ROADSTR studies for the Mobile Antineutrino Demonstrator

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Outline

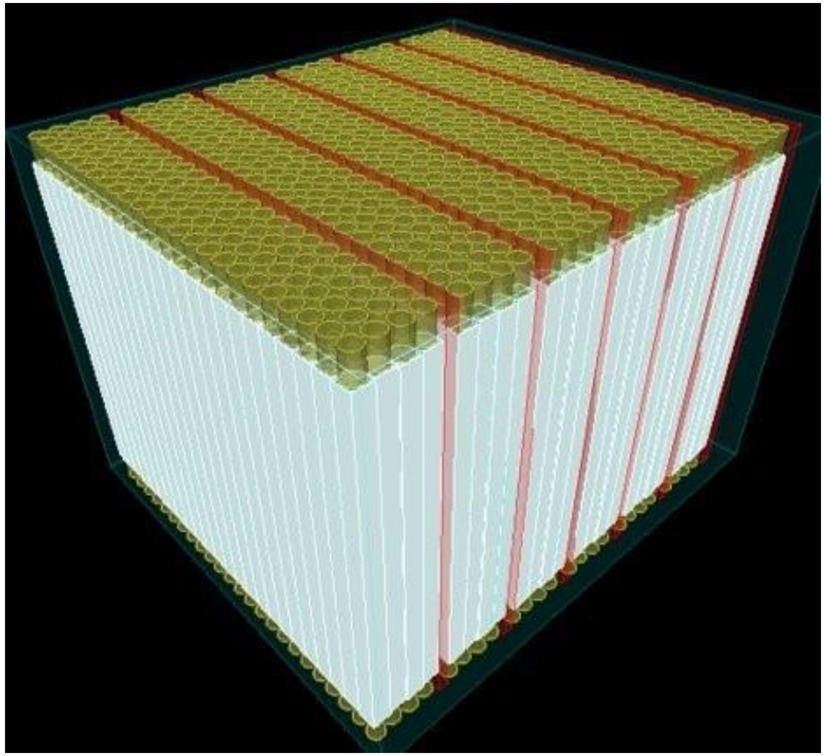
- Mobile Antineutrino Demonstrator TASK D
- Li-6 Loaded Plastic Scintillators
- Correlated Background Studies

Mobile Antineutrino Demonstrator

Task D focuses on creating an effective **Performance Assessment Framework** using simulation

How?:

- Fidelity of event reconstruction
- Fidelity of detector response
- Validation of background source terms



24X24 Scintillators with Mechanical Features for the MAD Detection System

Li-6 Loaded Plastic Scintillators

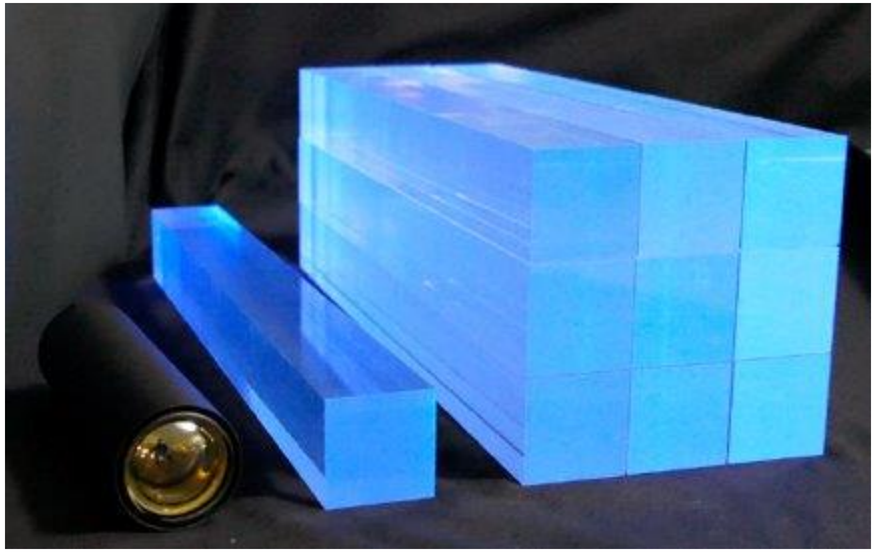
Large-scale 6Li-doped PSD plastic scintillators have recently been developed with Eljen Technology (EJ-299-50)

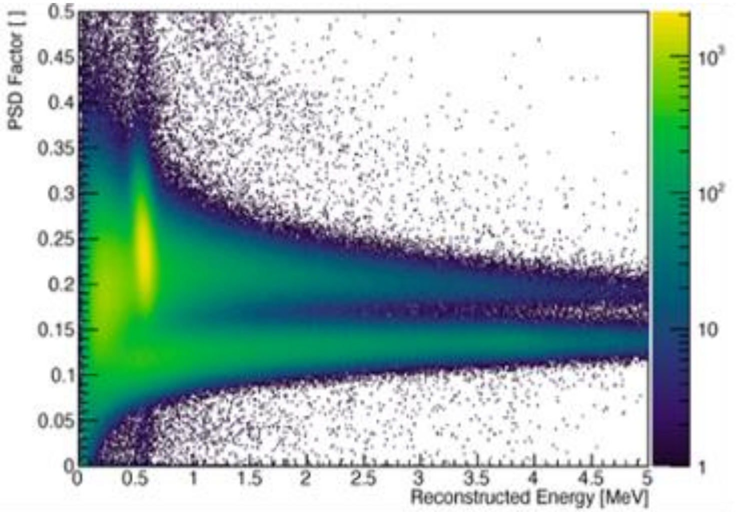
The ROADSTR Prototype is a testbed for:

- Demonstrating these materials for Inverse Beta Decay (IBD) detection

- Understanding and modeling neutron-correlated IBD backgrounds

- Long-term testing and validation of EJ-299-50 material





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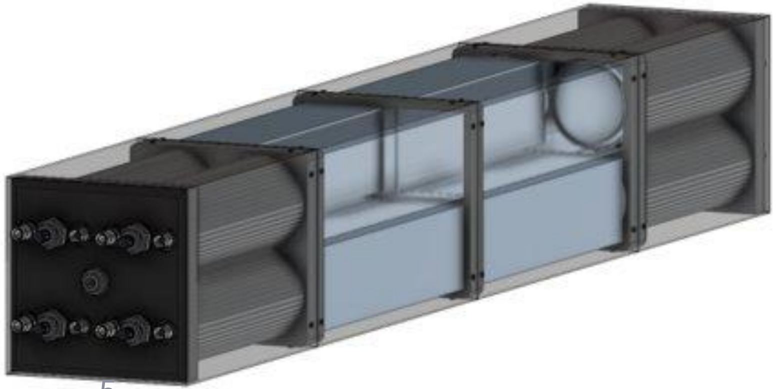
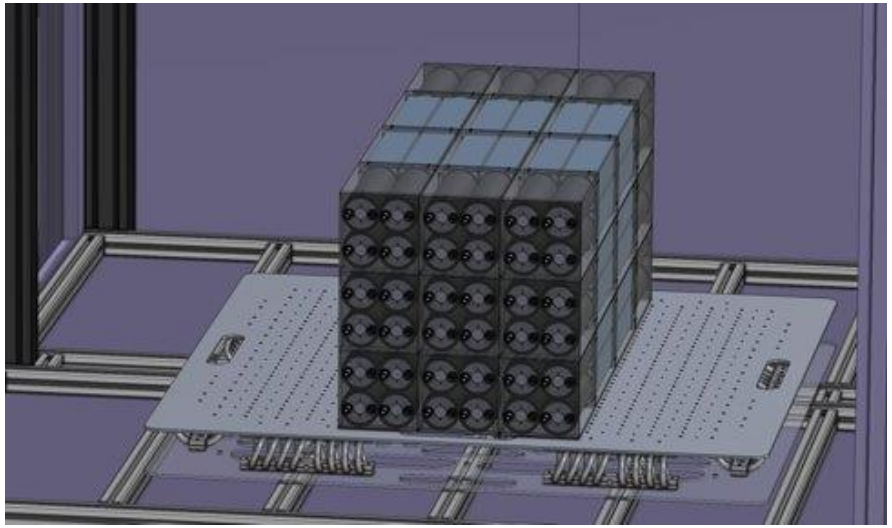
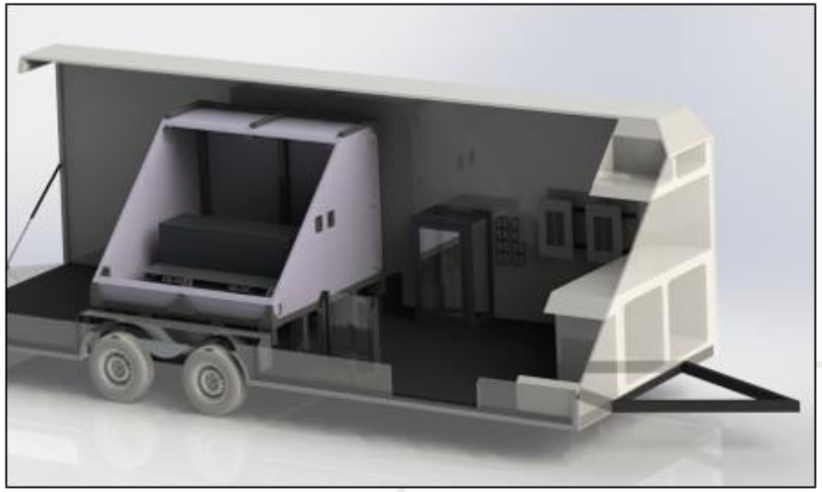
ROADSTR Prototype 6Li PSD Plastic Detector

- 6x6 array of EJ-299-50 ^{6}Li PSD plastic bars with double ended PMT readout
  - Optically coupled to Hamamatsu 2" PMT (R7724-100, H11284-100 Assembly)
  - Wrapped with 'ESR' multi-layer specular reflector
- Bar size: 55 x 55 x 500 mm^3 (1.5 liter)
- Bars packaged in 2x2 modules with 0.8mm Al walls
- 60-kg active mass – largest ^{6}Li PSD plastic scintillator detector operated so far
- Operated in trailer with 2" borated poly thermal neutron shield

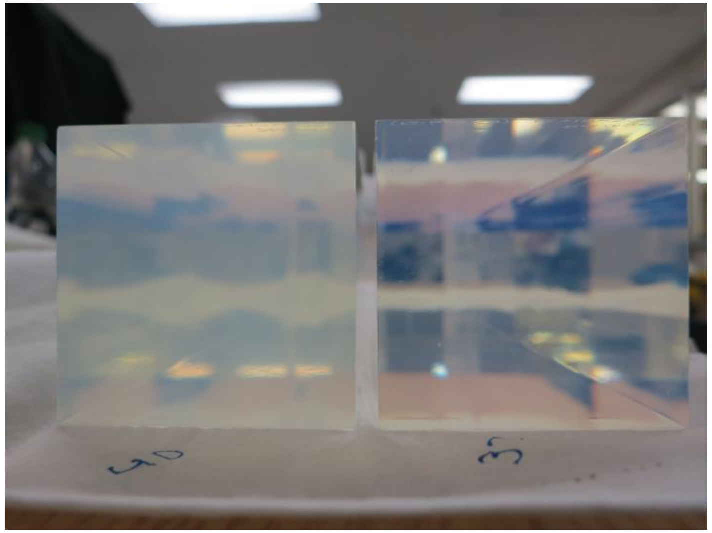


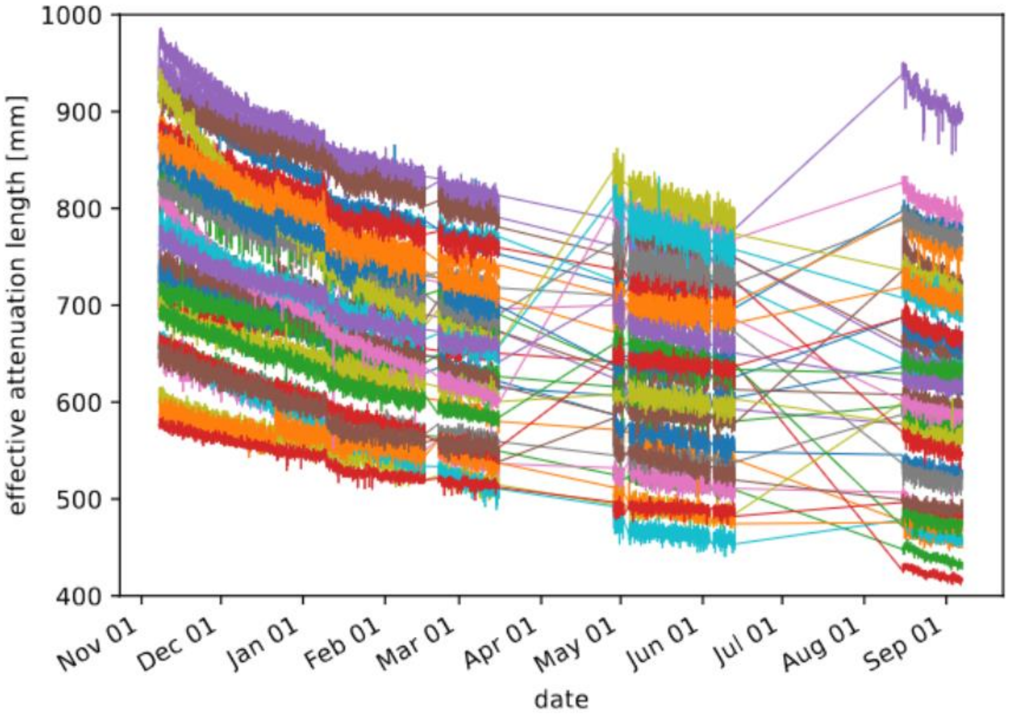


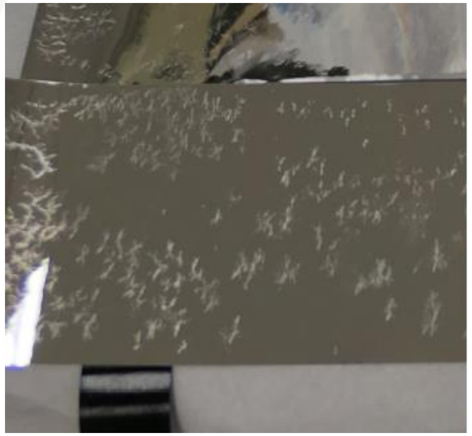


ROADSTR Refurbishment

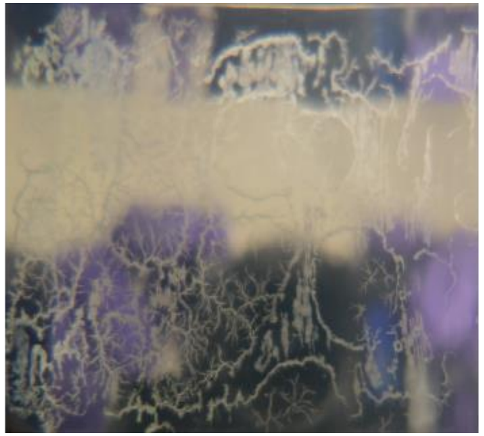
- Degradation of sensitivity occurs due to several environmental effects
- Out gassing leads to precipitate on the surface
- Reminder: These detectors are for long term usage



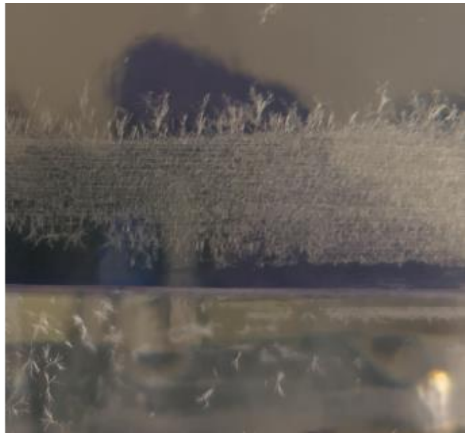




Crystalline/Flaking



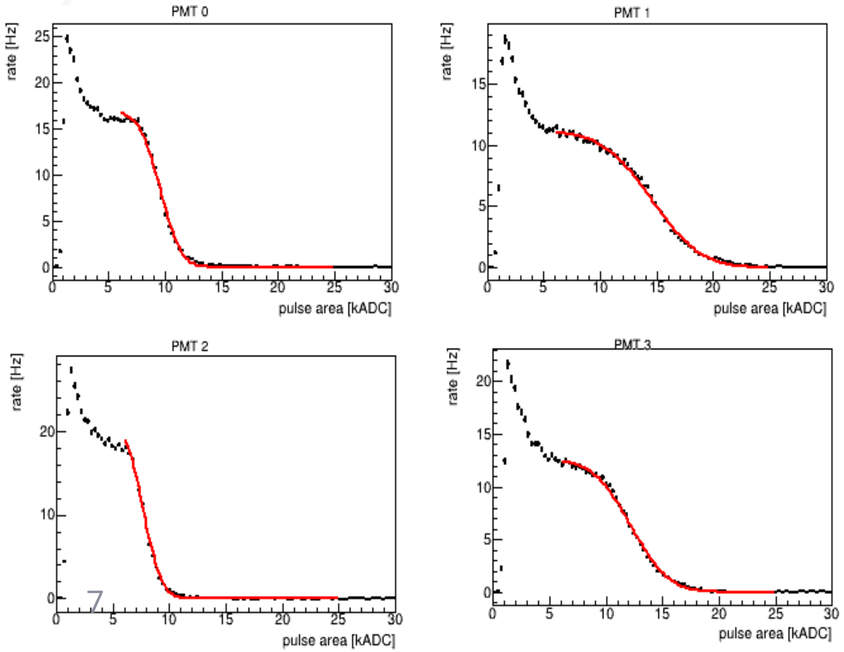
Semi-crystalline where reflector was sticking

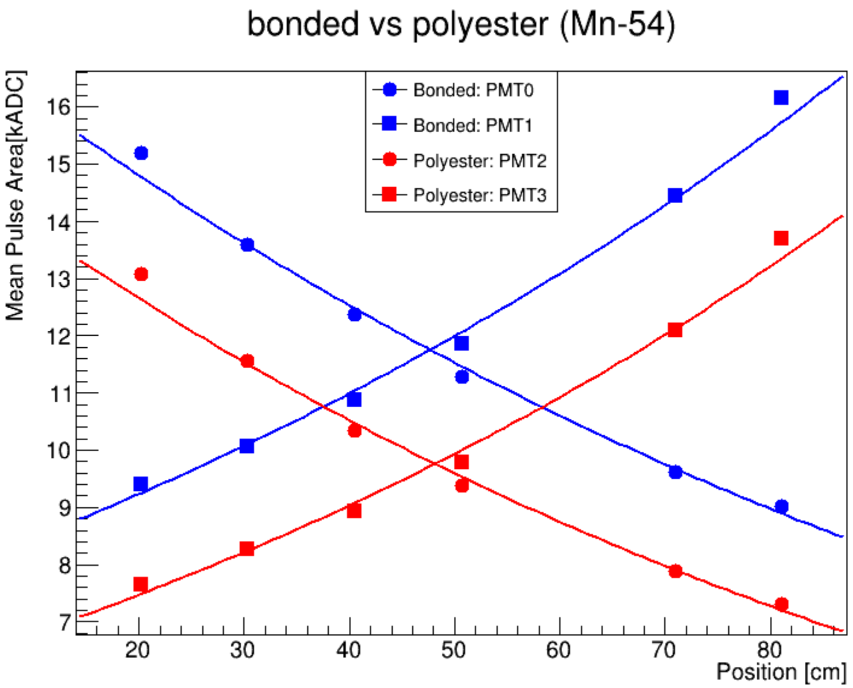


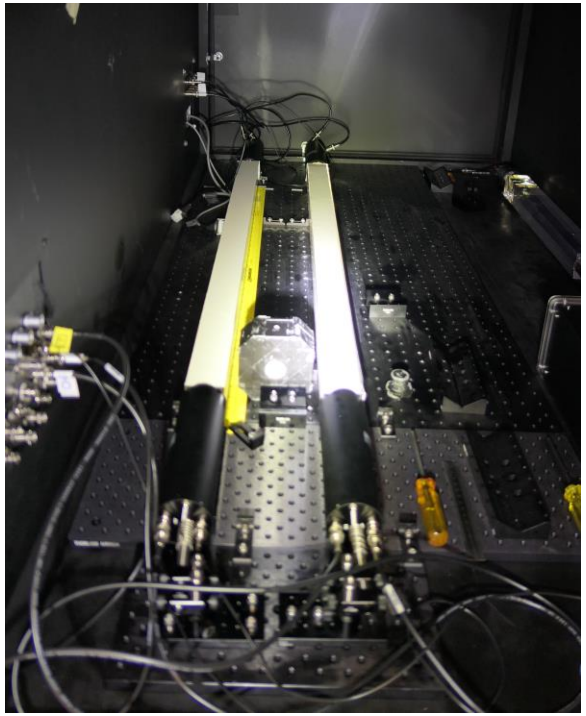
Flaking in lines

Attenuation Length vs Minimizing Outgassing

- Layering experiments beneath reflector were conducted to evaluate effects on attenuation length
- Mn-54 pencil beam along bar length
- Error Function fit of Comption Edge was performed



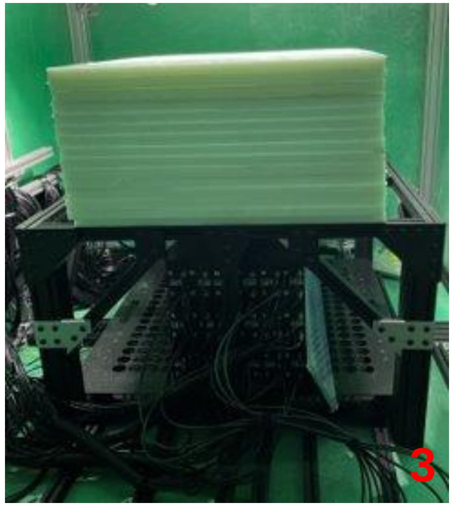




	Bonded Reflector	Polyester Layered
PMT 0	119.93 cm	104.43 cm
PMT 1	114.72 cm	110.57 cm

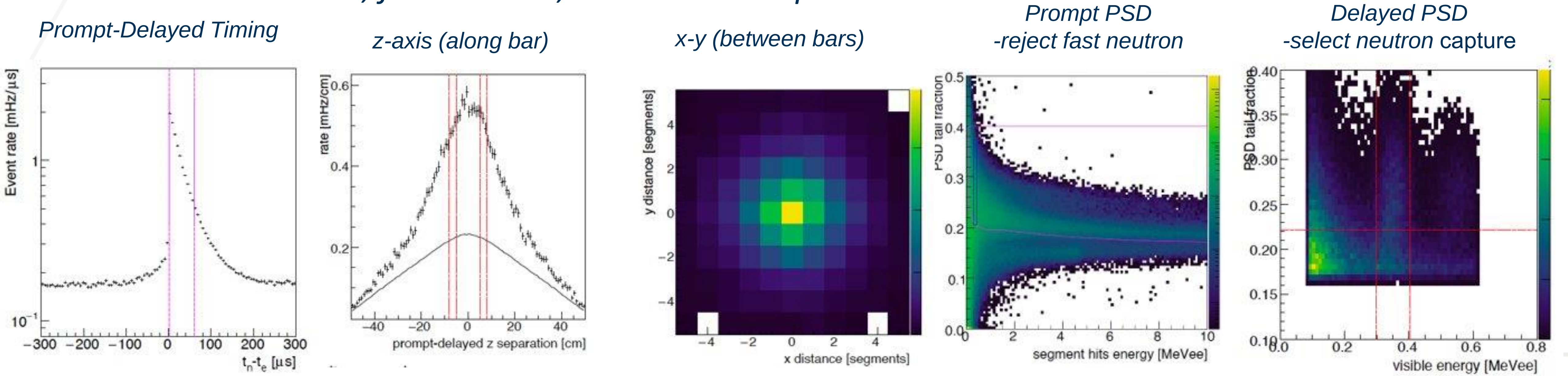
Correlated Background Studies

Location	#	Shield	Motivation
Surface Highbay	1	Unshielded	Baseline configuration with minimal overburden and shielding
	2	Trailer and 5cm B-poly shield	Effect of small shielding layer + thermal background neutron suppression
	3	- plus 40.5cm of polyethylene above	Effect of larger shielding layer
	4	- plus high-Z material	Effect of neutron multiplication/spallation source
	5	- plus high-Z material & intervening B-poly	Effect of neutron multiplication/spallation source & thermal neutron suppression
Basement	6	Unshielded	Effect of shallow ~10 m.w.e. overburden



Inverse Beta (Neutron Correlated) Event Selection

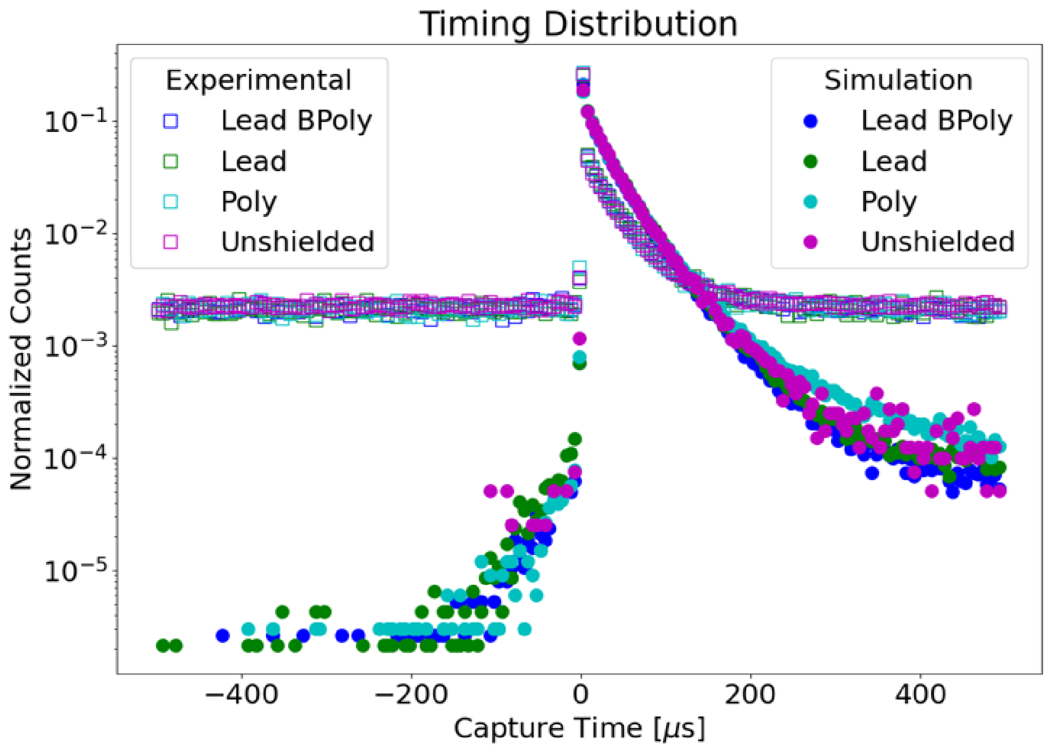
- Apply “PROSPECT-like” correlated selection to ROADSTR:
  - *Prompt-Delayed timing separation*
  - *Prompt-Delayed position separation*
  - *Prompt PSD cut to reject fast neutrons*
  - *Delayed PSD cut to select neut ron captures*
  - *Vetos on muon, fast neutron, and neutron capture events*



Framework migration to ROADSTR supported; finer segmentation & topological selections included

Performance Studies: Simulation Comparison

- Validated background simulation is an investment into above-ground operations
- Simulated with Cosmic Neutrons and Rays as our correlated background in GEANT4
- Characterize neutron mobility via"PROSPECT-like" correlated selection from events that are IBD-like
- Comparison of neutron lifetime to capture
- Shielding Cases
    - Polyethylene
    - Lead and 5% Borated Polyethylene
    - Lead



Time differences between prompt neutron and neutron capture in the system

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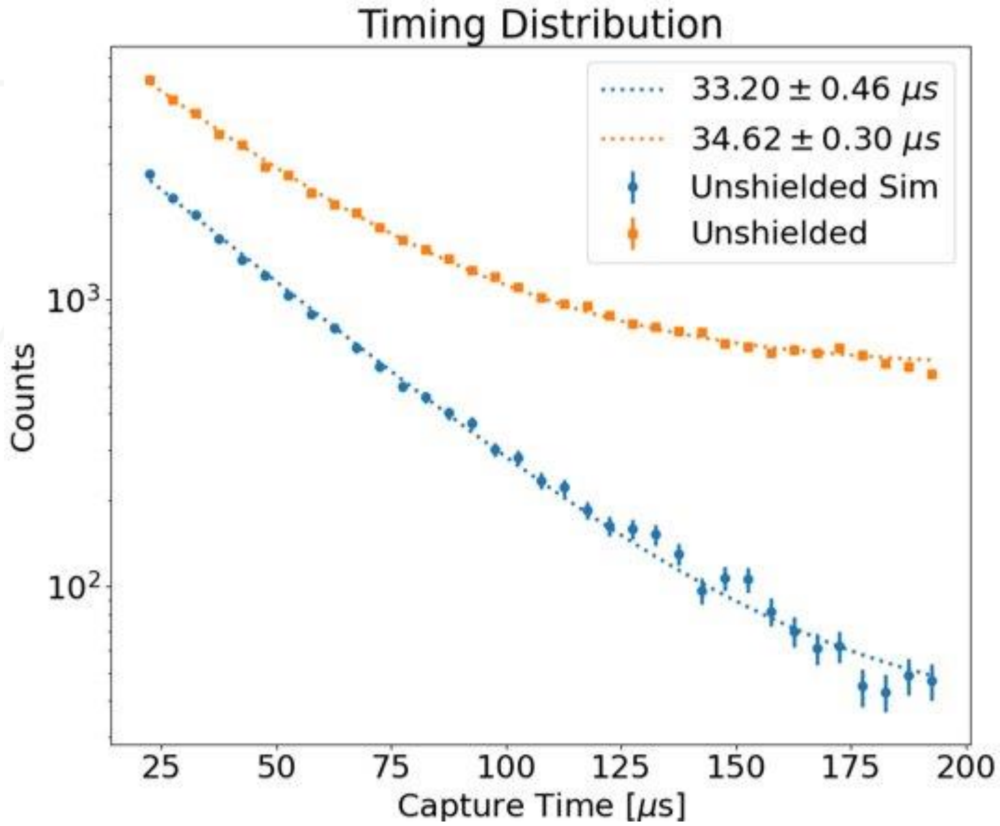
Work in progress: simulation and data comparison

Good agreement between data and simulation for neutron capture time across different configurations for a single-exponential fit



Configuration	Data	Simulation
Trailer and 5-cm B-poly shield	34.6 +/- 0.3 (μs)	33.2 +/- 0.5 (μs)
- plus 40.5cm of polyethylene above	34.0 +/- 0.7 (μs)	33.5 +/- 0.2 (μs)
- plus high-Z material	34.2 +/- 0.5 (μs)	34.6 +/- 0.2 (μs)
- plus high-Z material & intervening B-poly	33.6 +/- 0.4 (μs)	34.6 +/- 0.2 (μs)

Conclusions

- Work is ongoing to find a bonding layer to stop outgassing while not inhibiting attenuation length.

- Various measurements have supported background simulation validation & development of background prediction capability.

- Greater characterization of neutron mobility will be performed to further validate background prediction capabilities with simulation.

Backup Slides

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Additional Chart Layouts Examples