Position Sensitive Organic Glass Scintillator Bars for Neutron Time of Flight Spectroscopy

CAP Congress

9 June 2025

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Saint Mary's University

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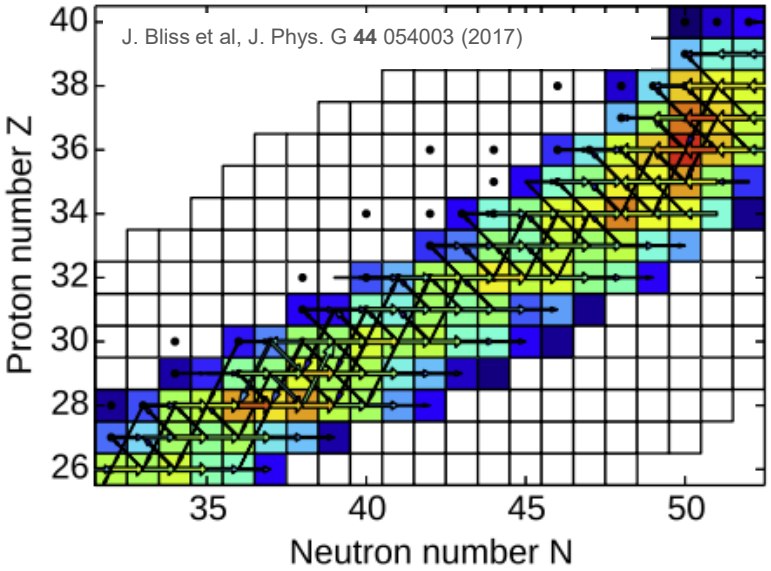
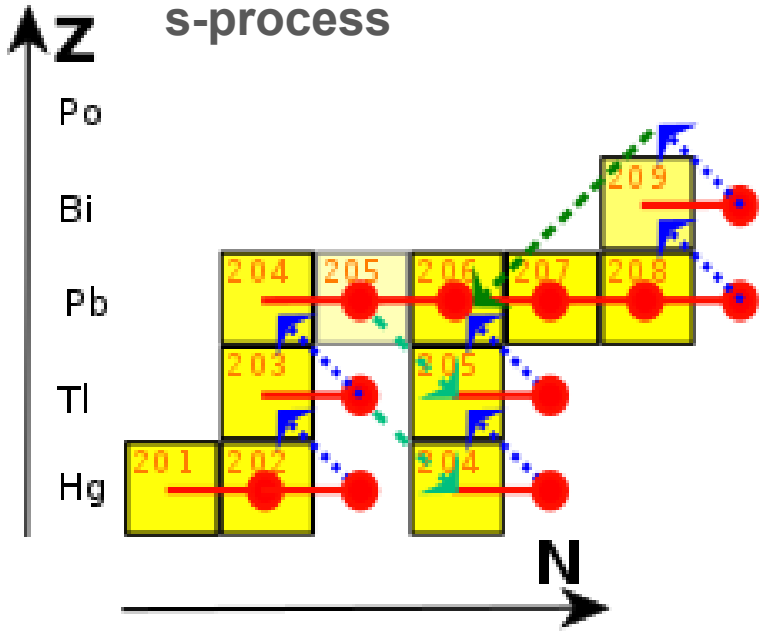
Motivation I: Direct measurements of (α, n) reactions (inverse kinematics)

- "Weak r-process" synthesizes "lighter" heavy elements Ag-Sr through series of (α, n) reactions – including on radioactive nuclei.
- s-process: ^{22}Ne(α, n) is the main neutron source in massive & AGB stars; literature discrepancies in its rate [also: ^{18}O(α, n), competes w/ ^{18}O(α,γ) neutron poison]

Weak r-process



s-process



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Motivation II: (d, n) Reactions (inverse kinematics)

- (d,n) reactions probe proton single-proton structure of excited states in the daughter.
- Useful tool for indirect measurements of astrophysical (p,γ) reactions, as well as shell evolution in proton-rich nuclei.

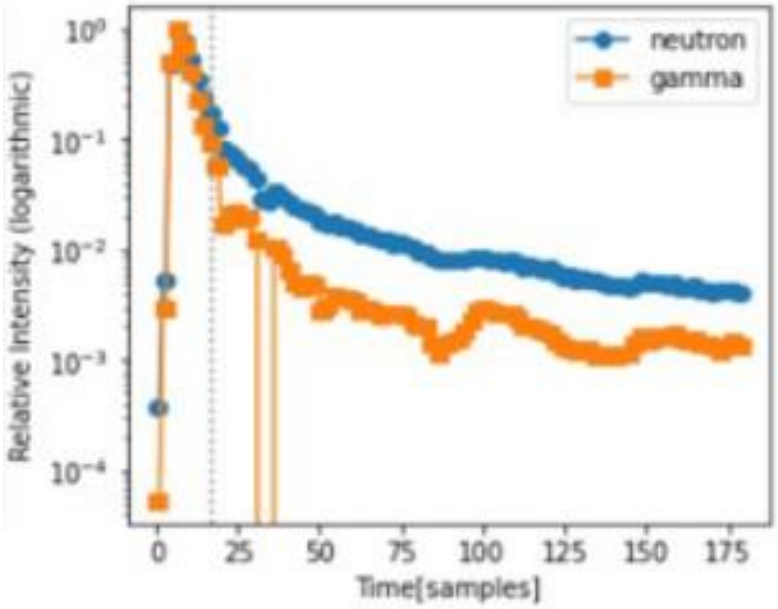
And more!

- Any experiment with the need to detect ~1-30 MeV neutrons – especially with a need for neutron energy information and n/γ discrimination.

Detector Requirements

Aim to detect ~1-30 MeV neutrons

- Timing resolution (<1 ns FWHM)
- Position resolution (few cm)
- Detection efficiency (>10%)
- Neutron/Gamma discrimination
- Large-area coverage (for a reasonable cost)



Organic Glass Scintillator (OGS)

- Liquid, poured into mold then set.
- Different response to neutrons and gamma-rays (pulse shape discrimination)
- Fast timing
- Bright scintillation response

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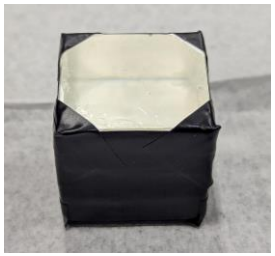
Today's Talk

DEMAND Array

- 3 cm x 3 cm x 3cm OGS cubes coupled to a single PMT
- Commissioned in a recent $^{22}Ne(\alpha, n)$ measurement at DRAGON
  - *Ben Reed Tuesday 4:15 PM, Nuclear Reactions*



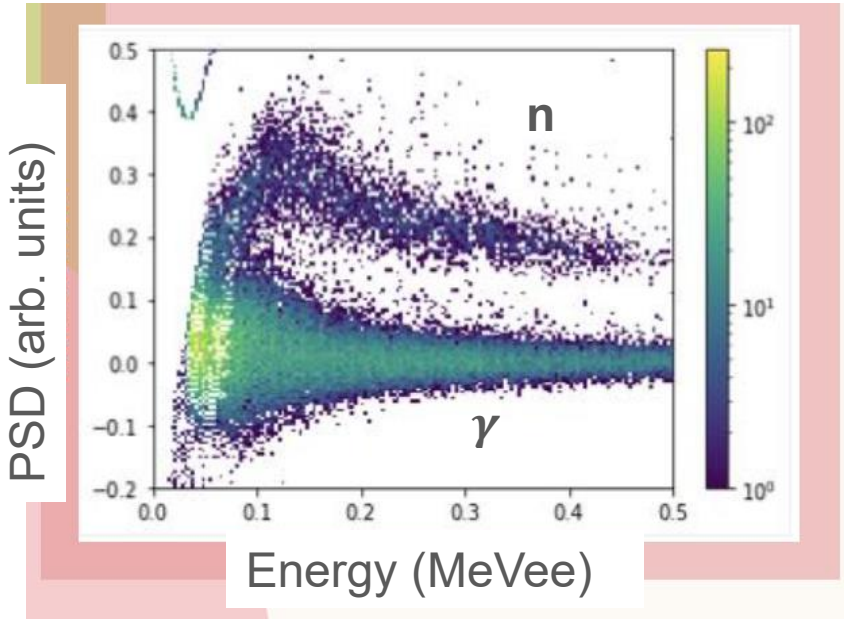
OGS Bar Development

- Benchtop work at SMU characterizing elongated bars of OGS

DEMAND Array: PSD Characterization

- Neutron-singles data from ^{22}Ne beam on ^{4}He gas target (DRAGON) → neutrons from ^{22}Ne(α, n)

PSD vs. Energy (single detector)



PSD for 250 keVee energy slice

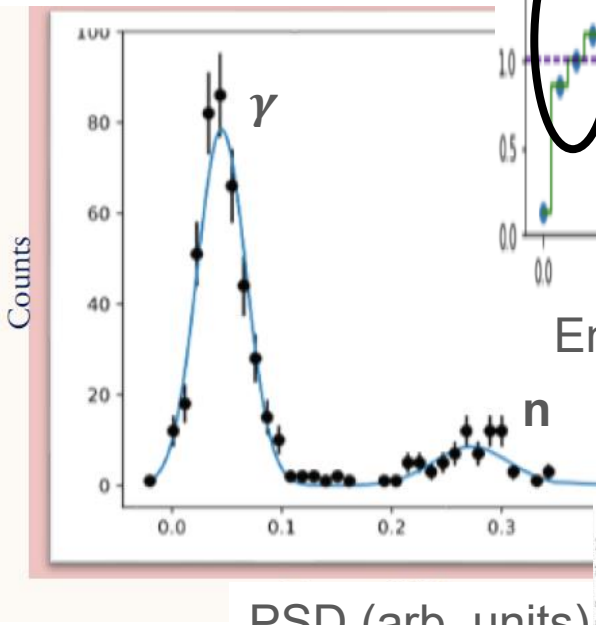
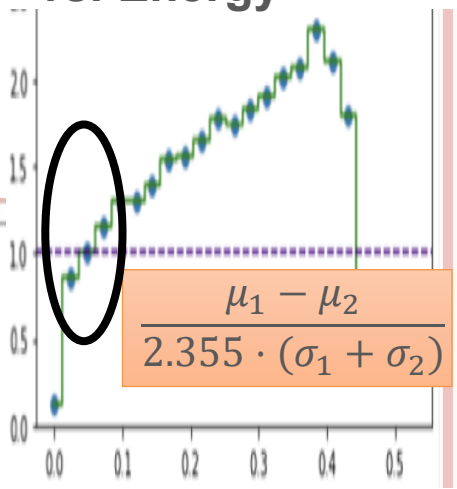
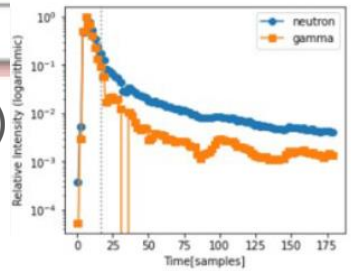


Figure of merit vs. Energy





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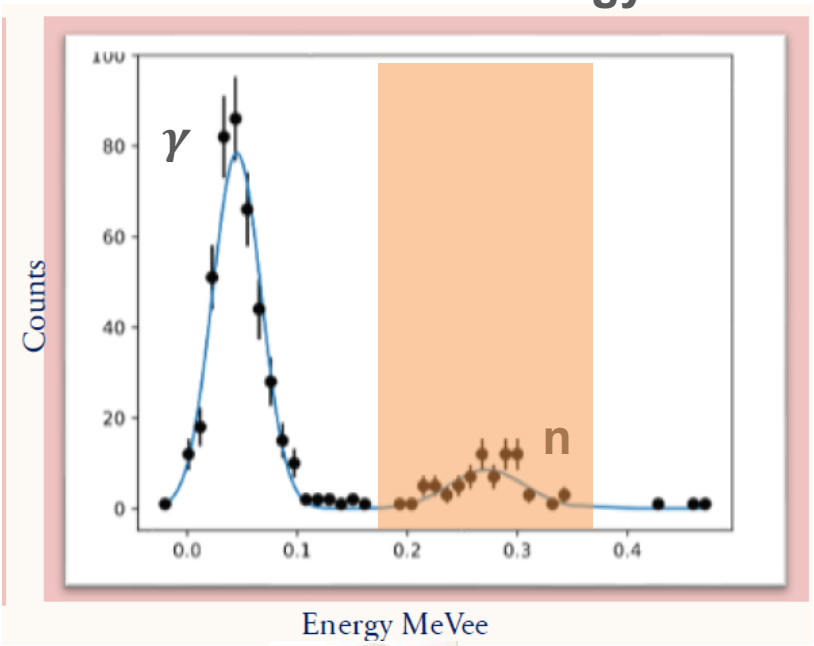
DEMAND Array: Singles Yield

- Extract neutron yield from individual PSD fits (integral of neutron peak)

PSD for 250 keVee energy slice

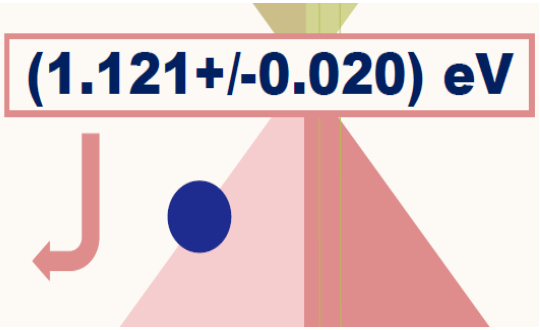


Preliminary strength of Ex = 11.83 MeV resonance in ^{22}Ne(α, n)

LITERATURE

- Harms 1991: 0.59eV
- Endt 1998: 0.61+/-0.9 eV
- Jaeger 2001: 1.067+/-0.042 eV
- Drotleff 1993: 1.105+/-0.120 eV

(1.121+/-0.020) eV



V. Harms et al, Phys. Rev. C 43, 2489 (1991)
P.M. Endt, Nucl Phys A 633, 1 (1998)
M. Jaeger et al, Phys. Rev. Lett. 87, 202501 (2001)
H.W. Drotleff et al, Astrophys J 414, 735 (1993)

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OGS Bars

- Future large-area array: reduce readout channels with “bar” geometry.

PMT (L)

PMT (R)

CAEN DT5742 Digitizer (5 GS/s)

Position

$T(L) - T(R)$ OR $\log\left(\frac{E(L)}{E(R)}\right)$

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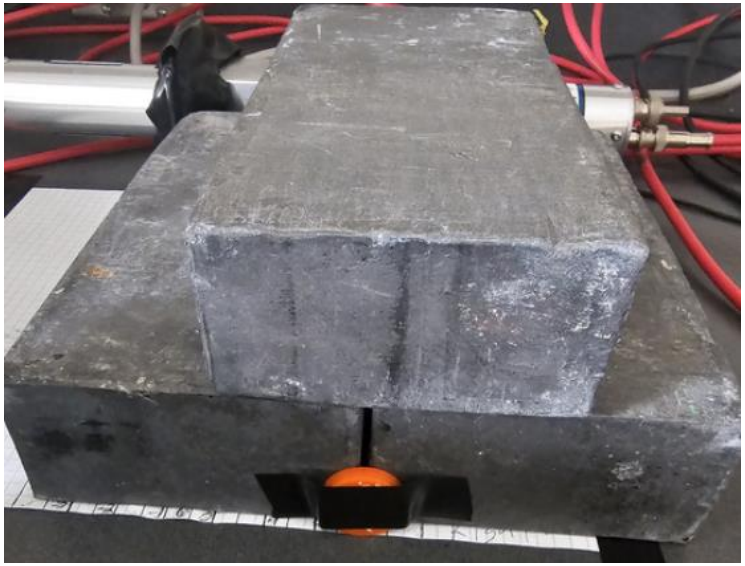
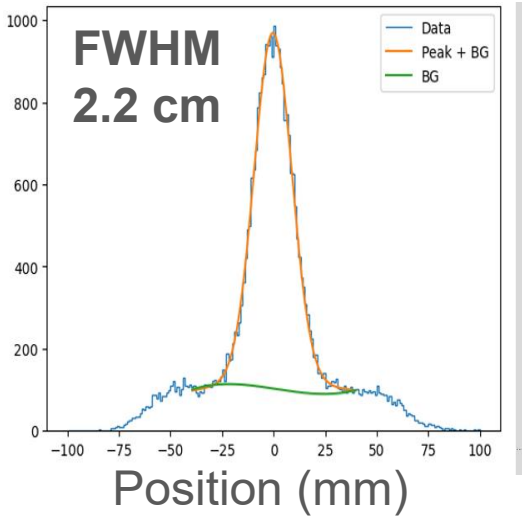
Position Resolution

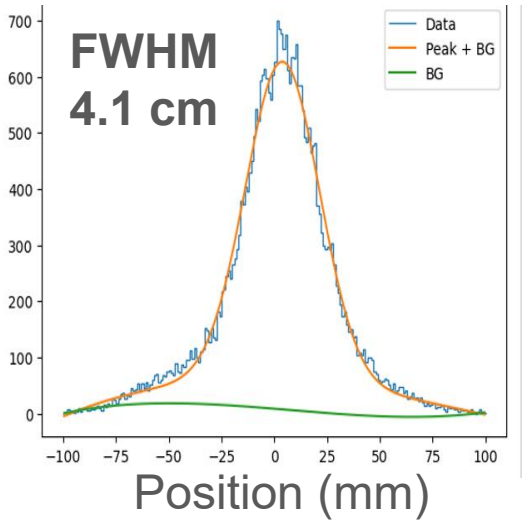
- Collimated ^{137}Cs source, moved along the bar length.
- Extract position using both methods.



Energy Ratio



Time Difference



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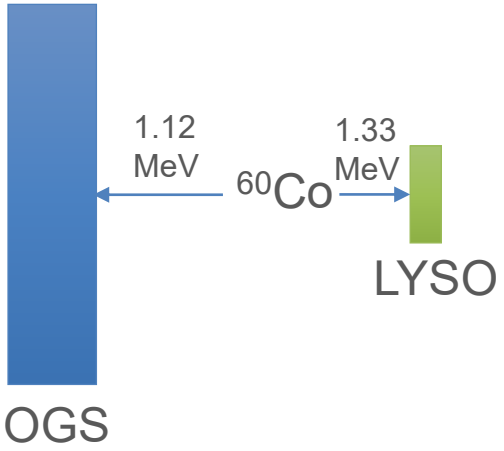
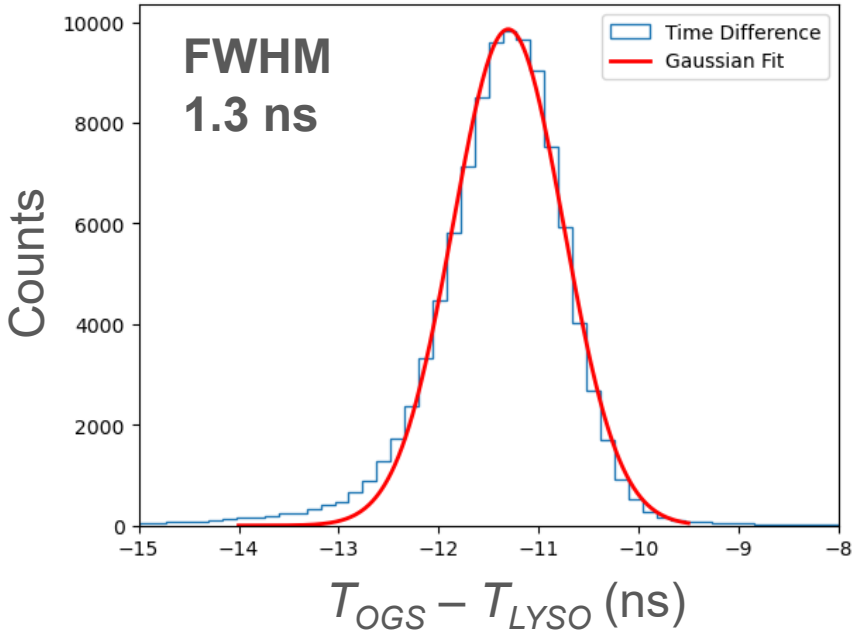
Time Resolution

- TOF between “reference” detector (LYSO scintillator), with ^{60}Co coincidence source



- 0.9 ns FWHM assuming equal LYSO + OGS contribution
- Next step: LYSO → LYSO measurement to determine LYSO contribution



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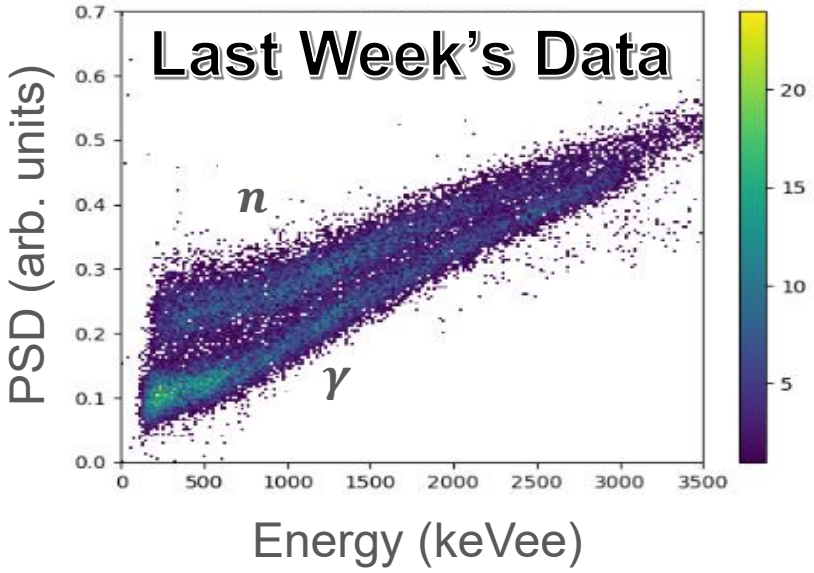
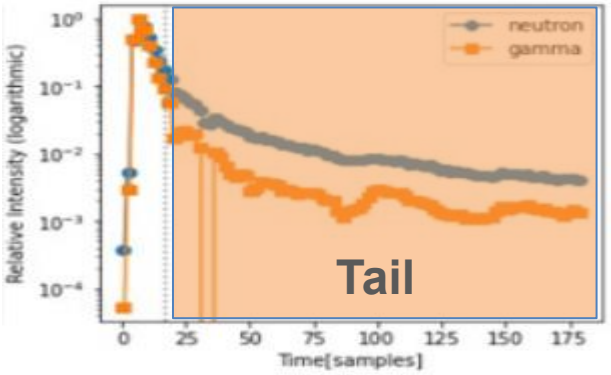
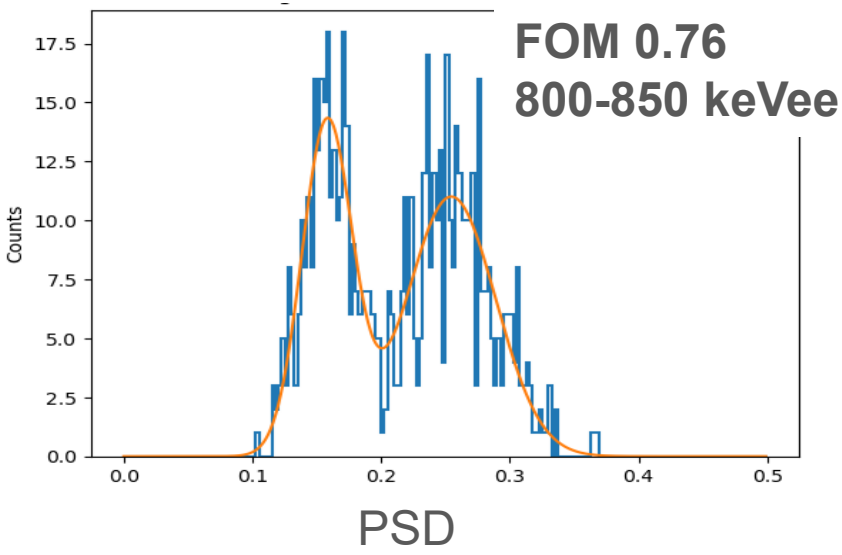
Pulse Shape Discrimination

- AmBe source – mixed neutron/gamma field
- PSD from Tail/Full vs. Full (offline w/ recorded waves)







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Thank you / Merci

DEMAND Collaborators

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Questions?

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