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The SHADES Project: Underground Measurement of the Low Energy ^{22}Ne(α,n)^{25}Mg Cross Section

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For the LUNA Collaboration

1. Motivation

- **Massive stars** (M > 8Mʘ) and Asymptotic Giant Branch (**AGB**) stars synthesise neutron-rich isotopes [1,2] across A ~ 60 – 90 and 90 – 209, respectively.
- Path proceeds via slow neutron-capture process (***s*-process**), where reactions **^{22}Ne(α,n)^{25}Mg** and ^{13}C(α,n)^{16}O are the dominant neutron sources.
- ^{22}Ne(α,n)^{25}Mg reaction rate is **weakly constrained at astrophysical temperatures** 100 – 300 MK.

2. Goals

(E_{thresh} = 561 keV)

- Measure ^{22}Ne(α,n)^{25}Mg across $\boldsymbol{E_\alpha}$ **= 600 – 886 keV** (E_{cm} = 507 – 750 keV)
- Remeasure E_α = 832 keV resonance, search for E_α = 635 keV resonance

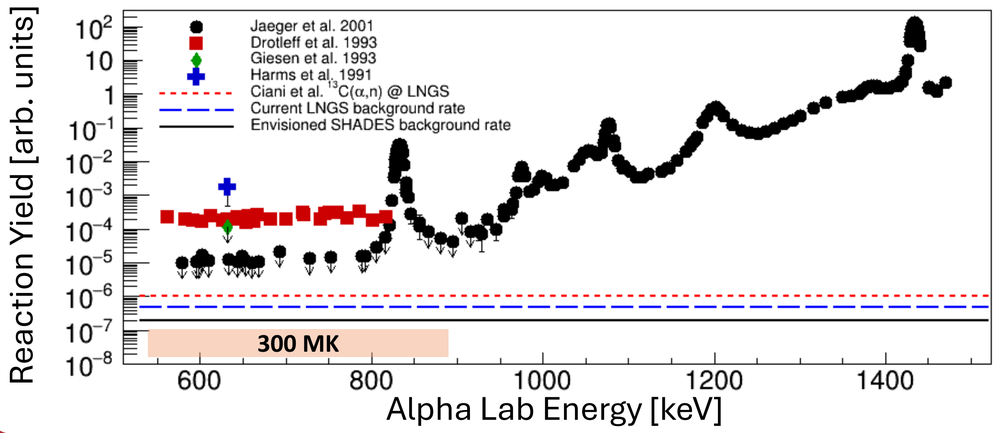


Fig 1. State-of-art of ^{22}Ne(α,n)^{25}Mg cross-section data. Data points from [3-6]. Black line shows envisioned sensitivity at SHADES + Belotti Facility.

3. Experimental Setup

- INFN – Laboratori Nazionali del Gran Sasso
  - **Ultra-low** background rates
- Accelerator: **Belotti Ion Beam Facility** [7], 3.5 MV
- Beam: **^{4}He^{1+}**, I ~ 300 – 500 eμA
- Target: **Enriched ^{22}Ne gas** ~ 2 mbar, 20 cm, 10^{18} atom/cm^2
- DAQ: COMPASS & Caen V1725SB/D digitisers 250 MSample/s

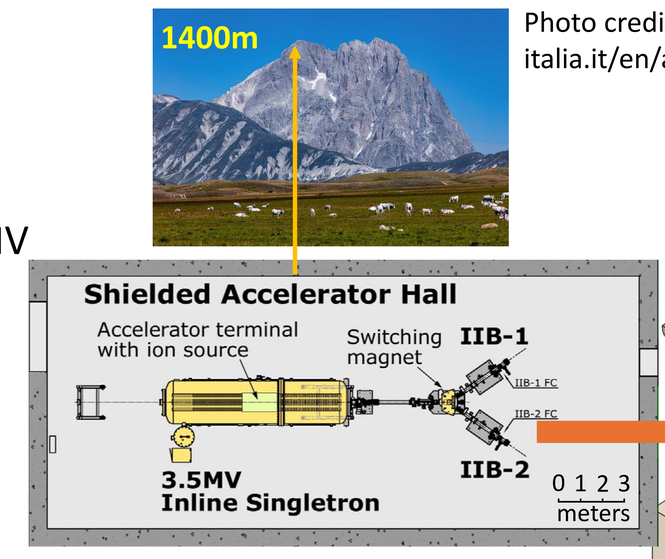


Photo credit: italia.it/en/abruzzo/

- Detector array: **SHADES** [8]
  - **S**cintillator-^{3}**H**e **A**rray for **D**eep-underground **E**xperiments on the ***S***-process
  - 12x EJ-309 liquid scintillators -> **neutron/gamma separation & n-moderation**
  - 18x ^{3}He proportional counters -> **reaction yield**
  - Borated polyethylene shielding

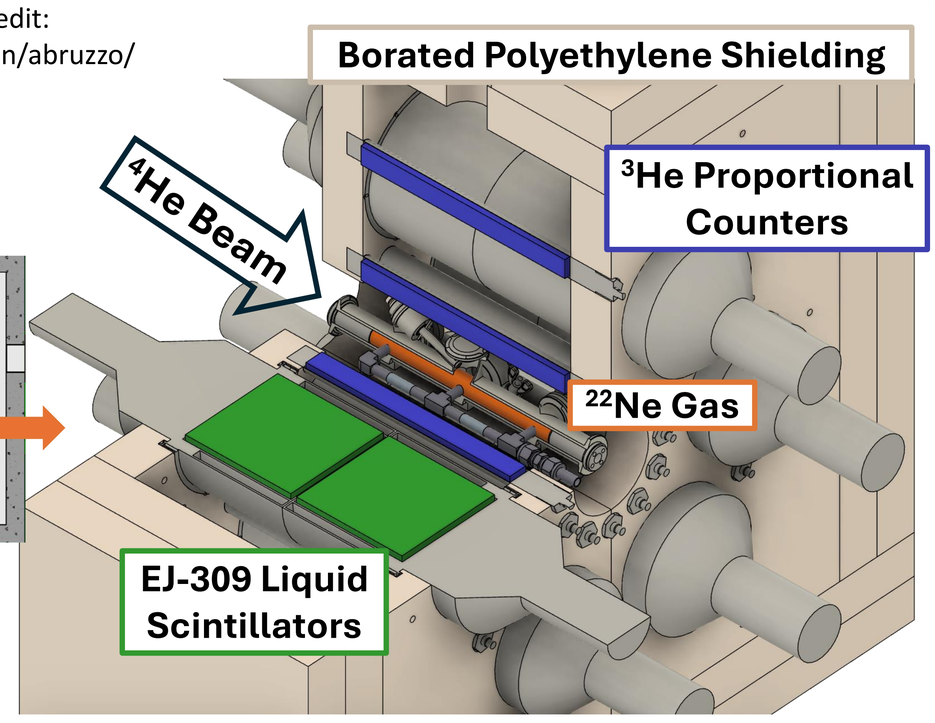
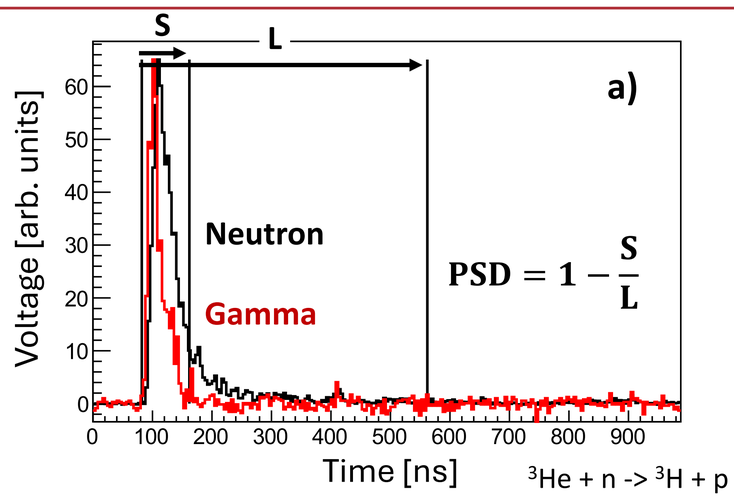
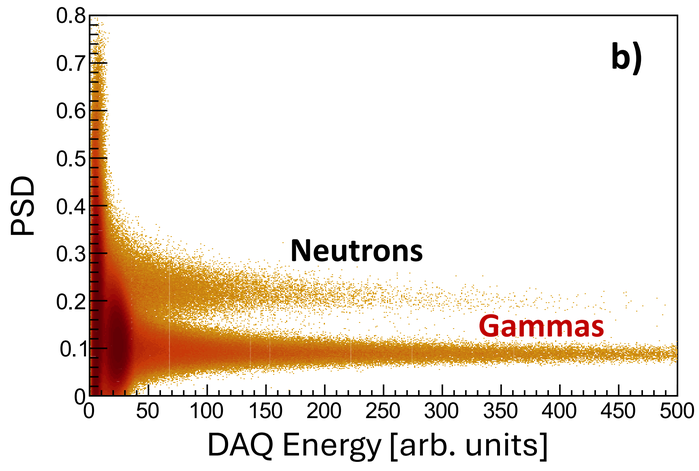


Fig 2. Computer-assisted drawing of SHADES detector array

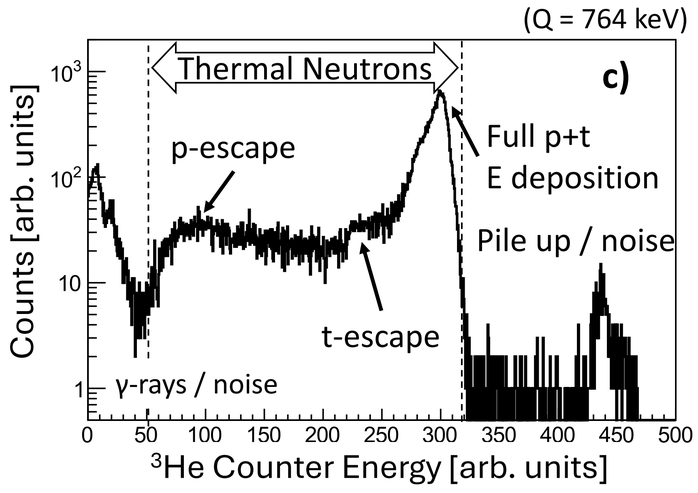
4. Preliminary Data Analysis

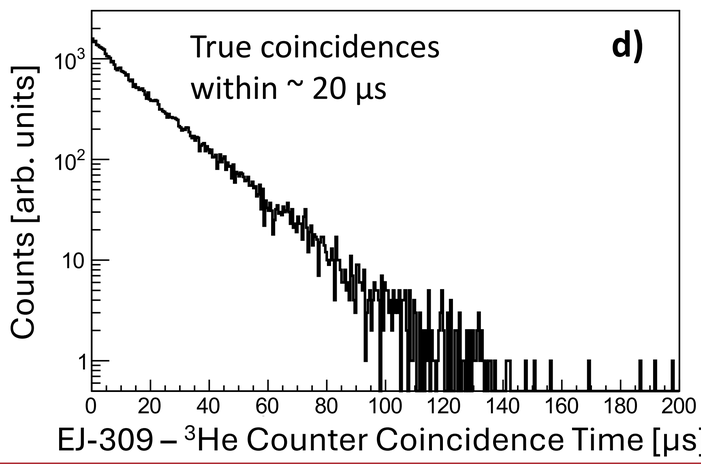
- **Calibration data**: AmBe neutron source
  - a) **Typical waveforms** after baseline subtraction
  - b) **Scintillator PSD** vs energy
  - c) **Energy spectrum** from ^{3}He counters
  - d) **Coincidence timing** between Scintillators and ^{3}He counters





^{3}He + n -> ^{3}H + p
(Q = 764 keV)





- March 2024: **First beam test** using ^{nat}Ne gas
- Encountered beam-induced background (BIB) from ^{13}C(α,n)^{16}O and ^{17}O(α,n)^{20}Ne **(preliminary)**
- Improvements made include **additional PE shielding** and covering beamline elements with Tantalum, Copper, and Gold

5. Future Work

- Autumn 2024: Additional beam tests to ensure low BIB
- Winter 2024: **^{22}Ne(α,n)^{25}Mg reaction cross-section measurements** with enriched ^{22}Ne gas
- Paper in progress: EJ-309 – ^{3}He counter prototype measurements of ^{7}Li(p,n)^{7}Be at Frankfurt.

6. References

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