Assembling, Installing and Calibrating The PROSPECT Short-Baseline Antineutrino Detector

Xianyi Zhang *On behalf of the PROSPECT Collaboration*

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ILLINOIS INSTITUTE OF TECHNOLOGY

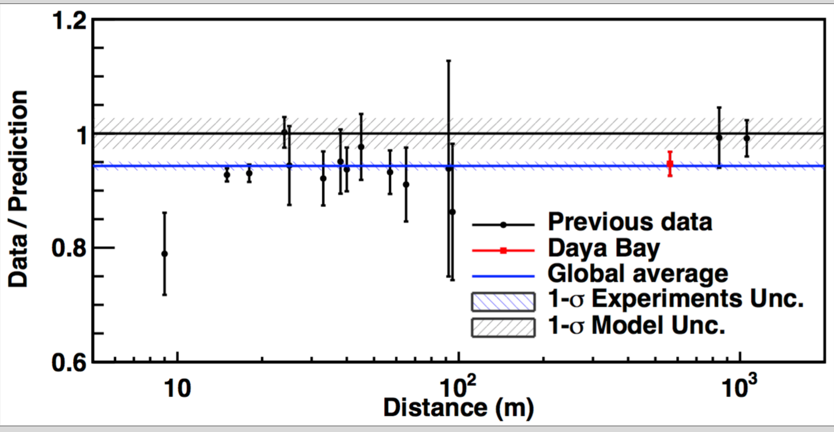
Abstract

PROSPECT is a short-baseline reactor antineutrino experiment designed to provide precision measurements of the fission product antineutrino spectrum of U-235 utilizing an optically-segmented 4-ton liquid scintillator antineutrino target. This measurement will enable the PROSPECT experiment to further investigate the origin of discrepancies between measured and predicted reactor antineutrino fluxes and spectra while simultaneously probing the possible existence eV-scale sterile neutrino oscillations independent of underlying reactor antineutrino flux models. The PROSPECT detector was assembled in late 2017, and began taking data in 2018 at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. This poster will overview design, assembly and deployment of the experiment's antineutrino detector. In addition, it will overview how energy, position, and pulse-shape discrimination calibrations are achieved for PROSPECT using in-detector LED and radioactive calibration sources, as well as intrinsic cosmogenic and radiogenic backgrounds.

Motivation

The reactor antineutrino anomaly:

- Global reactor antineutrino flux anomaly - 6% deficit from prediction [1].

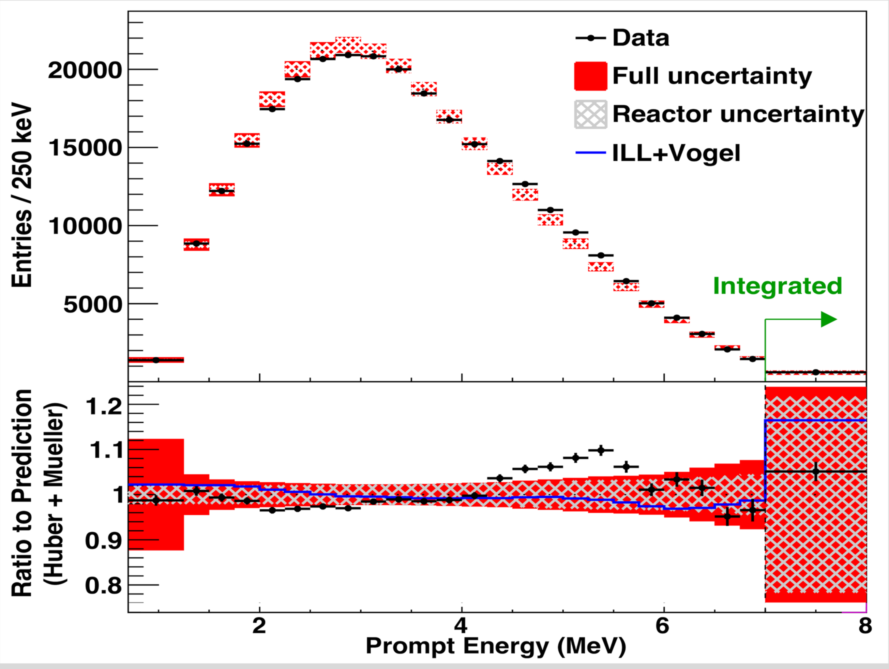


Questions raised:

- Hint of eV-scale sterile neutrino oscillation.
- Incomplete nuclear fission reactor model.

Spectral shape distortion

- Compare with nuclear model, 8-10% excess at 4-6 MeV prompt spectrum of inverse beta decay (IBD) [2].



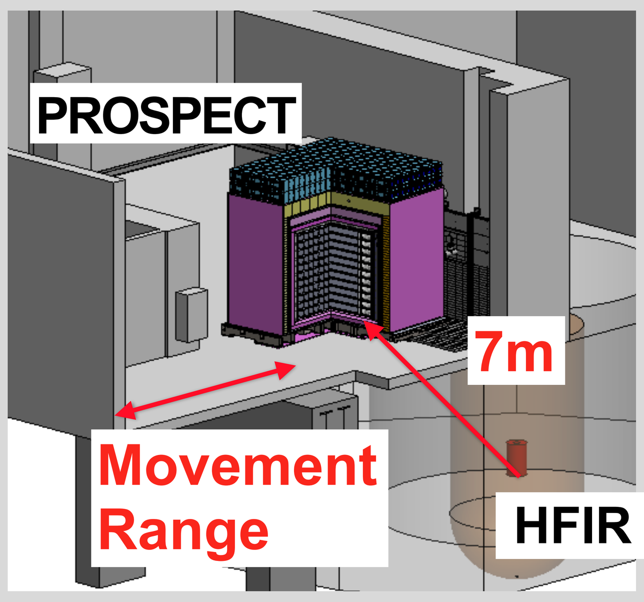
Experiment Design

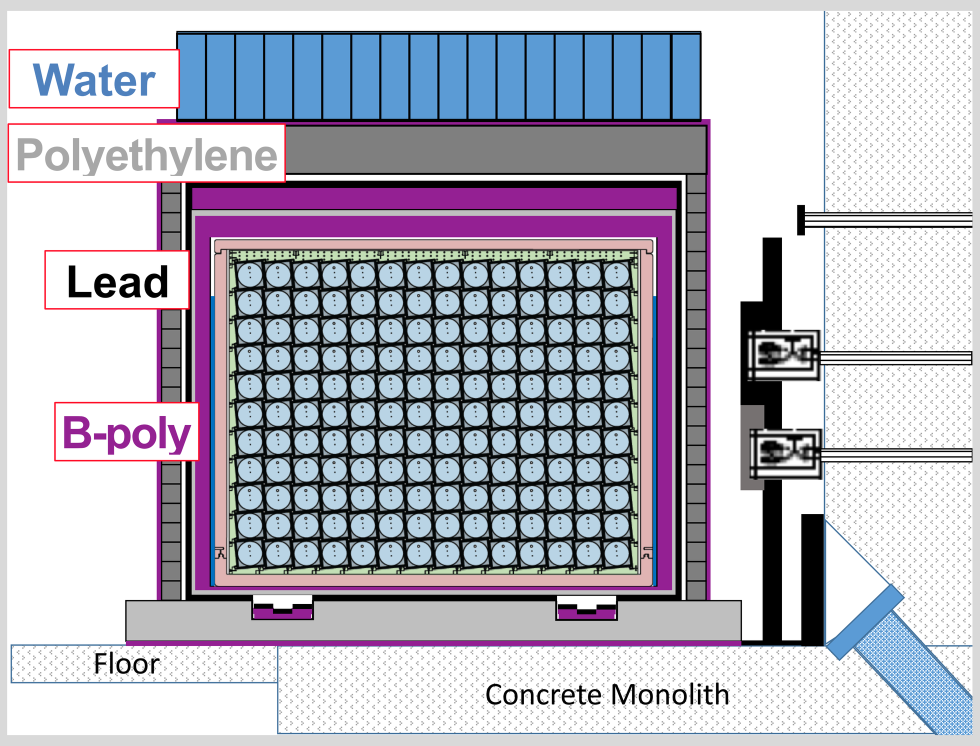
Antineutrino source - HFIR:

- Size: $d \times h$ = 43cm x 50cm.
- Power: 85MW.
- Antineutrino generated from U-235: >99%.
- Duty cycle: 47%.

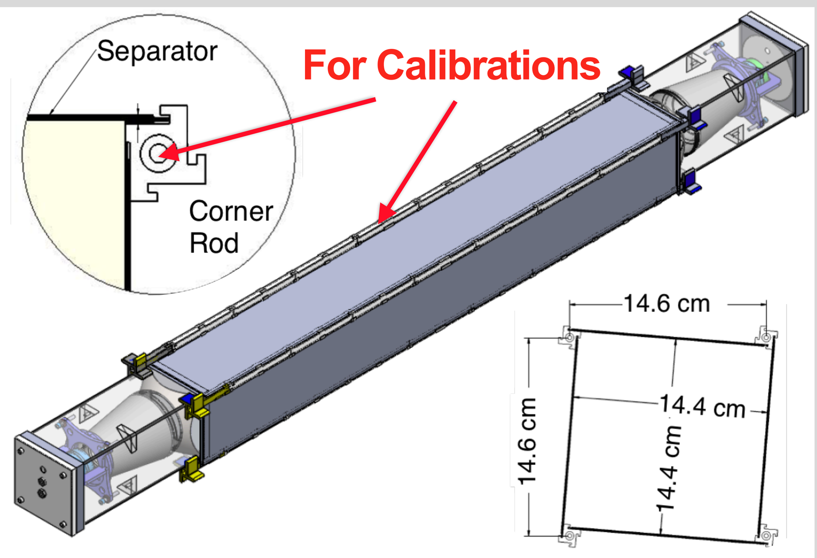
Antineutrino detector [3]:

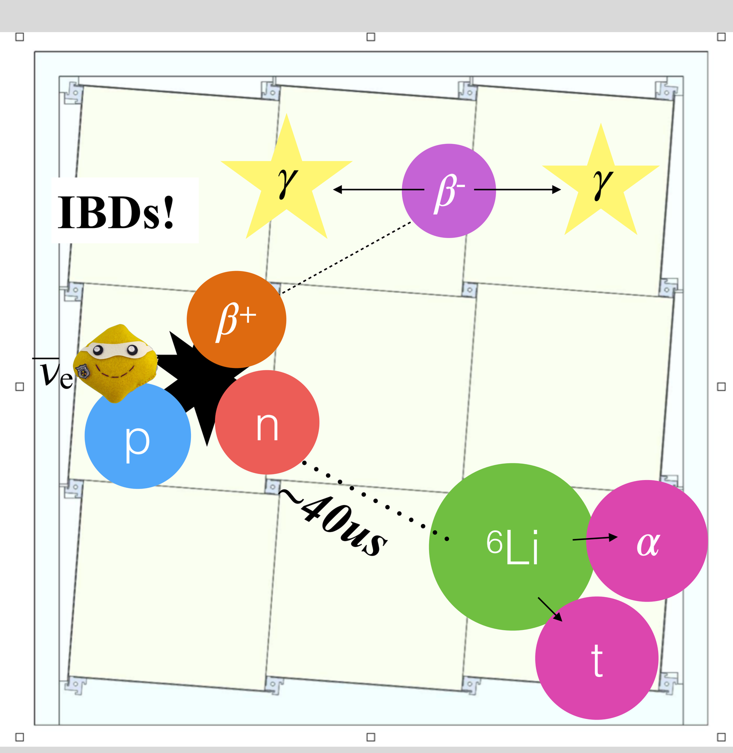
- Optically segmented into 154 cells.
- Li-6 doped liquid scintillator.
- Mass: ~4 ton.
- Baseline: 7-9 m.
- Each cell: 117.5 x 14.6 x 14.6 cm³.
- 5" PMT on each ends of cell.





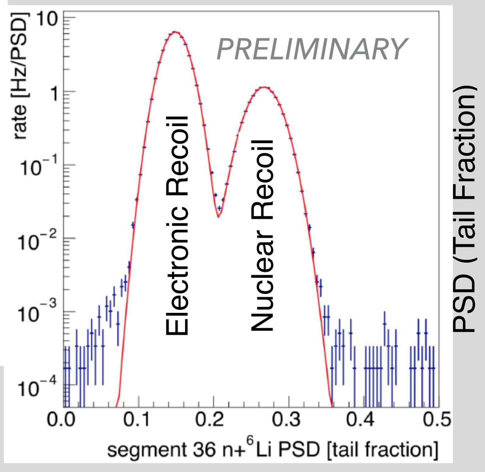
CHALLENGES:
- **Minimal overburden**
- **High reactor correlated background.**

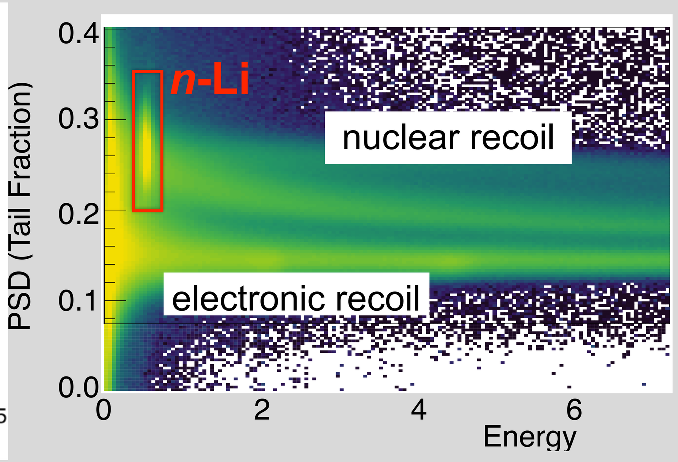




Measurement Strategy:

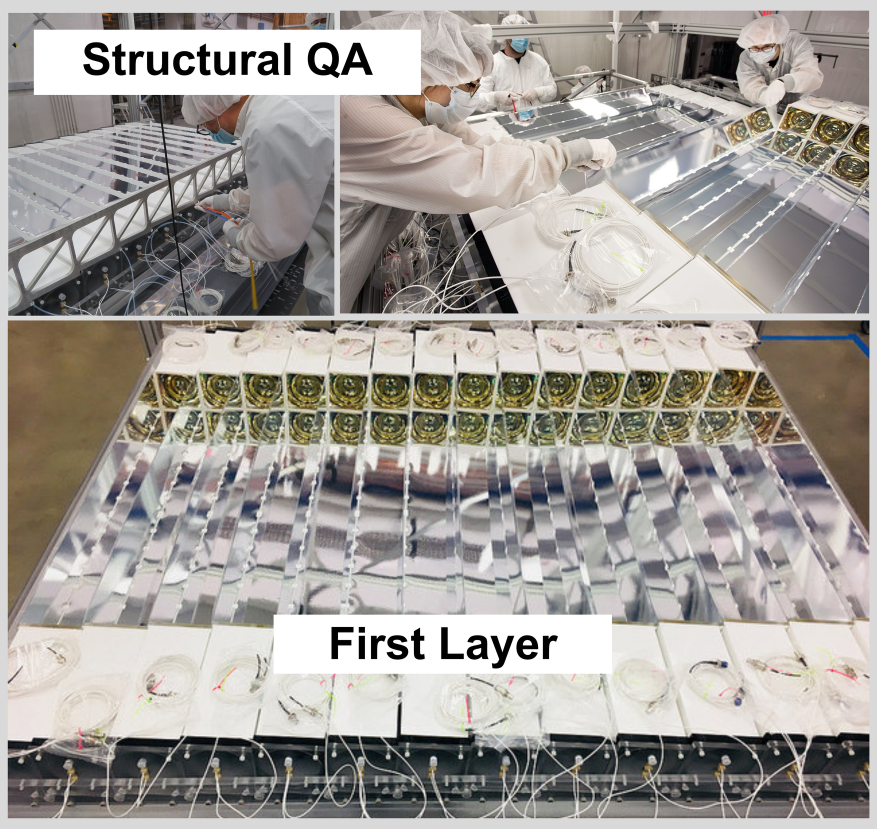
- IBD events are detected based on positron (prompt) and neutron captured by ^{6}Li (delayed by 40-50 μs) coincidence.
- Use pulse shape discrimination to distinguish prompt and delay events.
- Measure baseline dependent prompt IBD event spectrum.





Assembly and Installation

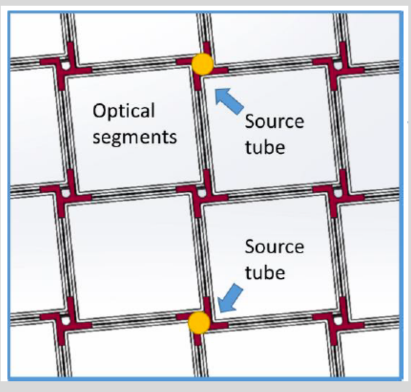
The fabrication of separator, supporting rods and PMT housing completed by Oct. 2017.
The PROSPECT AD was assembled in late 2017, after 3 months of assembly.
The detector was shipped to ORNL on Jan. 2018, installed onsite and started commissioning since Mar. 2018.



Calibration and Energy Response

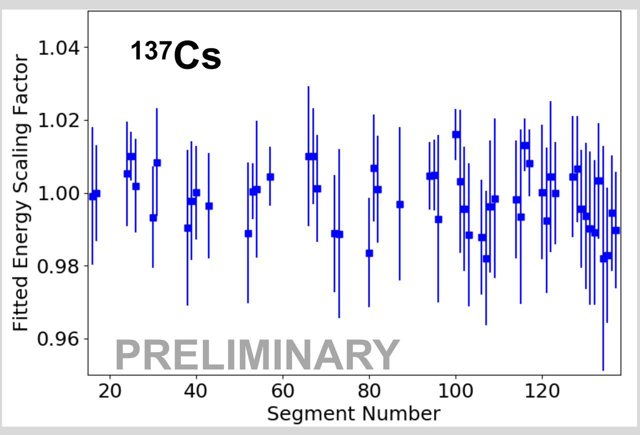
- **Source calibration: motor driven gamma and neutron sources (absolute and relative E scale calibration, and neutron capture life time).**

Source	Decay [keV]
^{22}Na	e⁺ → 511 γ, 1274 γ
^{60}Co	1173 γ, 1332 γ
^{137}Cs	662 γ
^{252}Cf	Spontaneous fission → n

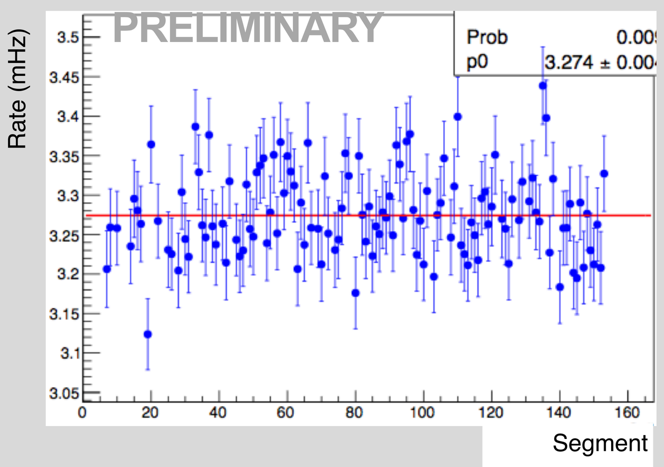


35 source tubes throughout AD

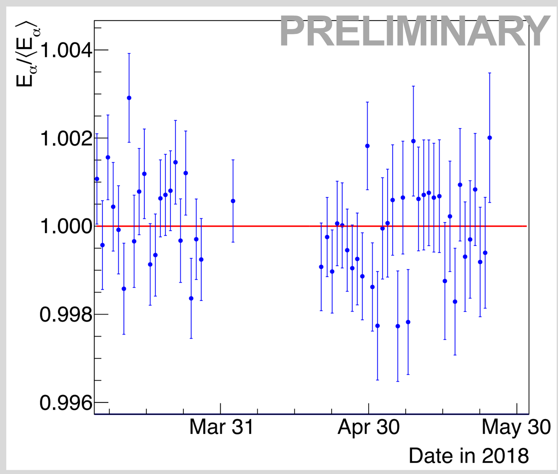
- **Ambient calibration:**
  - ^{212}Bi→^{212}Po→^{208}Pb (β-α energy and position calibration)
  - cosmogenic ^{12}B (β energy scale calibration)
  - cosmogenic neutron capture events (time dependent energy scale calibration)
- **Loaded ^{227}Ac calibration:**
  - ^{219}Rn→^{215}Po→^{211}Pb (relative cell mass calibration)



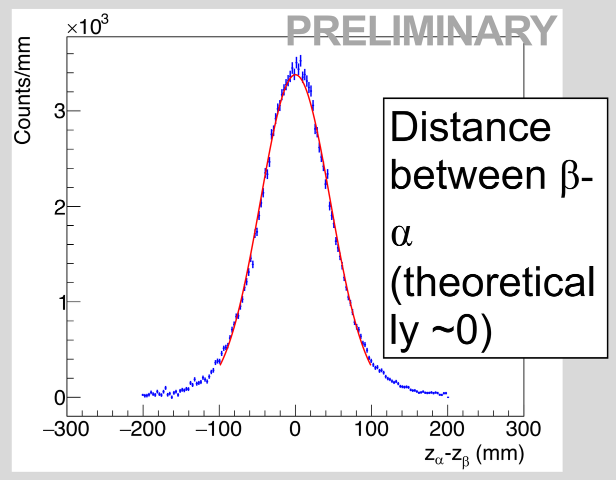
Relative E scale among cells vary within 2%.



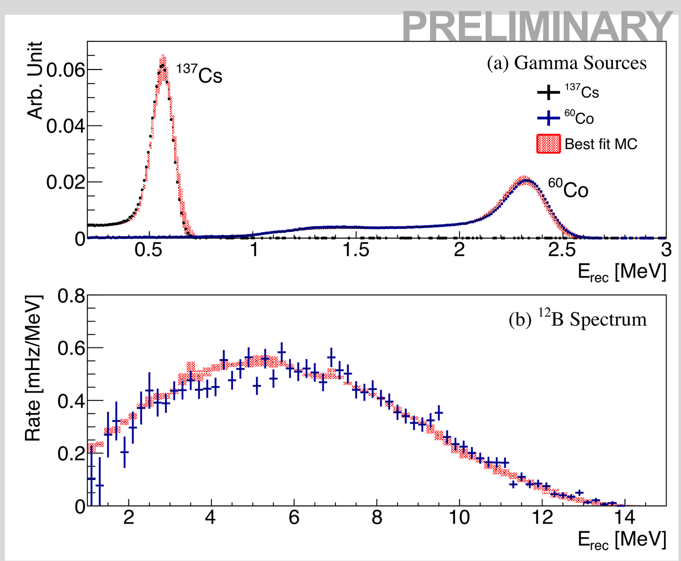
^{227}Ac RnPo rate among cells indicates variation of target mass.



Stability BiPo E scale within 2% during data taking.

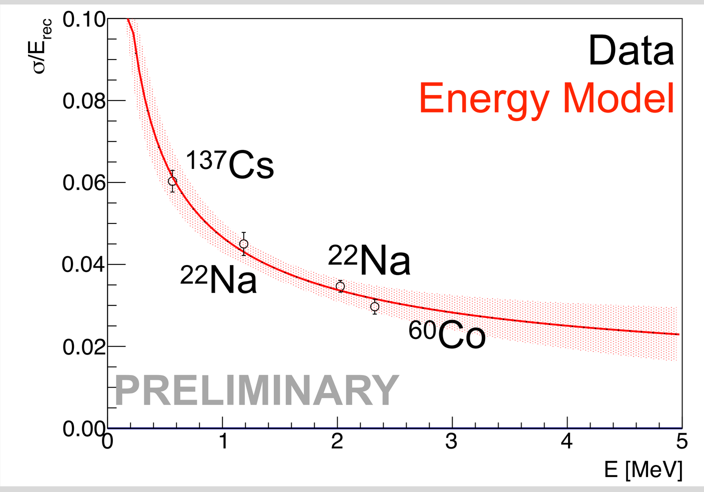


Resolution of positron reconstruction



γ and β⁻ reconstructed energy [4]

All calibration data here were fitted with with same nonlinearity, energy scale and resolution parameters simultaneously.



Reconstructed E resolution

Reference

[1] G. Mention *et al.* Phys. Rev. D 83, 073006
[2] Daya Bay collaboration, Phys. Rev. Lett. 116, 061801
[3] PROSPECT collaboration, J.Phys. G43 (2016) no.11, 113001
[4] PROSPECT collaboration, arXiv:1806.02784v1 [hep-ex]

*Related poster: Searching For Sterile Neutrinos With PROSPECT -P. T. Surukuchi