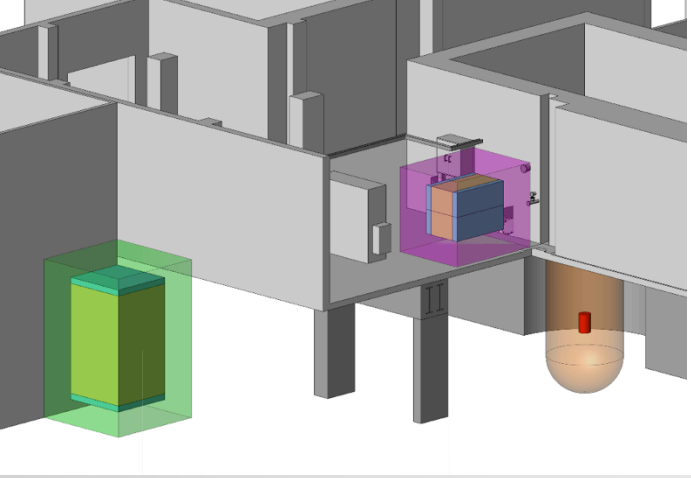
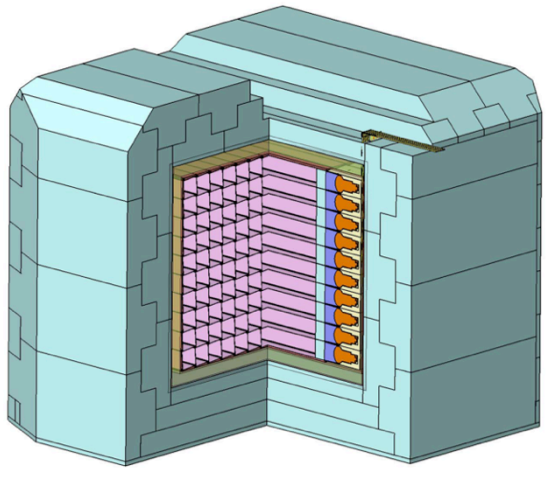
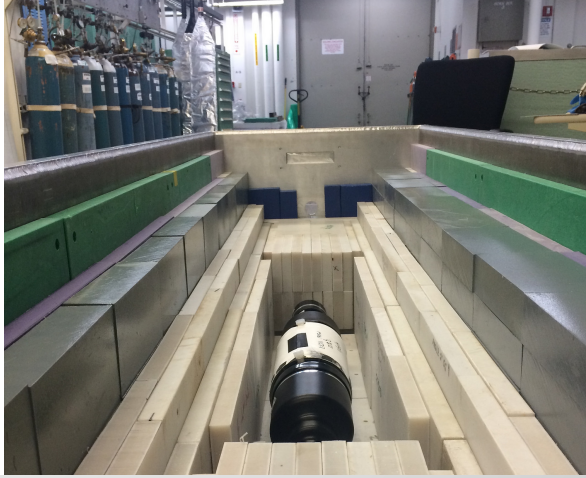
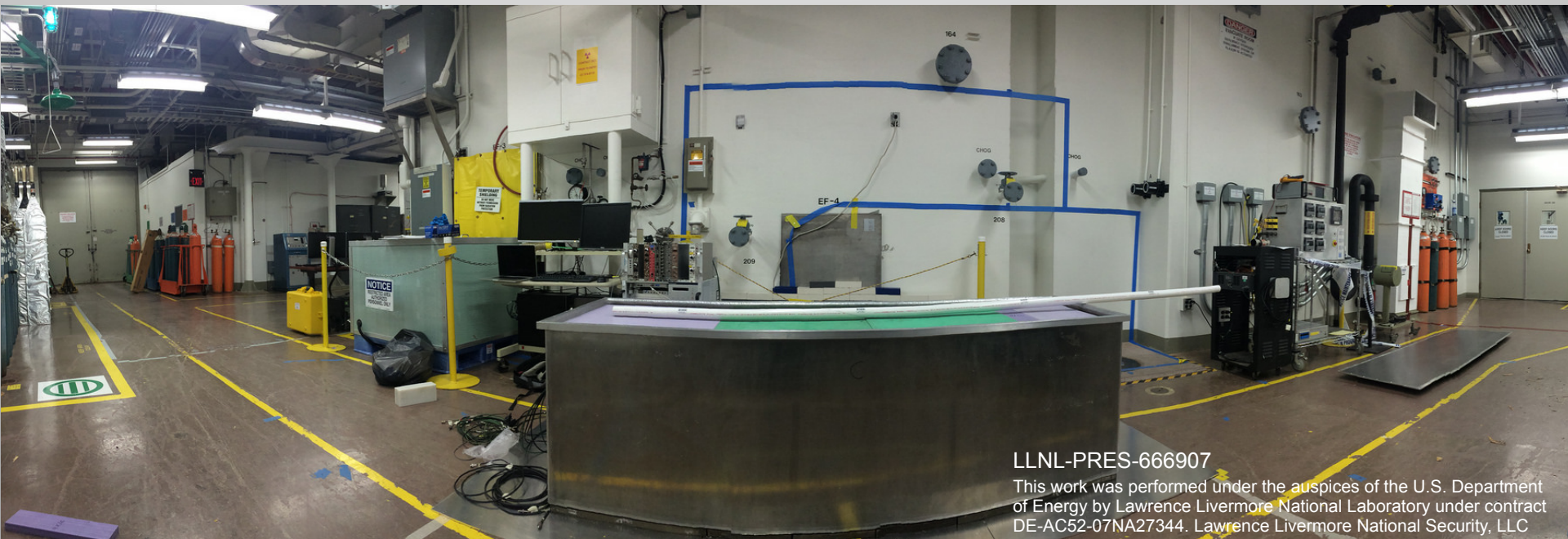






PROSPECT

A Precision Oscillation and Spectrum Experiment



LLNL-PRES-666907

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

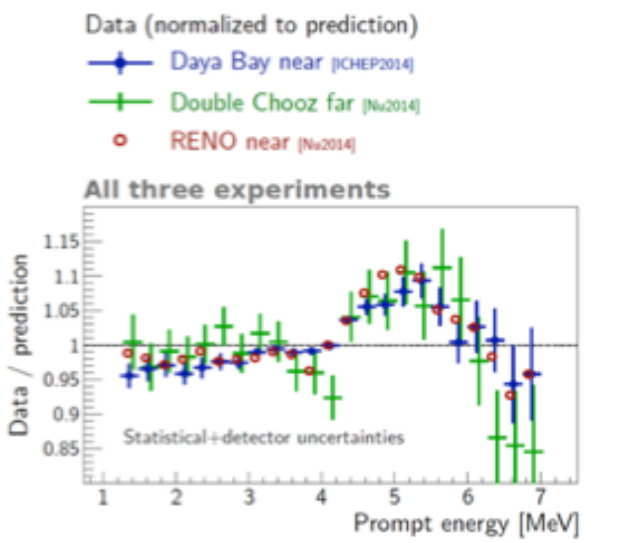
Motivations

Primary:

Understand reactor antineutrino emissions and resolve reactor anomaly

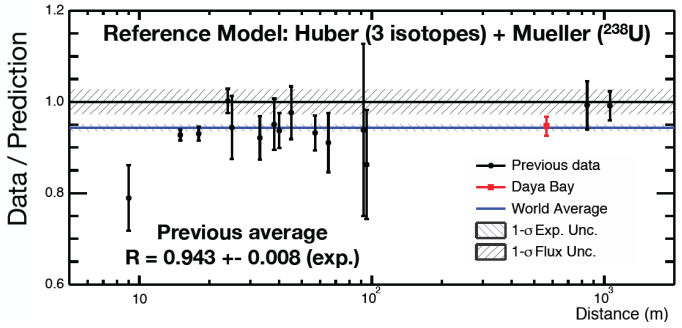
First precision measurement of ^{235}U reactor antineutrino spectrum

- additional constraint on flux models underlying reactor anomaly and newly observed spectral deviation



Short Baseline Oscillation search:

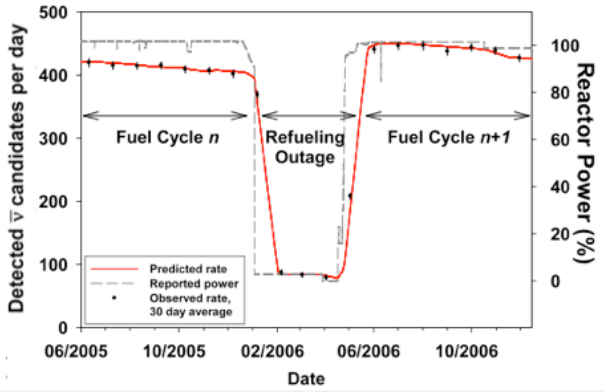
- short-baseline oscillation search to test hypothesis of sterile neutrinos and probe new physics



Additional:

Reactor Safeguards

- develop detection technology for operation near-surface
- monitoring demonstration at small research facility



PROSPECT Experimental Concept

Deploy two segmented liquid scintillator detectors at compact HEU research reactor

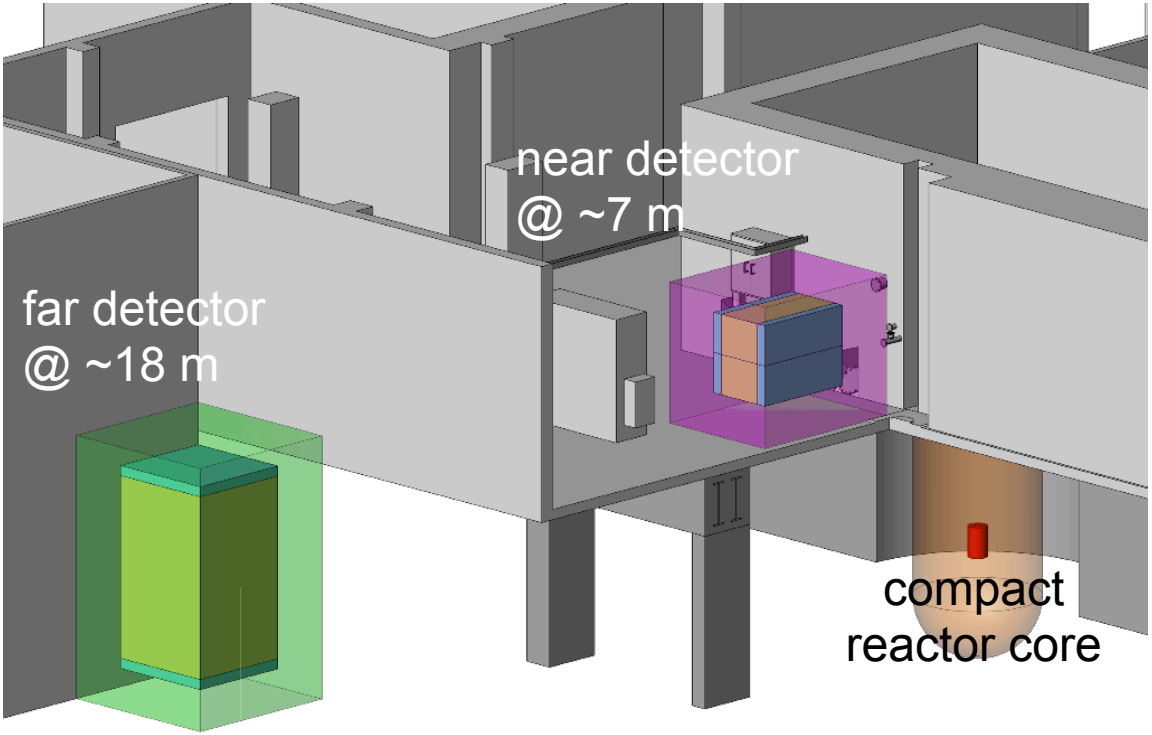
Phased Approach

Phase 1: Near detector *O*(2ton), 3 years,
HFIR selected as site for Phase I

- Precision spectrum measurement
- Movable detector for oscillation search at multiple baselines

Phase 2: Near+Far detector *O*(10ton), 3 years

- Enhanced oscillation search

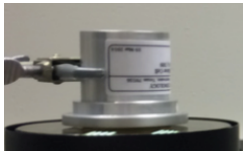


Unique Features

- ^{6}Li doped liquid scintillator in segmented detector
- Pulse Shape Discrimination: identify e.m./fast neutron/ neutron capture
- excellent energy resolution
- low inactive volume
- near detector movable to 1.2m longer baseline

Phased PROSPECT R&D at HFIR

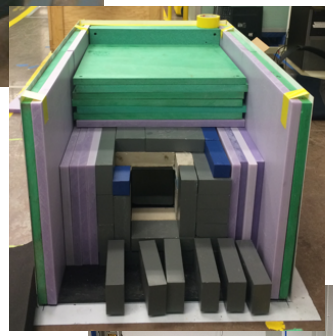
PROSPECT 0.1
Aug. 2014



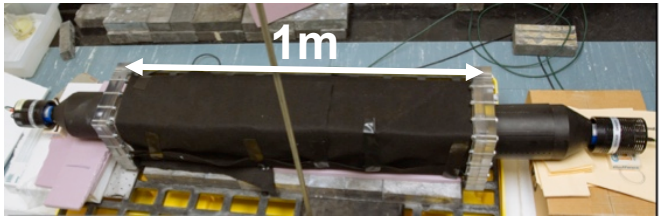
5cm
0.1 liter
LS cell

PROSPECT 2
Dec. '14/Jan. '15

12.5cm
2 liter
LS cell

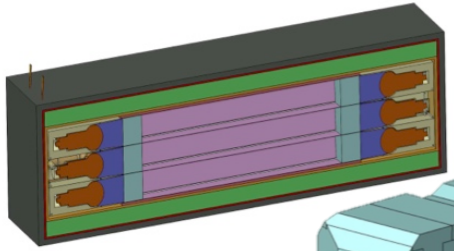


PROSPECT 20
Early 2015

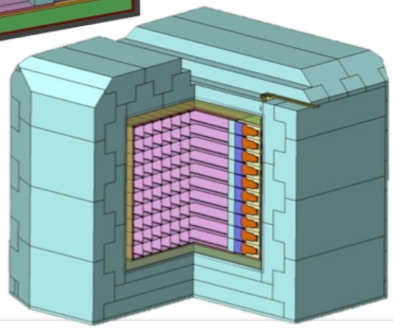


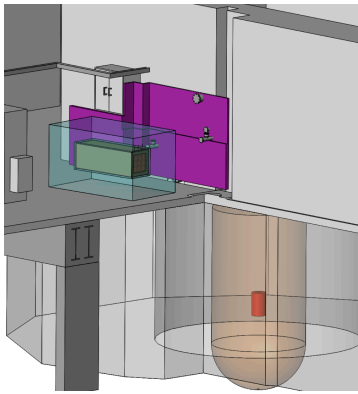
1m
20 liter
LS cell

PROSPECT N×20
Summer 2015*



N×20 liter
LS segments





PROSPECT 2ton
Summer 2016*

* Technically driven schedule

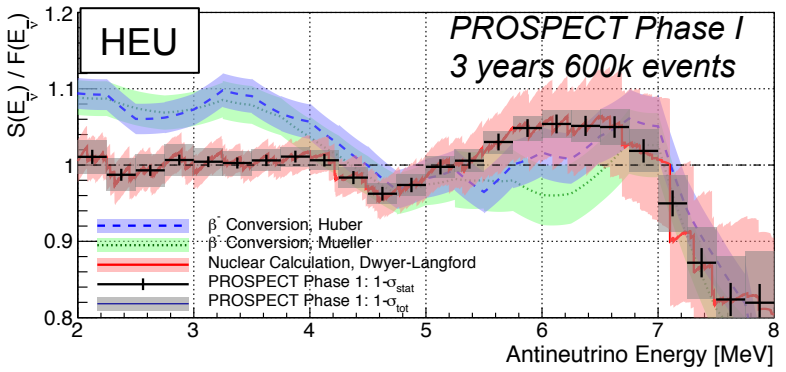
PROSPECT Physics Potential: ^{235}U Spectrum

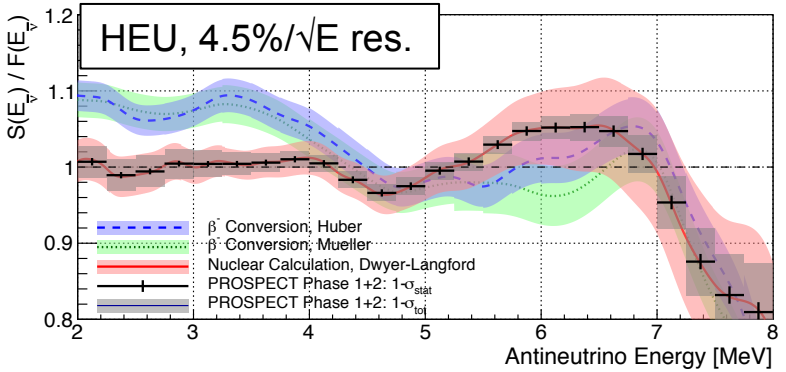
Precision ^{235}U spectrum measurement:

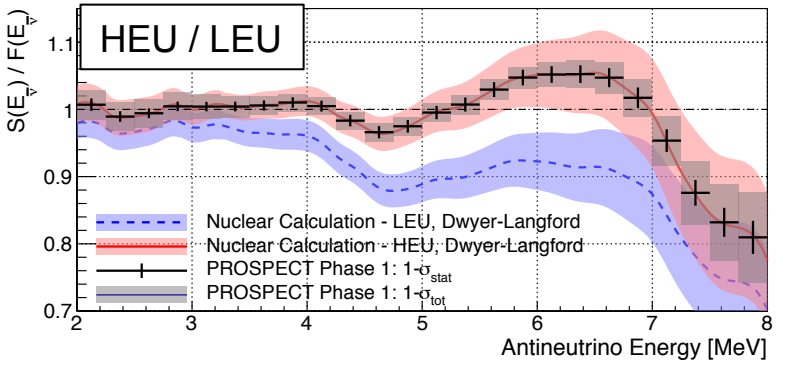
- complements existing LEU measurements, additional constraint on flux predictions from single well modeled core
- aids in understanding observed spectral discrepancies and may explain the underlying cause for the “reactor anomaly”
- useful for future reactor neutrino experiments such as JUNO and RENO-50, and reactor monitoring applications

Assumptions:

- 1:1 Signal:Background
- absolute detector energy scale systematics comparable to Daya Bay
- negligible uncertainty on the spectral shape of dominant backgrounds (reactor off measurement)
- negligible uncertainty due to temporal variations of background







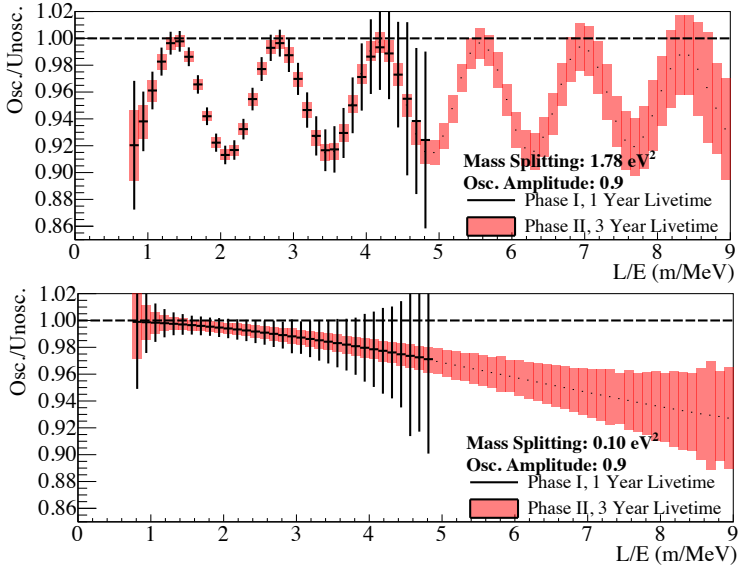
PROSPECT Physics Potential: Oscillation

Strategy Relative spectrum measurement over broad baseline span

PROSPECT N×20 Two position measurement can probe best fit region very soon (N≥16)

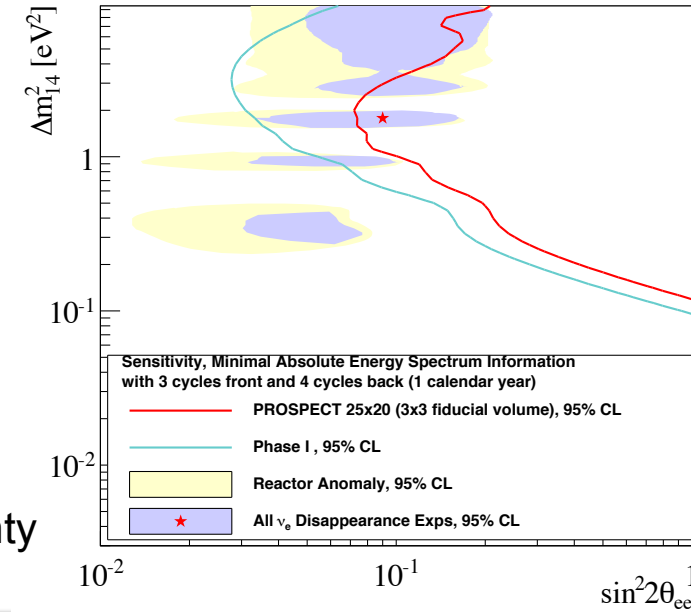
PROSPECT Phase I Two position measurement spans broad L/E range to rapidly provide significant physics reach

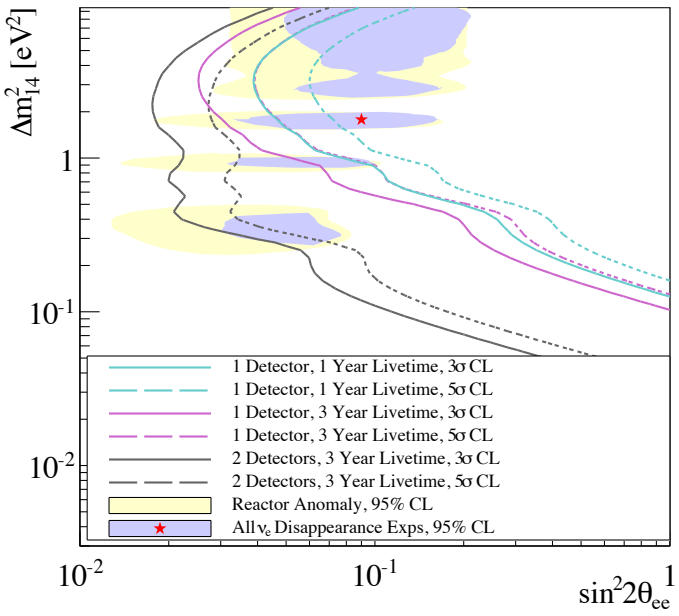
PROSPECT Phase II Extended L/E range, increasing sensitivity and accessing lower Δm^2



Assumptions

- No reliance on absolute shape/normalization
- 1:1 Signal:Background
- Detection Eff.: 30%
- 14.6cm position res.
- 4.5% energy res.
- 1% segment-to-segment normalization precision
- 0.5% bin-to-bin uncertainty (e.g. energy scale)





PROSPECT Phase I Detector Concept

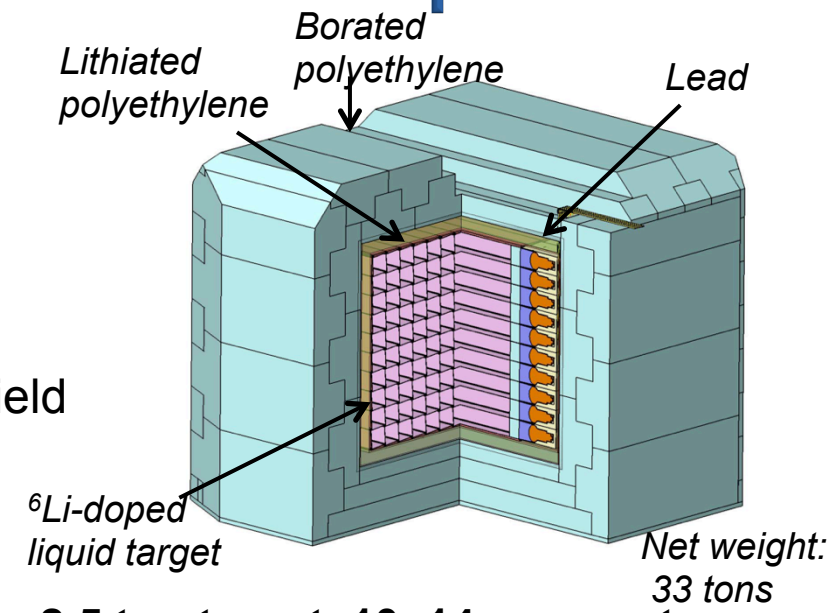
Provides large target mass and baseline span within HFIR facility constraints

Background reduction:

- Particle ID from ^{6}Li-LS with PSD
- Event localization from segmentation
- Neutron & γ-ray suppression from multi-layer shield

Positron energy containment/reconstruction:

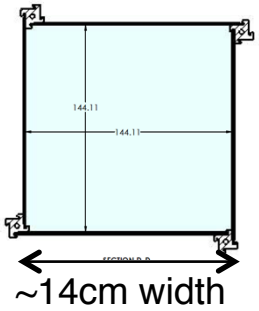
- Fiducialization from segmentation
- Well understood, uniform optical response from double-ended readout

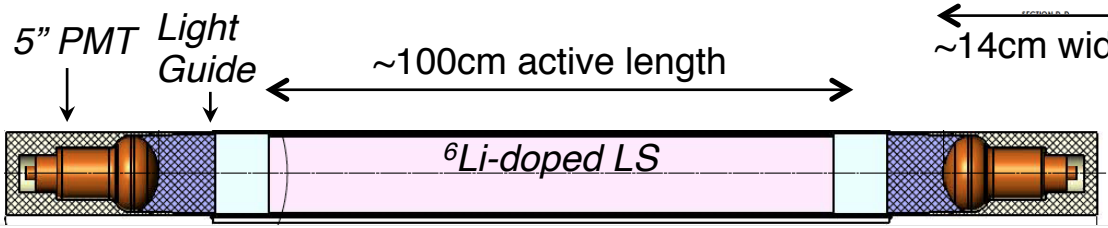


2.5 ton target, 10x14 segment array

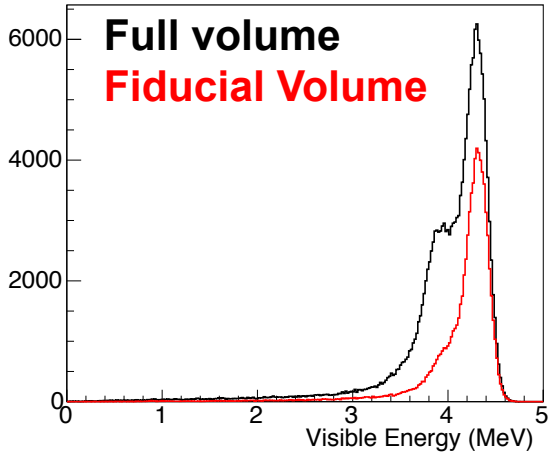
Segment Unit Cell

- < 3% inactive material (Bugey3 >15%)
- Use low-mass optical separators; support posts provide calibration access





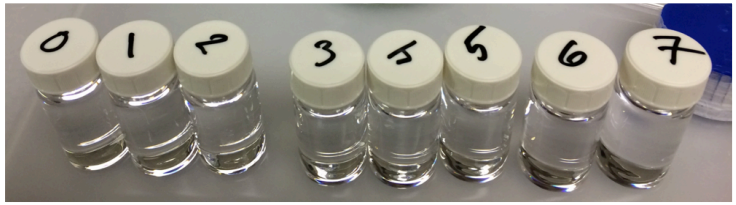
Simulation response: 3.5 MeV e^+



R&D Activities: Detector Development

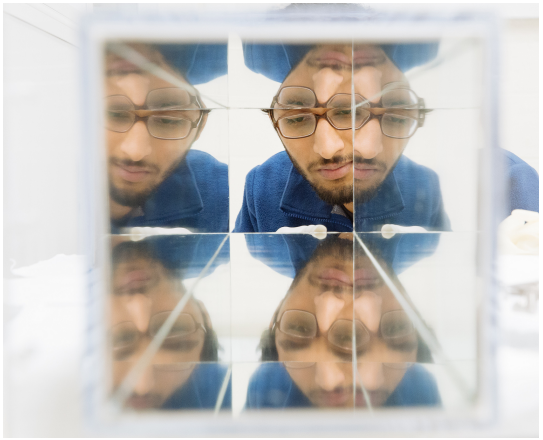
^{6}Li loaded liquid scintillator

Several candidates developed with good scintillation light yield, capture timing, PSD, compatibility



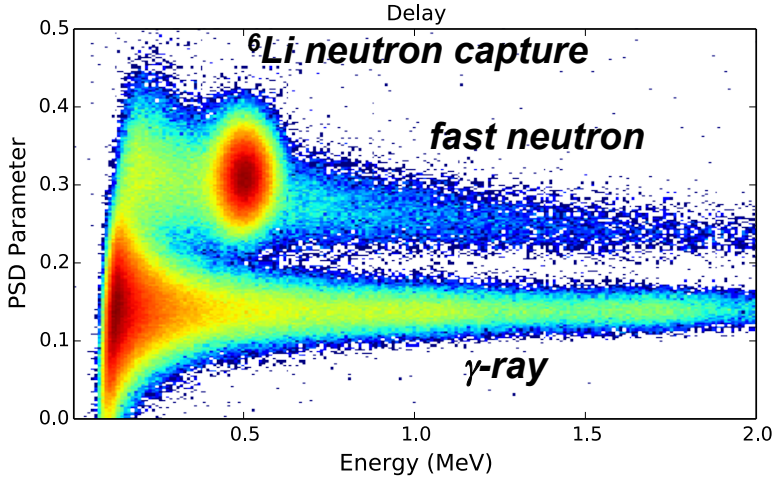
Low mass optical separators

Materials identified and fabrication methods developed



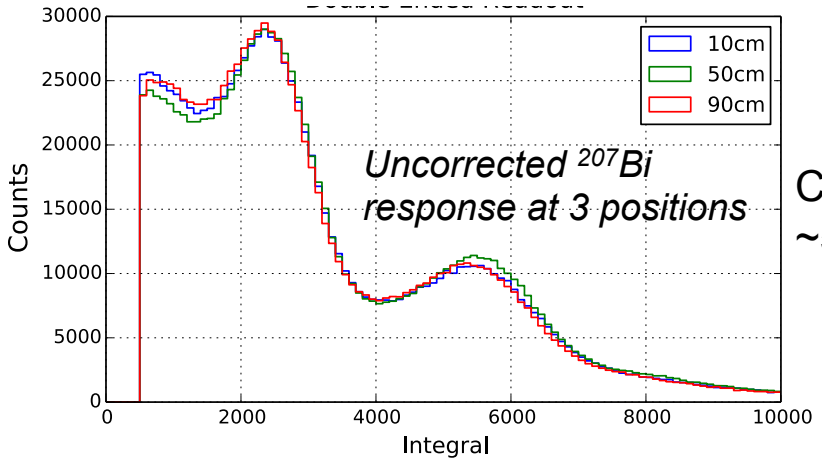
^{6}Li-LS testing

Discrimination of γ-rays, fast and thermal neutrons



1m long PROSPECT20 cell

Excellent optical uniformity and PSD performance



Collecting ~500 P.E./MeV

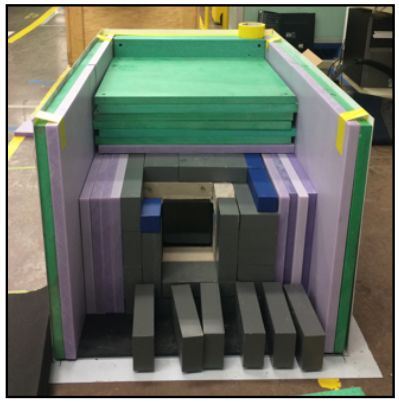
R&D Activities: Prototype Deployments at HFIR

Validate technology & background understanding; exercise HFIR work process

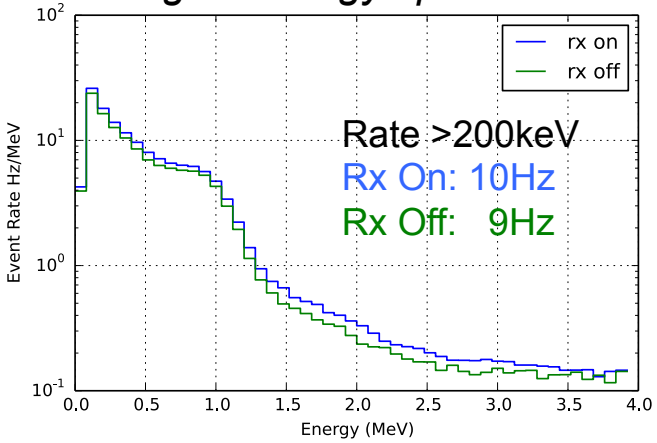
PROSPECT 2
Operating since Dec. '14

2 liter Li-LS detector, compact multilayer shield

- not representative of final shield design but useful for MC validation

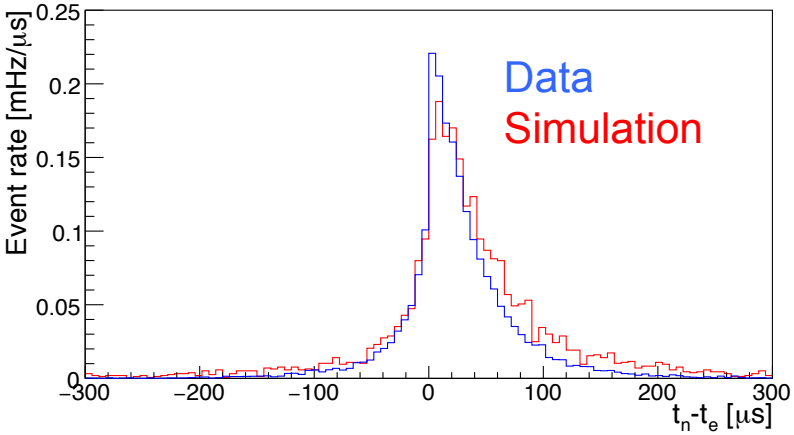


Singles energy spectrum

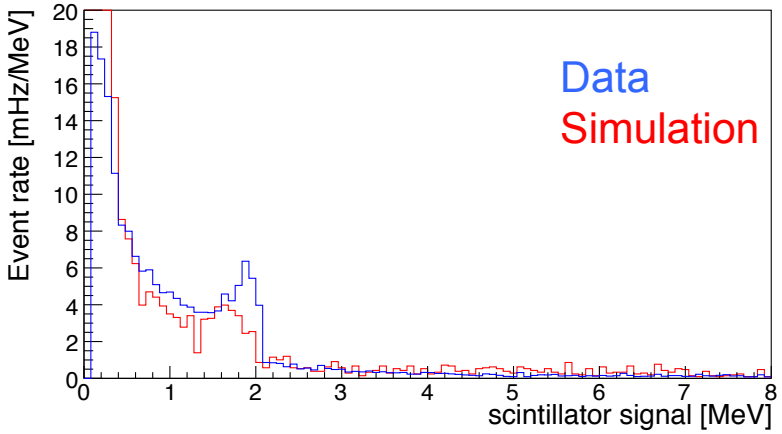


Singles rate dominated by material radioactivity
Good control of reactor correlated background

IBD-like pair time separation



IBD-like prompt energy

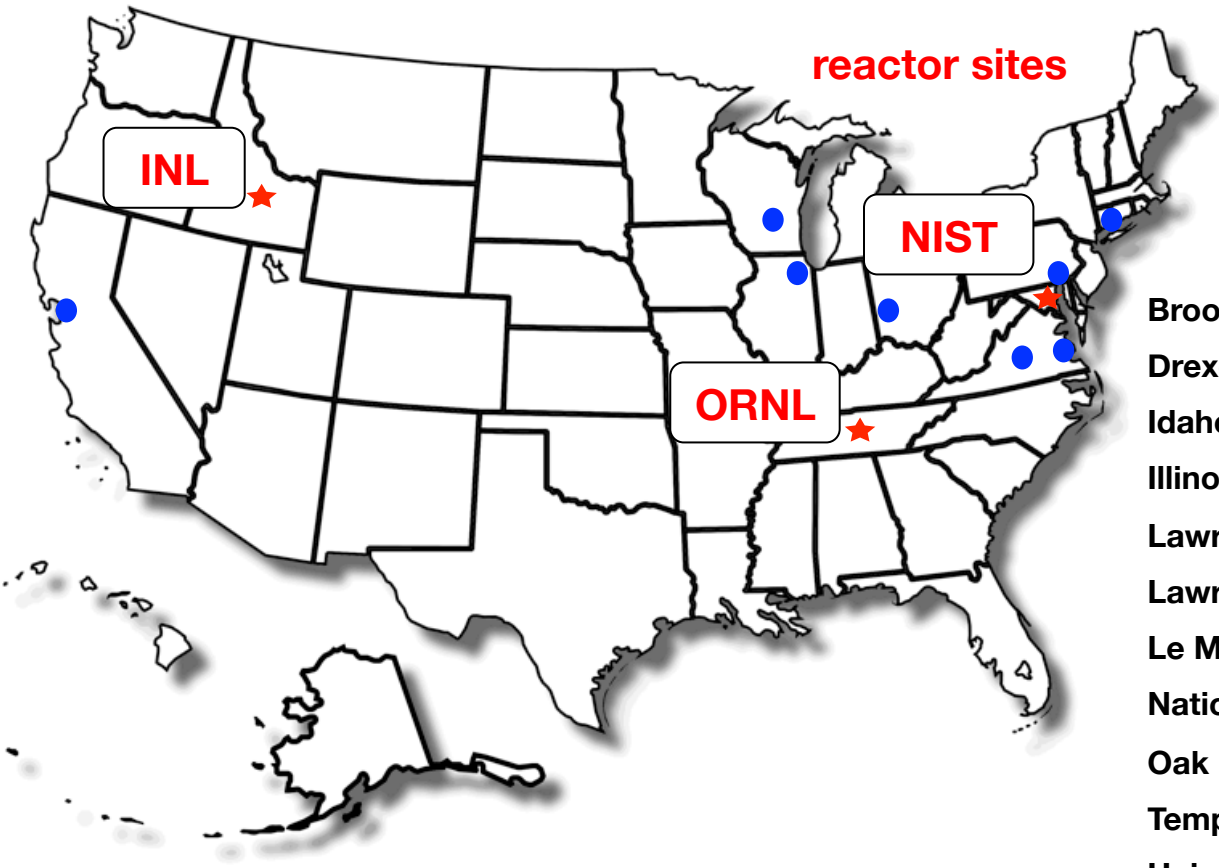


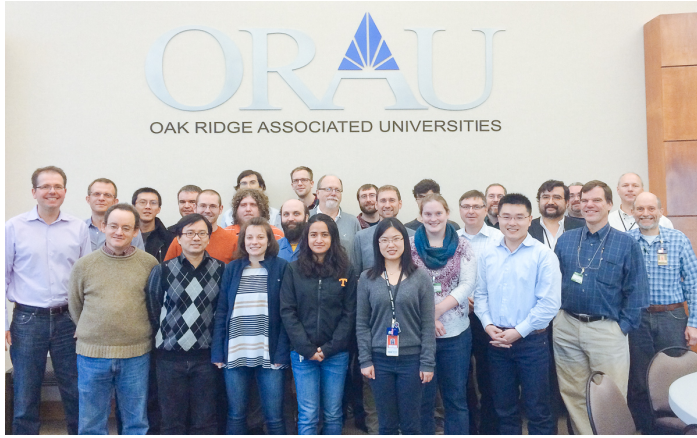
Cosmogenic background processes understood; data and simulation in good absolute agreement

Conclusion

- PROSPECT is a **phased approach** to understand antineutrino emission from reactors and to resolve the reactor neutrino anomaly
- PROSPECT is **pursuing development of antineutrino detectors for use at near-surface research reactors**, including ^{6}Li PSD capable liquid
- PROSPECT **has characterized backgrounds at HFIR** and other US reactor sites, operated prototype detectors at HFIR, and **established a working relationship on-site** with HFIR and the Physics Division at ONRL
- Data from PROSPECT2 show **good agreement between IBD-like events and simulations** and indicate that 1:1 signal-to-background is achievable
- PROSPECT is an **experienced collaboration** with expertise in design, construction, operation, and analysis of reactor experiments . Past projects include KamLAND, Daya Bay, Double Chooz, and non-proliferation efforts
- PROSPECT is **ready to scale up and proceed** with the design and construction of a 2ton, Phase I detector
- **Exploring collaboration** with SoLid group to fully leverage potential of technologies and resources

PROSPECT Collaboration





10 universities
6 national laboratories

Updated whitepaper
arXiv:1309.7647

Website
http://prospect.yale.edu/

Brookhaven National Laboratory
Drexel University
Idaho National Laboratory
Illinois Institute of Technology
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Le Moyne College
National Institute of Standards and Technology
Oak Ridge National Laboratory
Temple University
University of Tennessee
Virginia Tech University
University of Waterloo
University of Wisconsin
College of William and Mary
Yale University

R&D Activities: Site Characterization & Selection

Detailed assessment of 3 U.S. research reactors:
ATR, HFIR, NIST (*see later talks*)

Advantages

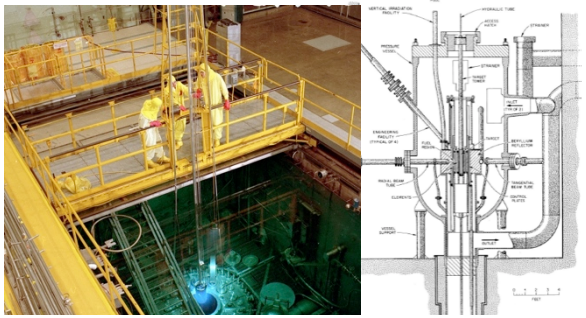
- Compact ^{235}U core
- Frequent outages for background measurement
- Multiple accessible baselines
- Detailed public core models

Logistics & Engineering

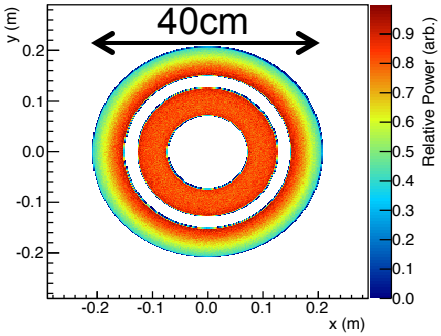
- Received excellent and enthusiastic host support
- Identified and examined detector locations in detail: floor loading, space and access constraints, certification, installation procedures

PROSPECT viable at all Sites

HFIR selected for PROSPECT Phase I



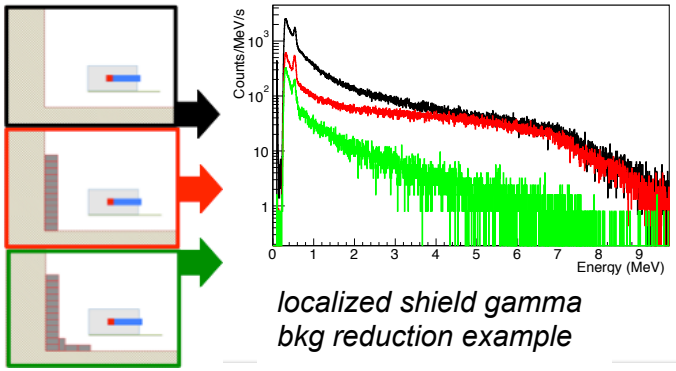
85 MW$_{th}$ @ 41% annual duty cycle



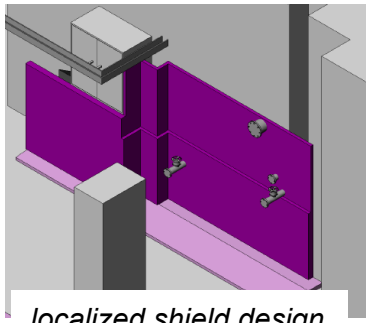
Core Fission Profile

Background Measurement *(paper in preparation)*

- Extensive surveys at all sites
- Identified background production/transport mechanisms & spatial distributions to inform shielding design

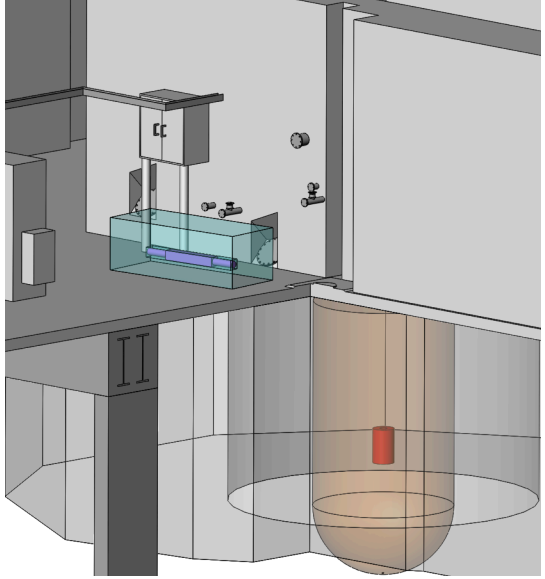


localized shield gamma bkg reduction example

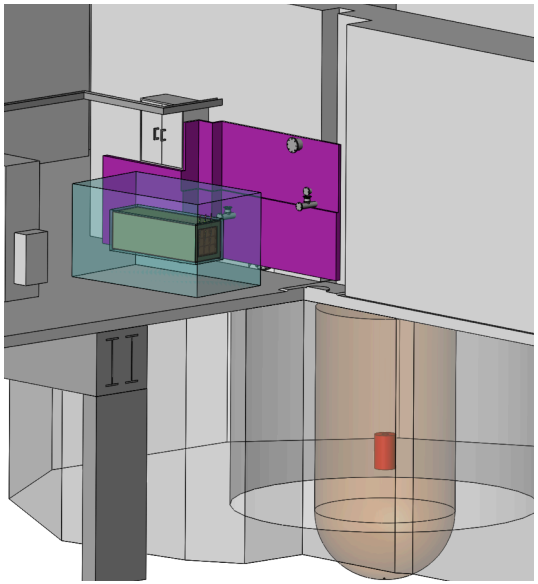


localized shield design

Future PROSPECT R&D



PROSPECT 20
1 meter ^{6}Li-LS single cell
Demonstrate full-scale segment performance



PROSPECT N×20
1 meter ^{6}Li-LS N cells
Demonstrate topology, fiducialization & energy resolution in multiple segment array

PROSPECT 2ton
1 meter ^{6}Li-LS 140 cells
Phase I physics