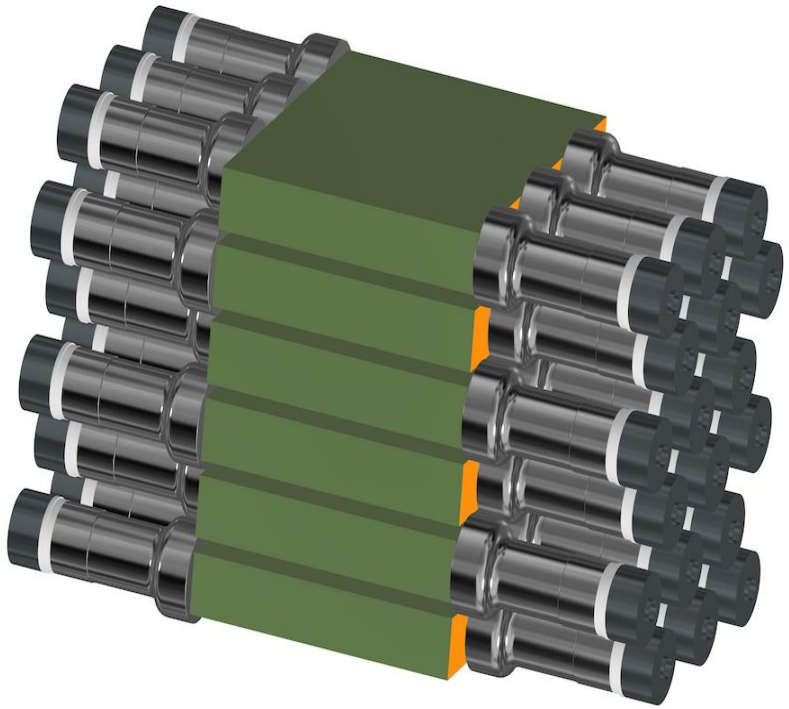
AN LNGS MOBILE NEUTRON DETECTOR (ALMOND): MAPPING AMBIENT NEUTRON BACKGROUND OF GRAN SASSO UNDERGROUND LABORATORY



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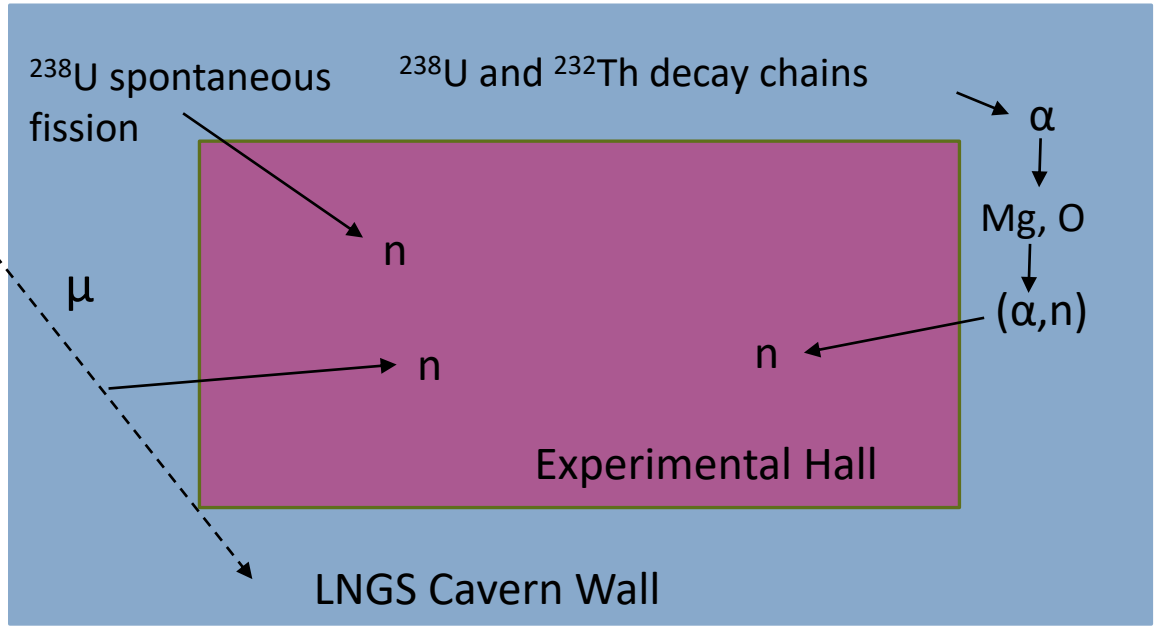
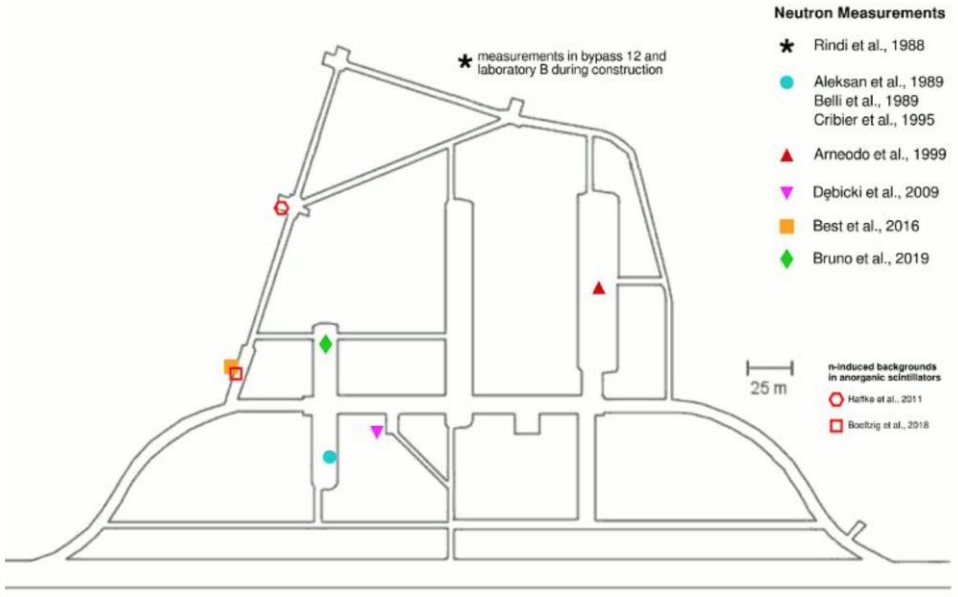
Supported by Federal Ministry of Research, Technology and Space

Melih Solmaz, TAUP Xichang 2025, 25.08.2025

Motivation

- Neutron flux is time and location-dependent
- Direct comparison between the past LNGS measurements is often difficult
- The mobile detector project intended to “draw” the ambient neutron “map” of LNGS
- ALMOND can also be deployed in other underground labs

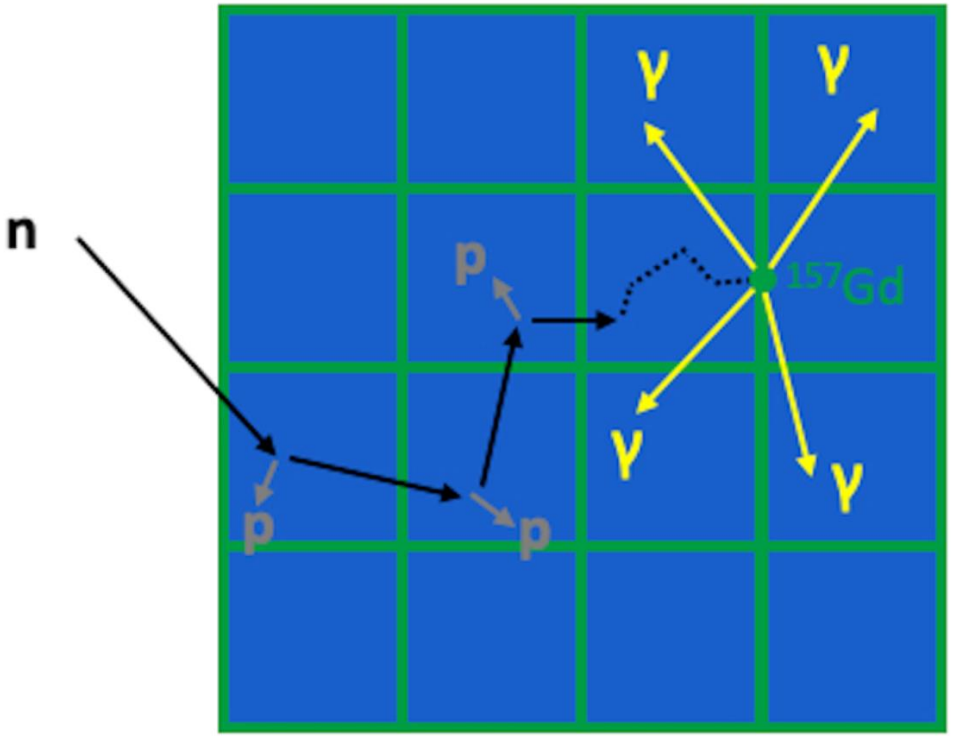


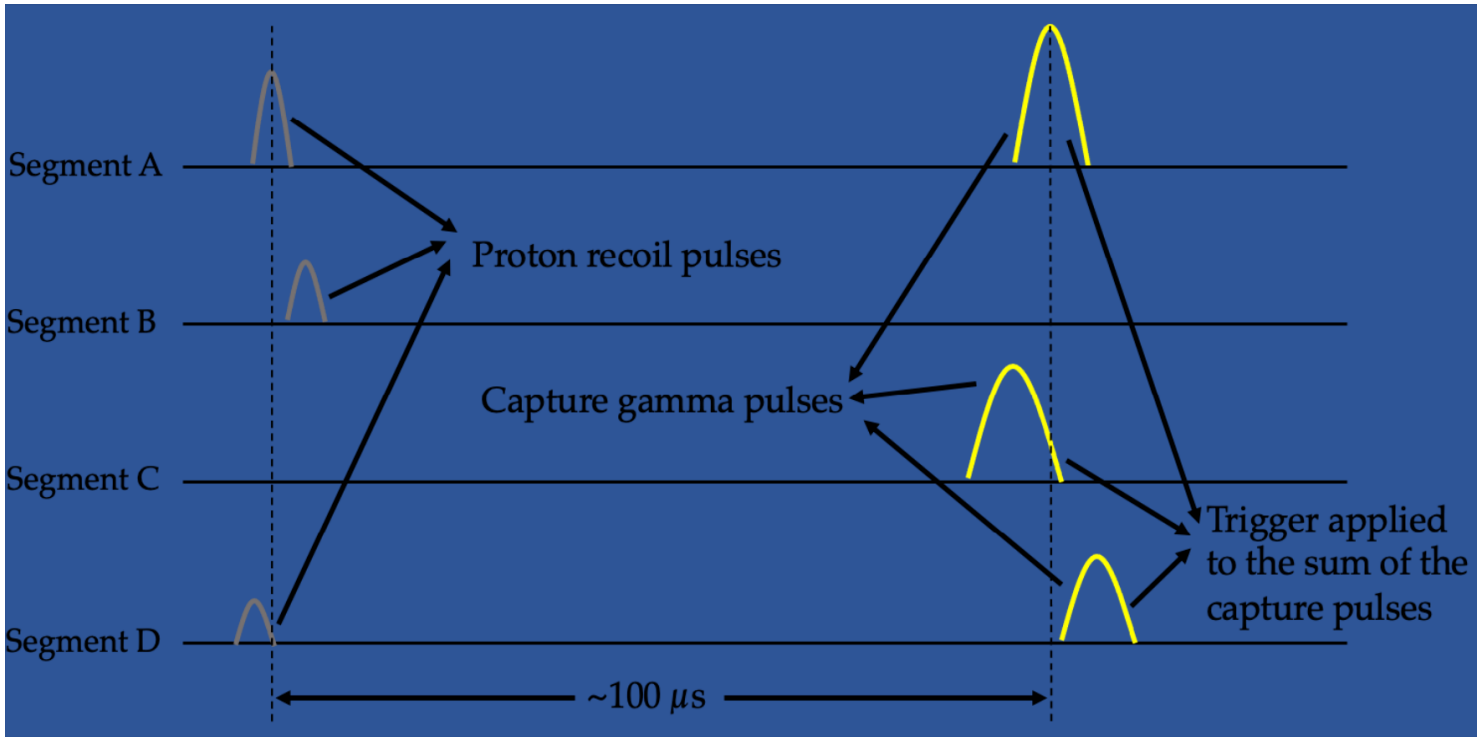


Detection Principle

At LNGS, the ratio of ambient gamma flux to that of ambient neutrons is ≈10^6

$$^{155}\mathrm{Gd} + \mathrm{n} \rightarrow {}^{156}\mathrm{Gd} + \gamma(8.53\,\mathrm{MeV}),\ \sigma \sim 60\,\mathrm{kb}$$
$$^{157}\mathrm{Gd} + \mathrm{n} \rightarrow {}^{158}\mathrm{Gd} + \gamma(7.95\,\mathrm{MeV}),\ \sigma \sim 250\,\mathrm{kb}$$

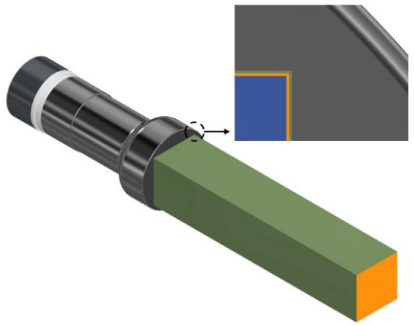


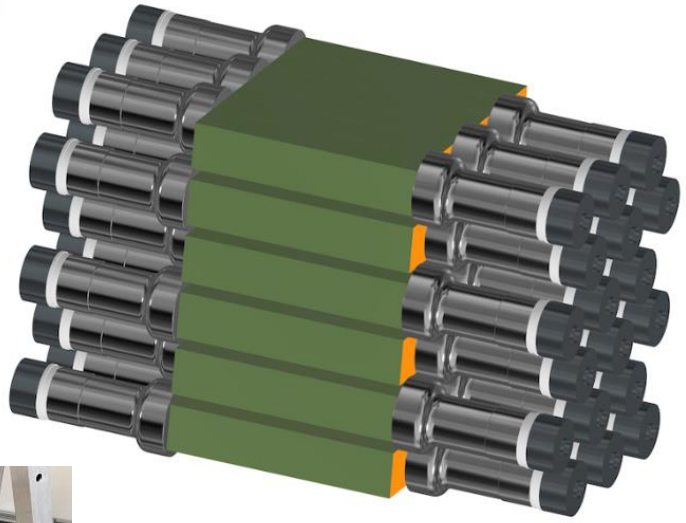


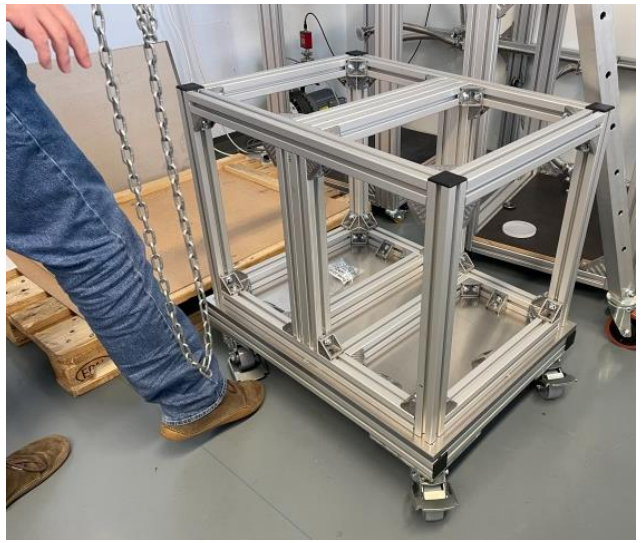
However, this coincidence provides background suppression!!!

Design Layout

- 36 detector modules in a 6x6 arrangement
- 5 cm x 5 cm x 25 cm EJ-200 plastic scintillator
- 3-inch 9302B PMT
- 100 µm gadolinium foils
- 16 mm thick lead shield

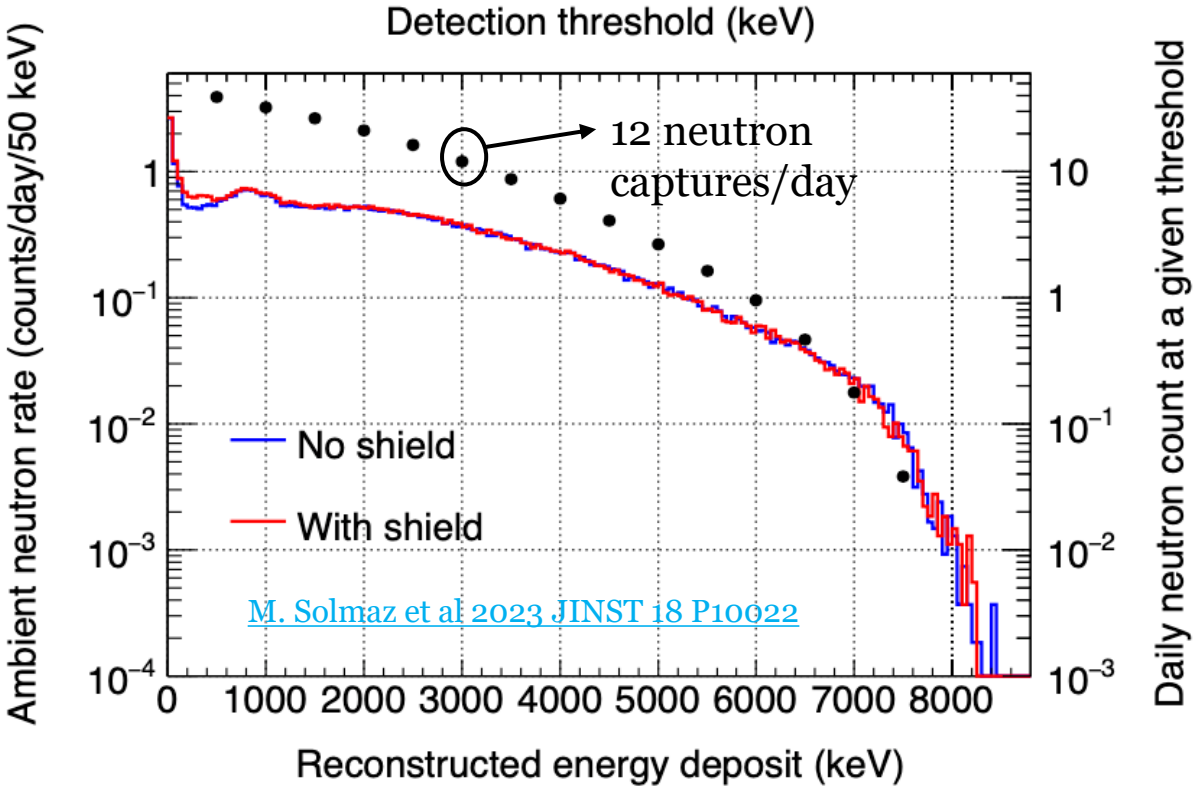




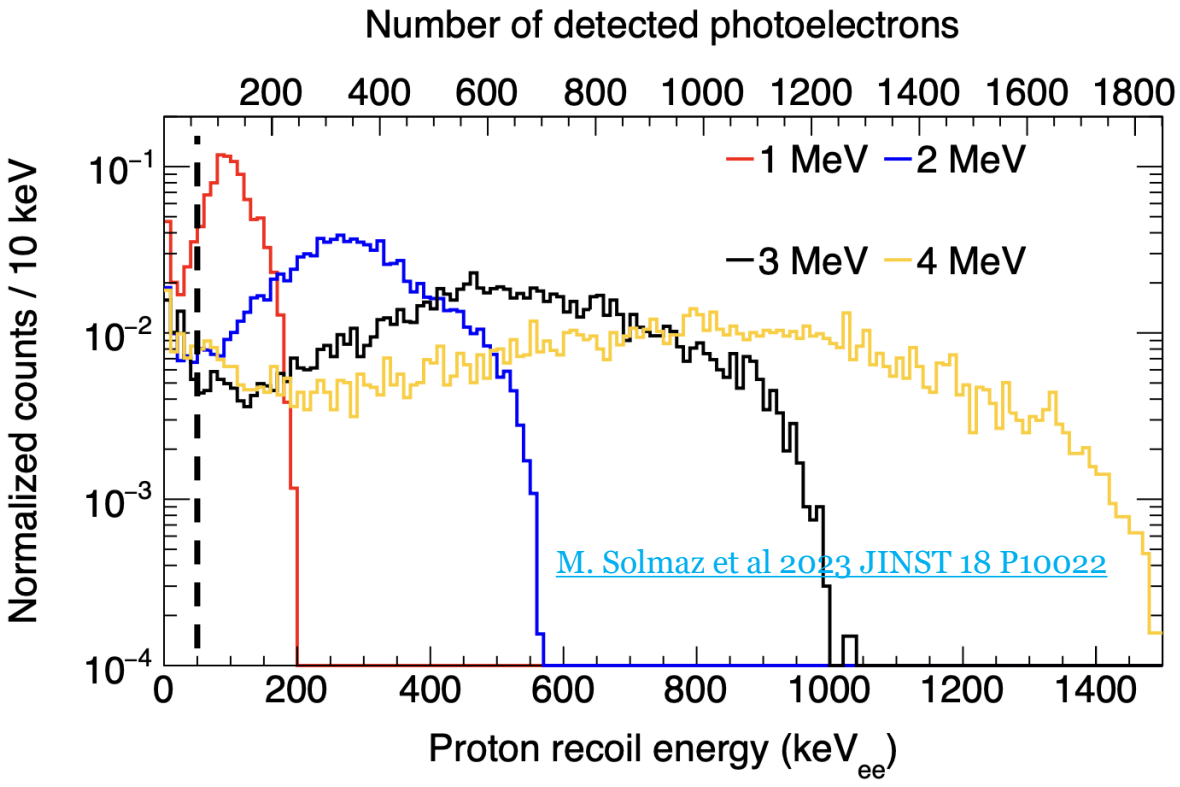


Design Goal

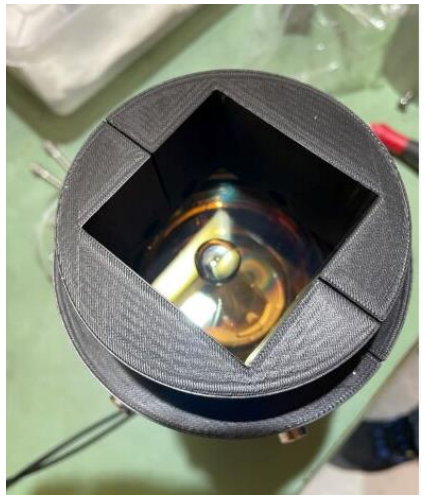
- Assuming proton recoil threshold of 50 keV_{ee}
- >85% of 1 MeV recoils pass the threshold
- Detection of ≈10 neutrons/day

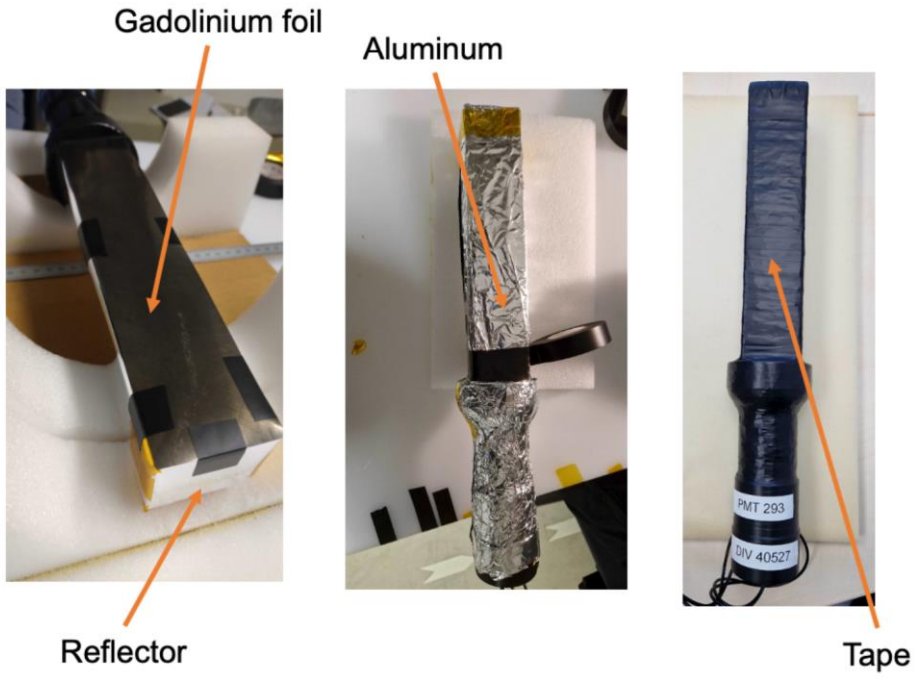


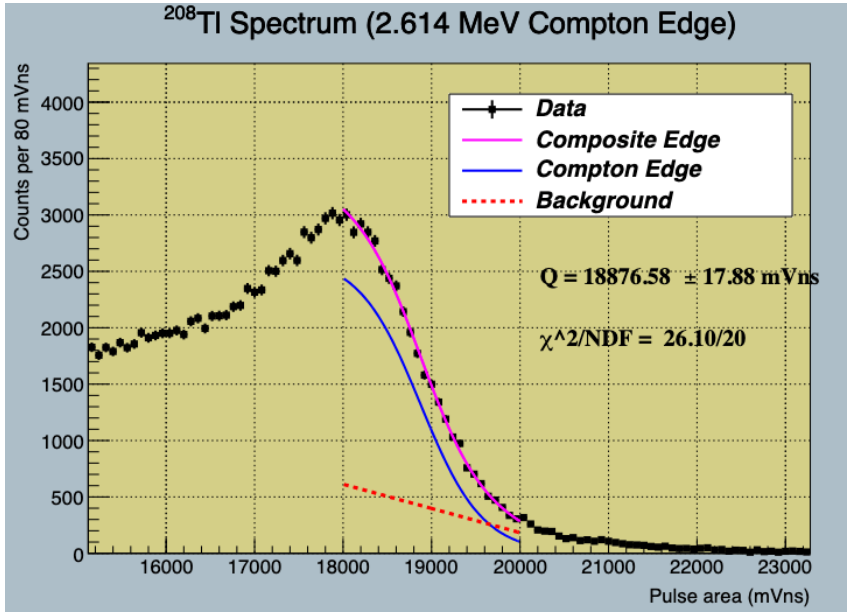
Neutron flux of 0.42 x 10^{-6} /cm²/s assumed

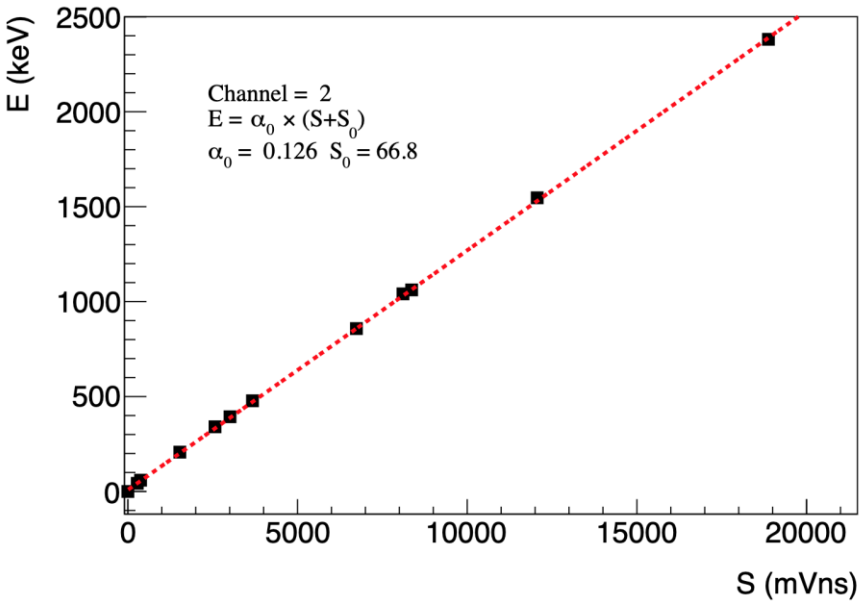


Detector Construction





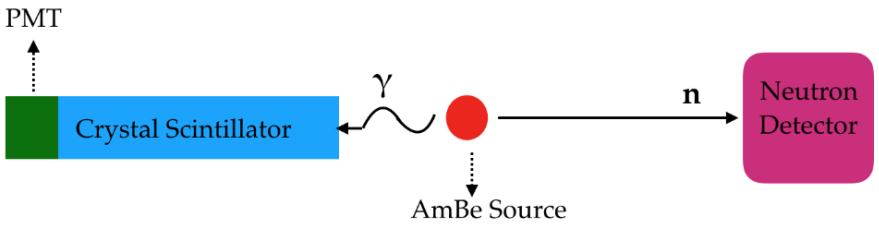


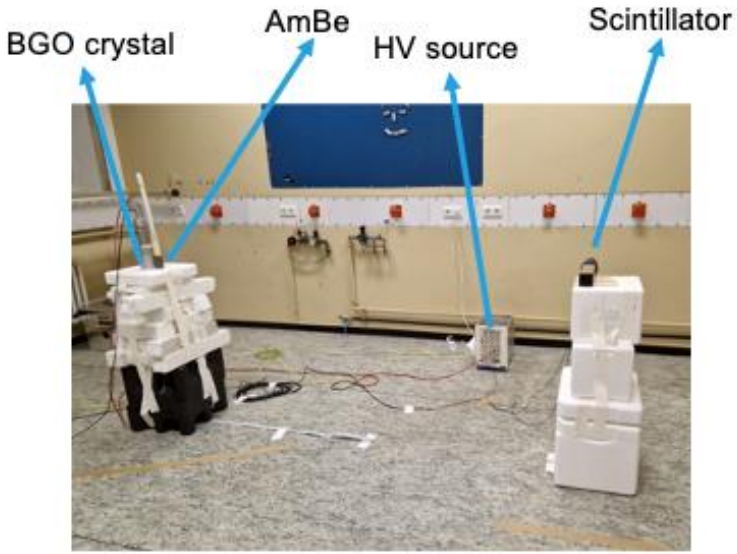


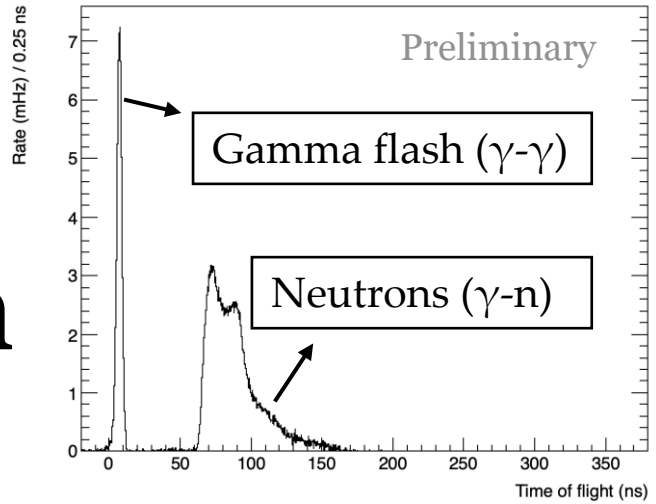
Calibration with Gamma Sources

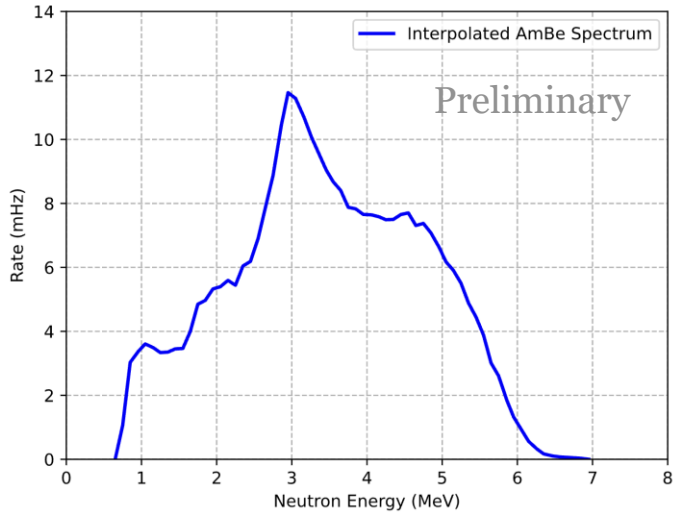
- ^{241}Am (59.5 keV)
- ^{133}Ba (0.356 MeV)
- ^{22}Na (0.511 MeV, 1.275 MeV)
- ^{137}Cs (0.662 MeV)
- ^{60}Co (1.17 MeV and 1.33 MeV)
- ^{207}Bi (0.570 MeV, 1.064 MeV and 1.770 MeV)
- ^{232}Th (2.614 MeV)

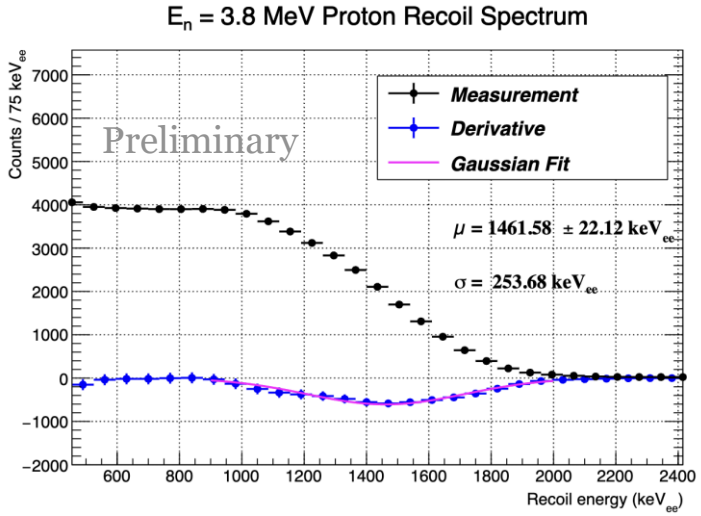
Proton Recoil Characterization

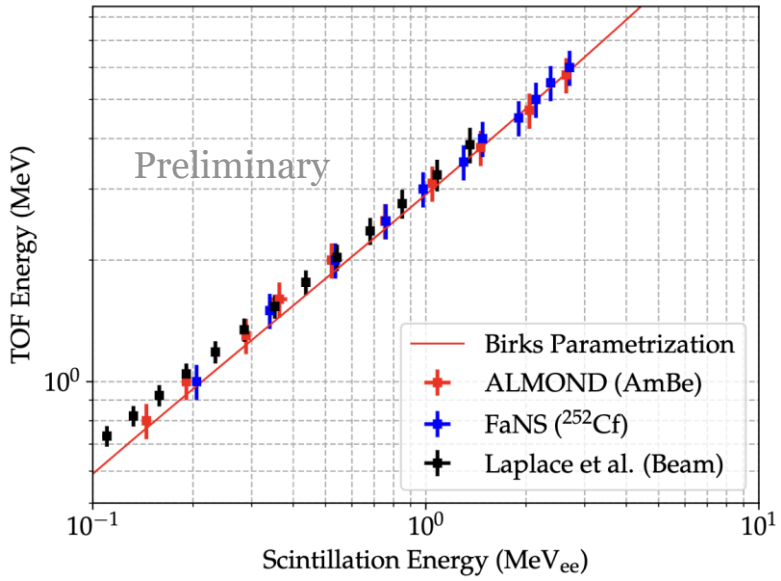




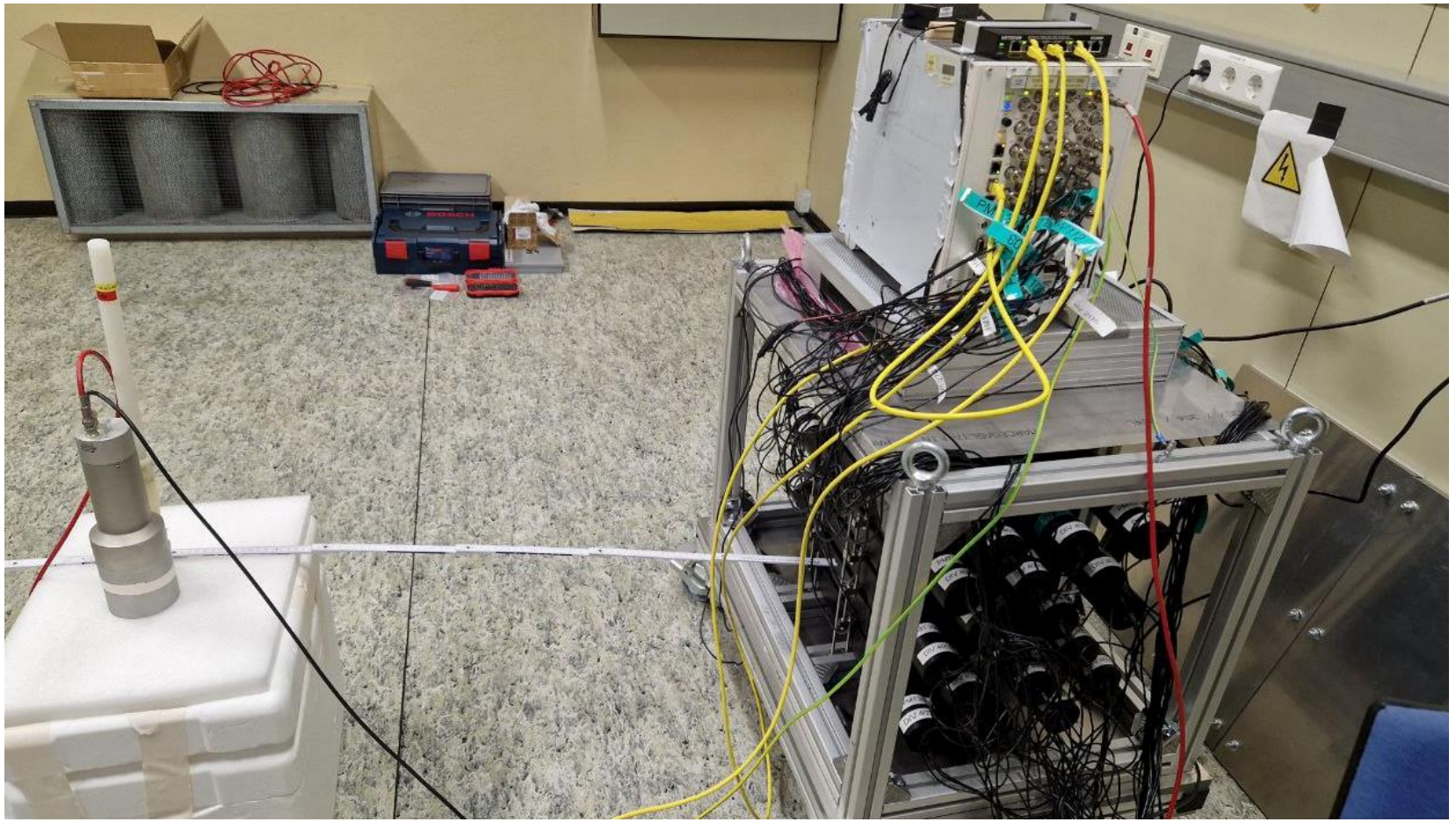






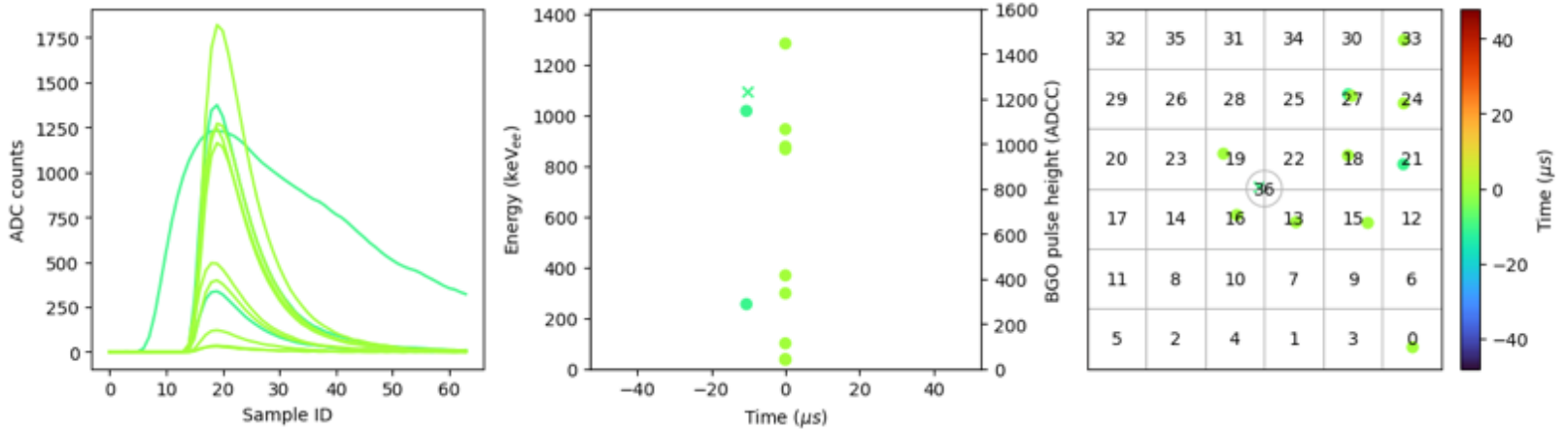


AmBe Neutron Capture Calibration at KIT

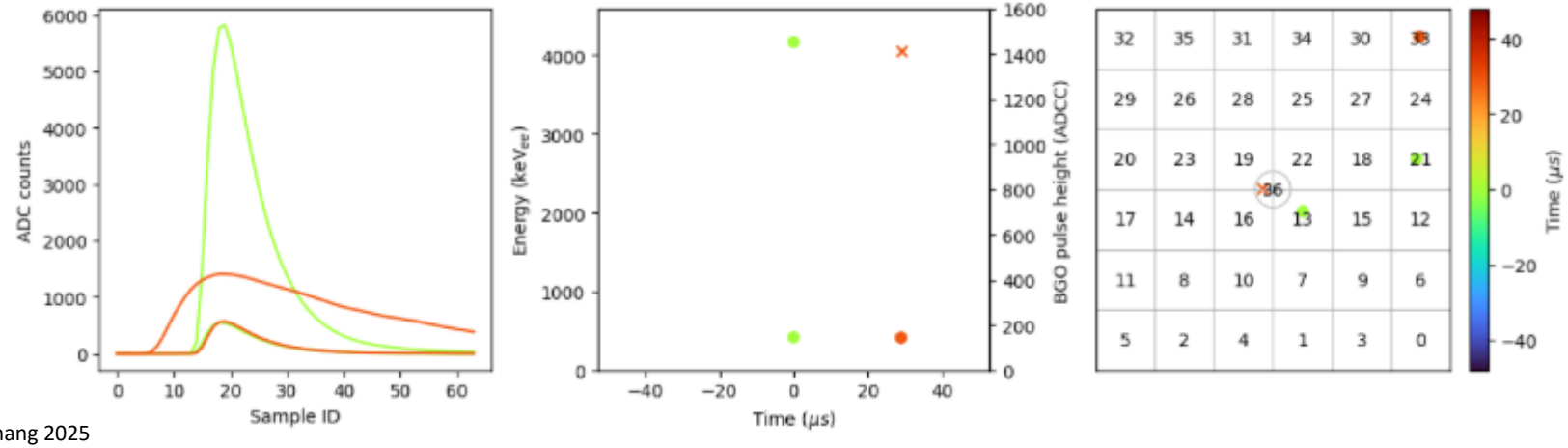


Event Identification

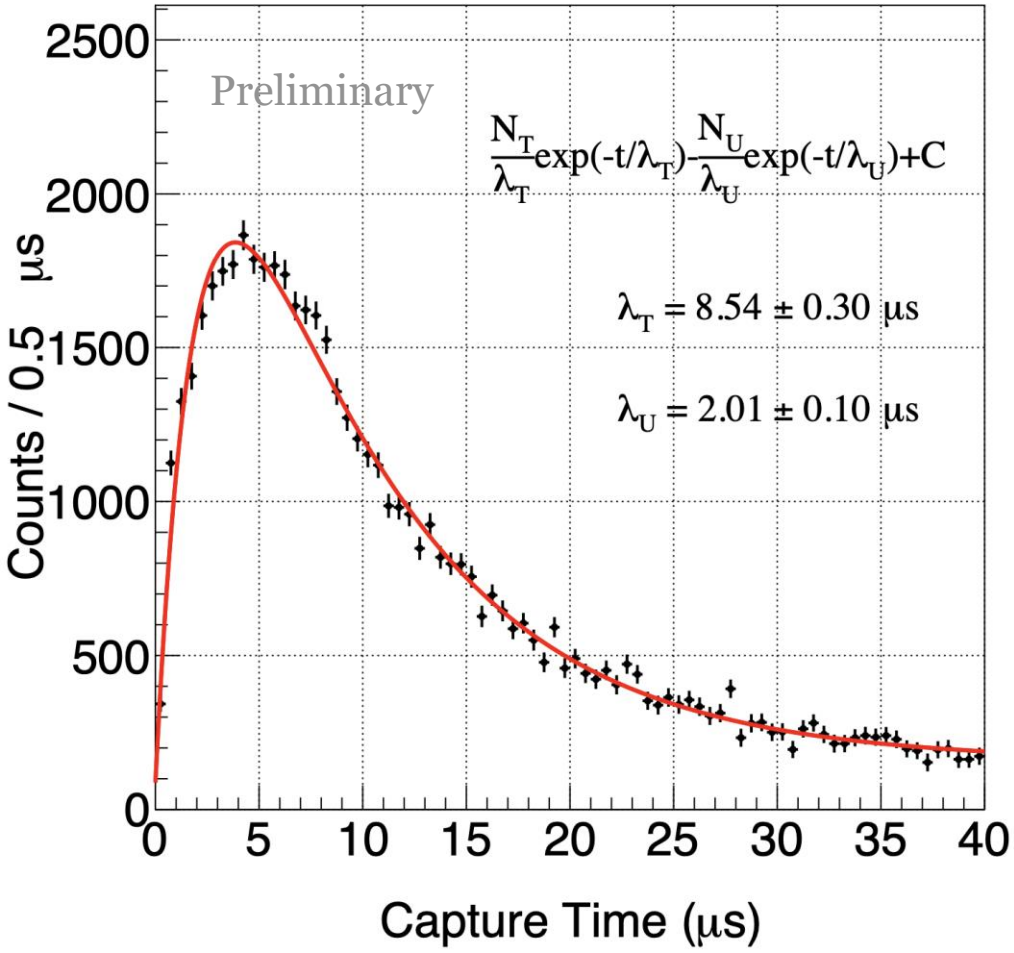
Signal region event

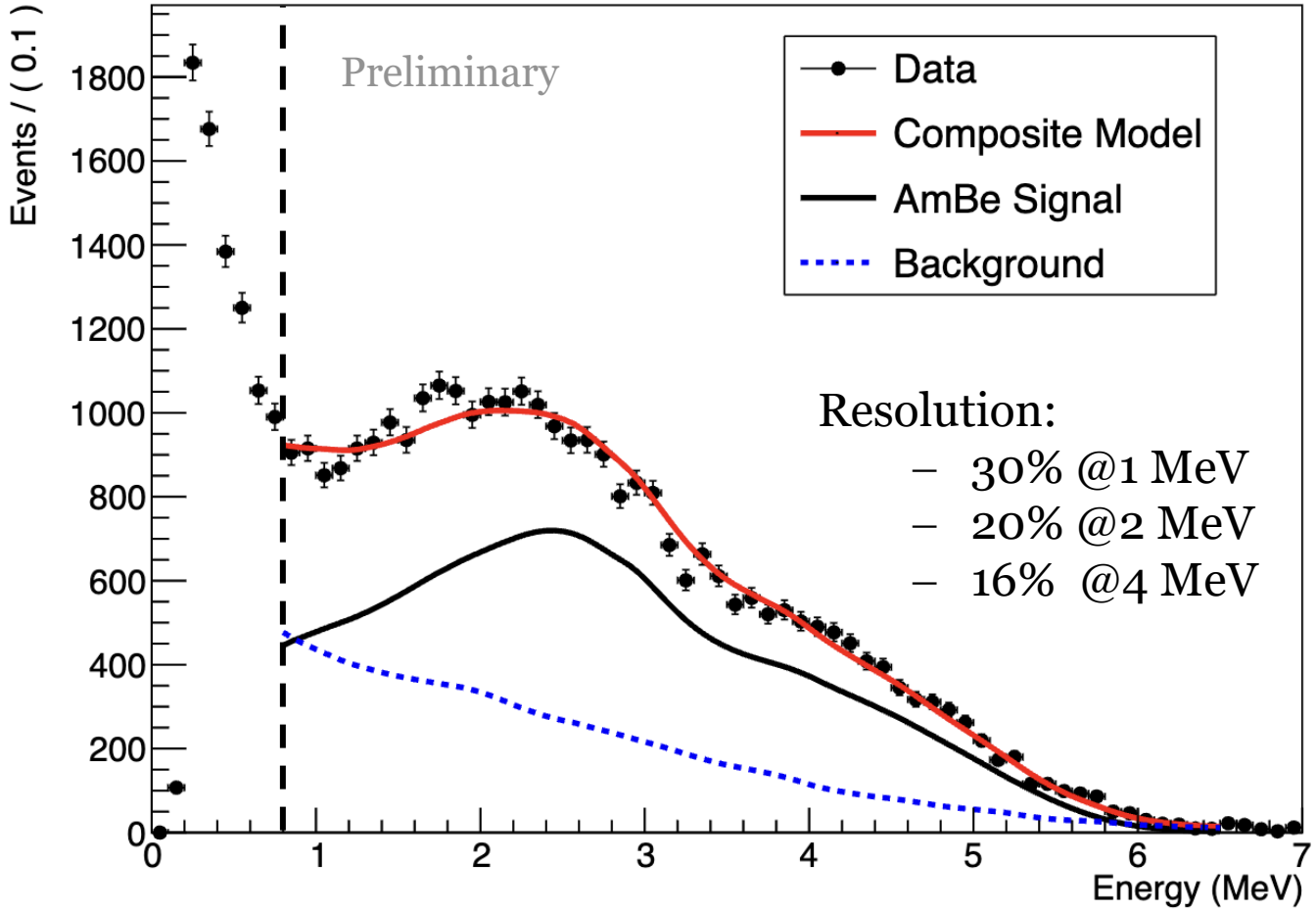


Background region event

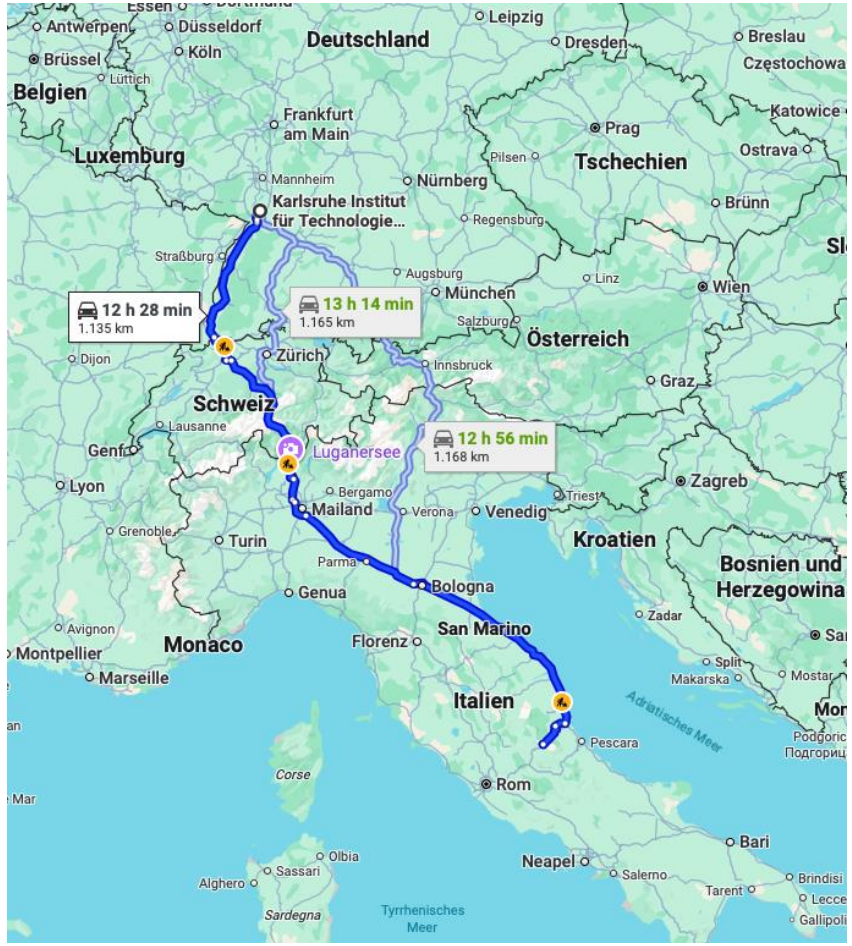


AmBe Calibration Results





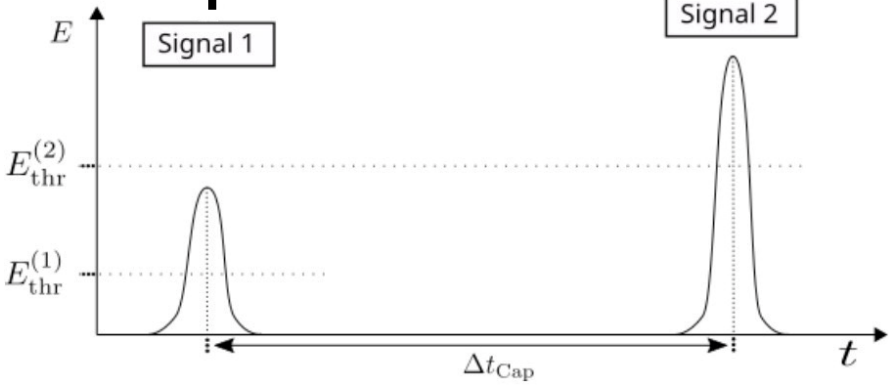
Commissioning of ALMOND at LNGS

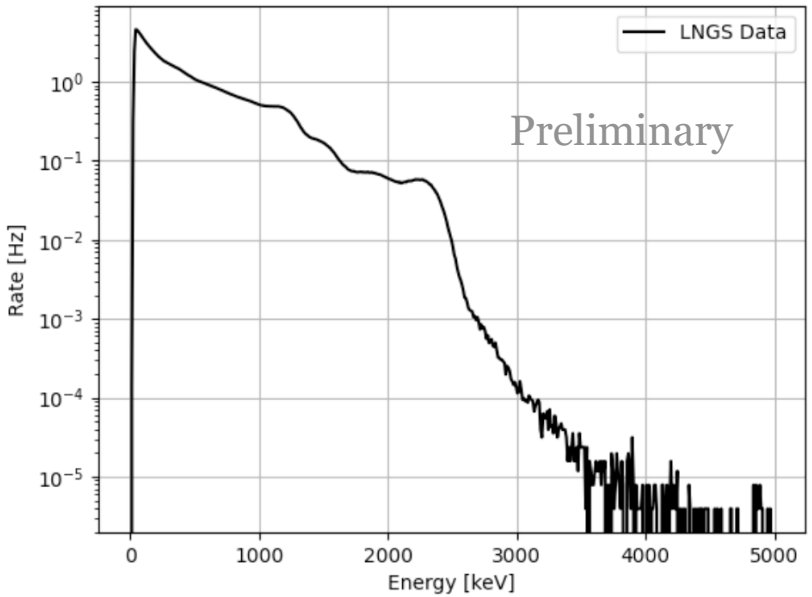


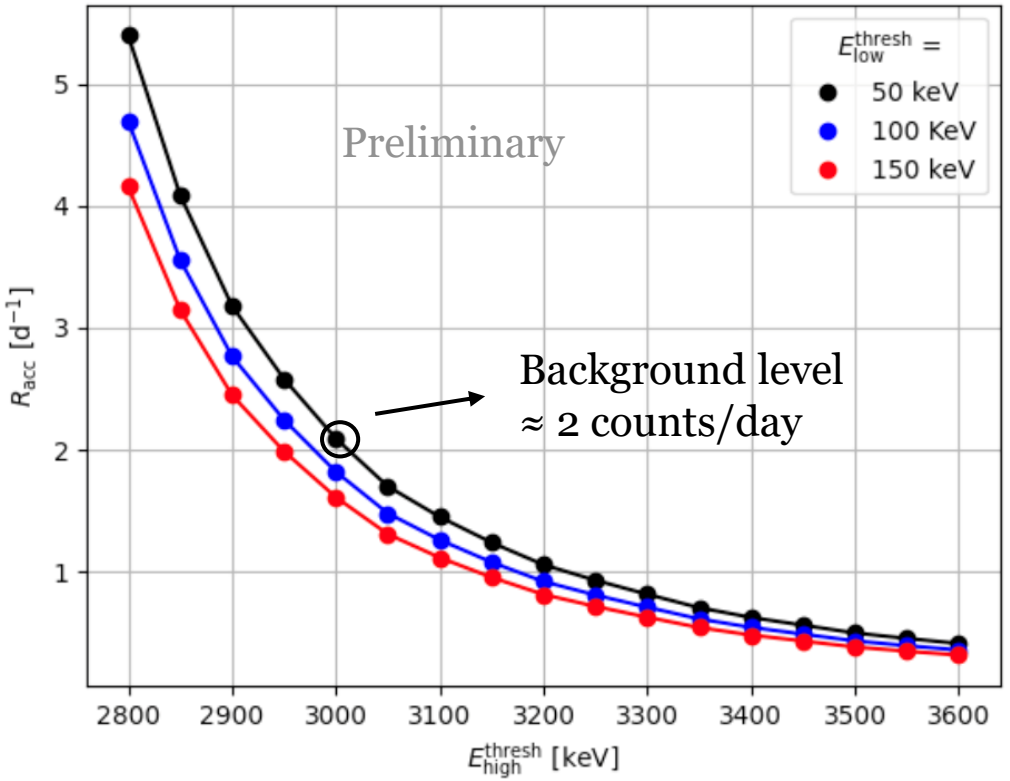
Gamma Background at LNGS

Fake recoil pulse: Ambient gamma (>50 keV)

Fake capture pulse: Pile-up of ambient gammas (>3 MeV)

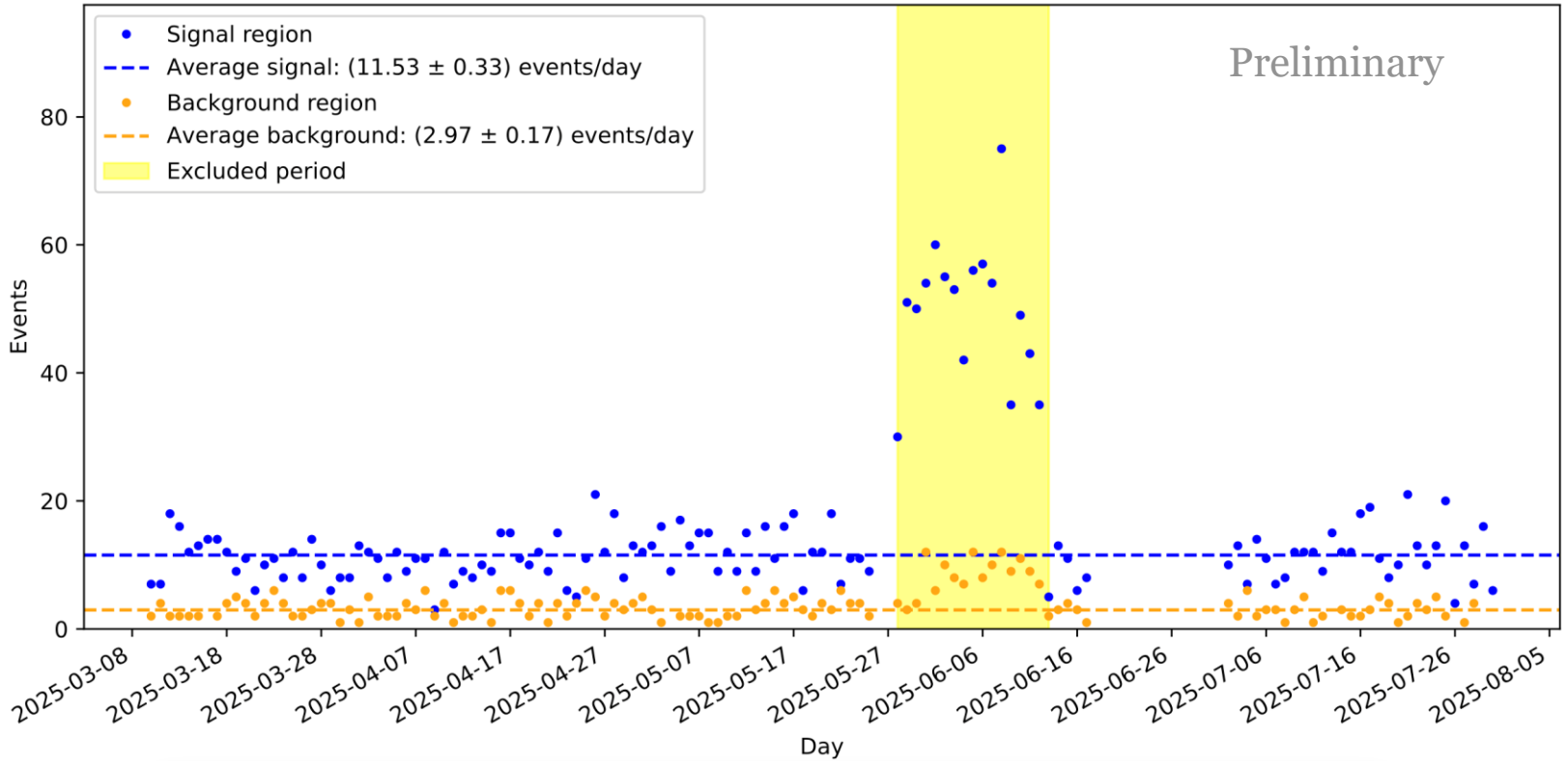


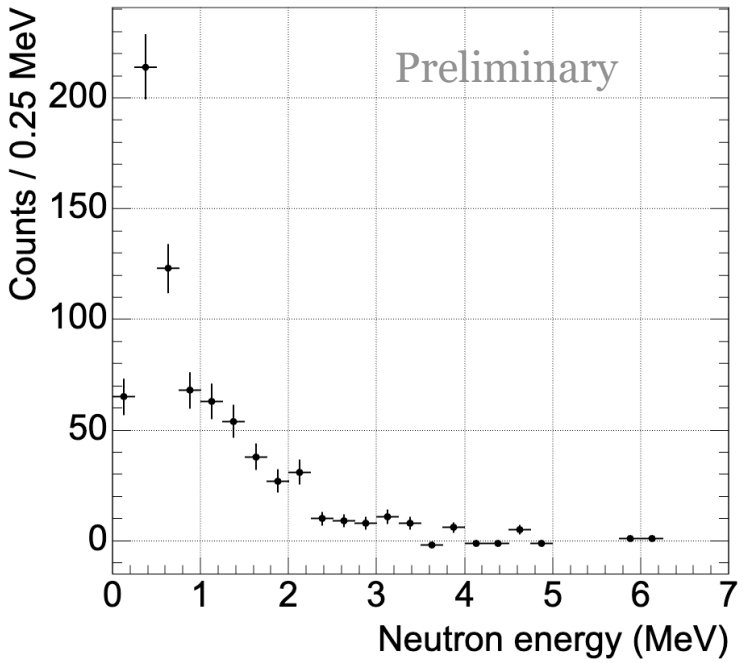




Gamma background mitigation is plausible

Ambient Neutron Measurement in Hall A





Conclusion

- Various gamma and neutron calibrations were carried out for the realization of the project
- Initial measurements show that the design was a success
- Ambient neutron measurement in Hall A was completed
  - The analysis to be refined
- **Measurement in Hall C currently taking place**
- Detailed analyses to benchmark neutron efficiencies and obtain the neutron flux numbers are ongoing

BACKUP SLIDES

Measurement with Polyethylene Shield

- Assessment of “internal” neutron background
- 20 cm polyethylene shield in all directions
- A month-long measurement campaign
- Preliminary results:
  - Signal region: 2.14±0.27 counts/day
  - Background region: 1.17±0.20 counts/day
  - Internal background: 0.97±0.34 counts/day

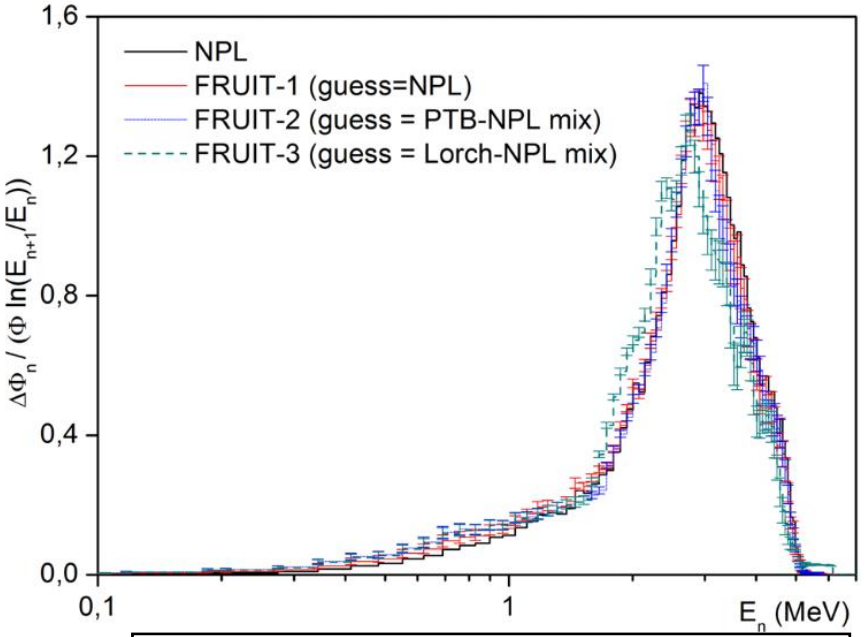
↓

NEGLIGIBLE

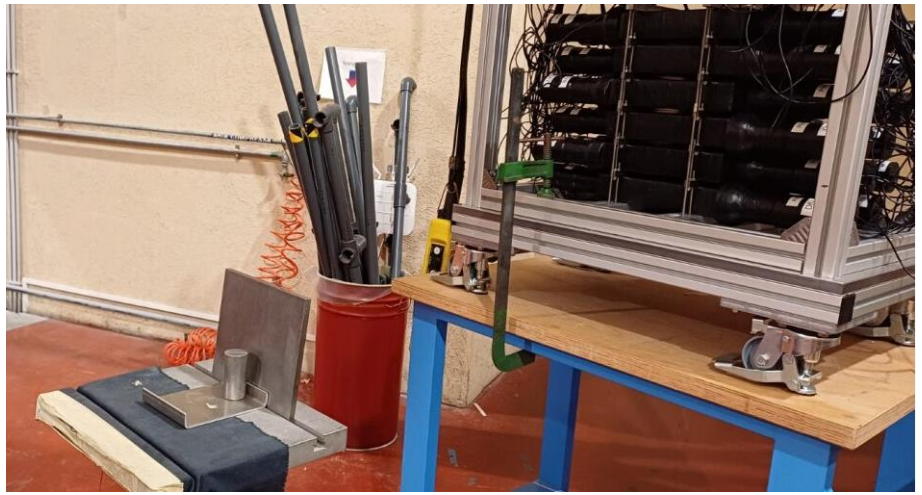
Neutron Calibrations at Frascati

DD Neutron Generator at 2.4 MeV

DD Calibration Run

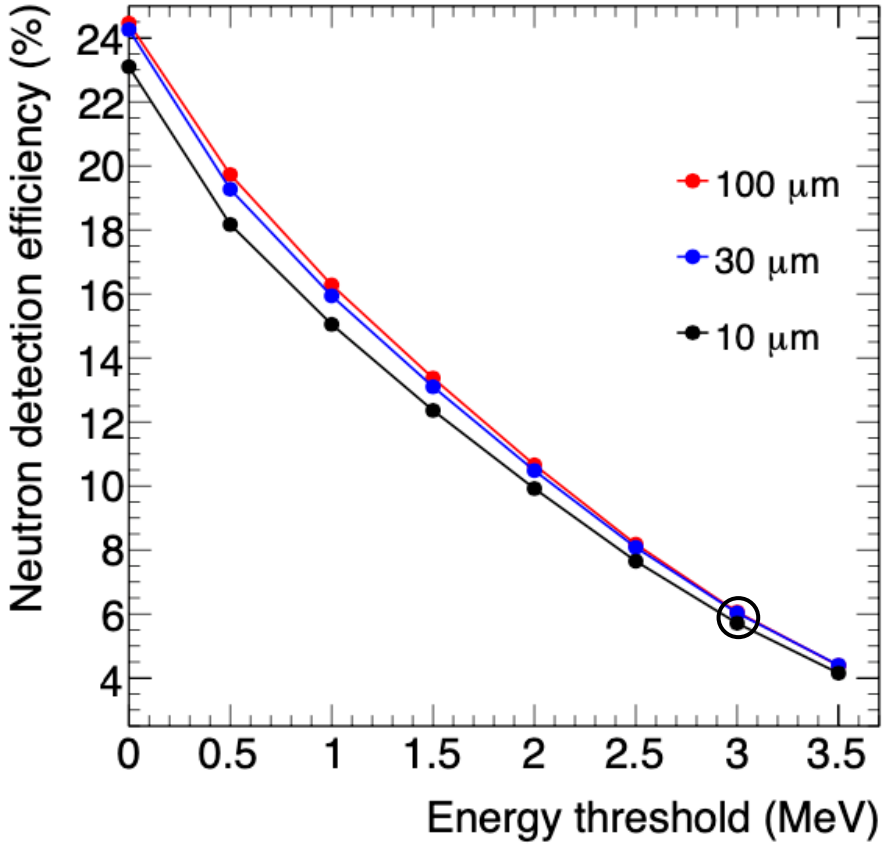


Frascati AmB Source Spectrum

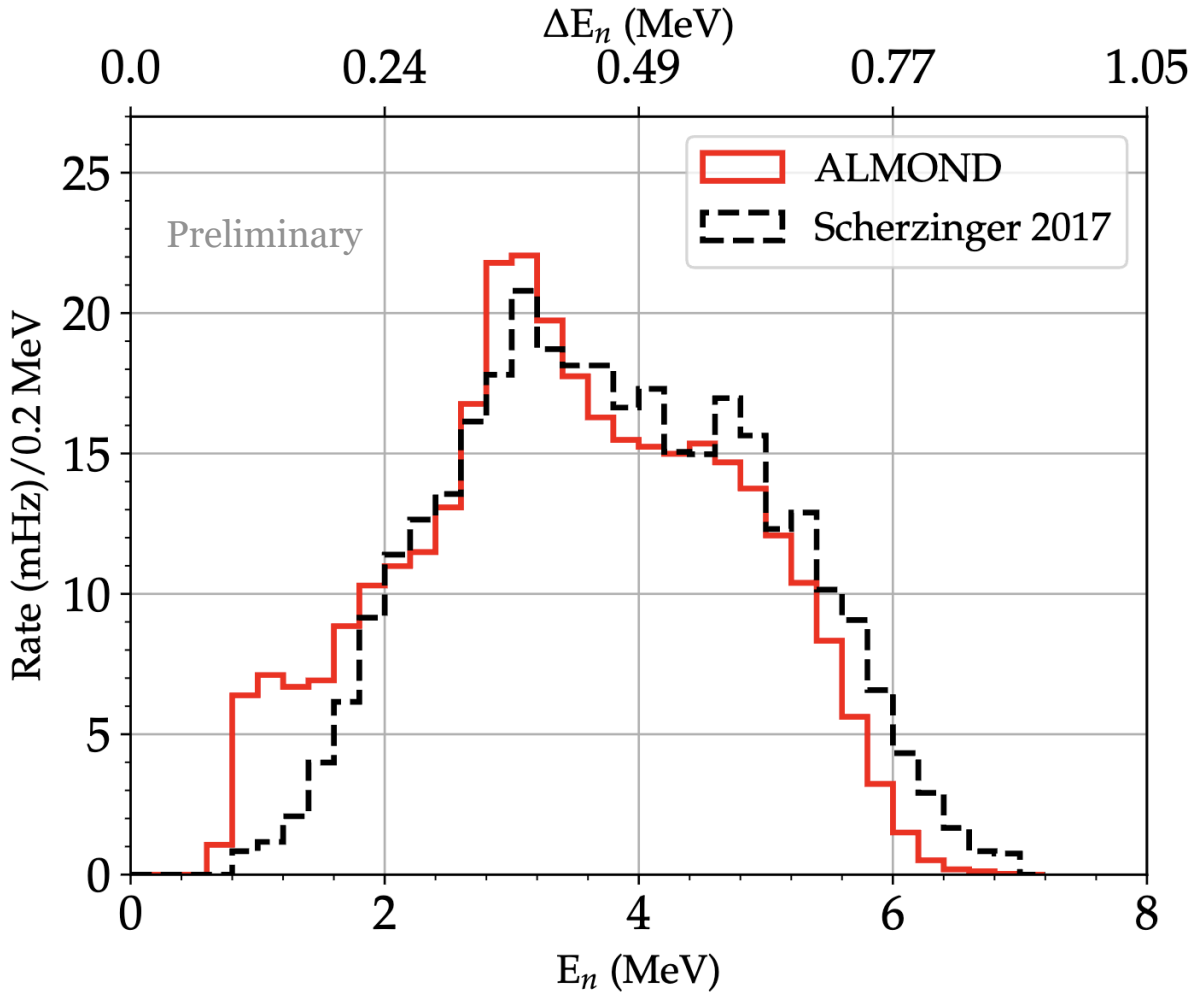


AmB Neutron Calibration Run

M. Solmaz et al 2023 JINST 18 P10022



^{252}Cf source simulations


ΔE$_n$ (MeV)
0.0
0.24
0.49
0.77
1.05
Preliminary
ALMOND
Scherzinger 2017
Rate (mHz)/0.2 MeV
0
5
10
15
20
25
0
2
4
6
8
E$_n$ (MeV)