Direct experimental determination for $^{22}Ne(\alpha,\gamma)^{26}Mg$ cross section for s-process

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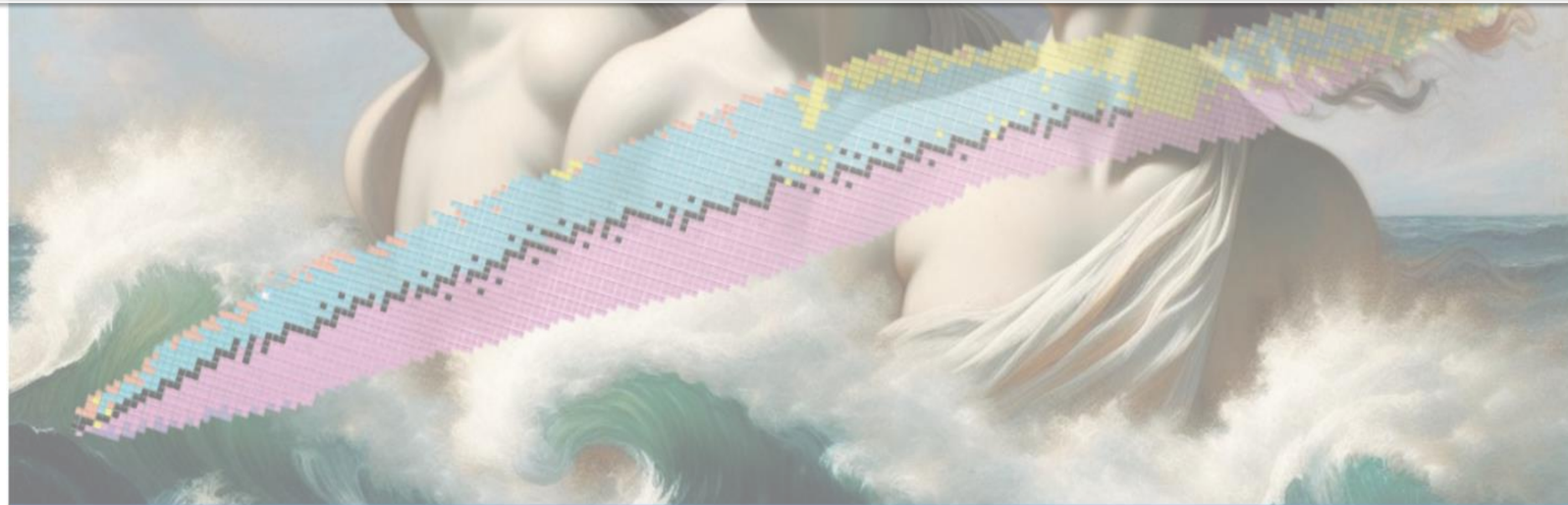
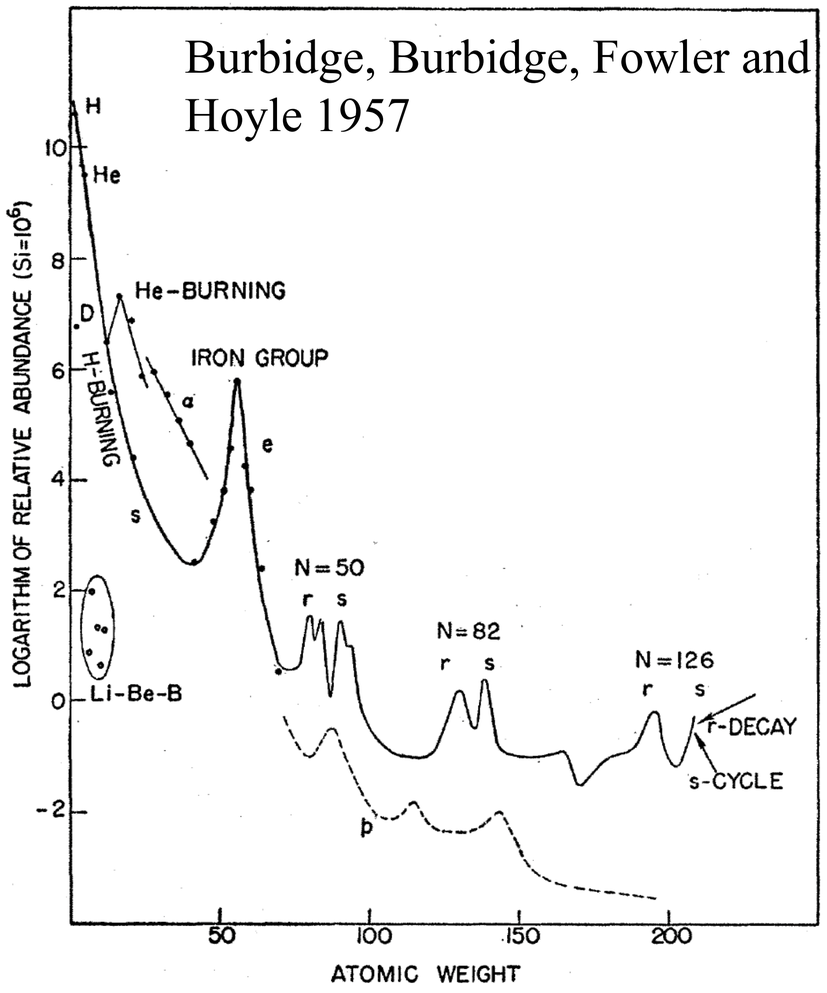


Astrophysical Motivation



$^{22}\mathrm{Ne} + \alpha$

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

Q= - 478.31 keV
(T>0.25 GK)

Massive stars

Weak
$s - process$
$60 \leq A \leq 90$

Asymptotic Giant Branch stars

Main
$s - process$
$60 \leq A$ up to Pb

$^{22}\mathrm{Ne}(\alpha, \gamma)^{26}\mathrm{Mg}$

Q=10614.7 keV

Main depletion ^{22}Ne channel

State of the art

$$N_A < \sigma v > = \left(\frac{8}{\pi\mu}\right)^{\frac{1}{2}} \frac{N_A}{(k_B T)^{3/2}} \int_0^{\infty} \boldsymbol{\sigma(E)} E e^{-E_r/k_B T} dE$$

Need to be known in the Gamow window

(E_α= 600 – 900 keV)

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- Low energy range
- Extremely low values of cross-section (~ pb)
- High level density in ^{26}Mg

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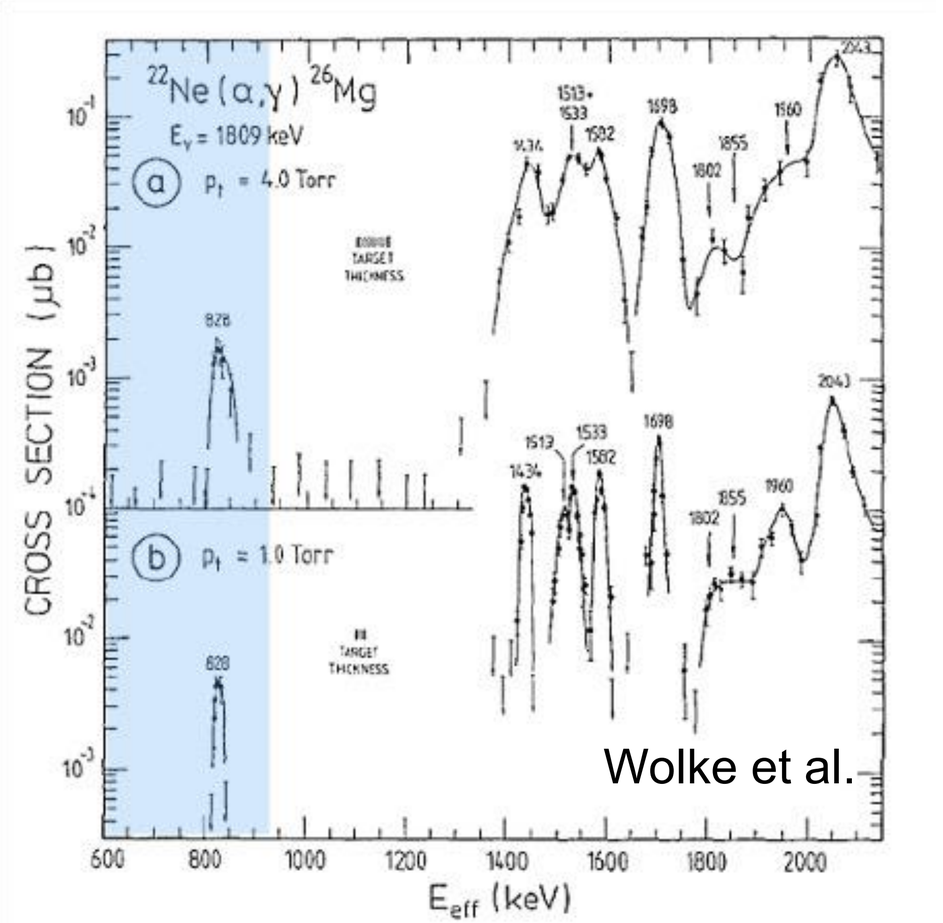
Do we have satisfying available data?



- No data from direct measurements except for the 830 keV resonance
- Discrepancies in indirect data
- Γ_α known only as UL

$^{22}\mathrm{Ne} + \alpha$

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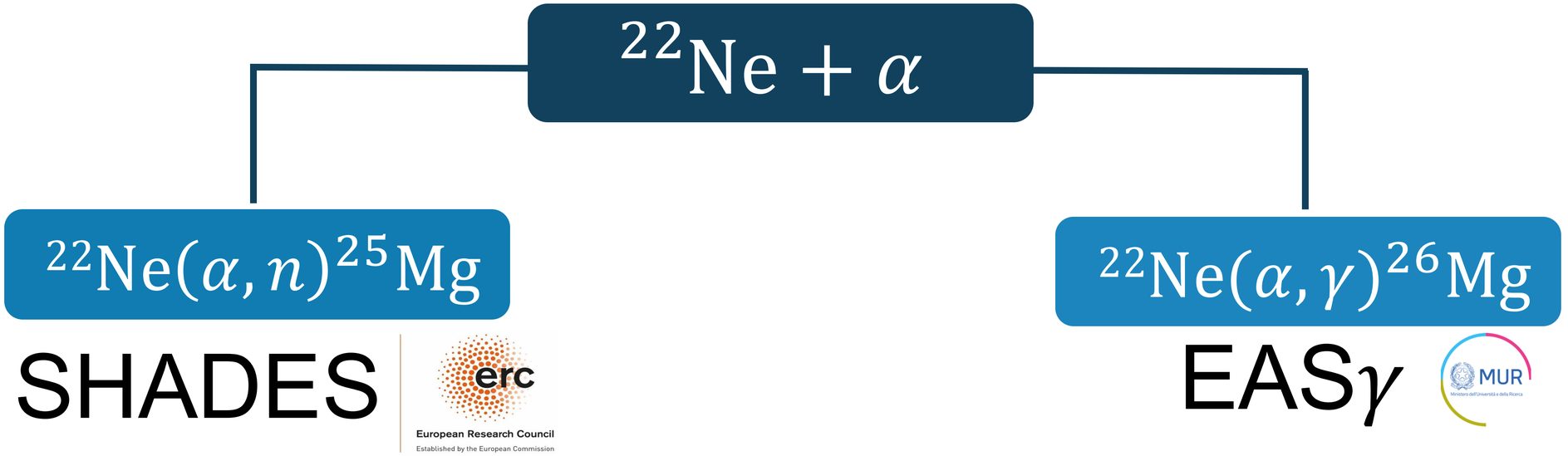
SHADES

$^{22}\mathrm{Ne}(\alpha, \gamma)^{26}\mathrm{Mg}$

EASγ



see A. Best's talk and D. Rapagnani's talk/poster for

- scientific rationale
  - preliminary results

T. Chillery poster for the

- experimental setup performance evaluation

$^{22}\mathrm{Ne} + \alpha$

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SHADES

European Research Council
Established by the European Commission

$^{22}\mathrm{Ne}(\alpha, \gamma)^{26}\mathrm{Mg}$

EASγ

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Scientific Goal

Experimental setup

Feasibility study results

Outlook

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Scientific Goal

Experimental study of $^{22}Ne(\alpha,\gamma)^{26}Mg$ in the energy range of astrophysical interest (600-900) keV

- Location deep-underground
- Beam induced background reduction
- High-efficiency NaI scintillator array

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

$^{7}Li(^{22}Ne,t)^{26}Mg$ in inverse kinematics at TRIUMF

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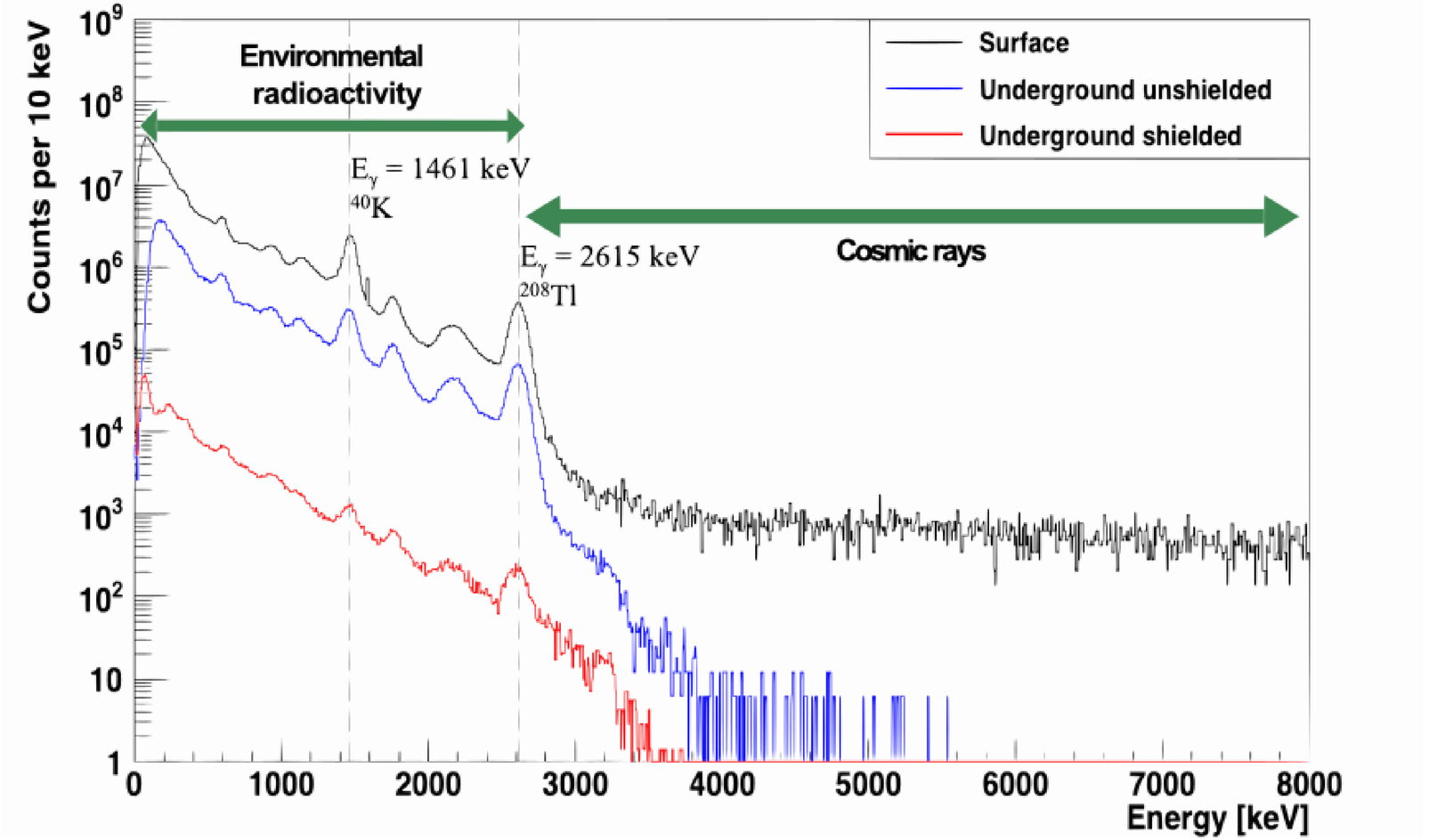
Deep-underground background measurement at the Bellotti IBF



Deep-underground the cosmic-rays background is completely suppressed above 2.6 MeV (blue line).
A suppression of 4 o.o.m is achieved below 2.6 MeV by surrounding the detectors with 15 cm of Pb shielding (red)

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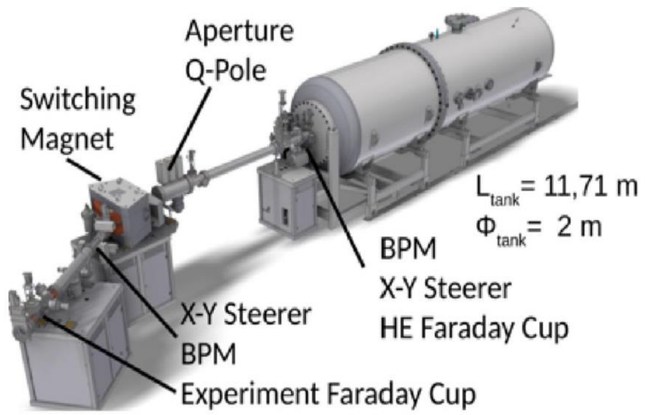
Experimental setup

➢ Accelerator

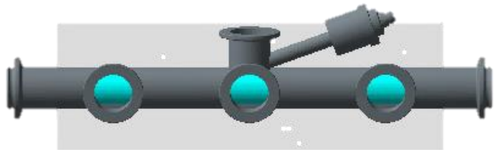
LUNA MV
$^4He^+$ beam
Up to 500 μA



https://userswww.pd.infn.it/~broggini/WhitePaper/main.pdf.

➢ Windowless recirculating gas target

99% enriched ^{22}Ne
$N_t = 10^{17}$ atoms/cm^3
length 22 cm, ∅ 2.2 cm



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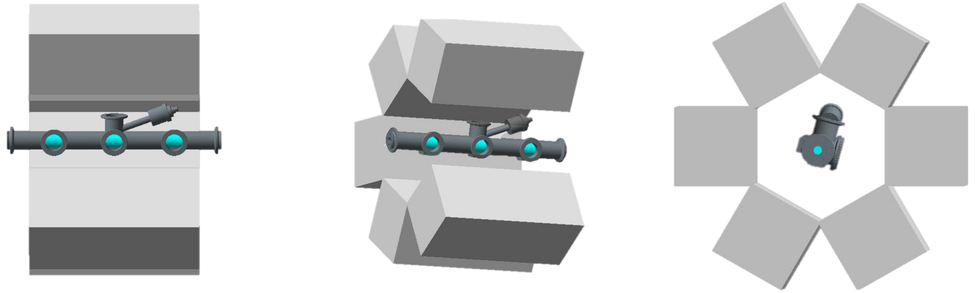
➢ Gamma-ray detection setup



η_{FEP} = 11% @ E_γ = 4 MeV

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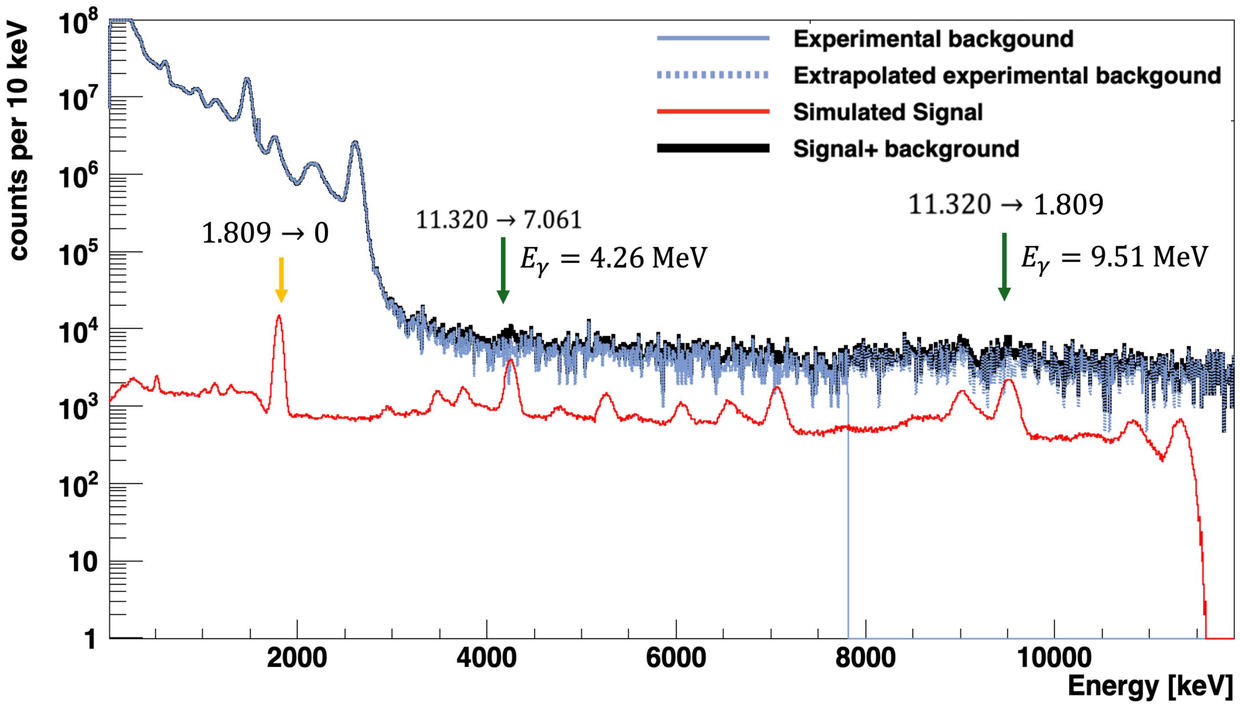
Simulation results

De-excitation from Ex=11.320 MeV (E_{res} = 832 keV)



Array response simulated on surface

EASγ
Simulation results

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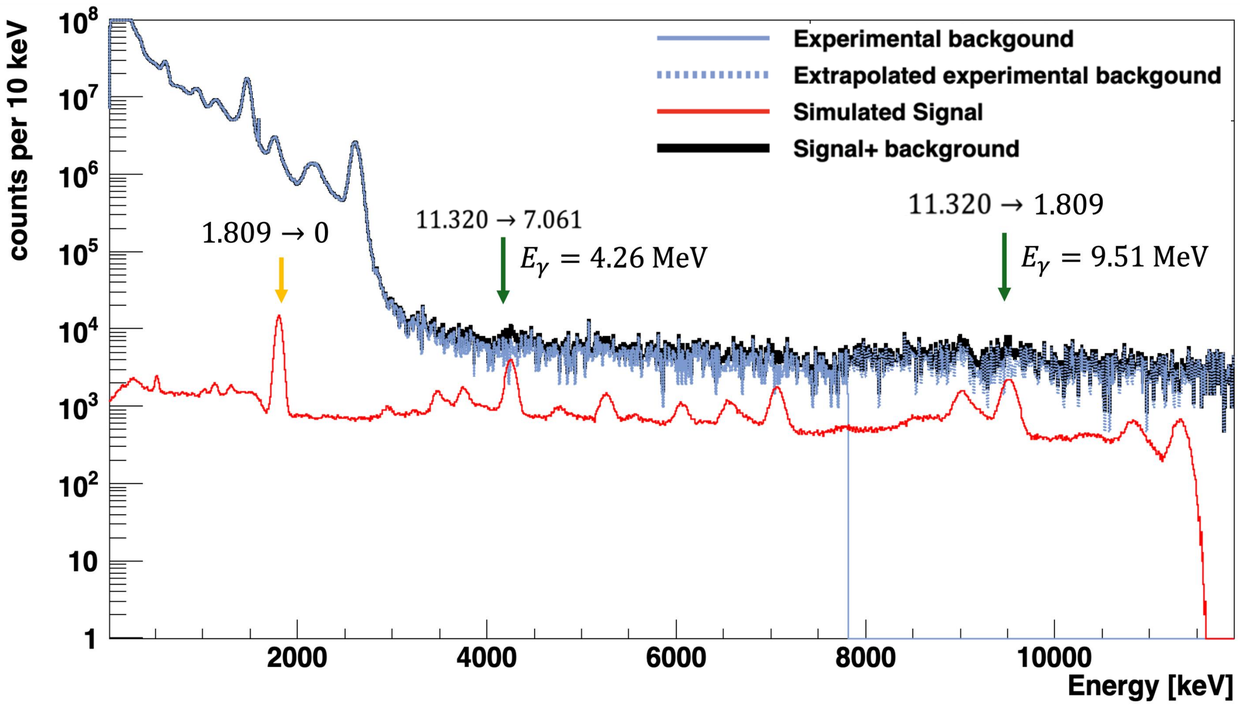

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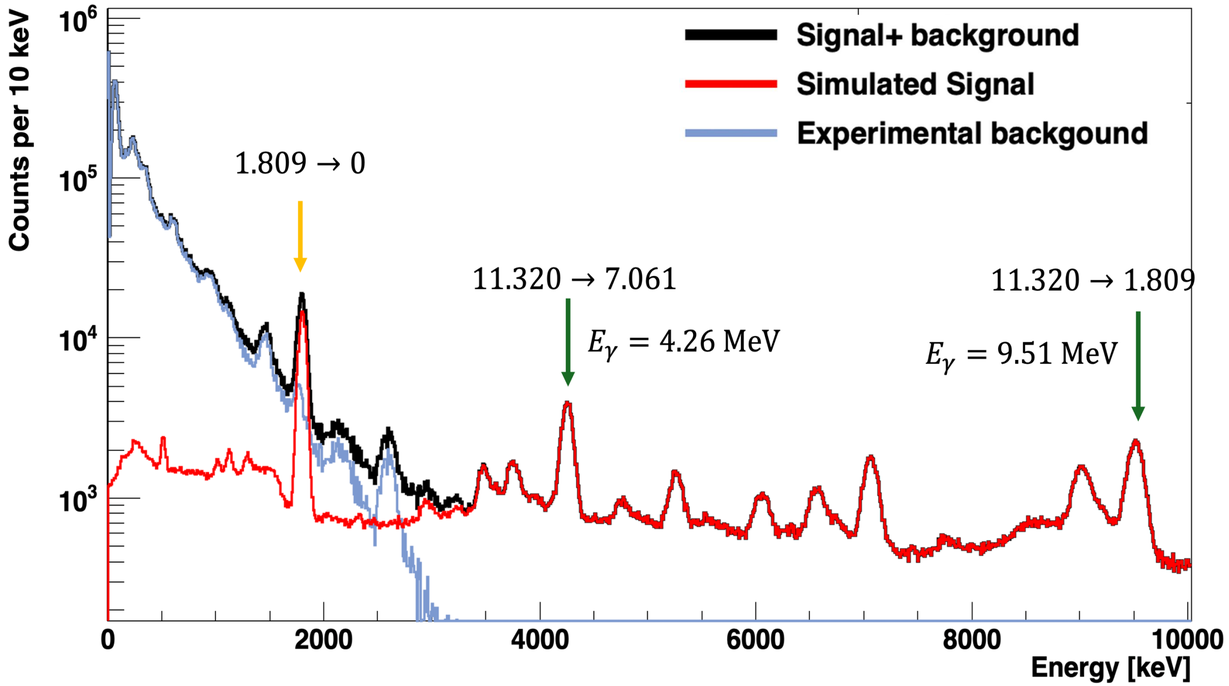

Array response simulated at Bellotti IBF and with 15 cm thick of lead shielding

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Simulation results

De-excitation from Ex=11.171 MeV (E_{res} = 651 keV)

- Large γ partial width
- Only accessible via indirect measurements

Giensen et al.	**Not observed**
Talwar et al.	**observed**
Texas A&M low energy	**Not observed**
Texas A&M high energy	**observed**

$\mathrm{Yield}_{11171}(\mathrm{UL}) = 3.01 \cdot 10^{-21}$ counts/s

$\mathrm{I} = 500\ \mu\mathrm{A.} \quad \rightarrow \quad \mathrm{N}\gamma \text{ in } 40 \text{ days} : 33$

EASγ
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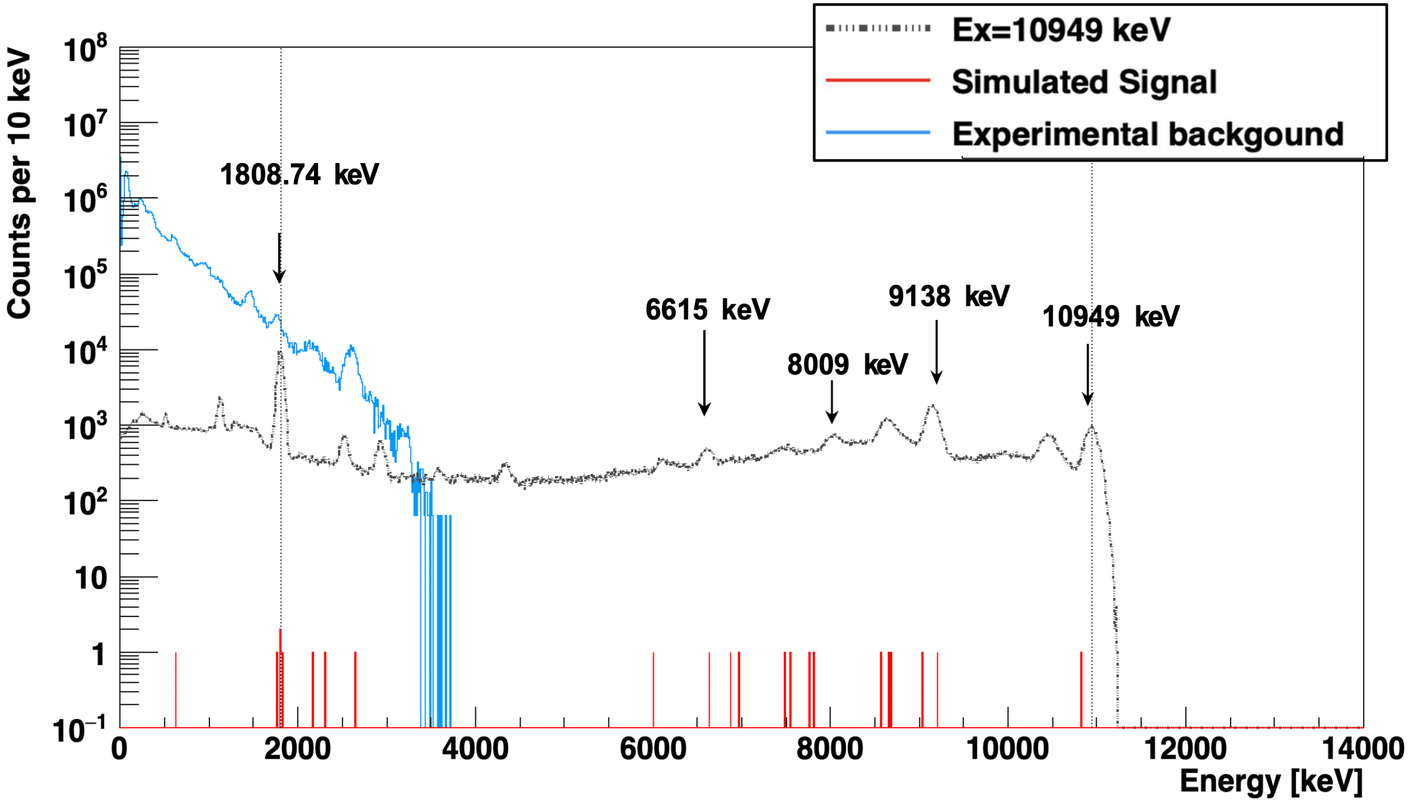

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Current status and outlook

- ☑ Gas target characterization
- ❑ Study of the beam induced background
- ❑ Design for the active/passive shielding
- ❑ Characterization of the NaI detector array

Direct measurement at the Bellotti Ion Beam Facility
scheduled for the beginning of 2026

Conclusions

- Low energy investigations strongly hampered by cosmic-ray background → lack of data except for the 835 keV resonance

- EASγ takes the advantages of low cosmic-ray background (INFN-LNGS) to improve sensitivity. Simulations to quantify this enhancement, other variables as beam induced background need to be considered though.

- Simulation for the de-excitation of 11.32 MeV state (835 keV resonance) shows clear detection of primary and secondary transitions, thanks to underground setup and lead shielding.

- An elusive state had been simulated (Ex=11.17 MeV) and if confirmed as an α-cluster state, it would significantly affect nucleosynthesis and stellar models.
  For the first time, the signal can be directly studied with EASγ.

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Thank you for the attention!