PROSPECT: The Precision Reactor Oscillation and Spectrum Experiment

TJ Langford
Yale University
October 31, 2015
Recent anomalous results in the measured flux and spectrum exist

- 5% flux deficit
- Bump: 10% local spectral deviation
- Indication of new physics?
Phased Experimental Plan

Physics Goals:
• Search for short baseline $\nu_e$ oscillations using detector segmentation
  • Distortions in energy spectrum that vary with baseline
  • Measure $^{235}$U antineutrino spectrum to illuminate the “Bump”

Experimental Strategy:
• Phase 1:
  • Sterile neutrino search, cover best fit region at $3\sigma$ in 1 year
  • Measure $^{235}$U spectrum with 100k events/year
• Phase 2: World-leading short baseline sensitivity

Challenges:
• Minimal overburden, cosmogenic backgrounds
• Reactor-related backgrounds
  • High energy ($\lesssim$10MeV) gammas
HFIR Research Reactor

- High Flux Isotope Reactor at Oak Ridge National Lab
- 85MW HEU compact-core reactor, 42% uptime
- PROSPECT activity for past 2 yrs
- Backgrounds fully characterized (arXiv:1506.03547)
- Unique location for a short baseline experiment
PROSPECT-0.1
Aug 2014
Spring 2015
5cm
0.1 liter
LS cell

PROSPECT-2
Dec 2014
Feb 2015
12.5cm
1.7 liter
LS cell

PROSPECT-20
March 2015
1m
23 liter
LS cell

PROSPECT-Nx30
Early 2016*
1.19m long
Nx30 liter
LS segments

PROSPECT Phase I
Late 2016*
120x30 liter
LS segments
15x15x119cm

*technically driven schedule
Segmented Antineutrino Detector

- 3ton LiLS detector
- 120 optical segments
  - 119x15x15 cm³ each
- Double-ended PMT readout
- Access for calibration sources between every cell
- Shielding package designed for surface backgrounds
Full-scale Test Detector

- **PROSPECT-20**
  - 23L test cell of 6Li-loaded Liquid Scintillator
  - 15x15x100 cm$^3$ detector
  - Measured Light collection: **530PE/MeV**
  - **4.5%@1MeV energy resolution**
  - Measured PSD Figure of Merit: 1.4 at (n,Li) capture
  - >99.9% background rejection
  - Double-ended readout
  - uniform light collection and position reconstruction

PROSPECT-20 Paper arXiv:1508.06575
Operation of PROSPECT-20 at HFIR

- Operated for four months at HFIR
  - Two HFIR cycles
- Shielding package roughly 25% mass of full shield
- Reactor-related backgrounds mitigated
  - Targeted local shielding
  - Active background rejection with LiLS
- Validation of background simulations for full PROSPECT detector
235U Spectrum Measurement

- Simulated Signal/Background > 1, validated by PROSPECT-20 at HFIR
- ~1000 inverse beta decays detected per day, 100k/year
- Best energy resolution of any reactor neutrino experiment (4.5%@1MeV)
- **Phase-I precision will surpass spectral model uncertainties**
  - Directly test reactor neutrino models
  - Produce a benchmark spectrum for future reactor experiments
Short Baseline Oscillation Search

- Segmented detector designed for oscillation search
  - Each cell is a separate “detector”
  - Oscillatory L/E between segments limits uncertainties from reactor
  - True oscillometry needed for confirmation of sterile neutrinos
- Probe best-fit region at >3σ in 1 year

- Sensitivity:
  - Phase I (1 yr) at 3σ
  - Phase I (3 yr) at 3σ
  - Phase I + II (3+3 yr) at 3σ
  - Phase I + II (3+3 yr) at 5σ
  - SBL Anomaly (Kopp), 95% CL
  - All νe Disappearance Exps (Kopp), 95% CL
  - SBL + Gallium Anomaly (RAA), 95% CL
  - Daya Bay Exclusion, 95% CL

- Best Fit Oscillation

- Mass Splitting: 1.78 eV; Osc. Amplitude: 0.092

- L/E (m/MeV)
  - Osc./Unosc.
    - 0 1 2 3 4 5 6 7 8 9

- Sensitivity vs. L/E

- 3σ, 1yr
• PROSPECT is designed to probe new physics at short-baselines

• Backgrounds have been characterized and test cells deployed at HFIR

• Design light collection and PSD performance validated by full-scale test cell

• **PROSPECT will cover the sterile neutrino best fit region at $3\sigma$ within its first calendar year**

• **PROSPECT will measure the $^{235}$U spectrum with the highest precision to-date**