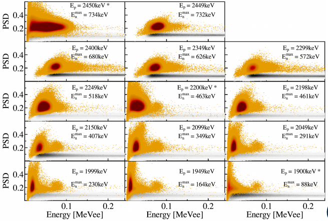
Neutron response characterisation of the SHADES detector array
Chetech-INFRA TNA meeting, Dresden, DE

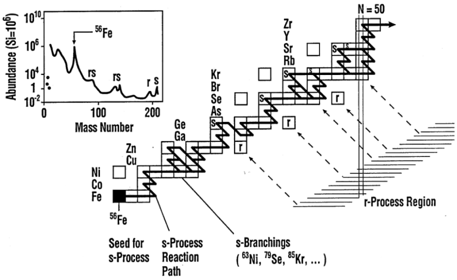


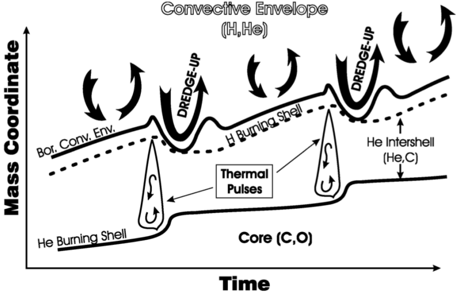
Andreas Best

INFN Naples
University of Naples “Federico II”

European Research Council
Established by the European Commission

s process

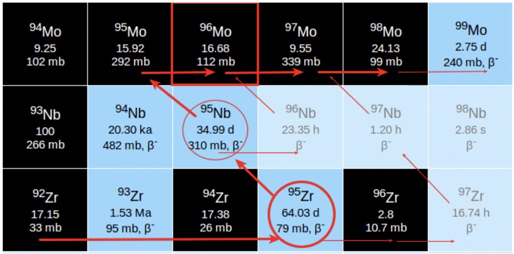


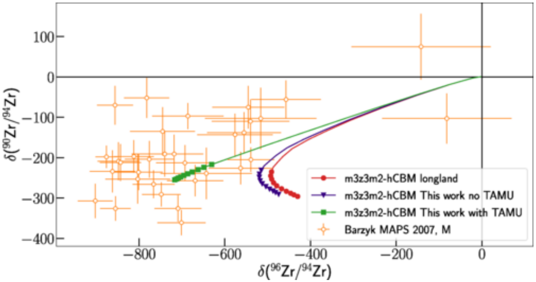


Kaeppeler et al. 2011 Straniero et al. 2006

- $\lambda_{(n,\gamma)} \ll \lambda_{\beta^-}$: nucleosynthesis follows valley of stability
- *Main s*: ^{13}C pocket in thermally pulsing AGB stars ^{13}C(α, n)^{16}O
- ^{13}C(α, n)^{16}O: T $\approx$ 90 MK, energy range 140 - 230 keV
- $^{22}Ne(\alpha, n)^{25}Mg$ late stages of main s process
- Strong, short neutron burst, T $\approx$ 250 MK: branch points
- $^{22}Ne(\alpha, n)^{25}Mg$ main source for *weak s* in massive stars: $60 < A < 90$

$^{22}\text{Ne}(\alpha, [n, \gamma])^{25,26}\text{Mg}$

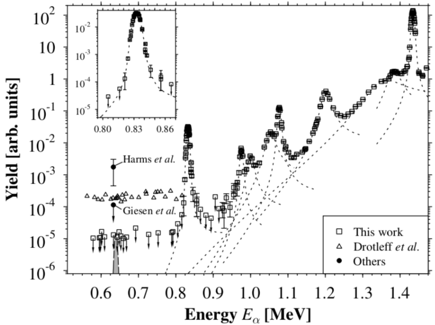




Adsley et al. PRC 103, 015805

- Determines branch point population
- Both channels important, both channels highly uncertain
- $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$: Q = - 478 keV, high level density, many possible resonances
- Reaction yield counts/hour or less - very difficult to measure
- Indirect infomation helps but does not provide full picture

State of the Art

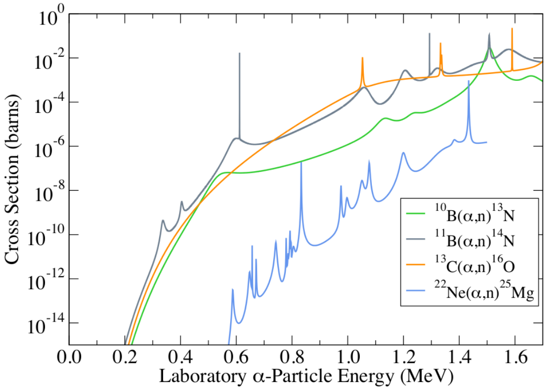


- (α, n): Jaeger et al. 2001
- Some remeasurements at $E_\alpha = 835$ keV since then (Hunt et al. 2019, Shahina et al. x2 (2022/24))
- Low energy region blocked by too high natural background on Earth's surface
- Additionally, beam induced backgrounds can be major problem

Recent progress

- Bunch of nuclear transfer/scattering experiments
- Comprehensive synthesis in Longland et al. 2012
- Measurements Adsley et al., Talwar et al. Jaytissa et al.. . . .
- Situation summarized in Adsley et al. 103, 015805 (2021)
- Updated in Wiescher et al. EPJ A (2023) 59:11
- Updated again + outlook in Best et al. EPJ A (2025) 61:99

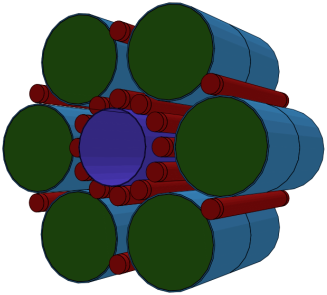
So these beam-induced backgrounds?

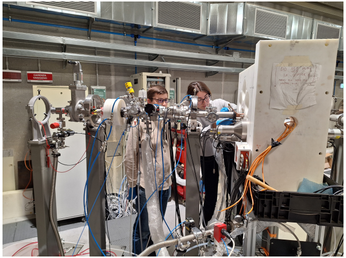


- Q-values:
  - ^{22}Ne = - 478 keV
  - ^{10}B = 1059 keV
  - ^{11}B = 158 keV
  - ^{13}C = 2216 keV

At least 600 keV gap - any kind of energy ID helps

SHADES ERC project





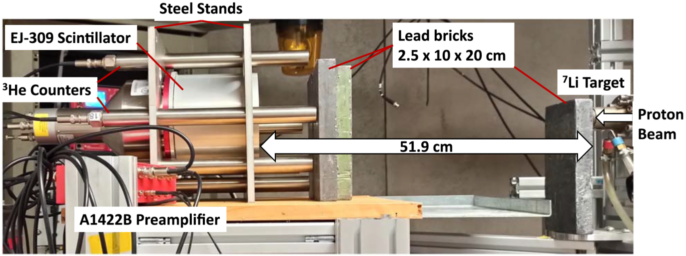
- 18 ^{3}He counters & 12 EJ-309 liquid scintillators
- Some kind of E sensitivity for BIB identification
- Gas target (recirculating) for long, uninterrupted runs
- New MV accelerator at the deep underground LNGS Bellotti Ion Beam Facility

European Research Council
Established by the European Commission

Motivation and goal of INFRA application

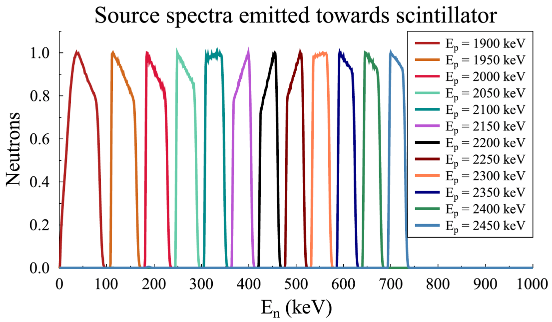
- Low energy quenching calibration
- Low energy neutron light yield threshold
- Coincidence timing between ^{3}He and EJ-309
- EJ-309 PSD performance at low energies
- FRANZ (Goethe-Uni Frankfurt) can provide tuneable low E neutron beam

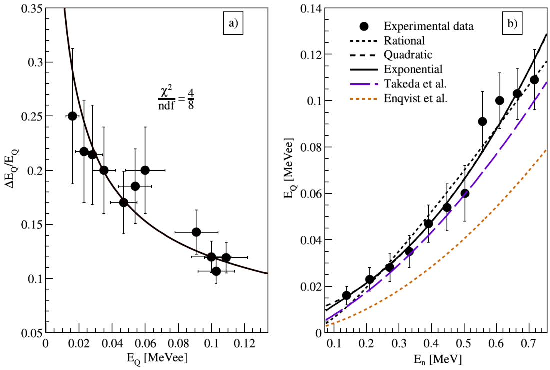
Experiment



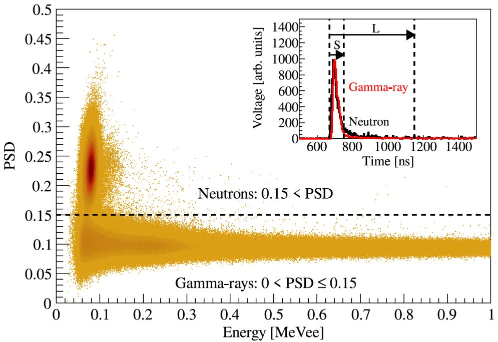
- FRANZ: KN van-de-Graaf + ^{7}Li target = ^{7}Li(p,n)
- proton beams between 1900 keV and 2450 keV, 50 keV steps
- Prototype array: 1 scintillator, 6 ^{3}He counters
- Digital DAQ for timing and pulses

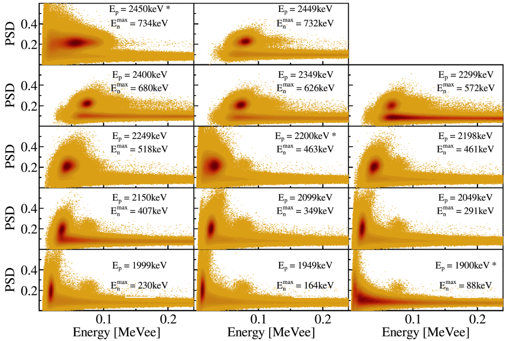
Light yield - E calibration





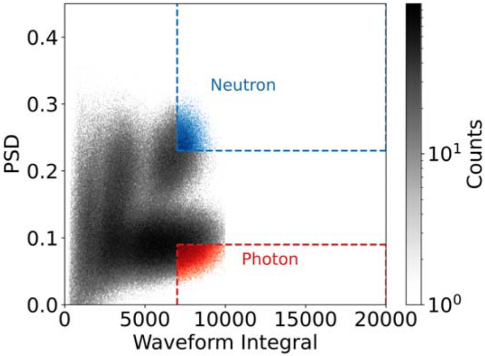
PSD - traditional

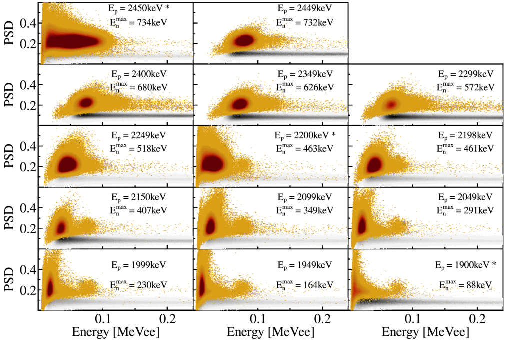




- Traditional "long v short" integral method works until ca. 460 keV (60 keVee)
- Small boron contamination responsible for locus at 80 keVee

PSD - ML





- GMVAE ML, semi-supervised trained on part of traditionally tagged pulses
- Works down to ca. 160 keV neutron energy

Coincidence timing

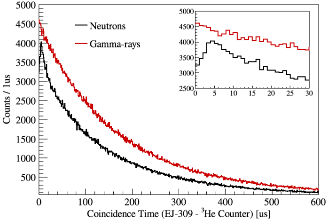


Figure 10. EJ-309–^{3}He counter coincidence time, selecting neutrons (black) and γ-rays (red) using the EJ-309 PSD. Inset: Zoom into region below 30 μs (Refer to online plots for color).

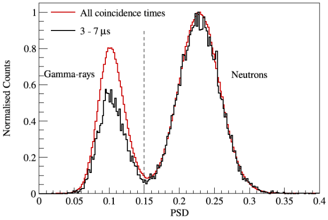
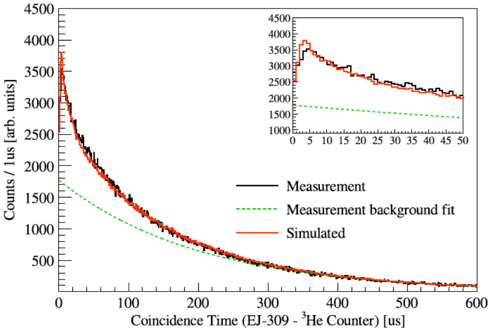
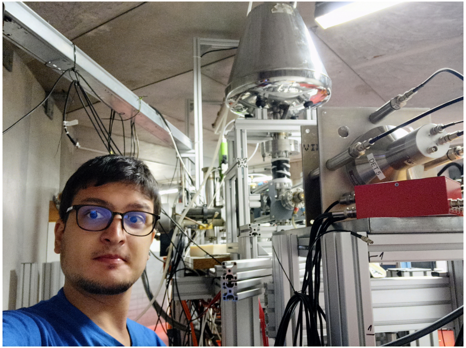


Figure 11. PSD for $E_p = 2449$ keV, gated on quenched energy $\leqslant$ 150 keVee. In red are all events, and in black are the events gated on coincidence time range 3–7 μs. The peak centered around PSD = 0.23 contains the neutron signals (Refer to online plots for color).



- Moderation + tof + charge collection time simulated in Geant4
- Moderated neutron peak at 5 μs

Conclusion



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A prototype neutron-detector array for future deep-underground *s*-process studies

Thomas Chillery[1,*], David Rapagnani[2,3], Chemseddine Ananna[4,5], Edoardo D'Amore[6,7], Gianluca Imbriani[2,3], Antonino di Leva[2,3], Daniela Mercogliano[2,3], Jakub Skowronski[6,7], Benjamin Brückner[8], Sophia Dellmann[9], Philipp Erbacher[8], Tanja Heftrich[8], René Reifarth[8,9], Mario Weigand[8] and Andreas Best[2,3]

- INFRA beamtime full success
- Achieved all planned goals + paper published
- Process quite straightforward, good local support