Precision Measurement of the Reactor Antineutrino Spectrum

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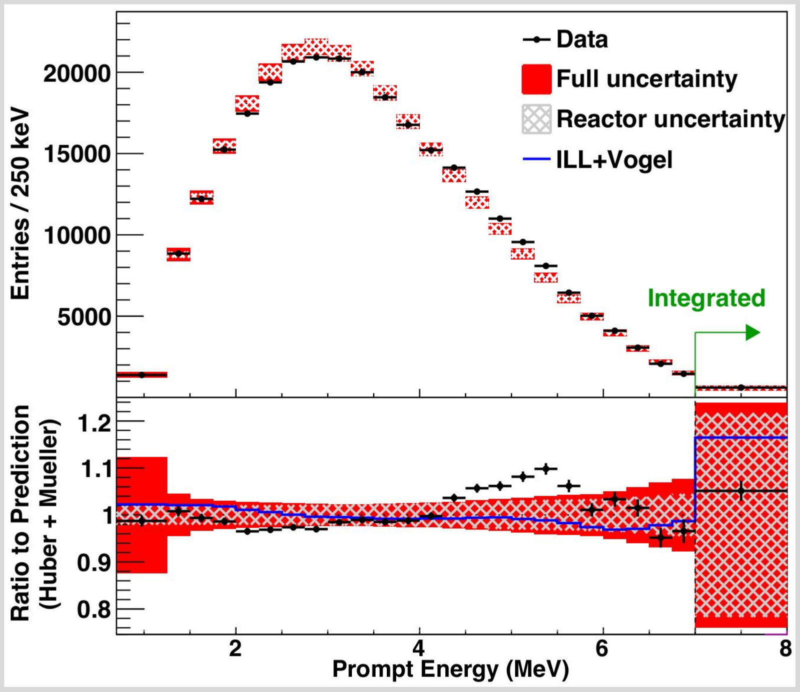
Abstract

PROSPECT, the Precision Reactor Oscillation and Spectrum Experiment, is a multiphase short baseline reactor antineutrino experiment that aims to probe eV-scale sterile neutrinos and precisely measure the antineutrino spectrum generated from a Highly Enriched U-235 (HEU) reactor. In Phase-I, a 3-ton movable optically segmented Li-6 loaded liquid scintillator detector will be deployed at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory at baselines ranging from 7-12m. With an energy resolution of < 4.5% at 1 MeV and a daily interaction rate of about 700 antineutrinos/day PROSPECT will make the highest precision measurement of an HEU reactor spectrum. In this poster, we describe PROSPECT's spectral measurement and its ability to shed light on the recently observed spectral discrepancies observed in the Θ_{13} reactor experiments.

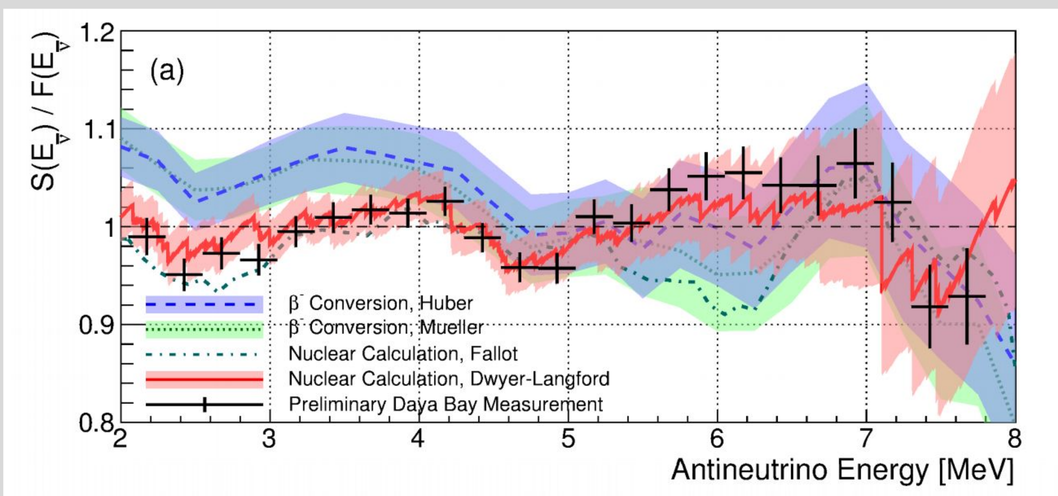
Motivation

The reactor antineutrino anomaly:

- The spectral measurement of the Θ_{13} reactor experiments disagree with the spectral models.
- Comparing with the ILL reactor antineutrino model, the 8-10% excess at 4-6 MeV indicates the discrepancy.
- The antineutrino spectrum predicted by *ab-initio* calculation shows discrepancies with the β conversion predictions.



Spectral measurement of the Daya Bay experiment [1].



Comparison between *ab-initio* and β conversion prediction [2].

Questions:

- Which isotope among the U-235, U-238, Pu-239 and Pu-241 isotopes contribute to the discrepancy?
- Which of the theoretical models are closer to fact?

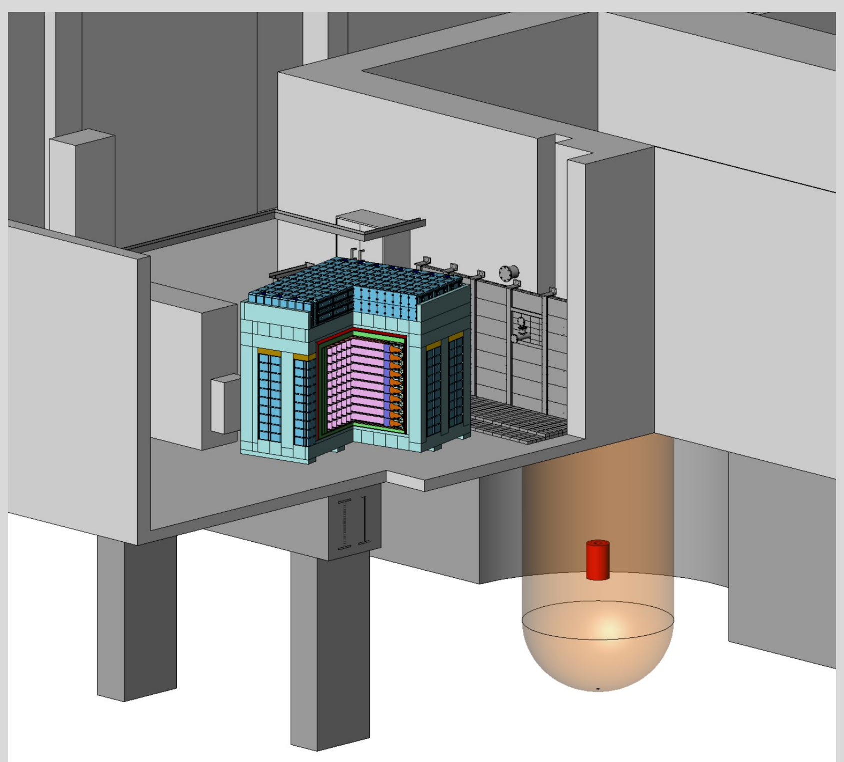
Experiment Design

Antineutrino source - HFIR:

- Size: d x h = 40cm x 50cm.
- Power: 85MW.
- U-235 enrichment: 93%.
- Antineutrino generated from U-235: >99%.
- Duty cycle: 41%.

The antineutrino detector:

- Optically segmented.
- Li-6 doped liquid scintillator (LiLS).
- Mass: 2980kg (fiducial: 1480kg).
- Baseline: 7-12m.
- Energy resolution: 4.5%/√E.

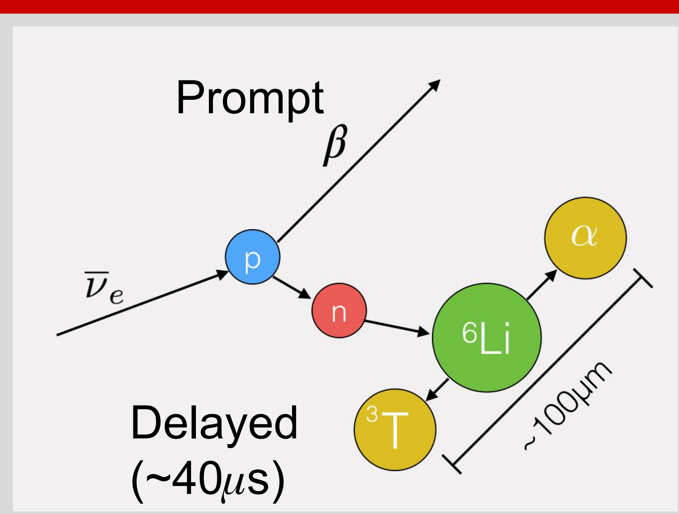


The on-site position of the reactor core and detector [3].

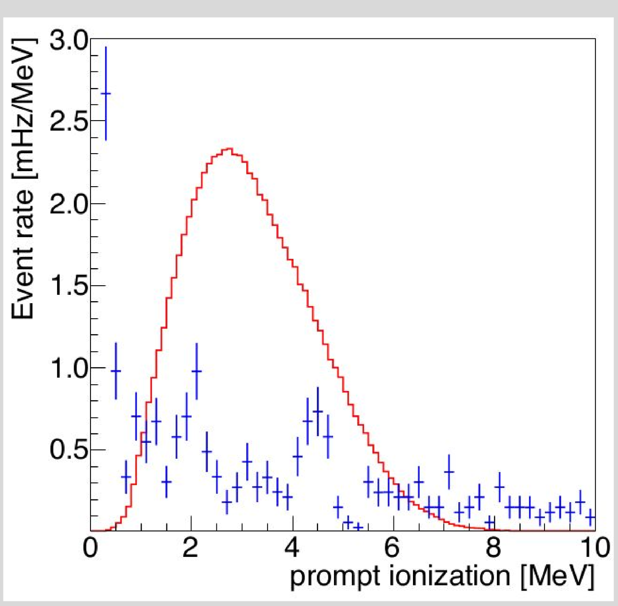
Measurement Strategy

Energy spectrum measurement:

- Careful calibration.
- Use Pulse Shape Discrimination (**PSD**) of LiLS to tag Inverse Beta Decay (**IBD**) event of the incoming antineutrino.
- PROSPECT will measure the spectrum of antineutrinos generated from HFIR by evaluating the prompt energy from IBD event.



IBD process in LiLS.



Simulated IBD spectrum in comparison with background [3].

Background subtraction:

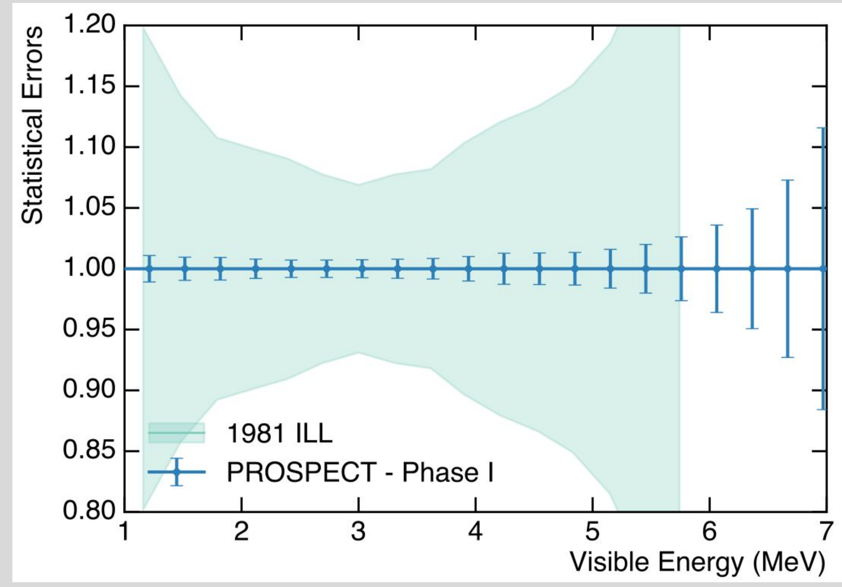
- On-site background study.
- Use PSD, topological cut and muon veto to subtract background.
- Measure background when reactor is off.
- The cosmogenic neutrons are the major source of background.
- Predicted S:B = 3:1.

Detection efficiency:

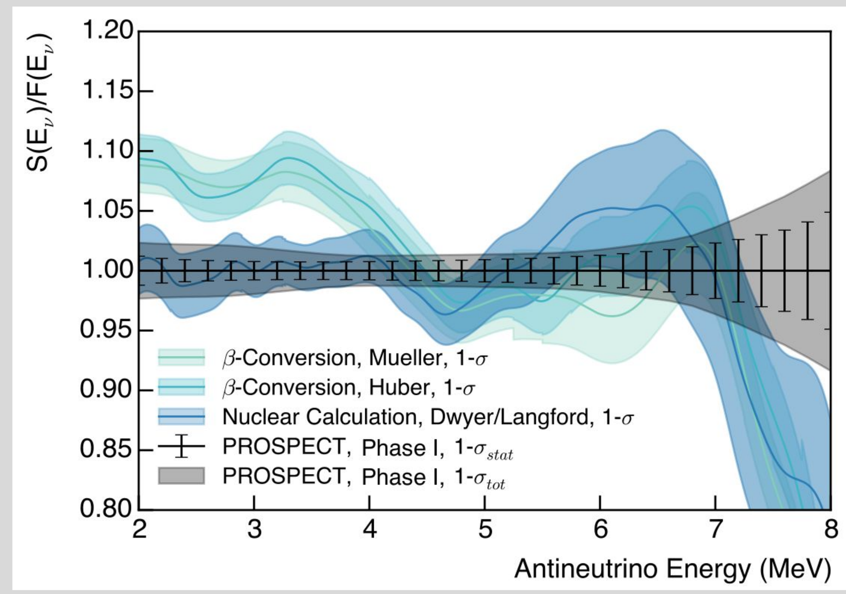
- IBD efficiency: 42%
- Event rate: 700/day, 115,000/yr

Precision of Spectrum Measurement

- Statistical uncertainty:<1.5% per bin.
- The major systematic is from energy scale uncertainty.
- The energy resolution (4.5%/√E) is better than previous reactor experiments.
- Compared with the previous ILL U-235 spectrum measurement, PROSPECT will have better statistical precision.
- Through an HEU measurement, we can better understand the U-235 contribution to the antineutrino spectrum.
- The other isotopes' contribution can be extracted when compared with LEU experiments.
- PROSPECT will provide an experimental reference of the reactor antineutrino spectrum model.



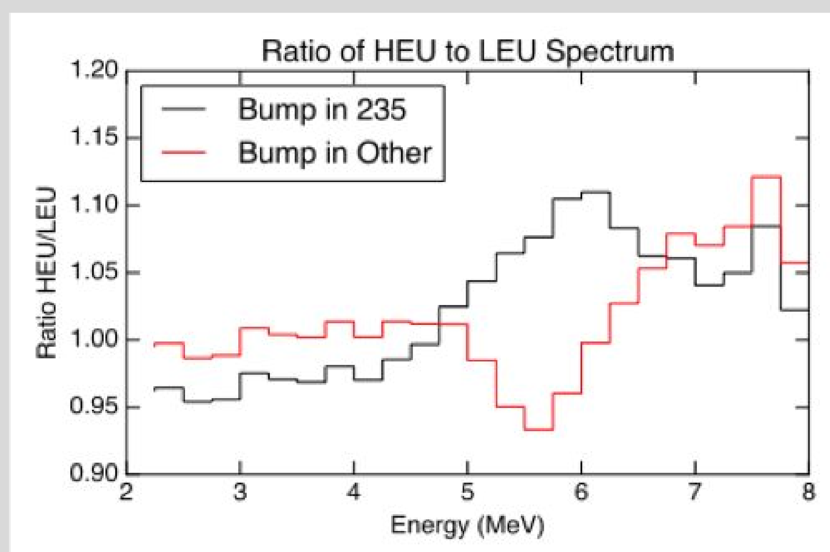
Statistical uncertainty (in 3 years) compared with ILL [3].



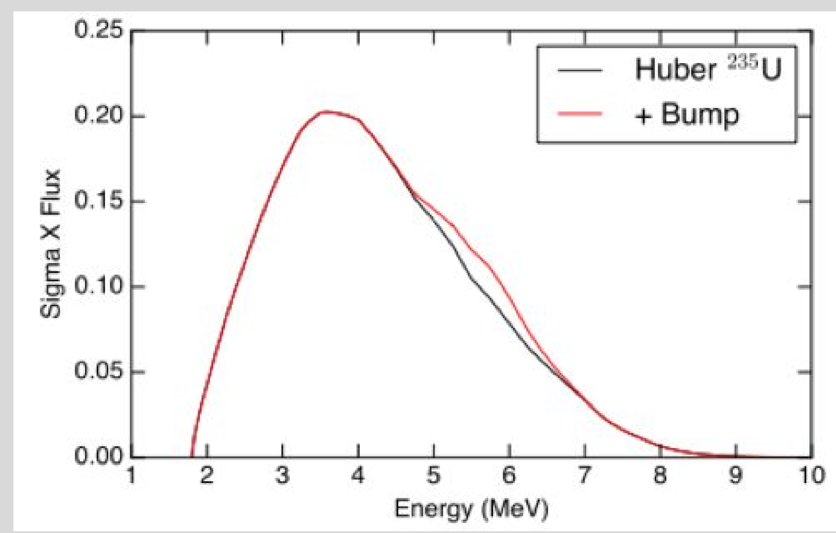
Statistical and total uncertainty (in 3 years) compared with theoretical models [3].

Preliminary Expectation of Measurement

- If the spectral deviation is all from U-235, we will be able to observe 20% excess in the "bump range" when compared with Huber's prediction [4].
- We will also observe ~10% excess compared with Daya Bay's spectrum.



Ratio of HEU/LEU.



Spectrum of U-235 predicted by Huber w/ and w/o the excess.

- If no excess in PROSPECT's HEU measurement, the deficit is from other isotopes [5].
- If all of the isotopes contribute the discrepancy, we expect to see no deficit between PROSPECT and Daya Bay, but a difference from β conversion predictions.

More from PROSPECT

Other posters:

- **T. Langford**, The development and characterize the PROSPECT detector
- **P. T. Surukuchi**, Design of PROSPECT Experiment
- **B. Littlejohn**, Mitigation of Near-Surface Cosmogenic Background for the PROSPECT Experiment
- **K. Gilje**, Searching for Sterile Neutrinos with the PROSPECT Experiment

PROSPECT Website

References

1. **Daya Bay Collab.**, arXiv:1607.05378
2. **D. A. Dwyer and T. J. Langford**, Phys. Rev. Lett. 114, 012502
3. **PROSPECT Collab.**, arXiv:1512.02202
4. **Patrick Huber**, Phys. Rev. C 84, 024617
5. **A. C. Hayes, et al.** Phys. Rev. D 92, 033015

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