New Measurement of the $^{27}Al(p,\alpha)^{24}Mg$ and $^{27}Al(p,\gamma)^{28}Si$ reaction cross section at LUNA

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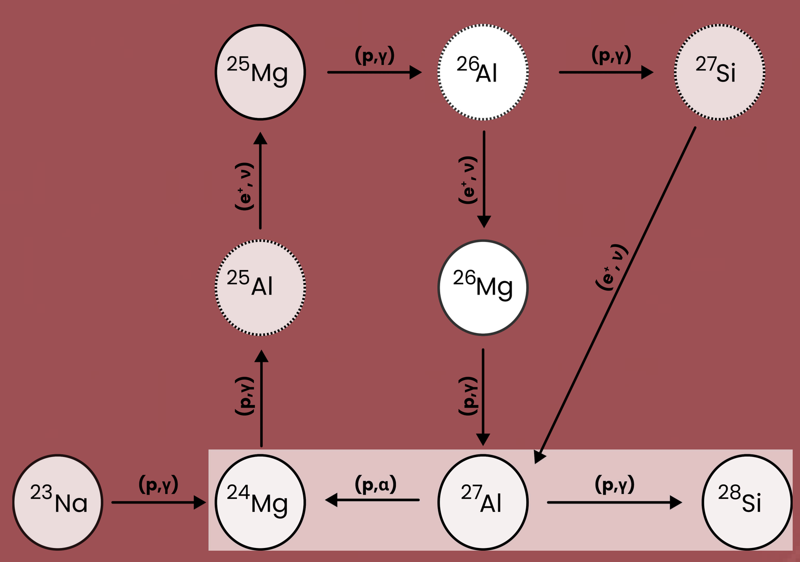
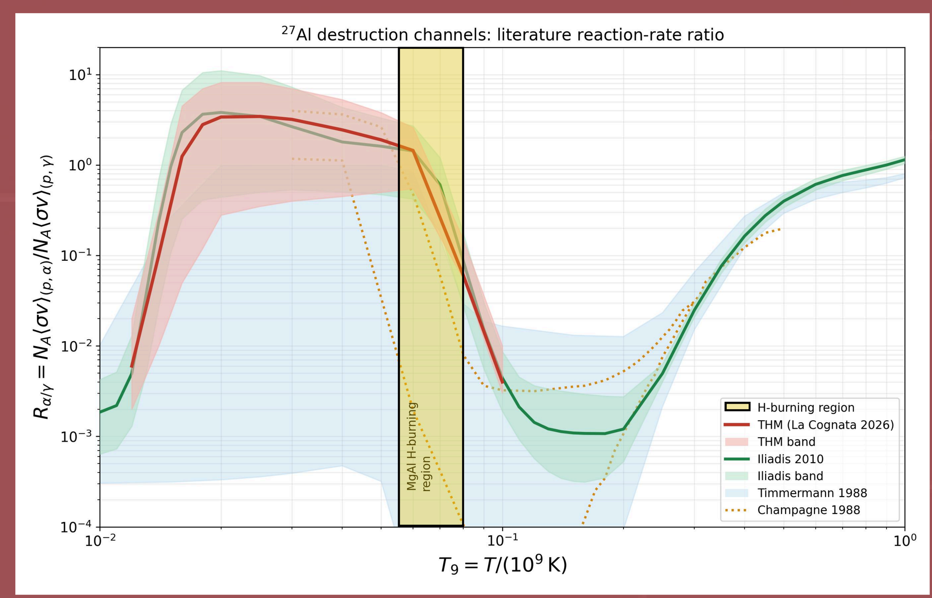
Astrophysical Motivation

^{27}Al is a branching point of the MgAl cycle. During stellar H-burning, ^{27}Al is destroyed through two competing channels: (p,α) and (p,γ)[1]. Their competition affects Mg and Al abundances, the interpretation of the Mg–Al anticorrelation observed in globular clusters[2] and ^{26}Al nucleosynthesis. The reaction rate ratio determines the closure of the Mg-Al cycle and the nucleosynthesis pathway to Si and P isotopes.



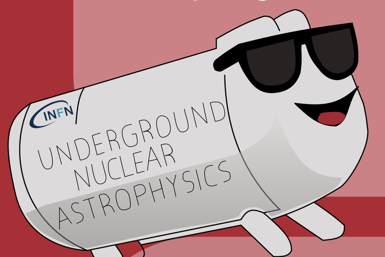
State of the Art

Low-energy resonances can dominate the stellar reaction rates, but their strengths are still poorly constrained [4]. Direct $^{27}Al(p,\gamma)^{28}Si$ resonance-strength measurements reach down to E_p~200 keV [3], whereas previous direct $^{27}Al(p,\alpha)^{24}Mg$ searches mainly provided upper limits [5]. Direct measurements of the lowest accessible resonances are therefore crucial to reduce the reaction-rate uncertainties.

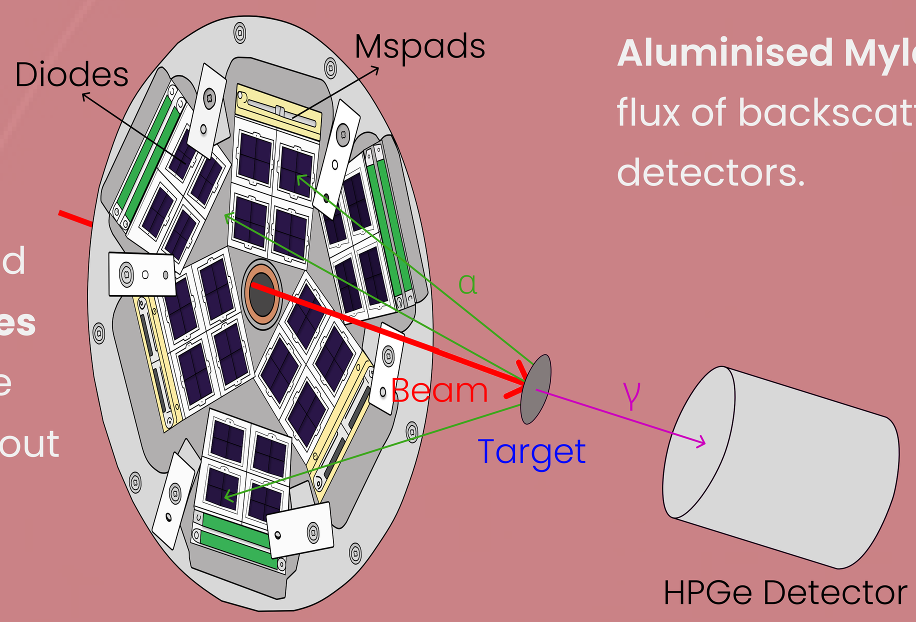


Experimental Setup

The experiment is performed at the **LUNA 400 kV** accelerator at INFN LNGS, where the underground location strongly suppresses the cosmic-ray background. A high-intensity proton beam (100–300μA) impinges on a water-cooled 27Al target.

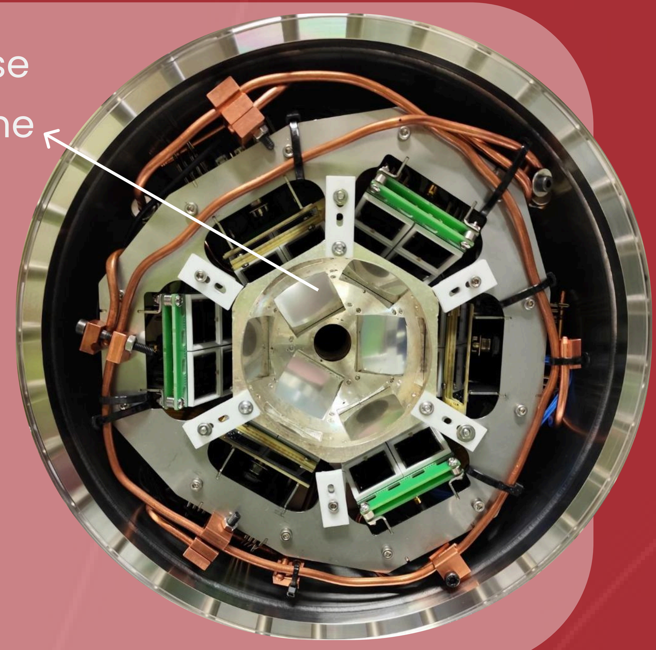


α-particles are detected at backward angles by a compact **Si array** composed of **24 Hamamatsu PIN diodes** and **3 MSPAD detectors**. The detectors are located at about 60 mm from the target.



Aluminised Mylar foils prevent the intense flux of backscattered protons reaching the detectors.

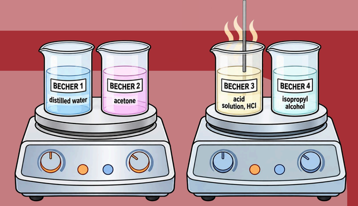
Gamma rays are detected by the **GeBochum HPGe detector**, positioned along the beam axis in close geometry.



Target Requirements

- **High stability** under intense proton irradiation;
- **Well-controlled thickness and reproducibility**, using targets with different thicknesses to assess systematic effects.
- High **chemical purity**, with particular attention to B contamination, which can generate a severe $^{11}B(p,3\alpha)$ background in the charged-particle spectra.
- **Different target compositions and production techniques** to investigate potential systematic effects;

Backings & Cleaning



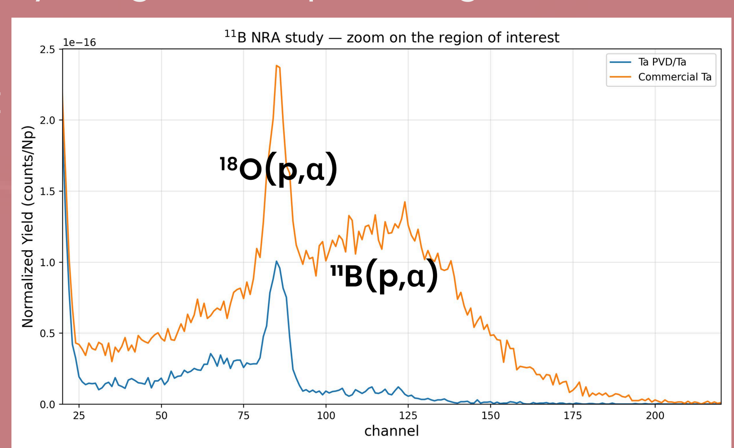
Ta PVD/ Ta backings

Commercial Ta substrates coated with a thin high-purity Ta layer by **Physical Vapor Deposition (PVD) - INFN LNL**

Methodology

1. **substrates cleaning**[6]
   - acetone + IPA → acid etching @ 80°C → DI-water rinse
2. **PVD surface treatment:** High-purity Ta deposited on the substrates by magnetron sputtering

→ minimize B, F and light element contaminants.



Same cleaning procedure, different backing surface:
Commercial Ta: 4.5×10¹³ ^{11}B atoms/cm² (~13 at. ppm)
Ta PVD/Ta: 8.2×10¹² ^{11}B atoms/cm² (~2 at. ppm)

Target Candidates & First target Tests Results

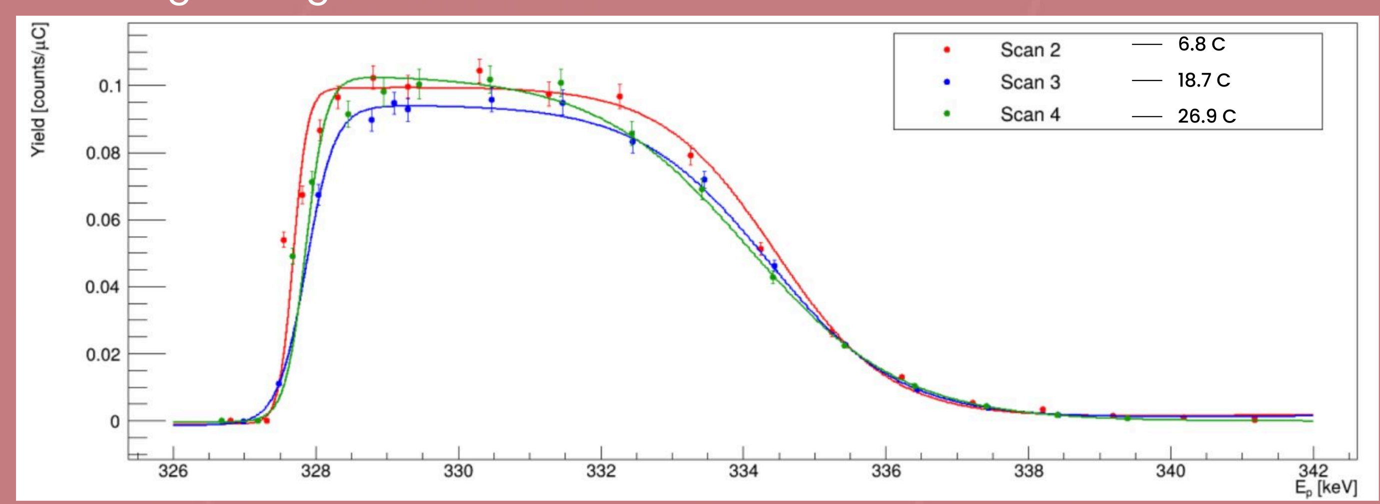
- **Thermally evaporated Al/Ta targets — ATOMKI**
- **Commercial high-purity Al disks**
- **Magnetron-sputtered Al/Ta targets — INFN LNL**

Potentially improved control of thickness, uniformity and reproducibility.

Evaporated ^{27}Al targets produced at ATOMKI were tested through **resonance scans** after each long run in order to monitor changes in target thickness and resonance position.

ATOMKI targets show stable yields under prolonged irradiation (up to 27 C).

Thicker target: longer irradiation lifetime.

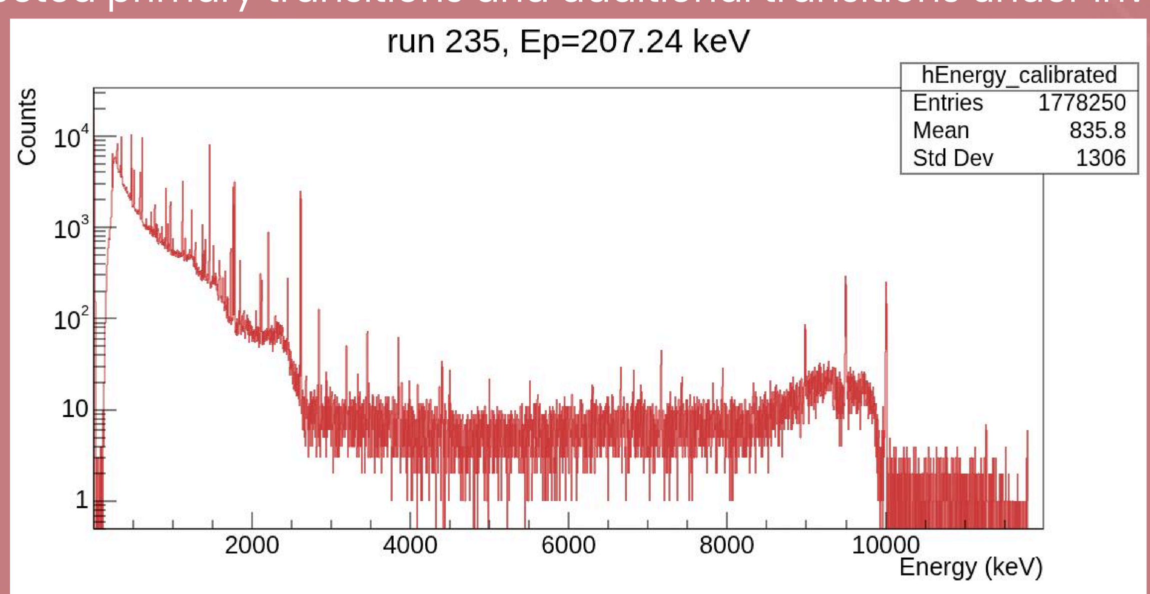


First Results - Sensitivity tests

long runs were performed on top of all four resonances at E_p≈207, 227, 296, 329 keV.

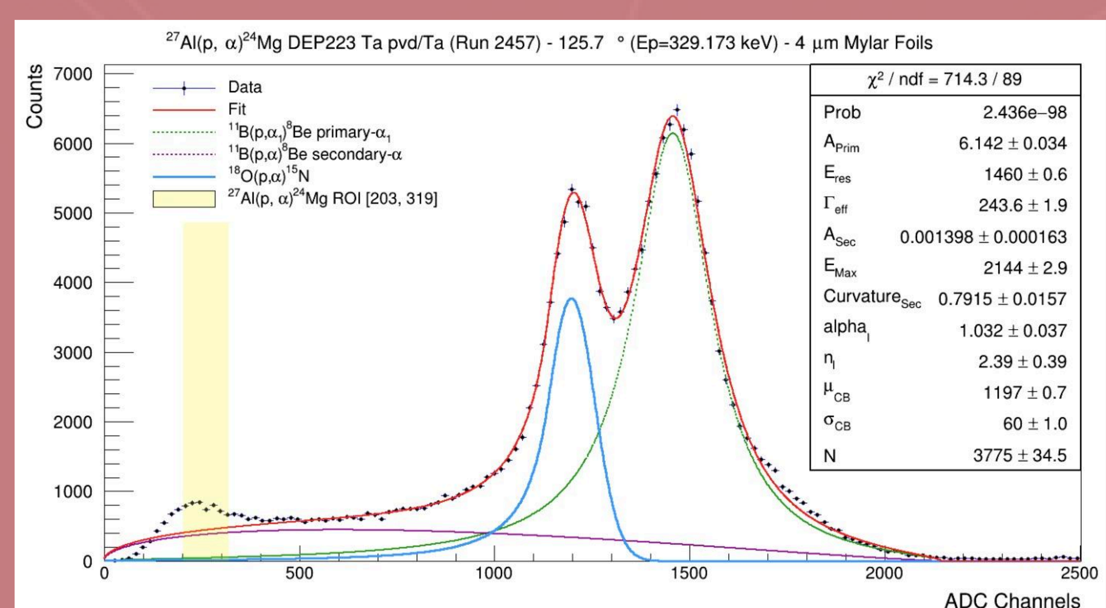
$^{27}Al(p,\gamma)^{28}Si$

Clear $^{27}Al(p,\gamma)^{28}Si$ signals were observed for all investigated resonances, including the expected primary transitions and additional transitions under investigation.



$^{27}Al(p,\alpha)^{24}Mg$

Preliminary long runs showed no clear evidence of the $^{27}Al(p,\alpha)^{24}Mg$ signal. The present sensitivity is limited by the low-energy background, in particular by ^{11}B contamination, detector noise and energy loss in the Mylar foils.



Improved electronics and thinner Mylar foils will be used to increase the (p,α) sensitivity

References:
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