Detector Development at the University of Surrey

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NuSec Detection Science Workshop 2026

11th February | National Physical Laboratory

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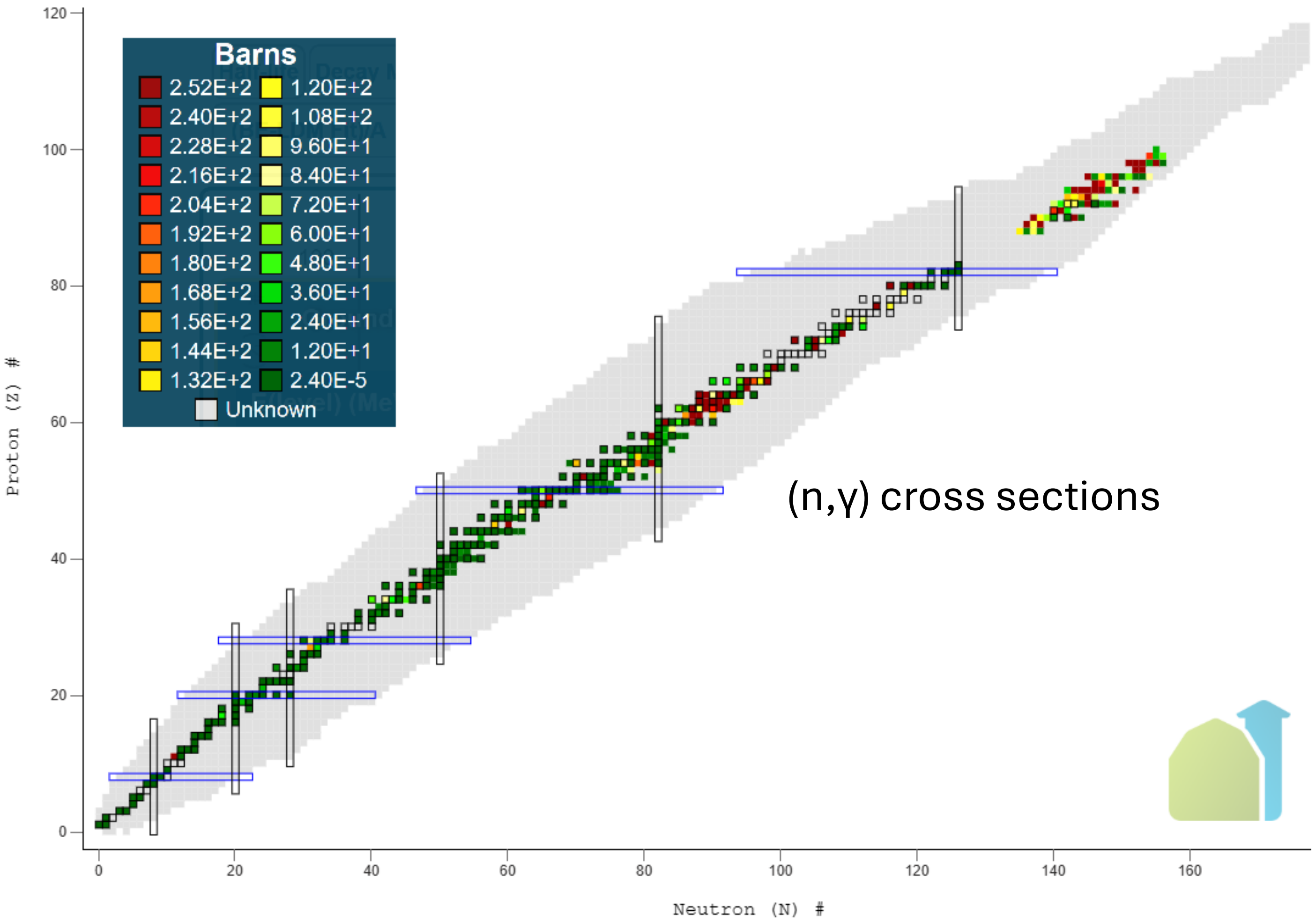
Overview

- Scintillator materials
- Waveform analysis methods
- BaF_2 case study - neutron tank
- $LaCl_3$, $LaBr_3$ and $CeBr_3$ case studies – NPL low scatter facility



https://www.nndc.bnl.gov/nudat3/

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Scintillator Materials

- Working on various scintillators: **<u>$LaCl_3$</u>**, **<u>$LaBr_3$</u>**, **<u>$CeBr_3$</u>**, $CdWO_4$, **<u>BaF_2</u>**, CaF_2, GAGG, BGO, CLYC, plastics, organic glass etc.

- Focusing on thermal and fast neutron energy regions, key areas for nuclear security and energy

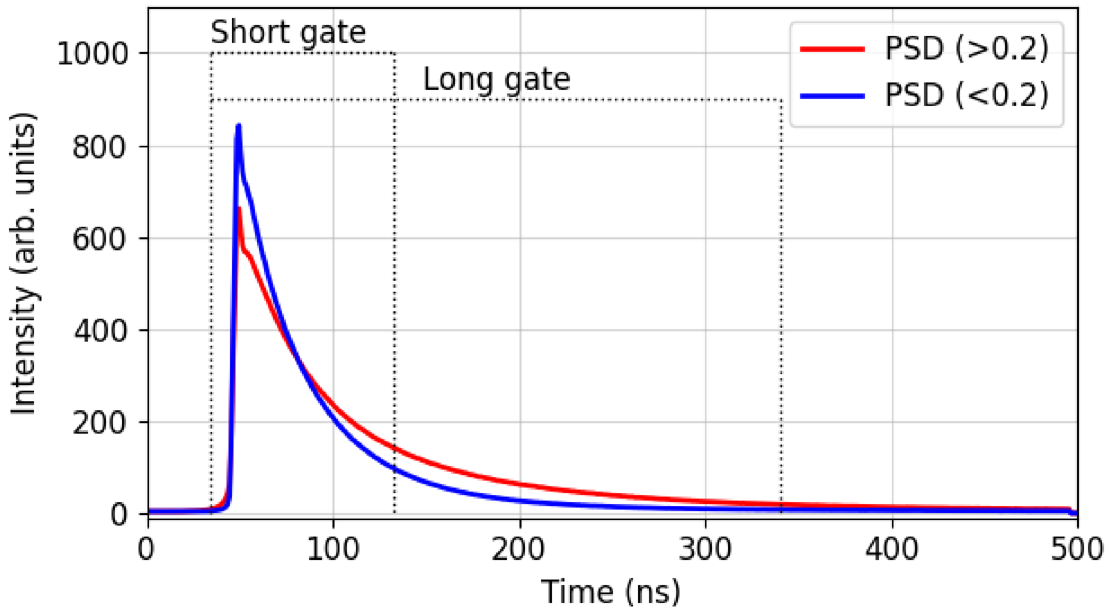
- Investigating both detectors for neutron measurements, or separating neutron background from gamma spectra

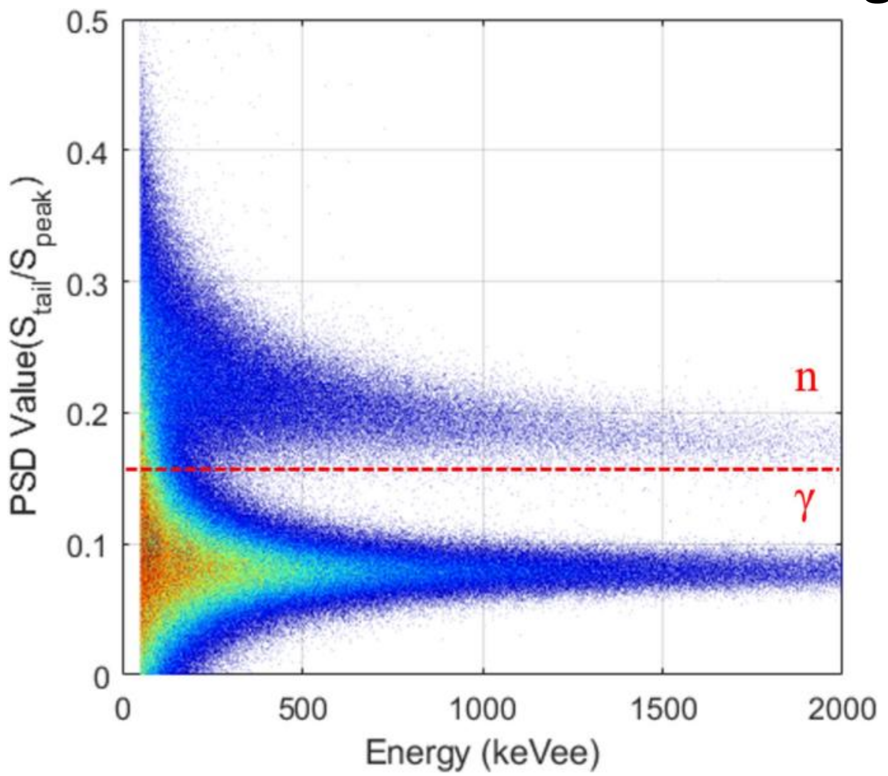
- Characterisation performed in house and at neutron facilities

Waveform Analysis

Pulse Shape Discrimination – Charge Integration

- Scintillation waveforms are dependent on the instigating radiation species
- Charge integrated pulse shape discrimination (PSD) is a well understood method of exploiting this to separate signals based on a ratio of short and long components

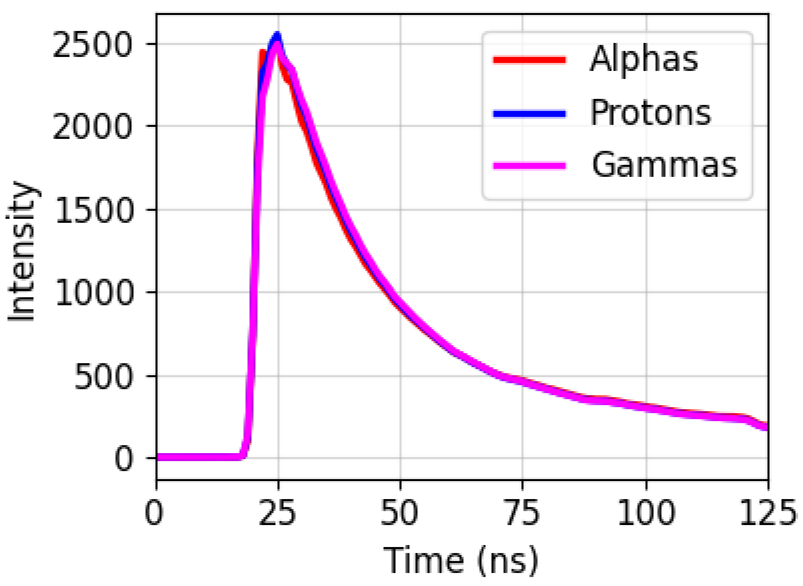


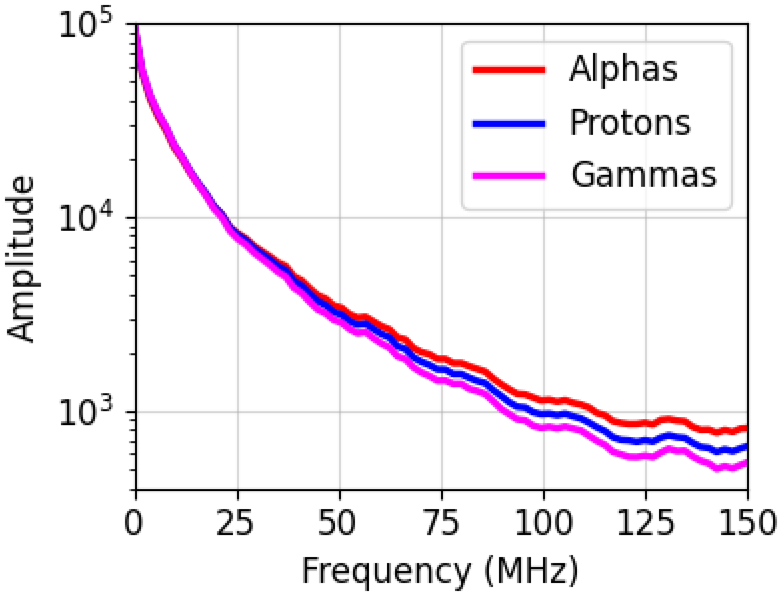


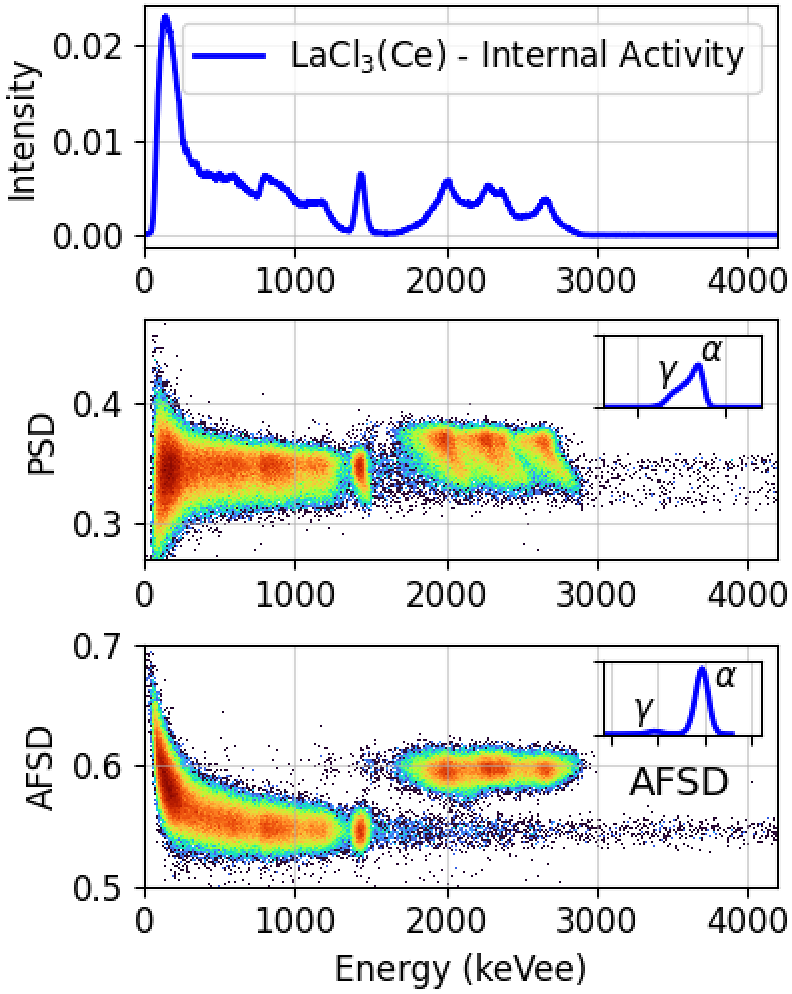
Boo, J., Hammig, M.D. and Jeong, M., 2021. Compact lightweight imager of both gamma rays and neutrons based on a pixelated stilbene scintillator coupled to a silicon photomultiplier array. *Scientific reports*, *11*(1), p.3826.

Pulse Shape Discrimination – Amplitude Frequency

- However, PSD performance varies wildly between materials
- Multiple methods addressing this, one of which is amplitude frequency shape discrimination (AFSD)
- This is implemented by passing a waveform through a fast Fourier transform, then performing charge integration

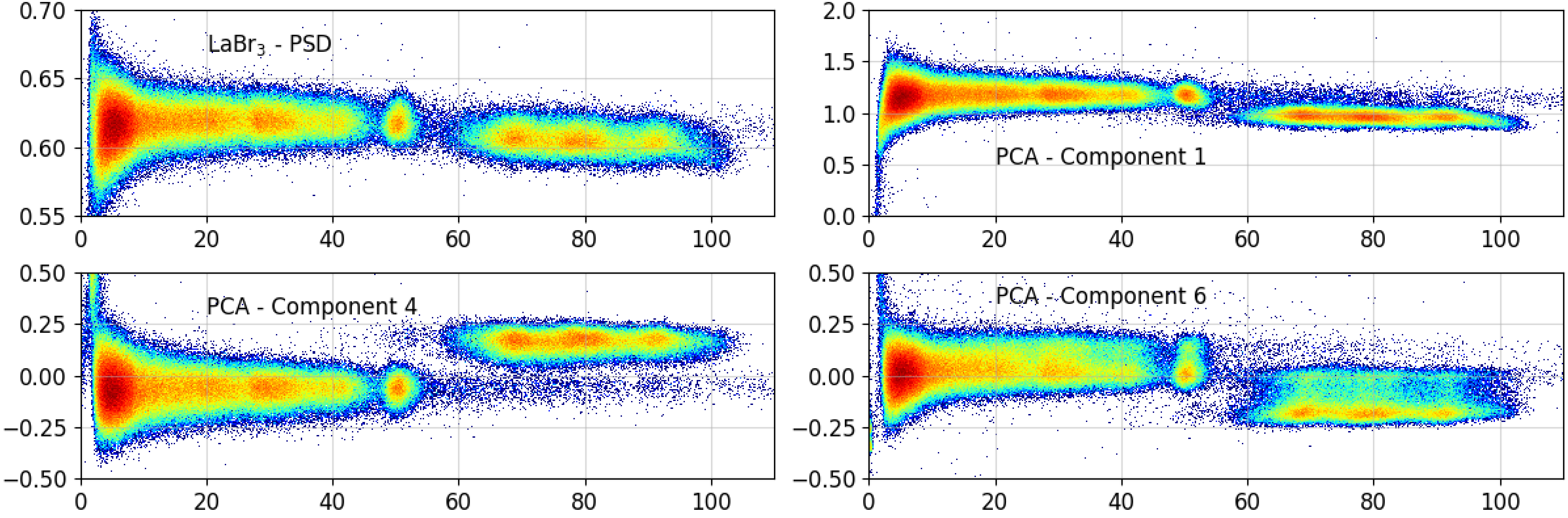






Other Analysis Methods

- Implementation of different methods onto FPGA systems
- Optimising parameters: windowing functions, normalization, zero padding
- Principal component analysis, ML, combinations of different methods etc.



BaF_2
Neutron Tank

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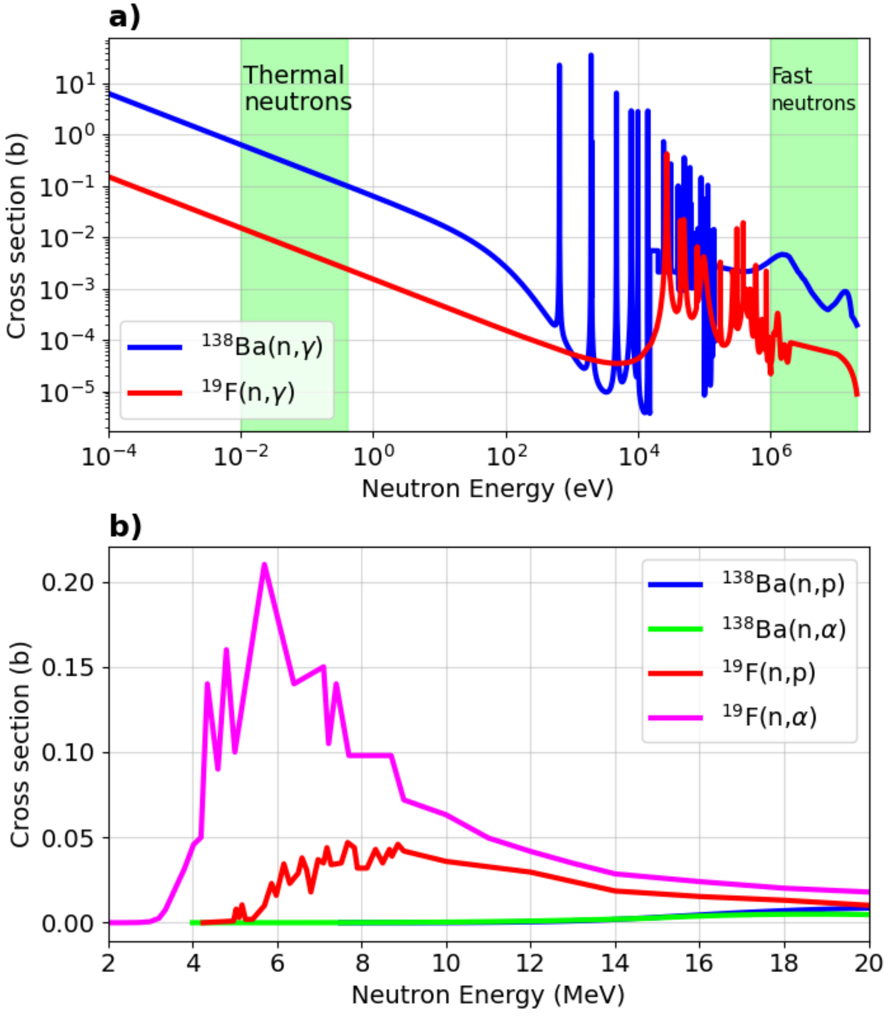
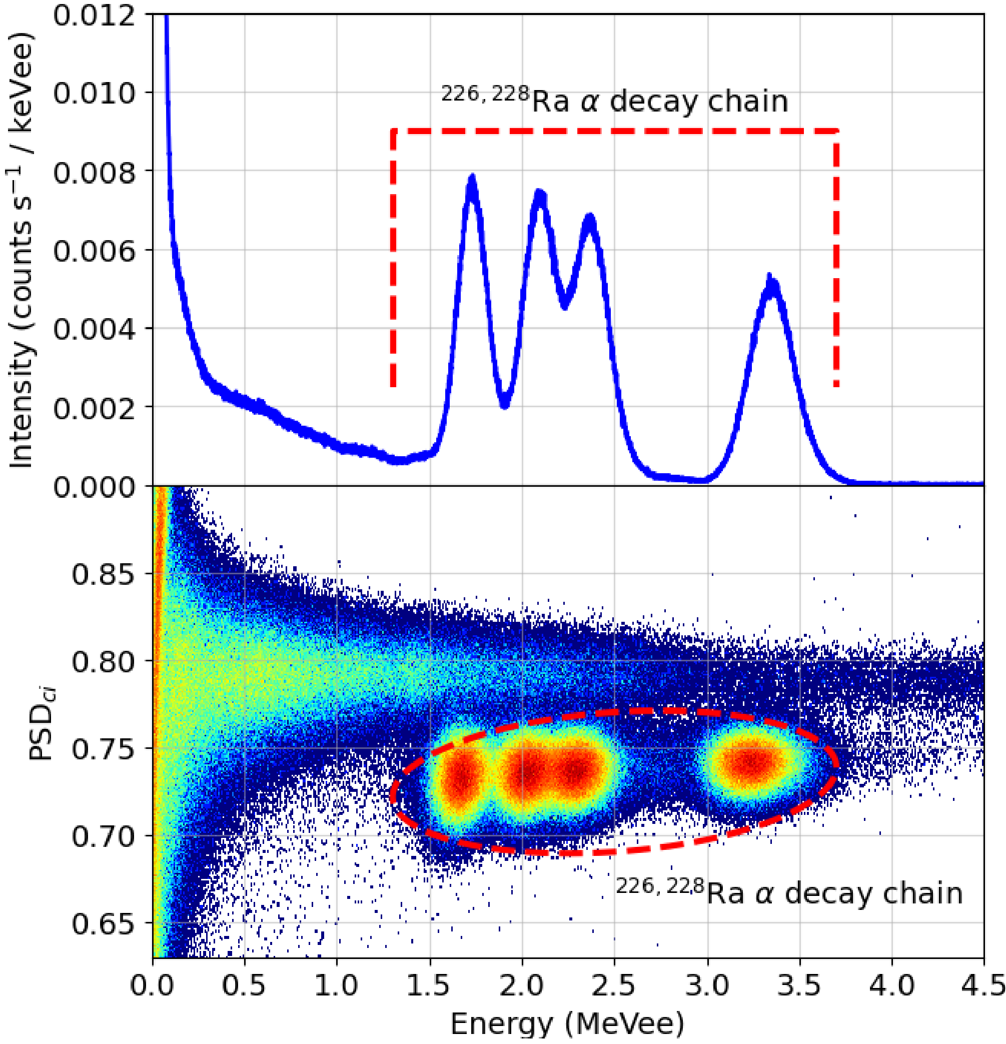
BaF_2 – Overview

- BaF_2 crystal coupled to PMT
- Sensitive across neutron energy range via different mechanisms
- Internal spectrum arising from Ra contamination





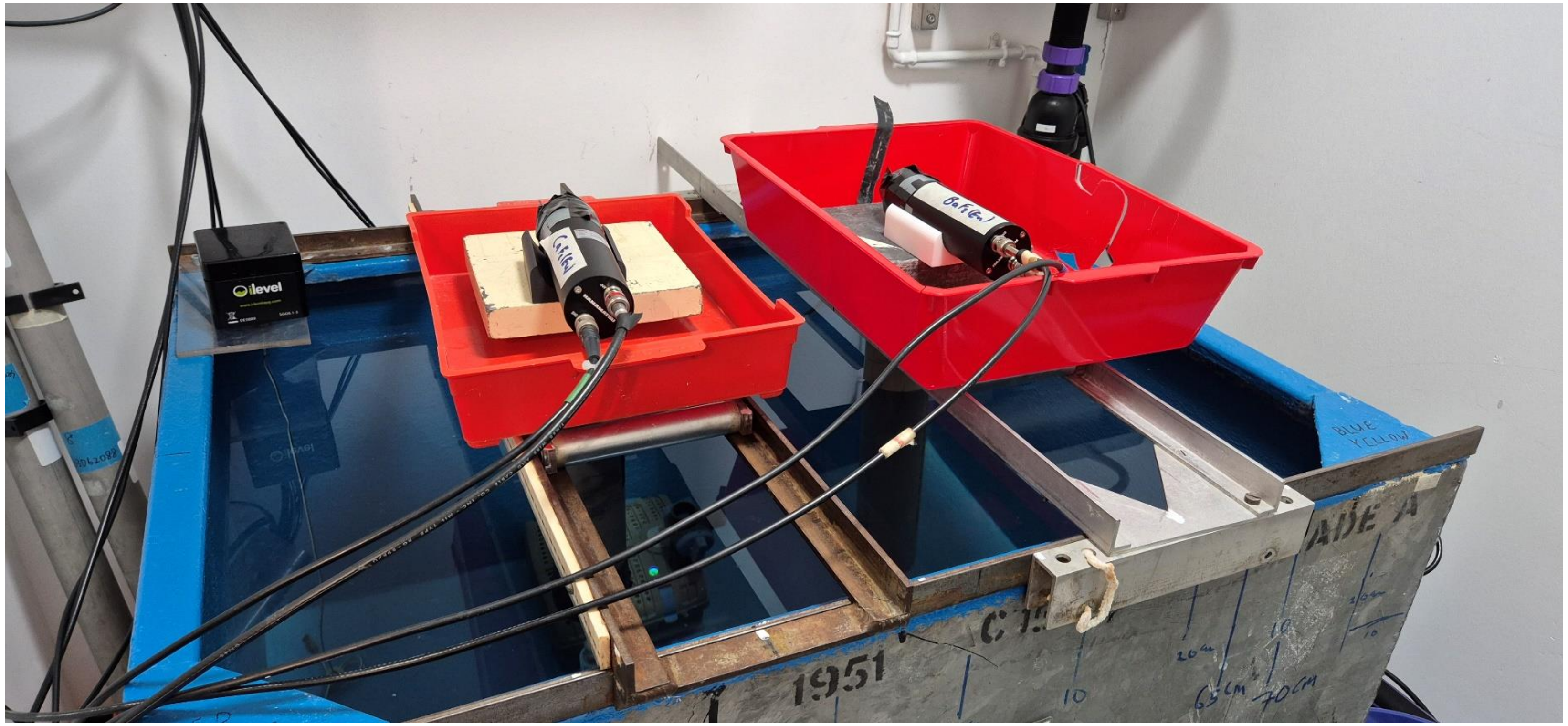
BaF_2 – Neutron tank measurements

- Measurements performed using AmBe source in a water tank

- Thermal neutron measurements shows enhanced gamma spectrum

- Fast neutron measurements show more signals in alpha band

- PSD can be used to remove internal background/fast neutron induced signals



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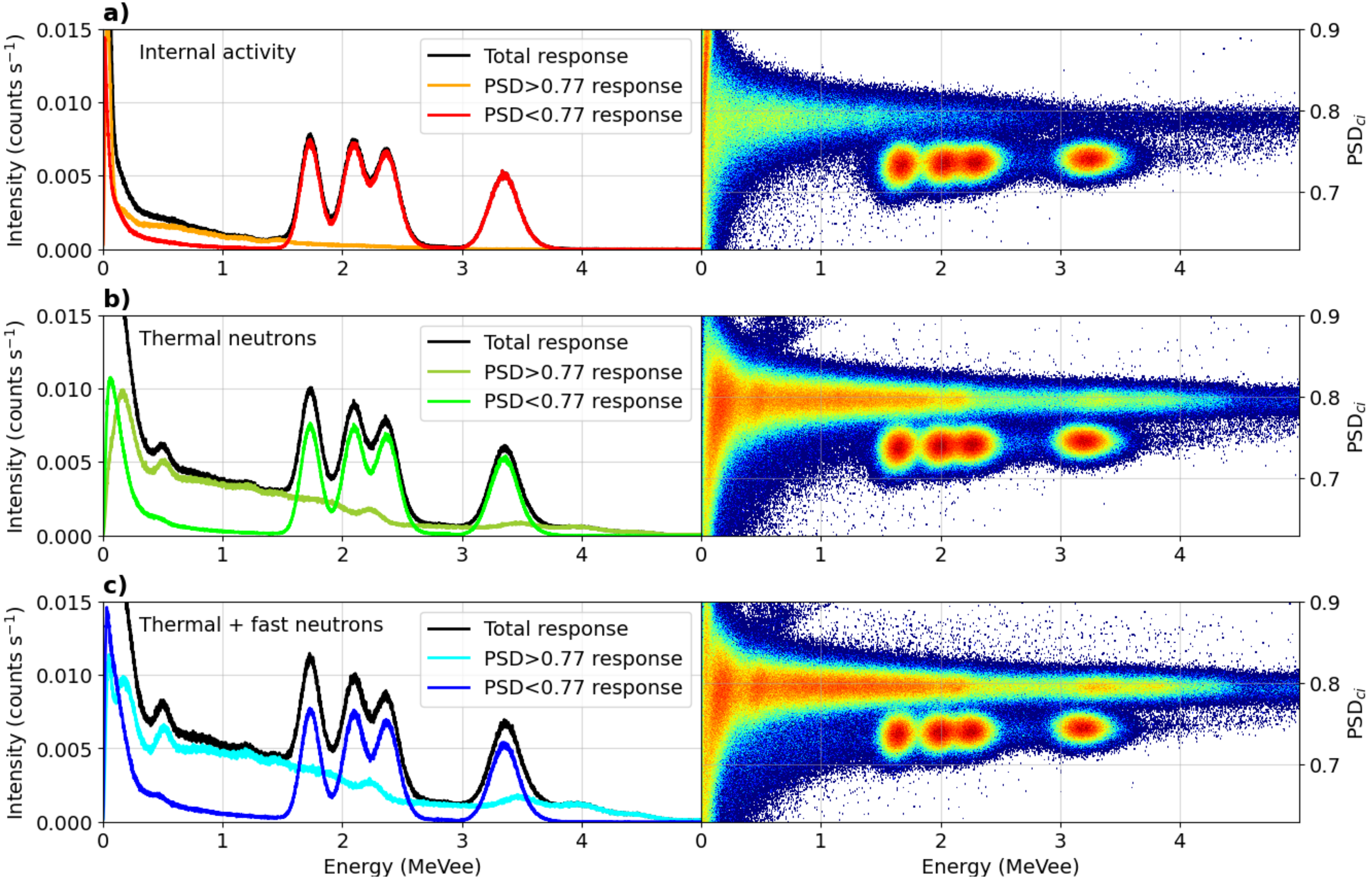

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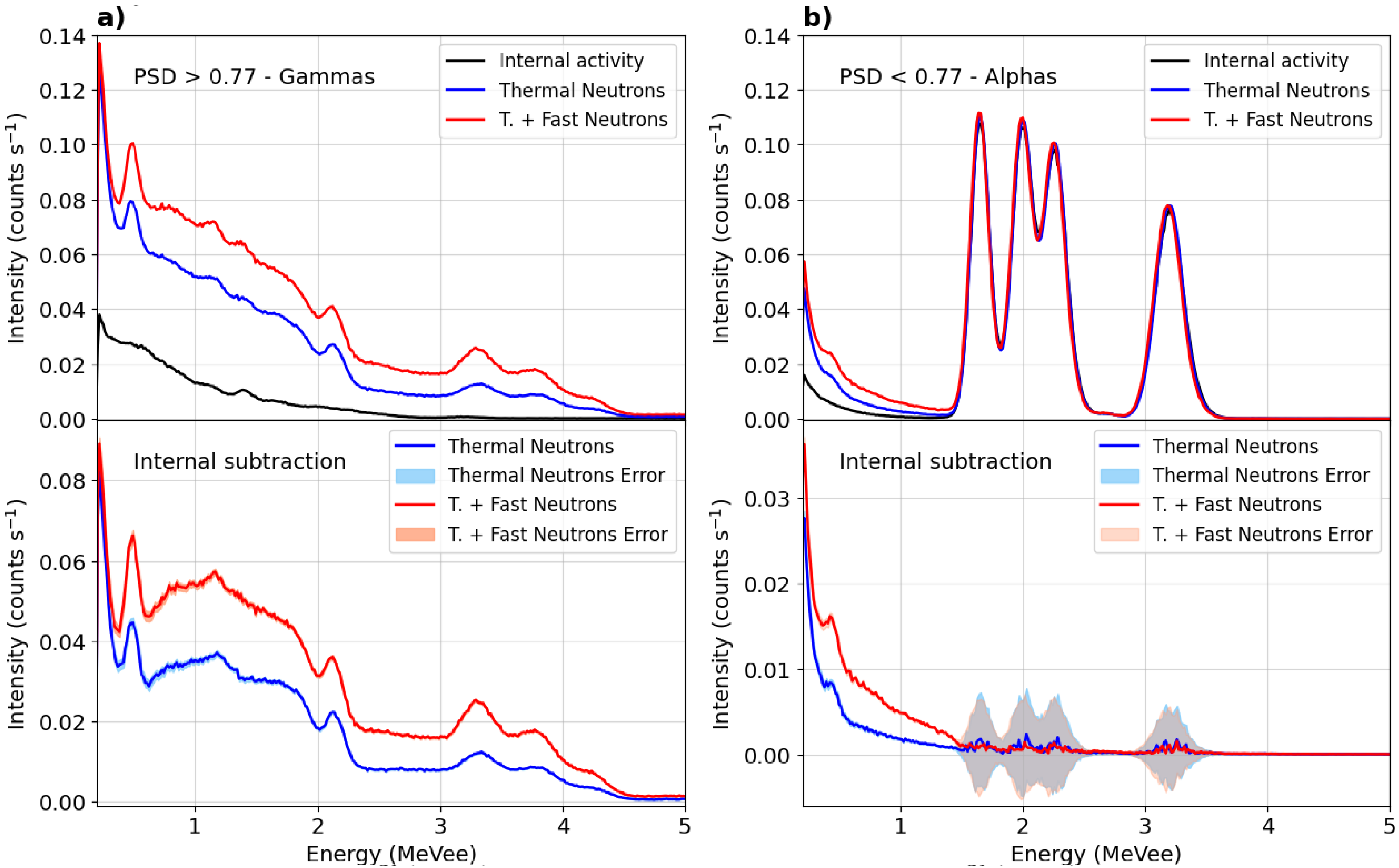
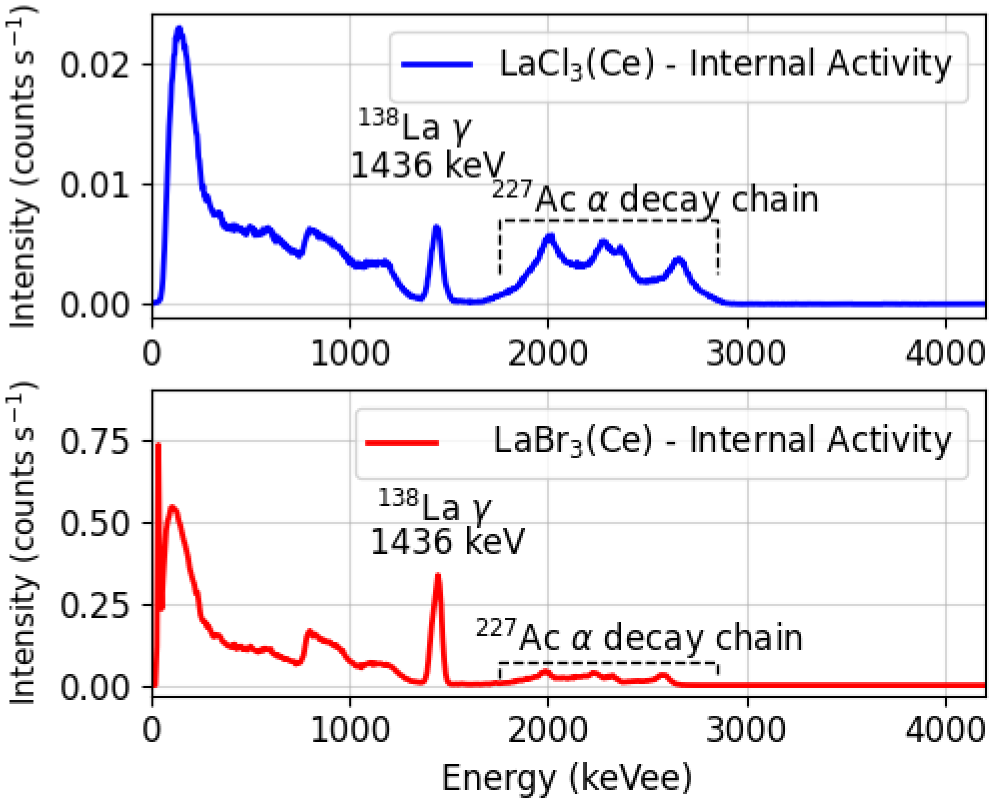
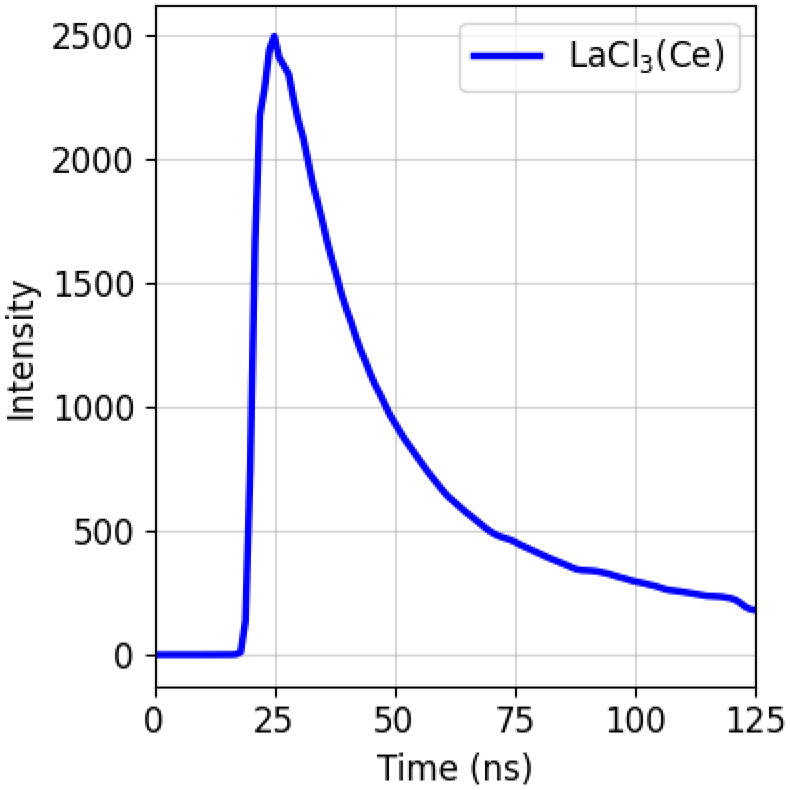


$LaCl_3$ and $LaBr_3$ NPL Neutron Facility

LaX_3 – Scintillators

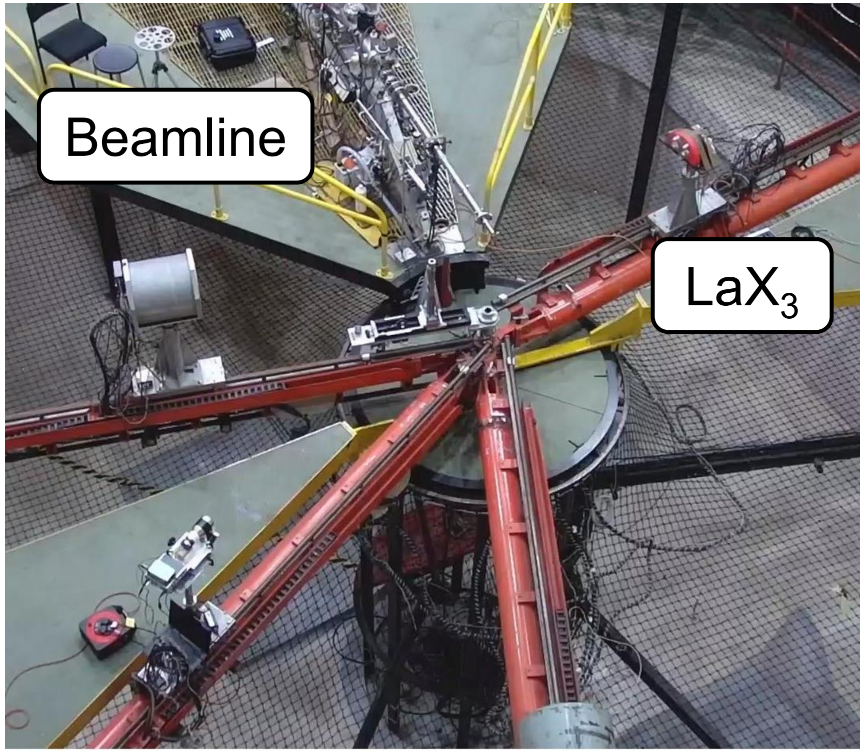
- LaX_3(X = Cl, Br) scintillators doped with Ce^{3+} have high energy resolution (2-4% at 662 keV), fast decay time (~30 ns) and have dual mode sensitivity (γ+n)
- Hygroscopic and non-trivial internal activity from La decay and Ac contamination
- Used in a range of facilities and instruments e.g. DESPEC, GRIFFIN etc.

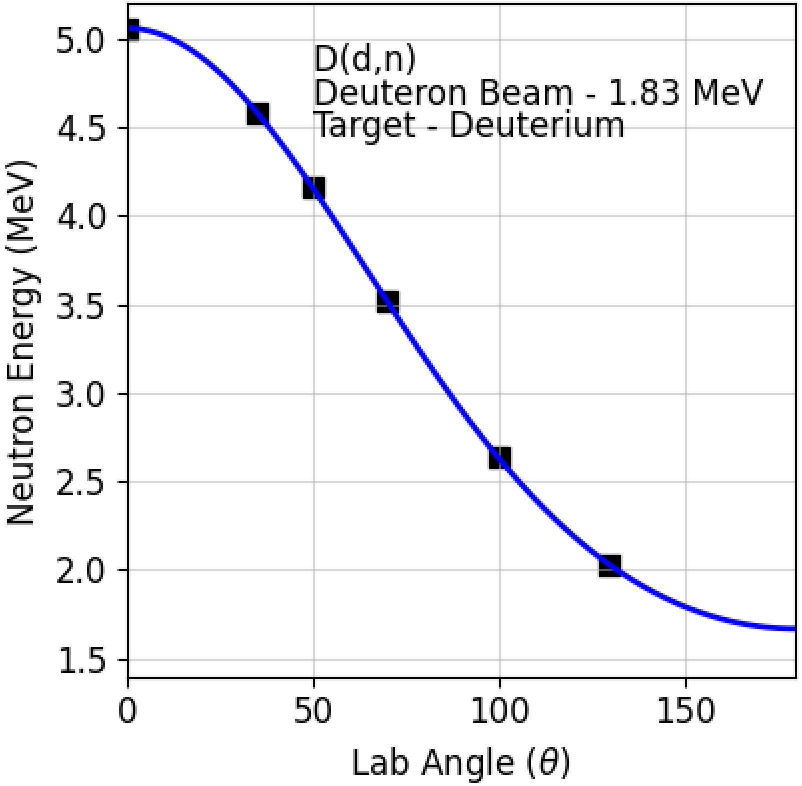


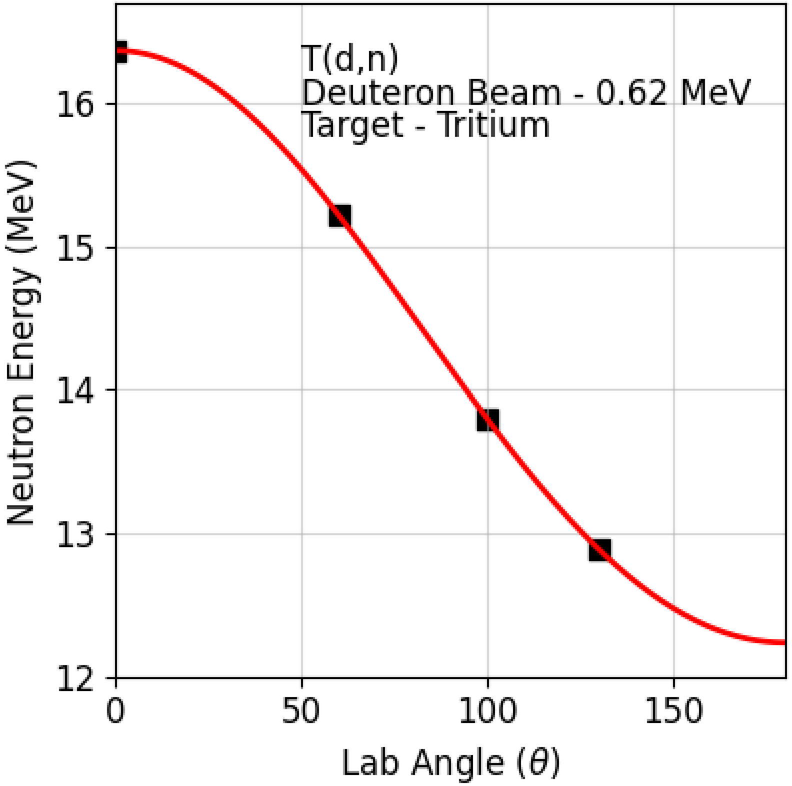


NPL Measurements

- Measurements taken at the NPL low-scatter facility in July 2025
- Deuteron beams impinged on deuterieum and tritium targets
- A range of monoenergetic neutron energies accessed by varying the beam energy and detector position







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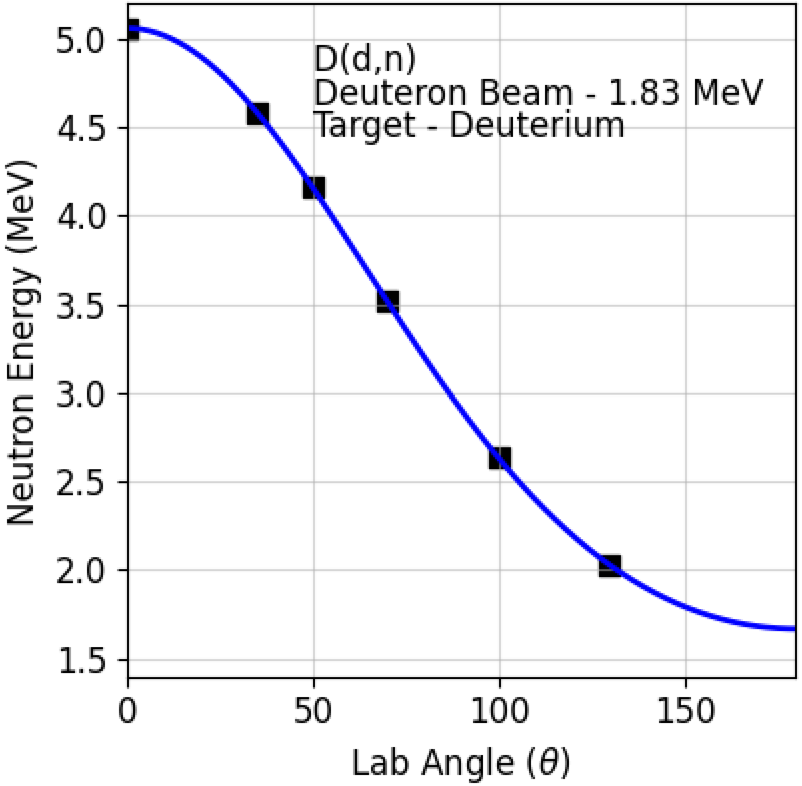
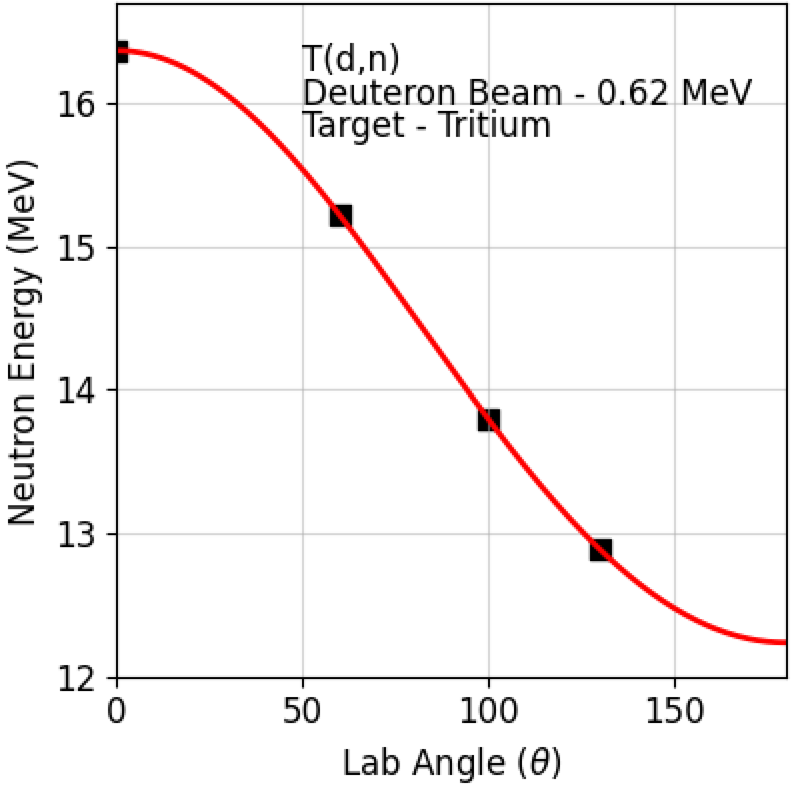
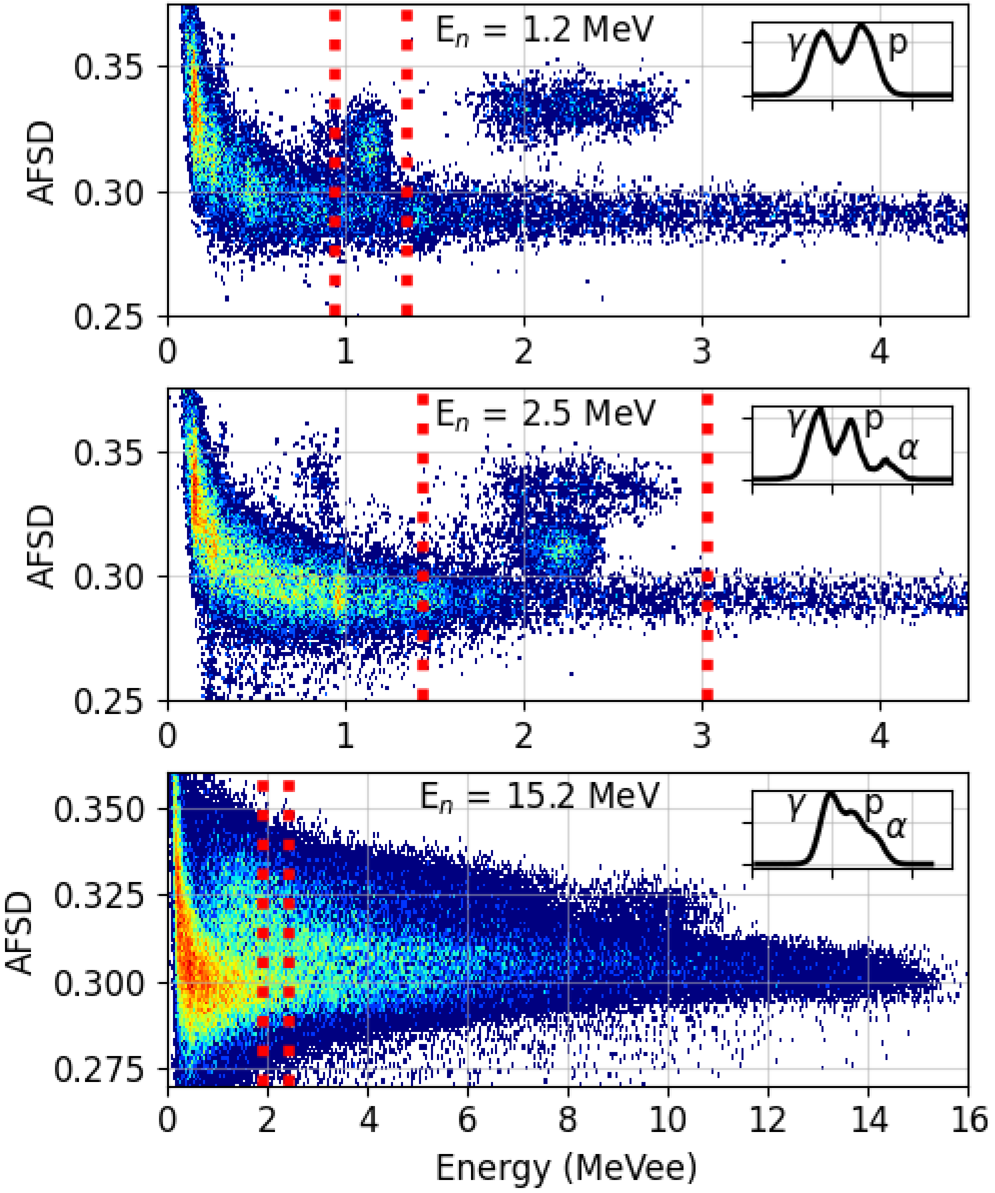
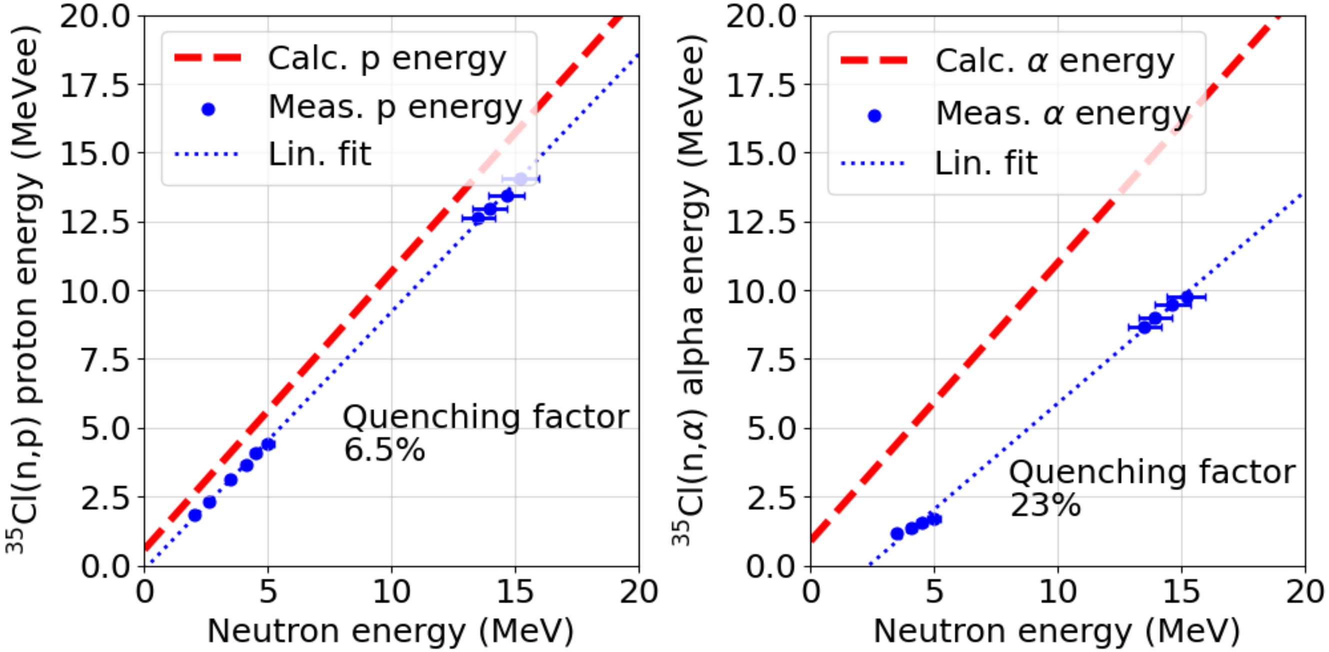




$LaCl_3(Ce)$ Results

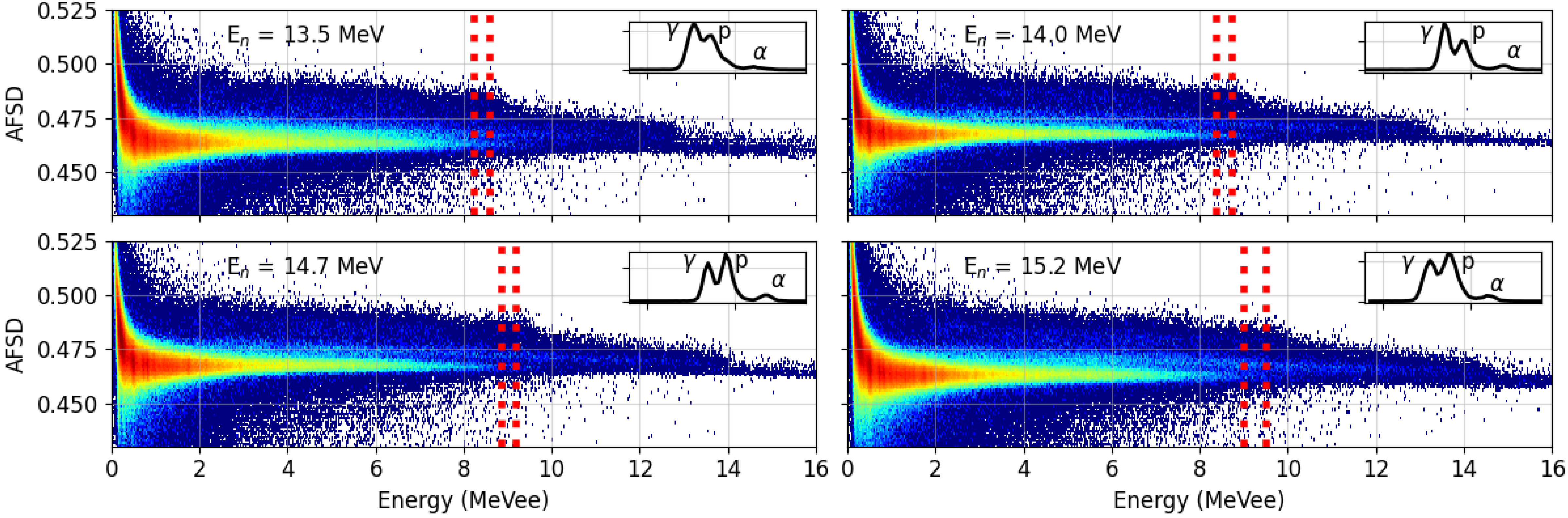


- AFSD improves separation by a factor of 2
- (n,p) and (n,α) peaks observed across all energies
- Linear response indicates neutron spectroscopy potential



$LaBr_3(Ce)$ Results

- Due to lower cross section in the E_n=1-5 MeV energy range, no clear response
- At higher energies, broad γ, proton and α distributions with α peaks
- Proton distributions appear to be spread across many excited states



$CeBr_3$
NPL Neutron Facility

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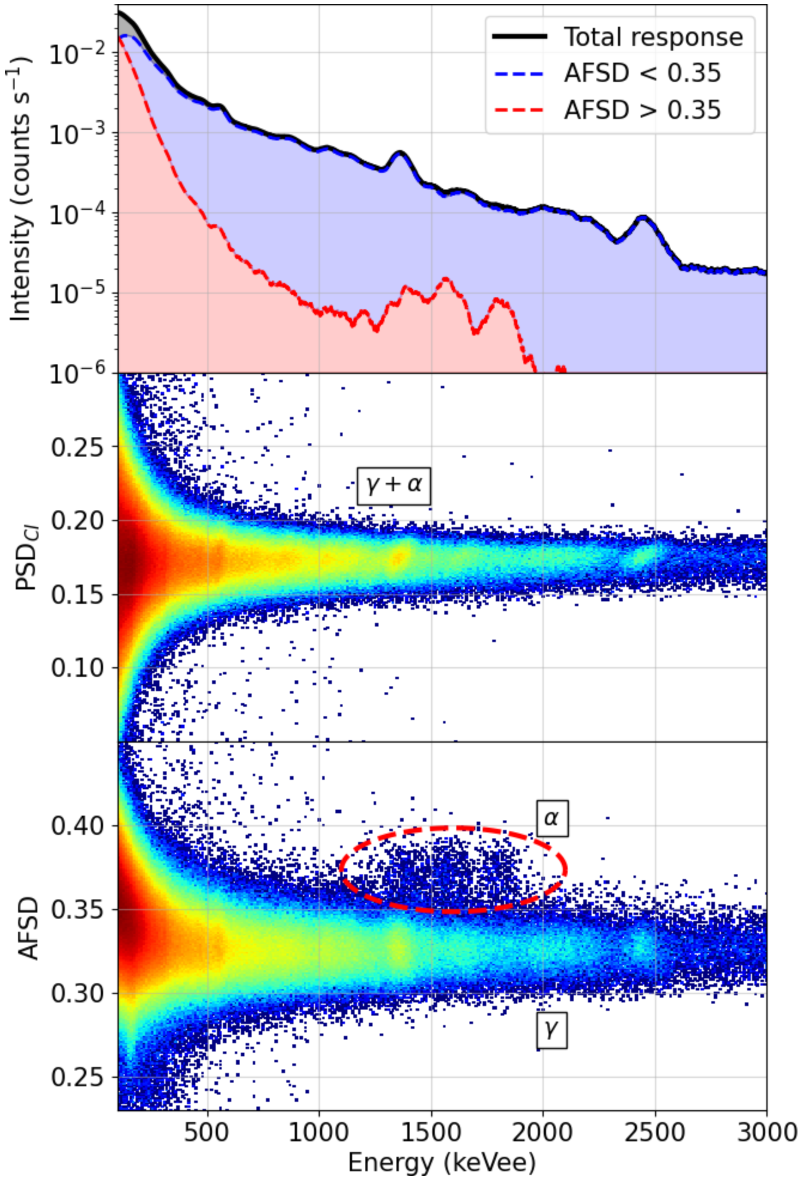
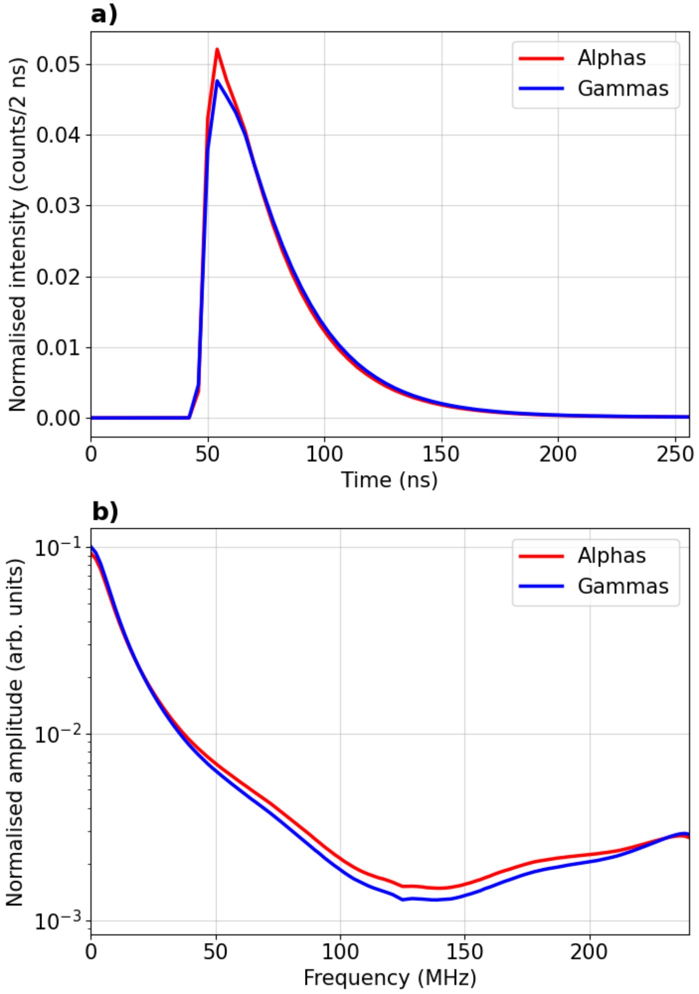
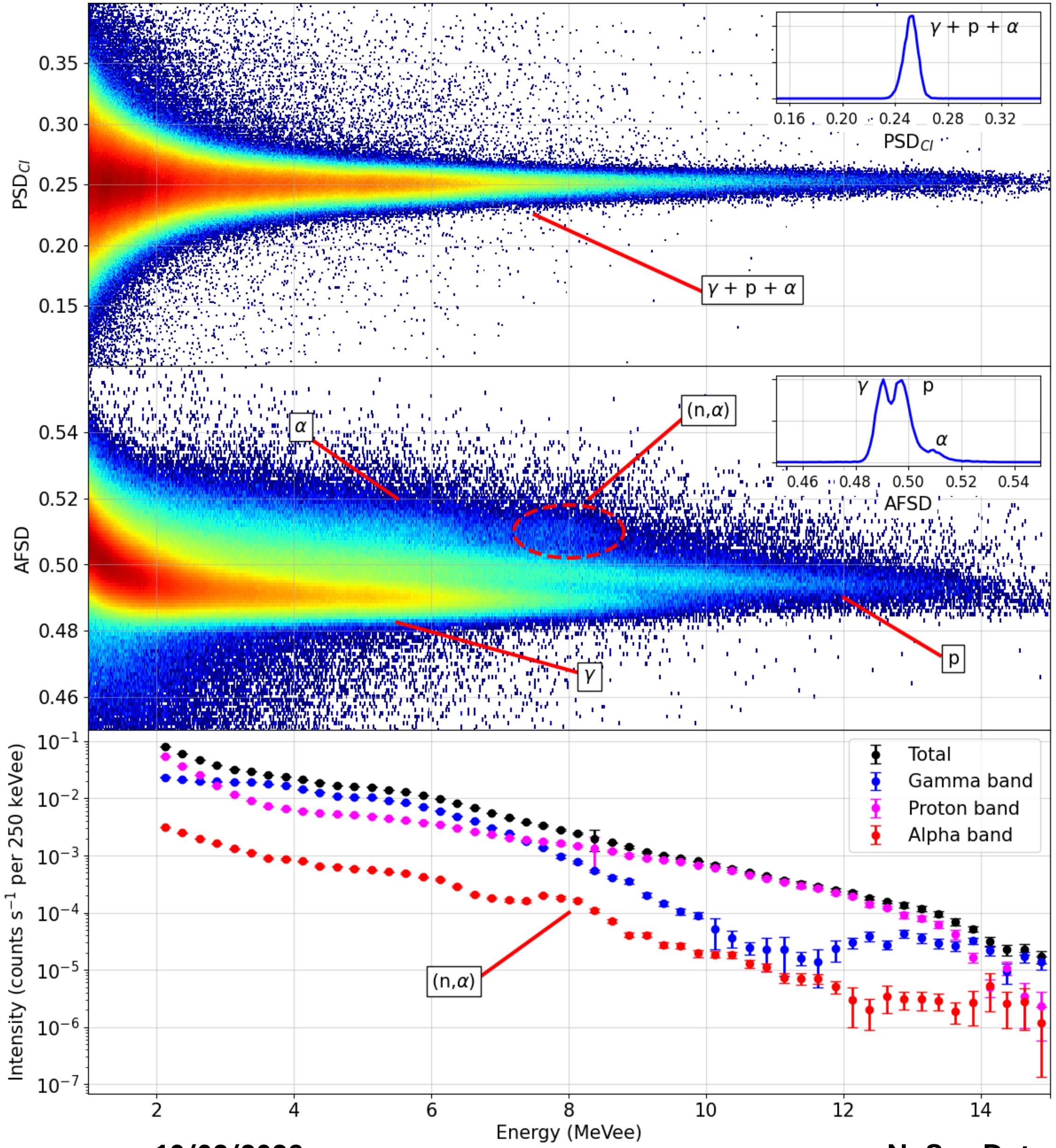
$CeBr_3$ AFSD Performance

- $CeBr_3$ scintillators have benefits over LaX_3 materials, but have no reported PSD capability
- AFSD method allows us to separate the low levels of Ac contamination in the internal spectra

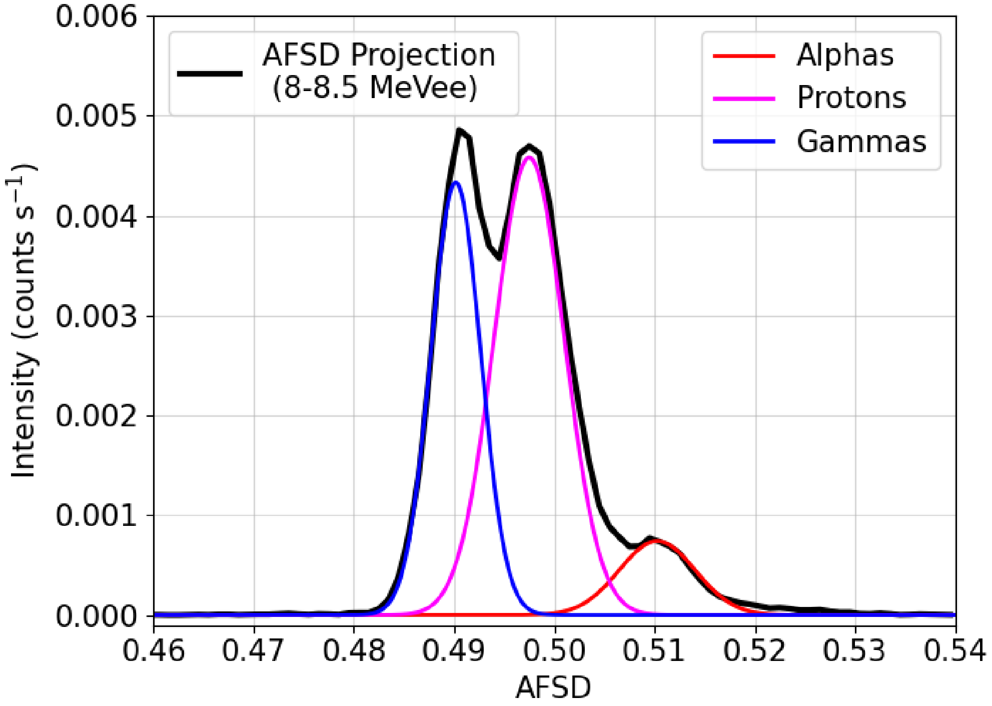




$CeBr_3$ Results



- Measurements taken during LaX_3 beam test with CeBr3
- T(d,n) measurements yield clear proton and alpha bands
- $CeBr_3$ can function as neutron detector, or neutron contributions can be accounted for



Thanks for listening!

Thanks to everyone who assisted in this work: Jacob Heery, Jack Henderson, Naomi Gadsby, Giuseppe Lorusso, Mike Bunce, Matt Taggart, Gemma Wilson, Abdul Alshammari, Gee Bartram, Chris Cousins, Katie Garrett, Connor O’Shea, Ed O’Sullivan, Sifa Poulton, David Thomas and Renjie Wu

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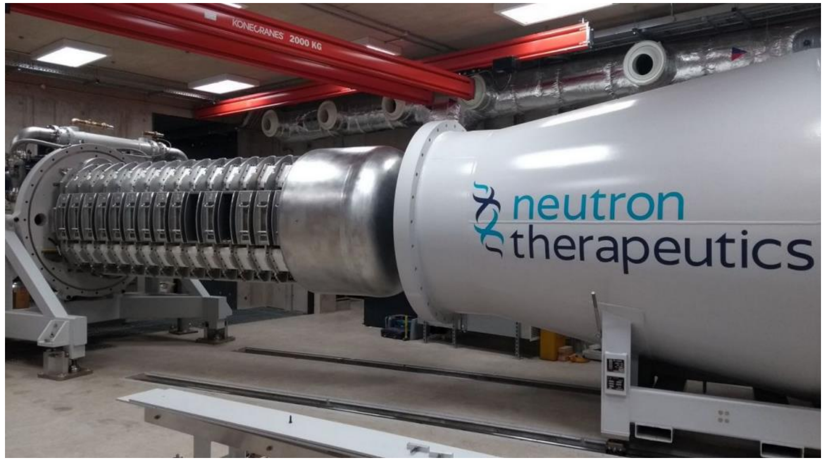
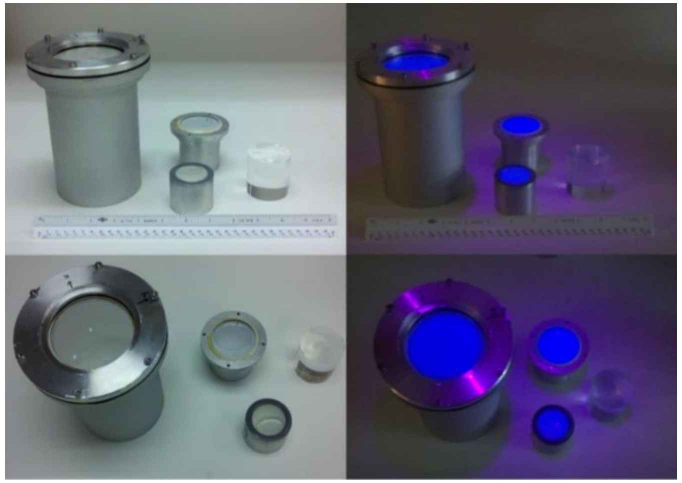
PhD Opportunity

Development of Scintillator-Based Neutron Detectors

- Explore neutron sensitive organic and inorganic scintillators, with the opportunity to utilise the UoB’s accelerator facilities (cyclotron and neutron irradiation facility)
- Investigate current waveform analysis methods, with the view of improving materials’ capability to distinguish between gamma and neutron induced scintillation
- Develop the university’s capacity to produce scintillation materials and detectors
- To apply, please reach out to **j.oneill.3@bham.ac.uk**





Any questions?

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