PROSPECT - A Precision Reactor Neutrino Oscillation and Spectrum Experiment

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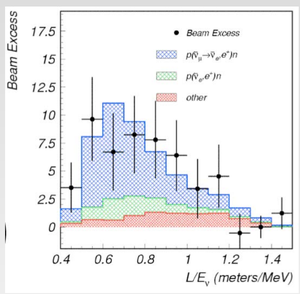
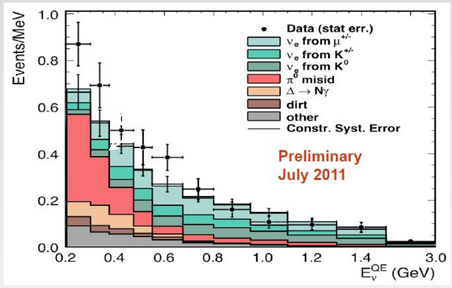
Wright Laboratory, Department of Physics, Yale University

See also: P03.053, P03.054, P03.056

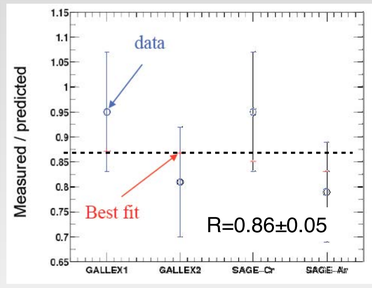
Neutrino Anomalies & Sterile ν Hypothesis

MiniBoone

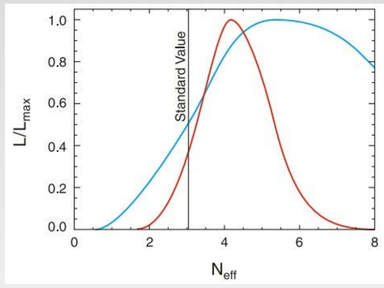




Ga Anomaly



Cosmology (WMAP)



Anomalies in Neutrino Data

LSND (ν_e appearance)
MiniBoone (ν_e appearance)
Ga calibration source anomaly
N_{eff} in cosmology
Short-baseline reactor anomaly ($\bar{\nu}_e$ disappearance)

If new oscillation signal,
implies $\Delta m^2 \sim O(1eV^2)$ and $\sin^2 2\theta > 10^{-3}$
➔ very short baseline oscillation for reactor ν

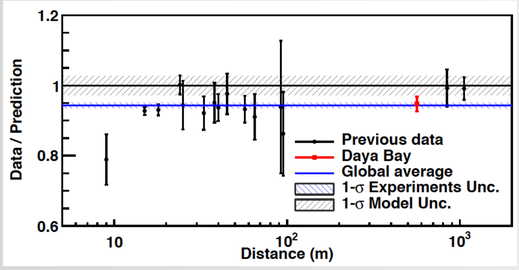
$$L_{osc} = 2.5\frac{E(MeV)}{\Delta m^2(eV^2)} \simeq 2-10\ m$$

Systematics or experimental effects?
➔ test each experimental effect.

"Light sterile neutrinos: A white paper", arXiv:1204.5379

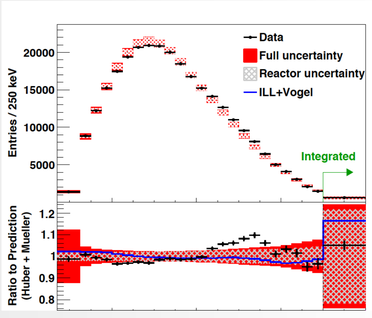
Reactor Neutrino Anomalies

Flux Deficit



Extra neutrino oscillations or artifact of flux predictions?

Spectral Deviation



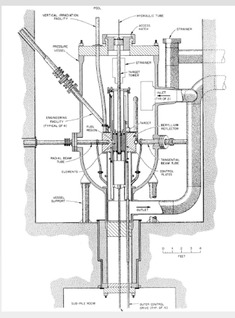
New feature in 4-6 MeV region of spectrum.

Understanding reactor flux and spectrum anomalies requires new reactor measurements

Phys.Rev.Lett. 116 (2016) 6, 061801 Daya Bay collaboration

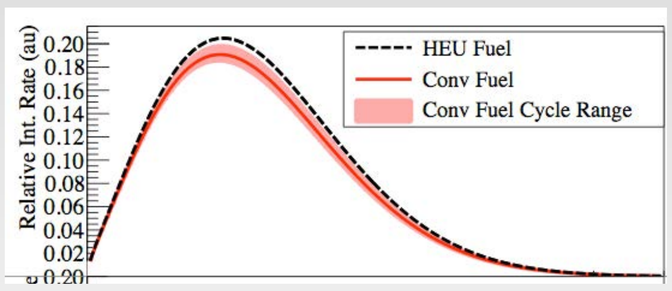
High Flux Isotope Reactor, ORNL as a Compact Antineutrino Source

High Flux Isotope Reactor, ORNL



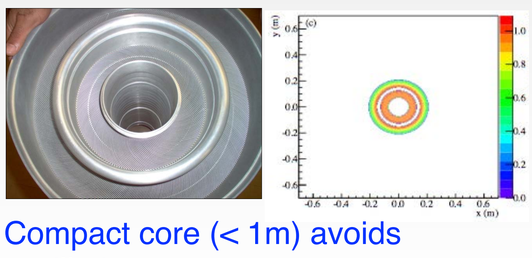
power: 85 MW (research)
fuel: highly enriched uranium (^{235}U)
core shape: cylindrical
size: h=0.5m r=0.2m (compact)
duty-cycle: 41%

HEU Reactor Spectrum

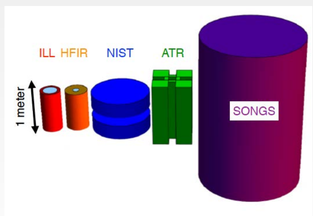


HEU core provides static spectrum of mainly ^{235}U.

Compact reactor core



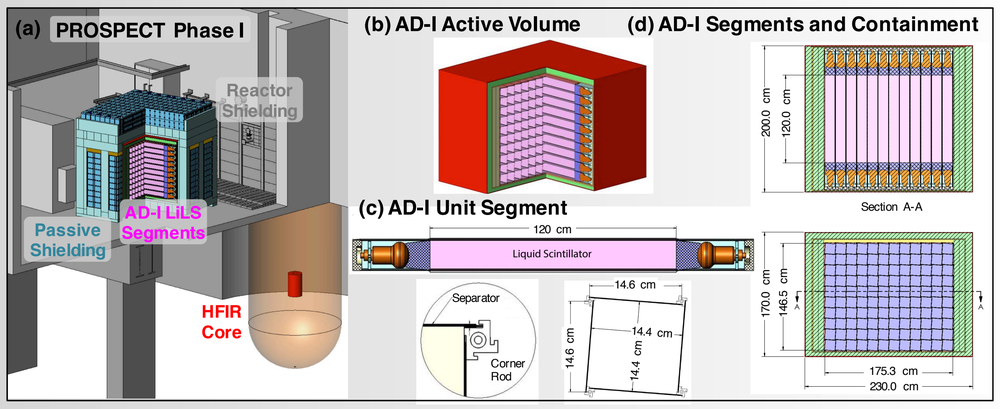
Compact core (< 1m) avoids oscillation washout



Nucl. Instrum. Meth. A806 (2016) 401–419, arXiv:1506.03547, PROSPECT collaboration

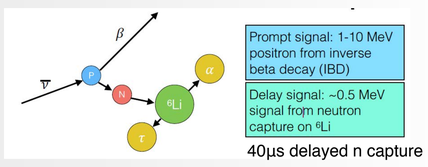
PROSPECT Detector System

A Segmented, ^6Li-Loaded Detector



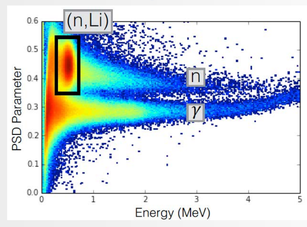
- 3000L of ^6Li liquid scintillator
- 100 scintillator loaded cells, ~15x15x120cm
- double ended PMT readout, light guides, <4-5%/√E resolutions
- thin optical separators, minimal dead material
- containment vessel, filled in place

Antineutrino Event Identification with ^6Li Doped Scintillator



signal	inverse beta decay (IBD) γ-like prompt, n-like delay
backgrounds	fast neutron n-like prompt, n-like delay
	accidental gamma γ-like prompt, γ-like delay

Pulse Shape Discrimination



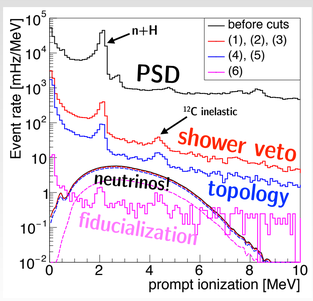
Background reduction is key challenge

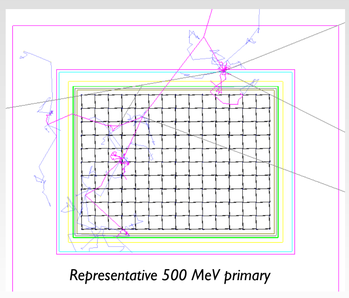
Background Rejection Via Segmentation

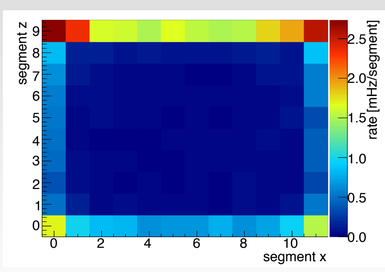
Background Reduction Steps

- Efficient PSD and neutron tagging
- Identification of multiple particle interactions
- Fiducialization

Active suppression by >3 orders of magnitude





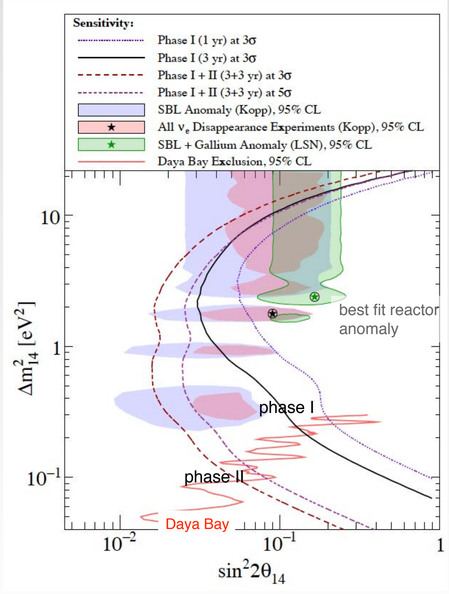


Ref: PROSPECT collaboration

PROSPECT Physics

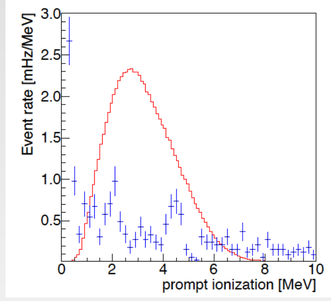
Precision Oscillation Experiment

4σ test of best fit after 1 year
>3σ test of favored region after 3 years
5σ test of allowed region after 3+3 years



Precision Spectrum Experiment

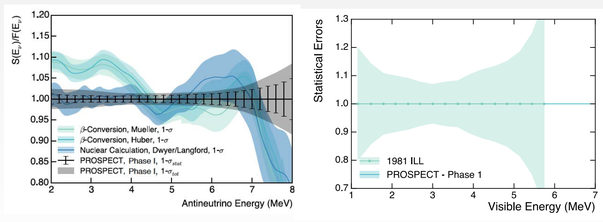
Measurement of ^{235}U spectrum



IBD signal
backgrounds
after analysis cuts

between 2-6 MeV:
average stat. precision < 1.5%,
systematics < 2%

Comparison of different reactor models



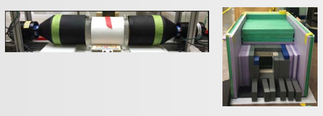
PROSPECT Detector and Shielding Development

PROSPECT-0.1
Characterize LS
Aug 2014-Spring 2015

5cm length
0.1 liters
LS, ^6LiLS

PROSPECT-2
Background studies
Dec 2014 - Aug 2015

12.5 cm length
1.7 liters
^6LiLS

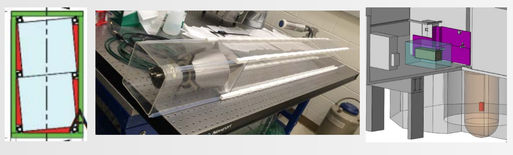


PROSPECT-20
Segment characterization
Scintillator studies
Background studies
Spring/Summer 2015

1m length
23 liters
LS, ^6LiLS

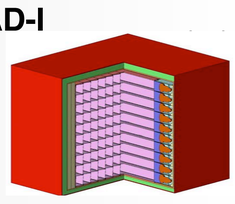
PROSPECT-50
Baseline design prototype
Winter 2015

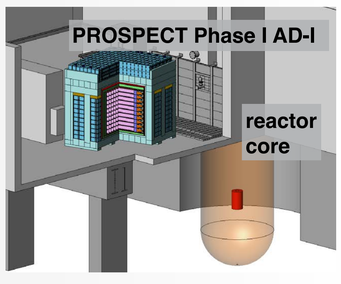
1x2 segments
1.2m length
50 liters
^6LiLS



PROSPECT AD-I

10x10 segments
1.2m length
~3 tons
^6LiLS





PROSPECT Publications
arXiv: 1506.03547, 1508.06575, 1512.02202

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