Bellotti Ion Beam Facility

at the Laboratori Nazionali del Gran Sasso

Matthias Junker
Head of Service for Accelerators
INFN - Laboratori Nazionali del Gran Sasso

Gran Sasso National Laboratories

People

127 staff + 155 associated

650 Scientific guests (291 foreign)

1334 involved scientists (852 foreign)

External buildings

Offices, workshops and lab spaces

Conference, seminar and lecture halls

Canteen, cafeteria

Shuttle bus to underground lab every 20 minutes

Underground laboratories

1400 m of rock overhead,

Cosmic ray flux reduction: 10^6

Underground Surface: 17800m^2

Underground Volume: 180000 m^3

Easy access from motorway also by trucks.

Claus Rolfs

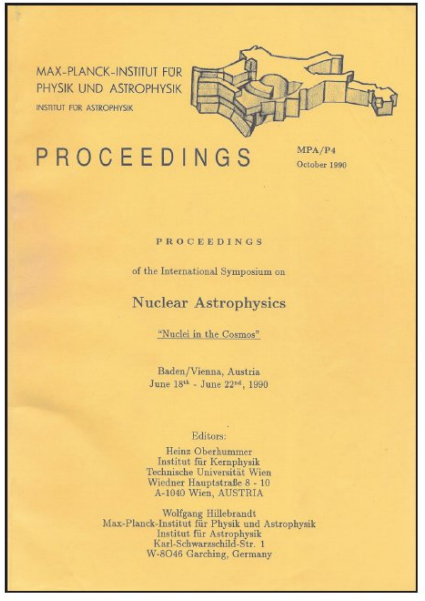
Gianni Fiorentini

1990 NIC I Baden bei Wien, Austria

G. Fiorentini, A. Pascolini; CERN Courier October 2004:

“During hors d'oeuvre, **Gianni Fiorentini** (…) asked **Claus Rolfs** why nuclear reactions could not be measured in the laboratory at the energies at which they occur in stars (…). By the time of dessert, they had realized that the solution was to install an accelerator in an underground laboratory.”

Courtesy J. Josè, NIC 2025



MAX-PLANCK-INSTITUT FÜR PHYSIK UND ASTROPHYSIK
INSTITUT FÜR ASTROPHYSIK

PROCEEDINGS

MPA/P4
October 1990

PROCEEDINGS

of the International Symposium on

Nuclear Astrophysics

"Nuclei in the Cosmos"

Baden/Vienna, Austria
June 18th - June 22nd, 1990

Editors:

Heinz Oberhummer
Institut für Kernphysik
Technische Universität Wien
Wiedner Hauptstraße 8 - 10
A-1040 Wien, AUSTRIA

Wolfgang Hillebrandt
Max-Planck-Institut für Physik und Astrophysik
Institut für Astrophysik
Karl-Schwarzschild-Str. 1
W-8046 Garching, Germany

Claus Rolfs

Gianni Fiorentini

Enrico Bellotti

1990 NIC I Baden bei Wien, Austria

G. Fiorentini, A. Pascolini; CERN Courier October 2004:
“

During hors d'oeuvre, **Gianni Fiorentini** (…) asked **Claus Rolfs** why nuclear reactions could not be measured in the laboratory at the energies at which they occur in stars (…). By the time of dessert, they had realized that the solution was to install an accelerator in an underground laboratory.
The director of the Laboratori Nazionali del Gran Sasso, **Enrico Bellotti**, was enthusiastic about the idea and the INFN president **Nicola Cabibbo** immediately endorsed it after receiving an informal letter of intent, which began:
"

We believe that the Gran Sasso laboratory offers a unique possibility for progress in the measurement of low-energy nuclear cross-sections, which are relevant for nucleosynthesis in stars and in the early universe, as well as for the evaluation of the solar-neutrino flux."
”

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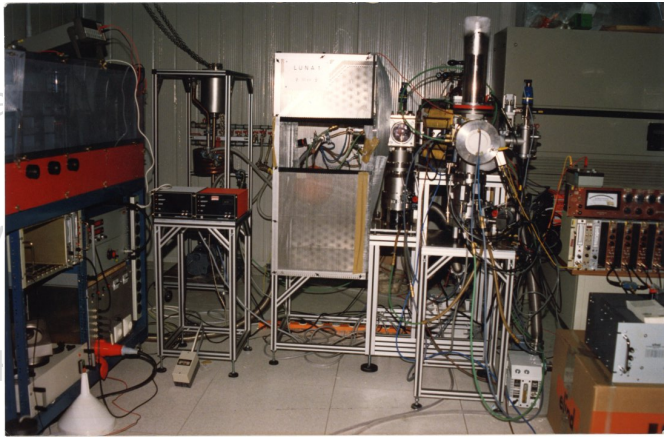
2000 NIC VI	Aarhus, Denmark
2002 NIC VII	Fuji-Yushida, Japan
2004 NIC VIII	Vancouver, Canada
2006 NIC IX	CERN, Switzerland
2008 NIC X	Mackinac Island, USA
2010 NIC XI	Heidelberg, Germany
2012 NIC XII	Cairns, Australia
2014 NIC XIII	Debrecen, Hunga
2016 NIC XIV	Niigata, Japan
2018 NIC XV	Gran Sasso, Italy
2021 NIC XVI	Chengdu, China
2023 NIC XVII	Daejeon, South

“Status of the project Laboratory For Underground Nuclear Astrophysics (LUNA)”

“(…) First background measurements with Silicon Surface Barrier Detectors were done [in the underground labs. of LNGS] in 1991 (…)”

“A transportable 30 kV accelerator was designed (…). This june (…) the accelerator was for the first time build up in the underground laboratory (…). The next limitation will be due to intrinsic radiation of the detector or radiation out of the target and the vacuum chamber material.”



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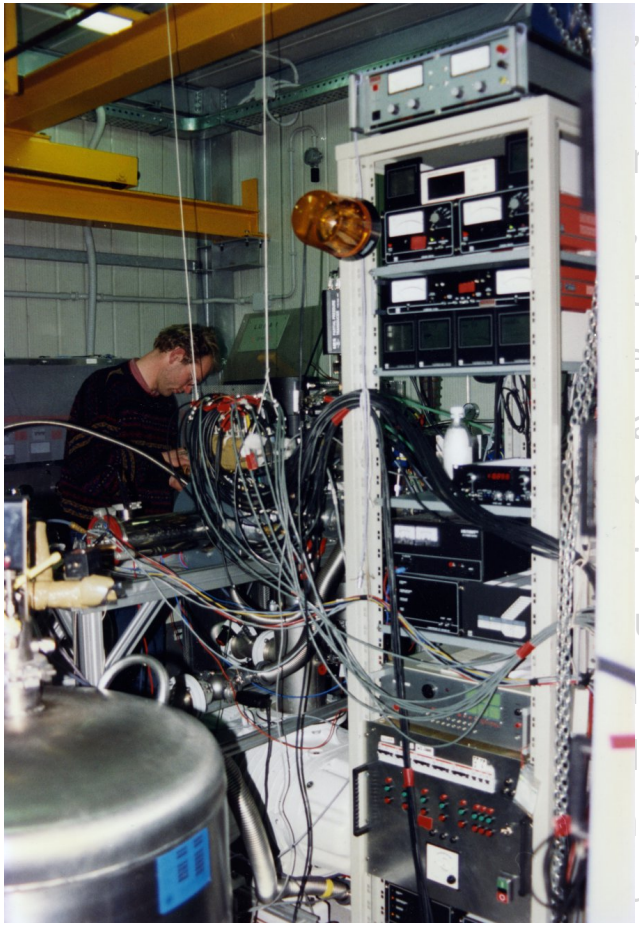
1994 NIC III Gran Sasso, Italy



“(…) The LUNA Project – Status and first results”

“ The 50 kV facility has been tested over a period of 3 month at Bochum University and then moved to LNGS in late 1993 (…). (It) is now installed underground at LNGS (…)”

“we could atain a background level of less than 1 event per week (…)”

“The experimental sensitivity has been improved, as compared to the previous [^{3}He(^{3}He,2p)^{4}He] experiment, by more than four orders of magnitude:

- a factor 3 in the beam current,
- a factor 20 in the detection efficiency (..)
- more than a factor 200 in the background reduction

We are now starting the experiment with the 50 KV accelerator facility installed underground at LNGS.”

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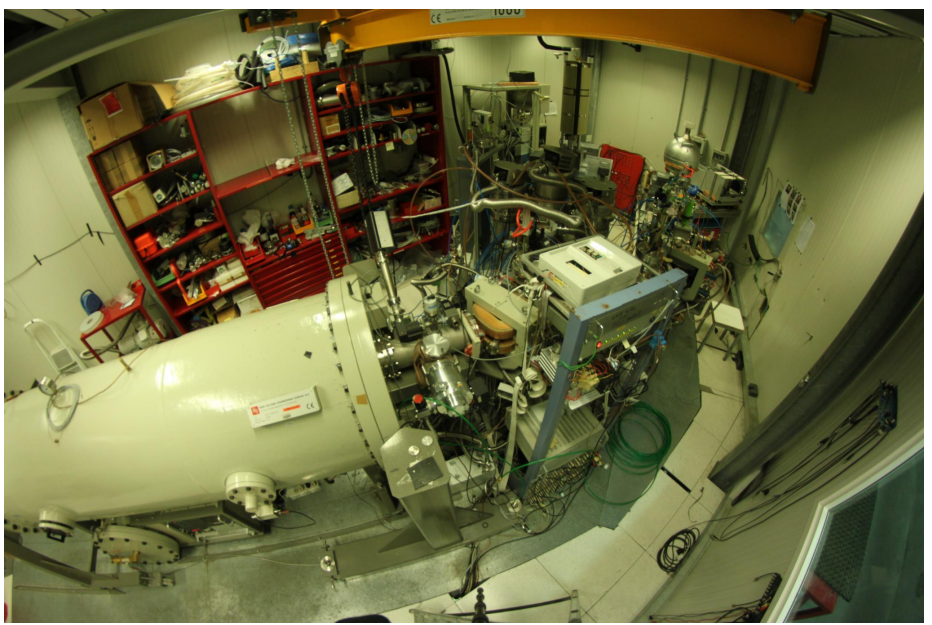
2000 NIC VI	**Aarhus, Denmark**
2002 NIC VII	Fuji-Yushida, Japan
2004 NIC VIII	Vancouver, Canada

“Advances in cross section measurements at low energies”

“In 1998 INFN has approved the funding for installing a new 400 kV accelerator in the underground laboratories of LNGS.
The accelerator has been constructed by High Voltage Engineering Europe B.V. (The Netherlands) and is actually being commissioned.”



Electrostatic Accelerators at LNGS

LUNA-50

- Pilot project to explore possibilities of Underground Nuclear
- Worldwide first underground accelerator laboratory
- Based on idea by C. Rolfs, G. Fiorentini, E. Bellotti
- Pathfinder for LUNA-400
- Astrophysics p-p chain - solar neutrino problem
- Dismissed 2002

LUNA-400

- Operated by LUNA Collaboration – funded by INFN — CSN 3
- Workhorse of the LUNA-Collaboration since 2000
- Big Bang, pp-chain, AGB Stars

LUNA-400 @ NIC 2025

Talk

D. Robb

"Underground Measurements of the $^{16}O(p,\gamma)^{17}F$ Reaction at LUNA"

Posters

#159 A. Boeltzig (HZDR)

"New underground study of the $^{19}F(p,\gamma)^{20}Ne$ reaction"

#201 A. Casciolli (Uni & INFN Padova)

"Recent results for the $^{12/13}C(p,g)^{13/14}N$ reaction cross section in a wide energy range at LUNA and at Felsenkeller lab."

#196 E. Masha (HZDR)

"The study of the $^{21}Ne(p,\gamma)^{22}Na$ reaction at LUNA and its astrophysical impact

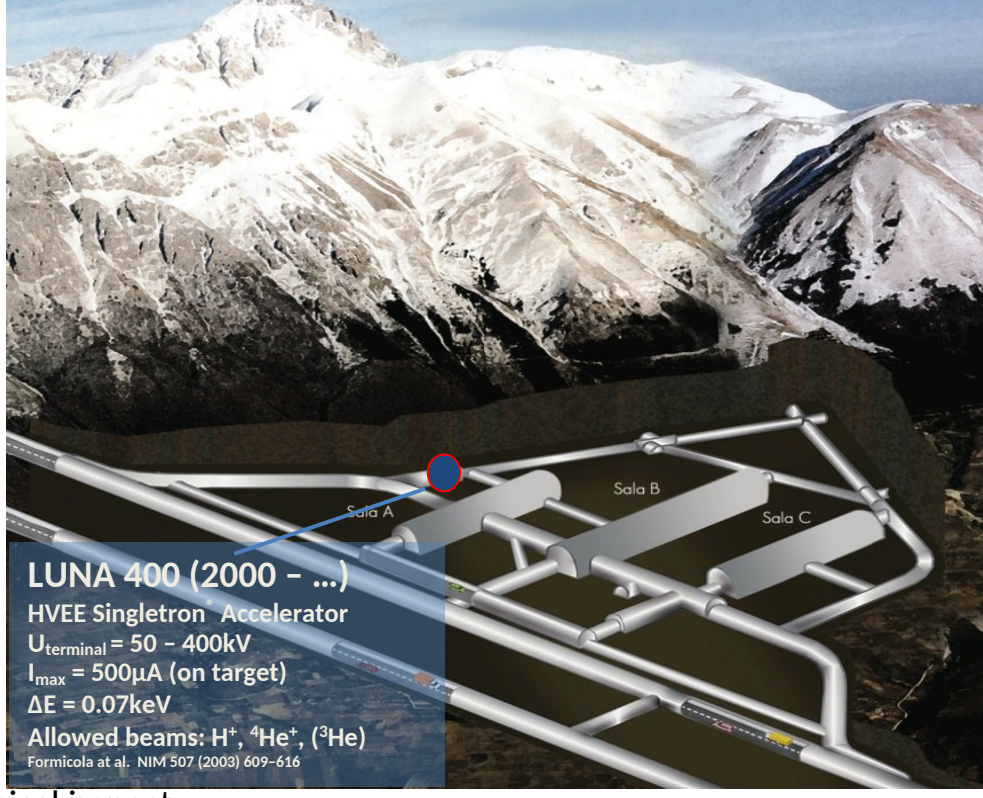
139 R. Sariyal (INFN Torino)

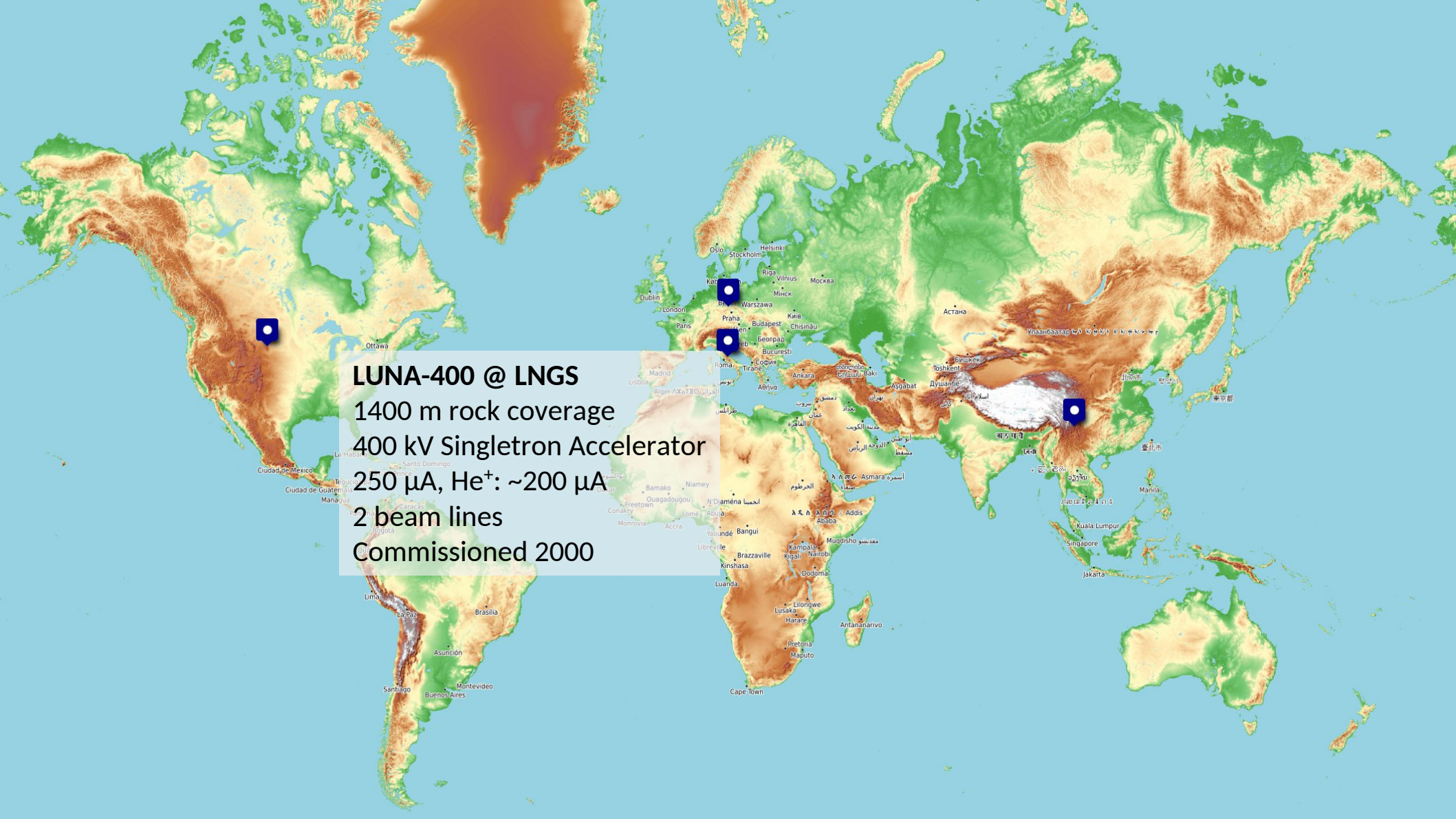
"The SOCIAL Project: Underground measurements of the $^{14}N(p, \gamma)^{15}O$ nuclear cross-section at LUNA."

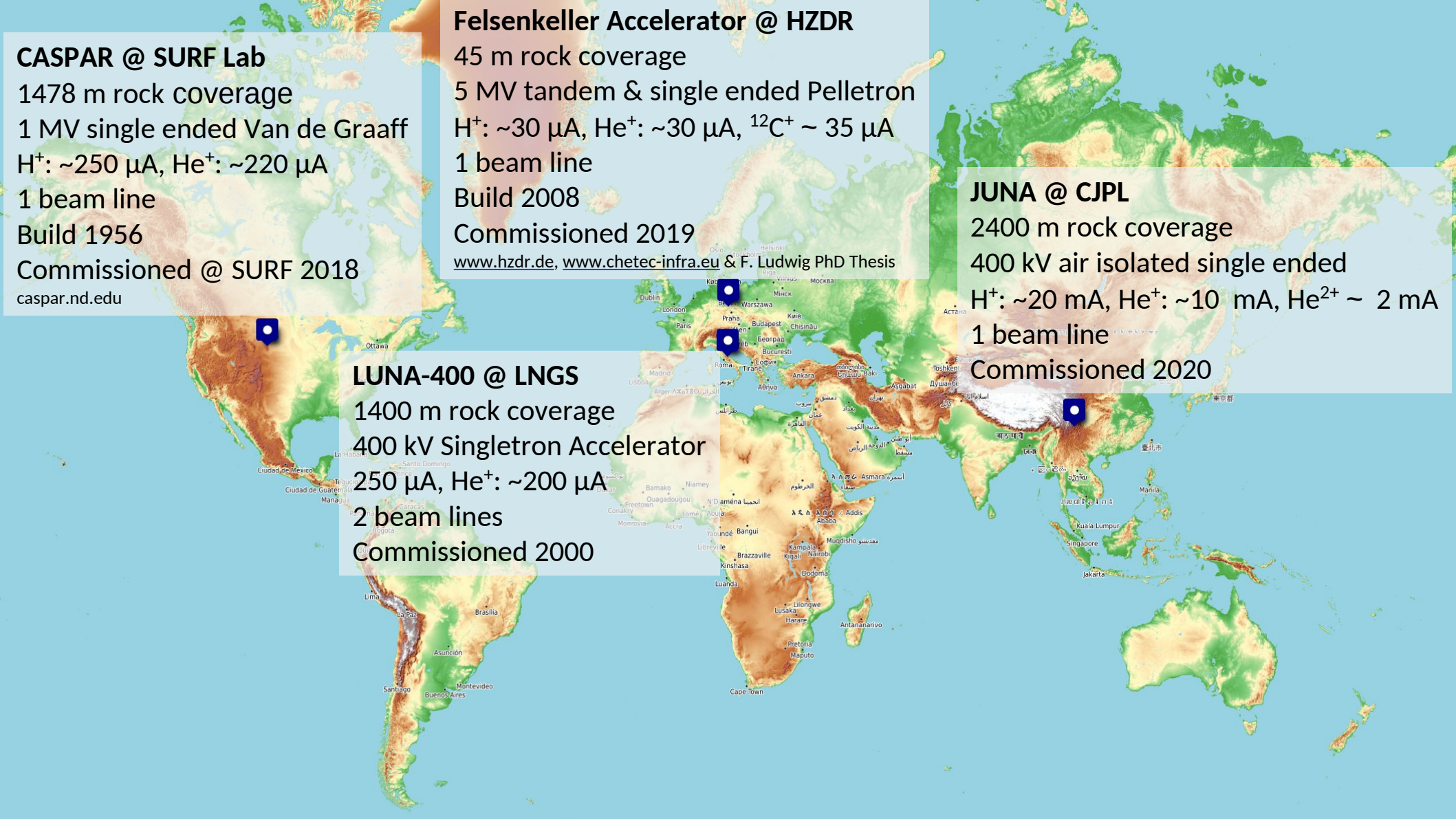
#190 D. Piatti (Uni & INFN Padova)

"Investigation of Stable Fluorine Targets for the $^{19}F(p,g)^{20}Ne$ Measurement at LUNA"

Since foundation, LUNA Collaboration has published over 70 papers on refereed journals (https://luna.lngs.infn.it)




LUNA-400 @ LNGS
1400 m rock coverage
400 kV Singletron Accelerator
250 µA, He^+: ~200 µA
2 beam lines
Commissioned 2000


CASPAR @ SURF Lab
1478 m rock coverage
1 MV single ended Van de Graaff
H^+: ~250 µA, He^+: ~220 µA
1 beam line
Build 1956
Commissioned @ SURF 2018
caspar.nd.edu
Felsenkeller Accelerator @ HZDR
45 m rock coverage
5 MV tandem & single ended Pelletron
H^+: ~30 µA, He^+: ~30 µA, $^{12}C^+$ ~ 35 µA
1 beam line
Build 2008
Commissioned 2019
www.hzdr.de, www.chetec-infra.eu & F. Ludwig PhD Thesis
JUNA @ CJPL
2400 m rock coverage
400 kV air isolated single ended
H^+: ~20 mA, He^+: ~10 mA, He^{2+} ~ 2 mA
1 beam line
Commissioned 2020
LUNA-400 @ LNGS
1400 m rock coverage
400 kV Singletron Accelerator
250 µA, He^+: ~200 µA
2 beam lines
Commissioned 2000

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2021 NIC XVI	Chengdu, China (online)
2023 NIC XVII	Daejeon, South Korea

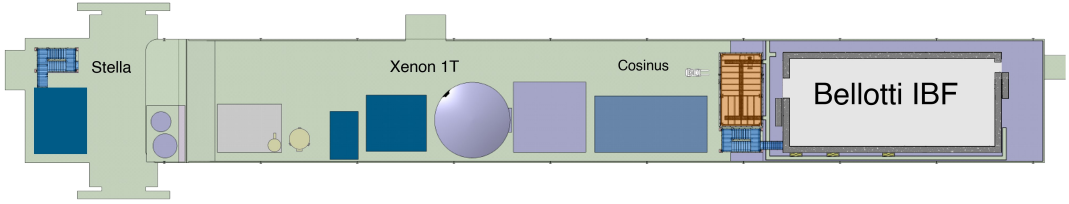
“Underground cross section measurements of stellar reactions at astrophysically relevant energies”

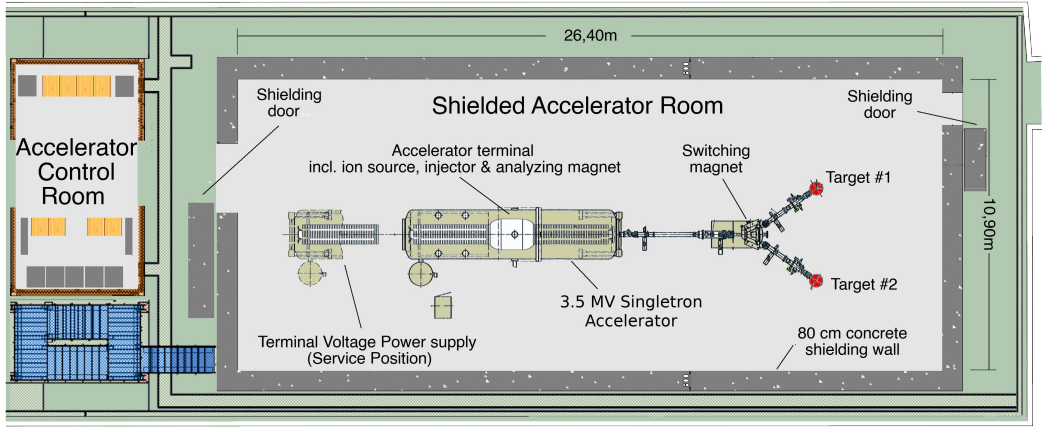
“The 400 kV LUNA accelerator and the unique low-background conditions of the underground LNGS laboratory have been and still are the perfect blend for the study of most of the proton-capture reactions involved in the stellar H burning.”

“(…) a beam of higher energy is required to extend these studies to reactions between heavier isotopes, (….). The LUNA MV project has been developed to overcome such a limit with the **new 3.5 single-ended accelerator to be installed in Gran Sasso** at the beginning of 2018.”

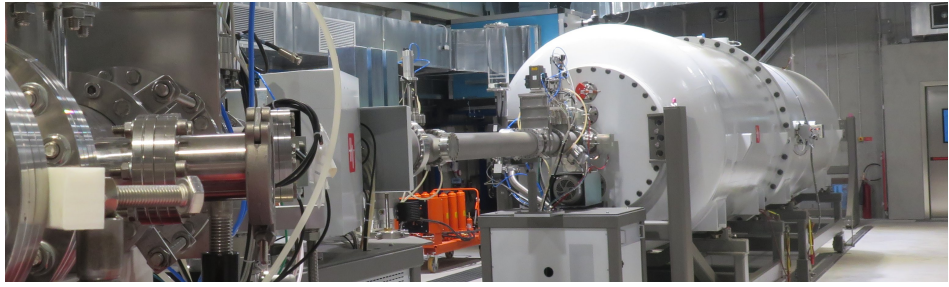
The LUNA-MV Project

- Initiated by LUNA Collaboration in 2007
- Total funding: 9 M€
  - Italian Ministry of Research (Progetto Premiale "LUNA-MV")
  - INFN Laboratori Nazionali del Gran Sasso
  - INFN Commissione Nazionale Scientifica III





Genesis of the 3.5 MV Singletron® Accelerator

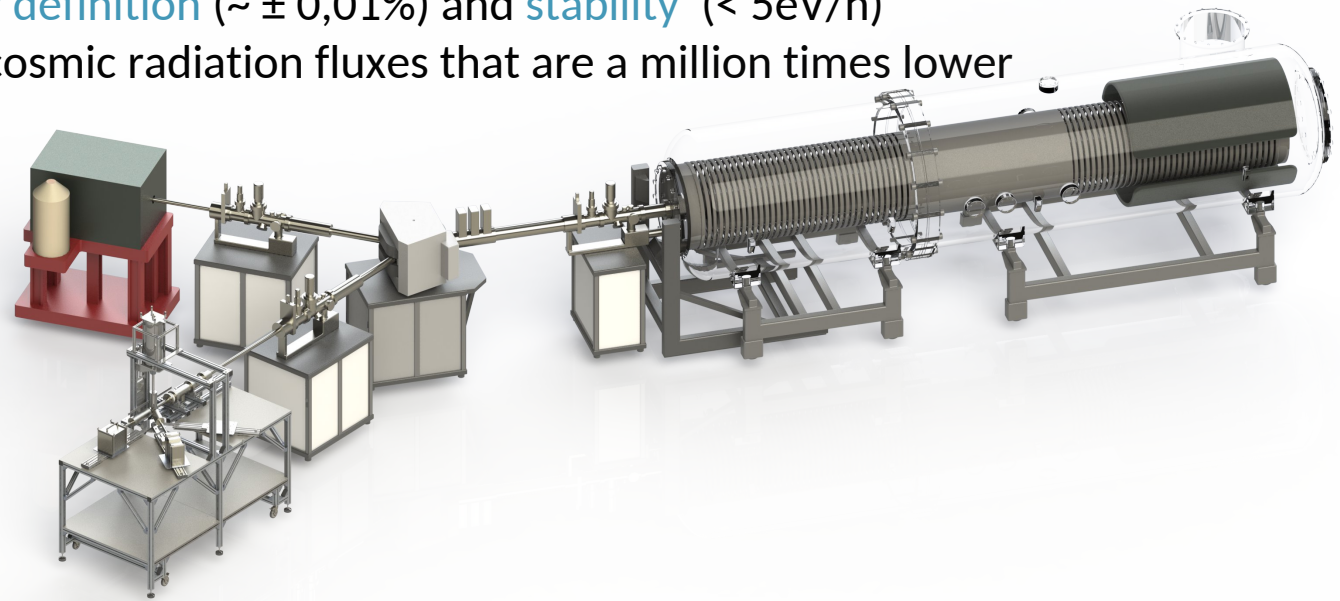


March 2007	Letter of Intend by LUNA-Collaboration
May 2015	Public tender for accelerator
May 2016	Contract signed with High Voltage Engineering Europe
December 2019	Factory Acceptance Tests at HVEE passed
October 2021	Start of mechanical installation at LNGS
May -November 2022	Installation and Commissioning at LNGS
December 2022	On- Site Acceptance Test passed
April 2023	All authorizations obtained (Radioprotection, Fire brigade, Pressure vessel, Environment)
June 2023	**Start of experimental activities in day time operation mode**
February 2024	**24/24 hours operations possible**
Great synergy of	**LUNA Collaboration** (Accelerator design and productions) **LNGS** (Infrastructures, Rules & regulations, Logistics, Project Management)

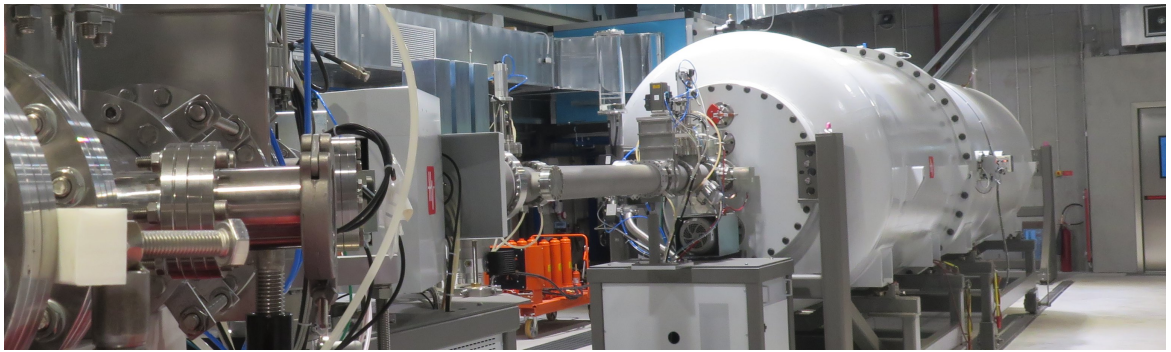
Specifications of the 3.5 MV Singletron

Ion specie	Terminal Voltage	
	0.3 MV— 0.5 MV	0.5 MV — 3.5 MV
$^{1}H^{+}$	≤ 500 µA	≤ 1000 µA
$^{4}He^{+}$	≤ 300 µA	≤ 500 µA
$^{12}C^{+}$	≤ 100 µA	≤ 150 µA
$^{12}C^{+2}$	≤ 60 µA	≤ 100 µA

- provides for excellent beam energy definition (~ ± 0,01%) and stability (< 5eV/h)
- experiments can be carried out at cosmic radiation fluxes that are a million times lower than those in surface laboratories




ENRICO BELLOTTI
ION BEAM FACILITY



Specifications of the 3.5 MV Singletron (2)

Maximum beam intensity on target at different terminal voltages

Ion specie	Terminal Voltage	
	0.3 MV— 0.5 MV	0.5 MV — 3.5 MV
$^{1}H^{+}$	≤ 500 μA	≤ 1000 μA
$^{4}He^{+}$	≤ 300 μA	≤ 500 μA
$^{12}C^{+}$	≤ 100 μA	≤ 150 μA
$^{12}C^{+2}$	≤ 60 μA	≤ 100 μA

Subject to limitations at LNGS to comply to neutron flux in underground lab.

$\Phi_n(\mathrm{LNGS}) = 3\ 10^{-6}\ \mathrm{n/(cm^2\ s)}$

Condition for Accelerator Operation at LNGS

→ No alteration of low neutron background underground

→ Limit to beam induced neutrons inside accelerator room: max. 2000 s^{-1}

→ Neutron monitors interlocked with Faraday cup in the Injector;

→ Beam intensity limited as function of accelerated ion species;

→ 80 cm concrete walls shielded accelerator room

→ Resulting calculated neutron flux Neutron flux OUTSIDE shielded accelerator room:

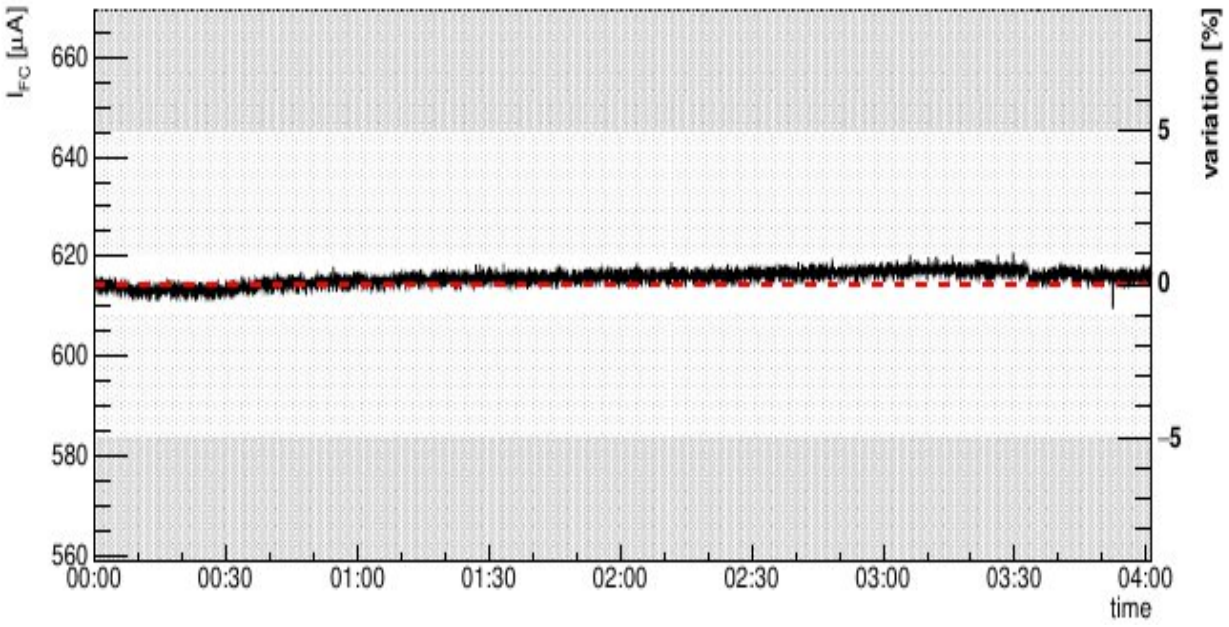
MCNP: $\Phi_n = 1.38\ 10^{-7}\ \mathrm{n/(cm^2\ s)}$ GEANT4: $\Phi_n = 3.40\ 10^{-7}\ \mathrm{n/(cm^2\ s)}$

→ Factor 2 – 10 LOWER than natural neutron flux than neutron flux underground

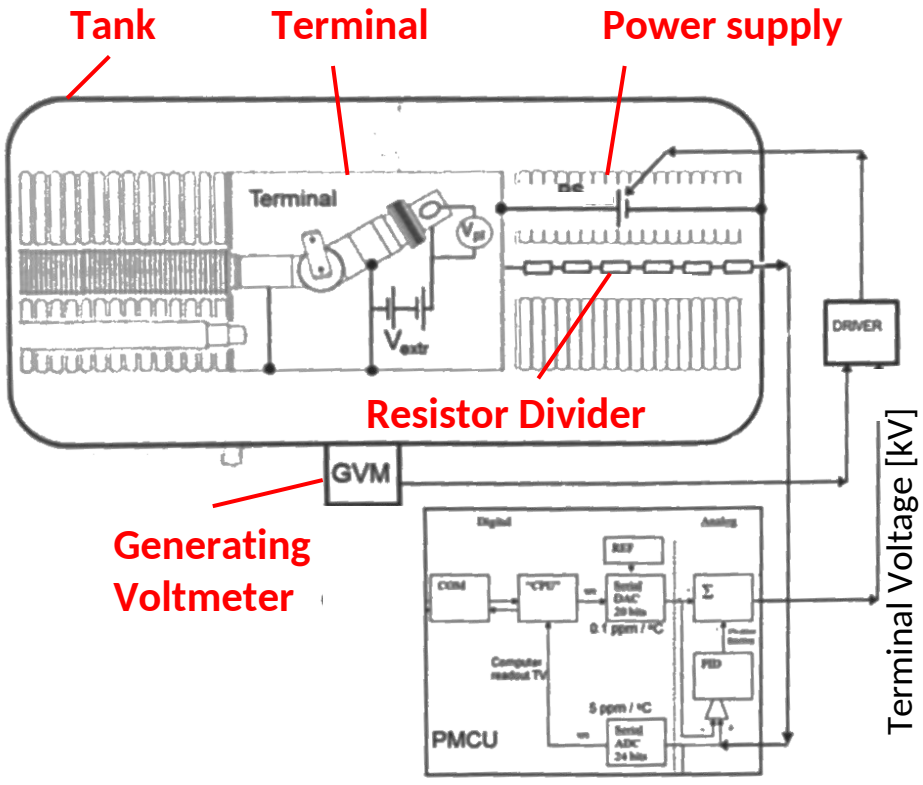
Specifications of the 3.5 MV Singletron (2)

Maximum deviation of beam intensity: ≤ 5% / h

α beam	
Beam energy	1 MeV
Beam Intensity on target	615 µA
Test duration	4 h
Beam current variation	≤ 1 %/h

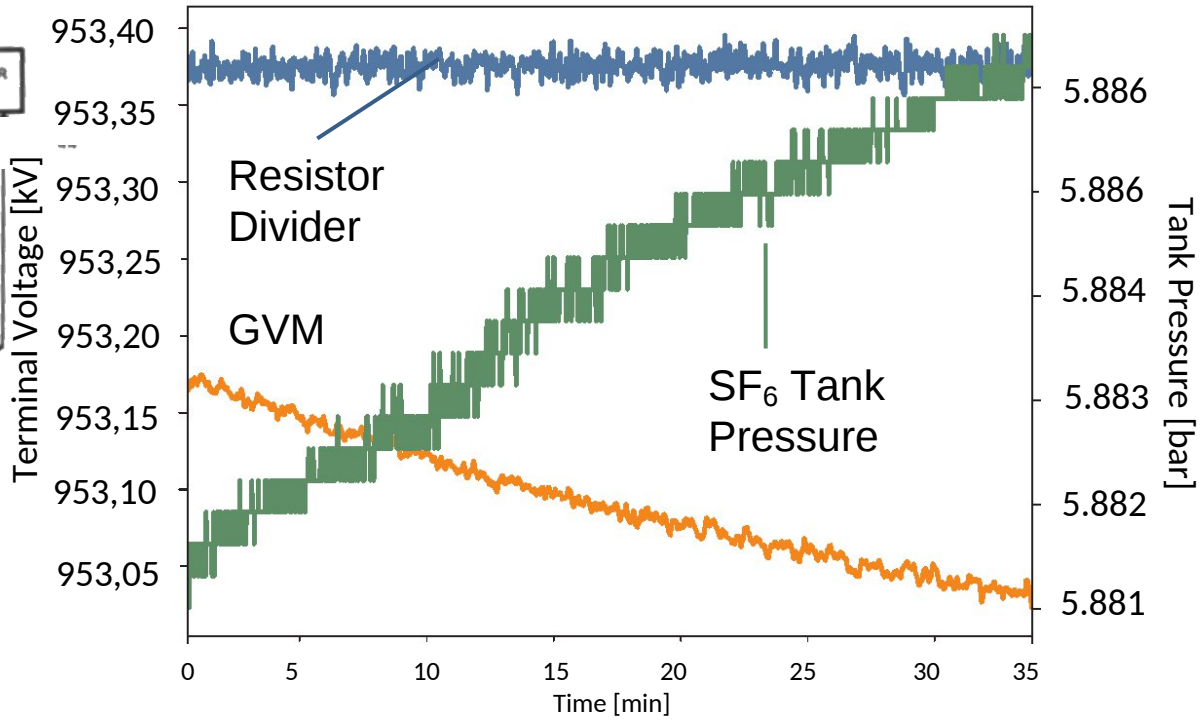


Beam energy Stabilization



Combination of

- Generating Voltmeter
- Resister divider
- Developed on purpose by HVEE



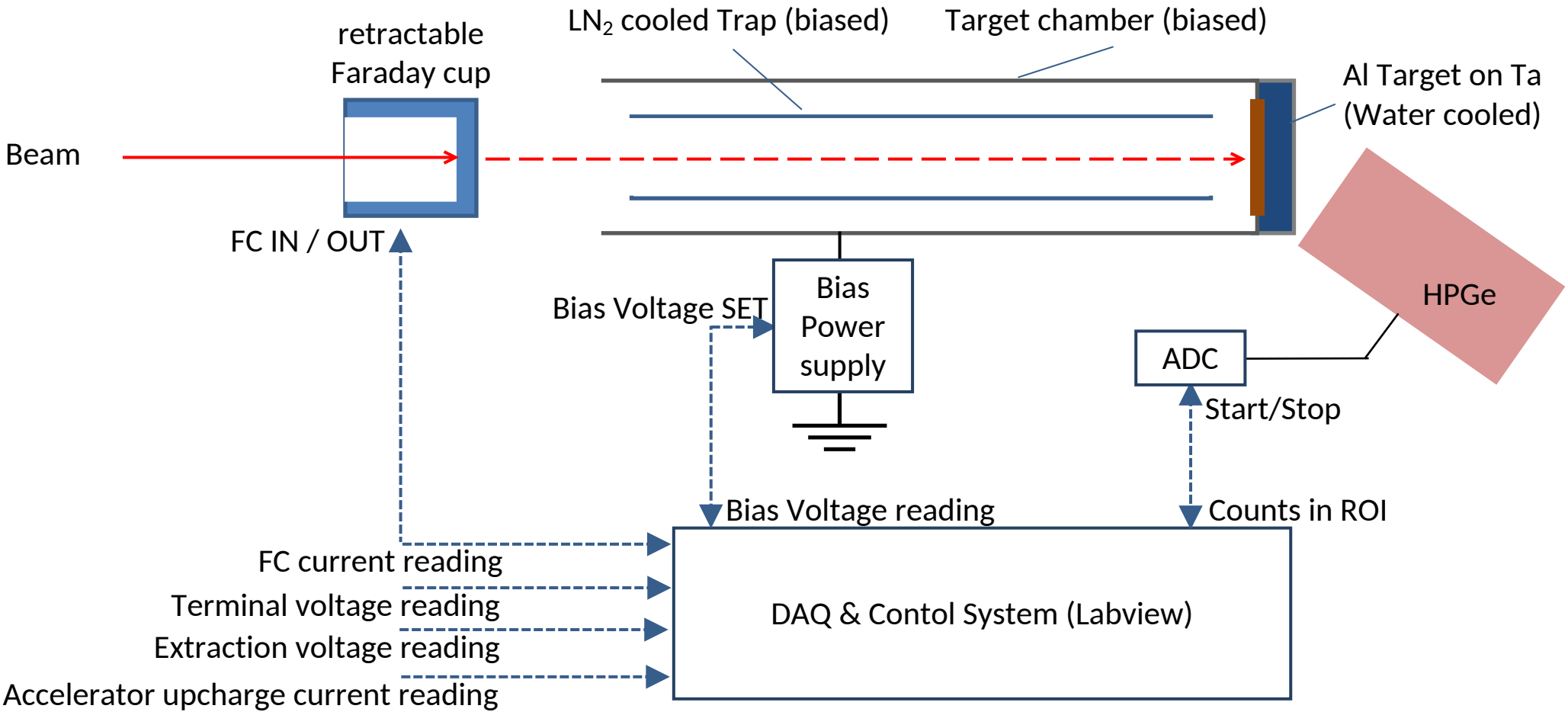
M. Mous (HVEE) - Poster at NIC 2018

Beam Energy calibration and stability using ^{27}Al resonances

$E_{r,\,lab}$ (keV)	Γ (eV)
632,23 ± 0.04	6,7 ± 0.5
991,86 ± 0.03	70 ± 10
1213,08 ± 0.06	< 100
1317,14 ± 0.07	35 ± 4
1587,49 ± 0.08	< 200
1799,75 ± 0.09	450 ± 60

Endt et al. (1990), Nuclear Physics **A521**

Beam Energy calibration and stability using ^{27}Al resonances



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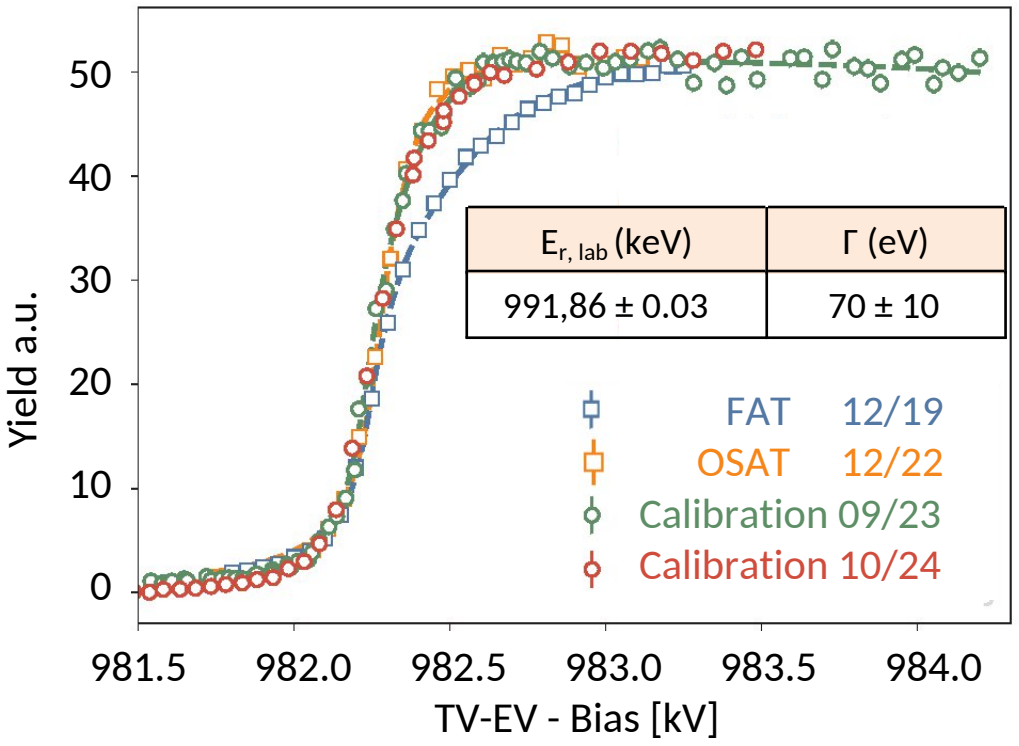

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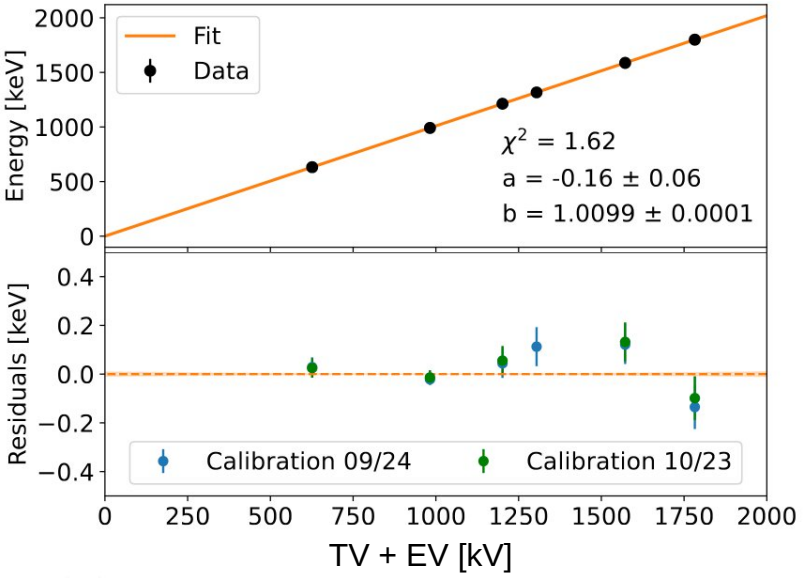
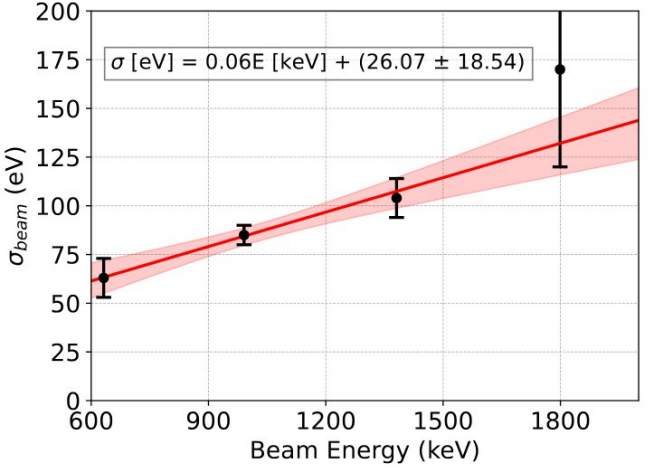
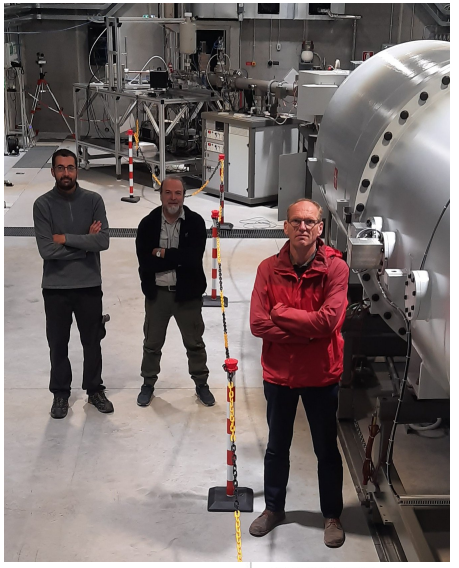




A. Compagnucci (GSSI & LNGS),
J. Skowronski (Padova)

The Bellotti Ion Beam Facility of LNGS



- 3.5 MV Singletron Accelerator
- Service for Accelerator operations

  Accelerator Operation & maintenance, User support

  1 Tecnologist, 2 Technicians, 1 Trainee
- Program Advisory Committee

  G. Cuttone (Chair), F. Hammache (Orsay), J. Josè (Barcellona)

- ChETEC INFRA Transnational Access Facility

frontiers | Frontiers in Physics

TYPE Perspective
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Check for updates

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EDITED BY
Jeter Hall,
SNOLAB, Canada

The deep underground Bellotti Ion Beam Facility—status and perspectives

Matthias Junker[1]*, Gianluca Imbriani[2], Andreas Best[2], Axel Boeltzig[3], Alessandro Compagnucci[1,4], Antonino Di Leva[2], Federico Ferraro[1], David Rapagnani[2] and Valentino Rigato[5]

[1]INFN Laboratori Nazionali del Gran Sasso (LNGS), Assergi, Italy, [2]Dipartimento di Fisica "E. Pancini", Università degli Studi di Napoli "Federico II" Naples and INFN, Naples, Italy, [3]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]Gran Sasso Science Institute, L'Aquila, Italy, [5]INFN Laboratori Nazionali di Legnaro (LNL), Legnaro, Italy

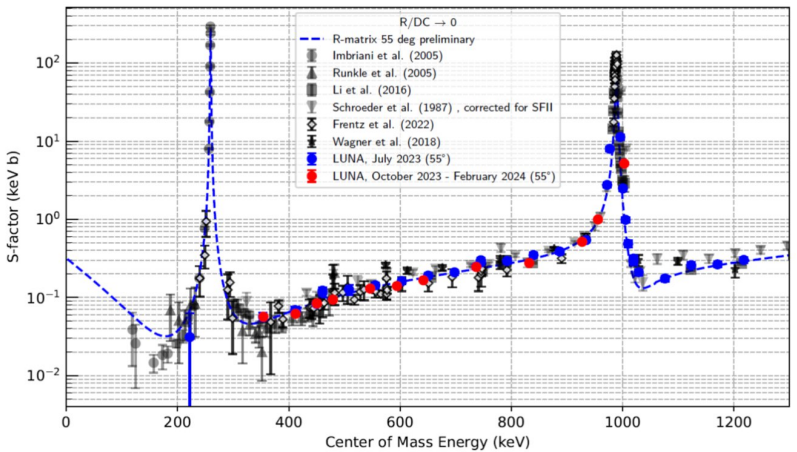
https://doi.org/10.3389/fphy.2023.1291113

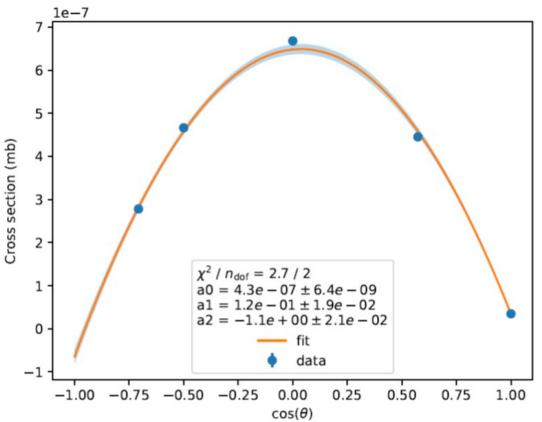
Science at Bellotti IBF

INVITED TALK

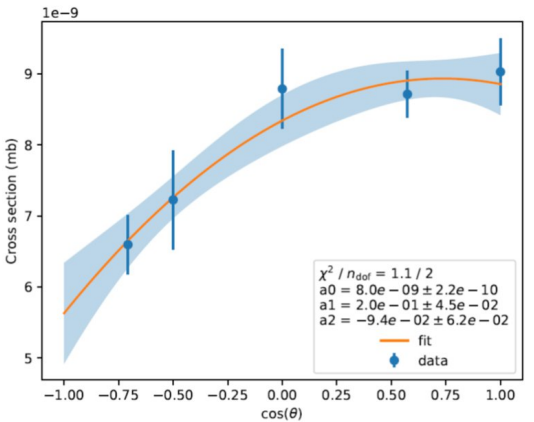
G. Gyurky:

“Underground Measurements of $^{14}N(p,\gamma)^{15}O$ and Other Key Reactions for Nuclear Astrophysics.”





(a) $R/DC \rightarrow 6.79$, $E_p = 807.5$ keV



(b) $R/DC \rightarrow 0$, $E_p = 504.4$ keV

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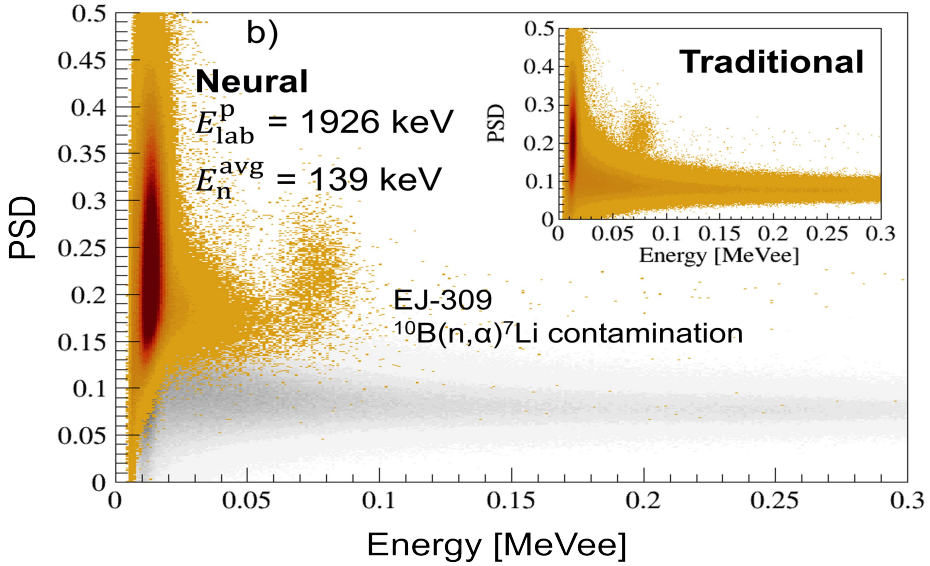
87 - T. Chillery (LNGS):

“A Prototype Neutron Detector Array for s-process Measurements"



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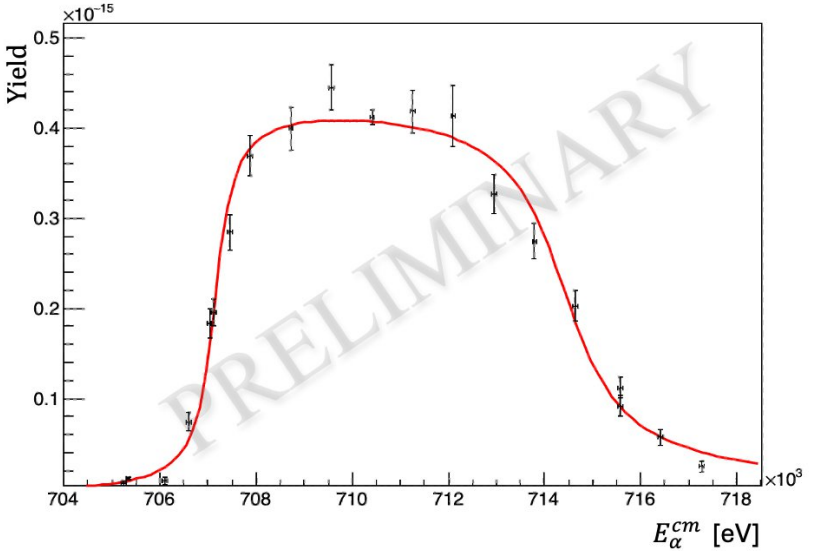
“Efficiency calibration of the SHADES array and the E_{cm}= 70 keV resonance in $^{22}Ne(\alpha,n)^{25}Mg$”



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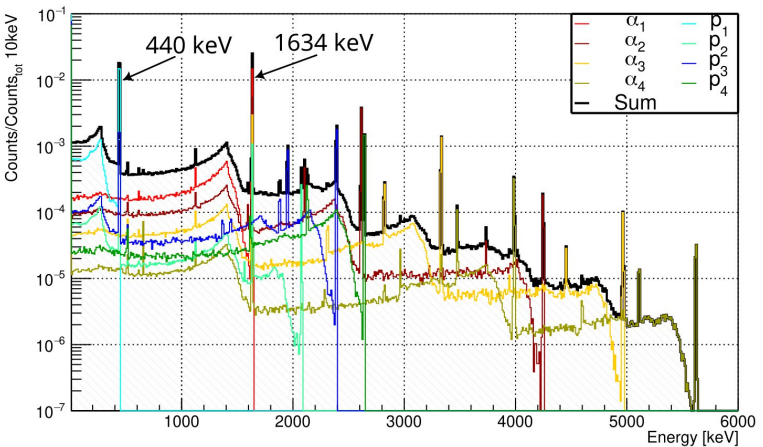
88 - R. Gesuè (GSSI & LNGS):

“The challenging direct measurement of the $^{12}C+^{12}C$ reaction rate”



Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DEL GRAN SASSO

CALL FOR PROPOSALS OF EXPERIMENTS WITH THE 3.5 MV ACCELERATOR OF THE BELLOTTI ION BEAM FACILITY OF LNGS

Researchers interested in performing experiments with the 3.5 MV Accelerator of the "BELLOTTI Ion Beam Facility" of LNGS in 2026 are invited to submit a written proposal to the Program Advisory Committee (PAC).

3rd call for proposal
for experiments in 2026
will be open July/August 2025

Perspectives at the Bellotti IBF

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

Workshop on Nuclear Physics, Astrophysics and Applications in Underground Laboratories

OCTOBER 8-10, 2025
Laboratori Nazionali del Gran Sasso
Assergi, L'Aquila, Italy

The workshop aims to bring together scientists interested in research at the deep underground Bellotti Ion Beam Facility (IBF) at INFN's Laboratori Nazionali del Gran Sasso (LNGS), to explore opportunities and challenges in an international context and to stimulate networking.

Topics

- Bellotti IBF in the international context of underground nuclear astrophysics
- Bellotti IBF for Physics beyond the standard model
- Perspectives in Applied Physics research at Bellotti IBF

Scientific advisory committeee

- Sandrine Courtin,University of Strasbourg, France
- Federico Ferraro, INFN-LNGS, Italy
- Alba Formicola, INFN-Roma 1, Italy
- Jordi Josè, UPC Barcelona/IEEC, Spain
- Matthias Junker, INFN-LNGS, Italy
- Matthias Laubenstein, INFN-LNGS, Italy
- Marcello Messina, INFN-LNGS, Italy
- Valentino Rigato, INFN-LNL, Italy
- Daniel Robertson, University of Notre Dame, Indiana, USA

Local organizing committeee

- Chair: Federico Ferraro, INFN-LNGS, Italy
- Riccardo Maria Gesuè, GSSI & INFN-LNGS, Italy
- Thomas Chillery, INFN-LNGS, Italy
- Dipali Basak, INFN-LNGS, Italy

Scientific secretary

- Fausto Chiarizia, INFN-LNGS, Italy

Contacts

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