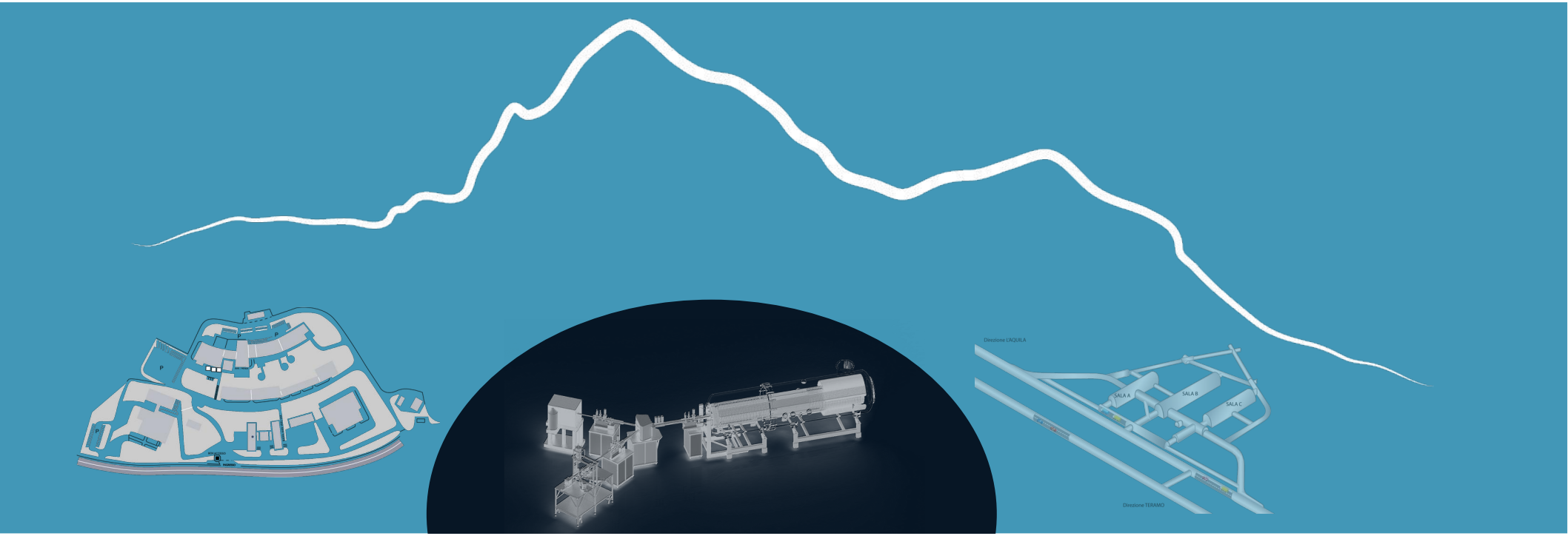
Bellotti Ion Beam Facility

at the Laboratori Nazionali del Gran Sasso



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

INFN facilities

Gran Sasso National Laboratories

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
Easy access from motorway also by trucks.

Internationality of the Gran Sasso National Laboratory

Total involved scientists: N. 1334*

Italian scientists: **N. 482**

Foreign scientists: **N. 852**

Scientific guests: N. 650*

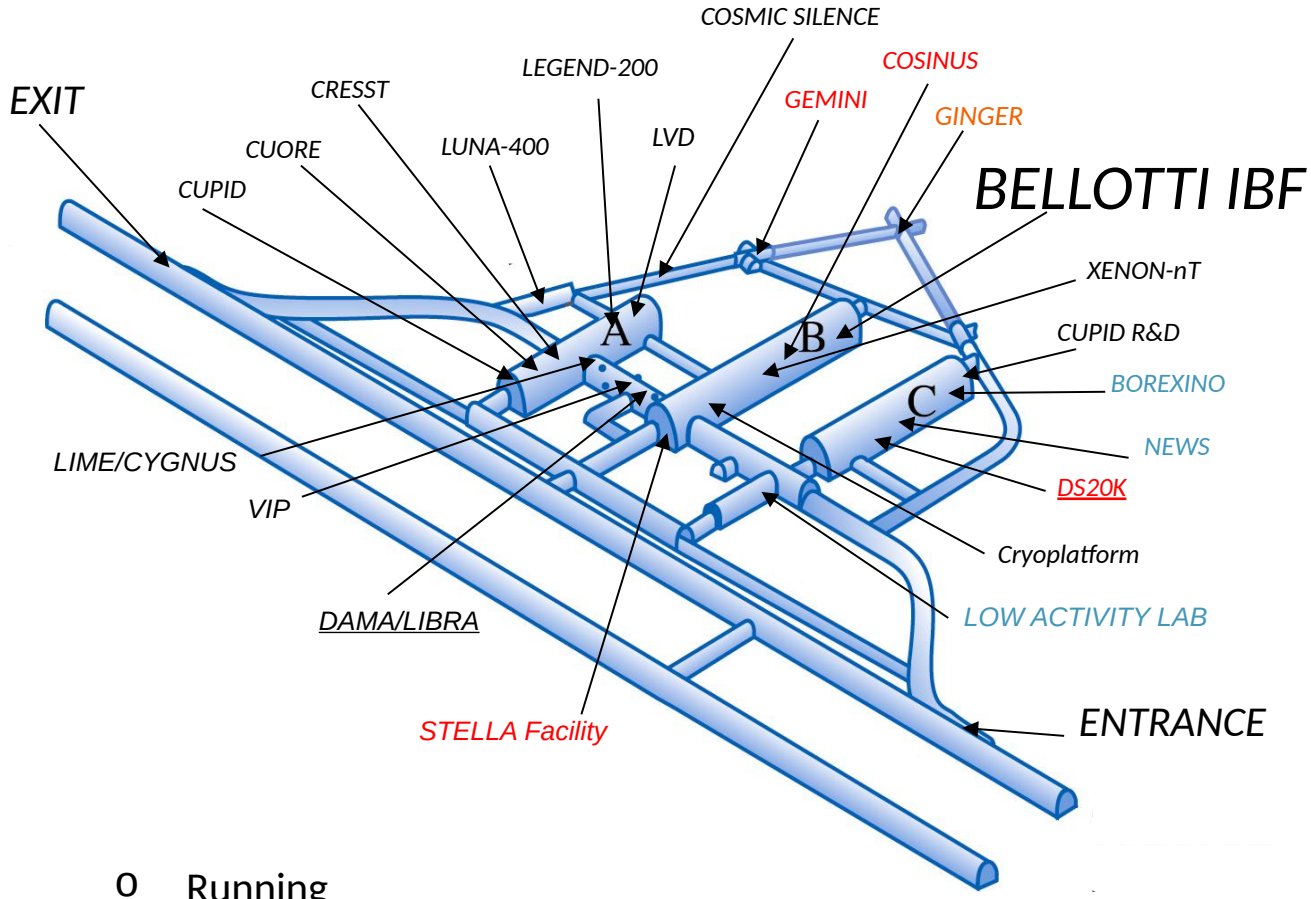
Italian guests: **N. 359**

Foreign guests: **N. 291**

*Data related to 2024

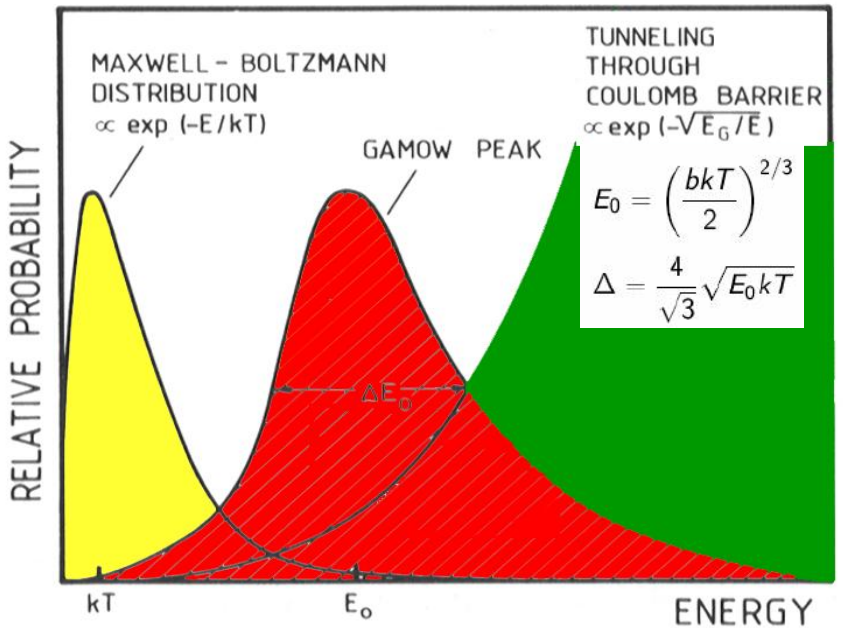
A look inside

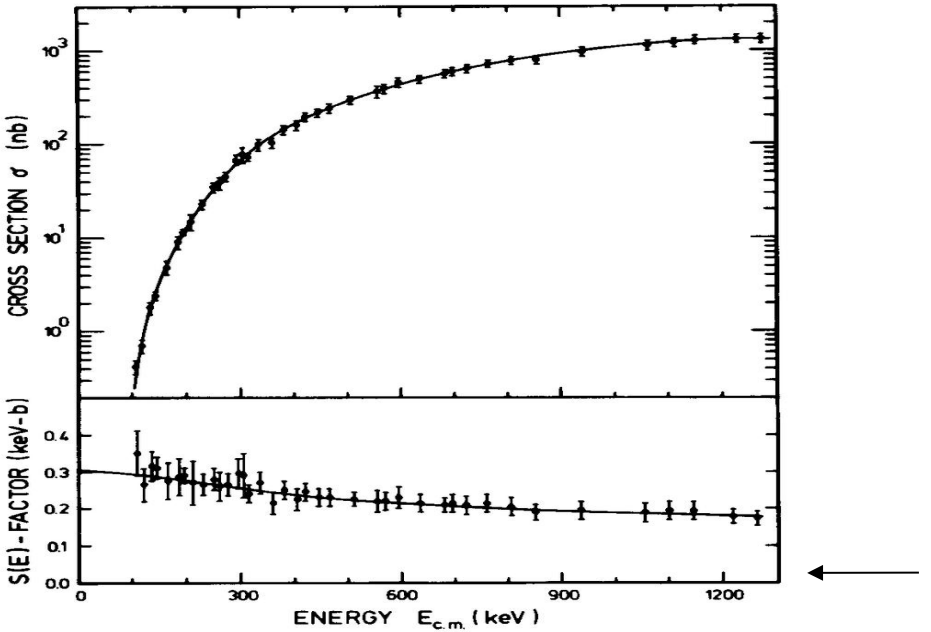
- The 3 experimental halls measure approximately 100 m in length, 20 m in width and 18 m in height
- About 22 experiments in data taking or under construction
- **STELLA**: the most sensitive laboratory to measure radioactive contaminants in materials
- **BELLOTTI ION BEAM FACILITY**: first under accelerator operated as a User Facitity



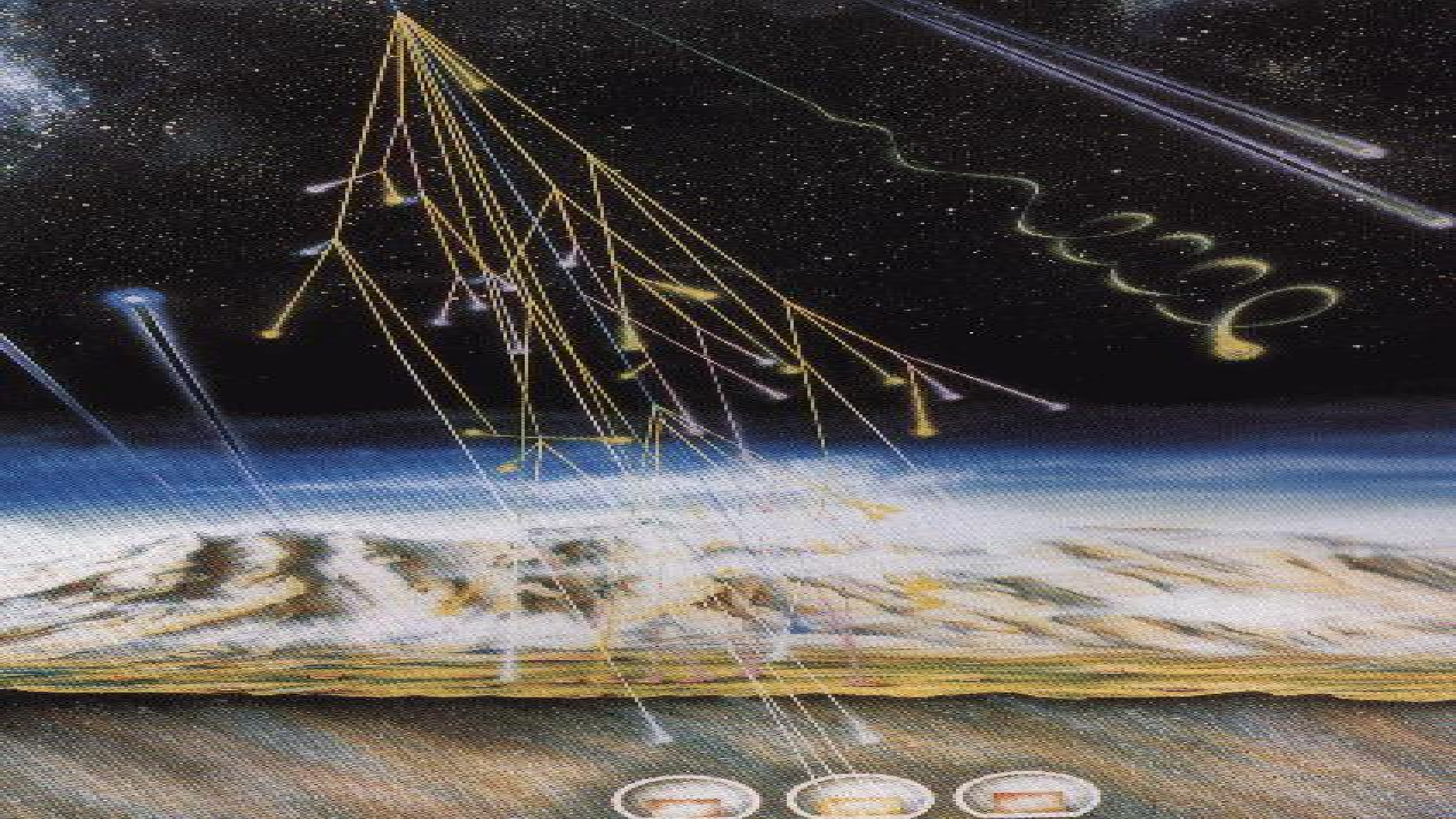
- Running
- Construction/Commissioning
- Decommissioning

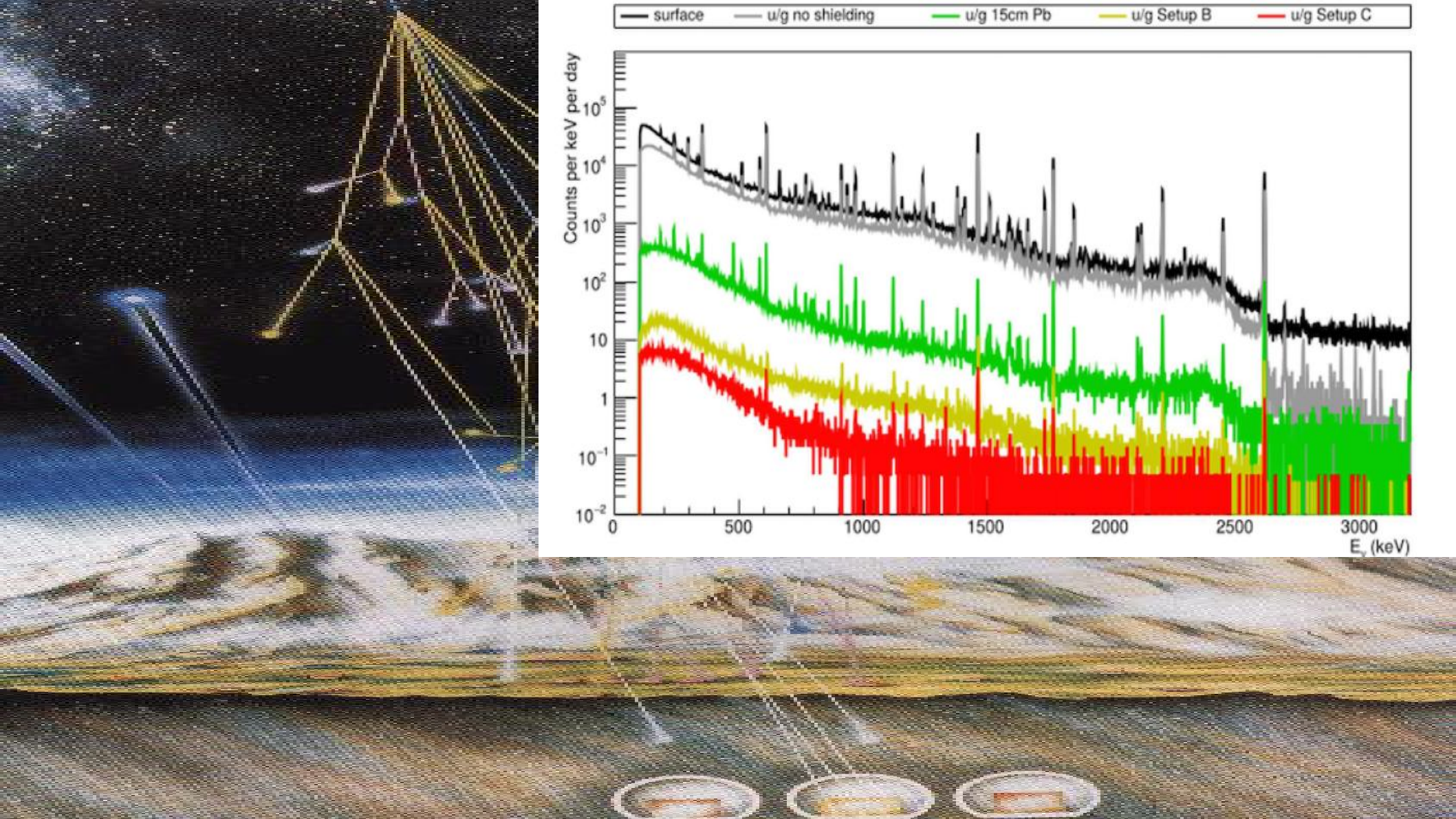
Why Nuclear Astrophysics Underground





Reaction	$E_{barrier}$ [keV]	Scenario	$T_{Scenario}$ [MK]	E_{gamow} [keV]	$\sigma(E_{Gamow})$ [barn]	E_{min} [keV]	$\sigma(E_{min})$ [barn]	Event rate
$^{3}He(^{3}He,2p)^{4}He$	1540	Sun	16.5	16.5	$2\ 10^{-14}$	16.5	$2\ 10^{-14}$	2 events / month
$^{14}N(p,\gamma)^{15}O$	2270	Sun	16.5	29	$9\ 10^{-18}$	70	$2.4\ 10^{-13}$	77 events / day
$^{12}C+^{12}C$	9400	Mass stars	1000	1800	$1\ 10^{-16}$ — $1\ 10^{-20}$	2100	$< 8\ 10^{-10}$	




surface
u/g no shielding
u/g 15cm Pb
u/g Setup B
u/g Setup C
Counts per keV per day
10^{5}
10^{4}
10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
0
500
1000
1500
2000
2500
3000
E_γ (keV)

Electrostatic Accelerators at LNGS

LUNA-50

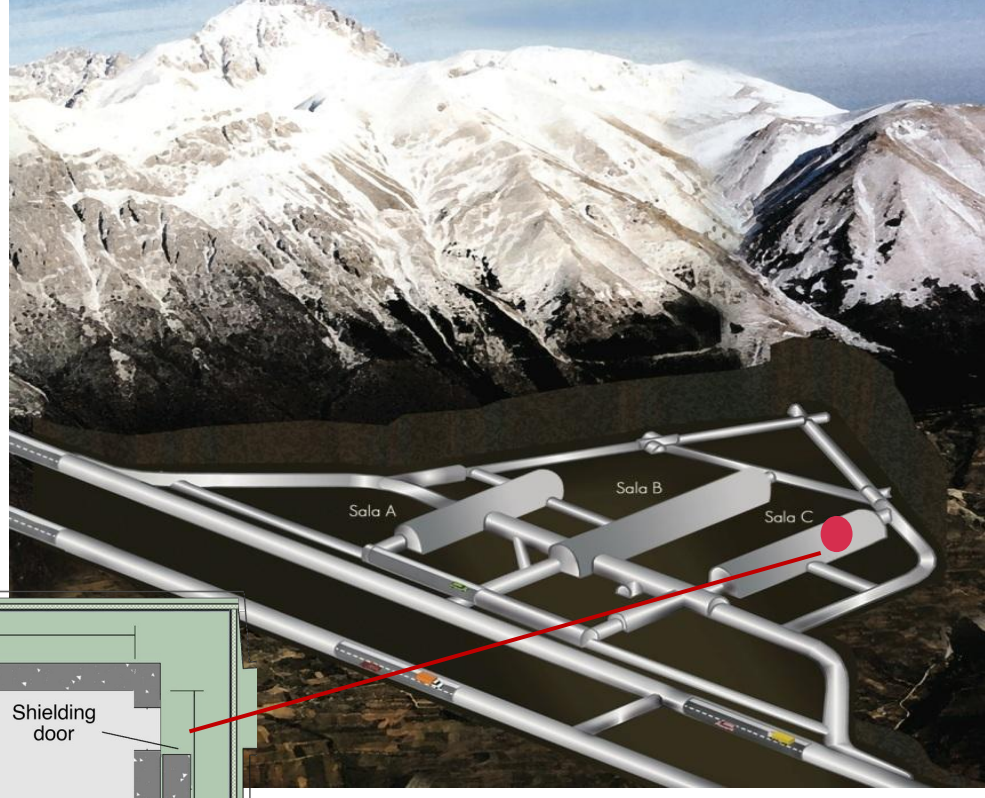
- Worldwide first underground accelerator laboratory
- Based on idea by C. Rolfs, G. Fiorentini, E. Bellotti
- Pilot project to explore possibilities of Underground Nuclear
- Nuclear Astrophysics
- Astrophysics p-p chain - solar neutrino problem
- Dismissed 2002

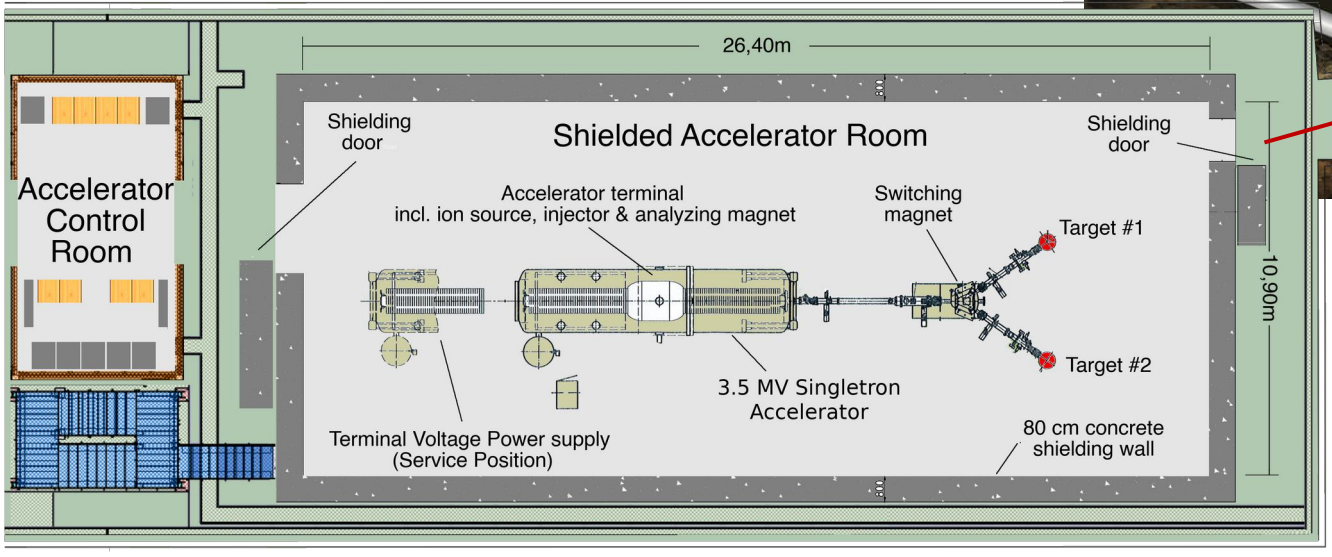
LUNA-400

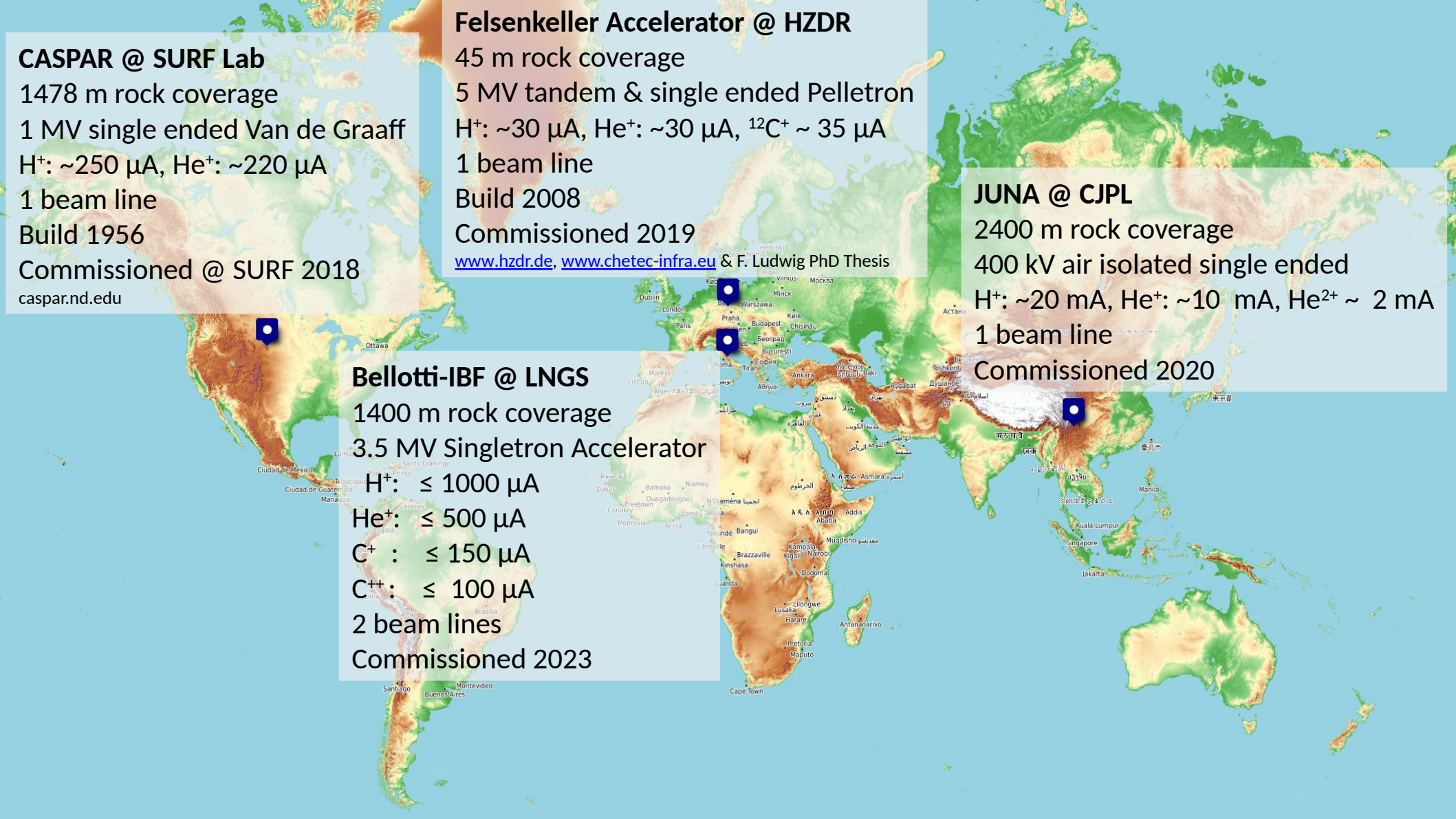
- Operated by LUNA Collaboration – funded by INFN predominantly (plus funding from Germany, Hungary, UK)
- Workhorse of the LUNA-Collaboration since 2000
- Big Bang, pp-chain, AGB Stars

The BELLOTTI Ion Beam Facility

- Initiated by LUNA Collaboration in 2007
- Total funding: 9 M€
  - Italian Ministry of Research (Progetto “LUNA-MV”)
  - INFN Laboratori Nazionali del Gran Sasso
- Operative since June 2023

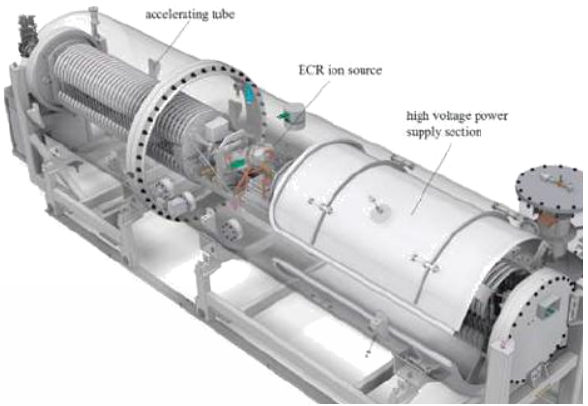




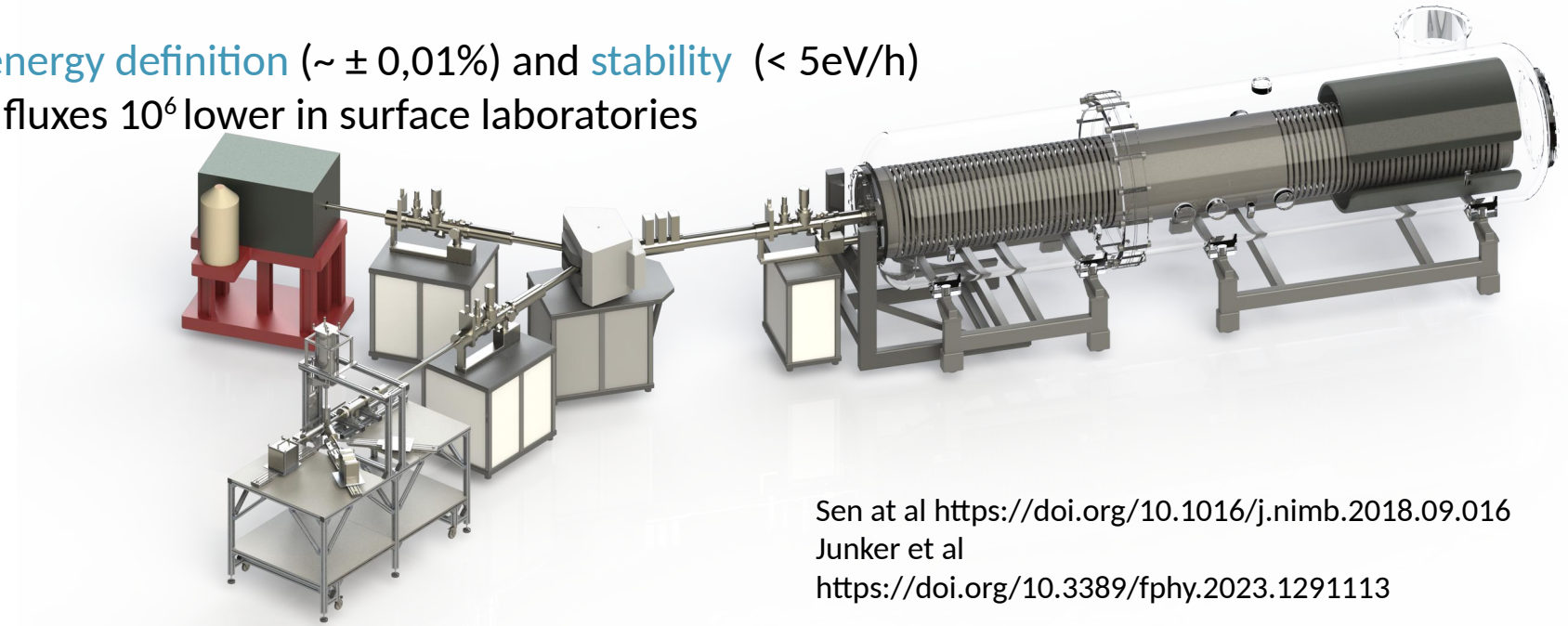

CASPAR @ SURF Lab
1478 m rock coverage
1 MV single ended Van de Graaff
H^+: ~250 µA, He^+: ~220 µA
1 beam line
Build 1956
Commissioned @ SURF 2018
caspar.nd.edu
Felsenkeller Accelerator @ HZDR
45 m rock coverage
5 MV tandem & single ended Pelletron
H^+: ~30 µA, He^+: ~30 µA, $^{12}C^+$ ~ 35 µA
1 beam 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
Bellotti-IBF @ LNGS
1400 m rock coverage
3.5 MV Singletron Accelerator
H^+: ≤ 1000 µA
He^+: ≤ 500 µA
C^+ : ≤ 150 µA
C^{++}: ≤ 100 µA
2 beam lines
Commissioned 2023

Specifications of the 3.5 MV Singletron

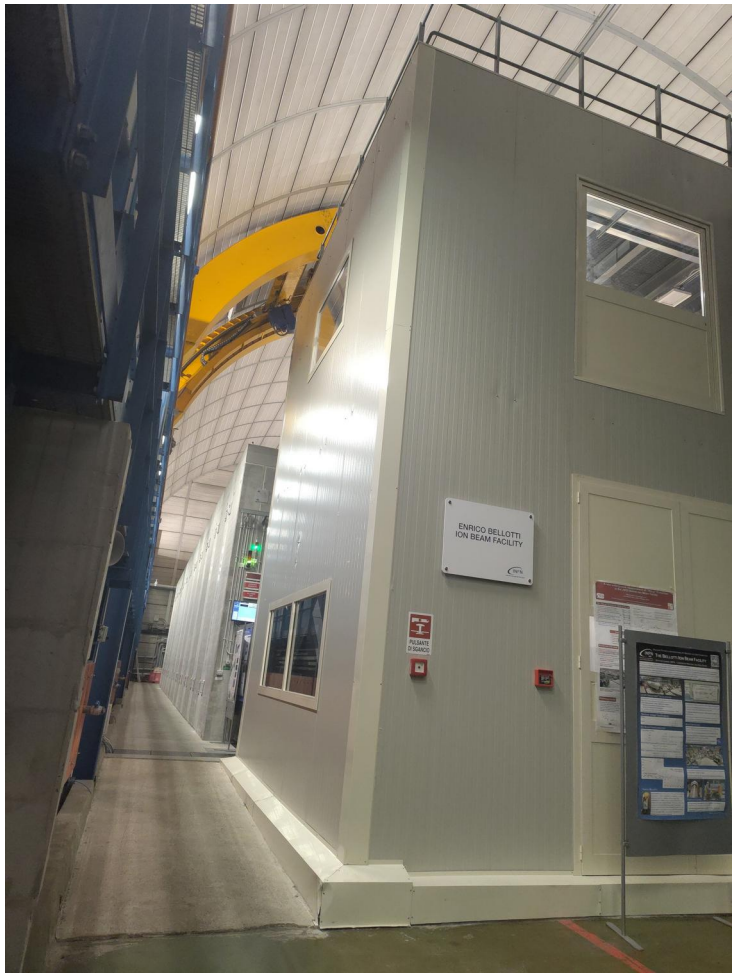
Ion specie	Terminal Voltage	
	0.3 MV— 0.5 MV	0.5 MV — 3.5 MV
$^{1}H^{+}$	≤ 500 μA	≤ 1000 μA
$^{4}He^{+}$	≤ 300 μA	≤ 500 μA
$^{12}C^{+}$	≤ 100 μA	≤ 150 μA
$^{12}C^{+2}$	≤ 60 μA	≤ 100 μA

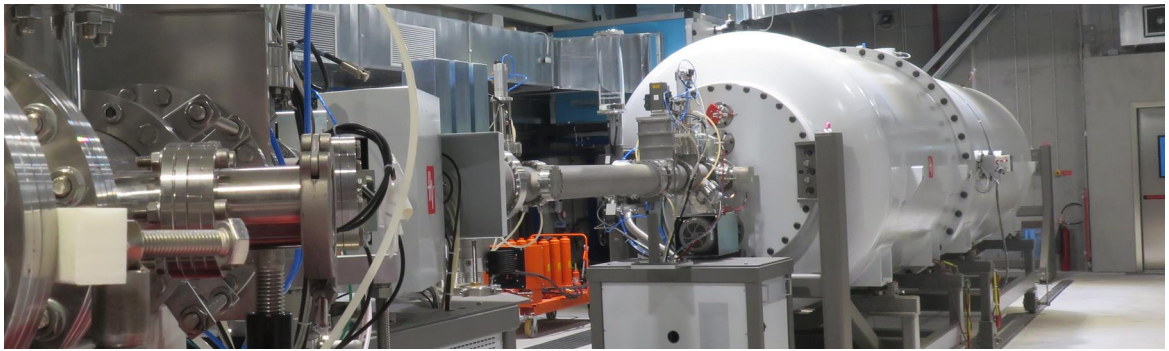


- excellent beam energy definition (~ ± 0,01%) and stability (< 5eV/h)
- cosmic radiation fluxes 10^{6} lower in surface laboratories

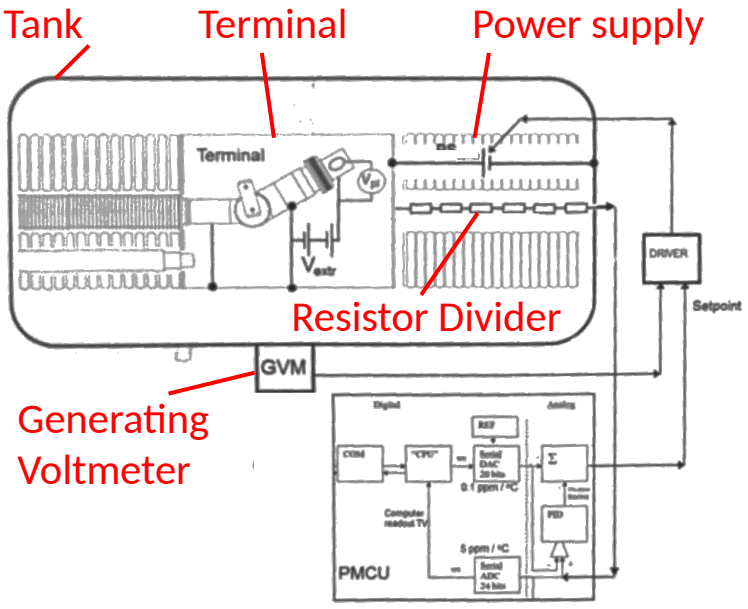


Sen at al https://doi.org/10.1016/j.nimb.2018.09.016
Junker et al
https://doi.org/10.3389/fphy.2023.1291113

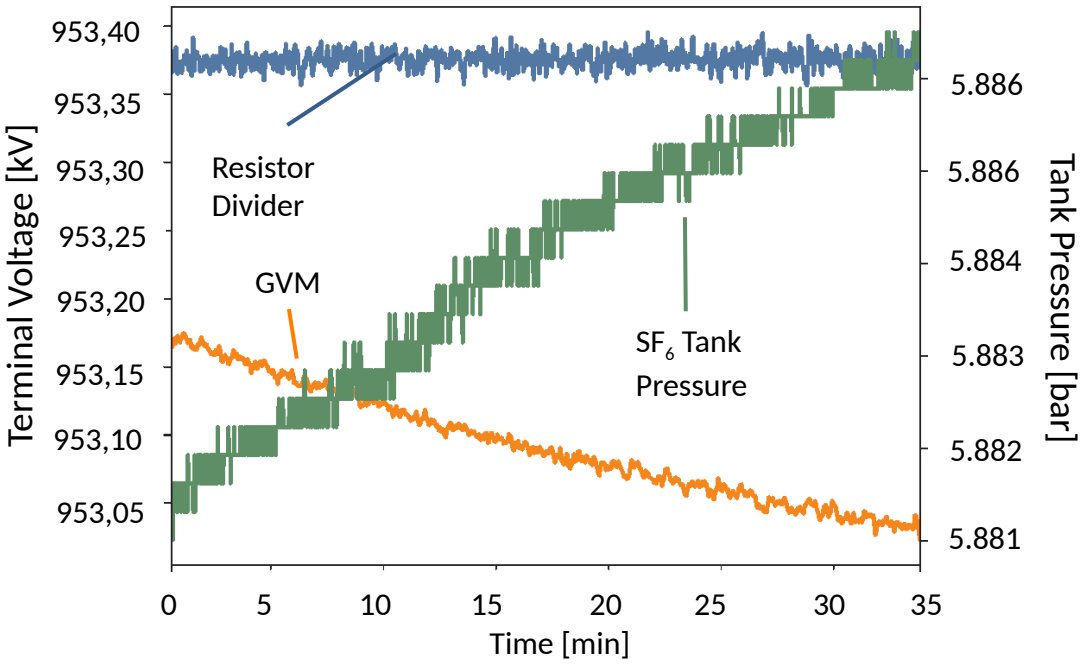

ENRICO BELLOTTI
ION BEAM FACILITY



Beam energy stability of the 3.5 MV Singletron



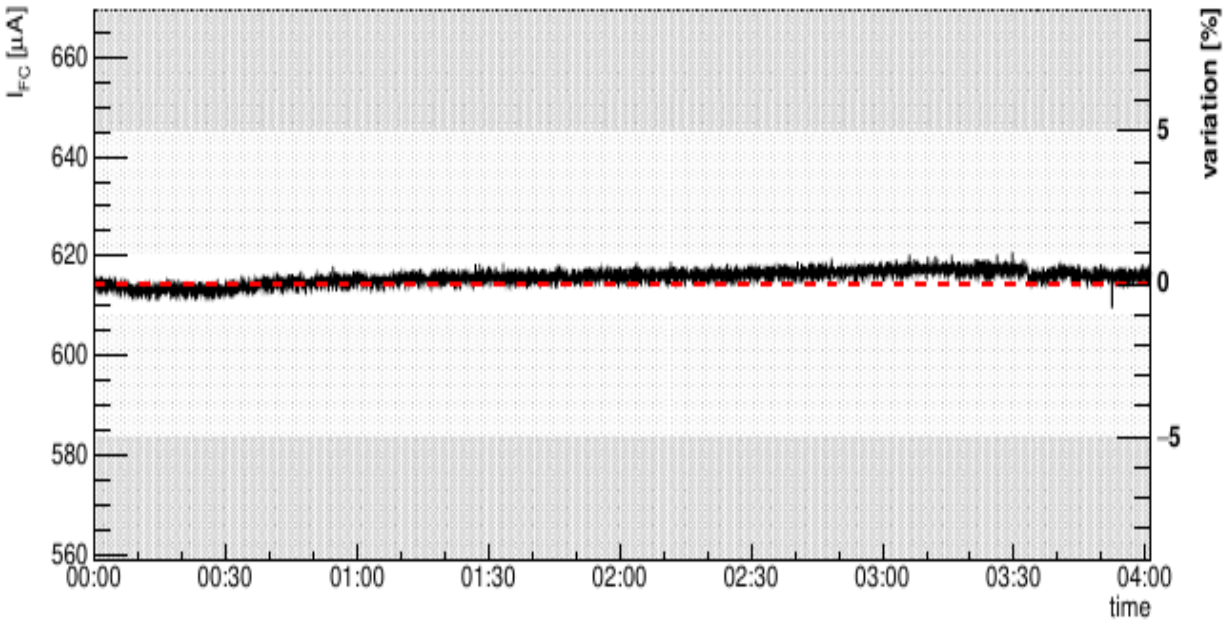
M. Mous (HVEE) - Poster at NIC 2018



Beam current stability of the 3.5 MV Singletron

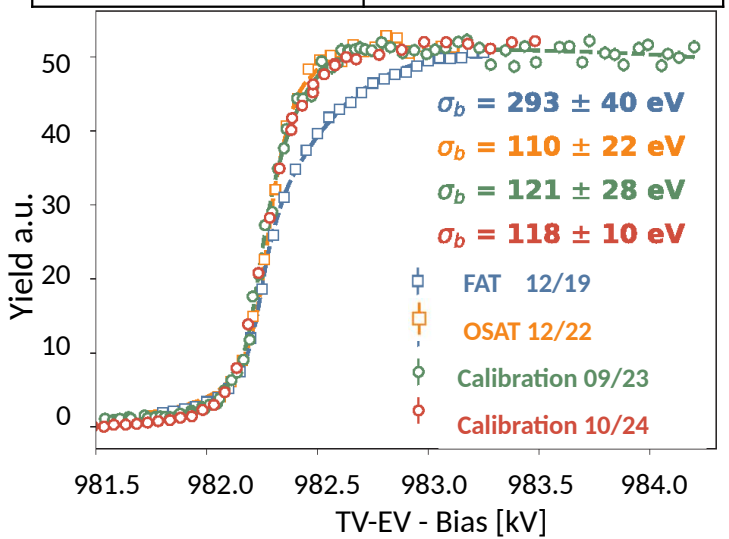
Maximum deviation of beam intensity: ≤ 5% / h

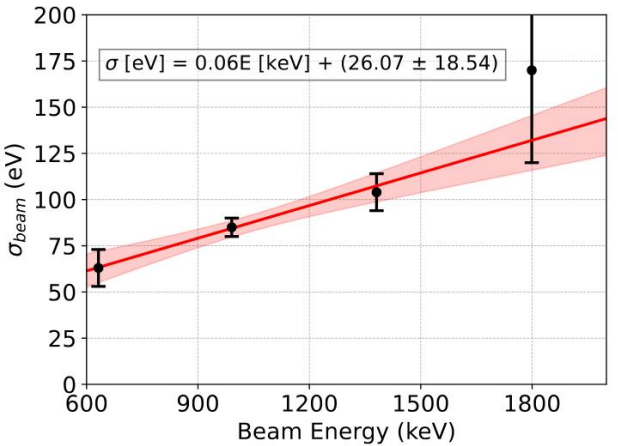
α beam	
Beam energy	1 MeV
Beam Intensity on target	615 µA
Test duration	4 h
Beam current variation	≤ 1 %/h

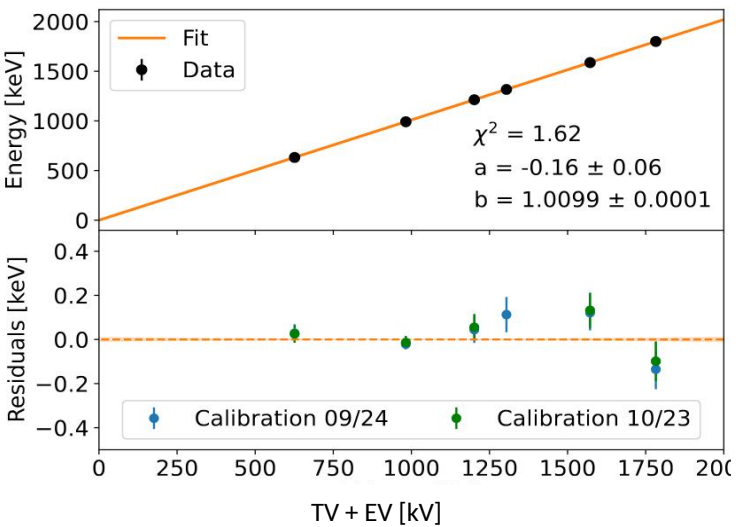


Beam Energy calibration and stability using ^{27}Al(p,γ) resonances

$E_{r,\,lab}$ (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

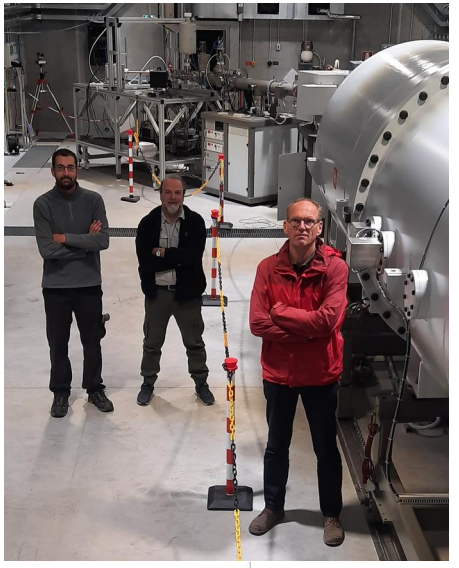






A. Compagnucci (GSSI & LNGS), J. Skowronski (Padova)

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, 2 Trainees

Program Advisory Committee

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

Calls for experiments issued once per year

(typically in early July)

ChETEC INFRA Transnational Access Facility

frontiers | Frontiers in Physics

TYPE Perspective
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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

Scientific program at Bellotti IBF

Solar CNO Hydrogen burning, Age of Globular Clusters and C production in AGB

$^{14}N(p,g)^{15}O$ *Data acquisition finished, first technical paper published*

A. Compagnucci, A. Formicola, M. Campostrini, et al., Eur. Phys. J. A 61, 191 (2025)

Neutron source for s-process

$^{22}Ne(\alpha,n)^{25}Mg$ *Data taking close to conclusion*

ERC Starting grant project "Shades" (P.I. A. Best, Naples)

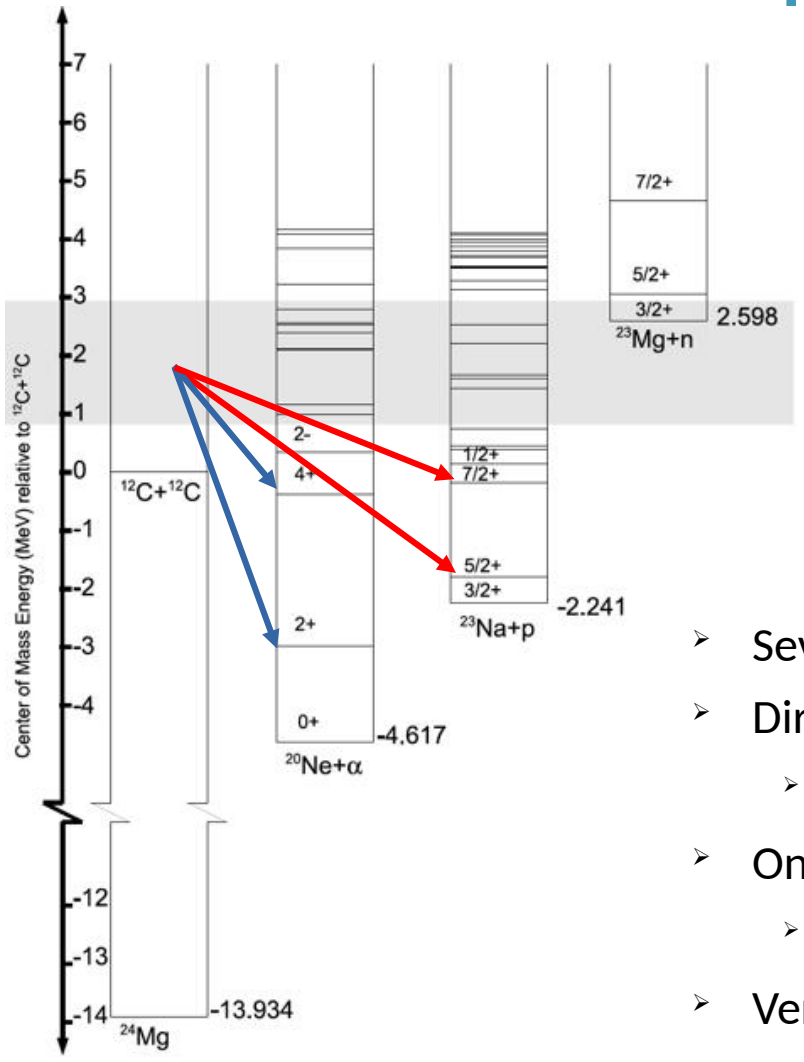
Carbon burning

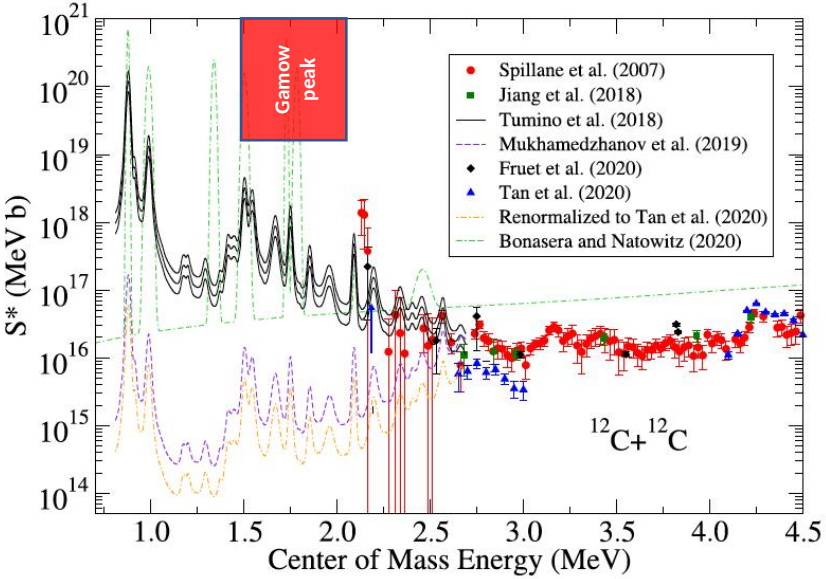
$^{12}C+^{12}C$ fusion *Data taking started*

Presently main science case,

Transnational access through ChETEC INFRA

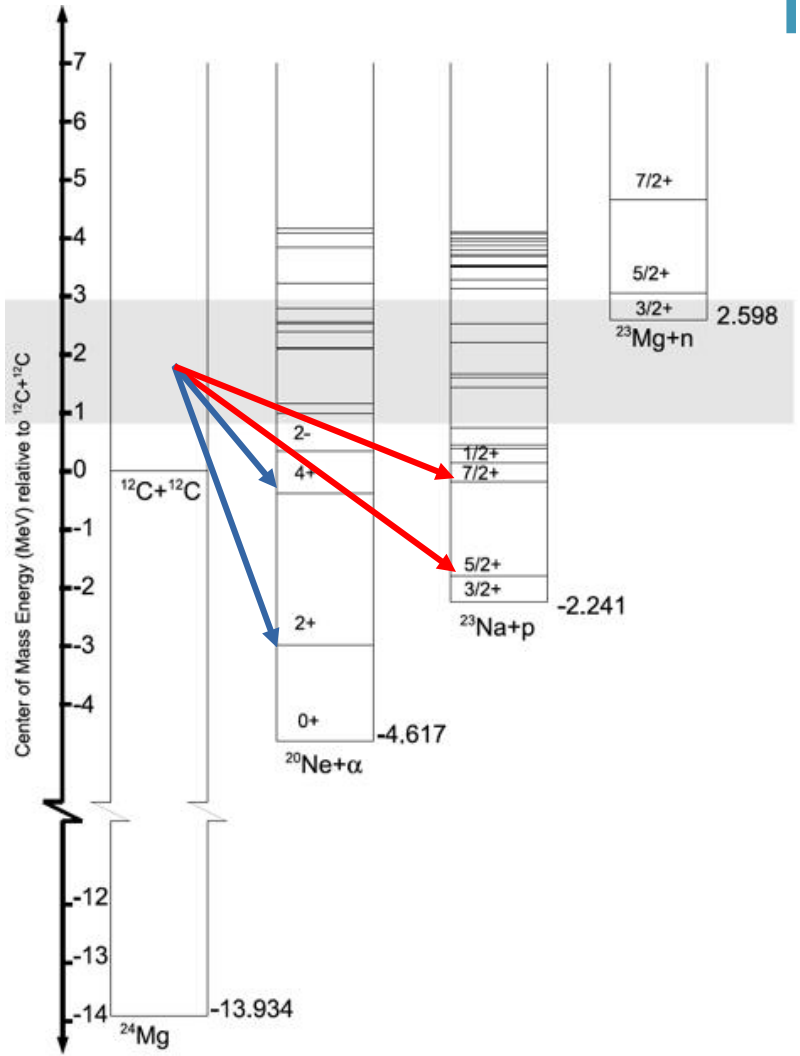
The $^{12}C+^{12}C$ Project

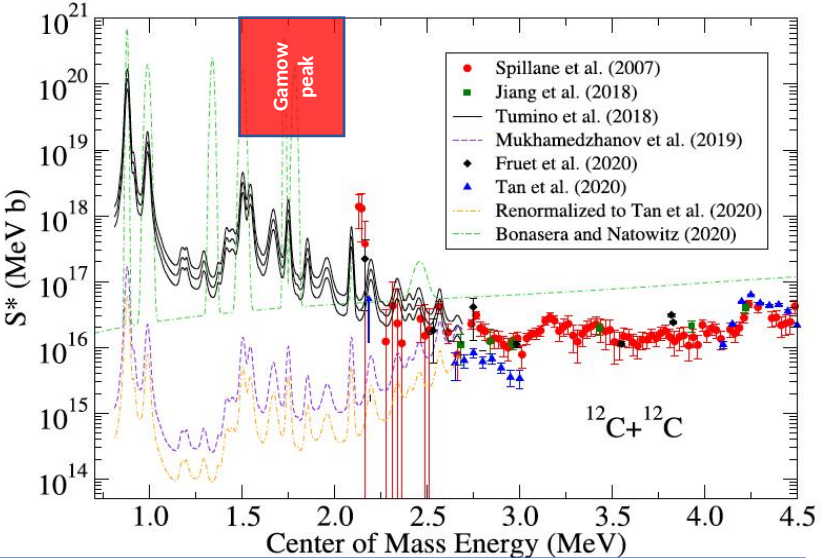




- Several datasets and models
- Direct measurements only above 2.1 MeV
  - large scatter in data, large uncertainties
- Only indirect measurements below 2.1 MeV
  - problems with normalization and other discrepancies
- Very large uncertainty below 2.5 MeV
- Presence of several states at low energies

The $^{12}C+^{12}C$ Project



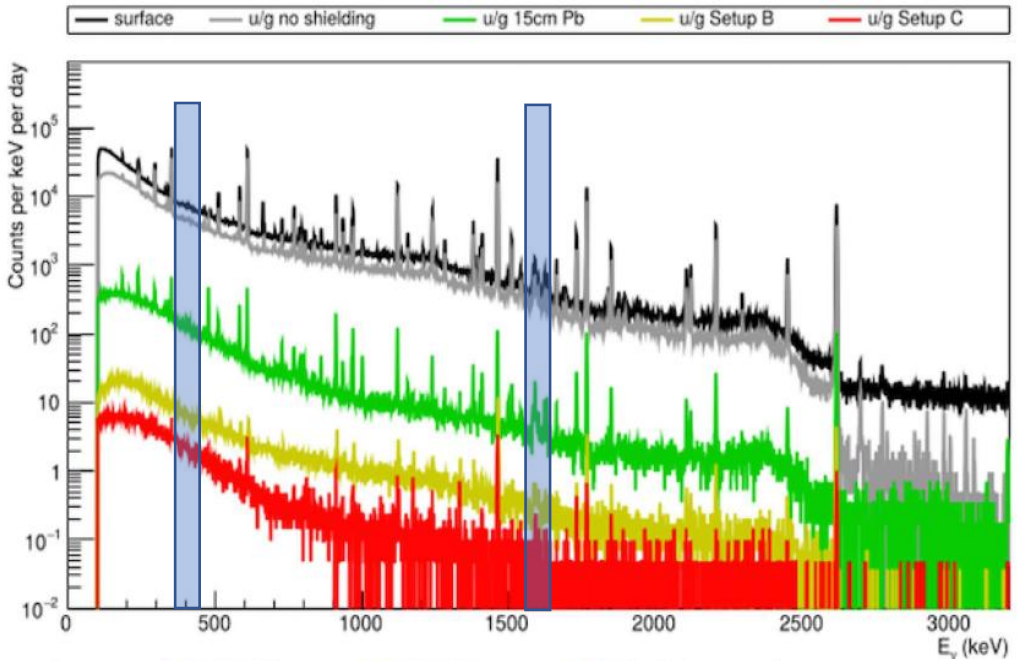


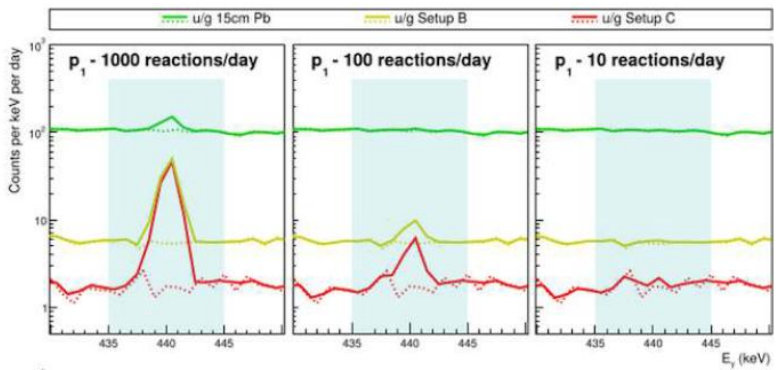
Reactions per day with 200 µA $^{12}C^{+}$ Beam

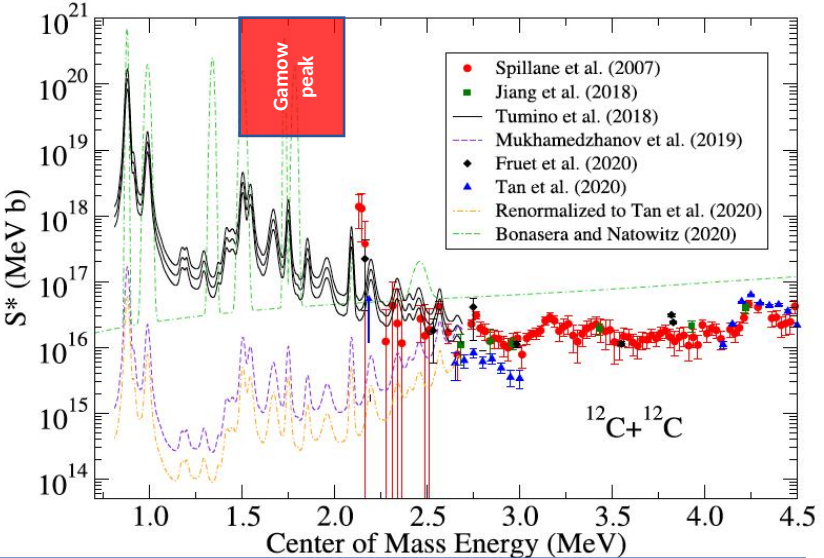
		c.m. Energy		
		1500 keV	1750 keV	2000 keV
α_1 (1640 keV)	Tumino 2018	3.5	350	5500
	No Resonant	0.038	7.5	525
	Mukhamedzhanov 2019	0.025	3.5	125
p_1 (440 keV)	Tumino 2018	1.5	150	2500
	No Resonant	0.02	3	200
	Mukhamedzhanov 2019	0.01	1.5	50

For details → Gesuè & Imbriani, today 17:40 in Nucl. Astrophys. Session

The $^{12}C+^{12}C$ Project







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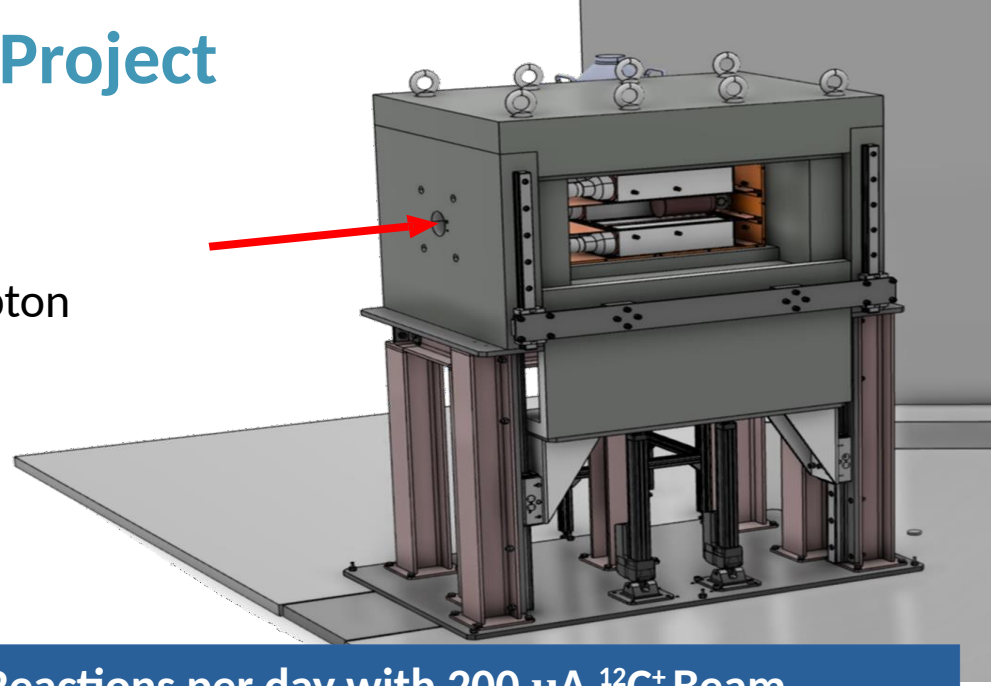
The $^{12}C+^{12}C$ Project

- 25 cm thick lead shielding
- HPGe rel eff. 150%
- 16 NaI detector as further active shielding/anti-Compton
- Beam intensity 200 pμA



Detectable Reaction rate [day^{-1}]		
Setup	α_1 (E_γ = 1634 kev)	p_1 (E_γ = 440 kev)
HPGe	> 5	> 13
HPGe + anti Comptom	> 3	> 10
Aimed stat. Uncertainty: 50 % Beam time per data point: 60 days		

Reactions per day with 200 μA $^{12}C^+$ Beam

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The $^{12}C+^{12}C$ Project

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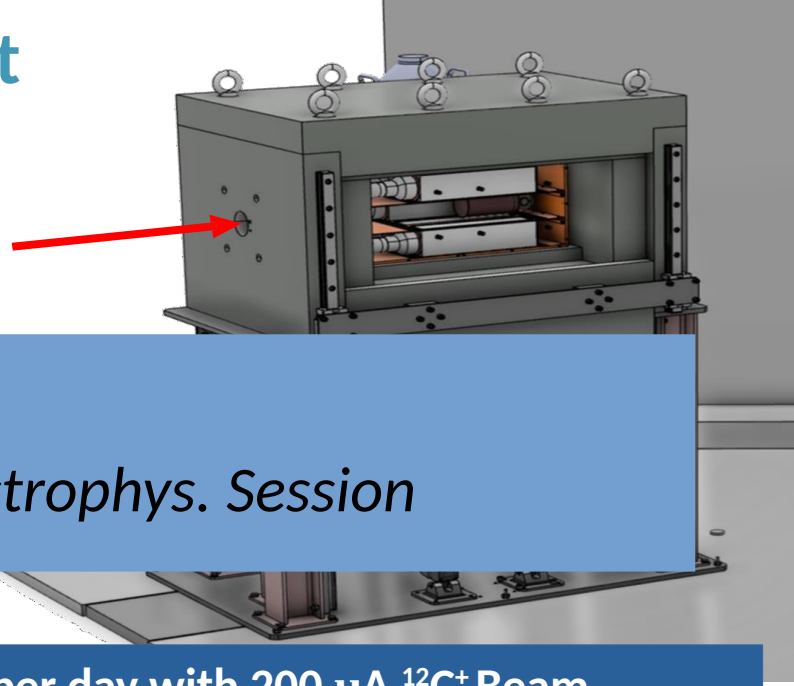
- Bean



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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

Invited Speakers

Matteo Campostrini, INFN-LNL, Italy

Giovanni Ciani, INFN Sez. Bari, Italy

Joao Cruz, Lisbon, Portugal

Bingshui Gao, JUNA, China

Simone Manti, INFN-LNL, Italy

Eliana Masha, HZDR,Germany

Denise Piatti, Univ. Padova & INFN-PD, Italy

Frank Strieder, SDSMT, USA

Xiaodong Tang, JUNA, China

Claudio Toni, Annency, France

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