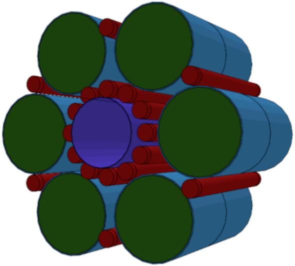
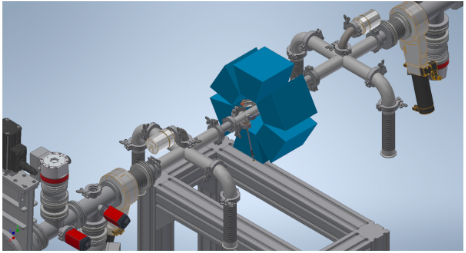
Measurement of the ^{22}Ne+α reactions at LUNA MV
ECT* - Trento - KRINA





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Ancient history

THERMAL PULSES; *p*-CAPTURE, α-CAPTURE, *s*-PROCESS NUCLEOSYNTHESIS; AND CONVECTIVE MIXING IN A STAR OF INTERMEDIATE MASS*

ICKO IBEN, JR.
University of Illinois, Champaign-Urbana
Received 1974 June 17; revised 1974 September 16

NEON-22 AS A NEUTRON SOURCE, LIGHT ELEMENTS AS MODULATORS, AND *s*-PROCESS NUCLEOSYNTHESIS IN A THERMALLY PULSING STAR*

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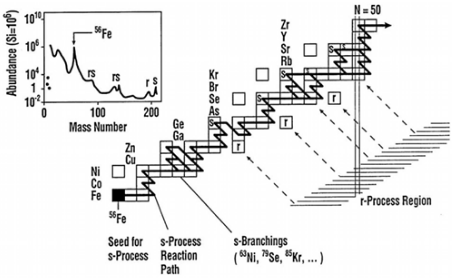
University of Illinois, Champaign–Urbana
Received 1974 August 21

"A very warm thanks to the referee of the first version of this paper for insisting that: not only can ^{22}Ne not act as a significant source of neutrons but, even if it does, both it and its progeny will use up all of the emitted neutrons, leaving none for the production of heavier s-process elements."

^{22}Ne$(\alpha,[n,\gamma])^{25,26}$Mg physics case: production of the heavy elements, and more



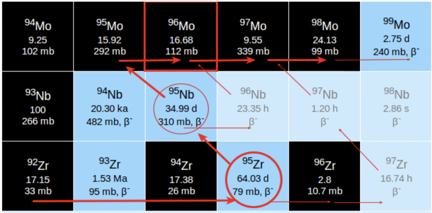
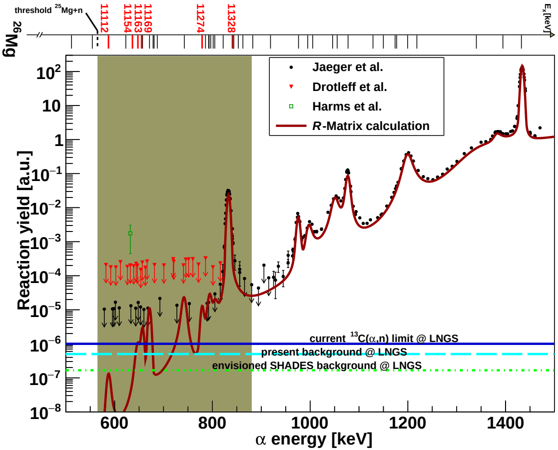


Figure 10. The same as Fig. 8, but for the *s*-path region close to the *s*-only isotope ^{96}Mo (red rectangle). While ^{93}Zr is practically stable on the time-scale of the *s*-process, ^{95}Zr acts as the main branching point.

- Main source for weak s process
- Effect on branch points in main s
- Formation of early solar system - cosmic grains in meteorites
- Mg isotope observations in stellar atmospheres
- We need both n and γ channels
- S. Cristallo's talk

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



R matrix courtesy of R. J. deBoer, University of Notre Dame/JINA

- Capabilities on surface exhausted (20 years since last direct data)
- Current lowest rate 2 reactions/minute
- Covers one resonance close to Gamow
- 300 keV of upper limits. . .
- Many states that can contribute
- Need improvement by more than 2 orders of magnitude

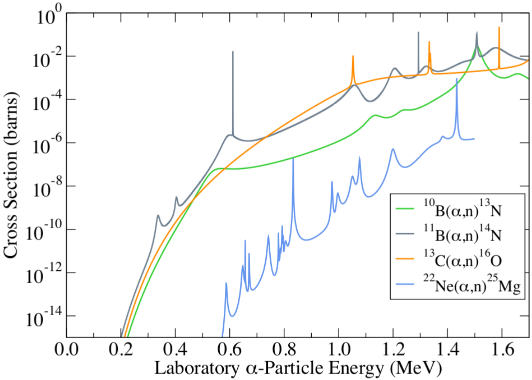
Low-energy states

Table 1. Properties of states in ^{26}Mg between the neutron threshold and the 832 keV resonance. Values taken from [15], except for the last row, which is from [14].

E_n [keV]	E_x [keV]	E_α [keV]	Jπ	Neutron width [eV]
19.92	11112	589	2+	2095
72.82	11163	649	2+	5310
79.23	11169	656	3-	1940
187.95	11274	779	2+	410
194.01	11280	786	3-	1810
243.98	11328	843 ?	?	171
235 [14]	11319	832	2+	Total width = 250 eV

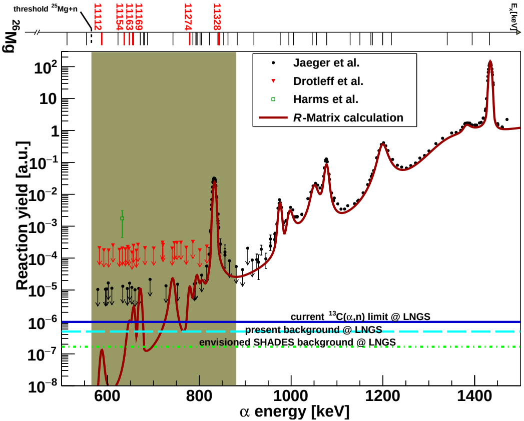
- nTOF study of energies and neutron widths (Massimi et al. PLB 768 (2017), 1)
- 832 keV state still a bit unclear w.r.t. n/α channel, energy
- No α widths are known
- Many indirect studies, but discrepancies (Adsley, Talwar, Ota etc)

Beam-induced backgrounds



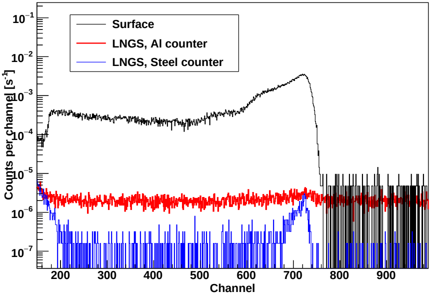
- Q-values:
  - ^{22}Ne = - 478 keV
  - ^{10}B = 1059 keV
  - ^{11}B = 158 keV
  - ^{13}C = 2216 keV

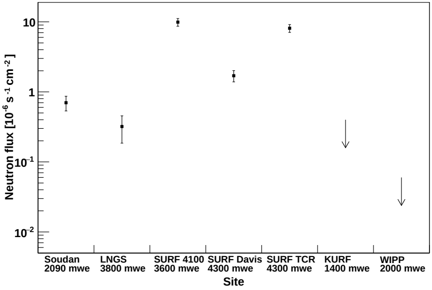
What to do?



- Drastic background reduction
- Large beam current increase
- Suppression/identification of beam-induced background

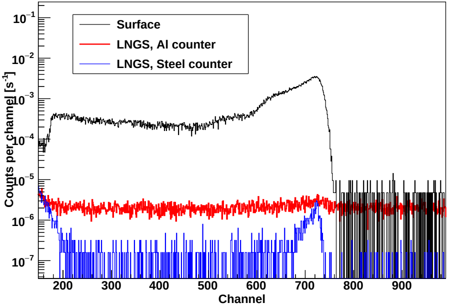
Advantages of going underground

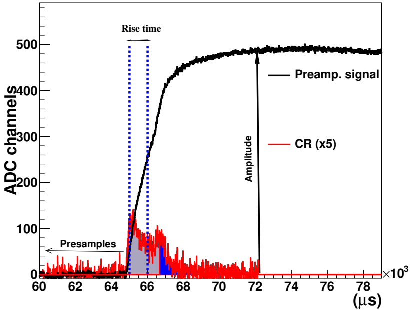




- Direct low-energy measurements limited by natural background
- LNGS $\approx$ 3400 m.w.e. underneath Gran Sasso mountain chain
- Cosmic-ray induced neutrons efficiently shielded against
- Residual flux from (α, n) and fission in rocks
- Neutron flux underground suppressed by ≈ 1000 w.r.t. surface

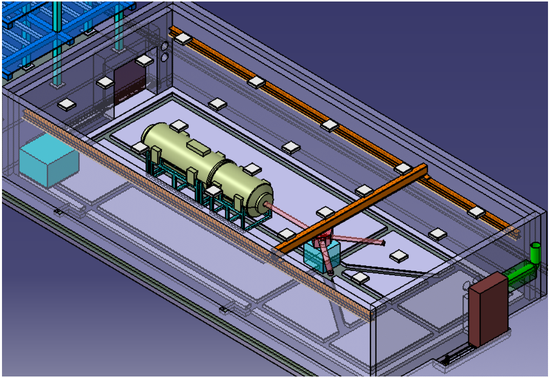
Background reduction





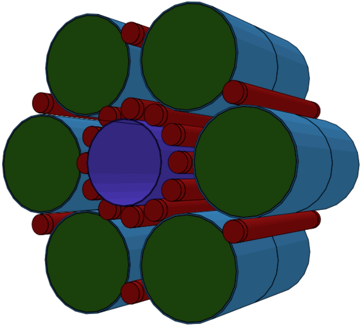
- Deep underground @ LNGS: Suppression of (thermal) neutron background by > 1000
- Additional clean detector material & PSD
- Extended gas target with enriched ^{22}Ne
- Coincidence/Anticoincidence
- Total background < 1 count/hour

Top-of-the-line accelerator

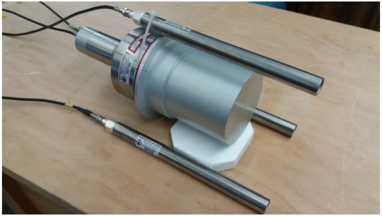


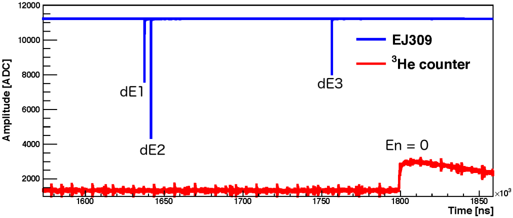
- Specifically designed to fit nuclear astrophysics needs
- Reaction rates of $< 1/\text{hour}$:
  - Beam current ($\approx 5\times$ Jaeger et al.): push signal-noise ratio
  - Current stability: measurements of the order of weeks
  - Energy stability: must not drift over long periods
- 350 - 3500 kV: cover entire astrophysical energy range
- Installed underground, in final acceptance phase

SHADES - detector array

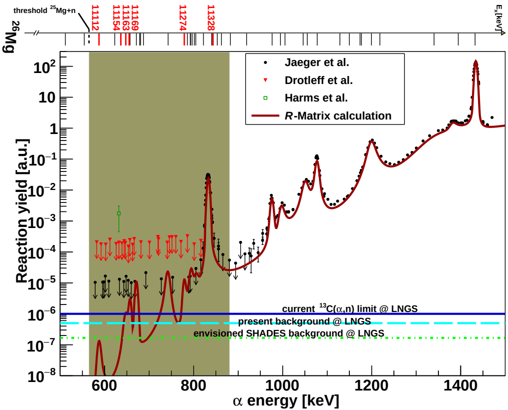


- Need to measure very low event rates
- Require some sort of energy sensitivity
- Hybrid detector array: ^{3}He counters & liquid scintillator
- High efficiency + energy sensitive
- Prototype built & tested



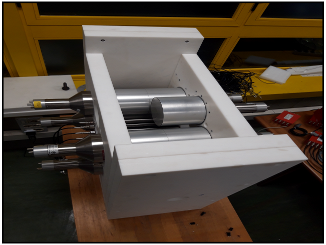


Goals



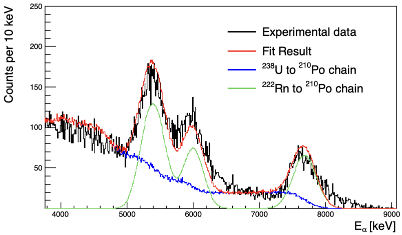
- Cover from threshold to 3.5 MeV
- $>$ two orders of magnitude improvement
- Comprehensive R matrix analysis
- Perform nucleosynthesis calculations with new data

Status I

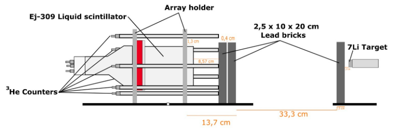


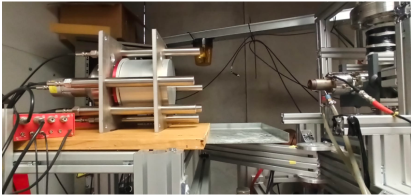
- 5(+1)-year, since February 2020
- Target+detector assembled
- Target characterisation at CIRCE started
- DAQ development underway
- Assembly at LNGS 2023
- Underground campaign at LUNA MV
- Data evaluation and astrophysical impact - collaboration with M. Pignatari/Budapest

Status II



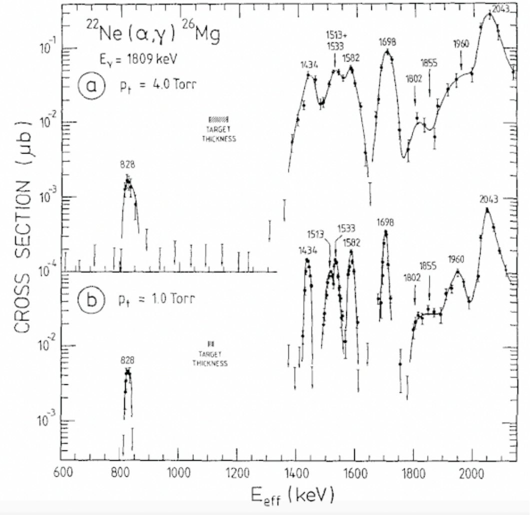
- Detector background investigated - publication drafted





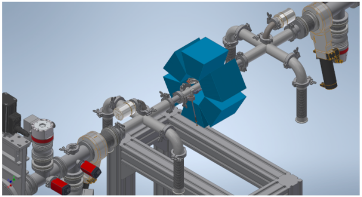
- Detector characterisation at FRANZ - under analysis

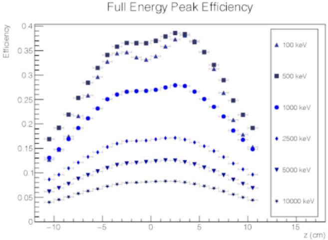
$^{22}Ne(\alpha,\gamma)^{26}Mg$ cross section



- Direct data Wolke et al. 1989 (!)
- Some remeaseurements of 830 keV res (TUNL)
- CASPAR + LUNA few new upper limits
- Vast terra incognita to explore

EASγ
Experimental and Astrophysical Study of $^{22}Ne(\alpha,\gamma)^{26}Mg$





- MUR project started 1. December 2022 - 4 years
- Synergize with ERC setup
- Small modifications to target
- High-efficiency γ-detection array
- Shielding under investigation
- Map out cross section of (α, γ) channel
- O. Straniero + astro postdoc for stellar analysis

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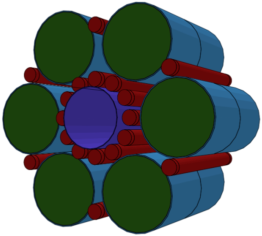
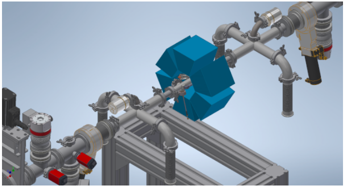
Summary + Outlook





- Steady influx of indirect data - some cross sections would be nice
- Push direct cross section towards Gamow energy with SHADES and EASγ
- Installation in 2023, data taking 2023-2024 (n channel)
- Wait for exciting (?) first news in 2025

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