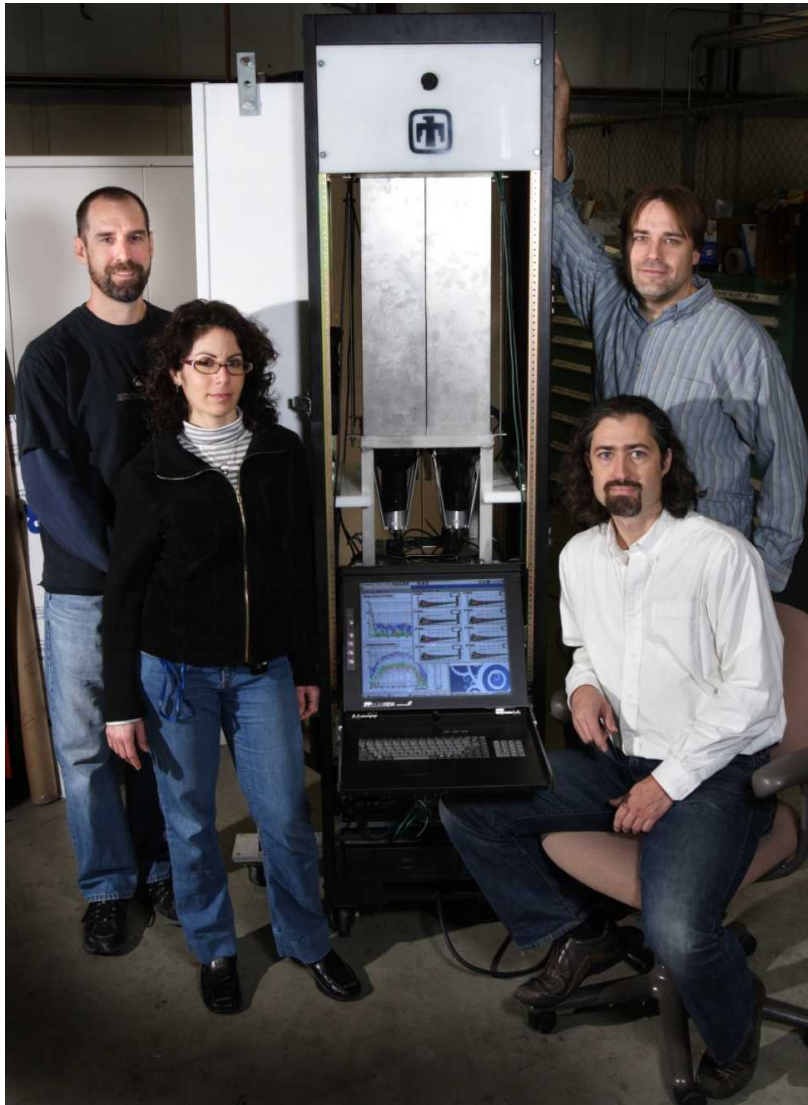


The Development of a Segmented Detector using ZnS:Ag/⁶Li

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Sandia National Laboratories, CA



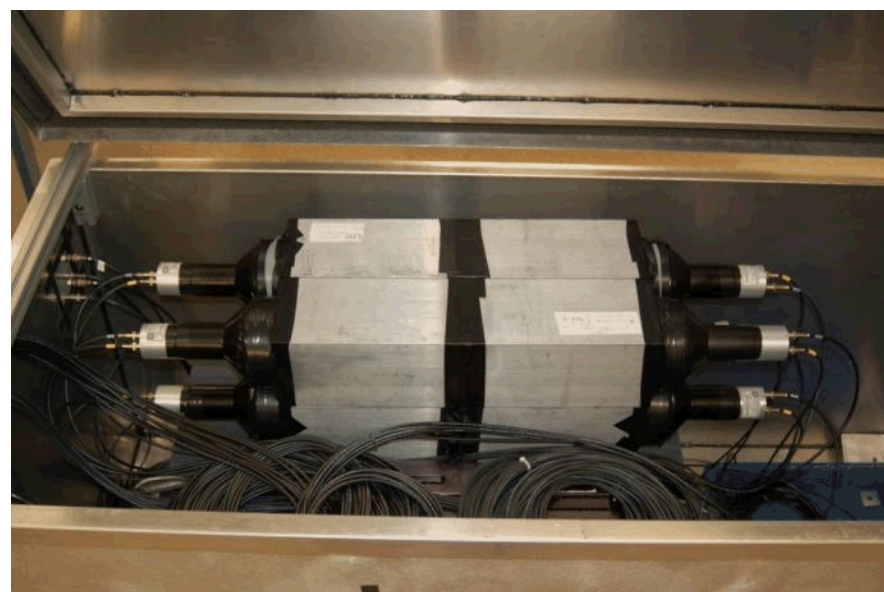
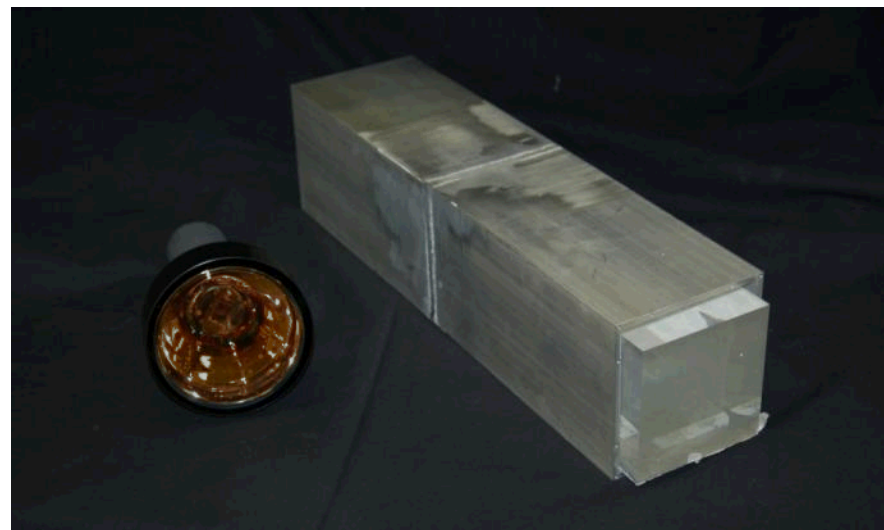


- As part of a joint SNL/LLNL project to develop aboveground detector technology, we deployed a 4-cell prototype segmented scintillator system
 - Aboveground shielded and unshielded runs in 2011
 - Belowground deployment in 2012-2013
- Very encouraged by performance of Segmented Scintillator prototype
 - This technology is focused on reducing the overall footprint and enabling a transportable detector that can be deployed in **high-background or unshielded locations**
 - Demonstrated **rejection of backgrounds** of 5 orders of magnitude even without an external shield

Segmented Scintillator Detector

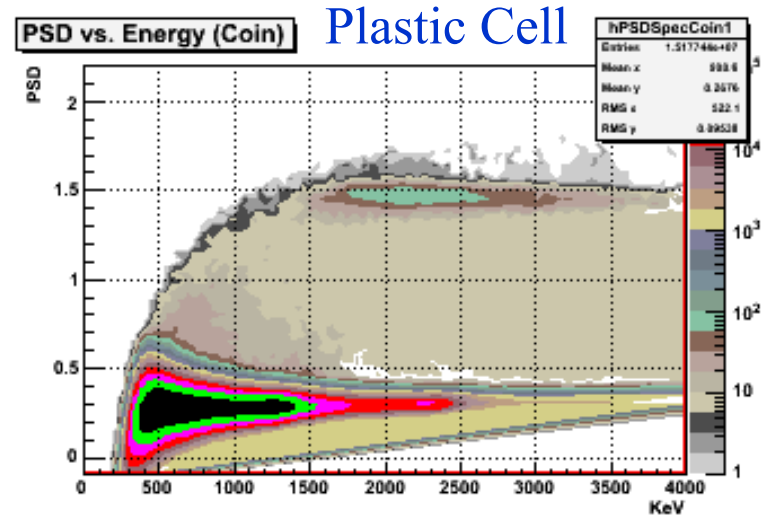
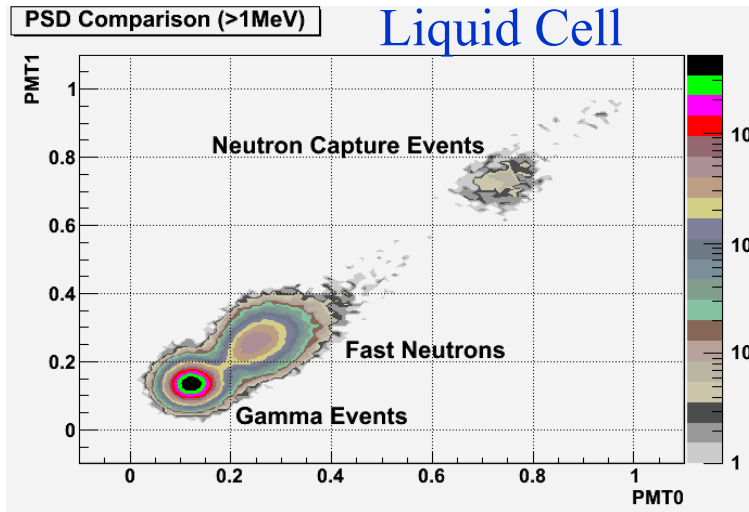


- Individual Segments contain organic scintillator with ZnS:Ag/⁶LiF screens on outer surface
 - 4 cells with plastic or liquid scintillator
- Use of ZnS:Ag with ⁶LiF allows identification of neutron capture
 - ZnS:Ag is sensitive to alpha from n-capture on Li
 - Very slow scintillator time constant (~100ns) allows pulse shape discrimination to separate n-capture from γ events
- With Liquid Scintillator, proton recoils are also easily identified
 - Allows a comparison to test need for additional rejection
- This 4-cell prototype was intended for first testing background rejection only



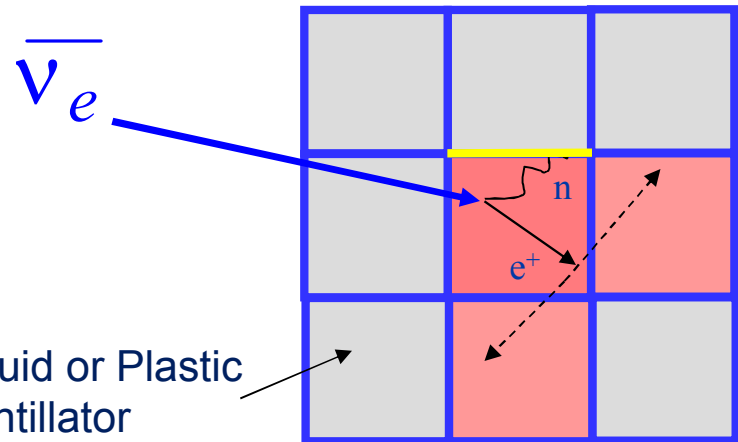
Particle Identification (PID)

Neutron identification through Pulse Shape Discrimination (PSD)



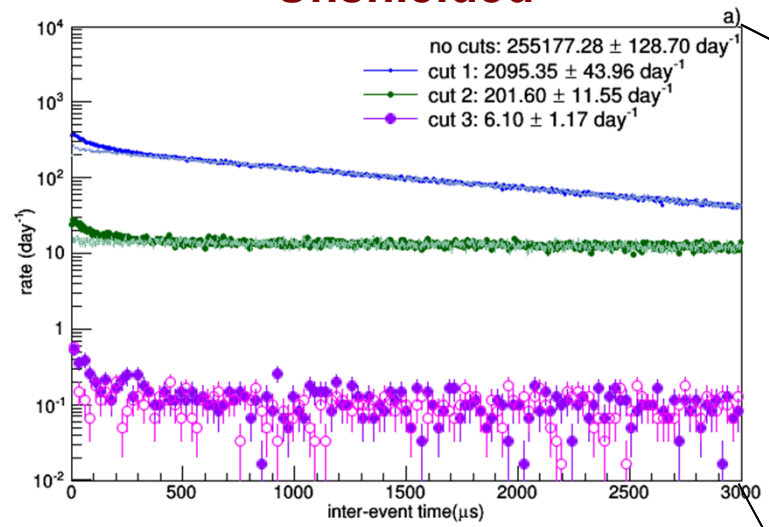
Positron Identification through Topology

- Positrons are rare in nature
 - Deposit most of their kinetic energy very quickly through standard ionization losses
- Positrons will annihilate into two back-to-back 511 keV gammas
 - Very distinctive signature
 - Gammas will travel ~2-5" through most scintillators

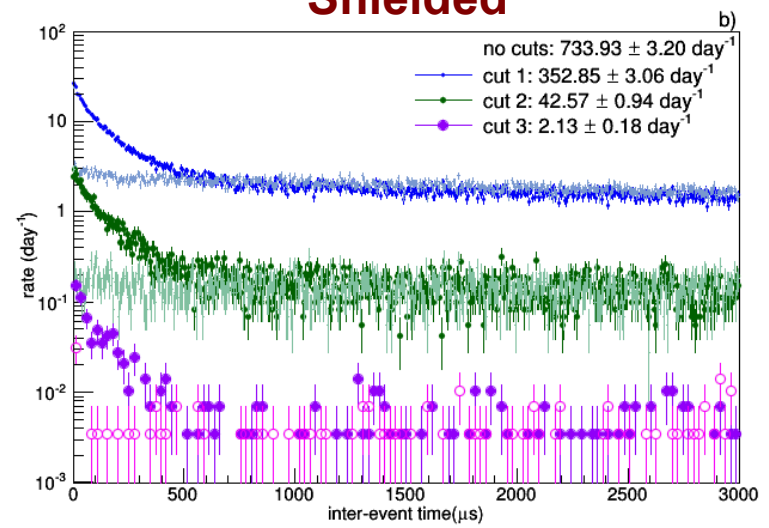




Unshielded



Shielded



No PID cuts
225,177 ev/day

Cut 1 = neutron PID only
2095 ev/day

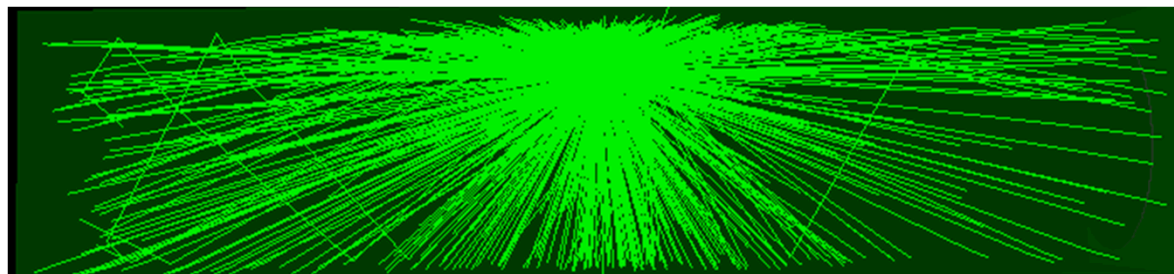
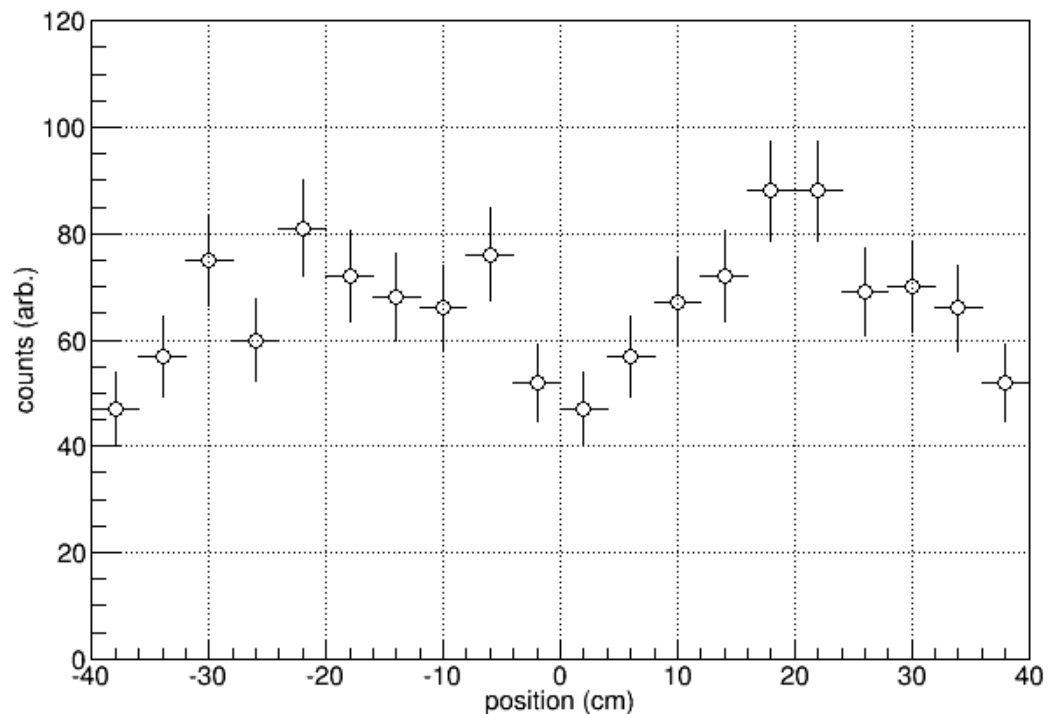
**Cut 2 = neutron PID +
 Loose positron topology**
202 ev/day

**Cut 3 = neutron PID +
 Strict positron topology**
6 ev/day

Expectation ~ 1 ev/day (cut 3)



Detected Neutron Events Along a Segment

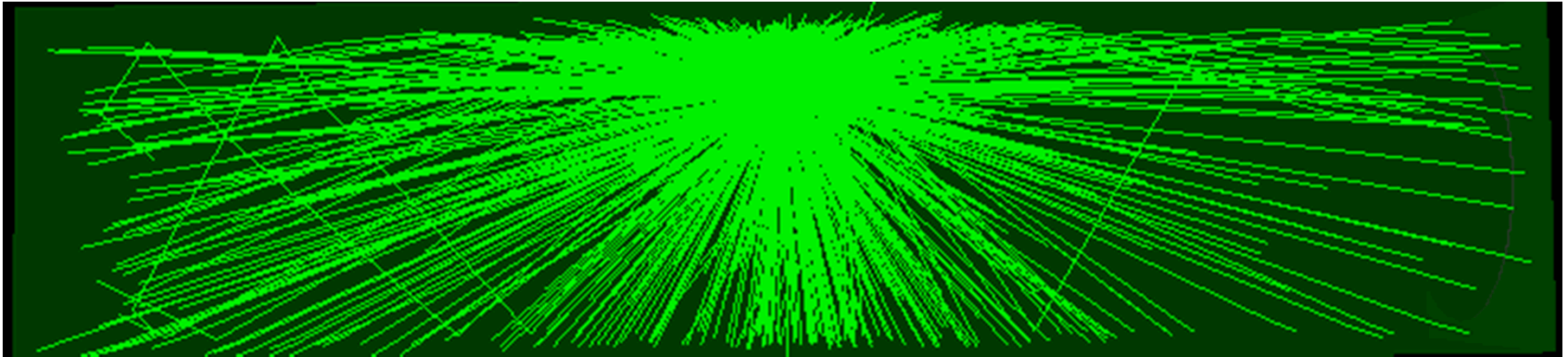


Optical grease coupled ZnS does not transmit light

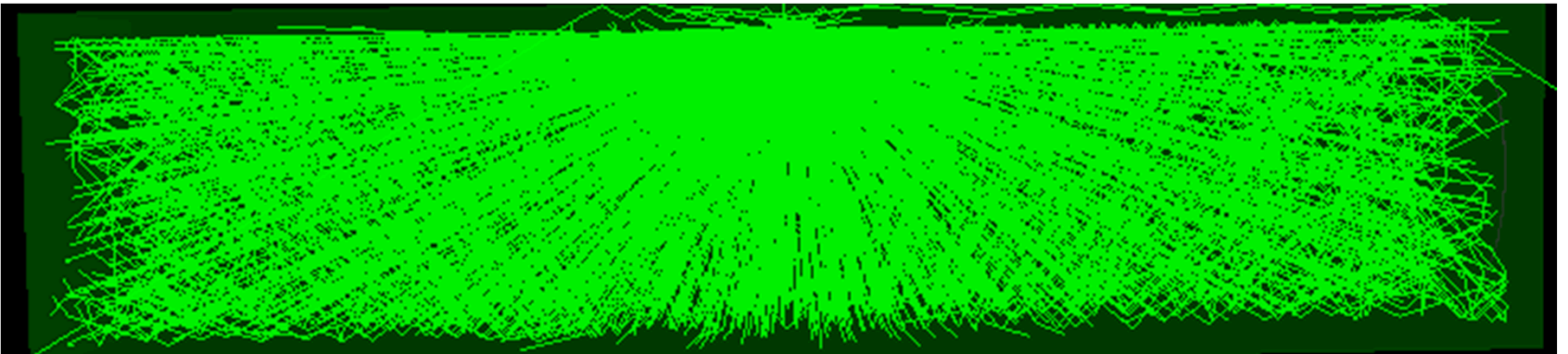
Montecarlo Comparison



Grease Coupled Normal Plastic Scintillator

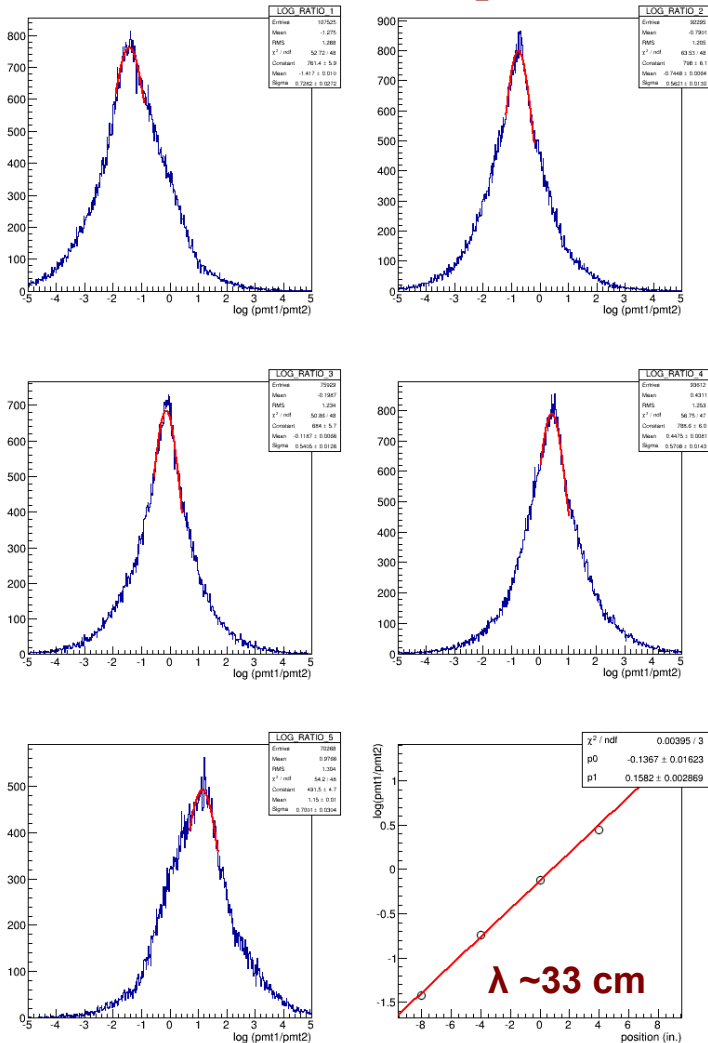


Air Gap with Wavelength Shifting Plastic Scintillator

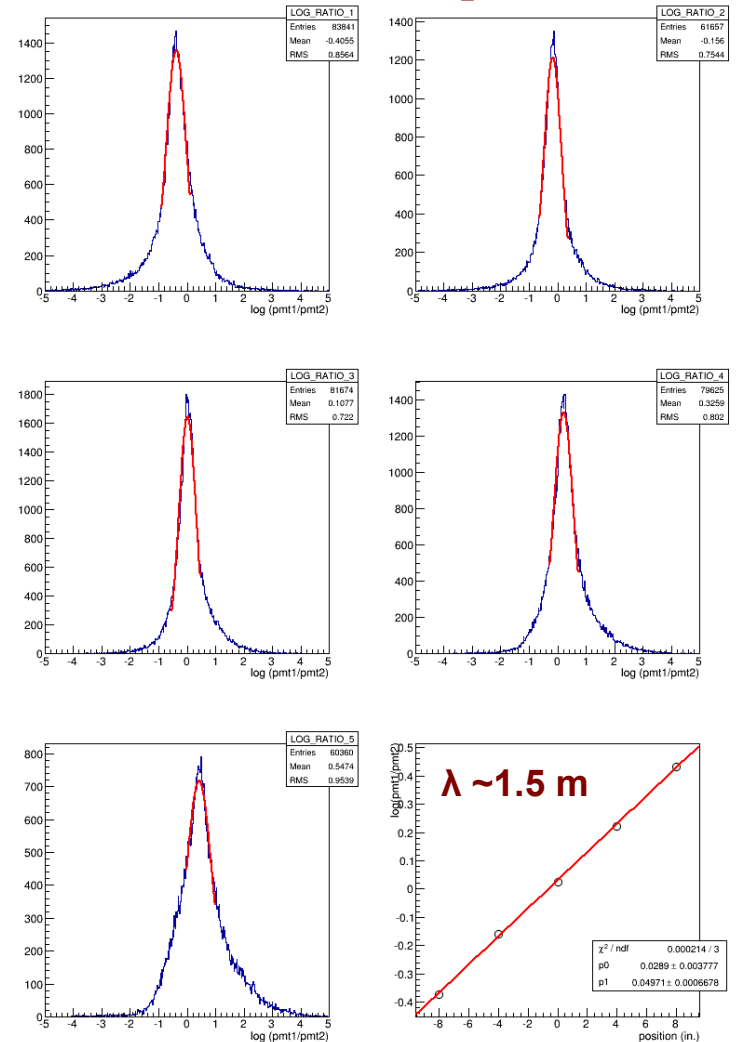


Direct Measurement of Optical Transmission

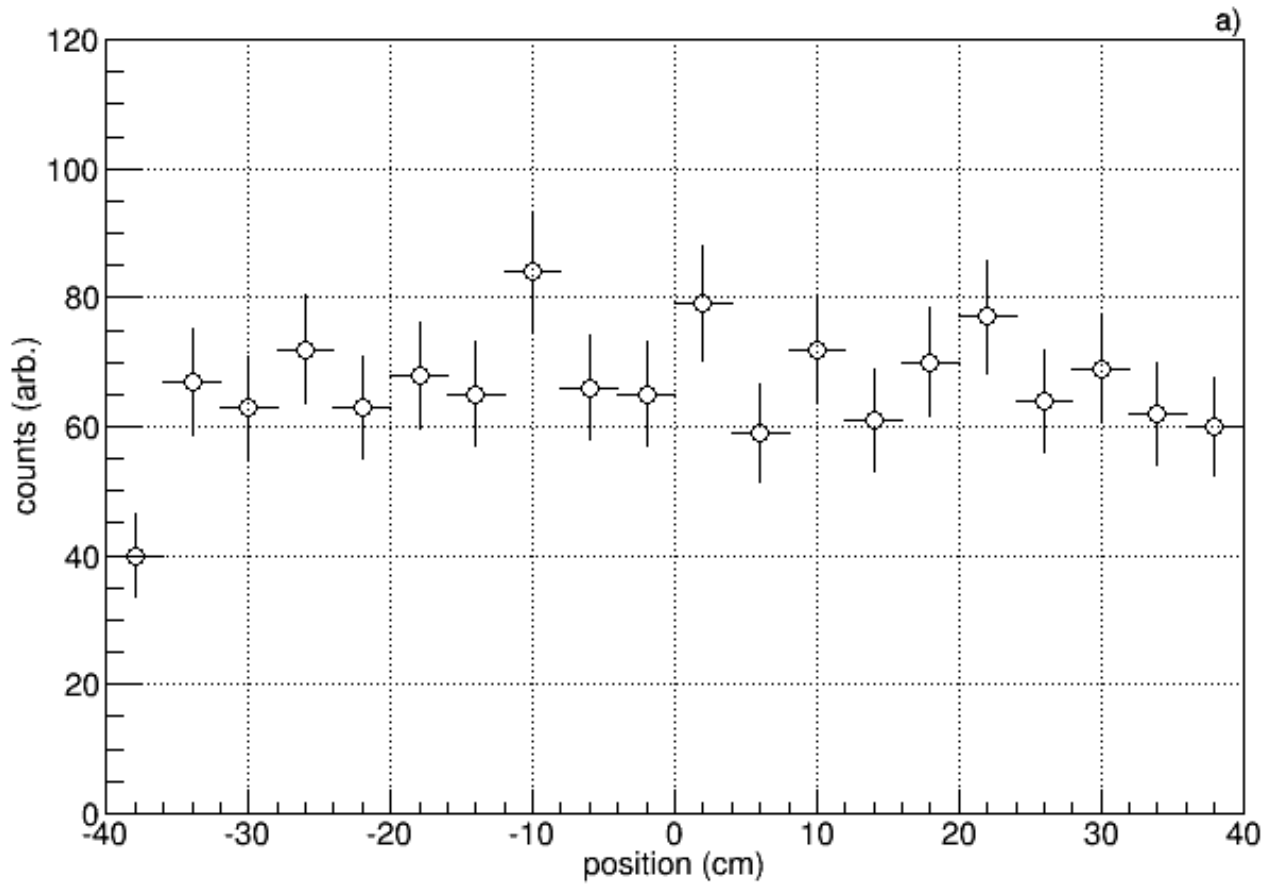
Old Cell: Grease-coupled Bar



New Cell: Air-coupled Bar

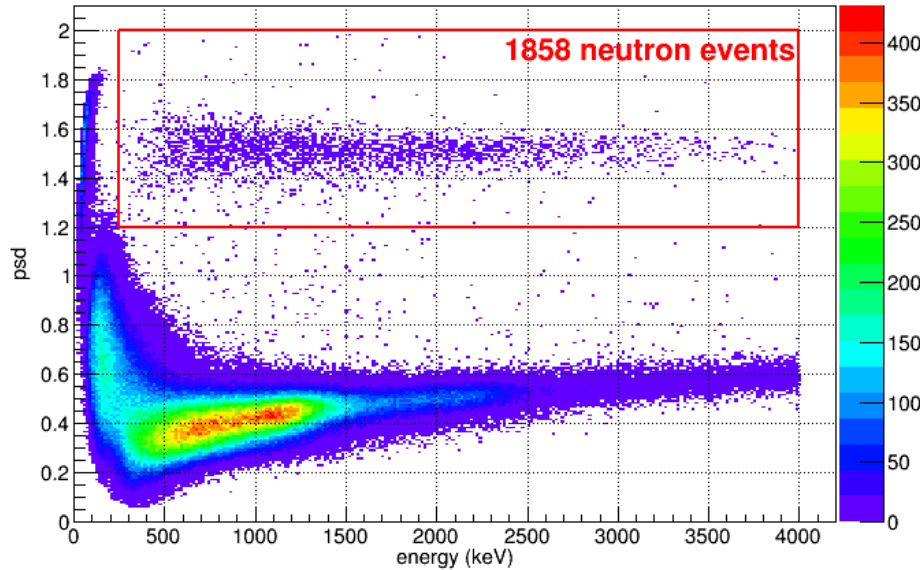


Neutron Data Confirms Improvement

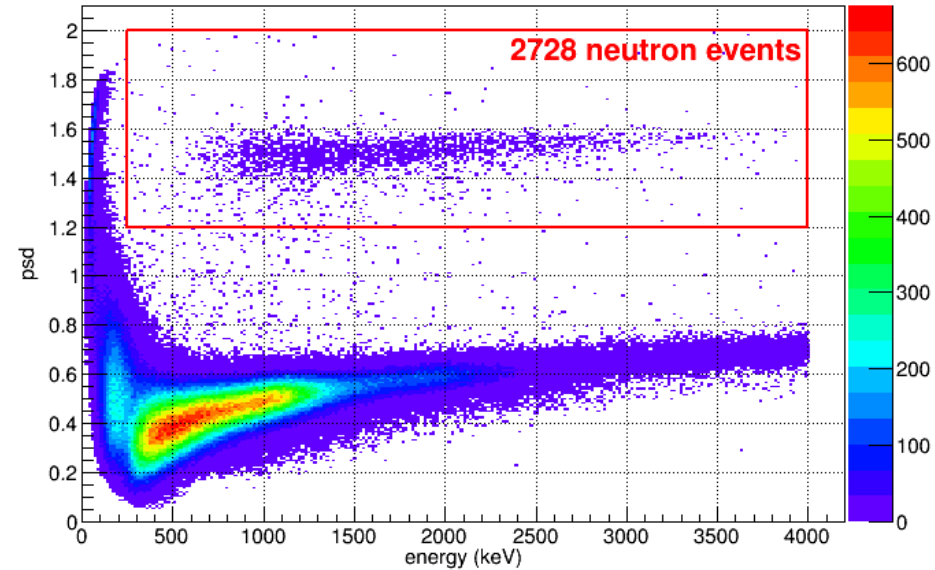


Even PSD Shows More Uniform Energy Collection

Old Cell: Grease-coupled Bar



New Cell: Air-coupled Bar



Neutron cuts:

- pulse-shape discrimination parameter greater than 0.6
- Individual pmt energy greater than 250 keV and
- less than 4000 keV

WLS Allows Extended Length



Test Bar	Attenuation length	Normalized neutron efficiency §
Original grease coupled 60cm	35.6 +/- 1.2 cm	10.1 +/- 0.9 %
WLS, air gap, 60 cm	118 +/- 7 cm	10.8 +/- 0.9 %
WLS, air gap, 120 cm	154 +/- 11 cm	12.6 +/- 1.2 %
WLS, air gap, 180 cm	200 +/- 20 cm	10.9 +/- 1.1 %

§ Efficiency calculated relative to a calibrated ³He detector and normalized to detector area

Conclusions



- **WLS based segments show good uniform detector response even at 1.8m length**
 - Overall efficiency is improved compared to previously deployed prototype
 - Probably could go to 3m
- **Antineutrino efficiency will improve as more segments are added**
 - Single electronics rack could house $\frac{1}{2}$ ton active volume (16 cells)
 - Future work will investigate how backgrounds scale with additional segments
- **The technology is easily deployed**
 - Robust solid state materials
 - Full PID allows simple analysis that can be easily automated