

# Nearfield Antineutrino Detector Optimization

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# Introduction

- Rising need for remote and live reactor monitoring.
- Short baseline reactor antineutrino detection poses a potential solution
- PROSPECT and similar projects created demand for field demonstration of the technology



# Background: Source

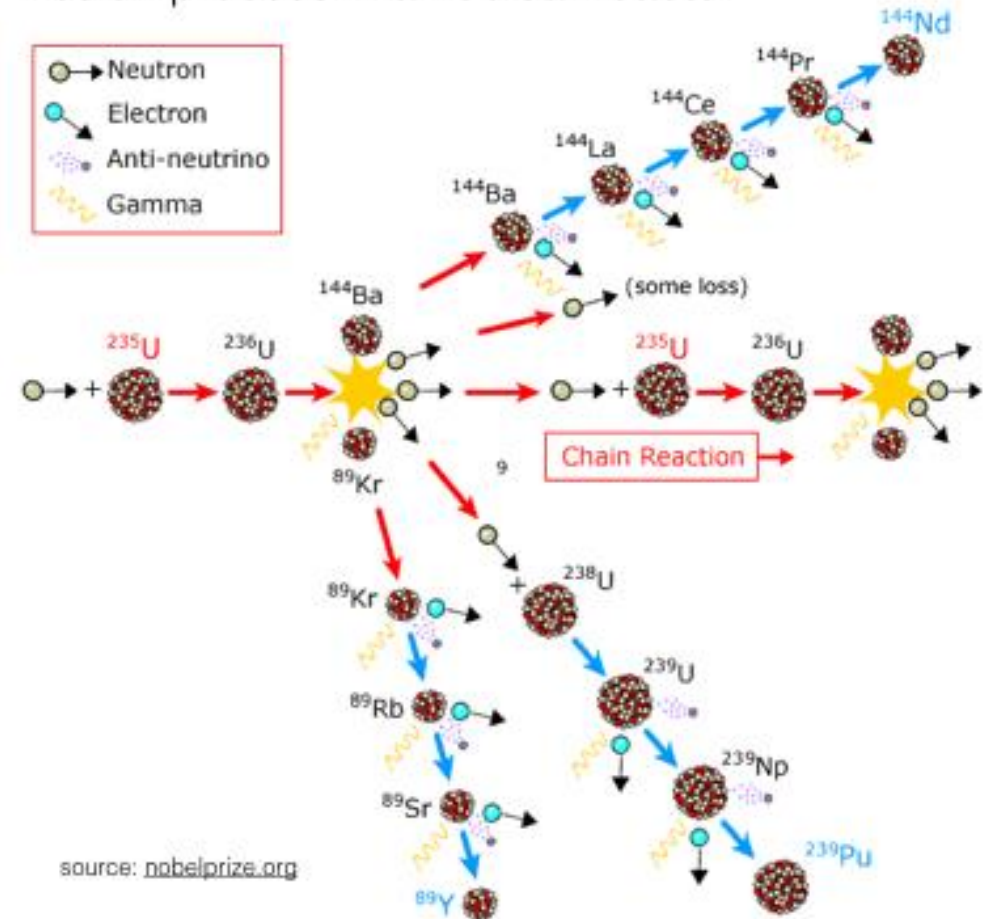
- 1 GW reactor produces  $10^{20}$  antineutrinos per second
- Inverse Beta Decay (IBD) cross section on  $10^{-44}$  cm<sup>2</sup>
- Antineutrinos detection can happen with proton rich materials
- Difficult to detect but even more difficult to spoof



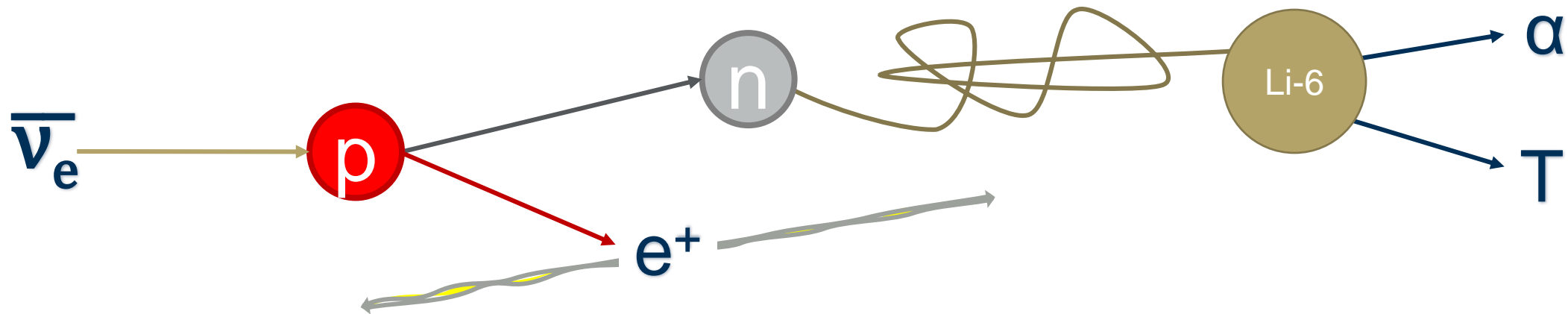
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fission process in a nuclear reactor



# Background: Detection

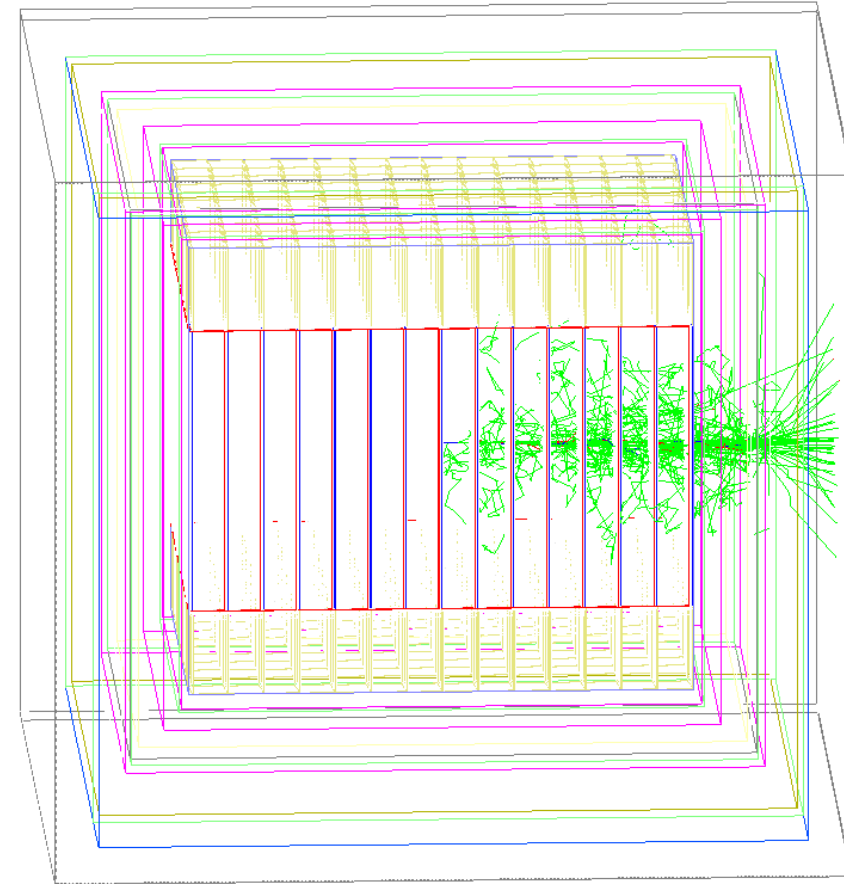


***IBD based detection uses Li-6 doped scintillators to capture all correlated aspects of the rare event***

# Background: Detection

- Intense shielding is necessary to reduce background events
- A 1-ton detector is needed to capture sufficient events
- The system must be well characterized to distinguish true IBD events from IBD-like events

**Optimization focuses on characterizing IBD like events**



*Simulation of PROSPECT with a single positron*

# Simulation

- High Fidelity analysis pipeline
- A GEANT4 based neutrino toolkit  
Scint-G4 allows high-fidelity modeling and IBD events.
- Data Analysis Framework Toolkit – DAFT
- Process data and simulation in the same manner

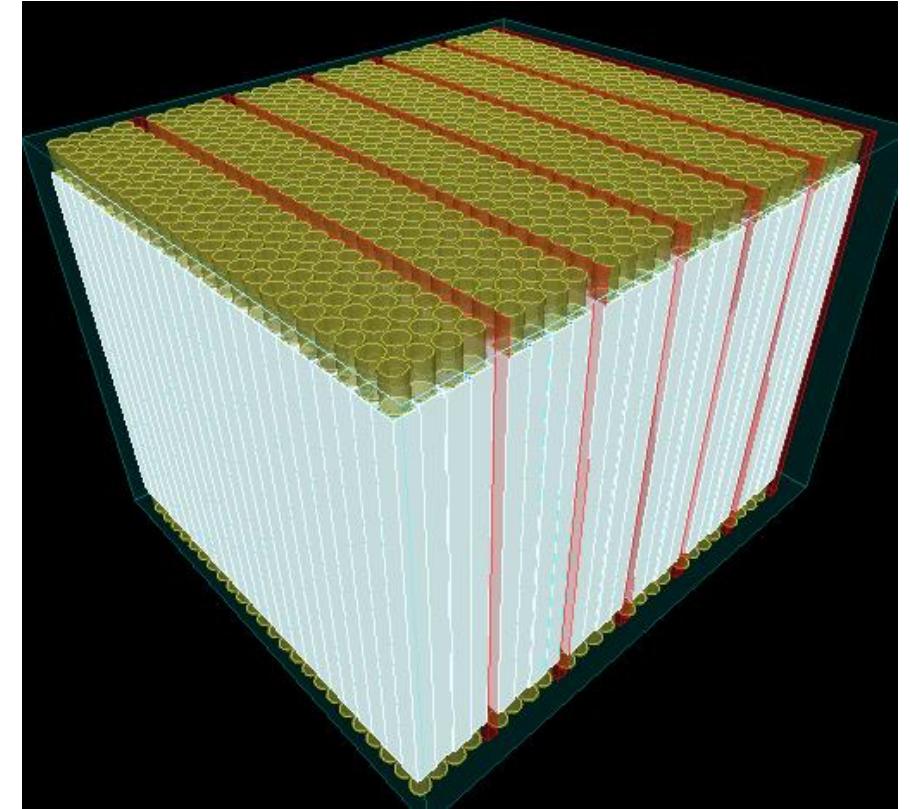


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# Mobile Antineutrino Demonstrator (MAD)

- Main detection system for the MAD collaboration
- 2D detector in the design stage
- Design like Prospect
  - Plastic Li-6 loaded scintillators
- Focus on detected energy/ position shifts according to mechanical choices.
  - Support, gaps, stagger

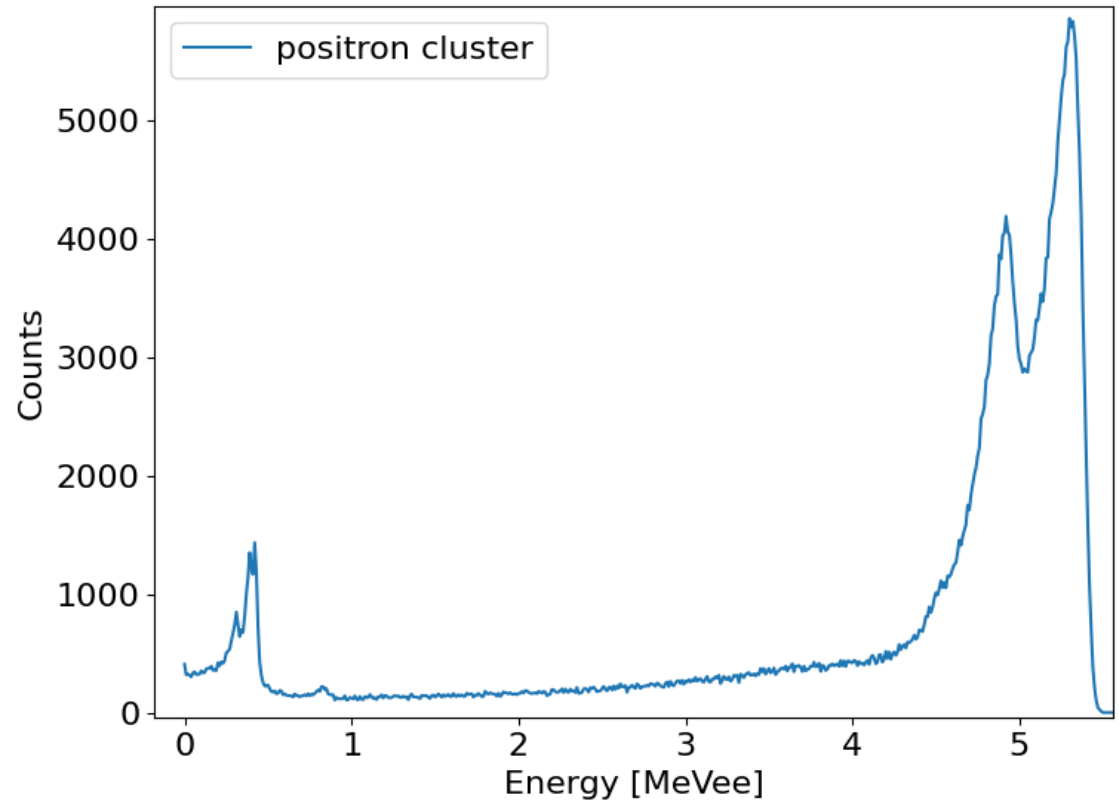


***24X24 Scintillators with  
Mechanical Features***



# MAD: Isotropic Positron Primaries

- Desire the energy resolution and energy response of scintillators
- Clustering the energy deposited across all bars allows us to reconstruct the original energy
- Electrons are the easiest case
- Positrons and Cosmic neutrons have longer chain reactions to follow



***Spectrum from 4.4 MeV  
positron primaries***

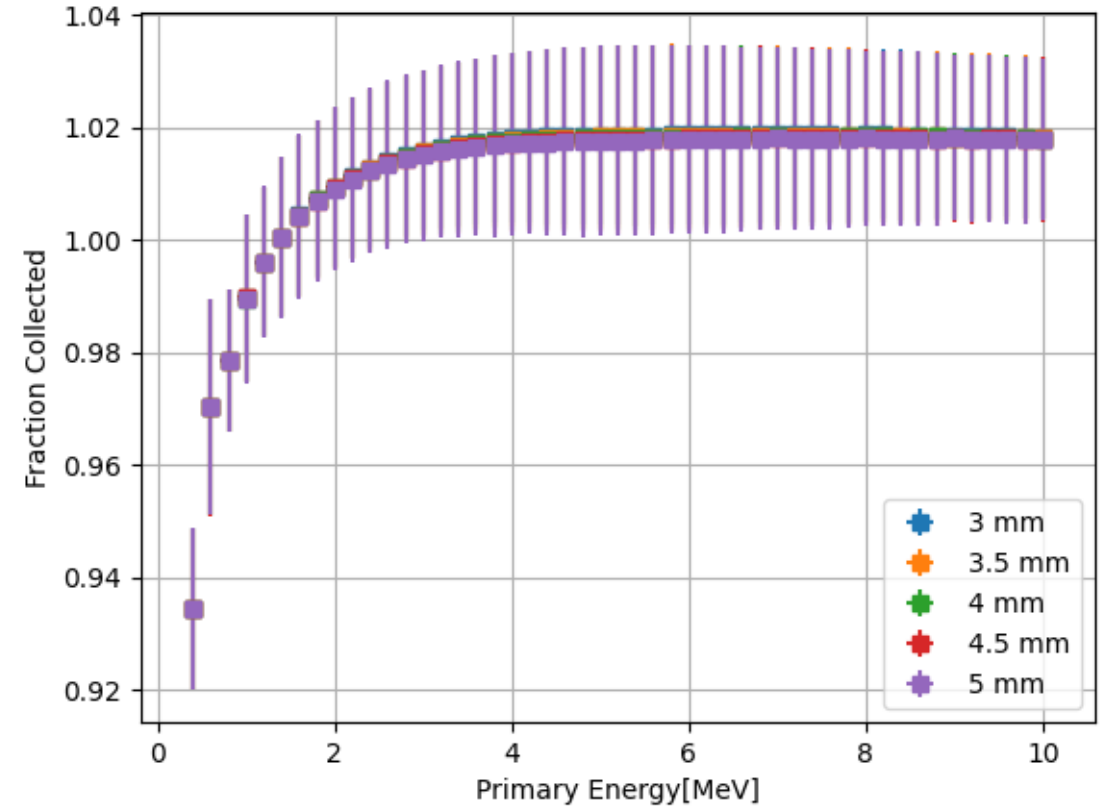
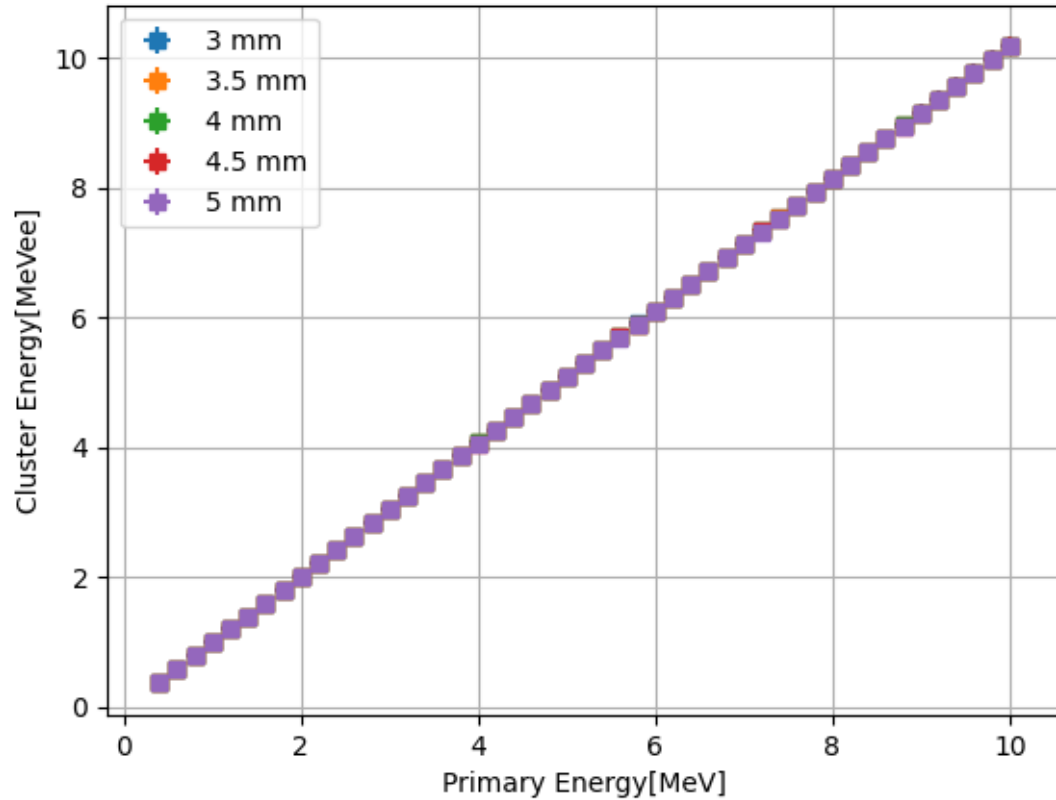


# MAD: Isotropic Electron Primaries



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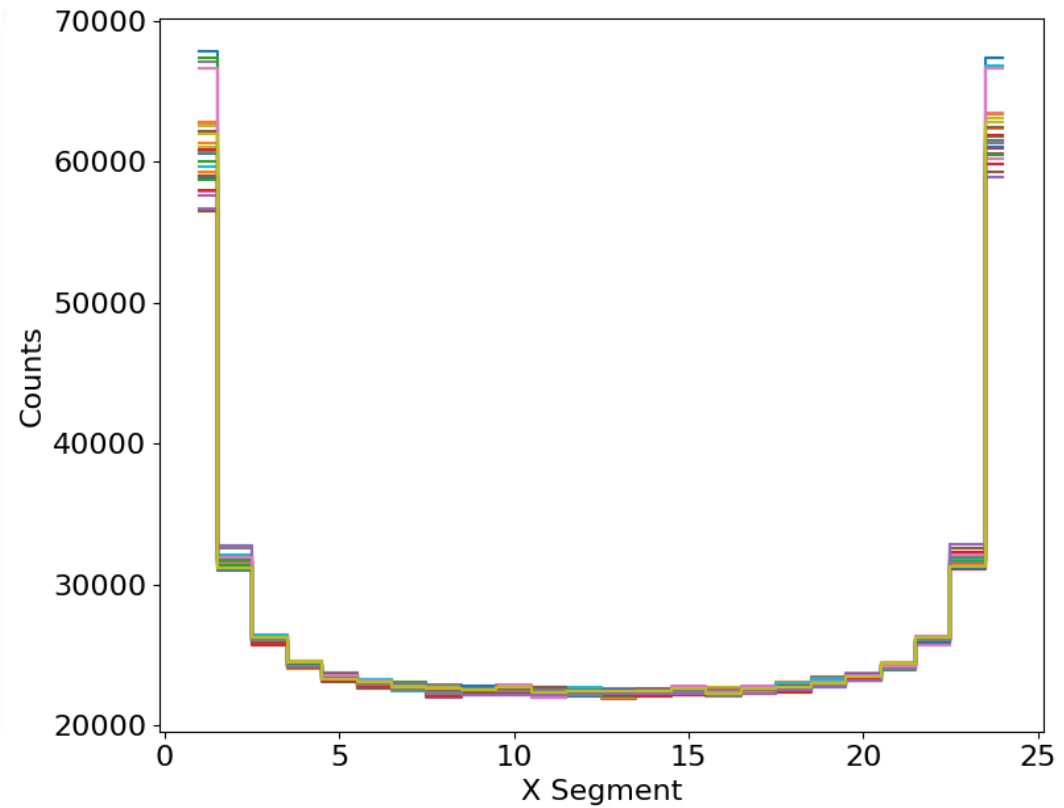
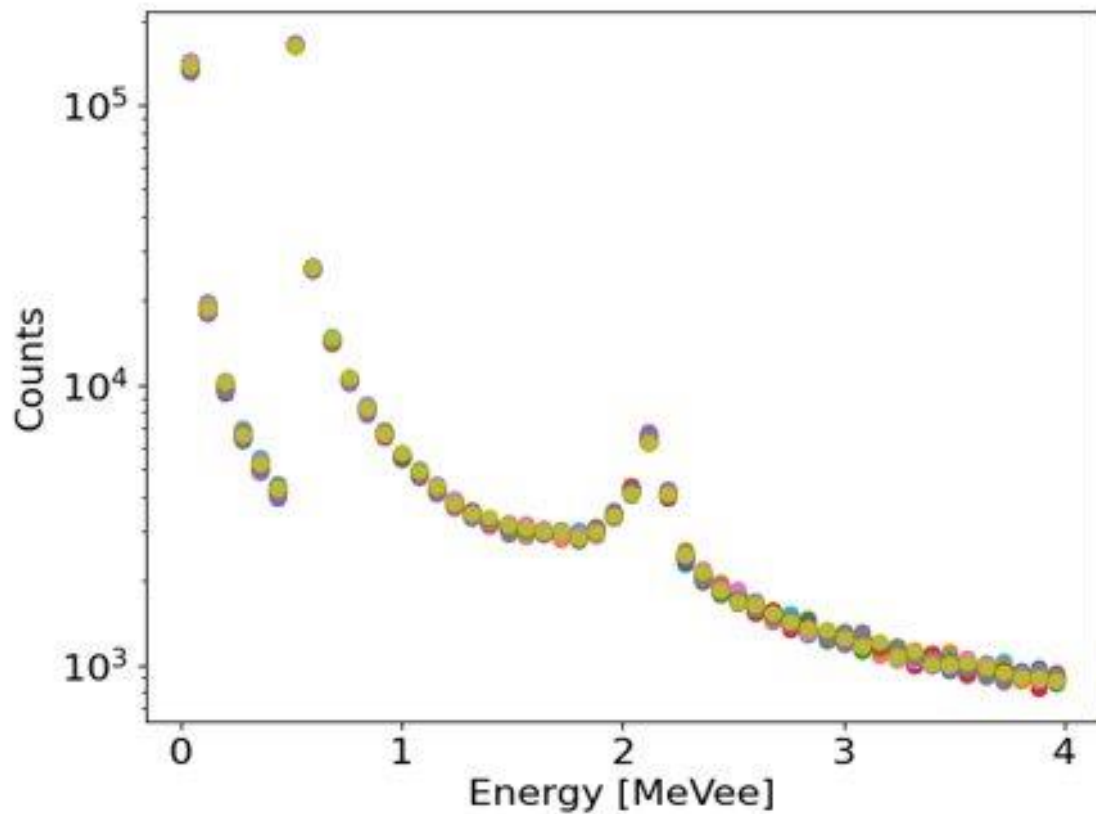
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Electron response in the detector appears to be minimally affected by the gaps between bars

# MAD: Cosmic Neutron Primaries

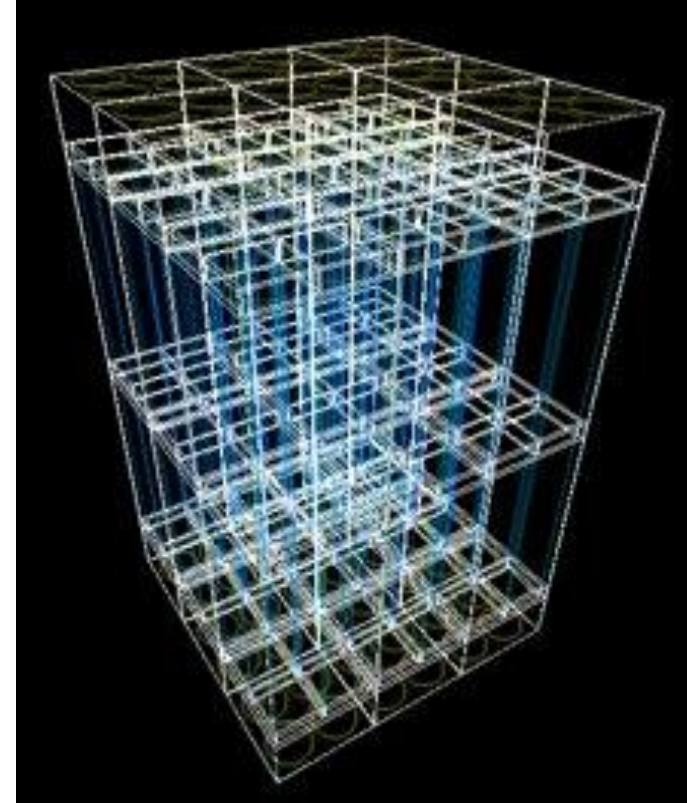
Cosmic Neutron Spectrum and Deposition for Varying Stagger, Gap, and Structural Aluminum Thicknesses



\*Shielding has not yet been designed

# Reactor Operations Antineutrino Detection Surface Testbed Rover (ROADSTR)

- Fully realized detector
- High Fidelity Simulation of Roadstr for background
- Characterize and validate detector response
  - Detection Efficiency
  - Energy Resolution
  - Lithium Rate
- Provide accurate background model for MAD



***Full Simulation of ROADSTR***

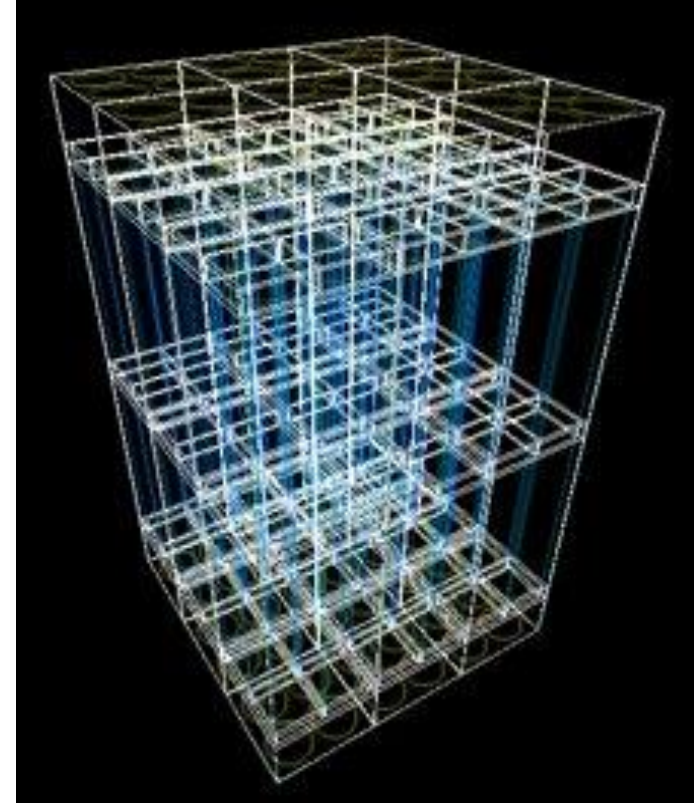
# ROADSTR Simulation



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- Study of background cosmic neutrons and rays with different shielding
  - Lead
  - Polyethylene
  - 5% Borated Polyethylene
- Scint-G4 and DAFT analysis pipeline
  - Cosmic Ray Shower generators
  - Cosmic Neutron generators



***Full Simulation of ROADSTR***

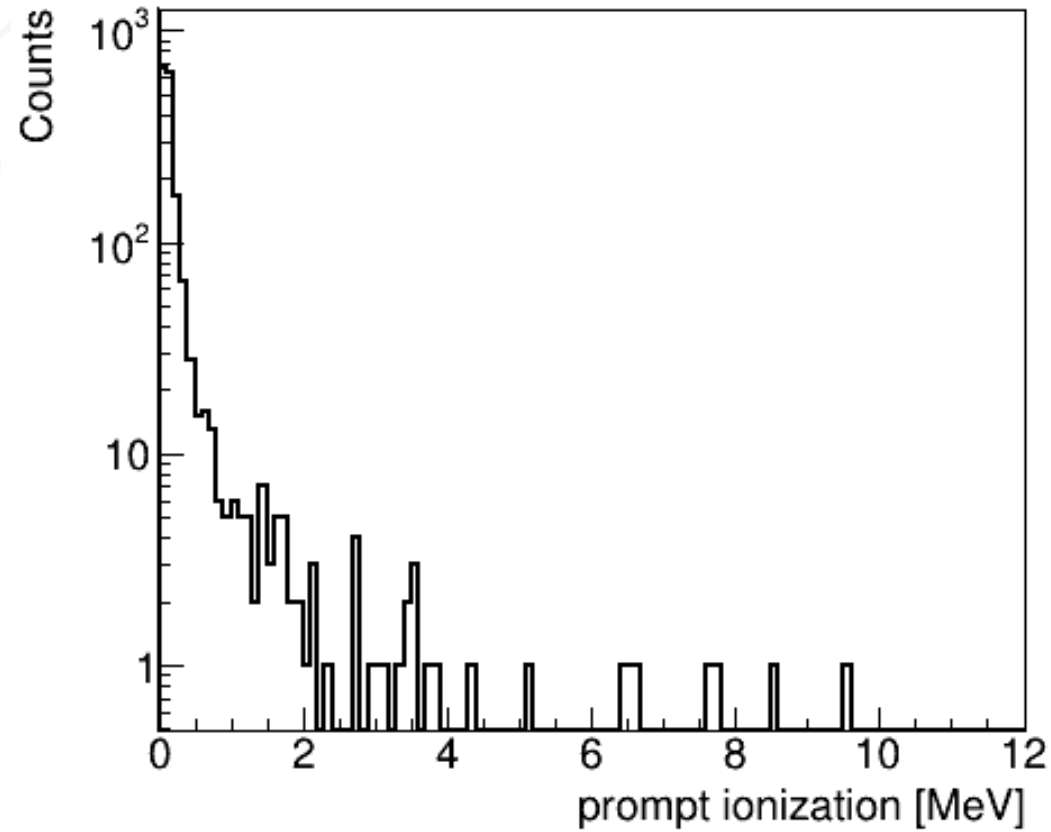
# Background Event Observables



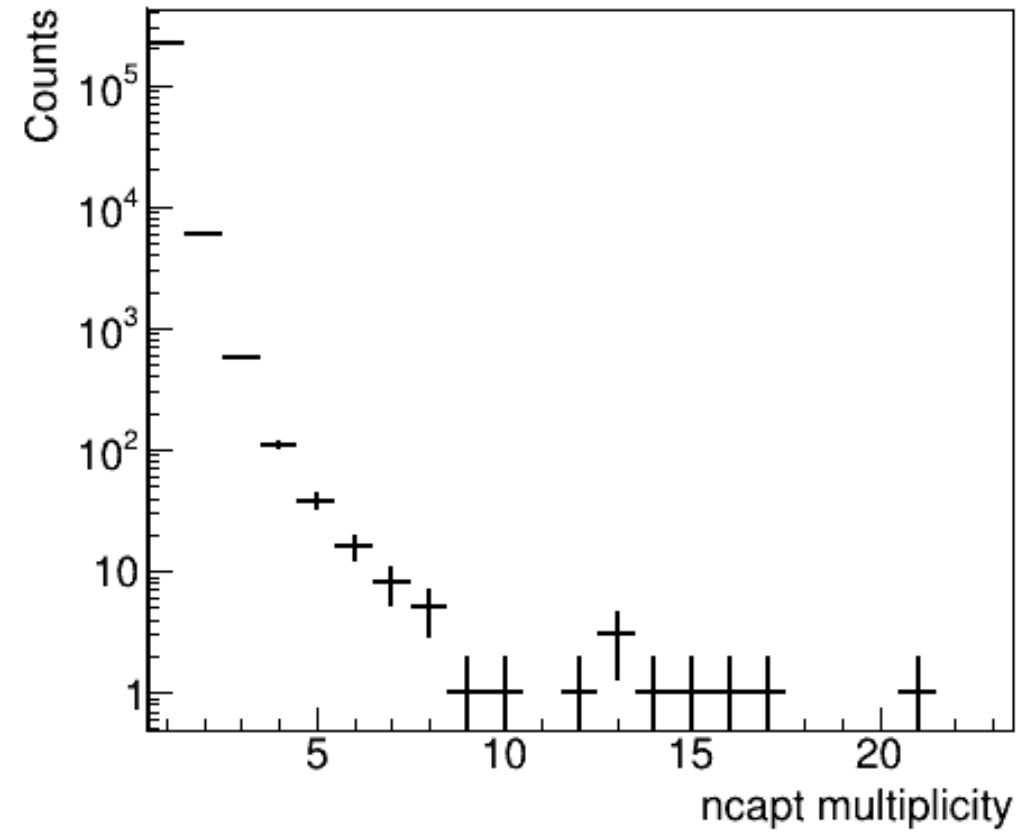
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IBD-like energy spectrum



neutron capture multiplicity



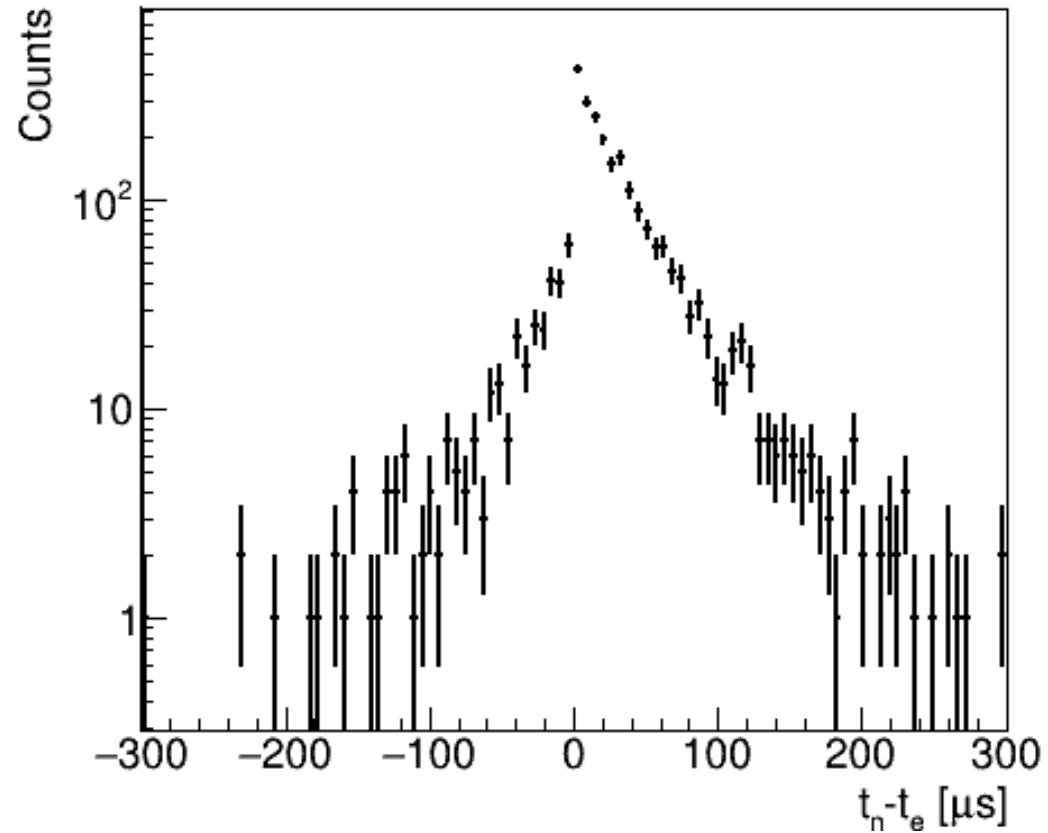
# Background Event Observables



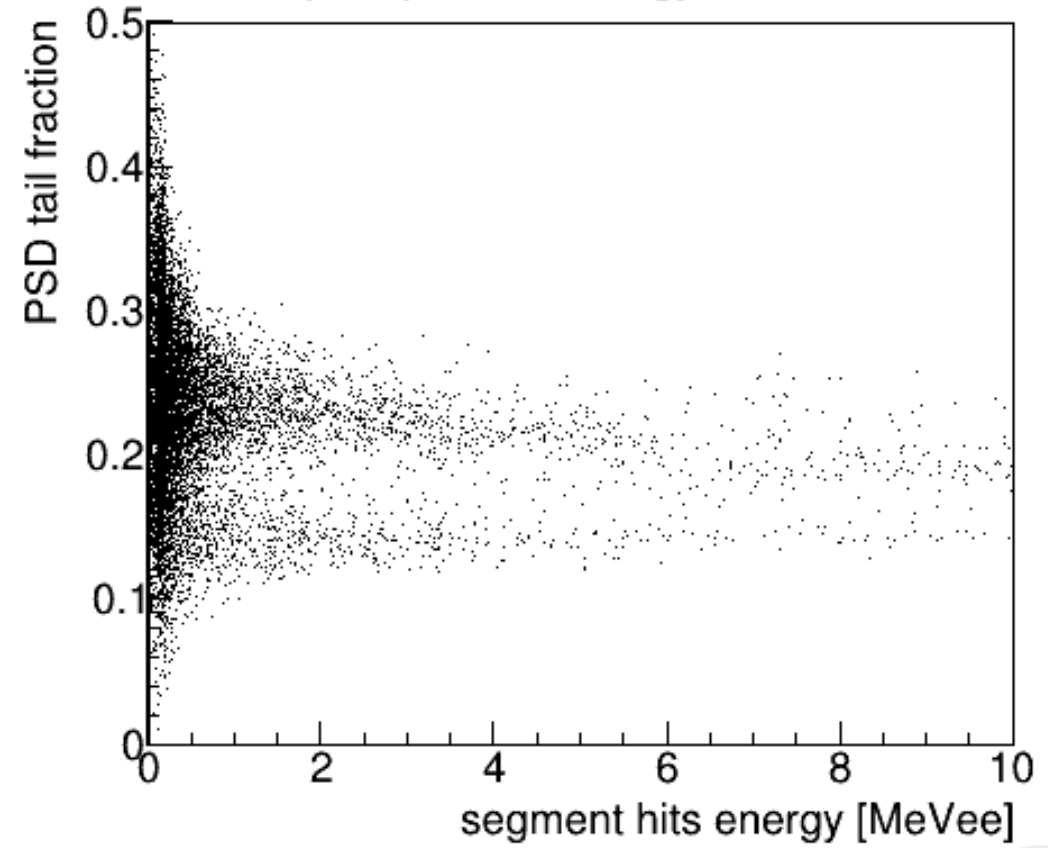
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IBD-like coincidence timing



prompt event energy/PSD



# Conclusion and Future Work



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- Mechanical Realization of the MAD system needs to shift focus to the edge layers for fluctuations in response
- Energy response matrices for the bulk detector have been made but region-specific ones will need to take its place
- Incorporate accurate scintillation response for MAD
- ROADSTR background data is being analyzed to improve MAD
  - Simulation comparison of background to be included as part of an instrumentation paper
  - A paper focusing entirely on background analysis





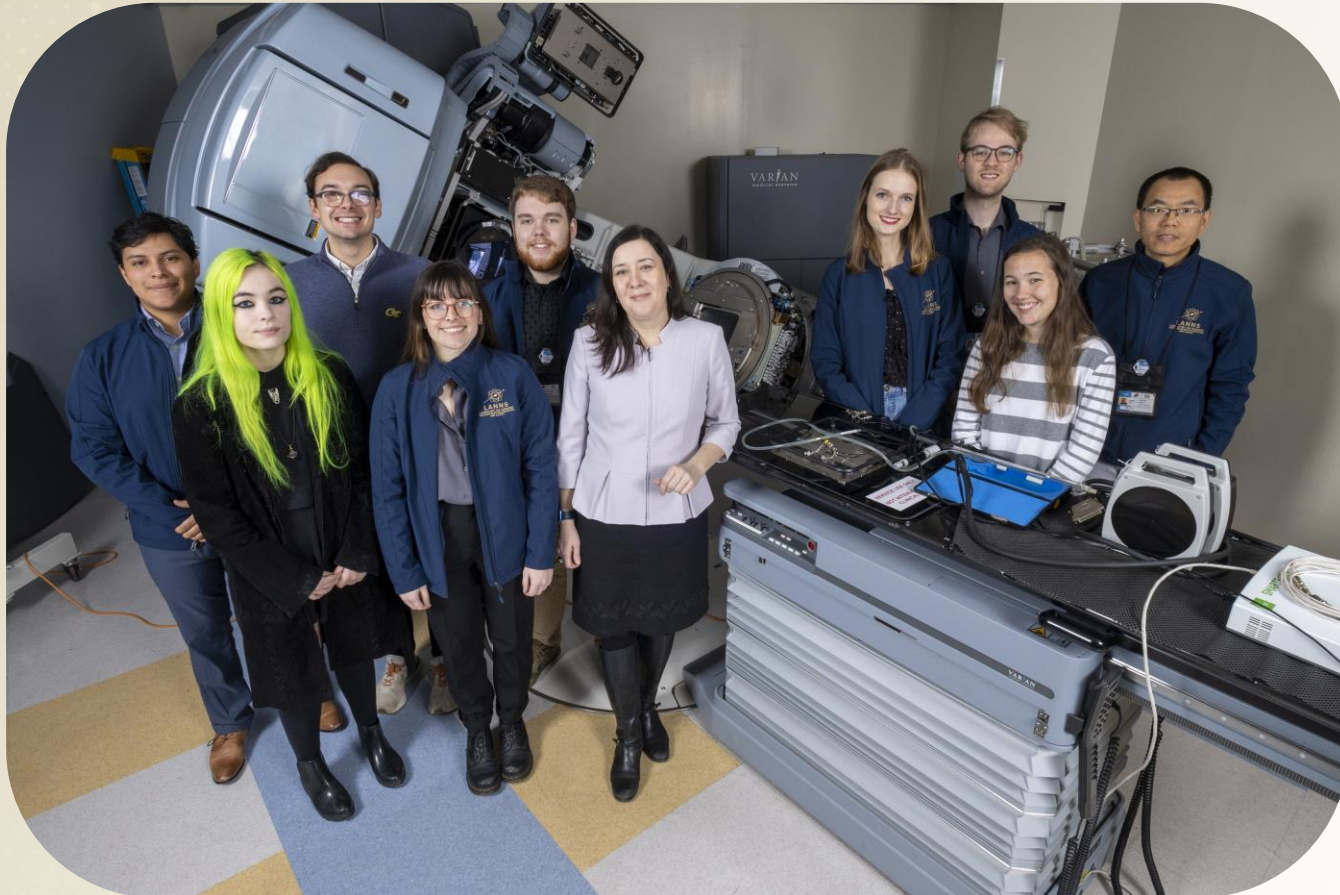
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# Acknowledgement

*Thank you to Xianyi Zhang, Michael Mendenhall, and Nathaniel Bowden for their contribution to work.*

# Thank you



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