PROSPECT: A Precision Reactor Oscillation and Spectrum Experiment

Pranava Teja Surukuchi

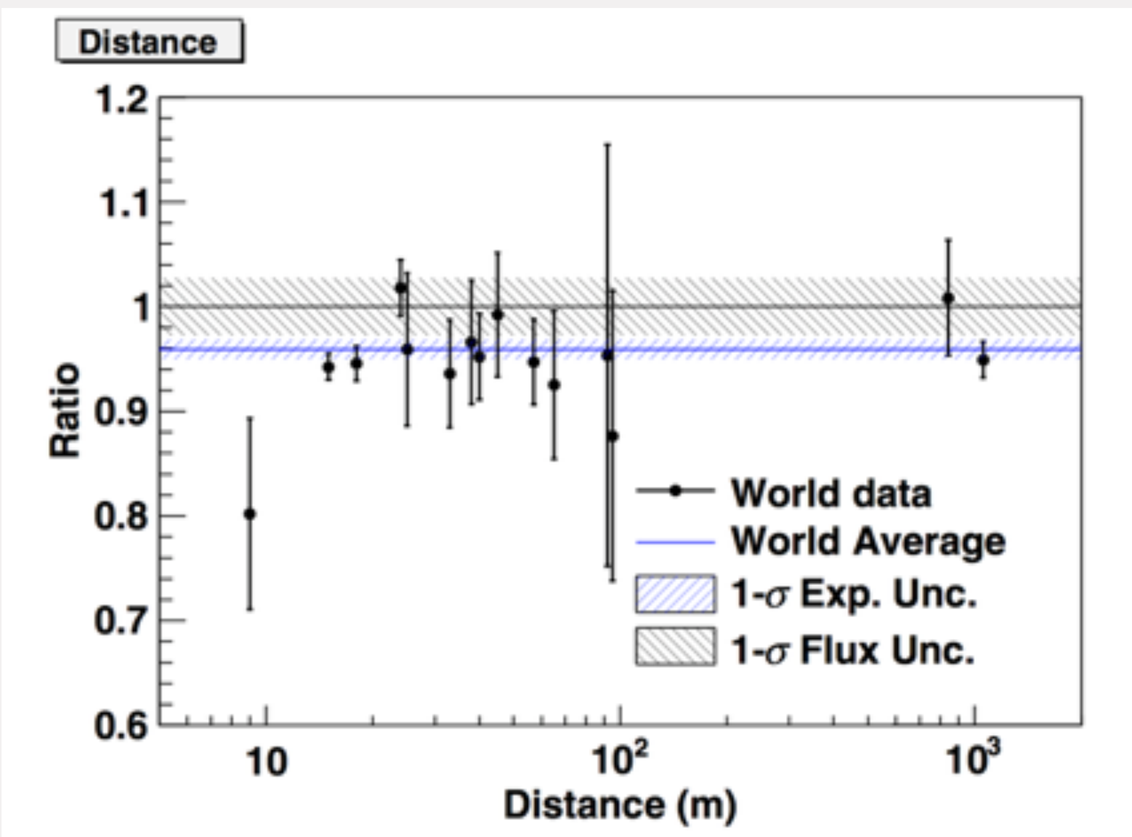
PROSPECT collaboration

Fermilab New Perspectives

Reactor Anomaly

Reactor antineutrino flux deficit

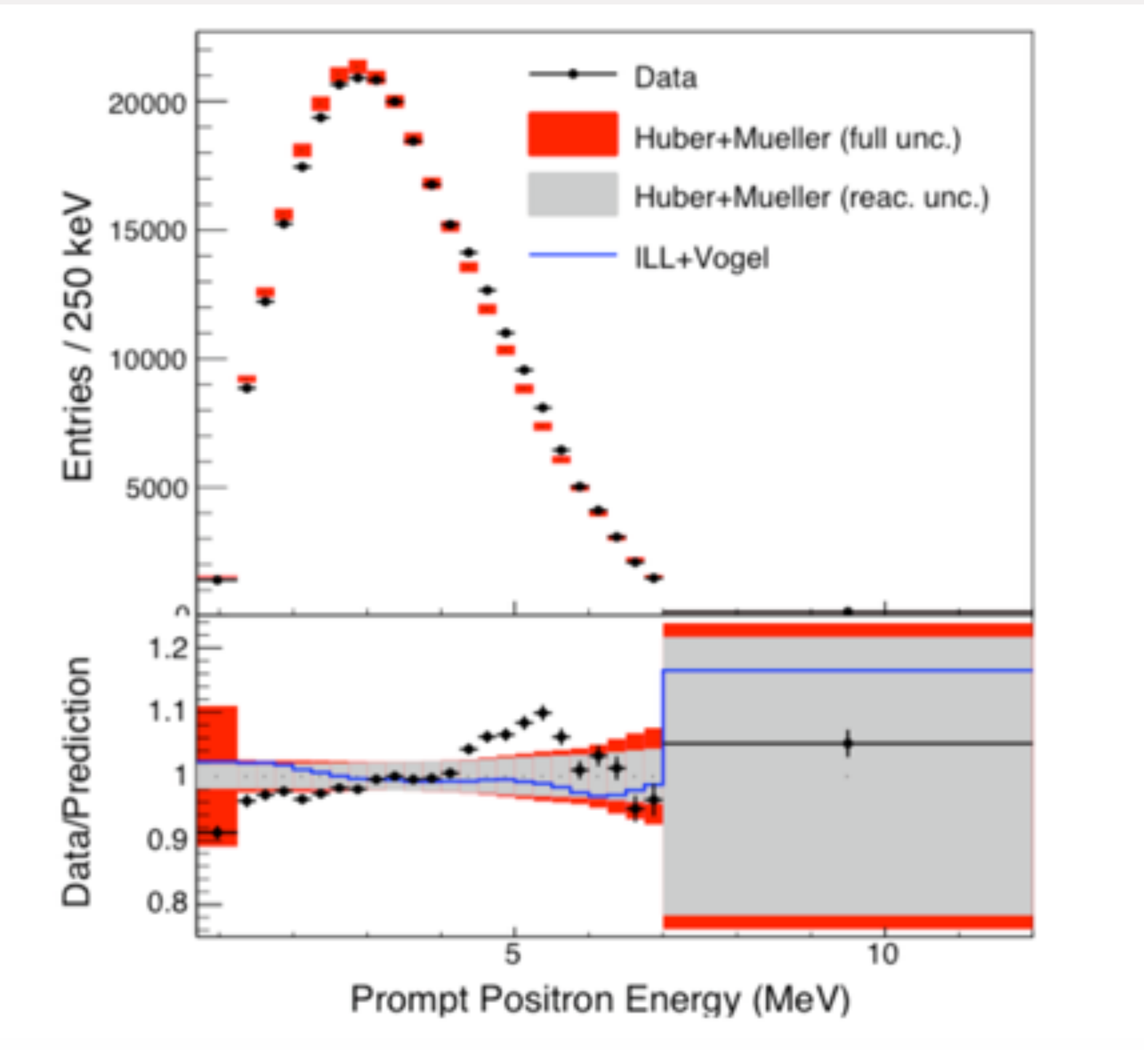
Comparison between reactor antineutrino flux predictions and measurements



arXiv:1303.0900

Spectral deviations

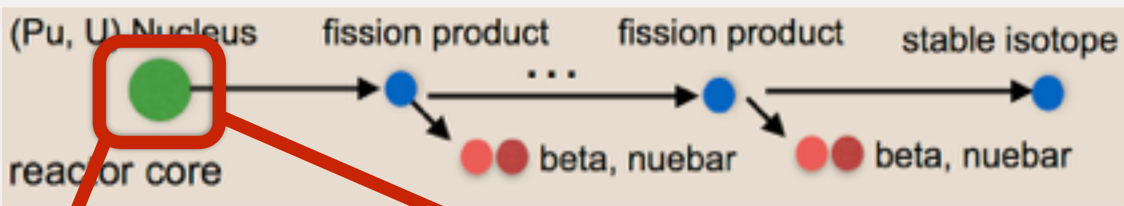
Daya Bay spectrum-only analysis

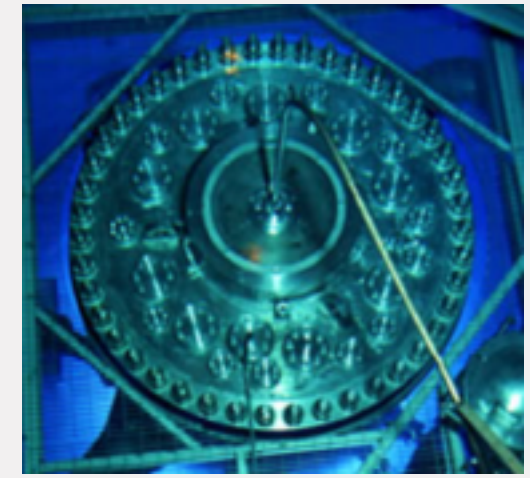


arXiv:1412.7806

Reactor Antineutrino Production

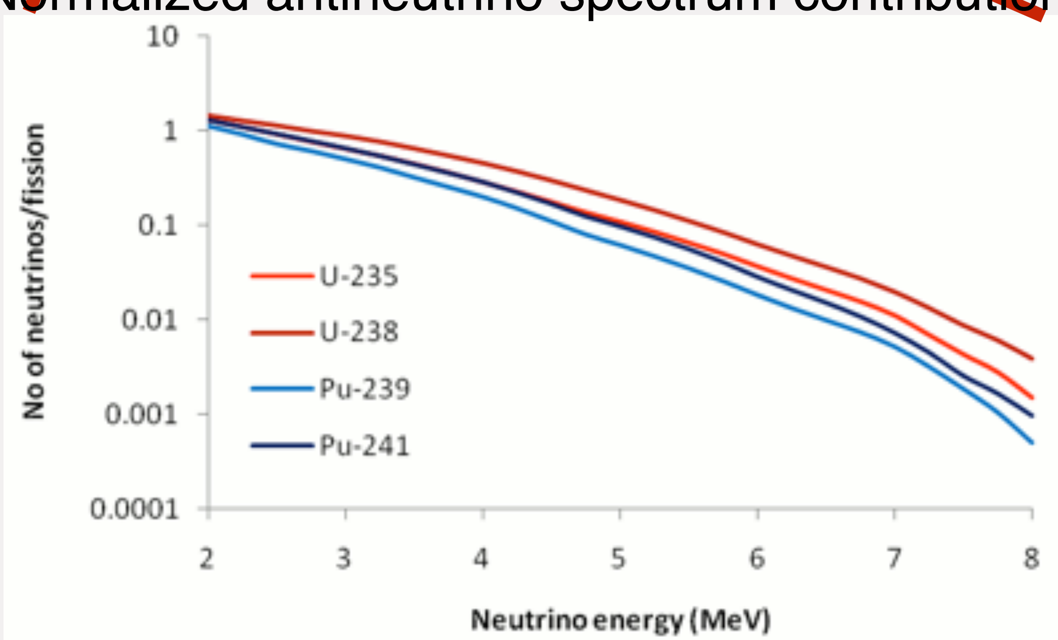
Neutron rich fission products beta decay and produce $\overline{\nu}_e$





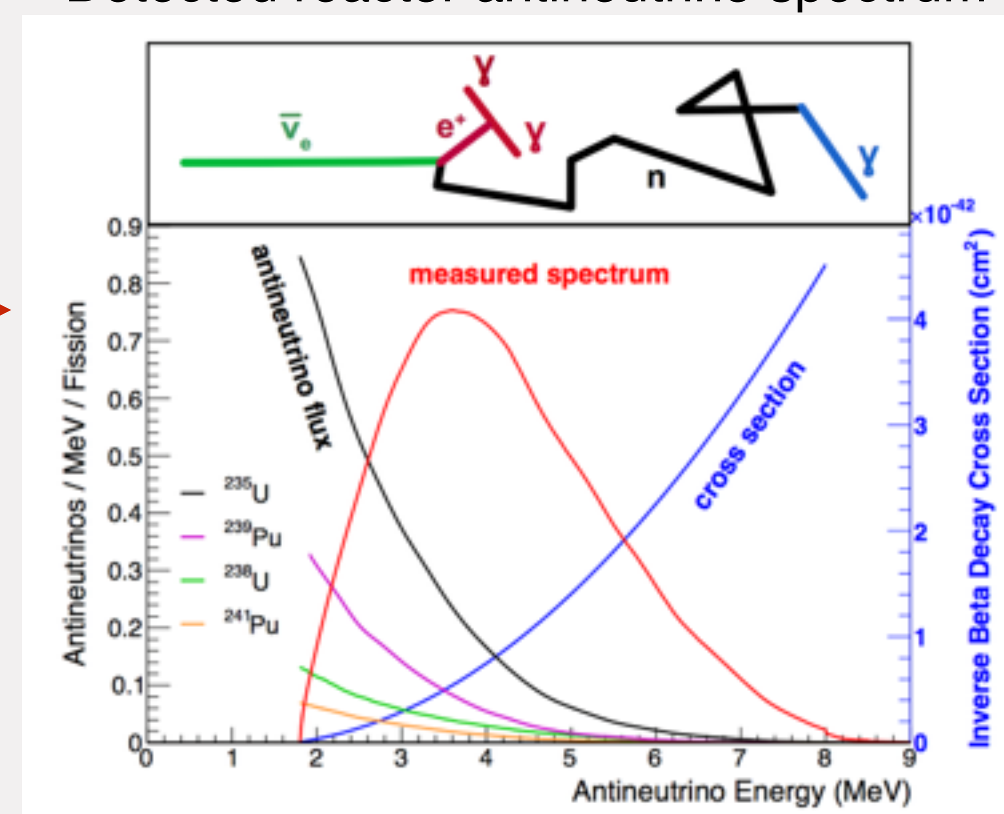
http://web.ornl.gov/

Normalized antineutrino spectrum contributions



arXiv:1101.2663

Detected reactor antineutrino spectrum



arXiv:1503.01059

$$S_{\rm tot}(E_{\overline{\nu}_e}) = \sum_k f_k S_k(E_{\overline{\nu}_e})$$

Reactor Anomaly Interpretation

Interpretation 1:

- Imperfect reactor antineutrino production models

Interpretation 2:

- Existence of eV-scale sterile neutrino

Confirmation:

- Make precise antineutrino measurements
- Short baseline oscillation experiment

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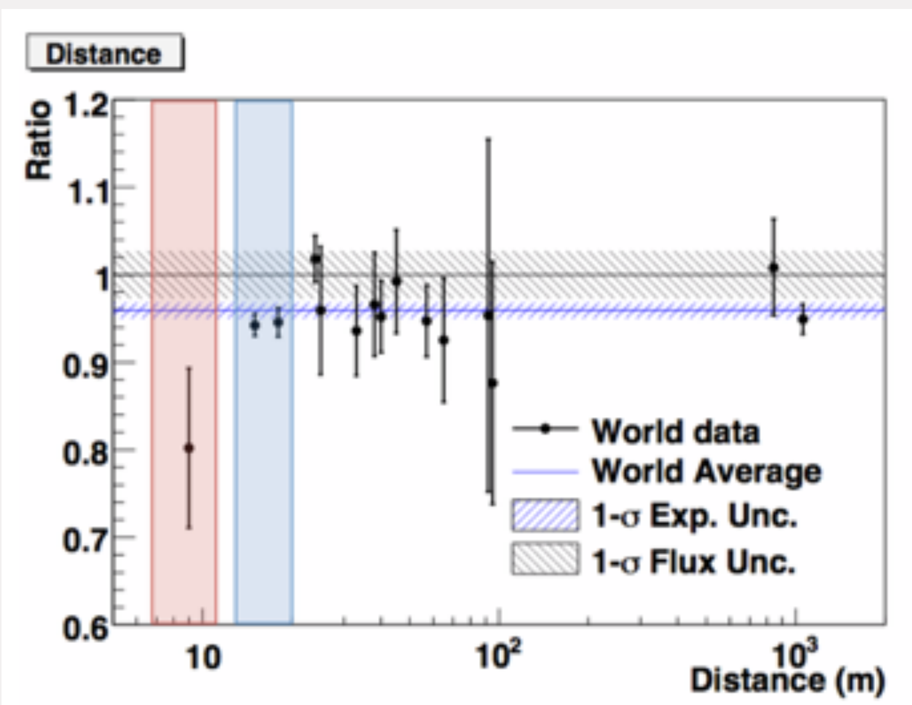
PROSPECT

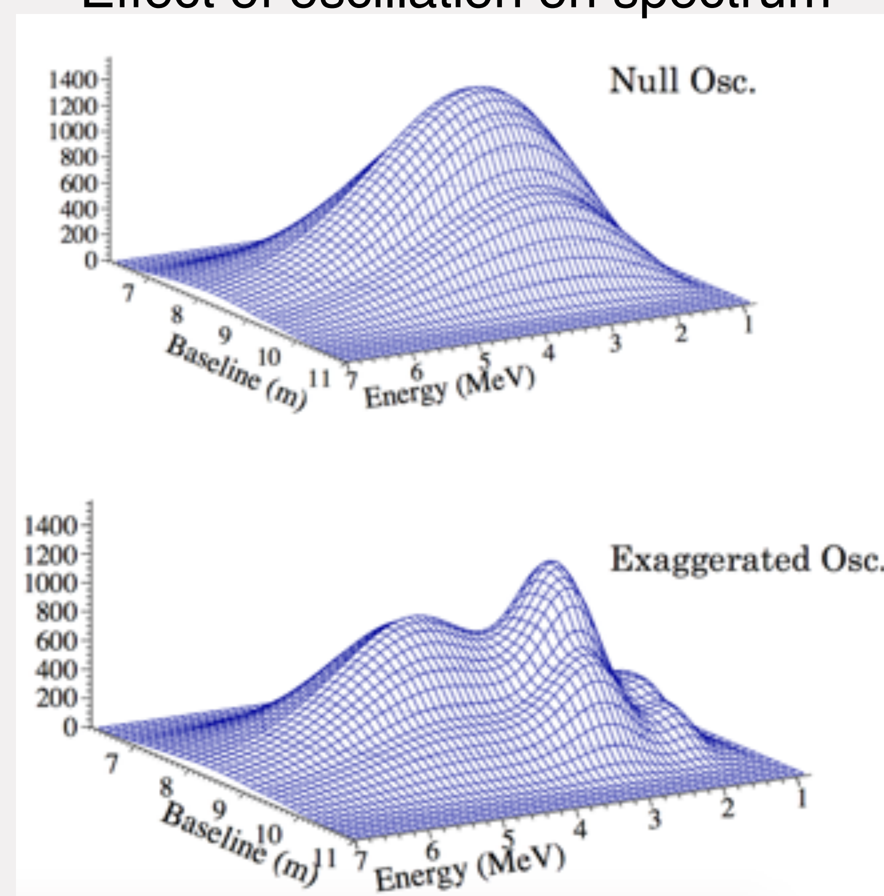
PROSPECT baselines



PROSPECT Near detector
PROSPECT Far detector

arXiv:1303.0900

Effect of oscillation on spectrum



PROSPECT

<u>Phased approach</u>

Phase 1 :

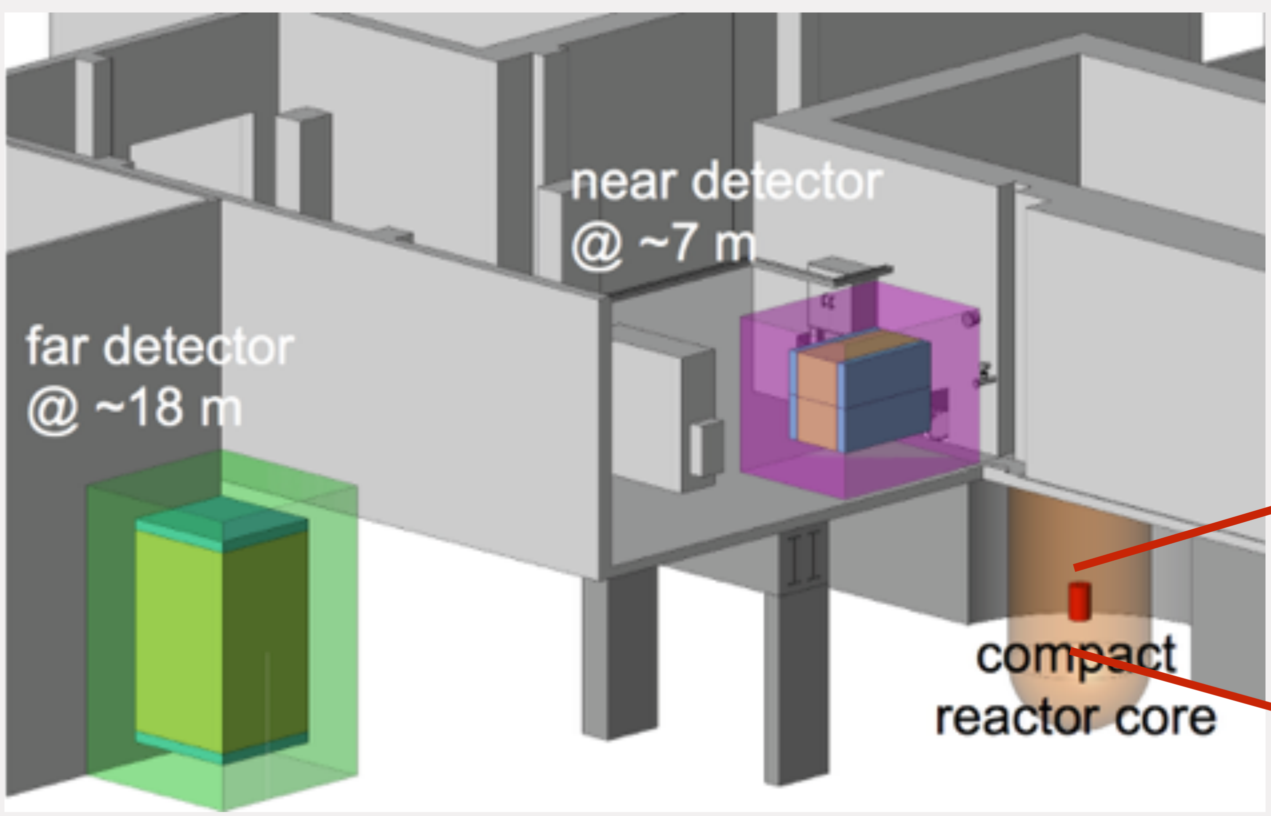
- Moveable near detector *O*(2 ton)
- Baseline ~ 7 m - 11 m

Phase 2 :

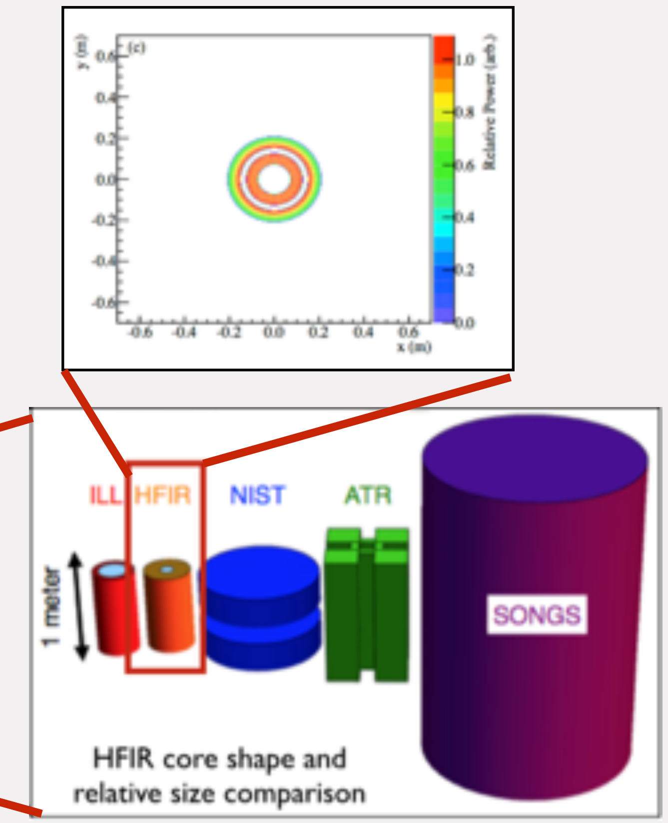
- Near + Far *O*(10 ton) detectors
- Baseline ~ 7 m - 20 m

Detector Site

- HFIR, highly enriched uranium (HEU) reactor at ORNL
- Operating power 85 MW
- 41 % up-time
- Small core-size



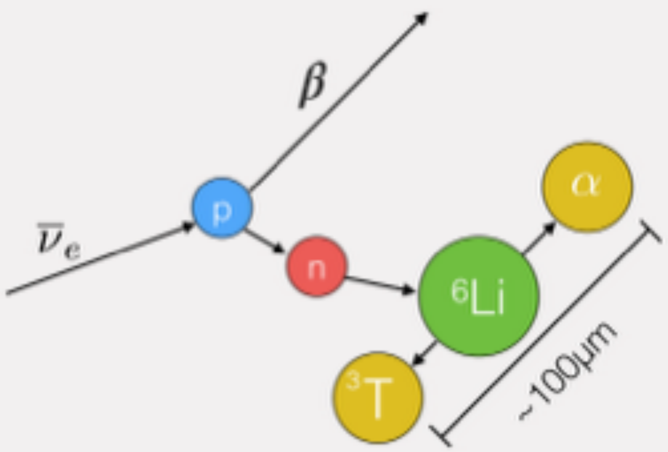
Phase-2 PROSPECT deployment schematic



arXiv:1309.7647

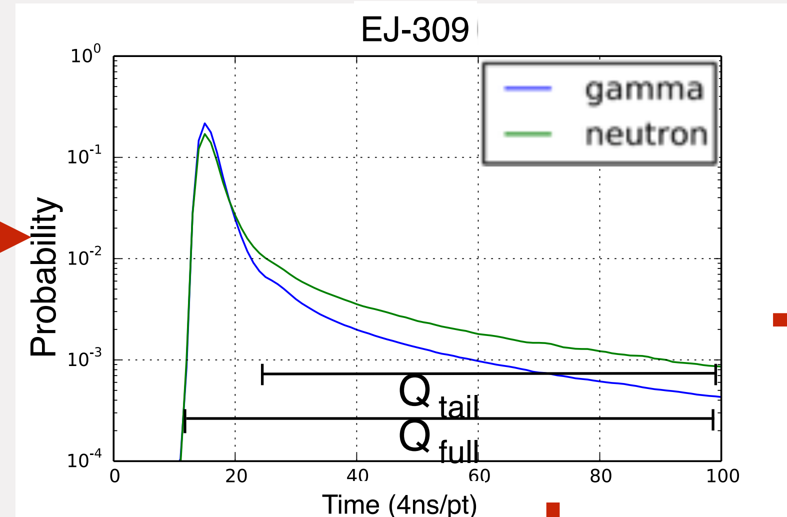
Detection mechanism

Lithium-loaded EJ-309 scintillator provides high background reduction



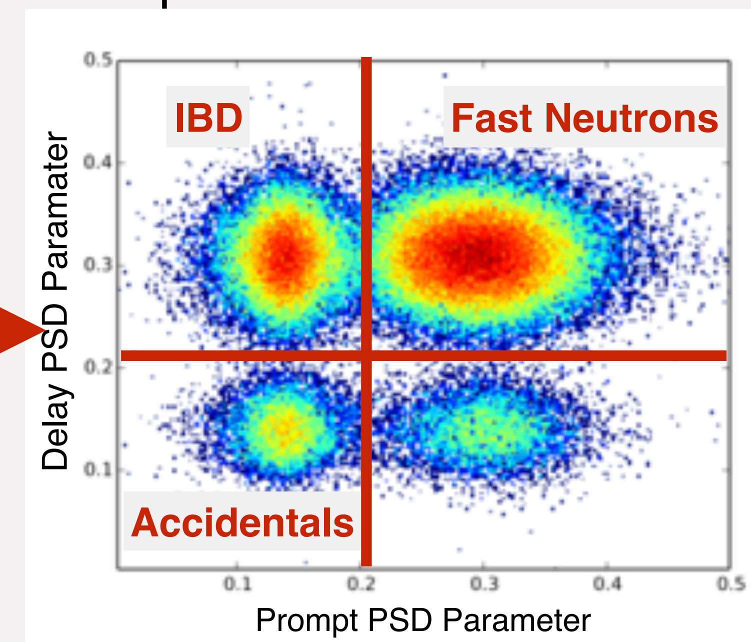
PROSPECT IBD detection mechanism

Signals detected by PMT



$$PSD = \frac{Q_{tail}}{Q_{full}}$$

Comparison of coincidences

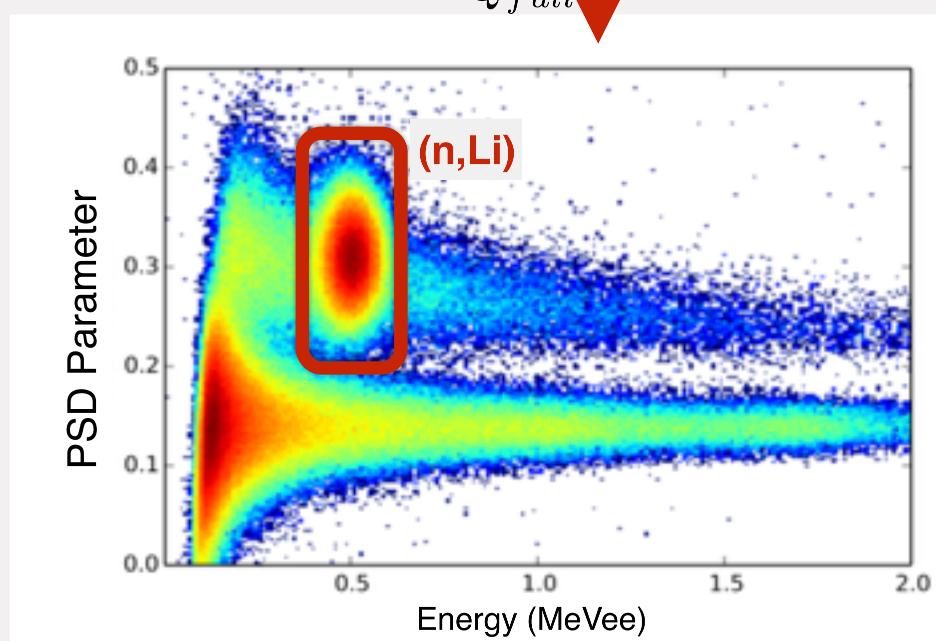


arXiv:1309.7647

Prompt signal: 1-10 MeV positron from inverse beta decay (IBD)

Delay signal: ~0.6 MeV signal from neutron capture on ^{6}Li **with PSD signature**

Coincidence Signature of event:
e-like prompt signal, followed by a ~50μs delayed neutron capture



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PSD capabilities in LiLS testcell

PSD Signatures

Inverse Beta Decay
γ-like prompt, n-like delay

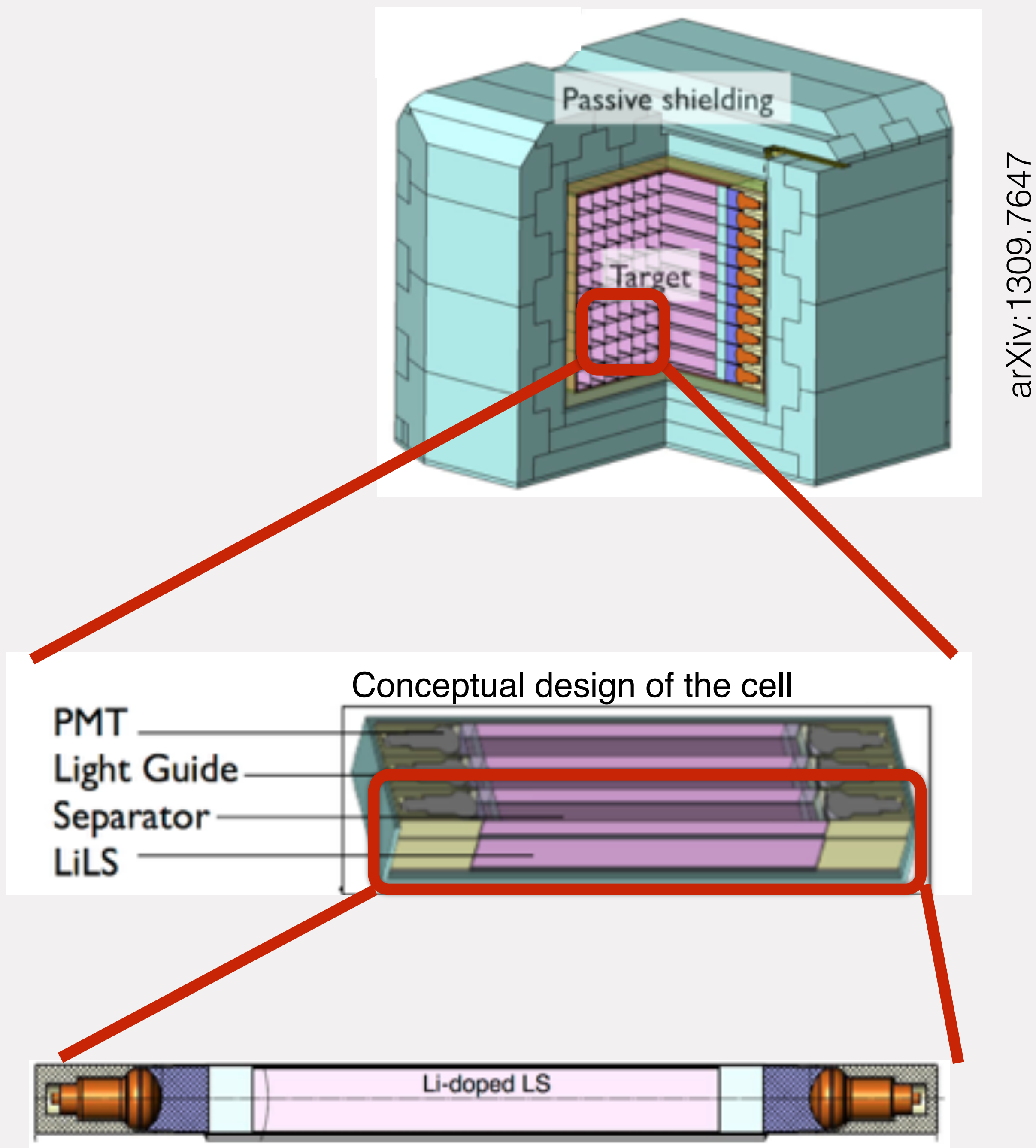
Fast Neutron
~~n-like prompt, n-like delay~~

Accidental Gammas
~~γ-like prompt, γ-like delay~~

Detector Design

- **<u>Segmentation with double-ended readout</u>**
  - Good light collection
  - Inherent position resolution
  - Good energy resolution
  - Excellent background reduction
  - Single detector oscillation analysis

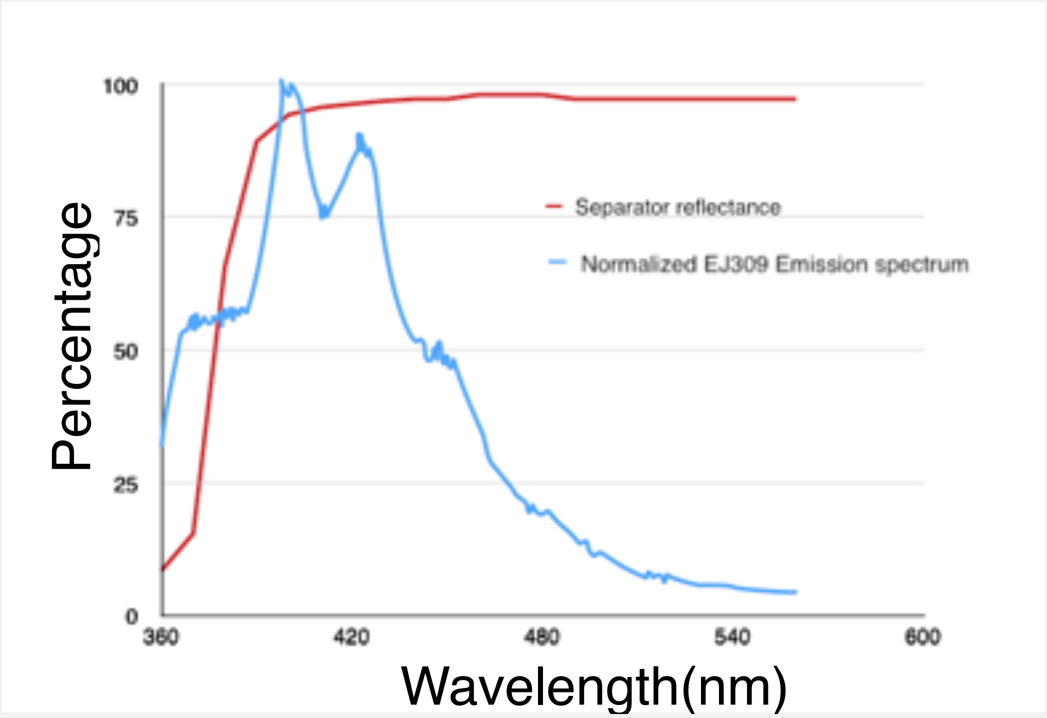
PROSPECT near detector conceptual design

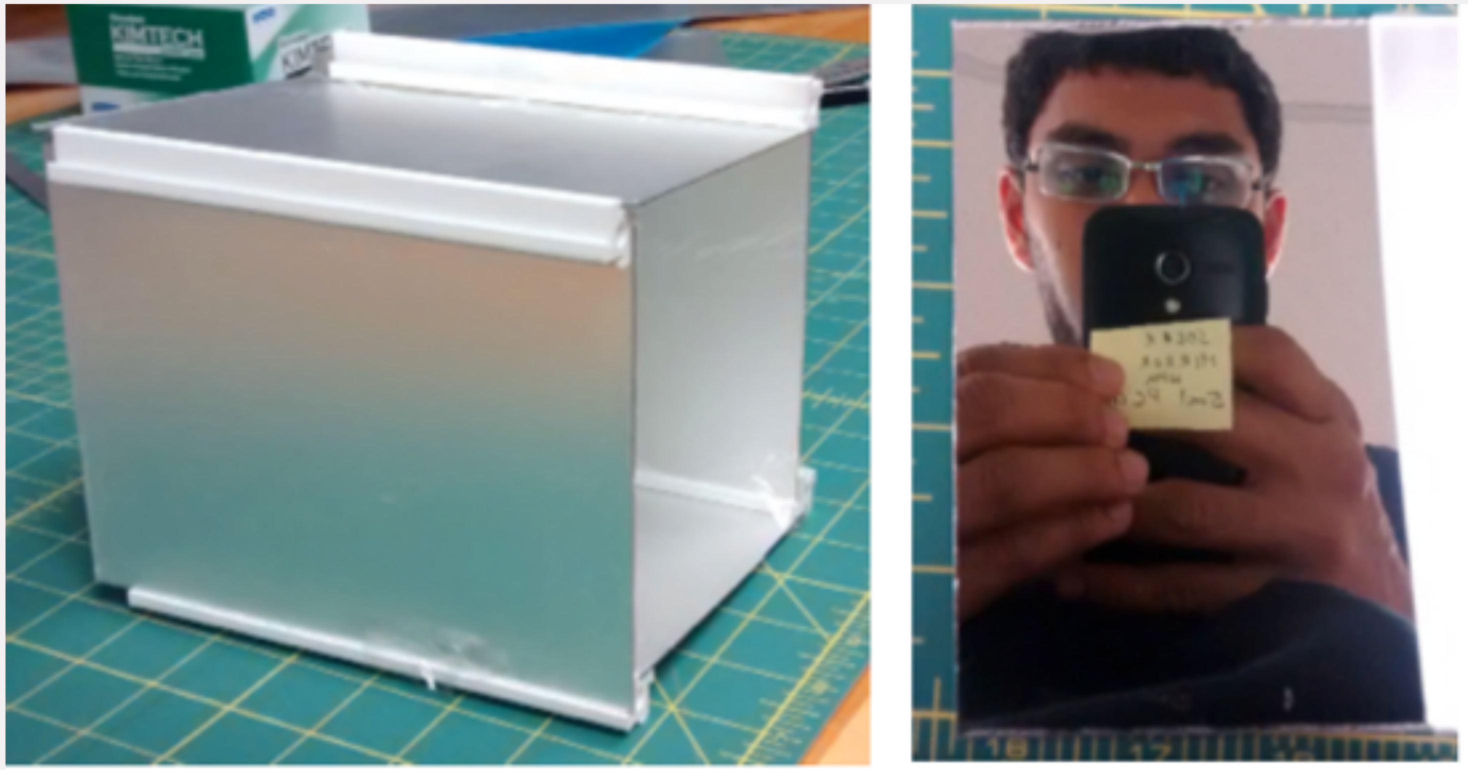


Detector Design

- **Optical separators**
  - Flat, rigid and low-mass reflectors
  - High reflectance in Li-EJ309 emission spectrum for good light collection
  - Separator production method already in place

Separator effectiveness at desired wavelength

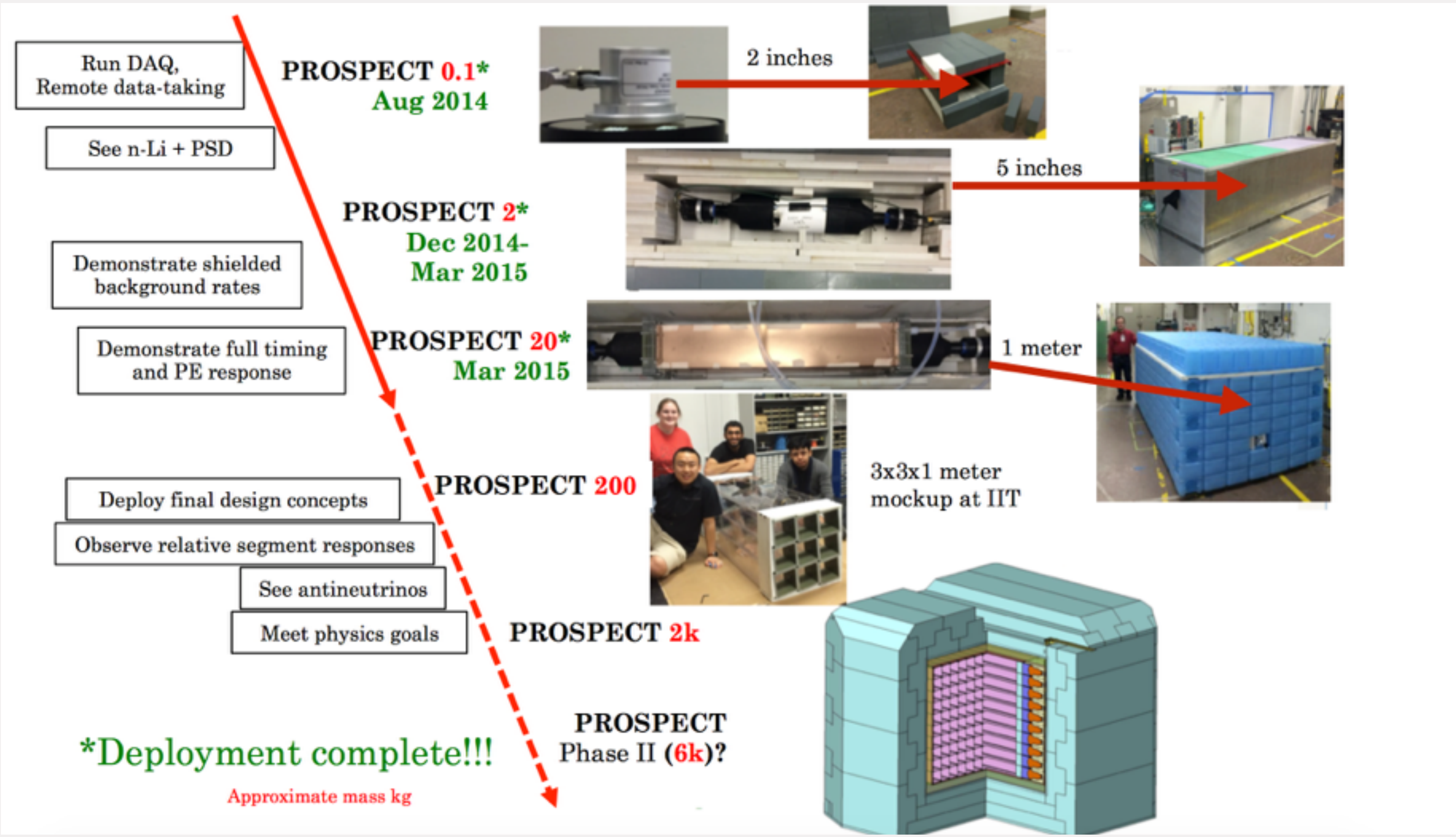




Short Mockup Segment

Specular Panel

Current Status

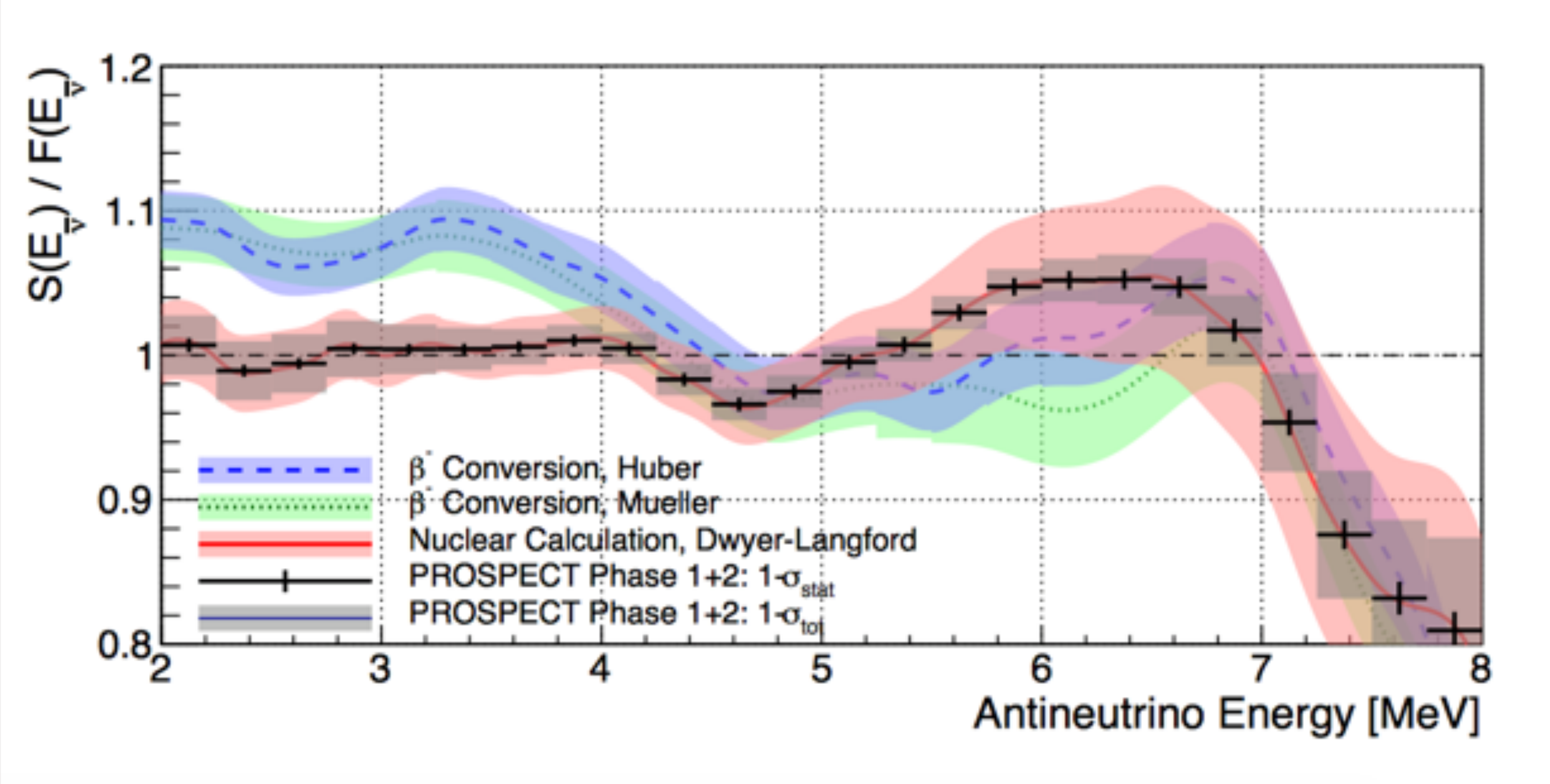


More about PROSPECT prototype detectors in X. Zhang's talk to follow

Spectrum Measurement

- Constrain reactor models using HEU
- Spectrum resolution goal: 4-5/√E %
- Inputs for future reactor experiments
- High statistics due to close proximity to the reactor (150k IBD/year projected for PROSPECT 2k)

Models of antineutrino spectrum from daughters of U-235

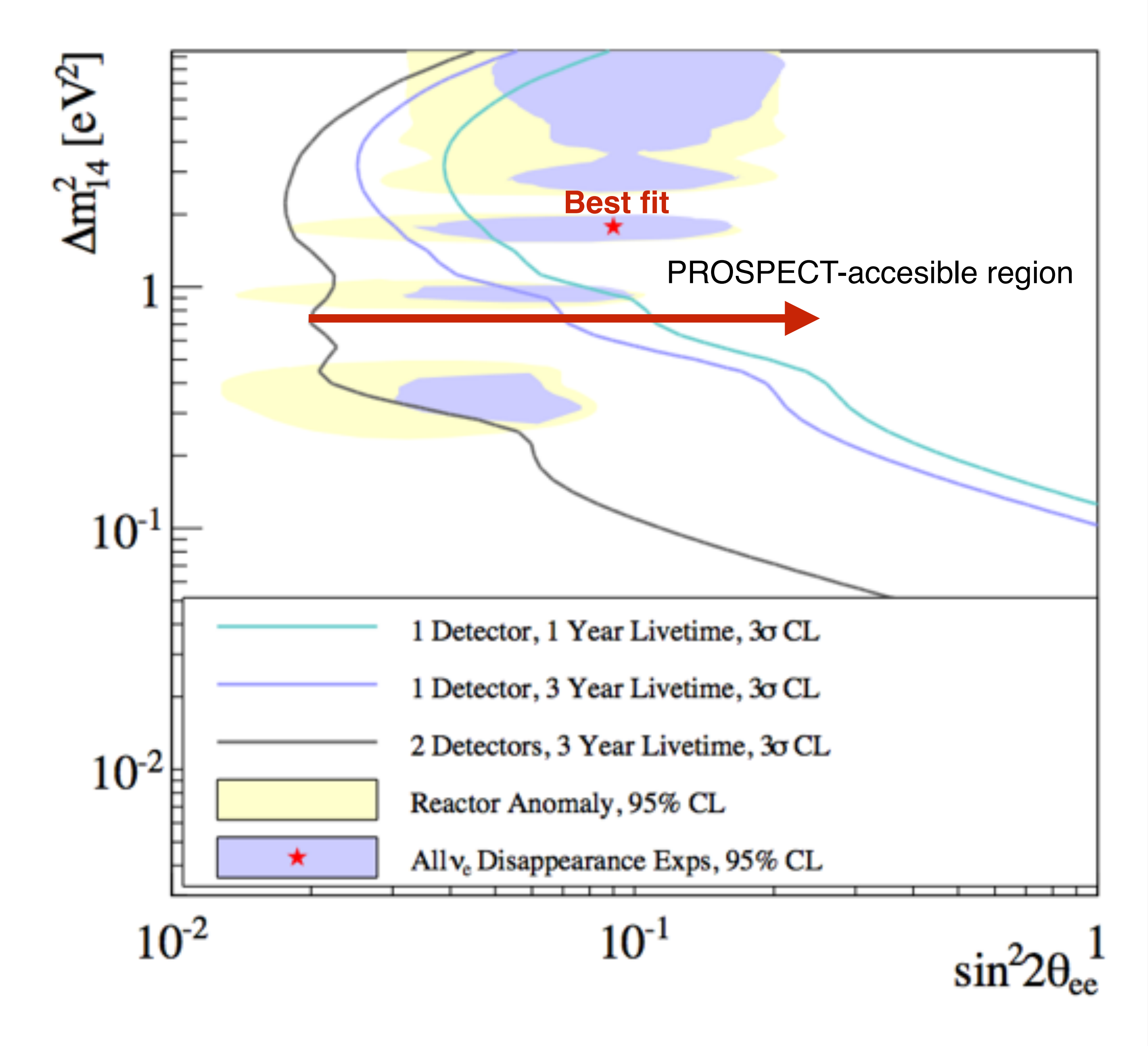


arXiv:1309.7647

Sterile Neutrino Search

- Independent from absolute measurement by exploiting segmented nature
- Assumptions
  - 4.5/√E % energy Resolution
  - 20 cm resolution
  - 1:1 signal to background ratio
- Sterile neutrino search complementary to Fermilab SBN program

Sensitivity of PROSPECT experiment

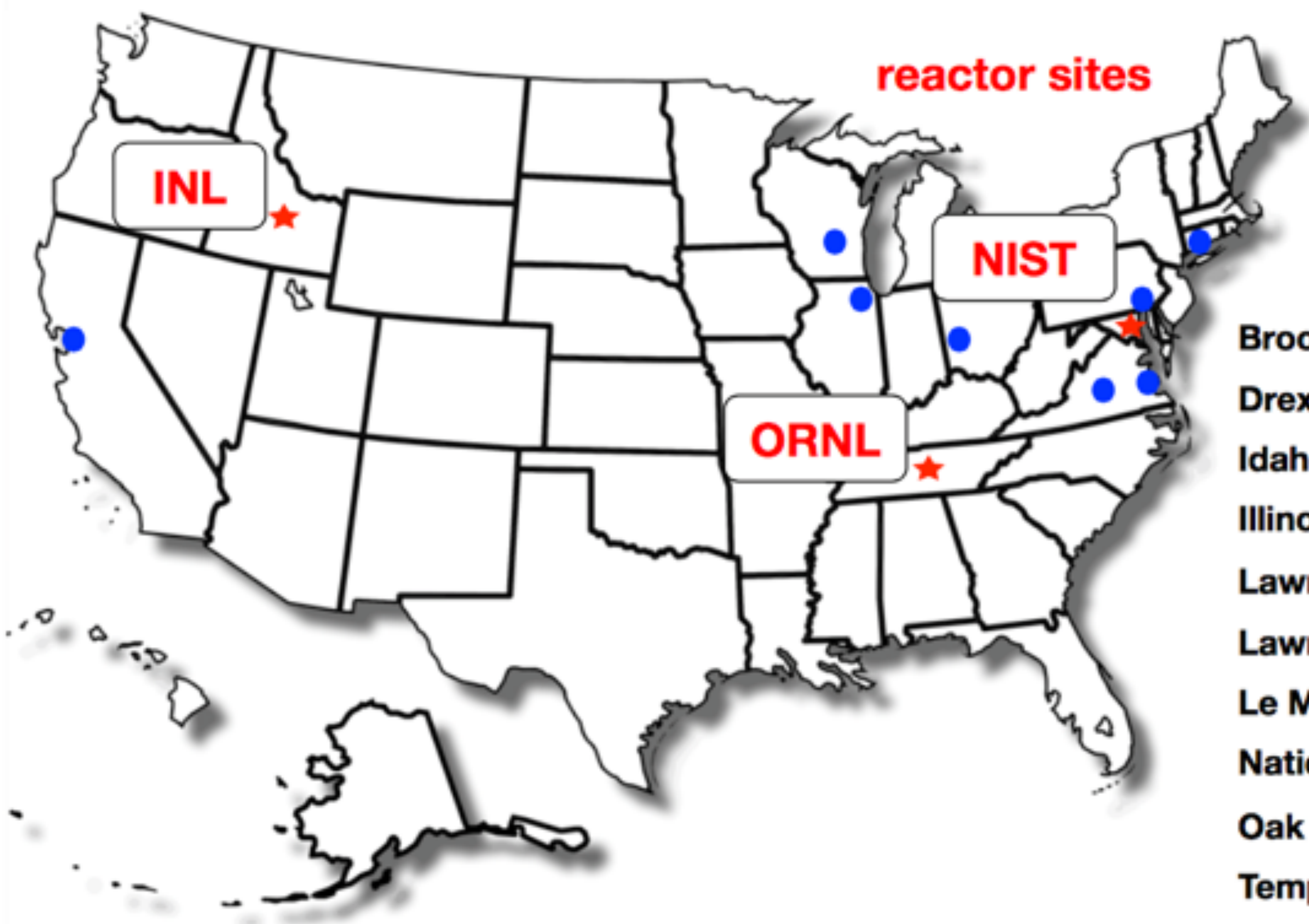


Summary

- More data are needed to address the existing reactor anomalies
- A LiLS-based detector design has been developed that can effectively reduce reactor- and cosmogenic related backgrounds
- Multiple prototype detectors have been deployed at HFIR paving way to build full-size detector
- Within one year, PROSPECT will test the existence of an eV-scale sterile neutrino and precisely measure antineutrino spectrum of U-235 reactor

Thanks

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

Additional slides

Reactor Antineutrino Prediction

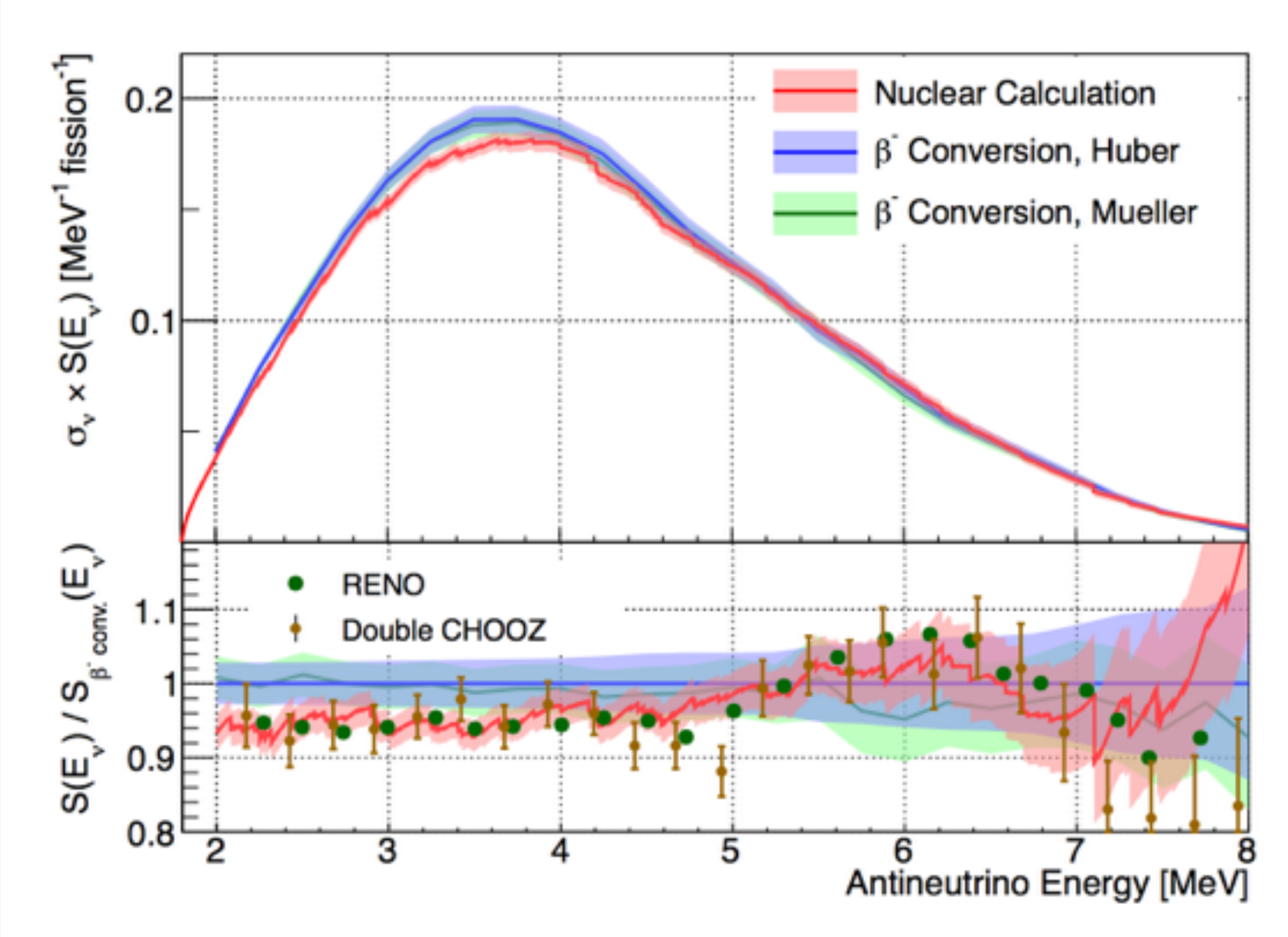
***ab initio* approach**

- Use nuclear databases to calculate the antineutrino spectrum for all beta branches.
    - Lack of information of several beta branches for precise calculation

Conversion approach

- Measure beta spectrum and convert to antineutrino spectrum using virtual beta branches
    - Forbidden decays are not included in the calculation, which leads to mistakes in calculations

Models of antineutrino spectrum from LEU reactor



arXiv:1407.1281