A brief sketch of the nuclear research by LNS groups at LNS

Marco La Cognata

INFN-LNS Nuclear physics coordinator

INFN
LNS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Nuclear Physics @ LNS

2019	2020	2021	2022/2023
ASFIN2	*ASFIN2*	*ASFIN2*	*ASFIN2*
JLAB12	*JLAB12*	*JLAB12*	*JLAB12*
NEWCHIM	*NEWCHIM*	*CHIRONE*	*CHIRONE*
NUMEN	*NUMEN*	*NUMEN*	*NUMEN*
n_TOF	*n_TOF*	*n_TOF*	*n_TOF*
	PANDORA	*PANDORA*	*PANDORA*
		+ EIC_NET (DOT.)	*EIC_NET*
			+ NUCL-EX (DOT.)

JLAB12, EIC_NET — ***Linea 1*** (QUARKS AND HADRON DYNAMICS)

CHIRONE, NUMEN_GR3
NUCL-EX.DTZ — ***Linea 3*** (NUCLEAR STRUCTURES AND REACTIONS DYNAMICS)

ASFIN, n_TOF
PANDORA — ***Linea 4*** (ASTROPHYSICS AND INTERDISCIPLINARY RESEARCHES)

Nuclear Physics @ LNS

2019	2020	2021	2022/2023
ASFIN2	*ASFIN2*	*ASFIN2*	*ASFIN2*
JLAB12	*JLAB12*	*JLAB12*	*JLAB12*
NEWCHIM	*NEWCHIM*	*CHIRONE*	*CHIRONE*
NUMEN	*NUMEN*	*NUMEN*	*NUMEN*
n_TOF	*n_TOF*	*n_TOF*	*n_TOF*
	PANDORA	*PANDORA*	*PANDORA*
		+ EIC_NET (DOT.)	*EIC_NET*
			+ NUCL-EX (DOT.)

To date, LNS hosts:

→ the **largest nuclear physics community** in Italy: ~90 researchers (60 FTE)

→ the **largest nuclear astrophysics community**

→ the two most innovative nuclear physics experiments inside INFN: **PANDORA and NUMEN**

Nuclear physics midterm plan

The ongoing upgrades and the forthcoming facilities have called for new ideas and physics programs to be carried out

LNS session (4-5 April 2022):
https://agenda.infn.it/event/28717/

Working group (Chair)	Topic	Speaker
Nuclear Dynamics (S. Pirrone)	Heavy Ion Collision – EOS Clustering Fission Dynamics	E. De Filippo A. Di Pietro E. Vardaci
Nuclear Structure (C. Agodi)	Nuclear Matrix Elements towards $0\nu\beta\beta$: theoretical model developments Selective Study of nuclear structure response with high intensity beams and advanced spectrometry Collective modes in nuclei with stable and unstable beams	A. Gargano F. Cappuzzello G. Cardella
Nuclear Astrophysics (R. Pizzone)	Nuclear and atomics input for the quiescent stellar evolution The «explosive» universe : BBN and explosive nucleosynthesis s and r process	A. Pidatella G. G. Rapisarda M. L. Sergi
Applications (S. Tudisco)	Medical Applications Laser-Matter Interaction Plasma traps	G. Petringa G. A. P. Cirrone D. Mascali

JLAB12-HPS

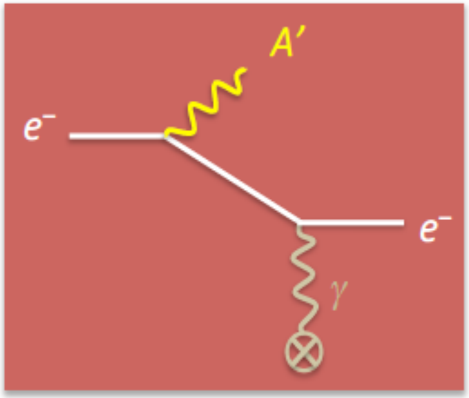
Few details about the physics

Search of the «heavy» or «dark» photon, linking the observable and the dark or hidden sectors → connection with dark matter search and with physics beyond the standard model.

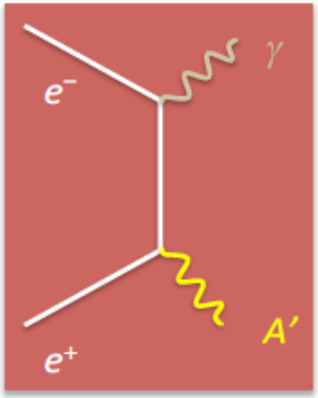
The search is carried out at Jefferson Laboratory, in a mass region from MeV to GeV

Production through:

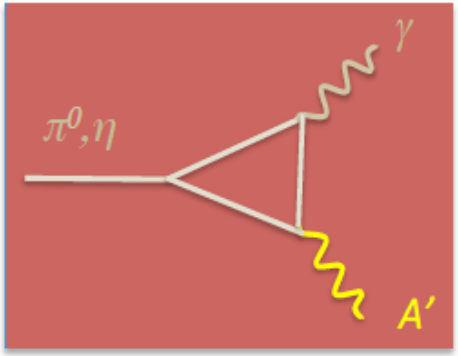
Bremsstrahlung: e N → e N A'



Annihilation: $e^+e^- \rightarrow \gamma A'$



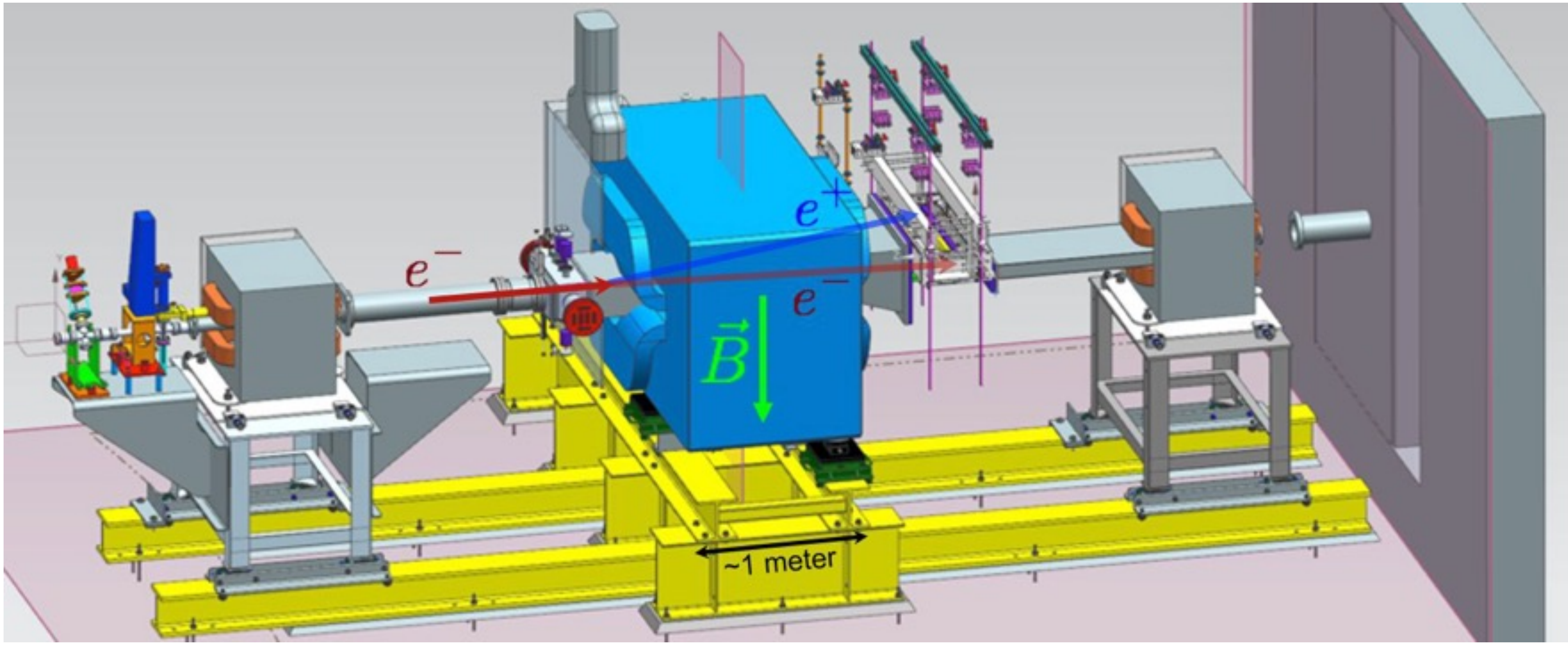
Meson decays



Following the interaction of an electron with some fixed target

Detection through the tracking of the e^+e^- couples produced in A' decay

HPS detection setup



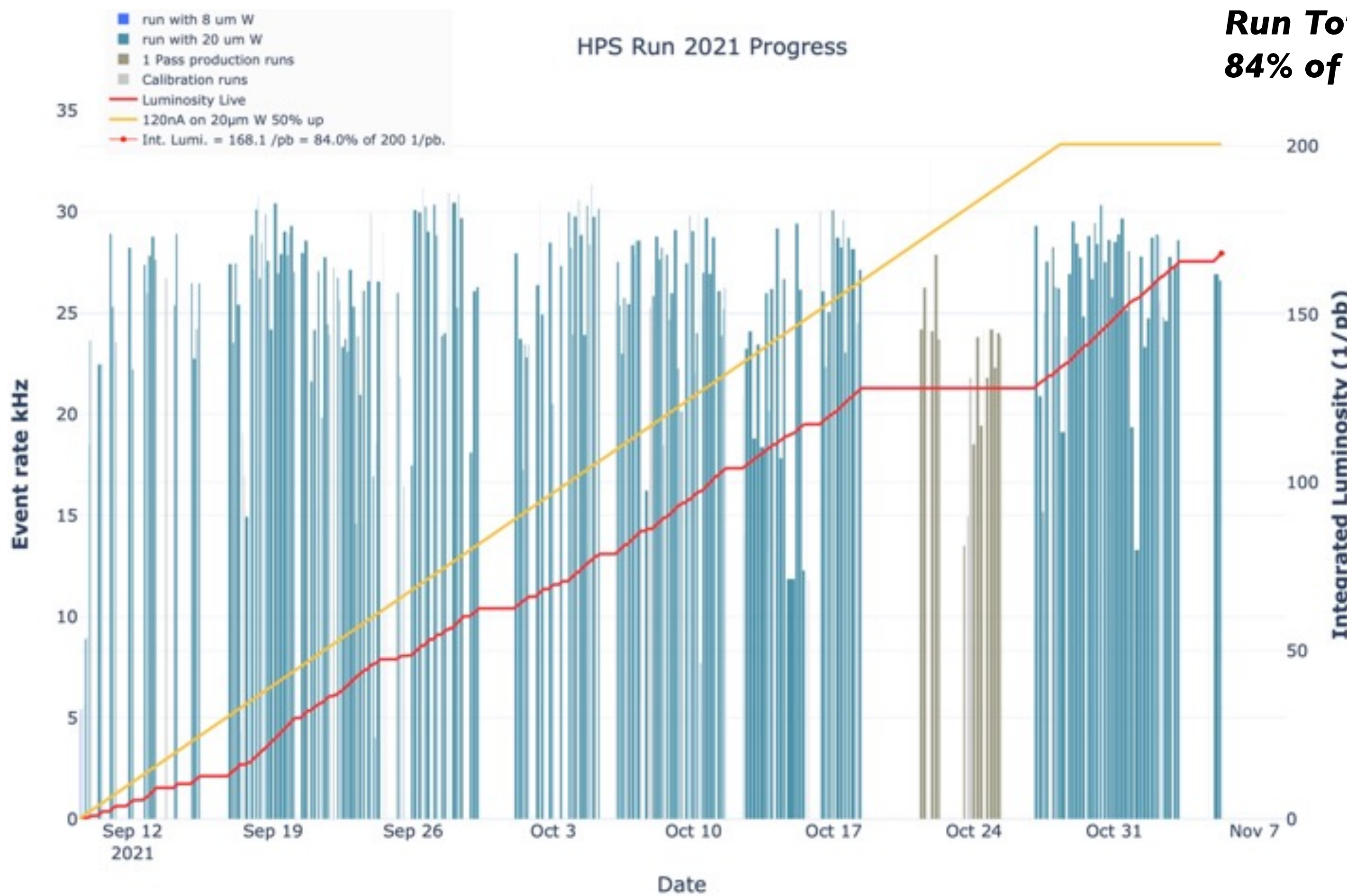
The experiments at JLAB carry out a broad range of studies, including the structure of the nucleon, quark and hadron dynamics (nuclei and hypernuclei)

The LNS group uses the CEBAF (Continuous Electron Beam Accelerating Facility) electron beam (1-11 GeV) at the Jefferson Lab (Hall B) for A' dark photon search

Activities 2022-2023

- HPS took data in 2021 @ 3.7 GeV
- From August 22 to November 1 2022.
- LNS contributed with 32 Shifts

Run Total = 168 pb⁻¹
84% of goal



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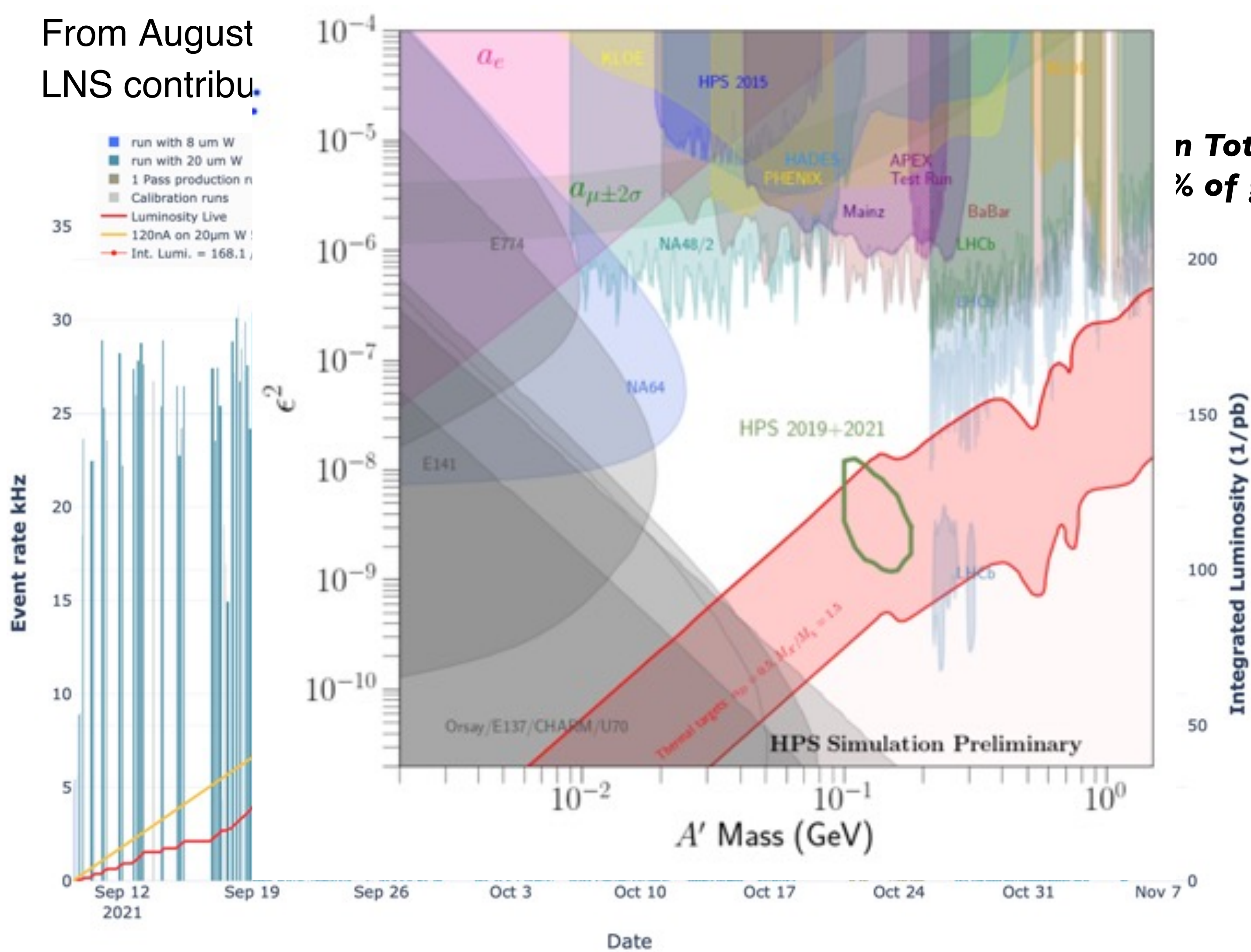


LINEA 1

The EIC project

The Electron-Ion collider will be installed at Brookhaven Nat'l lab and will make it possible to

- Span the 20-100 GeV energy range, upgradable to 140 GeV
- Achieve high luminosities, in the 10^{34} cm^{-2} s^{-1}
- Deliver highly polarized beams (~80%)

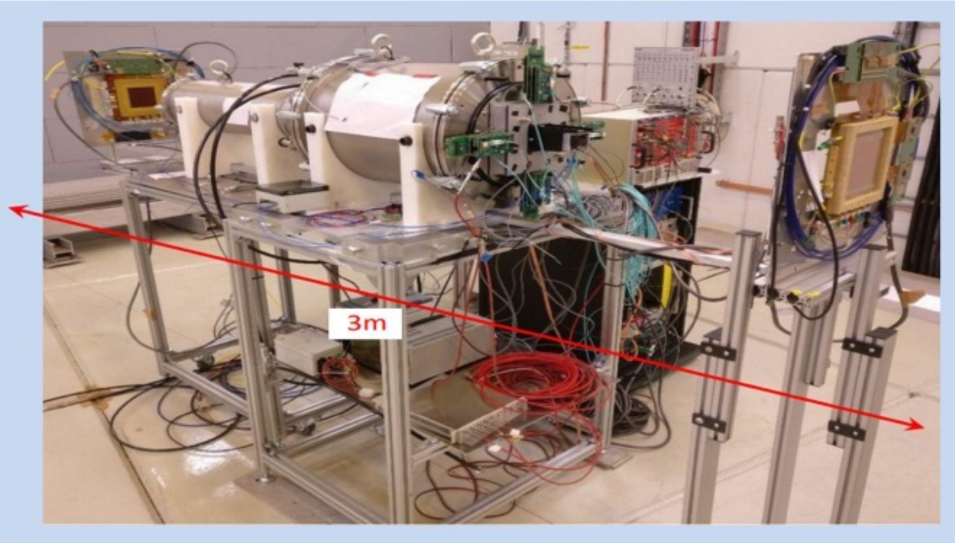
With the aim of studying

- Quark and gluon distributions (spin, momentum, space)
- Nucleon and hadron properties (QCD tests)
- Quark and gluon dynamics in dense nuclear matter and in nucleons

The LNS group is mainly focused on R&D activities on the DRICH for hadron ID

Successful commissioning of the DRICH prototype in 2021

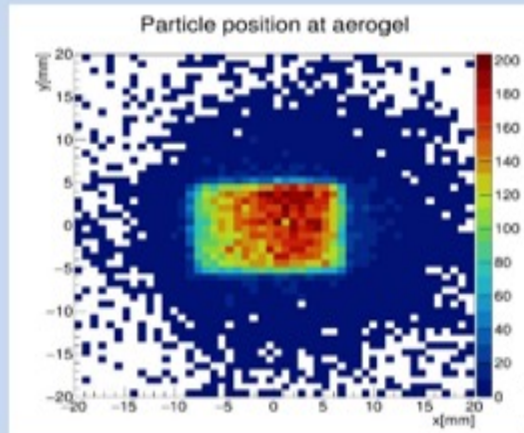
Dual radiator with aereogel

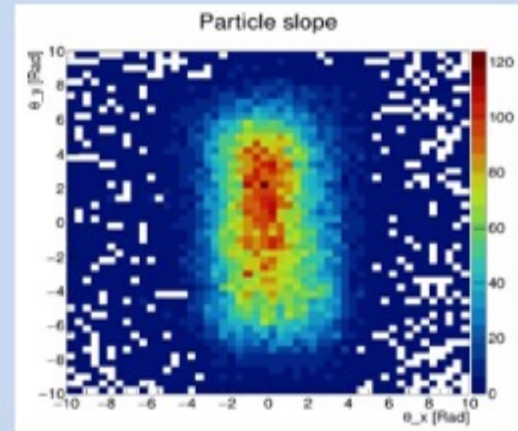


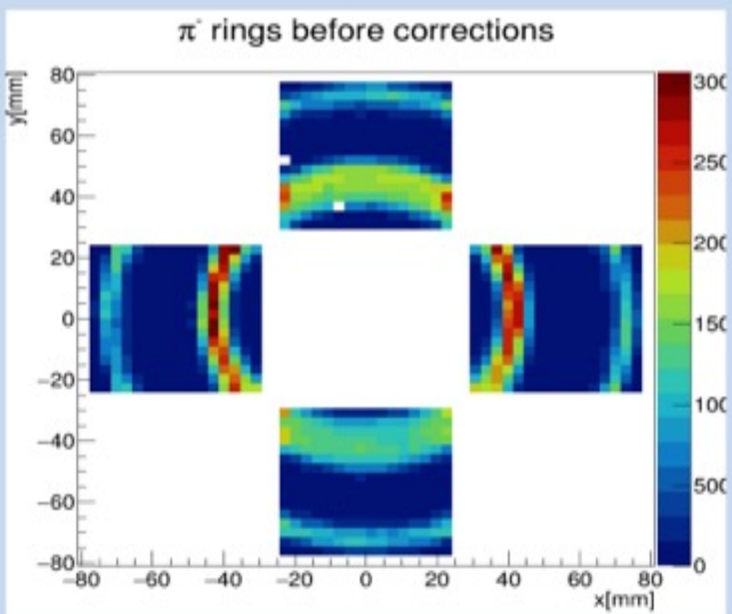
Cherenkov Rings

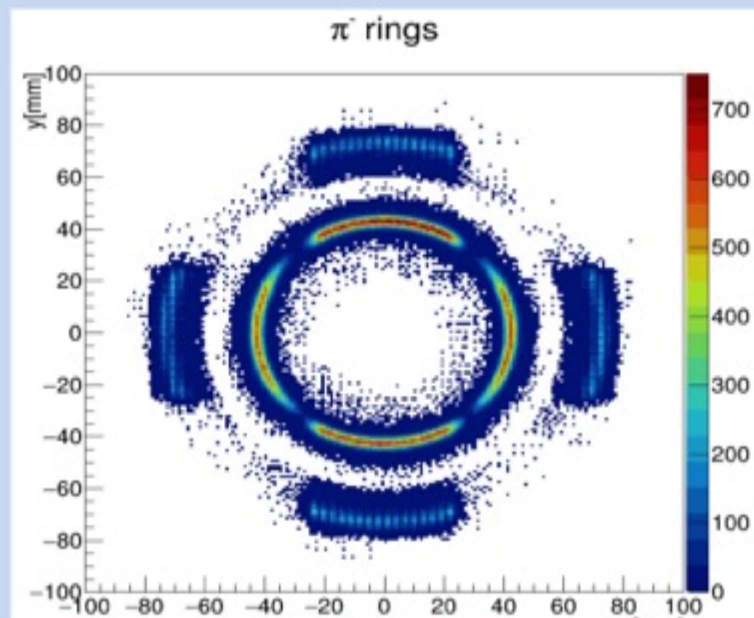
A tracking system based on two GEM detectors was used during the test beam to track the beam particles for measuring alignment and beam divergence.

The combination of the dRICH optical information and GEM track information allows to correct data on an event by event analysis.





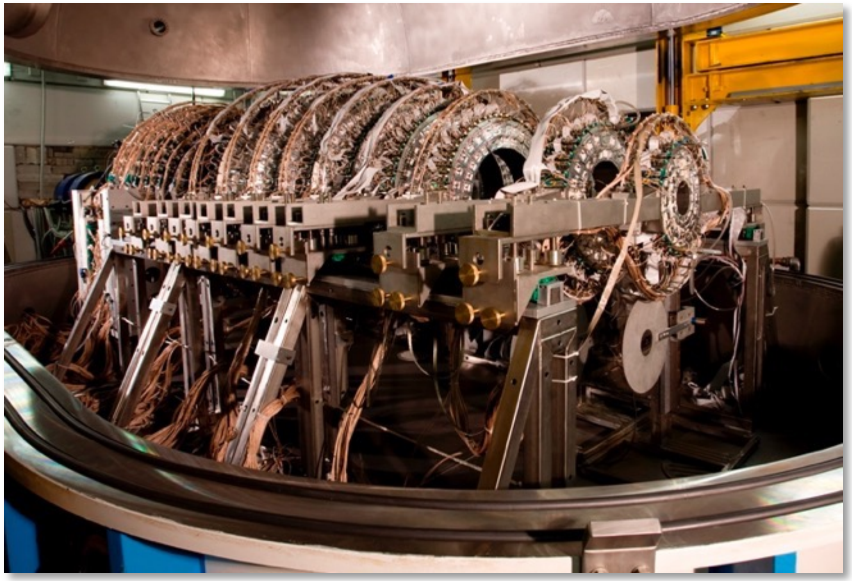




LINEA 3

CHIRONE

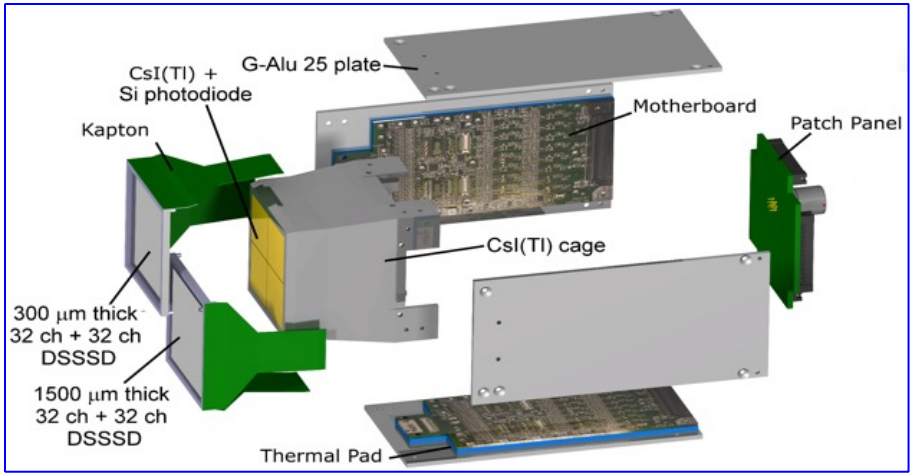
CHImera R3B hOdoscopes Neutrons Experiment



CHIMERA

Study of the dependence of reaction mechanisms on isospin with innovative detections systems (CHIMERA, FARCOS, neutron detectors)

→ Research on nuclear matter under extreme considition (EOS for neutron stars, clustering in light nuclei)



FARCOS: Femtoscope Array for COrrelations and Spectroscopy

- High energy and angular resolution Low thresholds (<1 MeV/A)
- Large Dynamic range (20MeV to 2GeV)
- Flexibility, modularity, transportability
- GET
- 20 telescopes

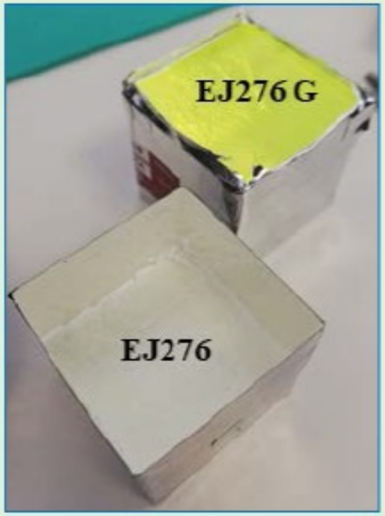
HIGHLIGHTS 2022

PRIN ANCHISE-2020

Period: 3 years starting June 2022
Fund: ~ 627KE MUR
Collaboration: INFN – UniCt – UniMe - PoliMI.
Coordinator and spokes: A.Pagano (INFN) – G.Politi (UniCt) - M.Trimarchi (UniME) - A.Castoldi (PoliMI).

Neutron detection - fully integrated with Charged particles detection - Reaction studies and spectroscopy with Stable and n-rich nuclei at Fermi energies.

Highly segmented Hodoscope (new material such as EJ276 coupled with Si-PMT) important tool to master the crucial problems of Cross talk for neutron detections.



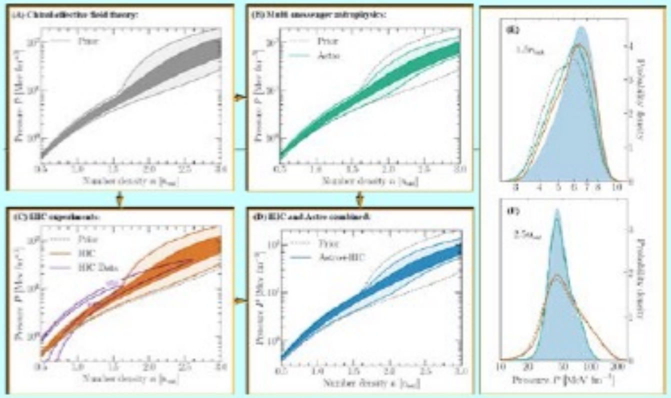
TOF, Pulse shaping (n,gamma, CP) and Digital Acquisition

EOS & SIMMETRY ENERGY

Constraining Neutron-Star Matter with Microscopic and Macroscopic Collisions, S. Huth et al. **Nature 2022**
https://www.nature.com/articles/s41586-022-04750-w

Combining HIC and astrophysical results in the same Bayesian analysis to constrain neutron matter EOS

« **HIC** » = FOPI + **ASY-EOS** (1-1.5 ρ_0) + AGS
« **Astro** » = GW, NICER (pulsar X-ray hot spots)



$$R_{1.4} = 12.01^{+0.78}_{-0.77}\ km \quad at\ 95\%\ CI$$

Advancing HIC experimental constraint to higher densities ≈2 ρ_0 is needed, a new experiment, ASY-EOS II (P.Russotto et al), is going to be asked (PAC-GSI 2022)

HIGHLIGHTS 2022

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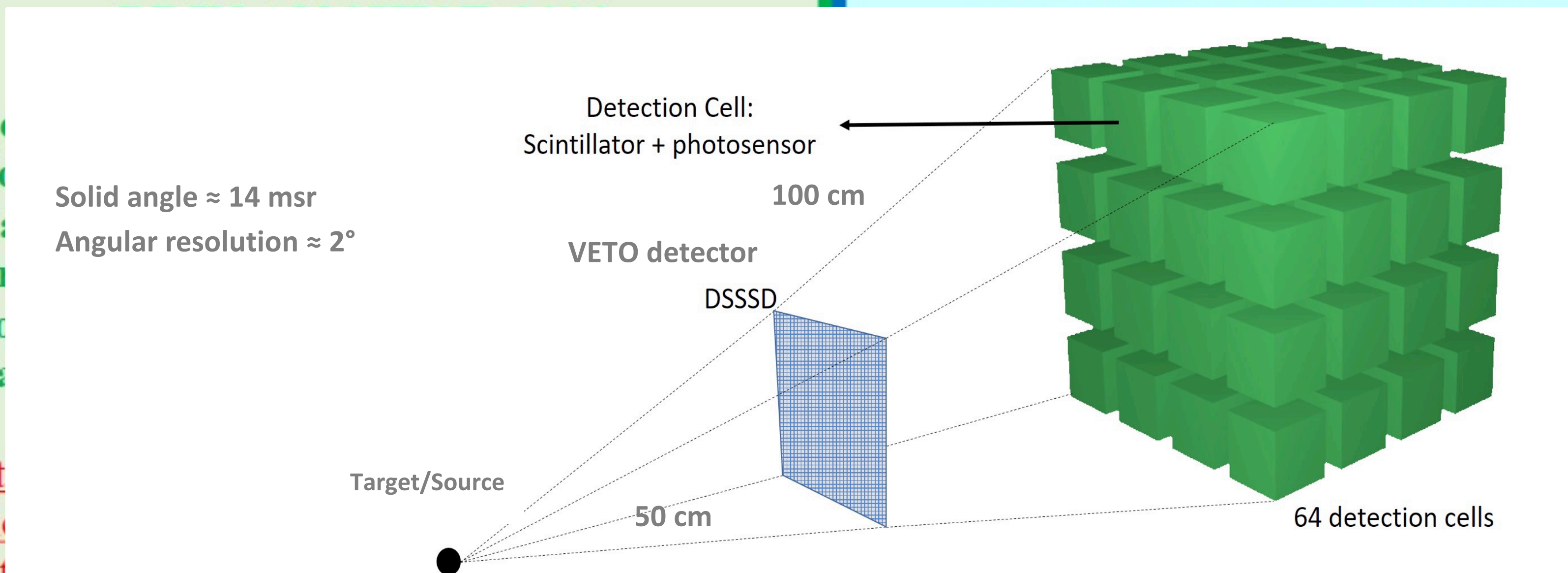

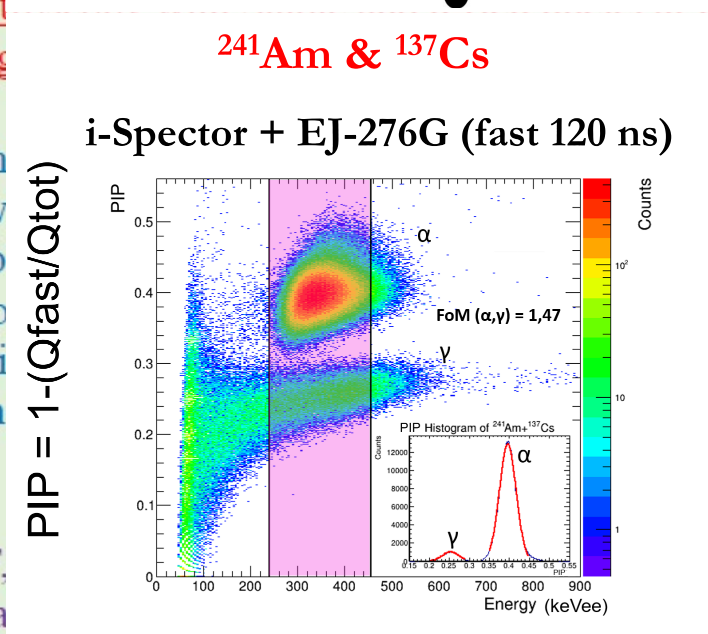

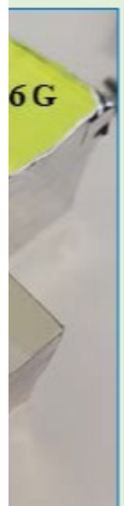

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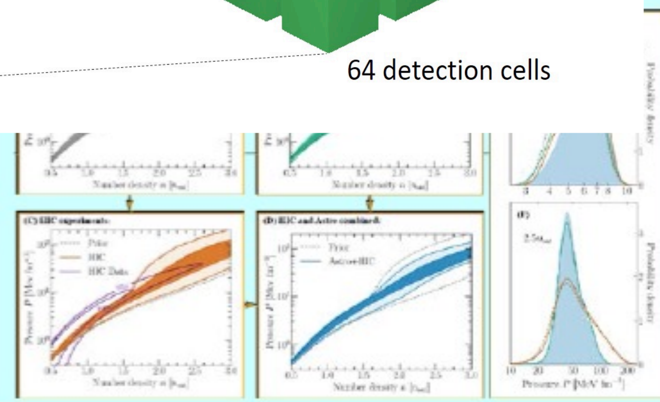

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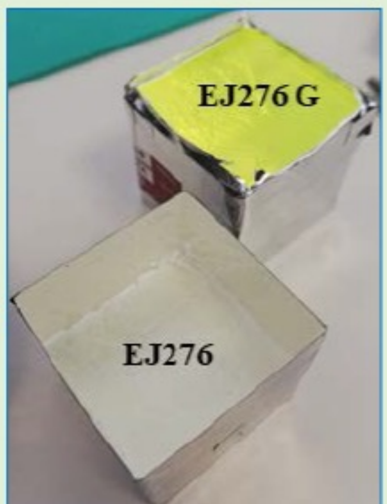

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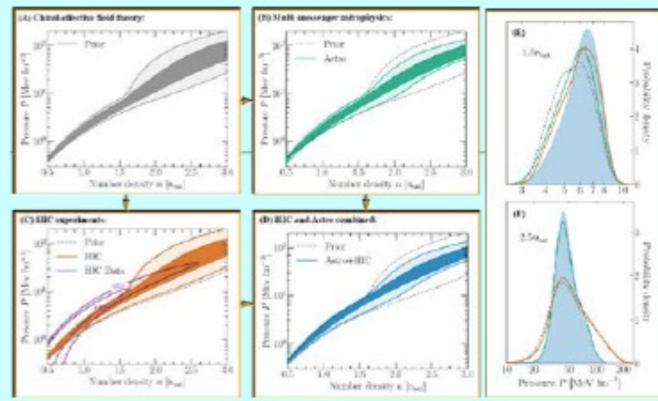

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LINEA 3

NUMEN_GR3

Extraction from measured cross-sections of "*data-driven*" information on Nuclear Matrix Elements for all the systems candidate for 0νββ
Use of nuclear reactions **(Double Charge Exchange reactions)** to stimulate in the laboratory the same nuclear transition occurring in 0νββ

Phase space factor

contains the average **neutrino mass**

$$\left(T^{0\nu\beta\beta}_{1/2}(0^+ \rightarrow 0^+)\right)^{-1} = G_{0\nu\beta\beta}\left|M^{0\nu\beta\beta}\right|^2 \left|f(m_i, U_{ei})\right|^2$$

0νββ decay half-life

Nuclear matrix element

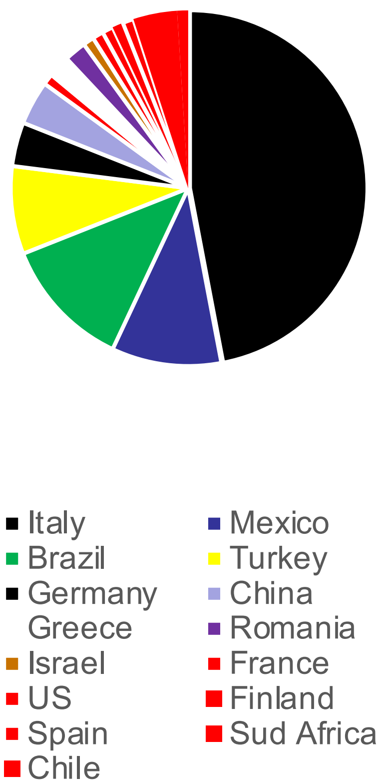
K800 Superconducting Cyclotron

MAGNEX magnetic spectrometer

A challenging perspective at LNS in nuclear science

Status of NUMEN

100 Researchers
40 Institutions
15 Countries



Phase 2 completed

- ✓ All the **experiments** in present condition recommended by the International Advisory Committee (chaired by F. Iachello) successfully performed. Several articles published
- ✓ **R&D for MAGNEX** upgrade completed. New technologies, e.g. SiC within SiCilia project, MTHGEM, HOPG etc..) (Technical Design Report ready)
- ✓ **Theory** deeply developed, showing that DCE reactions proposed by NUMEN are connected with Nuclear Matrix Elements for ββ decay

A broad collaboration inward LNS established

Leadership in the field: Japanese projects for DCE reactions could not reach enough sensitivity

Fostering other project to success: ERC-NURE, POT-LNS, TeBe MIUR …

Interdisciplinarity: Interest by different communities from nuclear and neutrino physics. NUMEN acts within different scientific commissions of INFN

Outreach: An intense outreach activity performed with high visibility for INFN frontiers in Astronomy and Space Sciences

ORIGINAL RESEARCH
published: 07 May 2021
doi: 10.3389/fspas.2021.659815

OPEN ACCESS

A Constrained Analysis of the $^{40}Ca(^{18}O,^{18}F)^{40}K$ Direct Charge Exchange Reaction Mechanism at 275 MeV

Manuela Cavallaro[1]*, Jessica I. Bellone[1], Salvatore Calabrese[1], Clementina Agodi[1], Stefano Burrello[2], Francesco Cappuzzello[1,3], Diana Carbone[1], Maria Colonna[1], N. Deshmukh[4], H. Lenske[5], A. Spatafora[1,3], L. Acosta[6], P. Amador-Valenzuela[7], T. Borello-Lewin[8], G. A. Brischetto[1,3], D. Calvo[9], V. Capirossi[9,10], E. Chávez[6], I. Ciraldo[1,3], M. Cutuli[1,3], F. Delaunay[11], H. Djapo[12], C. Eke[13], P. Finocchiaro[1], S. Firat[14], M. Fisichella[1], A. Foti[15], M. A. Guazzelli[16], A. Hacisalihoglu[17], F. Iazzi[9,10], L. La Fauci[1,3], R. Linares[18], J. Lubian[18], N. H. Medina[8], M. Moralles[19], J. R. B. Oliveira[8], A. Pakou[20], Luciano Pandola[1], H. Petrascu[21], F. Pinna[9,10], G. Russo[15], O. Sgouros[1], S. O. Solakci[14], V. Soukeras[1], G. Souliotis[22], D. Torresi[1], Salvatore Tudisco[1], A. Yildirin[14] and V. A. B. Zagatto[18] for the NUMEN collaboration

Edited by: Nunzio Itaco, University of Campania Luigi Vanvitelli, Italy

Reviewed by: Mengoni Daniele, National Institute of Nuclear Physics of Padova, Italy; Pierre Descouvemont, Université libre de Bruxelles, Belgium

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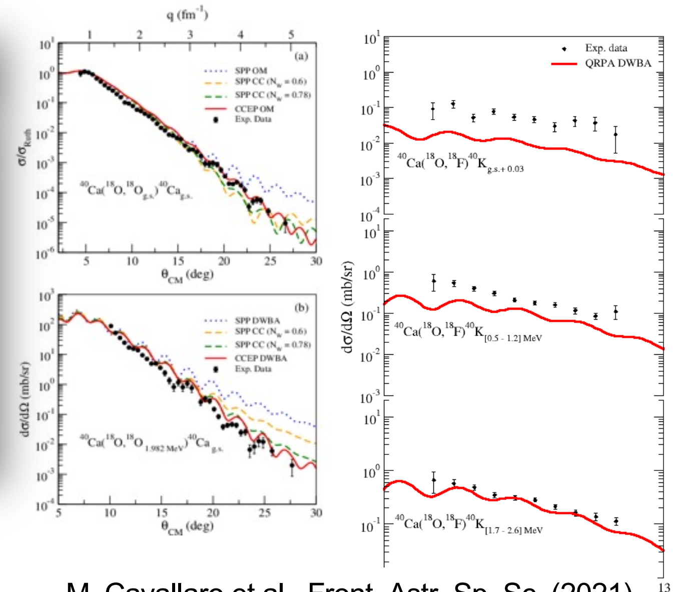
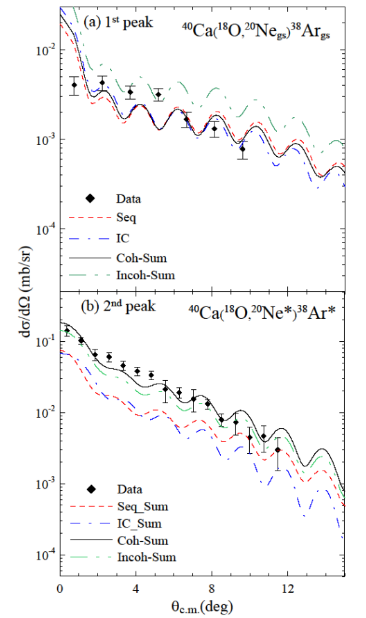


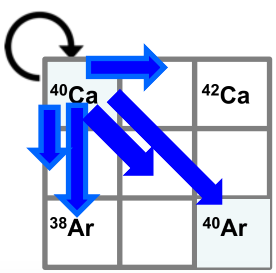
M. Cavallaro et al., Front. Astr. Sp. Sc. (2021)



J.L. Ferreira et al., PRC (2021)

A multi-channel approach to nuclear reactions

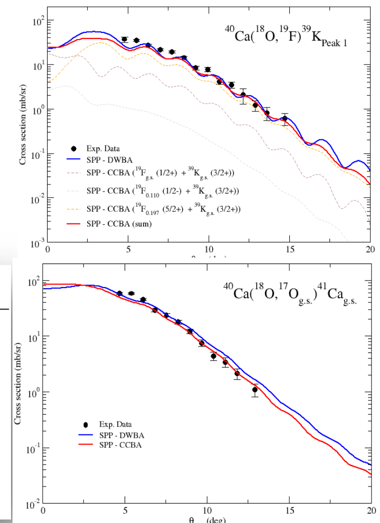
Consistent study (experimental and theoretical) of all the reaction channels competing with the double charge exchange to obtain a reliable description of the reaction mechanism and structure



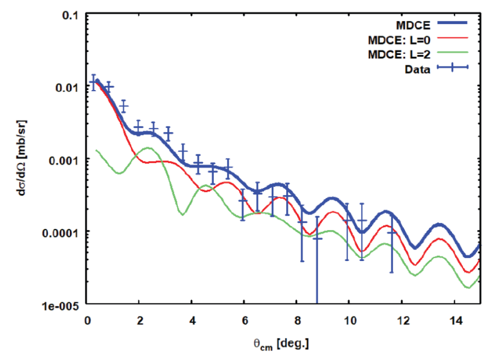
PHYSICAL REVIEW C 103, 054604 (2021)

Analysis of two-proton transfer in the $^{40}Ca(^{18}O,^{20}Ne)^{38}Ar$ reaction at 270 MeV incident energy

J. L. Ferreira,[1] D. Carbone,[2] M. Cavallaro,[2,*] N. N. Deshmukh,[2,3] C. Agodi,[2] G. A. Brischetto,[2,4] S. Calabrese,[2] F. Cappuzzello,[2,4] E. N. Cardozo,[1] I. Ciraldo,[2,4] M. Cutuli,[2,4] M. Fisichella,[2] A. Foti,[4] L. La Fauci,[2,4] O. Sgouros,[2] V. Soukeras,[2] A. Spatafora,[2,4] D. Torresi,[2] and J. Lubian[1]
(NUMEN Collaboration)



S. Calabrese et al. (to be submitted)

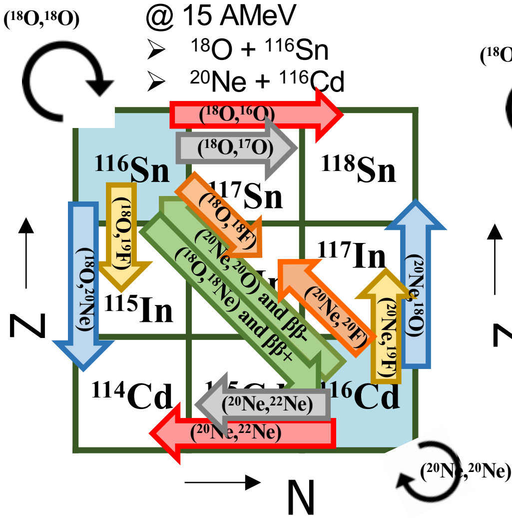


F. Cappuzzello, et al., EPJA (2015)
H. Lenske, et al., PPNP (2019)

Systems and reactions studied in NUMEN Phase 2

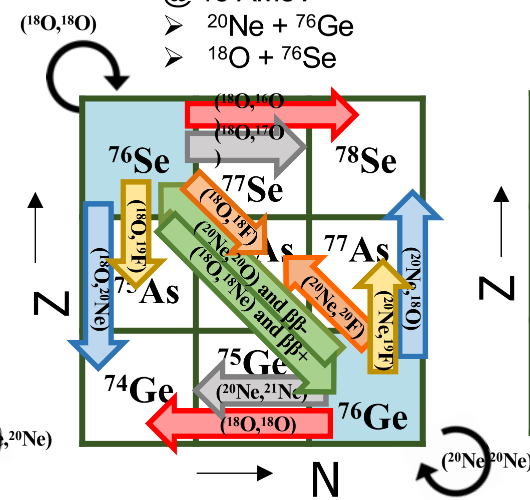
^{116}Cd - ^{116}Sn case

@ 15 AMeV
- ➢ ^{18}O + ^{116}Sn
- ➢ ^{20}Ne + ^{116}Cd



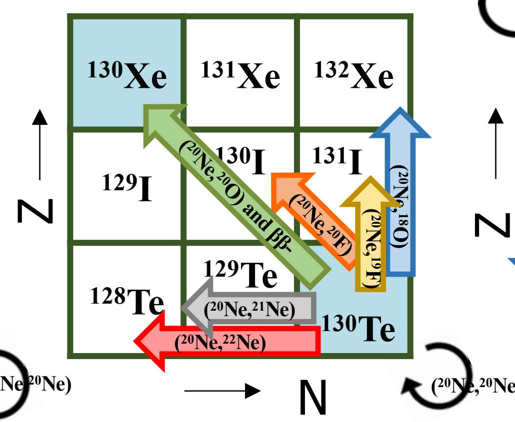
^{76}Ge – ^{76}Se case

@ 15 AMeV
- ➢ ^{20}Ne + ^{76}Ge
- ➢ ^{18}O + ^{76}Se



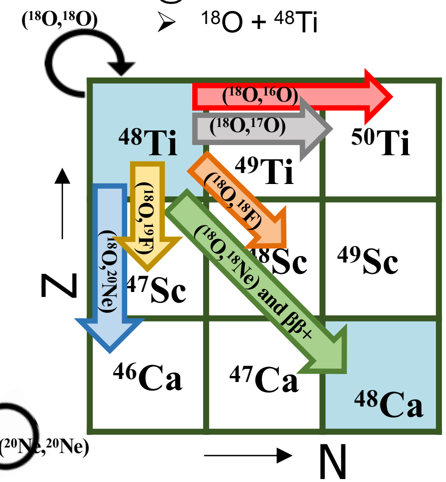
^{130}Te – ^{130}Xe case

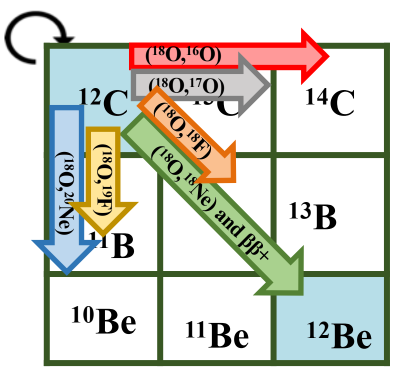
@ 15 AMeV
- ➢ ^{20}Ne + ^{130}Te



^{48}Ti – ^{48}Ca case

@ 15 AMeV
- ➢ ^{18}O + ^{48}Ti





^{12}C – ^{12}Be case at 2 beam energies

@ 15 AMeV
@ 22 AMeV

Last experiment performed at LNS after the COVID lockdown and before the shutdown of LNS facilities for the upgrade

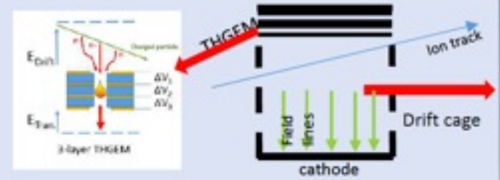
<u>The research activity includes:</u>

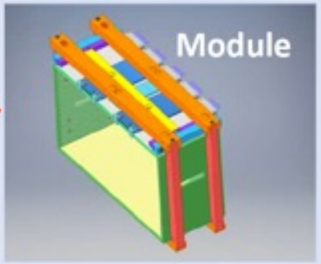
→ Theoretical work focused, for instance, on the Majorana mechanism and its connection with 0νββ

→ R&D for the development of novel detectors, e.g. for high rates

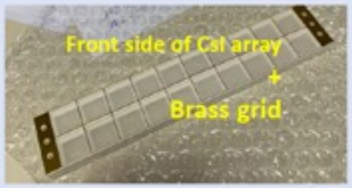
MAGNEX future detectors @NUMEN

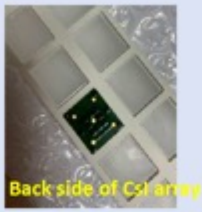
- The construction of a New **Focal Plane Detector:**
  - **New Gas- Tracker,** based on M-THGEM technology;



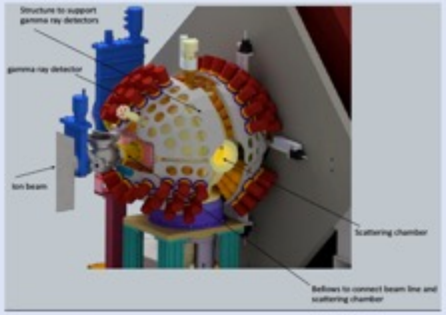


  - **New Wall of telescopes** of SiC-CsI detectors for ion identification (PID-wall) ;





- The introduction of a **gamma - array Calorimeter of $LaBr_3$**(G-NUMEN);



- The development of suitable **front-end and read-out electronics**, for a fast read- out of the detector signals, a high signal to noise ratio and adequate hardness to radiation;
- The implementation of a **suitable architecture** for **data acquisition, storage and data handling**;
- The development of the **technology for suitable nuclear targets** to be used in the experiments

LINEA 4

ASFIN2

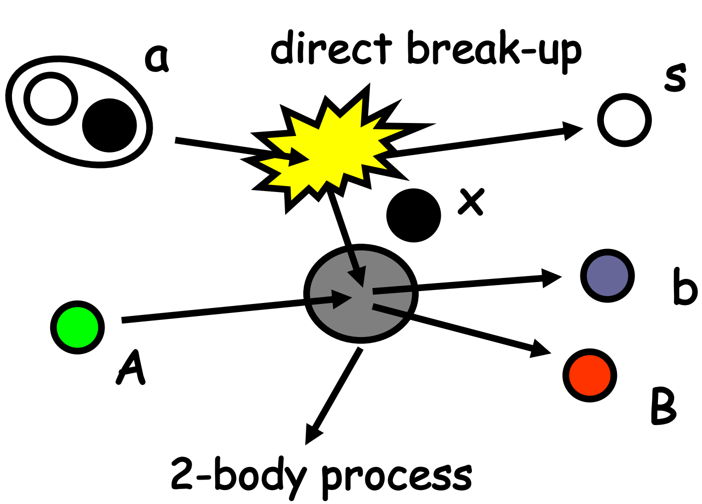
- ***Indirect methods allow to complement direct measurements*** overcoming several experimental difficulties (Coulomb barrier penetration effects, electron screening effects, background effects…);

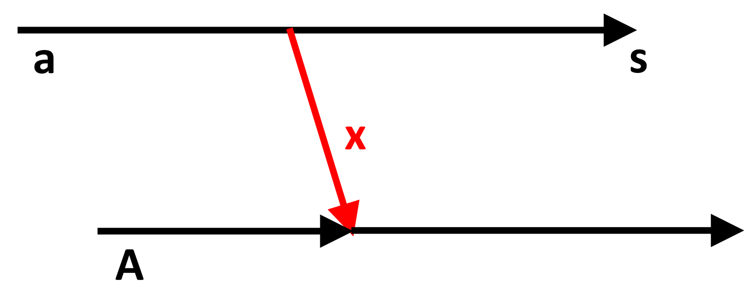
- ***ASFIN is active in the field*** of experimental nuclear astrophysics since 90's allowing to shed light on several astrophysical problems (BBN, stellar nucleosynthesis, explosive nucleosynthesis…)

- During the years, ***ASFIN applied THM but also ANC e Thick Target Inverse Kinematic (TTIK)*** methods for extracting nuclear reaction cross section of interest for astrophycis

- Indirect methods allow one to deduce the ***bare-nucleus S(E)-factor*** at ultra-low energies for astrophysical applications

Trojan Horse Method





The Asymptotic Normalization Coefficient (ANC) approach

Most important results 2021-2022

Annu. Rev. Nucl. Part. Sci. 2021. 71:345–76

ANNUAL REVIEWS

Annual Review of Nuclear and Particle Science

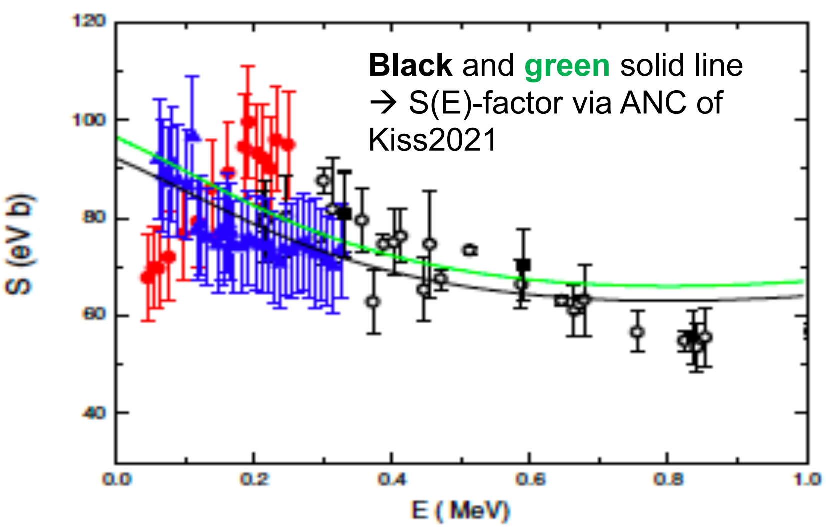
The Trojan Horse Method: A Nuclear Physics Tool for Astrophysics

Aurora Tumino,[1,2] Carlos A. Bertulani,[3] Marco La Cognata,[2] Livio Lamia,[2,4,5] Rosario Gianluca Pizzone,[2] Stefano Romano,[2,4,5] and Stefan Typel[6,7]

PHYSICAL REVIEW C 104, 015807 (2021)

Indirect determination of the astrophysical S factor for the ^{6}Li$(p,\gamma)^7$Be reaction using the asymptotic normalization coefficient method

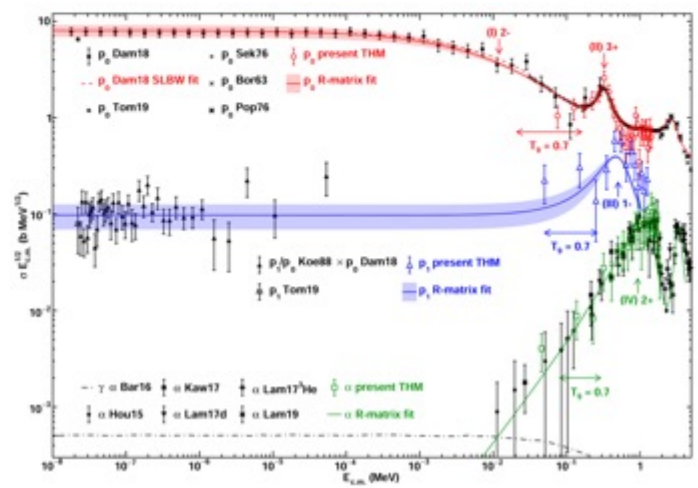
G. G. Kiss,[1,*] M. La Cognata,[2,†] R. Yarmukhamedov,[3,‡] K. I. Tursunmakhatov,[3,4] I. Wiedenhöver,[5] L. T. Baby,[5] S. Cherubini,[2,6] A. Cvetinović,[2] G. D'Agata,[7] P. Figuera,[2] G. L. Guardo,[2,6] M. Gulino,[2,8] S. Hayakawa,[9] I. Indelicato,[2,6] L. Lamia,[2,6,10] M. Lattuada,[2,6] F. Mudò,[2,6] S. Palmerini,[11,12] R. G. Pizzone,[2] G. G. Rapisarda,[2,6] S. Romano,[2,6,10] M. L. Sergi,[2,6] R. Spartà,[2,6] C. Spitaleri,[2,6] O. Trippella,[11,12] A. Tumino,[2,8] M. Anastasiou,[5] S. A. Kuvin,[5] N. Rijal,[5] B. Schmidt,[5] S. B. Igamov,[3] S. B. Sakuta,[13] Zs. Fülöp,[1] Gy. Gyürky,[1] T. Szücs,[1] Z. Halász,[1] E. Somorjai,[1] Z. Hons,[7] J. Mrázek,[7] R. E. Tribble,[14] and A. M. Mukhamedzhanov[14]



The Astrophysical Journal Letters, 915:L13 (14pp), 2021 July 1
https://doi.org/10.3847/2041-8213/ac061f

Constraining the Primordial Lithium Abundance: New Cross Section Measurement of the ^{7}Be + n Reactions Updates the Total ^{7}Be Destruction Rate

S. Hayakawa,[1] M. La Cognata,[2] L. Lamia,[2,3,4] H. Yamaguchi,[1,5] D. Kahl,[6,19] K. Abe,[1] H. Shimizu,[1] L. Yang,[1,20] O. Beliuskina,[1,21] S. M. Cha,[7,22] K. Y. Chae,[7] S. Cherubini,[2,3] P. Figuera,[2] Z. Ge,[8,21] M. Gulino,[2,9] J. Hu,[10] A. Inoue,[11] N. Iwasa,[12] A. Kim,[13] D. Kim,[13,22] G. Kiss,[8,23] S. Kubono,[1,8,10] M. La Commara,[14,15] M. Lattuada,[2,3] E. J. Lee,[7] J. Y. Moon,[16] S. Palmerini,[17,18] C. Parascandolo,[15] S. Y. Park,[13,24] V. H. Phong,[8,25] D. Pierroutsakou,[15] R. G. Pizzone,[2] G. G. Rapisarda,[2] S. Romano,[2,3,4] C. Spitaleri,[2,3] X. D. Tang,[10] O. Trippella,[17,18] A. Tumino,[2,9] and N. T. Zhang[10]



Physics Letters B 826 (2022) 136917

Contents lists available at ScienceDirect

Physics Letters B

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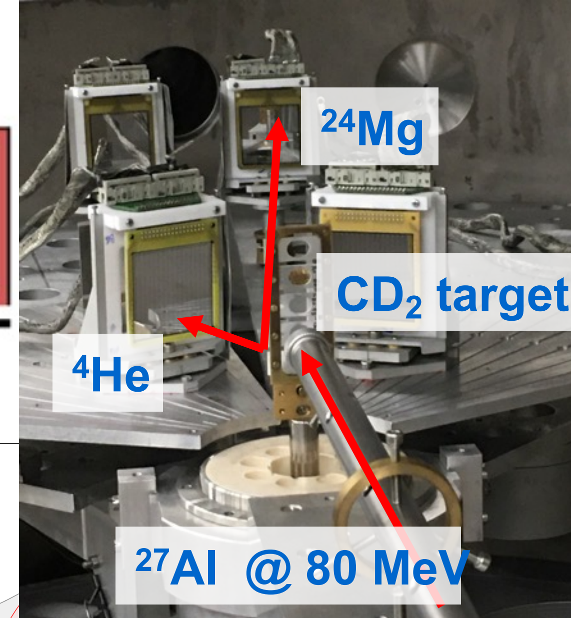
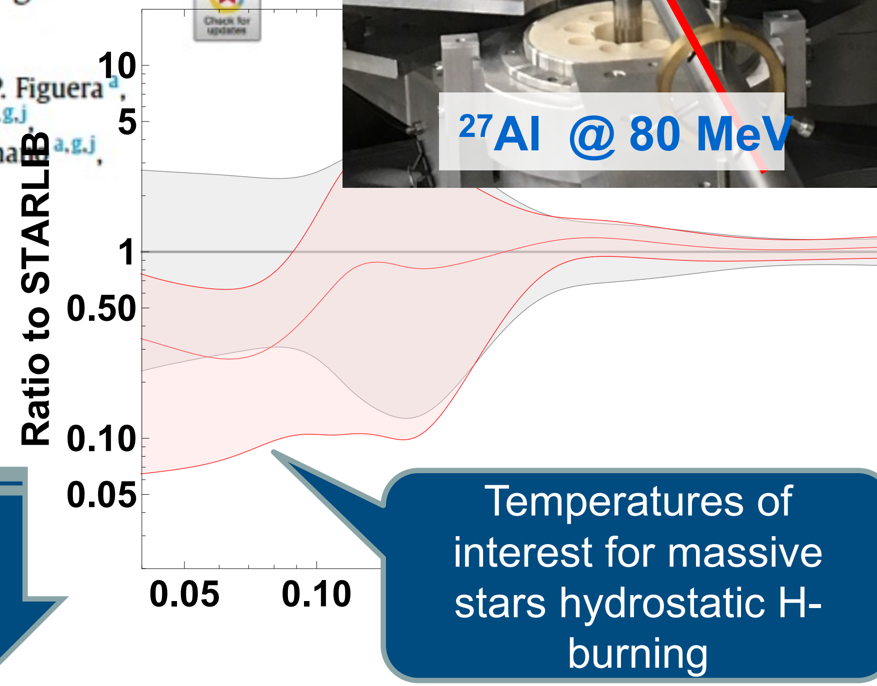
Exploring the astrophysical energy range of the $^{27}Al(p,\alpha)^{24}Mg$ reaction: A new recommended reaction rate

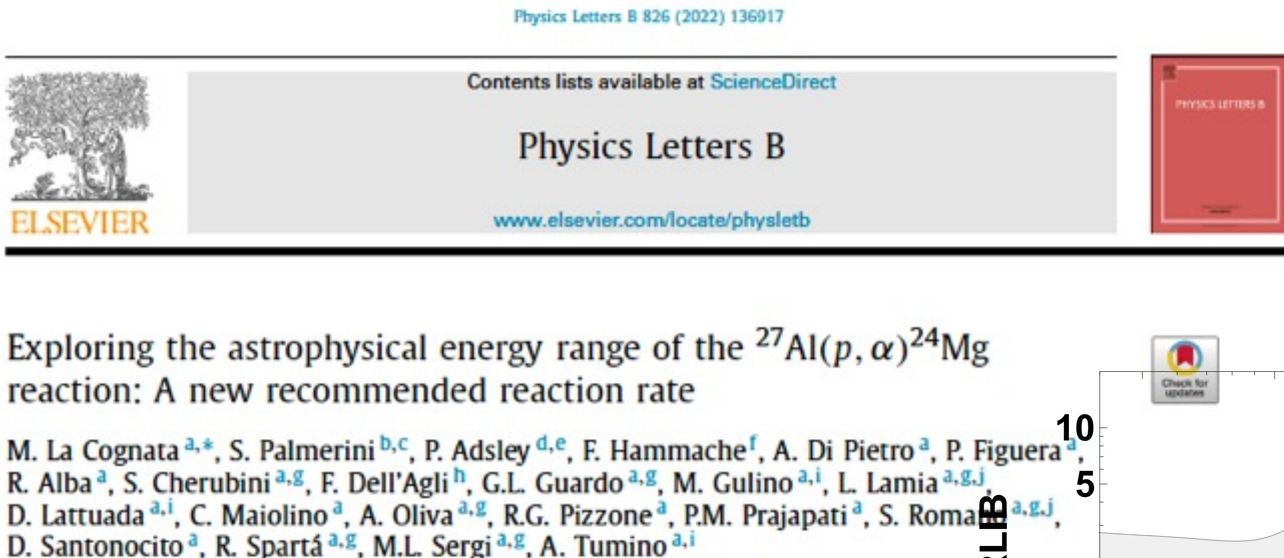
M. La Cognata[a,*], S. Palmerini[b,c], P. Adsley[d,e], F. Hammache[f], A. Di Pietro[a], P. Figuera[a], R. Alba[a], S. Cherubini[a,g], F. Dell'Agli[h], G.L. Guardo[a,g], M. Gulino[a,i], L. Lamia[a,g,j], D. Lattuada[a,i], C. Maiolino[a], A. Oliva[a,g], R.G. Pizzone[a], P.M. Prajapati[a], S. Romano[a,g,j], D. Santonocito[a], R. Spartá[a,g], M.L. Sergi[a,g], A. Tumino[a,i]





First time observation of a 80 keV resonance occurring exacting at the Gamow energy makes it possible to calculate a factor of 3 lower rate than presently used in nucleosynthesis models

Road to indirect study of the ^{26}Al+n reaction channels via a devoted THM experiment running at TRIUMF (Vancouver, Canada).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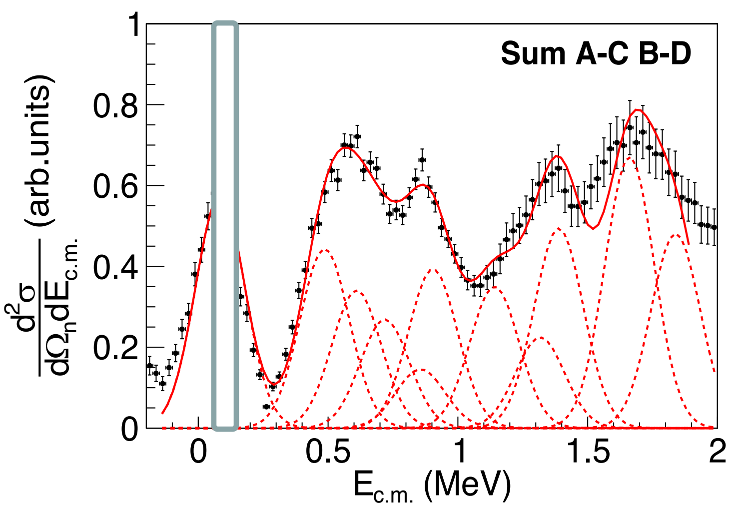
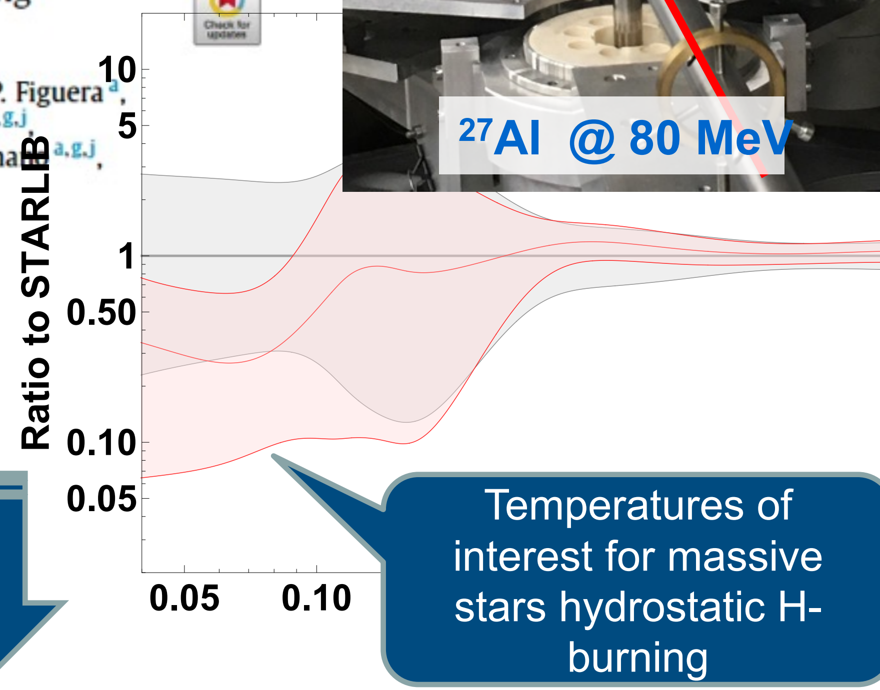
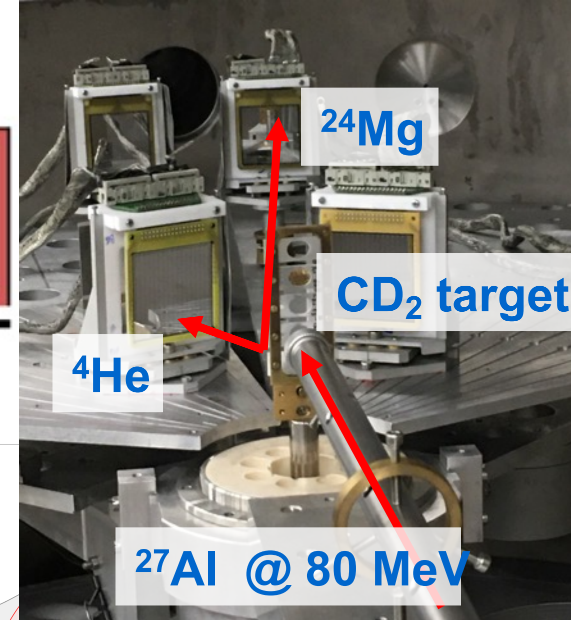




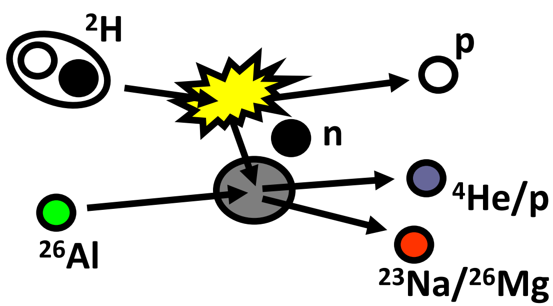


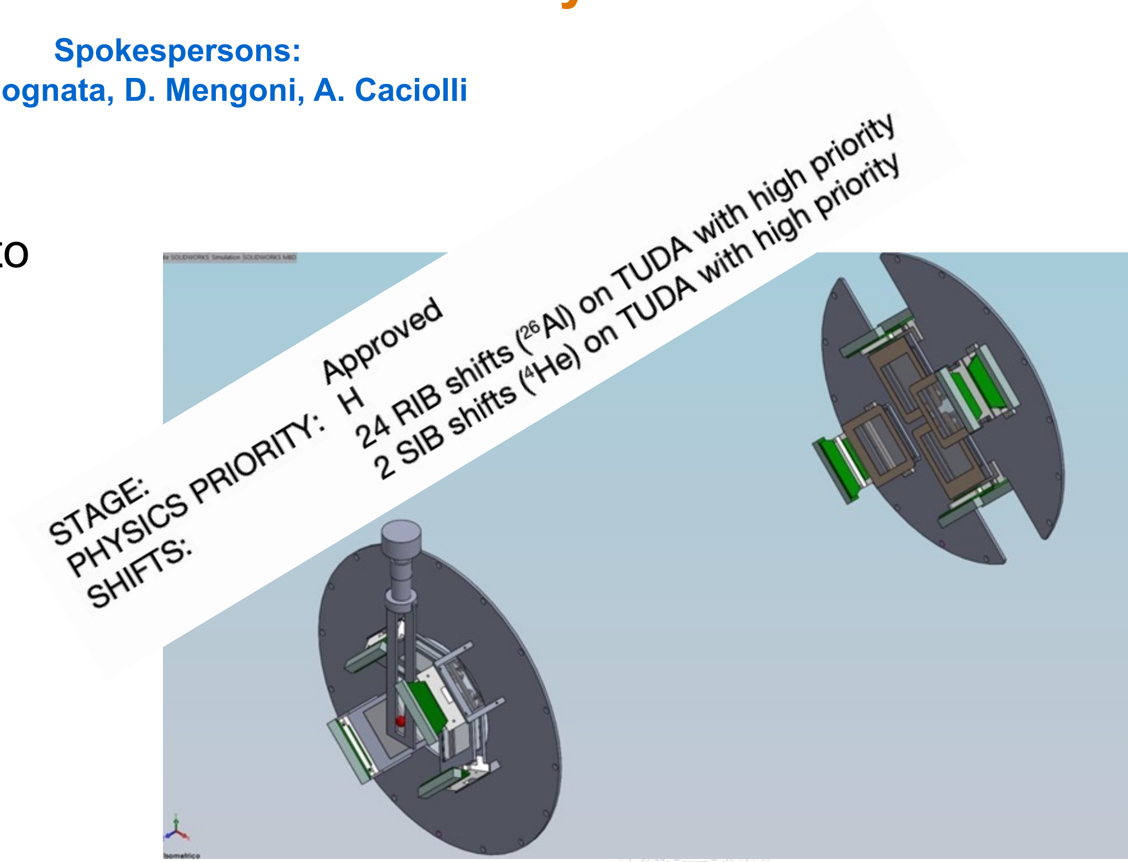
Road to indirect study of the ^{26}Al+n reaction channels via a devoted THM experiment running at TRIUMF (Vancouver, Canada).

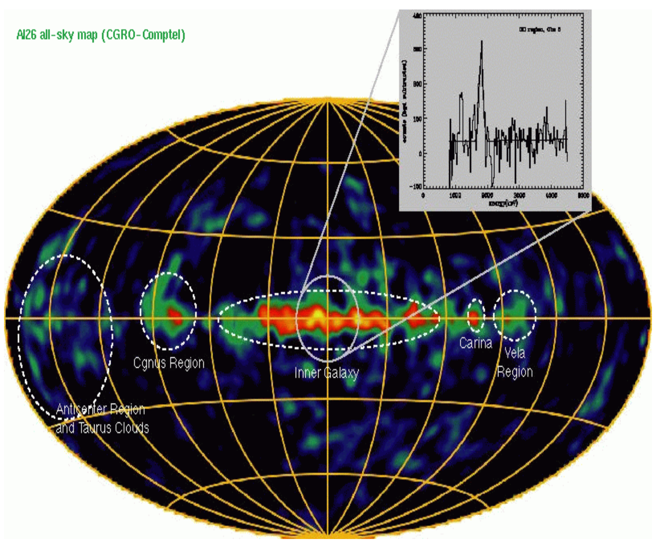
The 26Al(n,p/α) reaction measured by the THM

Spokespersons:
M. La Cognata, D. Mengoni, A. Caciolli

Use of *d* quasi-free breakup to induce reactions on ^{26}Al







Observation of 1808.65 keV γ-rays from the decay of ^{26}Al to ^{26}Mg in the interstellar medium demonstrated that ^{26}Al nucleosynthesis does occur in the **present Galaxy**. The present-day equilibrium mass of ^{26}Al was found to be $2.8 \pm 0.8\ M_{sun}$.

The irregular distribution of ^{26}Al emission seen along the plane of the Galaxy provided the main argument for the idea that **massive stars** dominate the production of ^{26}Al. (Diehl et al 2006)

Neutron stars counting: NS birth rate has been estimated to be $10.8^{+7.0}/_{-5.0}$ NSs/century, while the CCSN rate is estimated to be 1.9+/-1.1 SNe/century from measurements of gamma-ray from ^{26}Al. Additional sources necessary?

LINEA 4

n_TOF: *Neutron Time Of Flight*

nTOF

The experiment uses the high neutron flux produced at CERN for investigating neutron induced reactions of interest in many fields:

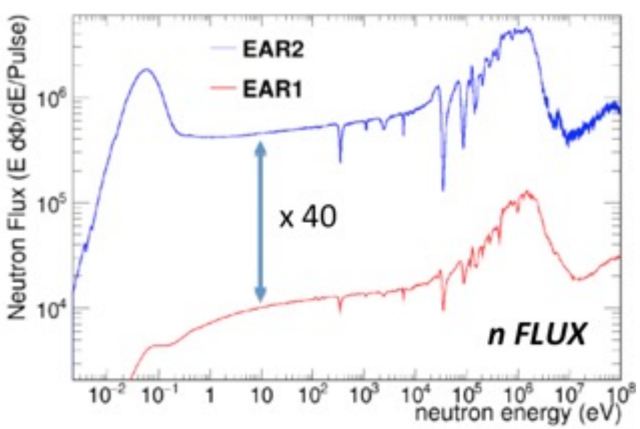
→ *Applied physics (fission reactors, waste transmutation, material studies…)*

→ *Nuclear astrophysics (s-process, fission recycling in the r-process…)*

→ *Basic science (fission, spectroscopy…)*

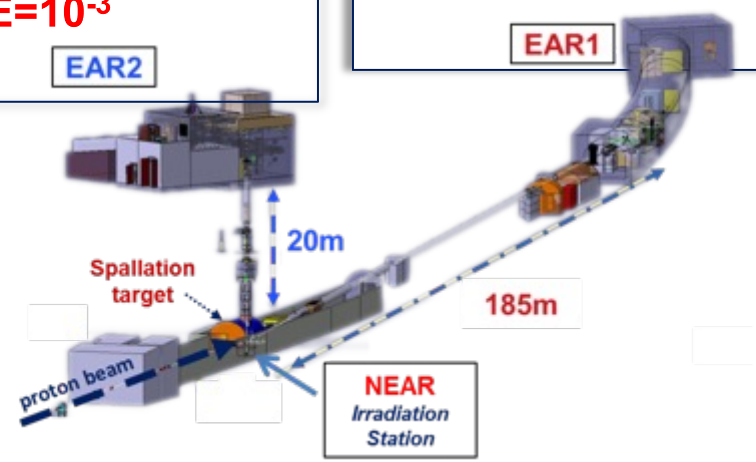
Neutrons produced by spallation.
PS proton beam on a lead target

- ***20 GeV/c***
- ***$7 \cdot 10^{12}$ protons/pulse***
- ***Repetition rate 0.8 Hz***



Experimental Area 2
25 meV<E_n<300 MeV
10^6 n/cm^2/pulse
ΔE/E=10^{-3}

Experimental Area 1
25 meV<E_n<1 GeV
10^5 n/cm^2/pulse
ΔE/E=10^{-4}

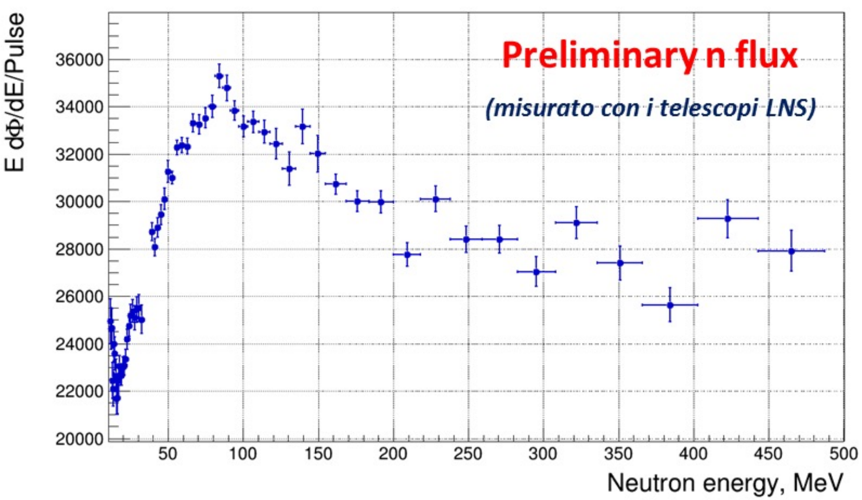


LNS & n_TOF

Recent results

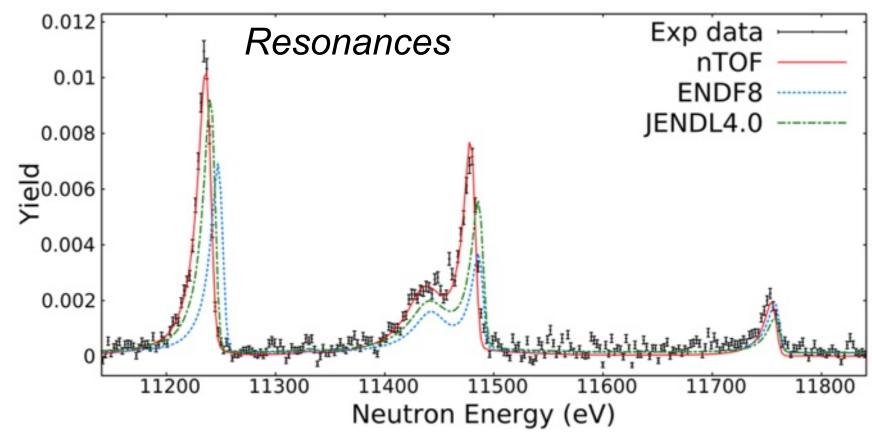
^{235}U(n,f): 15MeV ÷ 1GeV

Extremely laborious data analysis, almost completed. Thanks to the measurement of the neutron flux at energies of hundreds of MeV, we will shortly provide the first experimental data of the 235U(n,f) cross section over 200MeV.



^{140}Ce(n,γ): s process

Data analysis completed. Resonances analyzed up to 65 keV. From preliminary calculations, however, a good agreement is found with the activation measurement at 30 keV, even if there are significant differences with low-energy nuclear libraries.



Universe **2021**, *7*(6), 200

Open Access | Communication

First Results of the ^{140}Ce(n,γ)^{141}Ce Cross-Section Measurement at n_TOF

by Simone Amaducci [1,2,*], Nicola Colonna [3], Luigi Cosentino [1], Sergio Cristallo [4,5], Paolo Finocchiaro [1], Milan Krtička [6], Cristian Massimi [7,8], Mario Mastromarco [9], Annamaria Mazzone [3,10], Alberto Mengoni [11], Stanislav Valenta [6], Oliver Aberle [9], Victor Alcayne [12], Józef Andrzejewski [13], Laurent Audouin [14], and nTOF coll.

LNS & n_TOF

Recent results

^{235}U(n,f): 15MeV ÷ 1GeV

Extremely laborious
completed. Thanks to t
neutron flux at energies
will shortly provide the f
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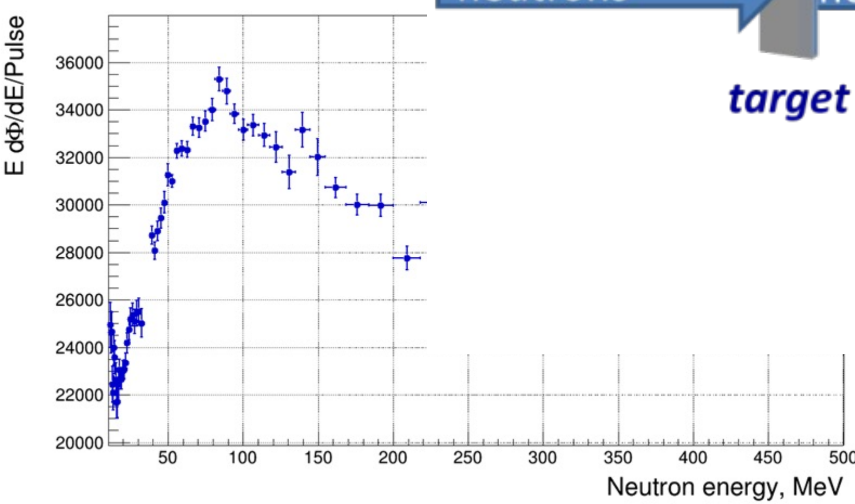

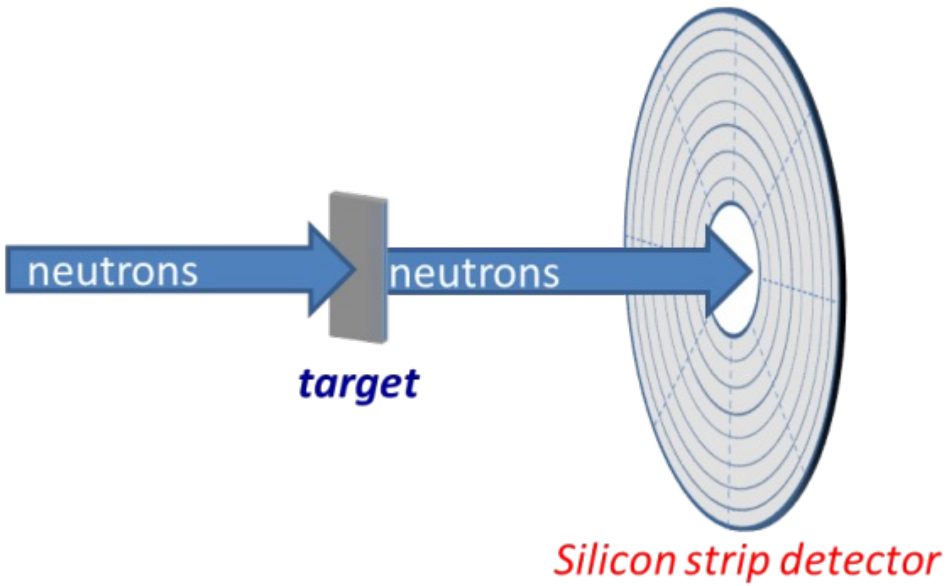

^{140}Ce(n,γ): s process

Data analysis completed. Resonances analyzed
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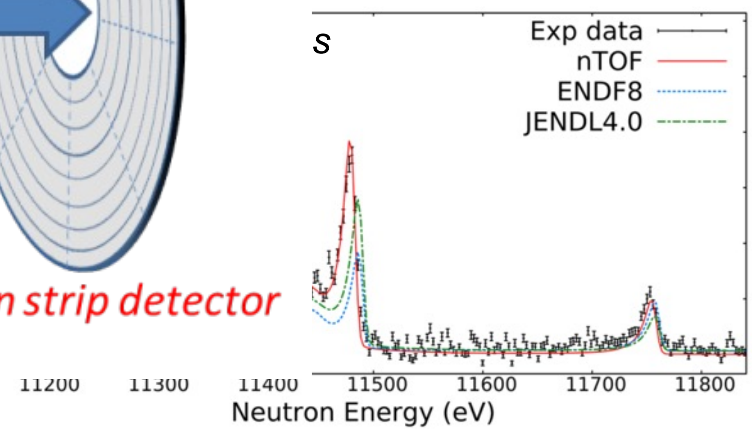

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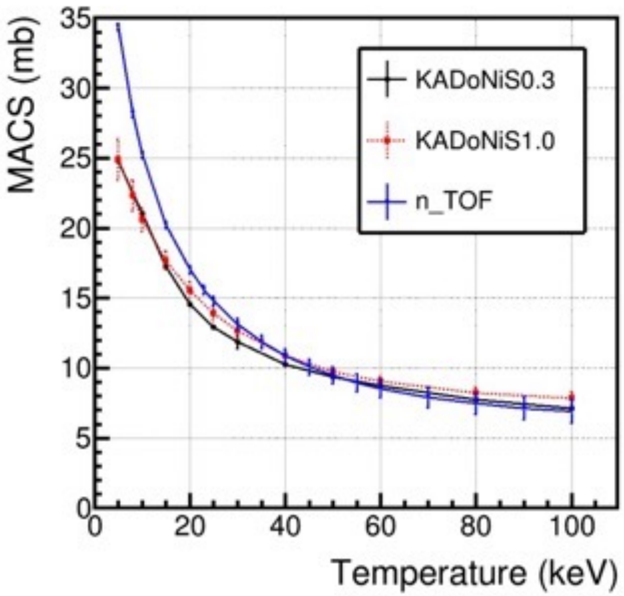
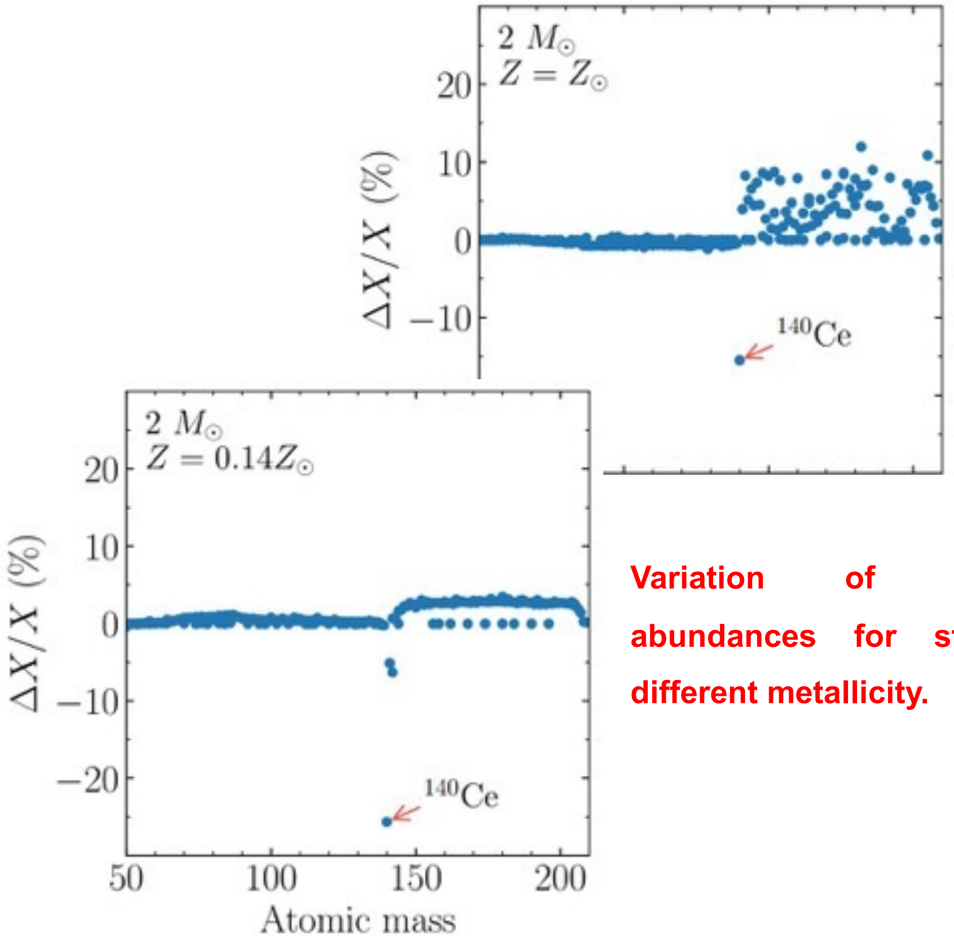
Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DEL SUD

$^{140}Ce(n,\gamma)$: s process

Data analysis completed, MACS definitive, good agreement with the activation measurement at 30 keV. Important variations in the abundance of 140Ce and for all heavier elements predicted by the stellar models.



MACS up to + 40% higher at 5 keV than in the literature.



Variation of isotopic abundances for stars of different metallicity.

PANDORA: an interdisciplinary facility to be installed at LNS

PANDORA facility will consist of:

1) **Superconducting Magnetic Plasma Trap:** it contains a plasma made of multiply charged radioisotopes
2) **HpGe Array:** it consists of 14 detectors to measure the γ rays emitted after β-decays
3) **Plasma Diagnostics System:** it consists of RF, optical and X ray spectrometers allowing direct correlation of β-decay rate to plasma density and temperature

It could *"add unique research capability"* [CVI-report 2019] in Astrophysics and Nuclear Astrophysics in laboratory

1) **for the first time, β-decay measurements** in plasmas; → **Huge impact on nuclear physics and stellar nucleosynthesis**
2) **plasma opacity measurements in conditions similar to kilonovae ejecta**; → **Heavy elements production in n-star merging**
3) **an unprecedented setup for applications**: it will be the biggest B-minimum magnetic trap with potentiality as ion source; as testbench for magnetic fusion; as radiation source for Archeometry. → **New ion and radiation sources for science and technology**

PANDORA_GR3: articoli WoS → 12 / talks → 9

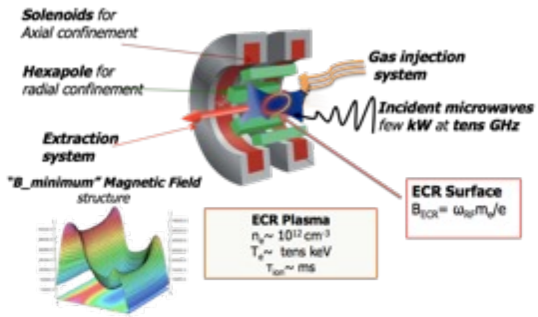
Study of beta-decay properties of highly ionized atoms of astrophysical interest:

Investigation of the dependence of decay rate on plasma parameters (T_e, ρ_e, CSD)

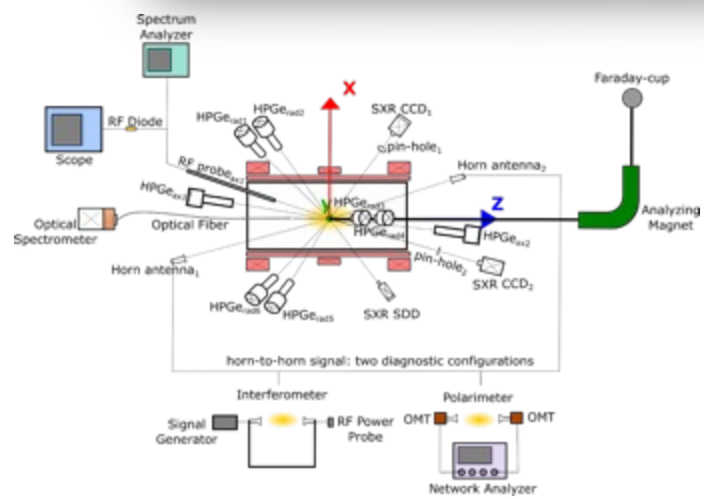
Build a magnetic trap for hot plasmas excited by e.m. waves

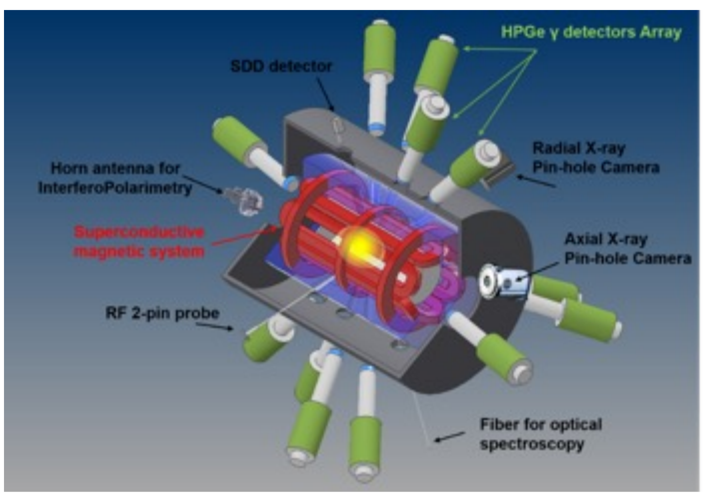
Three main pillars:

- Plasma trap
- HPGE detector array
- multidiagnostic system



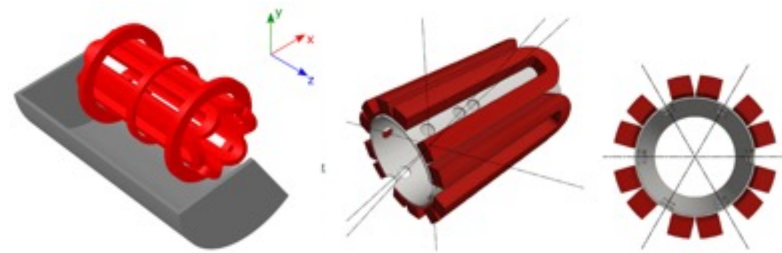
PANDORA plasma multidiagnostics systems





An innovative multi-diagnostic system used to correlate plasma parameters to nuclear activity has been proposed. It is based on several detectors and non-invasive techniques (*Optical Emission Spectroscopy, RF systems, InterferoPolarimetry, time- and space-resolved X-ray spectroscopy*)

Magnetic Trap procurement



The magnetic system, fully superconductive, consists of:

1. #3 axial coils that generates the axial magnetic field;
2. #6 hexapole coils that generates the radial magnetic field.

Trap requirements were defined and procurement officially started in May 2021:

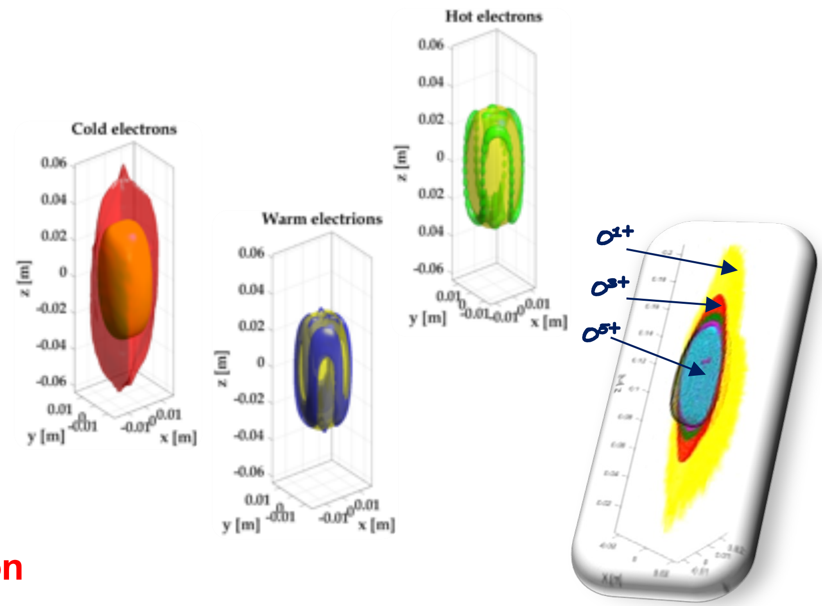
- Competitive Dialogue to choose the BEST TECH. SOLUTION
  - 3 ''potential suppliers'' have presented their project
  - the RUP has started procedures to exchange informations with suppliers
  - **Different ideas were submitted – critical issues raised**

PANDORA-GAMMA Coll. Agreement signed in Oct. 2021 to use 16 HPGe detectors of GALILEO

- **Time window from 2023 till the end of 2025**

  Development of dedicated HPGE - electronics
  - Possibility to work at high rates (up to about 50 or 60 kHz on each detector)

  Definition of an acquisition system stable for long run (experiments running for months)



Plasma modelling: → Stepwise ionization: from electron energy-density 3D maps to charge state distribution

Thanks for your attention