



Present and future of Nuclear Astrophysics at LNGS

GSSI Science Fair
12 February 2026

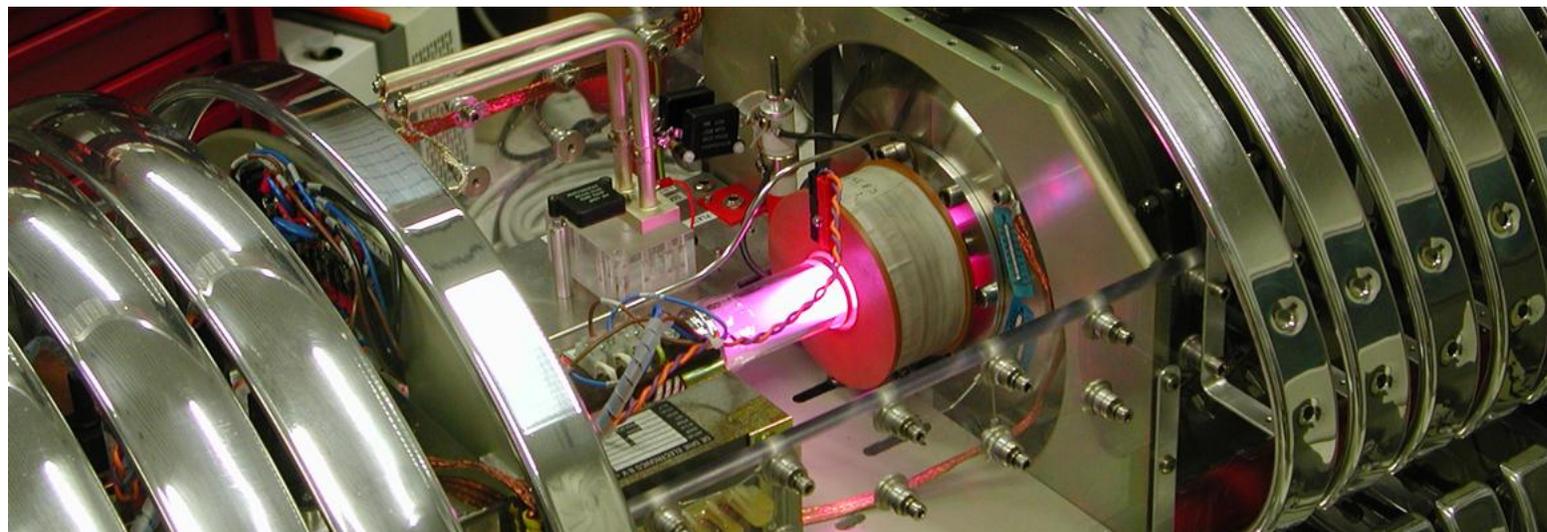
Federico Ferraro

INFN - Laboratori Nazionali del Gran Sasso



LUNN

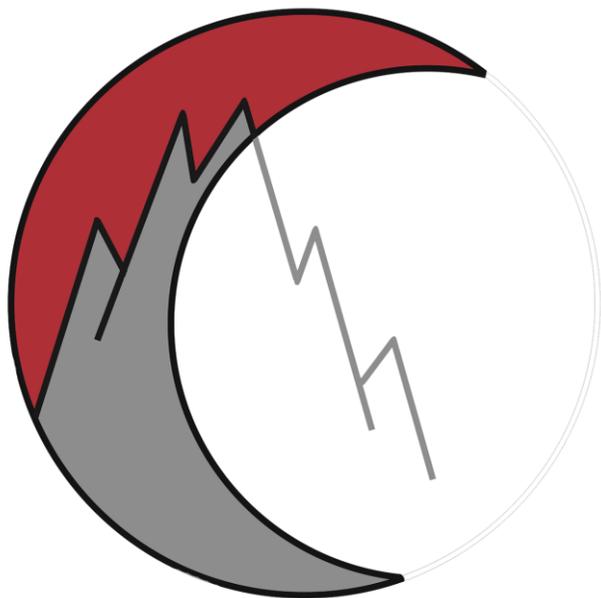
Laboratory for Underground
Nuclear Astrophysics



has been the only underground accelerator for nuclear astrophysics
for over 30 years

measures **nuclear cross sections** impacting:

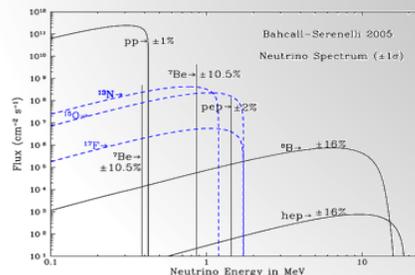
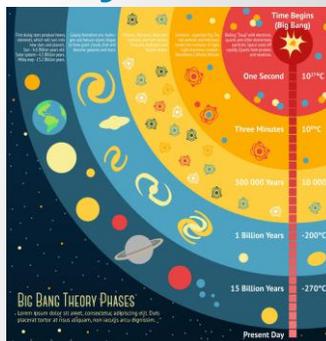
solar physics	(solar neutrinos)
cosmological model	(baryon density)
big bang nucleosynthesis	(Big Bang Nucleosynthesis)
stellar nucleosynthesis	(H, He, C burning)



LUNN

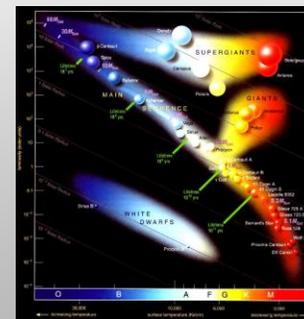
Laboratory for Underground Nuclear Astrophysics

Evolution of early universe

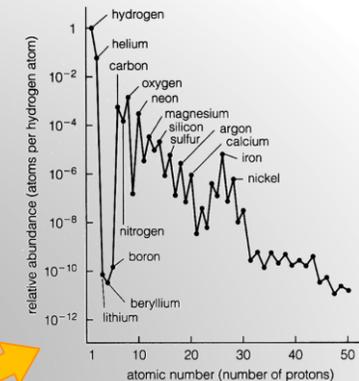


Solar neutrinos

Stellar evolution



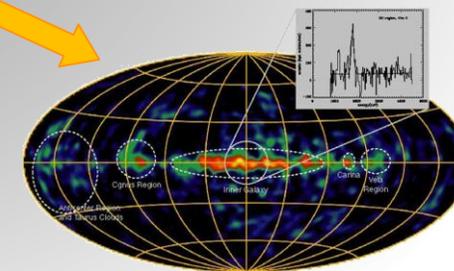
Nucleosynthesis



Nuclear cross sections



Solar system



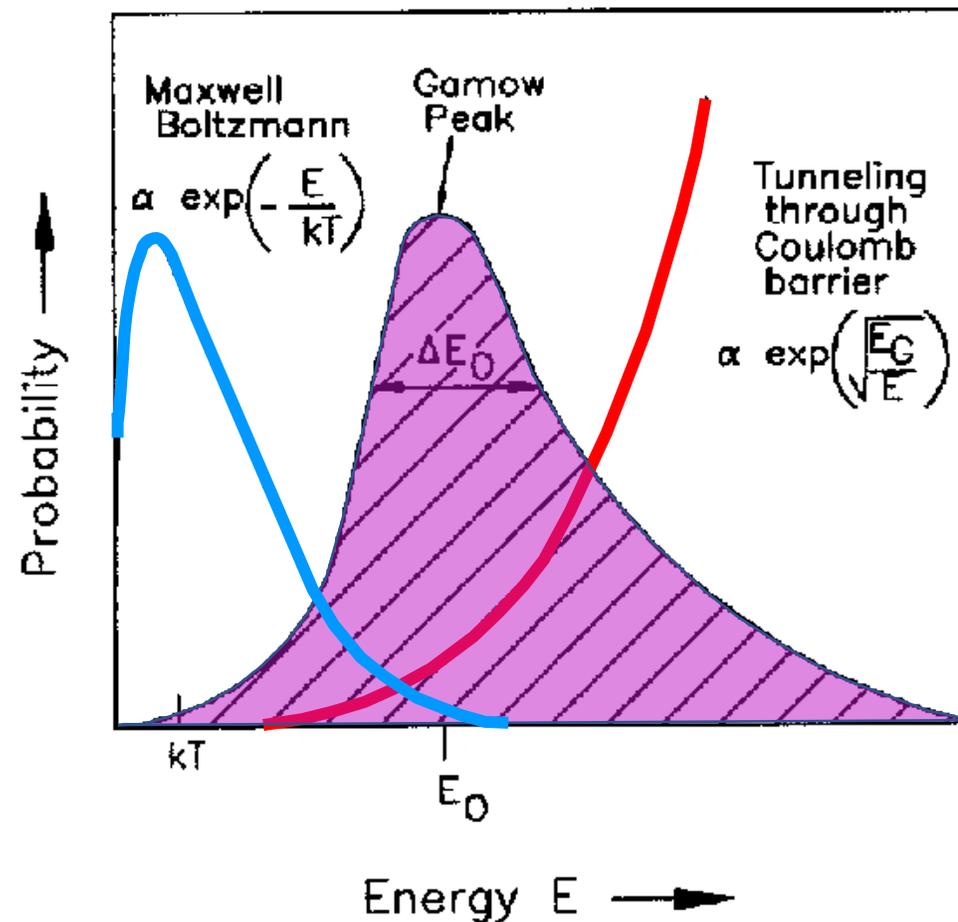
(Oberlack et al., 1996; Pluschke et al., 2001)
Astronomy

How do such nuclear reactions take place?

Nuclear reactions take place at **very-low energy**

The energy interval is determined by

- Relative velocity distribution
- Tunnelling probability



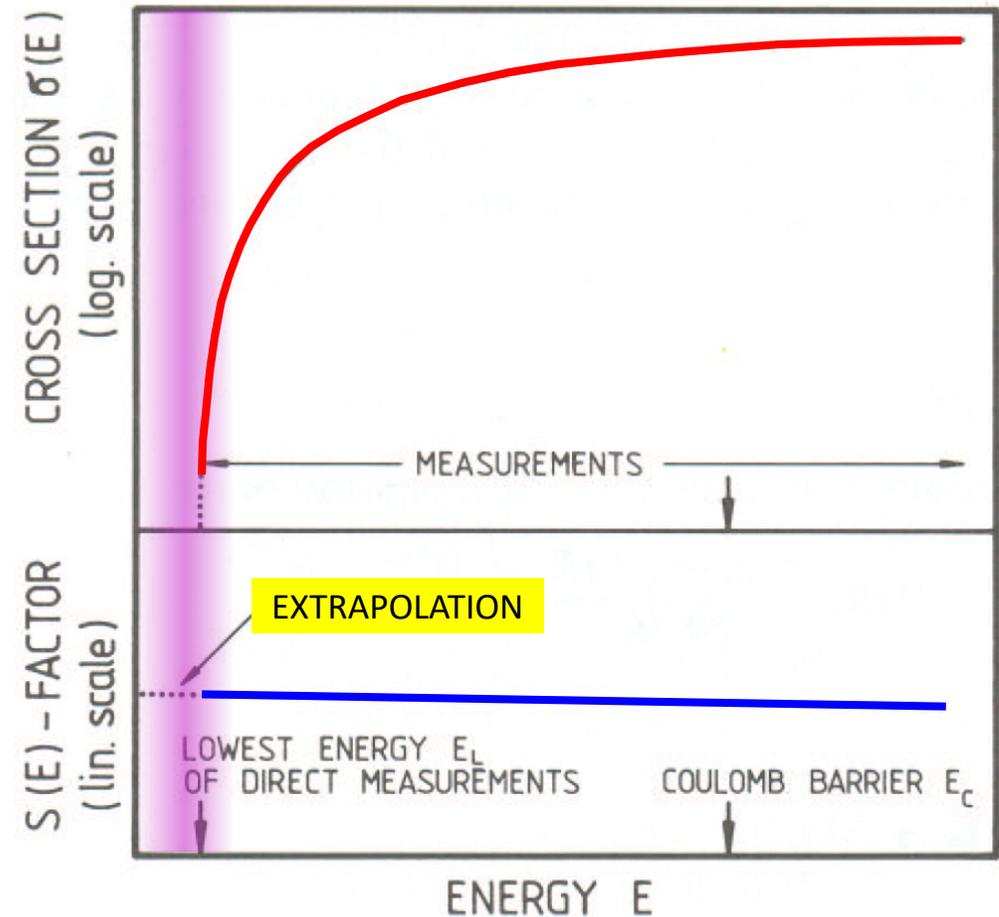
Low energy leads to small cross section...

Cross section too small at the relevant energies!

Factorizing the cross section like this

$$\sigma(E) = \frac{1}{E} e^{-2\pi\eta} S(E)$$

it is possible to measure $S(E)$ at high energy and **extrapolate** down to the interesting energy range



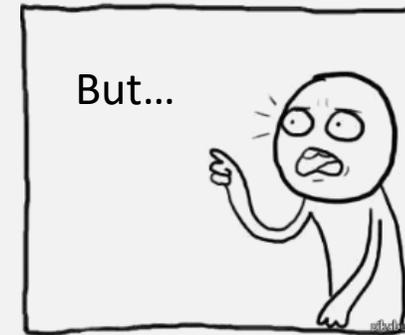
...small cross section leads to rare events...

Counting rate too low at the relevant energies!

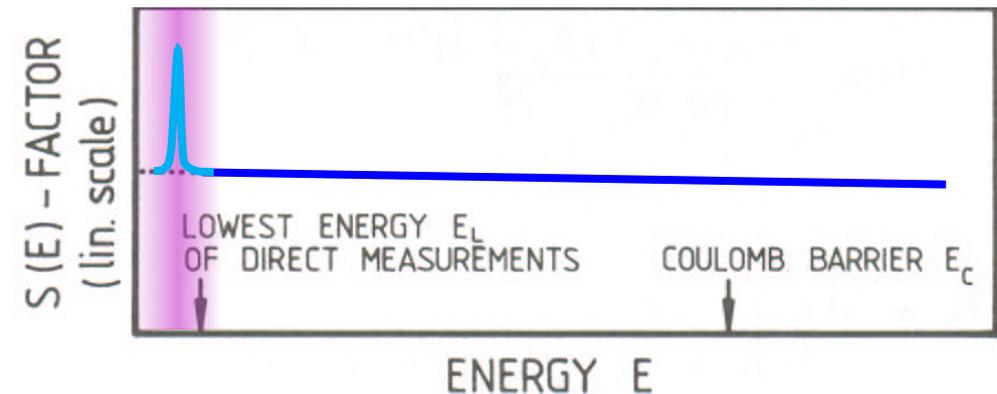
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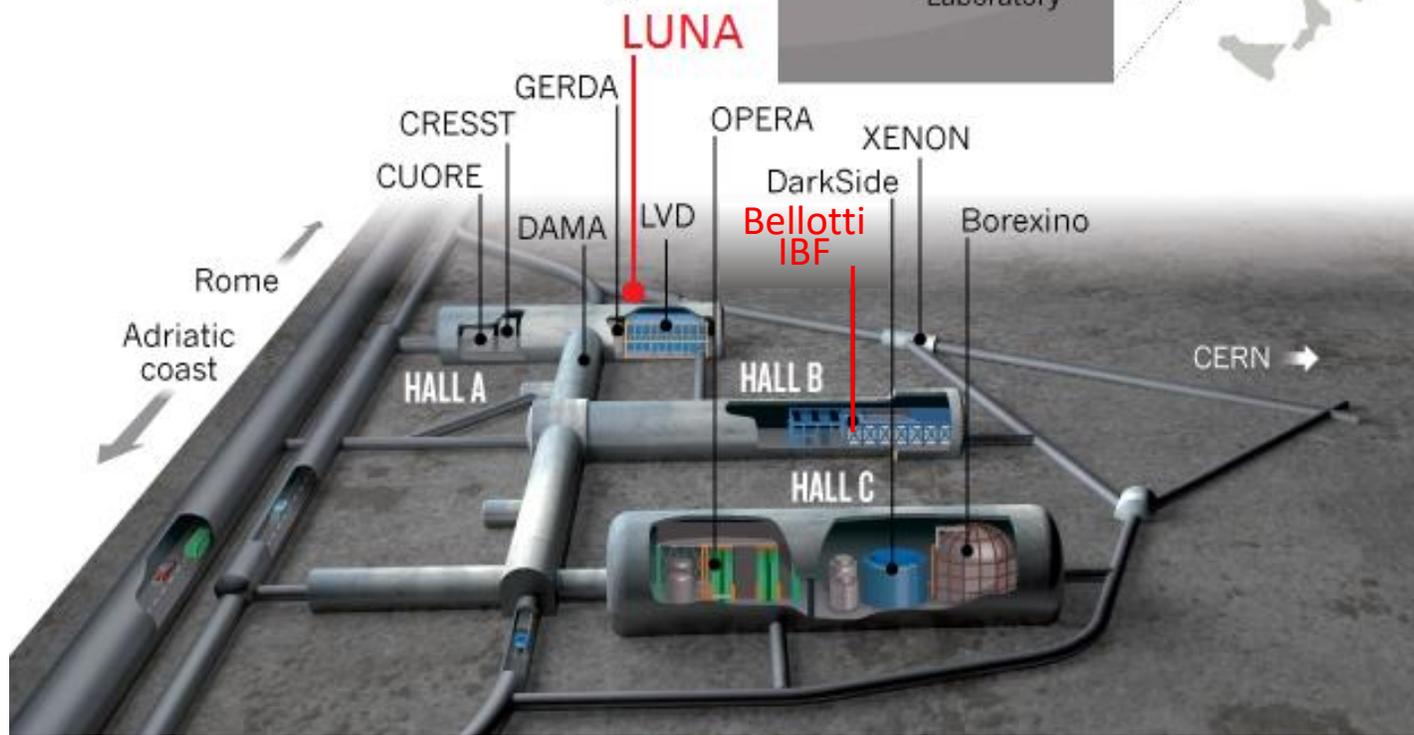
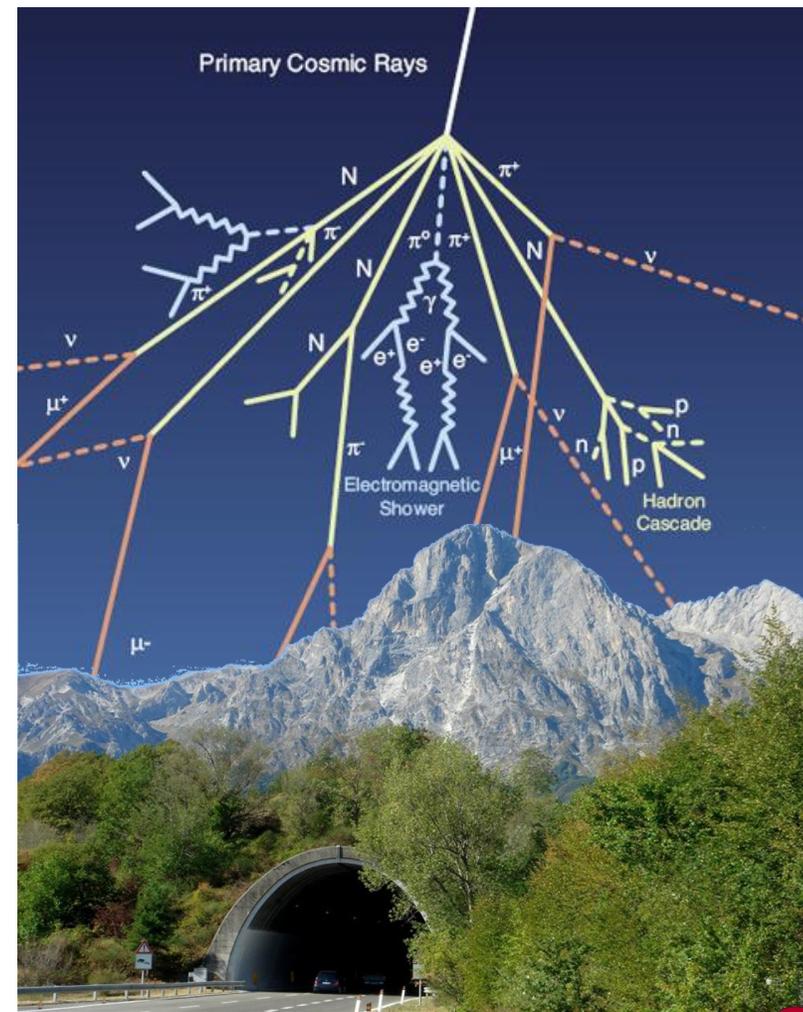
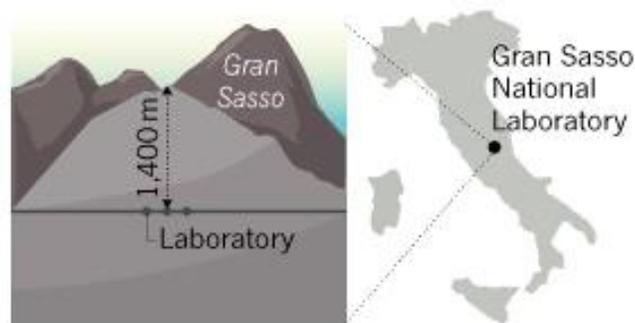


unexpected low-energy resonances may be present in the extrapolation region!

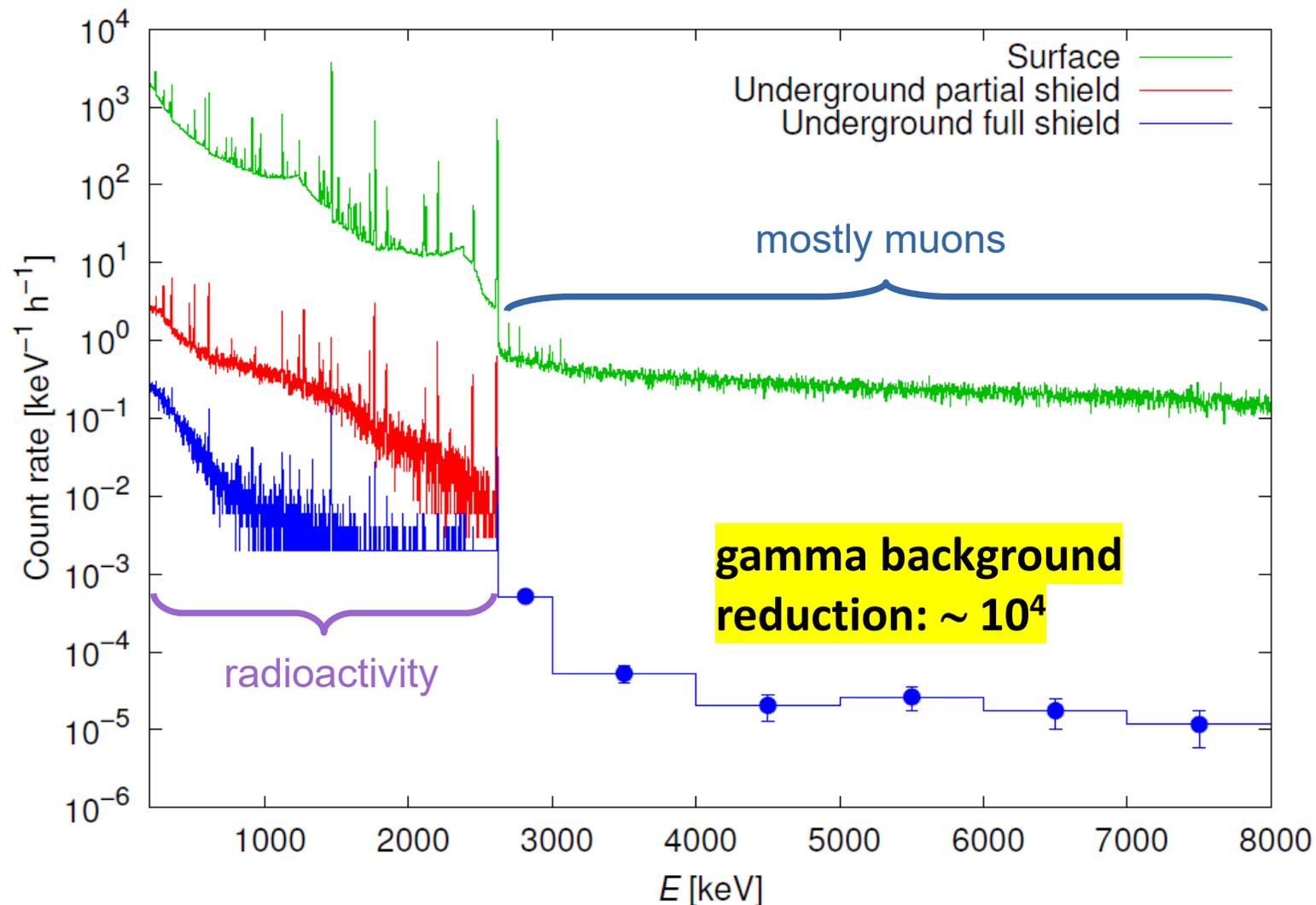


The Gran Sasso National Laboratory (LNGS)

Min. overburden: 3400 mwe
 muon flux reduction: $\sim 10^6$
 neutron flux reduction: $\sim 10^3$

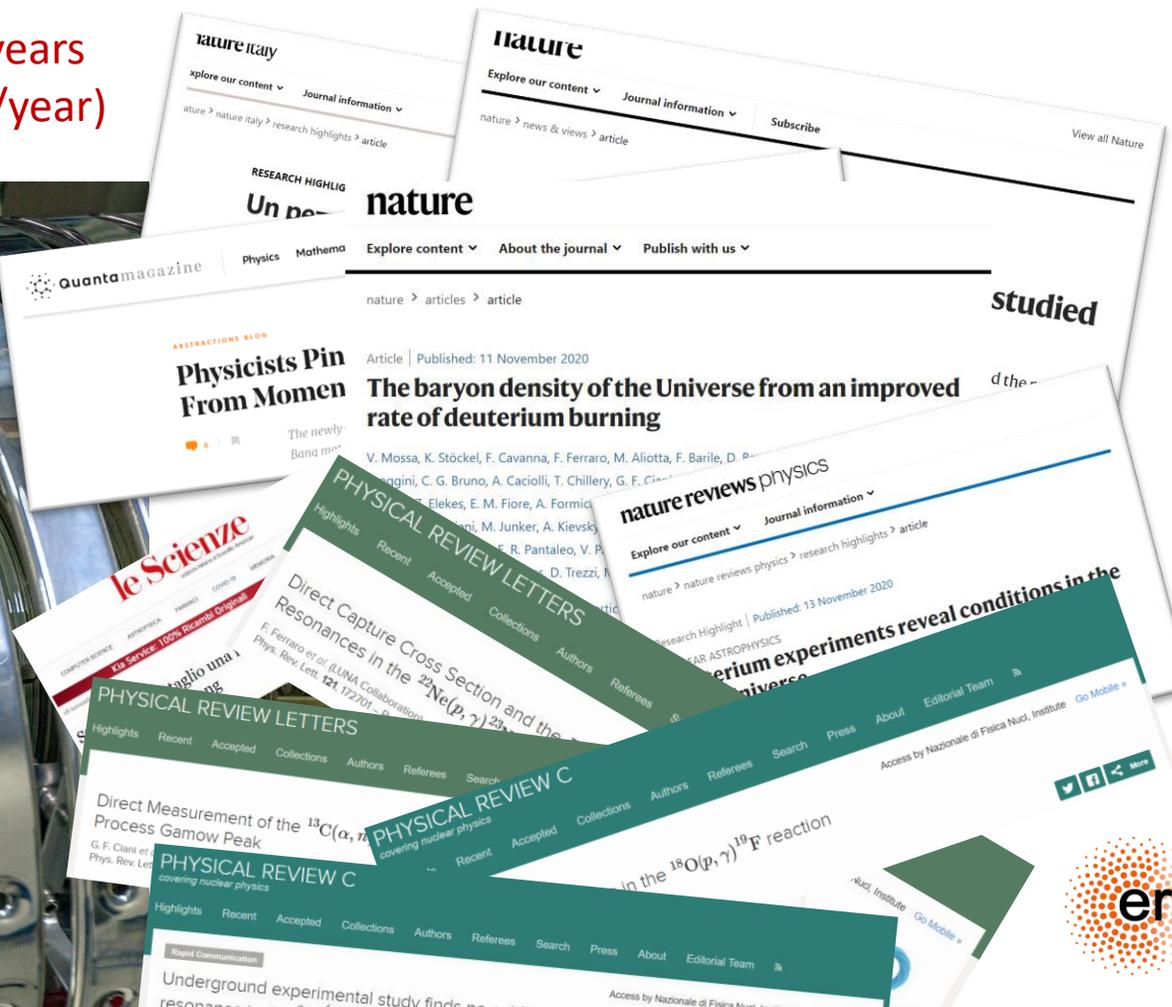
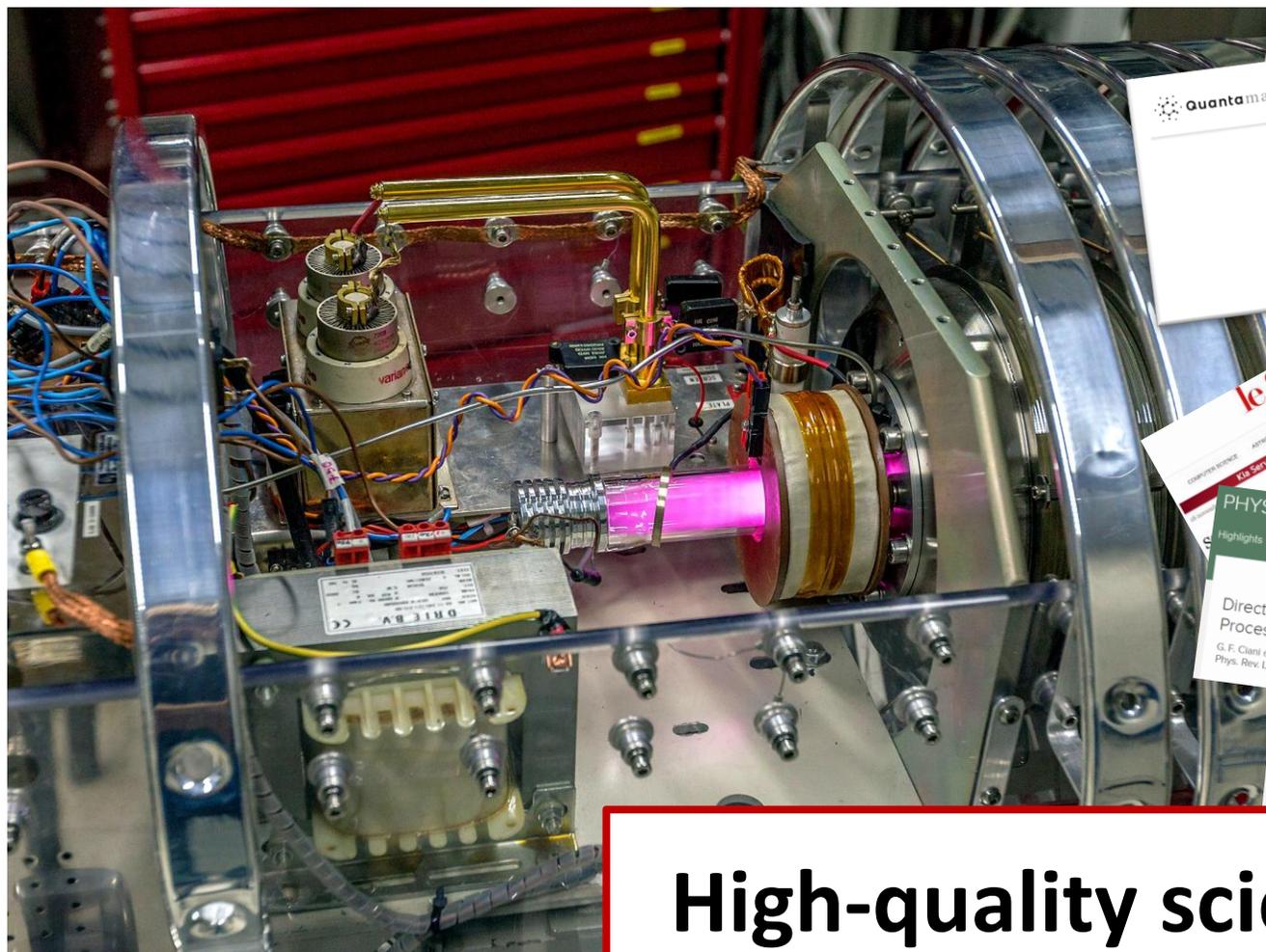


Gamma background reduction @ LNGS



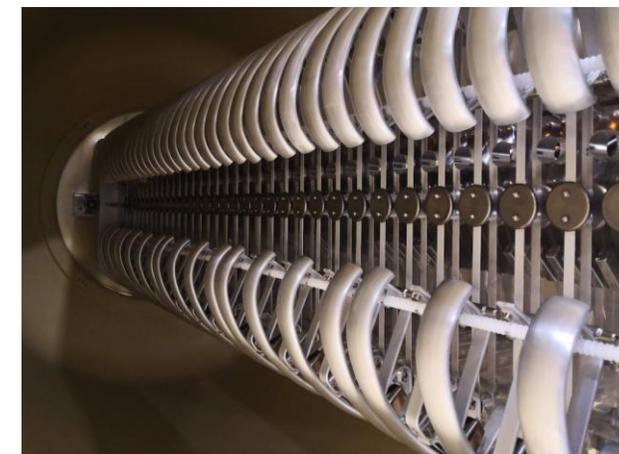
LUNA 400 kV

>95 papers in 35 years
(approx. 3 papers/year)



High-quality scientific output and fallout!

LUNA @ Bellotti Ion Beam Facility



$^{14}\text{N}(p,\gamma)^{15}\text{O}$: bottleneck of the CNO cycle **DONE**

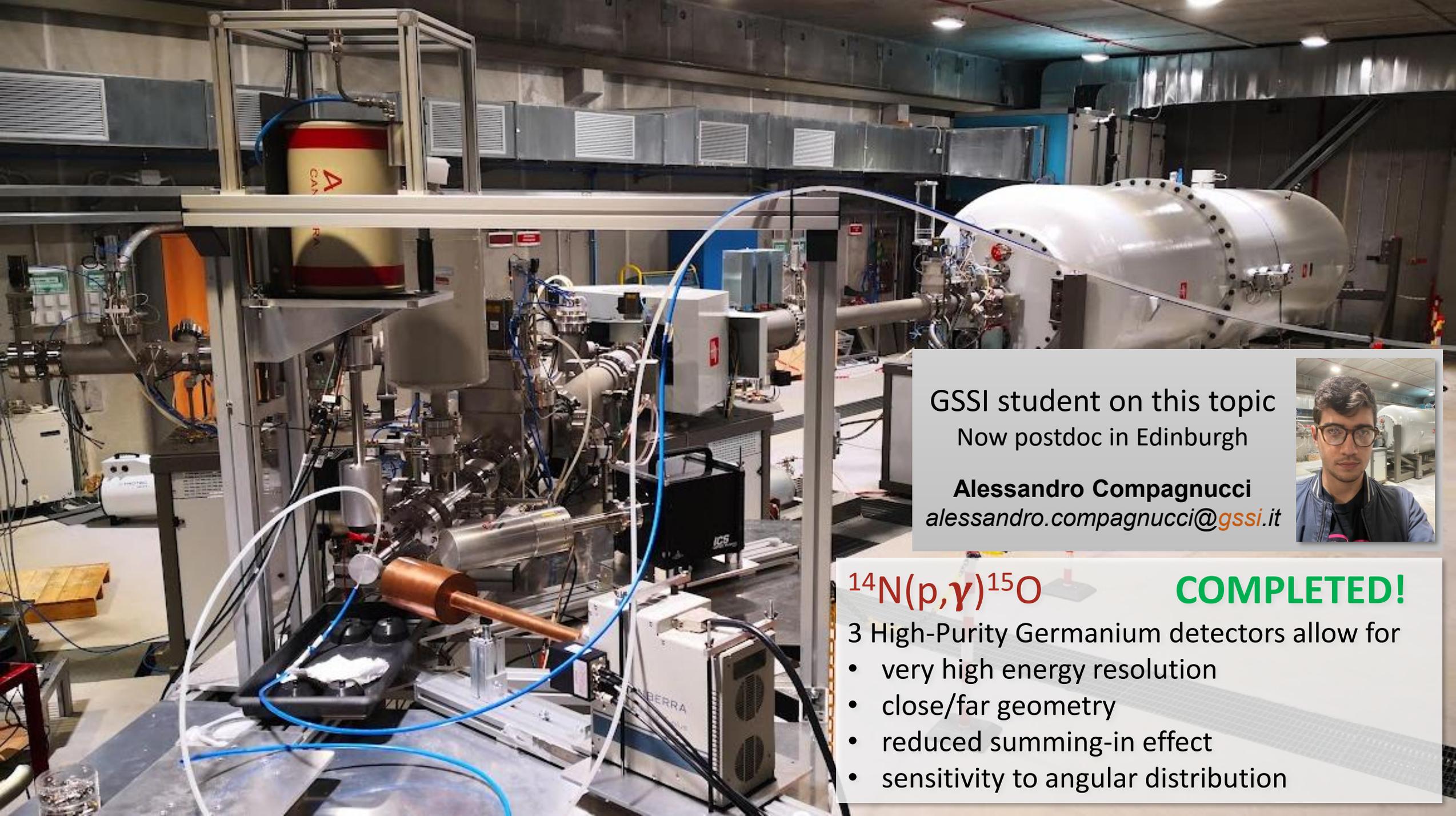
$^{22}\text{Ne}(\alpha,n)^{25}\text{Mg}$: neutron source for the s-process in AGB and massive stars

$^{22}\text{Ne}(\alpha,\gamma)^{26}\text{Mg}$: main competitor of the $^{22}\text{Ne}(\alpha,n)^{25}\text{Mg}$ in AGB and massive stars

$^{12}\text{C}+^{12}\text{C}$: trigger of C burning in the stars

Lots of activities going on at LNGS!





GSSI student on this topic
Now postdoc in Edinburgh

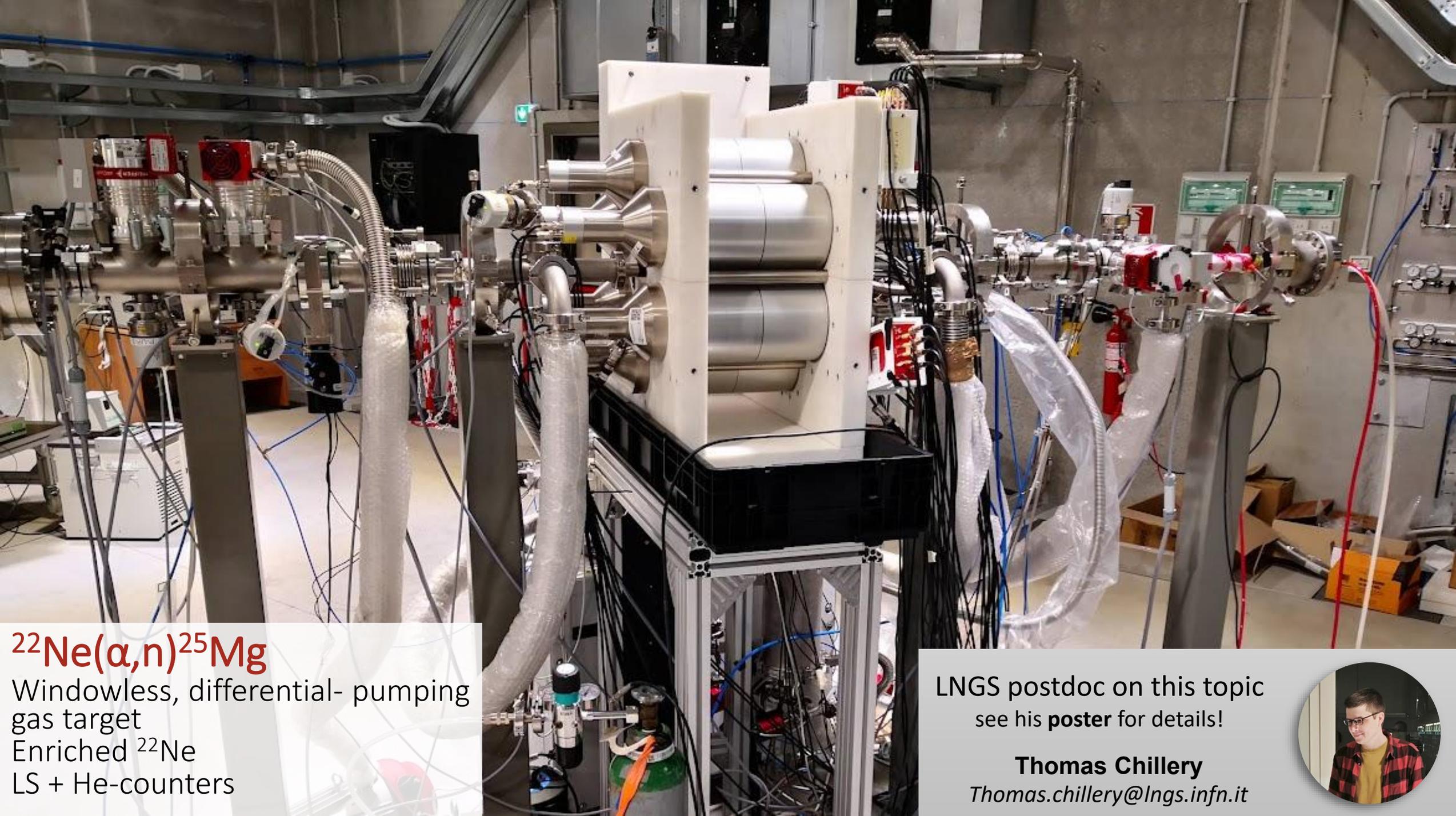
Alessandro Compagnucci
alessandro.compagnucci@gssi.it



COMPLETED!

3 High-Purity Germanium detectors allow for

- very high energy resolution
- close/far geometry
- reduced summing-in effect
- sensitivity to angular distribution



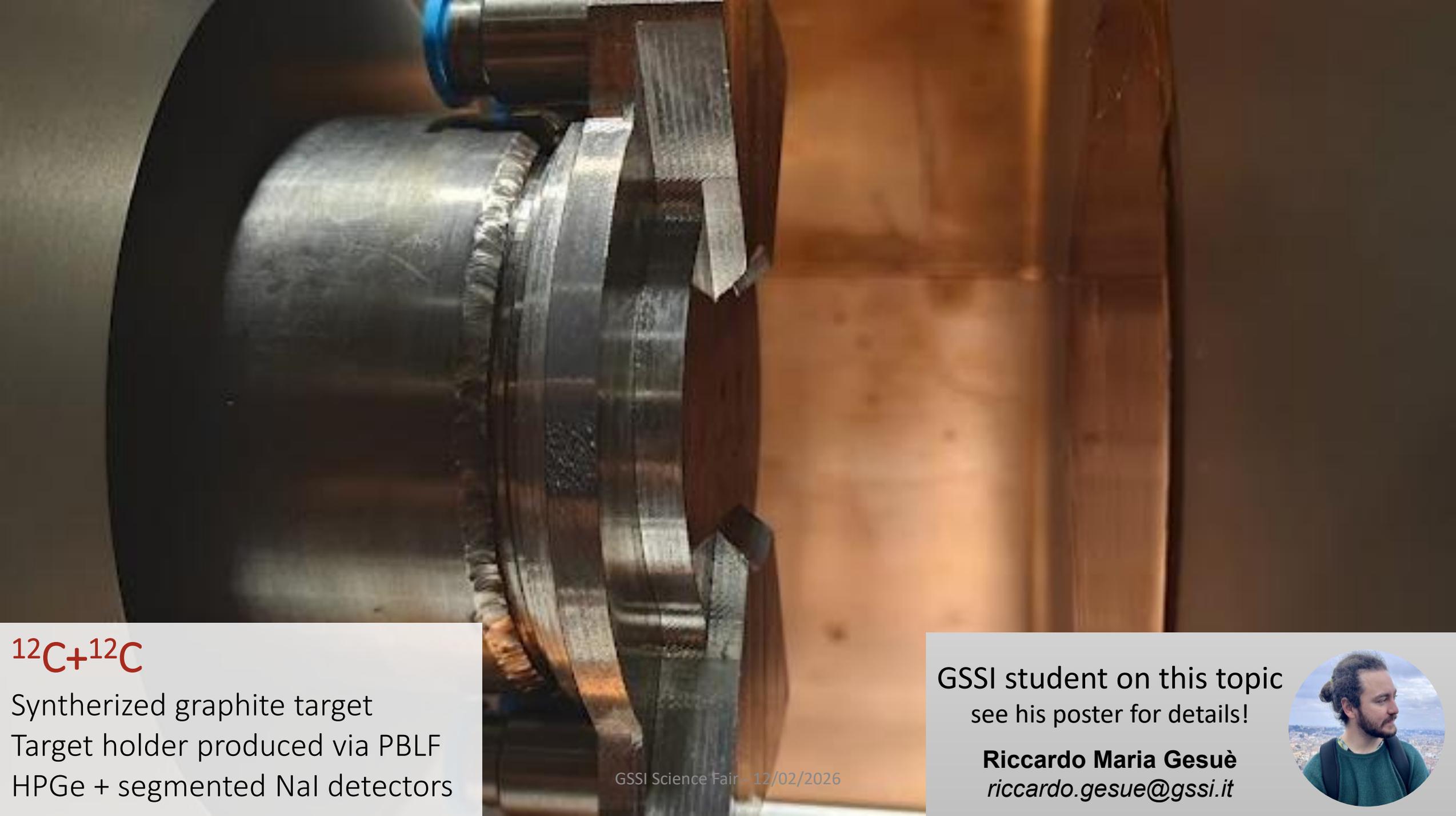
$^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$

Windowless, differential- pumping
gas target
Enriched ^{22}Ne
LS + He-counters

LNGS postdoc on this topic
see his **poster** for details!

Thomas Chillery
Thomas.chillery@lngs.infn.it





$^{12}\text{C}+^{12}\text{C}$

Synthesized graphite target

Target holder produced via PBLF
HPGe + segmented NaI detectors

GSSI Science Fair - 12/02/2026

GSSI student on this topic
see his poster for details!

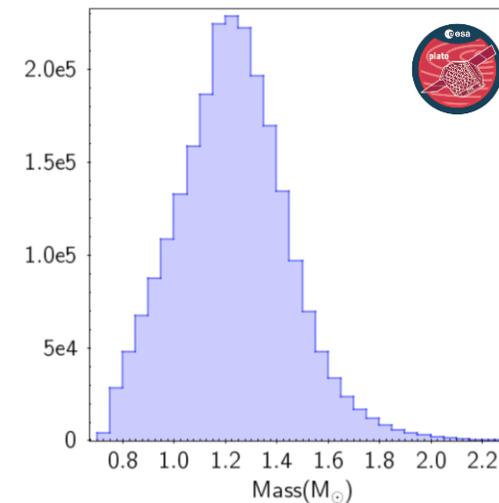
Riccardo Maria Gesuè
riccardo.gesue@gssi.it



erc LUNANOVA is going to start soon!



LUNANOVA is a European research initiative financed by an ERC Synergy grant (14 M€). Its goal is to study with unprecedented precision the reactions responsible for the production of **solar neutrinos** and better understand the **physics of the Sun** and stars of similar masses.



Neutrino origin	Uncertainty on measured flux	Uncertainty on predicted flux
pp	0.4%	0.6%
${}^7\text{Be}$	1.8%	7.7%
${}^8\text{B}$	1.9%	13%
${}^{13}\text{N}+{}^{15}\text{O}$	13%	17%

A new 600 kV single-ended electrostatic accelerator will be installed underground!

We will **suppress nuclear physics uncertainties** on the fluxes predicted by solar (stellar) models to break the degeneracy between nuclear and solar (stellar) physics

LUNA people on site

Interested? Come talk to us!



Matthias Junker



Poster

Riccardo Maria Gesu 



Poster

Thomas Chillery



Federico Ferraro

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Dipali Basak

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