis + β-decay branching
- r-process cosmic sites
- Nuclear reaction rates in stars
- Compact binary object spectroscopy (*kilonova transient):* to characterize composition and to identify GW events

The PANDORA Multi-Diagnostic Setup



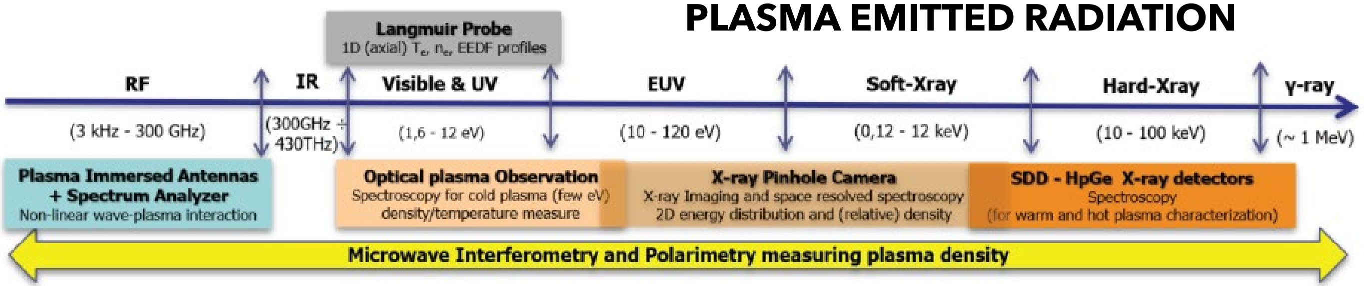
Typical ECR Ion Source

The PANDORA Multi-Diagnostic Setup



PANDORA Facility

PLASMA EMITTED RADIATION

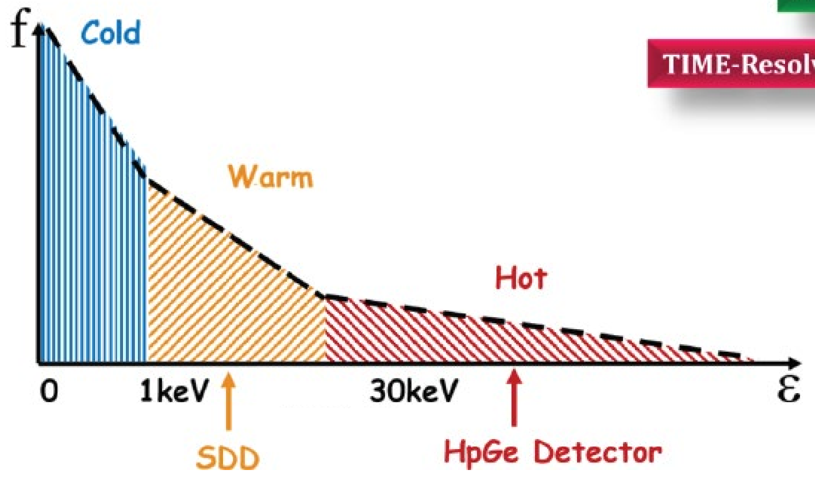


Typical Electron Energy Distribution Function (EEDF)
Three different regions can be individuated in a typical spectra

Volume-Integrated Spectroscopy

SPACE-Resolved Soft X ray Spectroscopy

TIME-Resolved RF +Soft/Hard X ray Spectroscopy



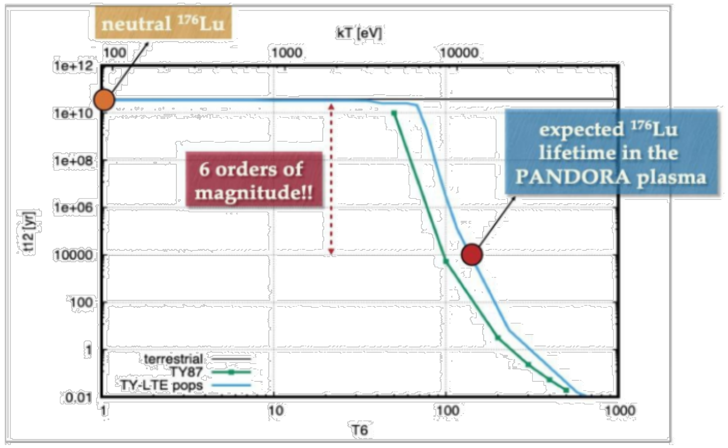
PANDORA Talk@Sif2021 → E. Naselli "Status of the PANDORA project at INFN-LNS"

AsFiN

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

PANDORA: β-decay Measurements

- Three suitable candidates for experiments (among more than 100 initial cases!), based on scientific impact, trap size, magnitude of stellar-enhanced effects, type of element



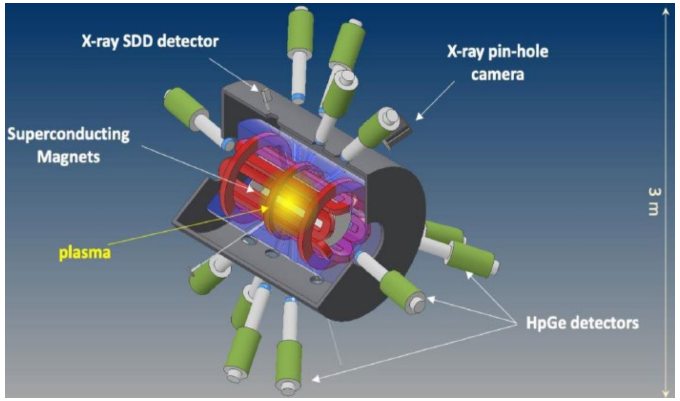
^{176}Lu → **Cosmo-chronometer/thermometer –** Expected theor. reduced lifetime ~ **6 orders of magnitude**

^{134}Cs → **s-process branching in AGB stars -** Expected theor. reduced lifetime ~ **3 orders of magnitude**

^{94}Nb → **s-process branching in AGB stars -** Expected theor. reduced lifetime ~ **4 orders of magnitude**

METHOD

- **Plasma** buffer (H, He, Ar) **host radioisotopes** fluxed into the trap, maintained in dynamical equilibrium **for ~ days/weeks**
- After isotopes decay, **daughter nuclei** still confined **emit γ-rays** of hundreds of keV
- Gamma are detected through **HpGe array γ-detector array** surrounding the trap
- In-plasma **measured radioactivity correlated to plasma density and energy**, monitored via a multi-diagnostic setup
- **CORRELATION BETWEEN PLASMA PARAMETERS AND NUCLEAR LIFETIME IS THE CRUCIAL POINT OF THE MEASUREMENTS**.

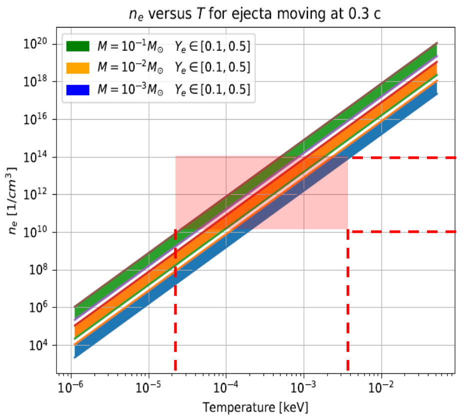


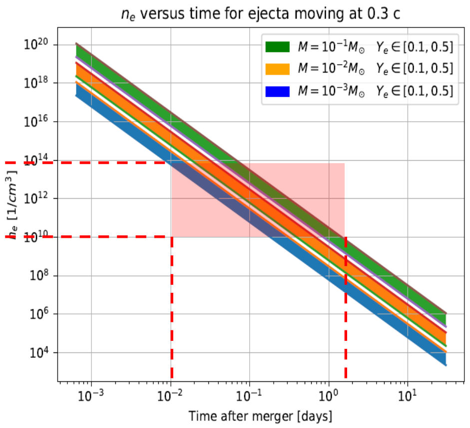
- *PANDORA Talk@Sif2021 → B. Mishra "Predicting β-Decay Rates of Radioisotopes "*

PANDORA: Plasma Opacity Measurements

- **EM transient** signals known as **kilonovae** (KN) emitted by merging compact objects
- KN observed as **follow-up of the gravitational-wave** (GW) event GW170817, spectroscopic info on the **composition/dynamics of ejecta** arising from the merging
- **r-process nucleosynthesis sites**, making the study of KN a novel challenge for nuclear astrophysics in the MMA era.

Opacity of ejecta fundamental for reliable predictions on the KN light curve. **Mismatch between obs. vs. theory**, models oversimplified, lacking detailed atomic database





Pidatella A. et al, Il Nuovo Cimento C, 2-3, (2021), 10.1393/ncc/i2021-21065-x
O. Korobkin et al., Mon. Not. R. Astron. Soc., 426 (2012) 3-1940:1949
Radice D. et al., Astrophys. J., 869 (2018) 2-130

PLASMA CONDITIONS REPRODUCIBLE IN ECR trap (e.g., PANDORA) $10^{10} \div 10^{14}\ cm^{-3}$

REPRODUCIBLE EVOLUTION STAGE IN LAB @ $\sim 10^{-2} \div 1$ day : BLUE KILONOVA, VISIBLE LIGHT

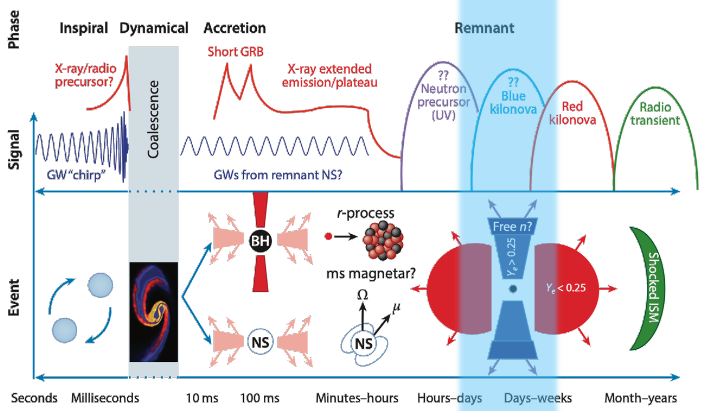


Figure 1

Phases of a neutron star (NS) merger as a function of time, showing the associated observational signatures and underlying physical phenomena. Abbreviations: BH, black hole; GRB, γ-ray burst; GW, gravitational wave; ISM, interstellar medium; n, neutron; UV, ultraviolet; Y_e, electron fraction. Coalescence inset courtesy of D. Price and S. Rosswog (see also Reference 15).

R.Fernández, *et al.*, Annu. Rev. Nucl. Part. Sci. 2016. 66:23-45

Article | Published: 23 October 2019

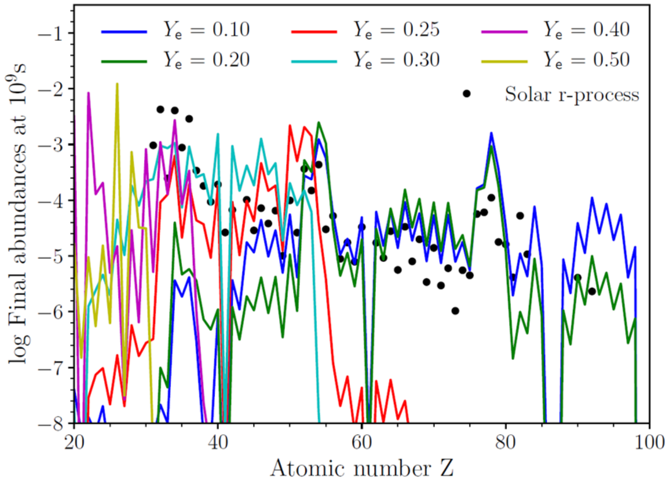
Identification of strontium in the merger of two neutron stars

Darach Watson, Camilla J. Hansen, Jonatan Selsing, Andreas Koch, Daniele B. Malesani, Anja C. Andersen, Johan P. U. Fynbo, Almudena Arcones, Andreas Bauswein, Stefano Covino, Aniello Grado, Kasper E. Heintz, Leslie Hunt, Chryssa Kouveliotou, Giorgos Leloudas, Andrew J. Levan, Paolo Mazzali & Elena Pian

Nature **574**, 497–500 (2019) | Cite this article

Watson, D. et al, Nature volume 574, 497-500 (2019)

PANDORA: Plasma Opacity Measurements



IDENTIFICATION OF PHYSICS CASES

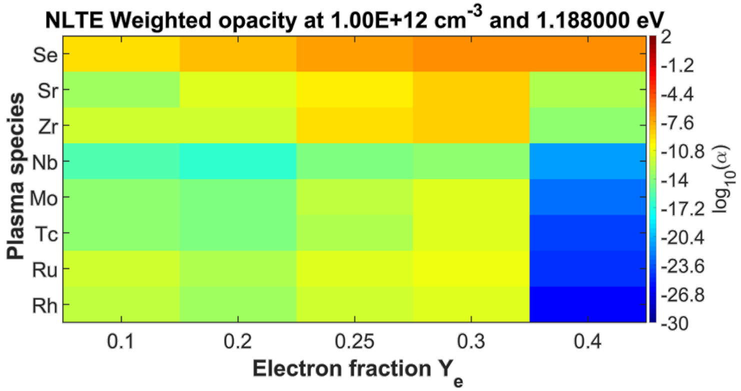
- **Time-dependent r-process elements abundances from SKYNET**, with distribution of ejecta properties (entropy, electron fraction and expansion timescale) from astrophysical simulations → **LIGHT R-PROCESS ELEMENTS, LOW NEUTRON RICHNESS**

- **MEAN OPACITY vs. T**, weighted with abundances from SKYNET: **synthetic spectra** of opacity from **FLYCHK → Selenium and Strontium** most suitable for experiments

METHOD: OPTICAL EMISSION SPECTROSCOPY (OES) + INTERFERO-POLARIMETRY

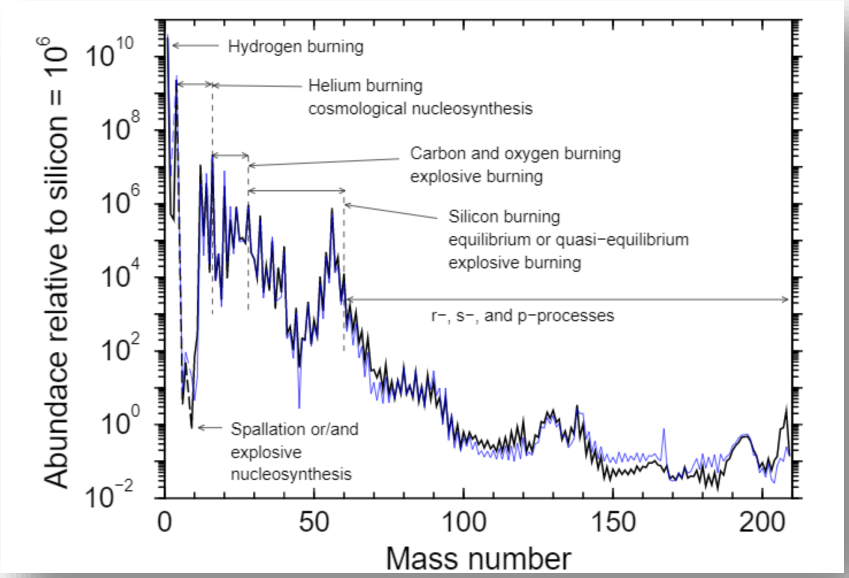
- **OES** to monitor plasma density and temperature via **line-ratio method**, and analysis of **emitted light to extract opacity** of radiation-interacting plasma

- Interfero-polarimetry measurements – effect of plasma on EM radiation measuring **Faraday rotation angle**



Pidatella A. et al, Il Nuovo Cimento C, 2-3, (2021), 10.1393/ncc/i2021-21065-x

Conclusions



MAIN GOAL : KNOWLEDGE OF NUCLEAR REACTION RATES --> ARE DIRECT MEASUREMENTS ENOUGH?

@ INFN-LNS ASFIN & PANDORA COMMON GOAL:

- NEW APPROACHES TO NUCLEAR ASTROPHYSICS FEASIBLE IN LABORATORY
- EXPERIMENTAL SYNERGY FOR STELLAR MODELS
- PHYSICS LINKS: S- AND R-PROCESS NUCLEOSYNTHESIS

NUCLEAR REACTION RATES

ASFIN: application of THM to n-induced reactions; r-process nucleosynthesis in n-star mergers--> **EXPERIMENTAL NUCLEAR INPUTS/OUTPUTS**

PANDORA : on construction experimental facility @LNS, plasma trap to measure weak-interaction rates of radionuclides in strongly ionized environment --> **EXPERIMENTAL WEAK-INTERACTION INPUTS/OUTPUTS**

Conclusions

A - It is possible to measure the bare nucleus cross section σ_b (or the bare nucleus Astrophysical Factor $S_b(E)$) at Gamow energy for reactions involving charged particles and neutron.

B - One of the few ways to measure the electron screening effect; comparison with direct data;

C - Measurements of radiative capture reaction cross section at Gamow energy;

D - Application to the radioactive beam measurements;

E – Measurements of β-decay lifetimes at stellar conditions;

F – Shed light on plasma opacity for compact stellar objects

Method complementary to direct measurements (Multi Diagnostic Experiments)

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

AsFiN Collaboration

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INFN Istituto Nazionale di Fisica Nucleare

PANDORA Collaboration

HAVE A LOOK AT OTHER PANDORA COLLABORATION TALKS @ SIF2021

- **BHARAT MISHRA (UniCT - INFN-LNS) -** "Predicting β-Decay Rates of Radioisotopes Embedded in Anisotropic ECR Plasmas"
- **EUGENIA NASELLI (INFN-LNS) -** "Status of the PANDORA project at INFN-LNS: in-plasma β-decay investigations of nuclear astrophysical interest"

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

Also collaborating in the nuclear fusion research programme for the Divertor Tokamak Test (DTT) project

Plasmas for
Astrophysics
Nuclear
Decay
Observation and
Radiation for
Archaeometry

Thank you for your attention