

Background and Detector Response Studies With PROSPECT Prototype Detectors

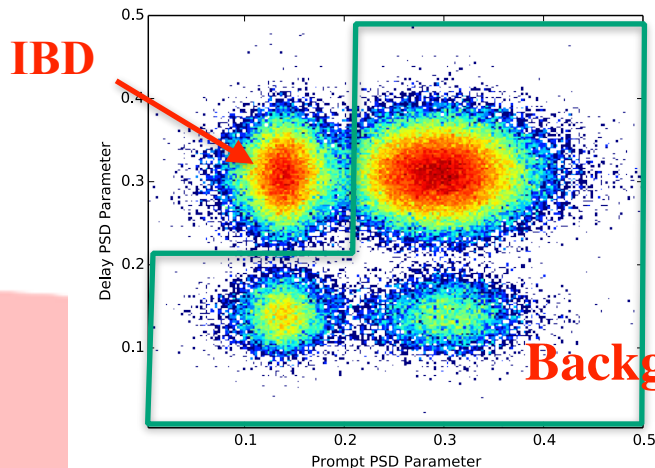
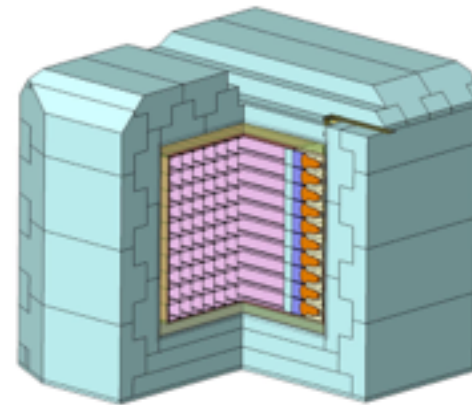
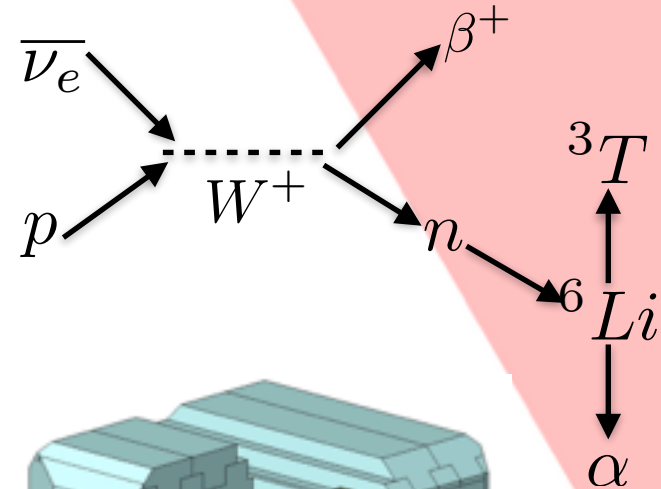
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The Detection Method of PROSPECT

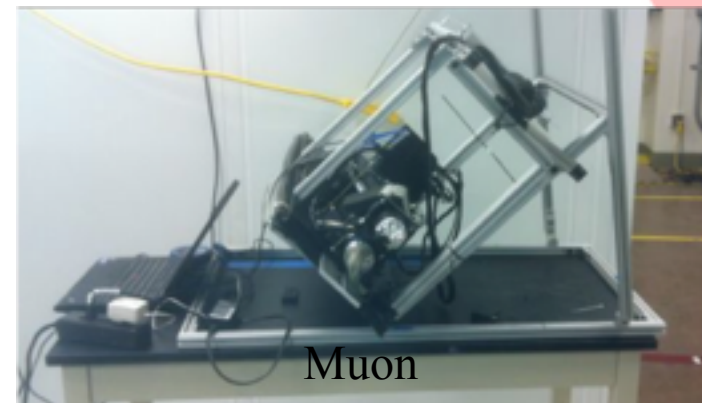
- PROSPECT detects inverse beta decay (IBD) of anti-neutrino from highly-enriched U-235 reactor with optically segmented Li-6 doped liquid scintillator cells.
- Pulse shape discrimination (PSD) of PMT response is method mainly used to identify the IBDs in detector.



- Backgrounds of near reactor location are significant for short baseline experiment.
- The energy resolution of cells is important.

Background Measurement

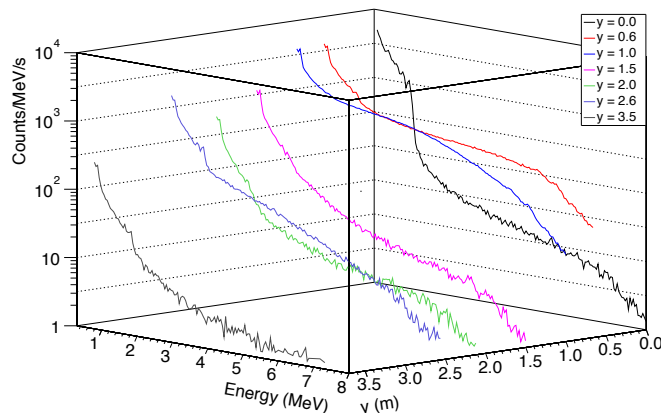
- Three main sources of background including:
 - Gamma-ray;
 - Fast and thermal neutron;
 - Muon from cosmic ray.
- To characterize the backgrounds, spectroscopy and flux of each background is measured, pictures shows some instruments used.
- Background measurement of reactor on and off are compared.



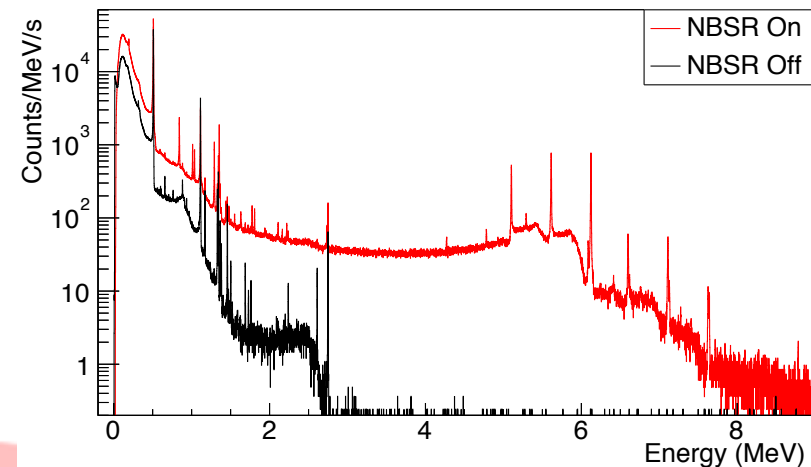
Instruments we utilized to measure backgrounds

Background Measurement

- Characterization of background:
 - Significant spatial variations in gamma and neutron backgrounds from local construction at site.
 - Near reactor locations shows higher reactor-correlated background.
 - Neutron interaction with water and structural material is significant source of gamma background.
 - Muon background rate is dependent on the overburden of site



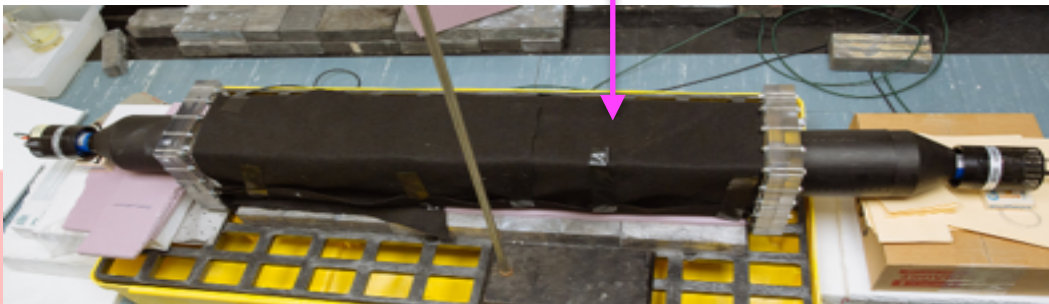
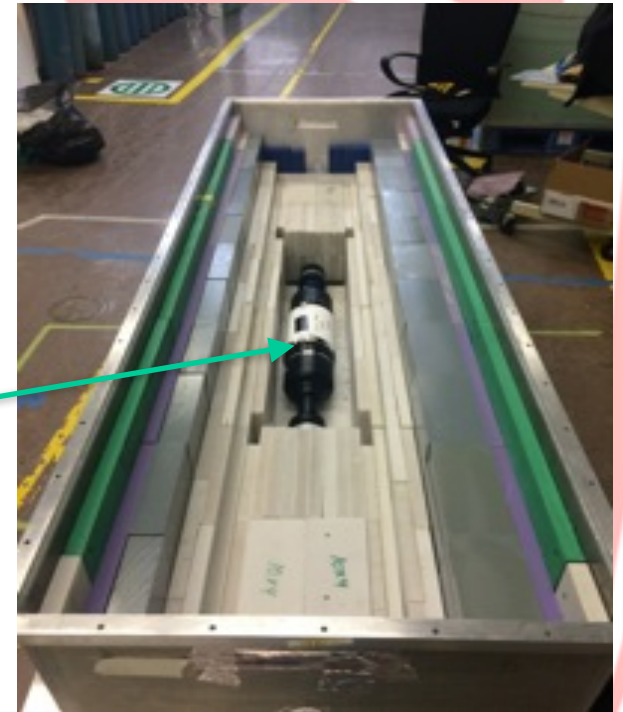
Gamma spectroscopy vs. Y-location around the wall surrounding reactor



Gamma spectroscopy, reactor on and off

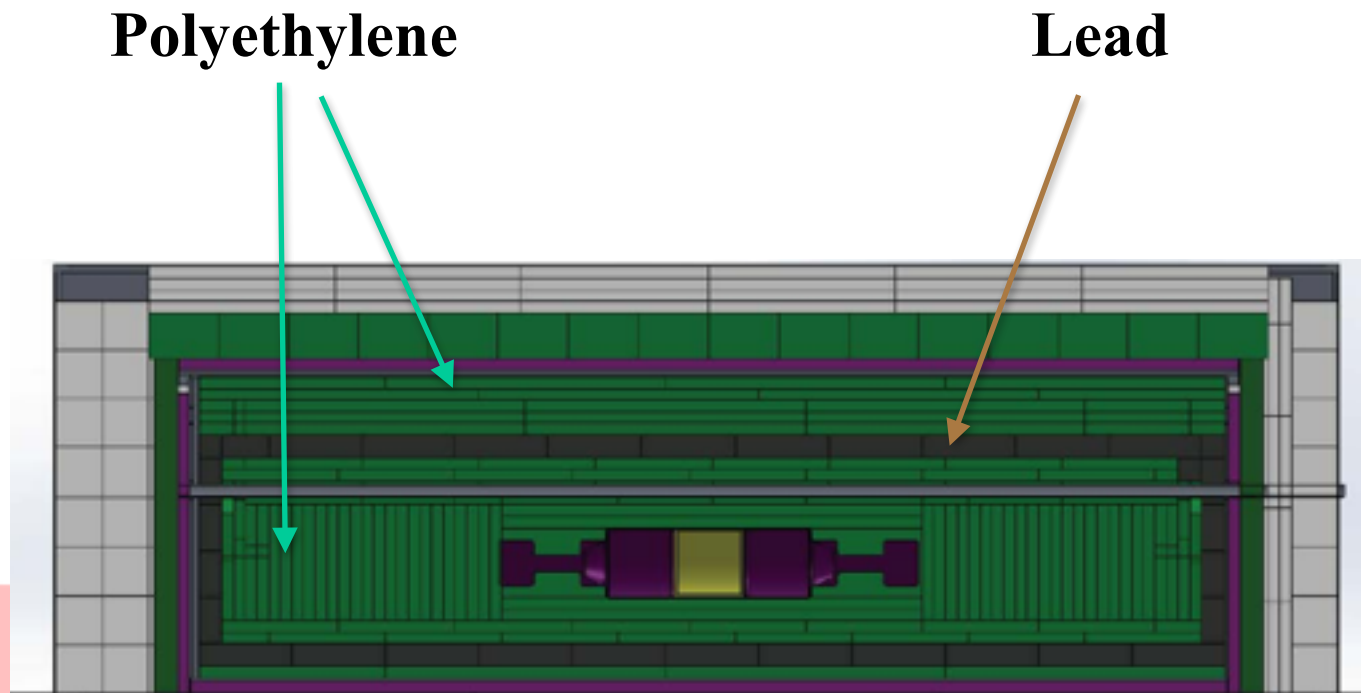
The prototypes of PROSPECT

- Prototypes of PROSPECT detector were deployed to study the performance of scintillator cells and shielding of background
- **PROSPECT-2**: 12.7 cm, 1.7L cylindrical EJ309 cell with PMT on each end, to develop detector shielding and demonstrated background reduction
- **PROSPECT-20**: meter-long, 23L rectangular Li-6 loaded EJ309 cell with PMT on each end, to study light collection and PSD in different configurations



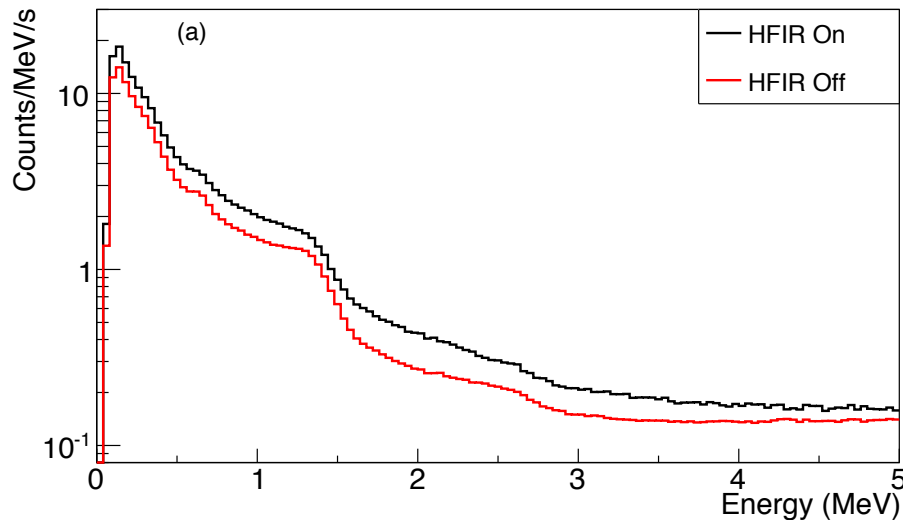
PROSPECT-2 Background Shielding

- PROSPECT-2 was deployed within multilayer shielding to reduce gamma and neutron background.
- Detector installed at near reactor location of High Flux Isotope Reactor (HFIR) in Oak Ridge National Laboratory(ORNL).

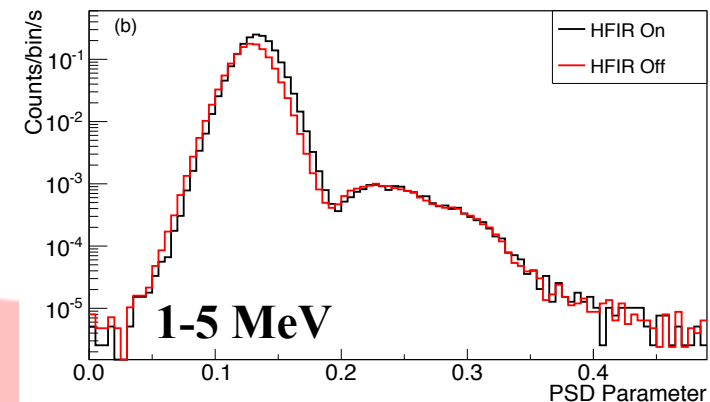
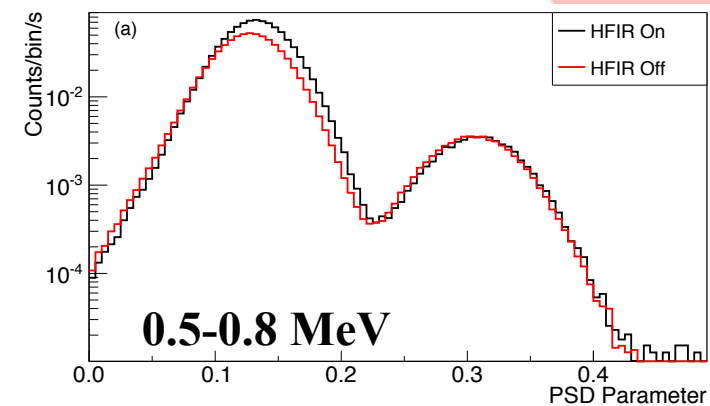


PROSPECT-2 Background Shielding

- Total energy deposit plot obtained from PROSPECT-2 shows more similar results between reactor on and off data.
- PSD distribution are compared for reactor on and off data. Similarity of higher energy distribution indicates no reactor-correlated neutron. An effective background reduction is achieved.

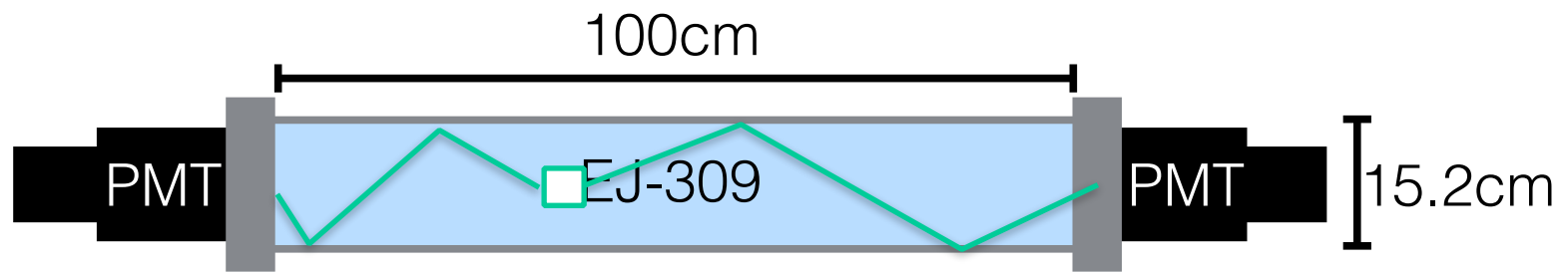


Total energy deposition reactor on and off, HFIR



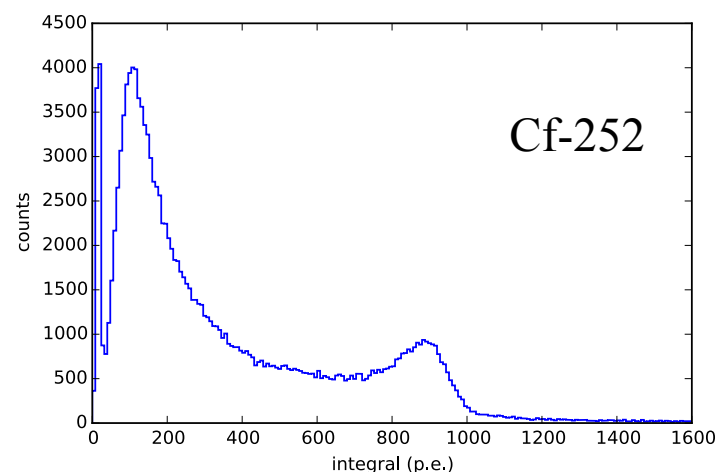
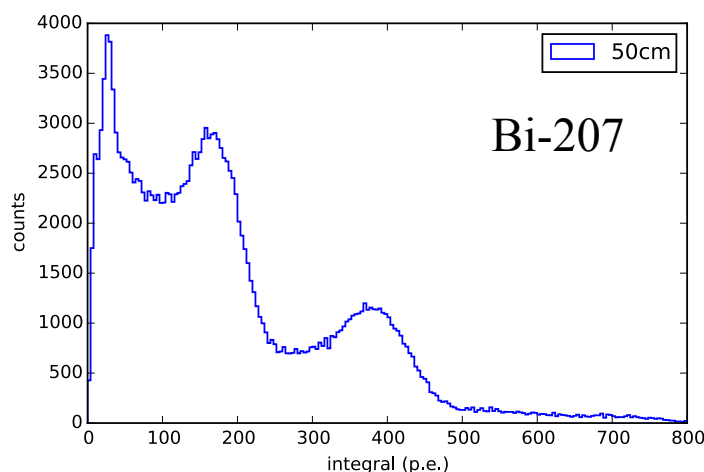
Performance of a full-sized test cell

- Two prototype detectors were constructed to demonstrate a PROSPECT unit cell.
- One detector filled with Li-6 loaded EJ309 and deployed at the near detector location at HFIR.
- The other filled with commercial LS (EJ309) at Yale to study light collection and PSD response in varied reflector, PMT and DAQ configurations.
- Gamma and spontaneous fission sources are deployed along the elongated cell of PROSPECT-20.

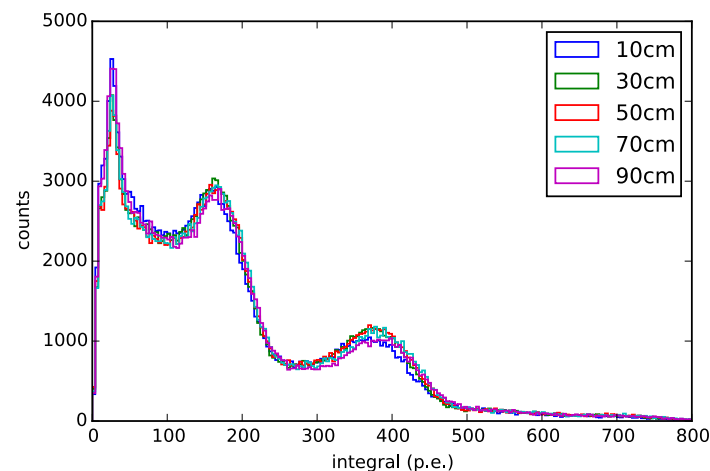
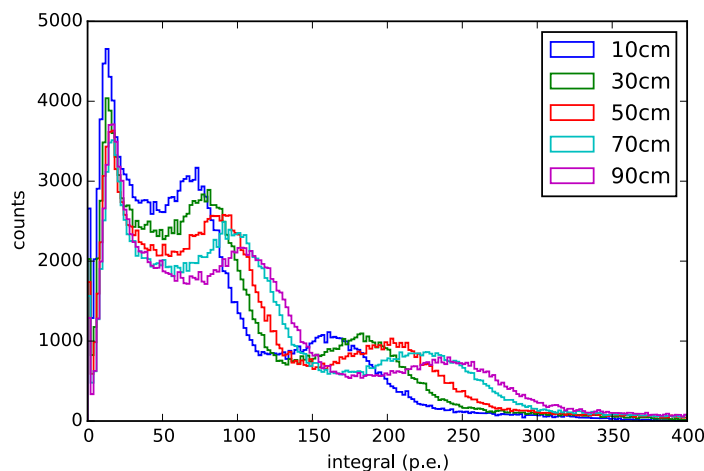


Light Collection Studies

- Absolute light collection, the spectra show the response of two PMTs from Bi-207 and Cf-252;



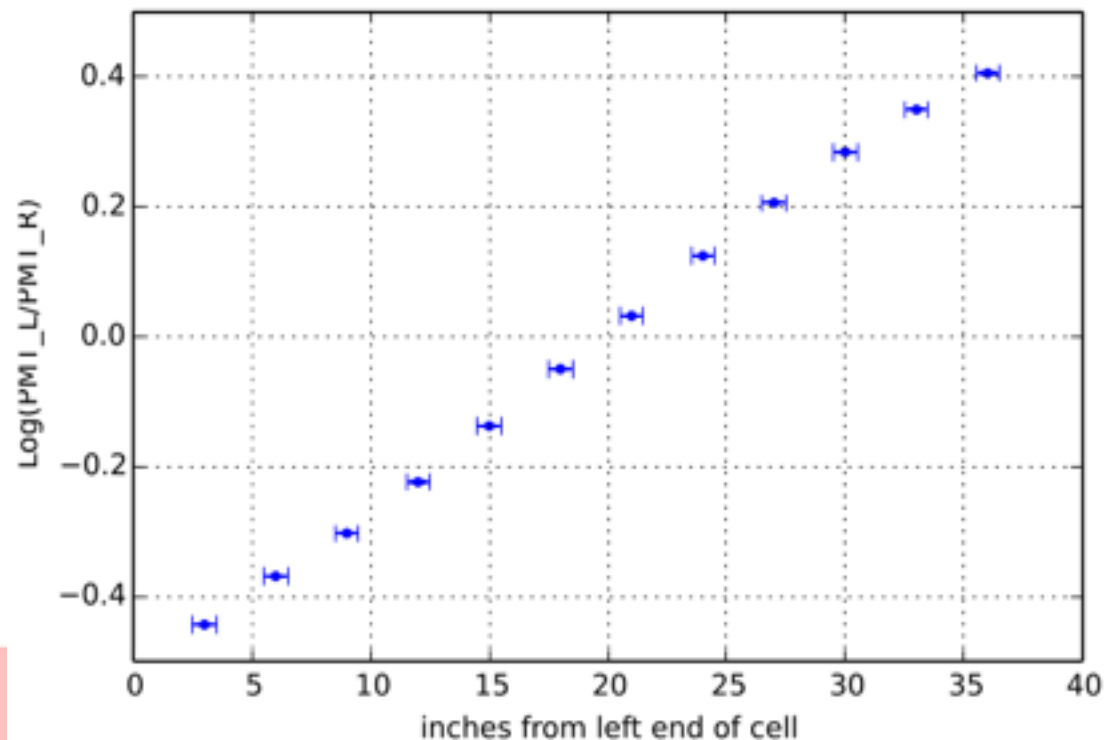
- Z-dependent of light collection: left shows integral of one PMT, right shows the average of both PMTs. Double ended readouts are uniform.



Light Collection Studies

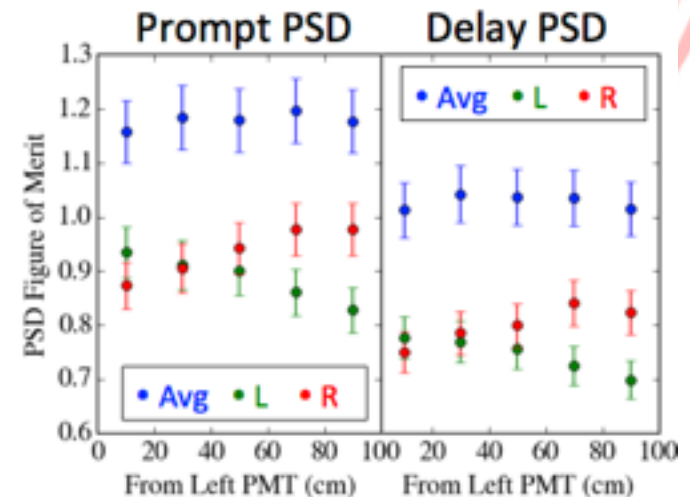
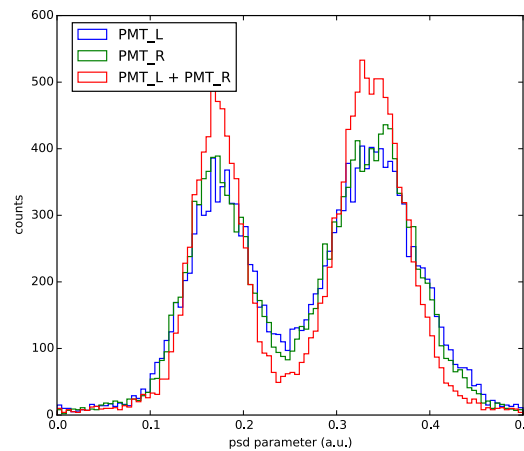
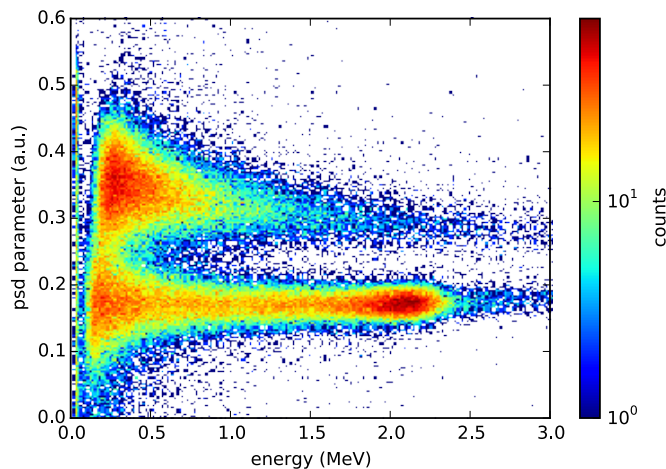
- Position reconstruction in PROSPECT-20, the difference of integrals between left and right PMT depends on the position of event, this ability is provided by double ended result.

$$\log \frac{Q_{PMTL}}{Q_{PMTR}}$$



PSD Studies

- Cf-252 calibration source is deployed near the detector to study PSD performance.
- Left figure shows PSD verses energy of events. Two bands representing gamma and neutron detected.
- Using two PMTs increases the uniformity and overall PSD performance of the cell (figure at center).
- Right figure shows z-dependence of PSD, good uniformity of PSD is achieved by averaging left and right PMT's integral.



Summary

- Background study has characterized main sources of background for short baseline reactor neutrino experiment.
- Shielding of PROSPECT-2 shows good reduction of near reactor background. Reactor correlated thermal and fast neutron are eliminated. Quoted uncertainties are statistical only.
- PROSPECT-20 demonstrates light collection and PSD's uniformity.
- Effective position reconstruction shown with two-PMT setup of PROSPECT-20.
- Multiple prototypes have demonstrated key aspects of the PROSPECT design.

The background features abstract red geometric shapes. In the top-left corner, there is a pattern of small, tilted red squares. In the top-right corner, a series of red lines radiate from a single point, creating a fan-like effect. A solid red shape is also visible in the top-right area. A thick red horizontal bar spans the bottom of the slide.

Thank you!