PROSPECT: The Precision Reactor Oscillation and SPECTrum experiment

David Martinez Caicedo on behalf of PROSPECT Collaboration
Illinois Institute of Technology

July 7th
EPS conference on High Energy Physics
Venice,Italy

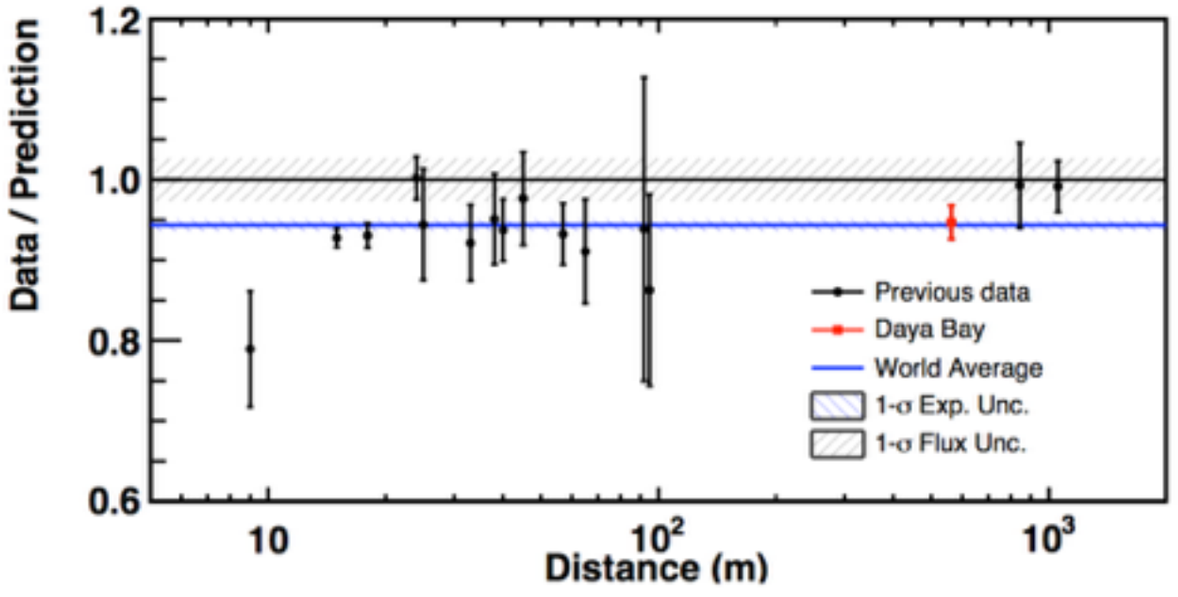
Outline

- Motivation: Why we need a short baseline reactor neutrino experiment?
- The PROSPECT Experiment
- PROSPECT: Detector construction status
- PROSPECT: Physics goals

Why do we need a short baseline reactor neutrino experiment?

Reactor antineutrino anomaly

- Deficit in measured antineutrinos at different baselines
- Measurement agrees between different detector technologies and reactors
- ~6% deficit with respect to 2011 Huber/Mueller Flux prediction



PhysRevLett.116.061801

Phys. Rev. D 83, 073006

Reactor antineutrino anomaly

- Deficit could come from SBL sterile neutrino oscillations

- Consistent with hints of 1 eV sterile neutrinos (LSND, MiniBooNE, Gallex)

- In order to interpret CP violation results we need to know if sterile neutrinos exist.

- !DUNE needs the anomaly explanation!

The impact of sterile neutrinos on CP measurements at long baselines

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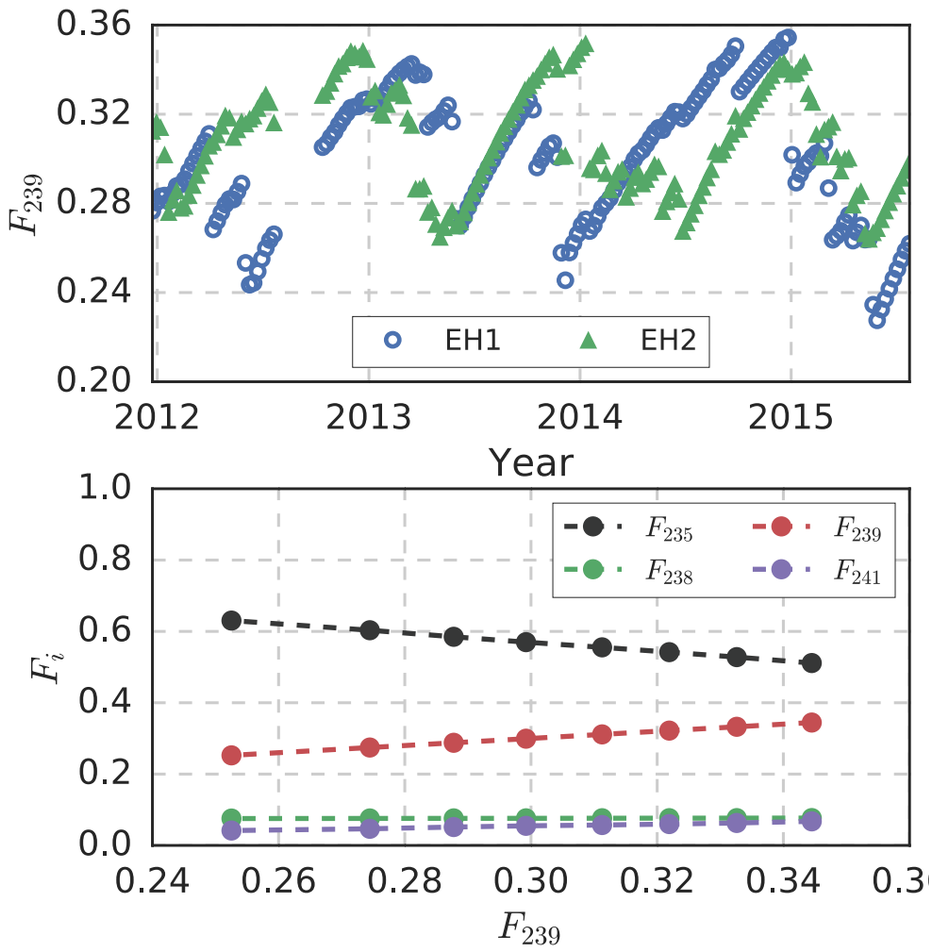
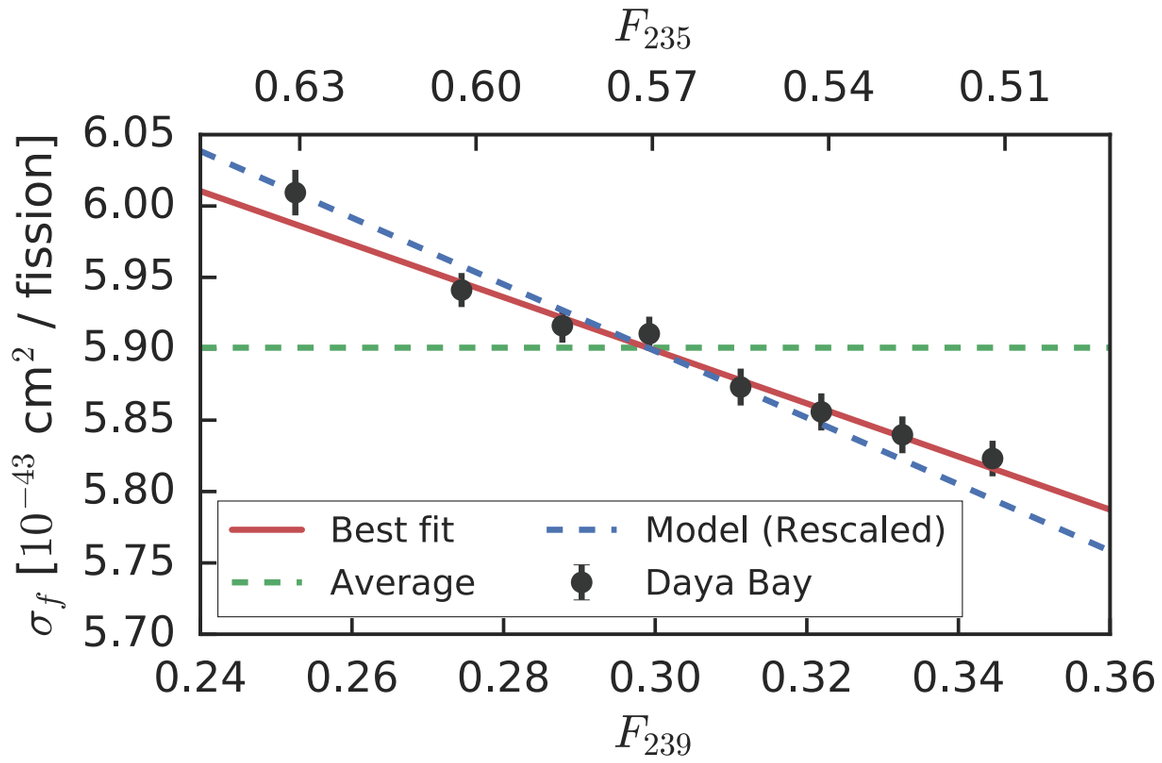
ABSTRACT: With the Deep Underground Neutrino Experiment (DUNE) as an example, we show that the presence of even one sterile neutrino of mass ~1 eV can significantly impact the measurements of CP violation in long baseline experiments. Using a probability level analysis and neutrino-antineutrino asymmetry calculations, we discuss the large magnitude of these effects, and show how they translate into significant event rate deviations at DUNE.

10.1007/JHEP11(2015)039

Evolution of the Reactor Antineutrino Flux and Spectrum at Daya Bay, PhysRevLett.118.251801





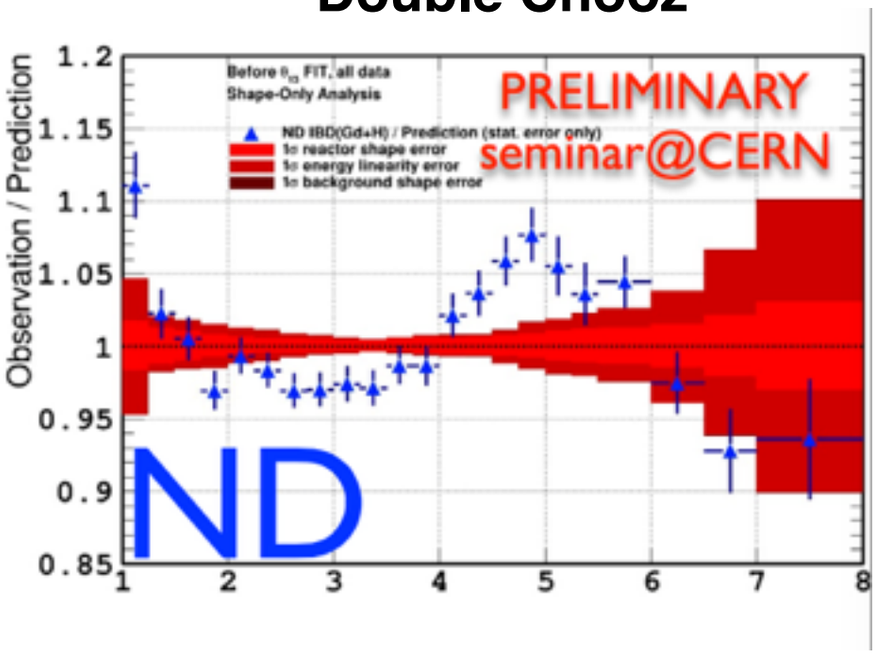
Observed correlation between antineutrino flux and reactor fuel composition with 2.2M IBD in Daya Bay near detectors favors ^{235}U as cause of Reactor Antineutrino Anomaly(RAA)

RAA cause	$\Delta\chi^2$/ndf	p-value
^{235}U	0.17/1	0.68
^{239}Pu	10.0/1	0.00016
All isotopes	7.9/1	0.0049

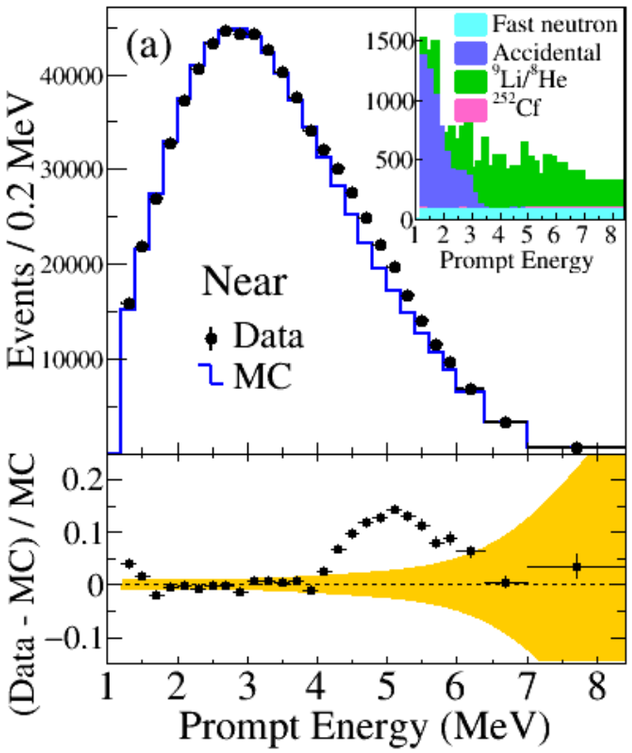
Spectral anomaly “The bump”

- Prompt energy spectrum disagree with predictions
- Excess of events around 5 MeV in the IBD prompt energy spectrum seen by Daya Bay, RENO and Double Chooz.

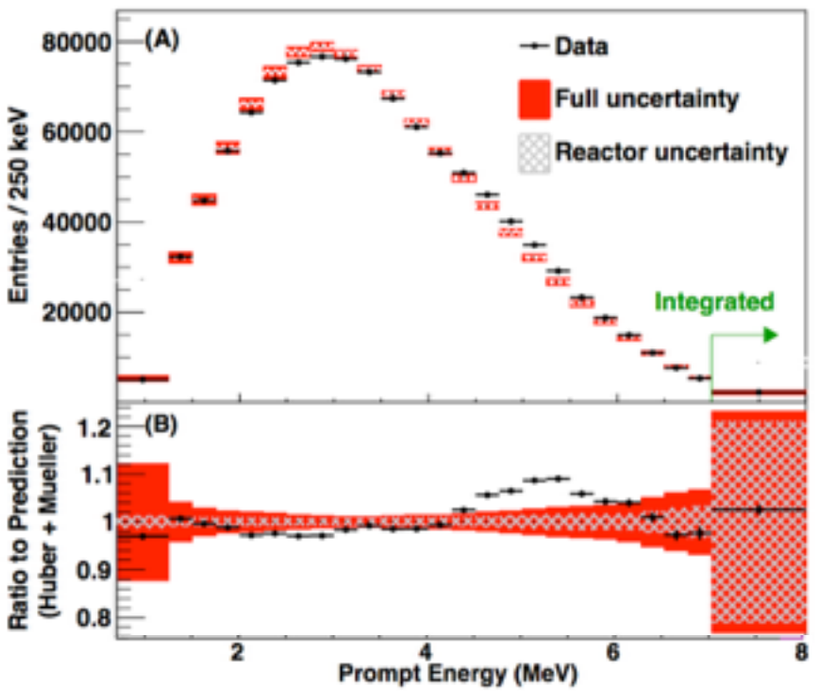
Double Chooz



RENO, Neutrino2016



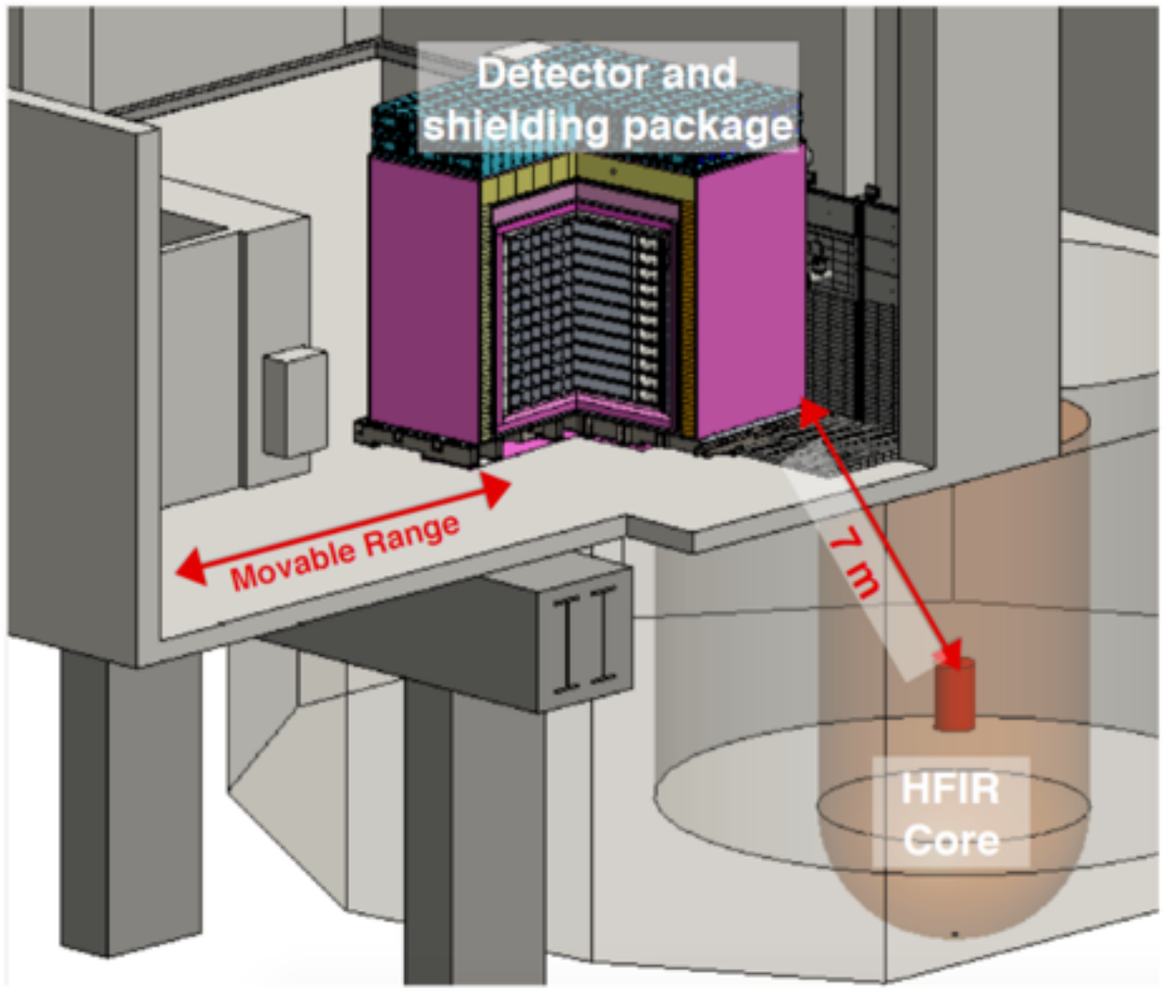
Daya Bay, Chin. Phys. C 41(1) (2017)

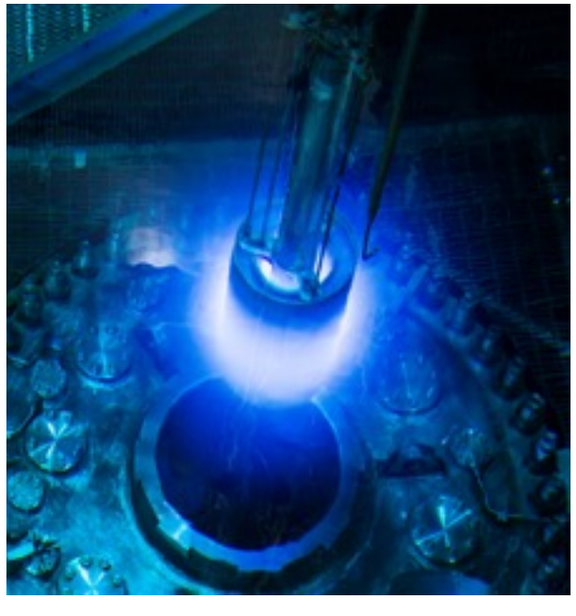


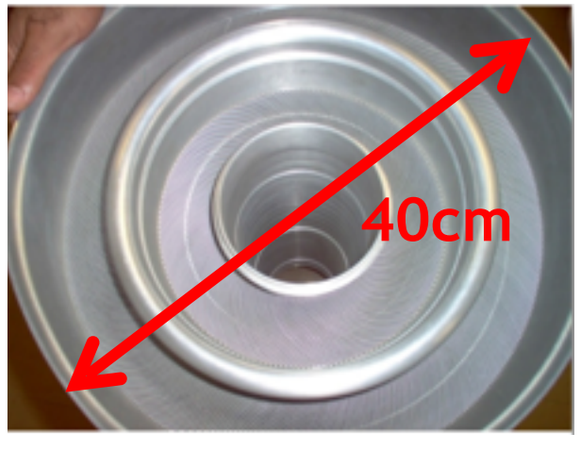
PROSPECT Experiment

ILLINOIS INSTITUTE OF TECHNOLOGY

- Model independent search for neutrino oscillations in the eV-scale sterile states
- Precision measurement of an HEU reactor spectrum with the best energy resolution up to date
- Complementing existing LEU reactor measurements.
- Antineutrino source: High Flux Isotope Reactor at ORNL
  - 85 MW Thermal power research reactor
  - Highly enriched uranium reactor >93% ^{235}U
  - Compact cylindrical core (0.5 m high, 0.4 m wide)

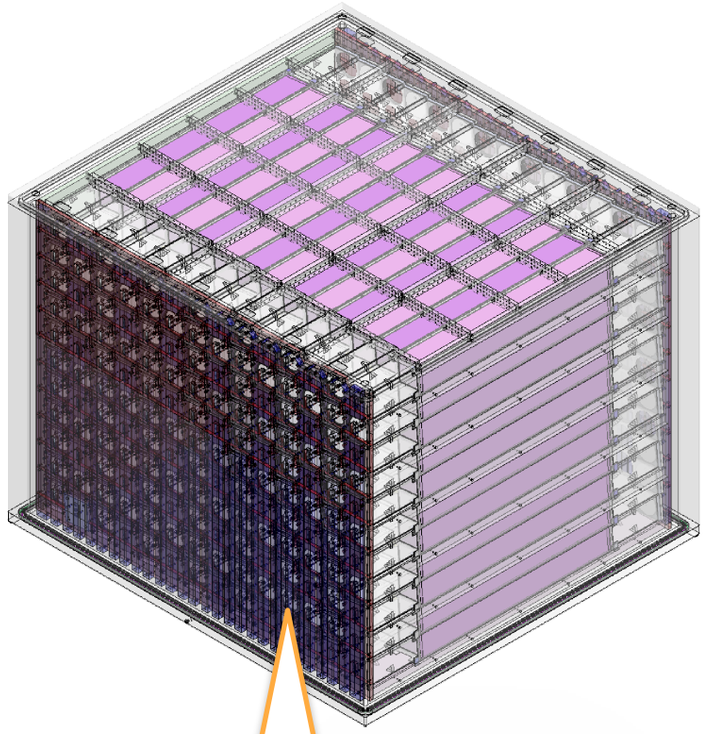


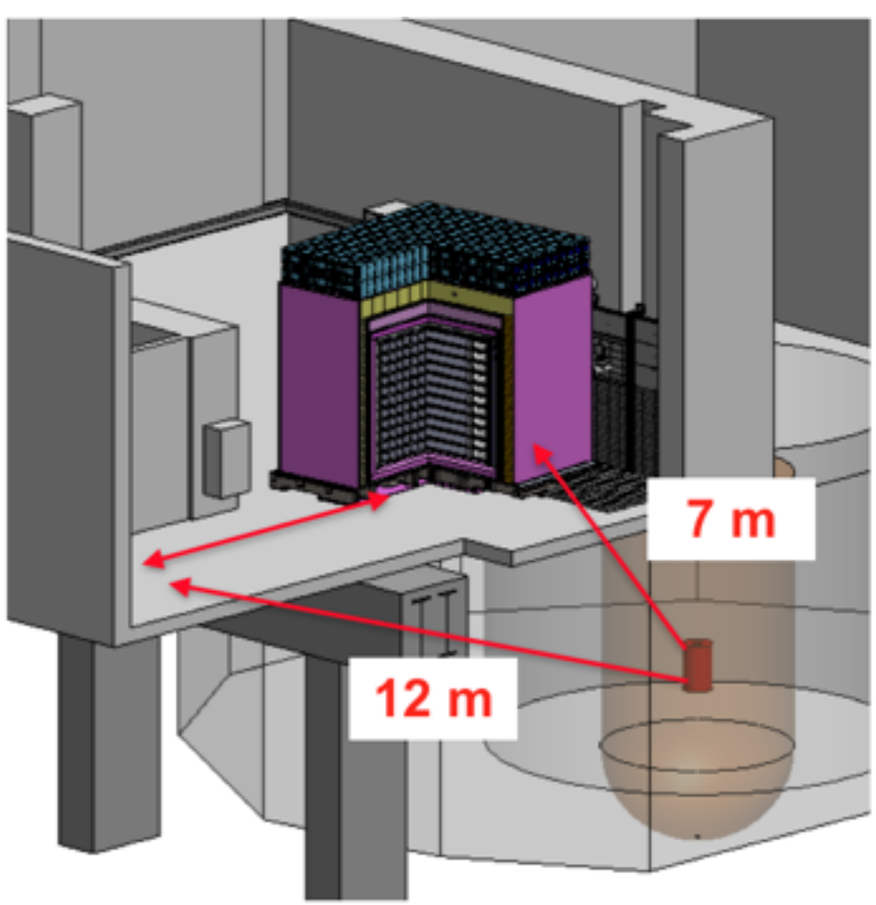


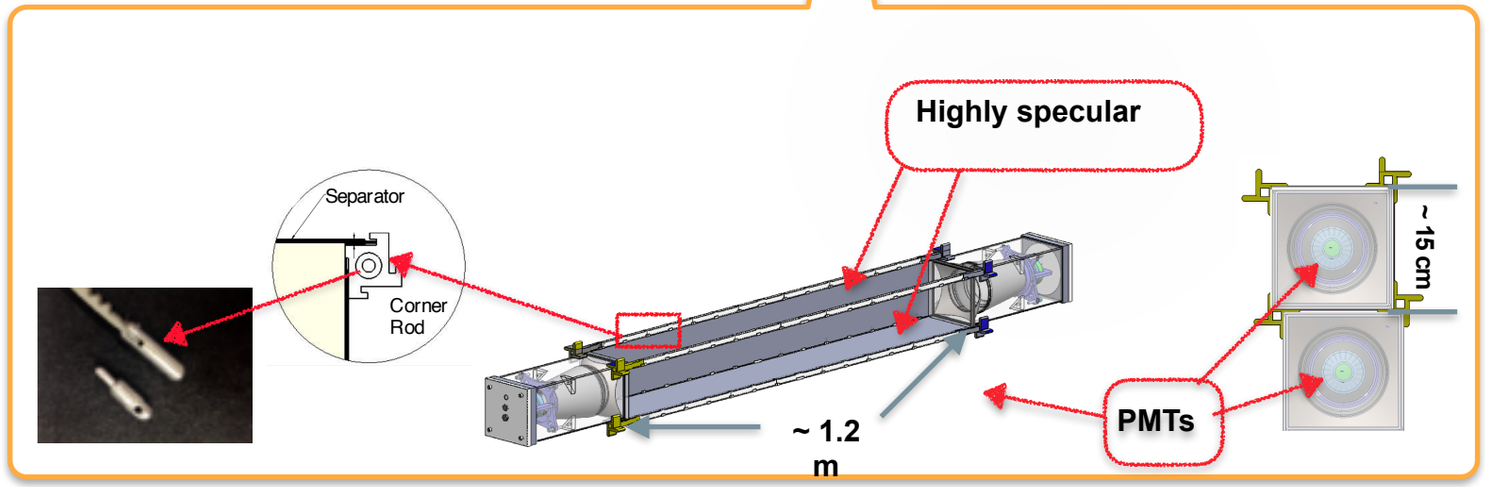


Detector Design

- Optically segmented Li6-doped liquid scintillator (LiLS) antineutrino detector (AD). ~4 ton of LiLS
- 14 X 11 elongated elemental AD (cells) are separated with low mass reflector panels
- Detector is movable: baseline 7-12 m
- Double ended readout
- Access for calibration sources between cells

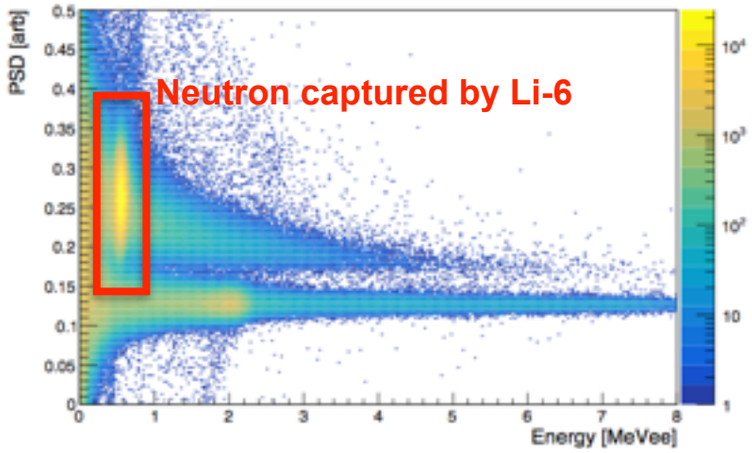


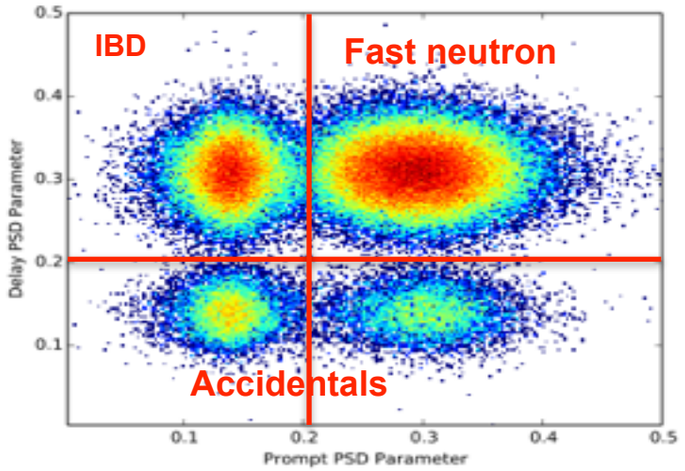


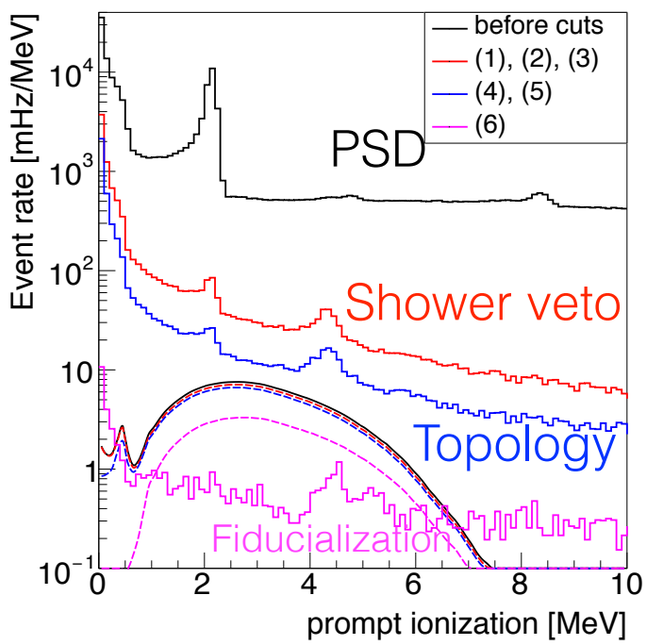


Event detection and selection in PROSPECT

- Detect inverse beta decay on Li6LS
- The pulse shape discrimination (PSD) of scintillator distinguish between the beta+ and n-like events
- PSD selection reduce the rate of accidentals.
- Main background is the cosmogenic neutron
- S:B ~ 3:1, IBD like event rate after background subtraction ~160K events/year



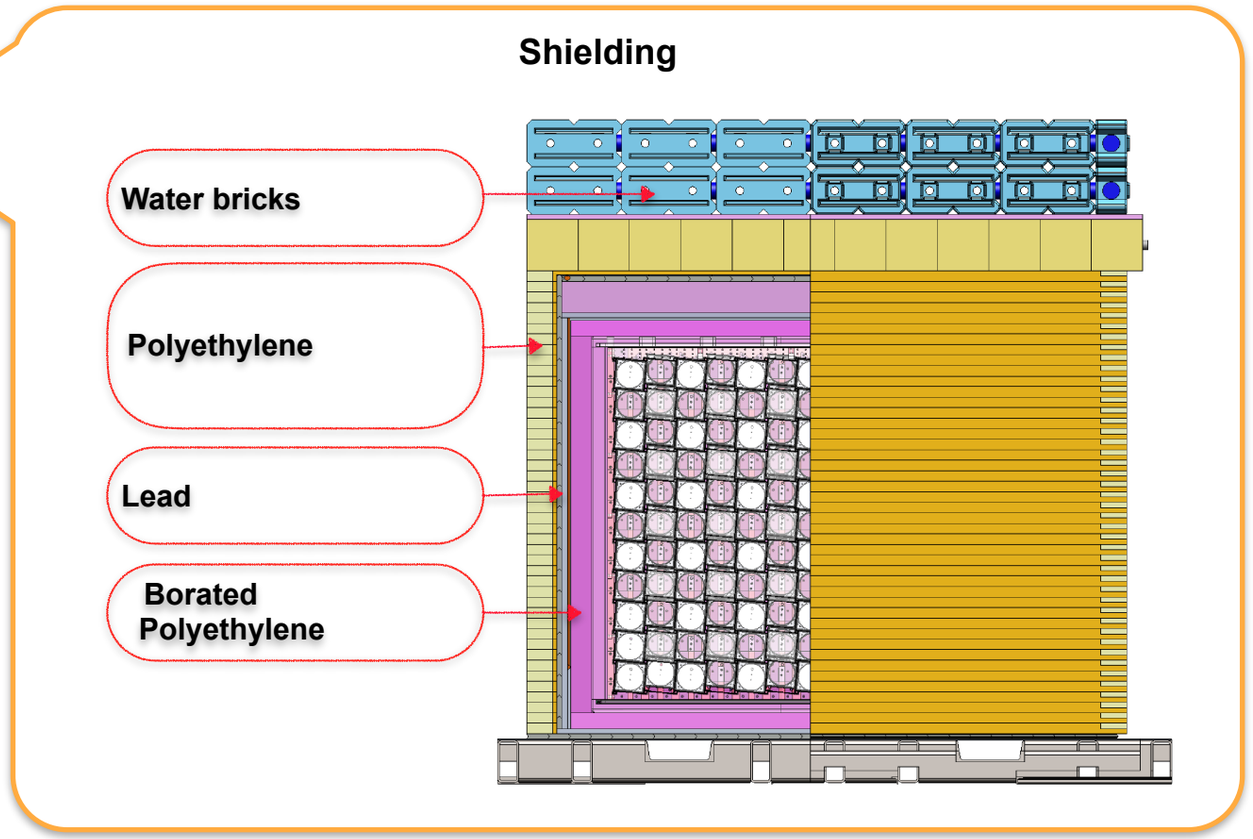




Background characterization

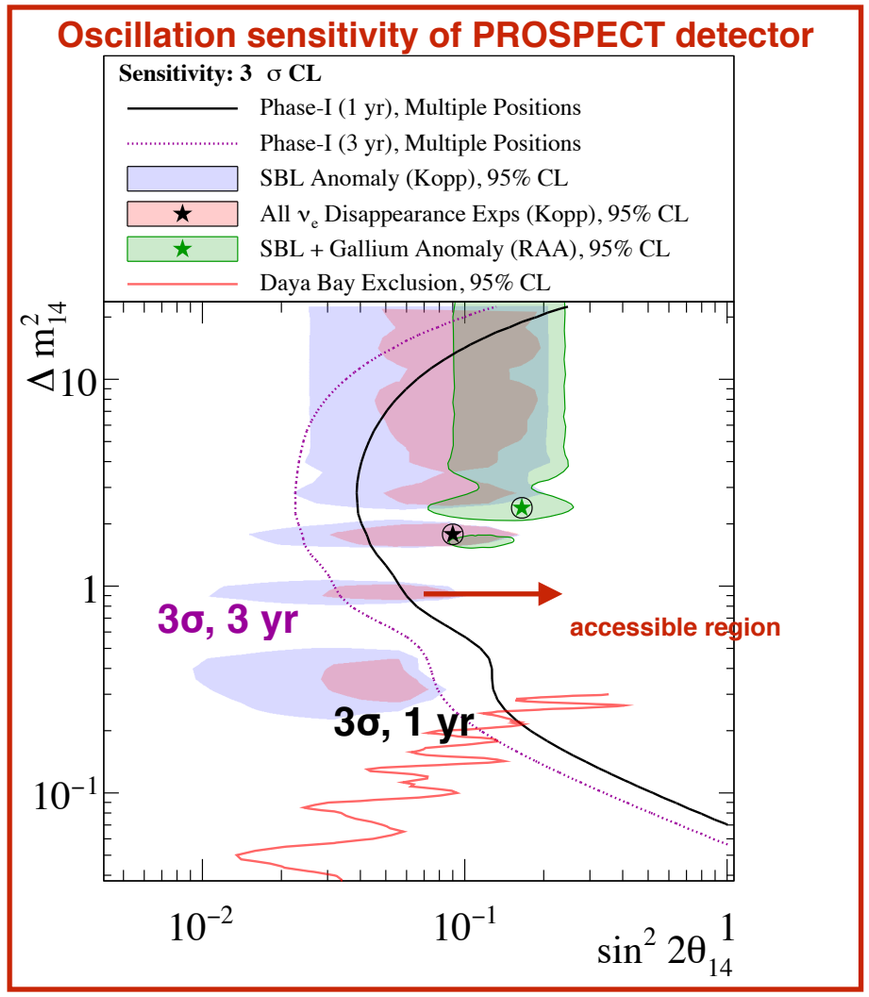
- Main sources of background: gammas, thermal and fast neutrons and muons

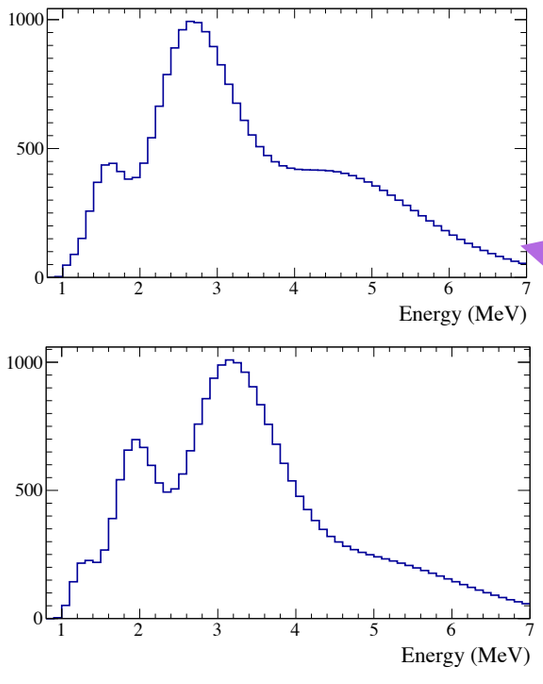
- Developed shielding configurations based on onsite background measurements and prototyping

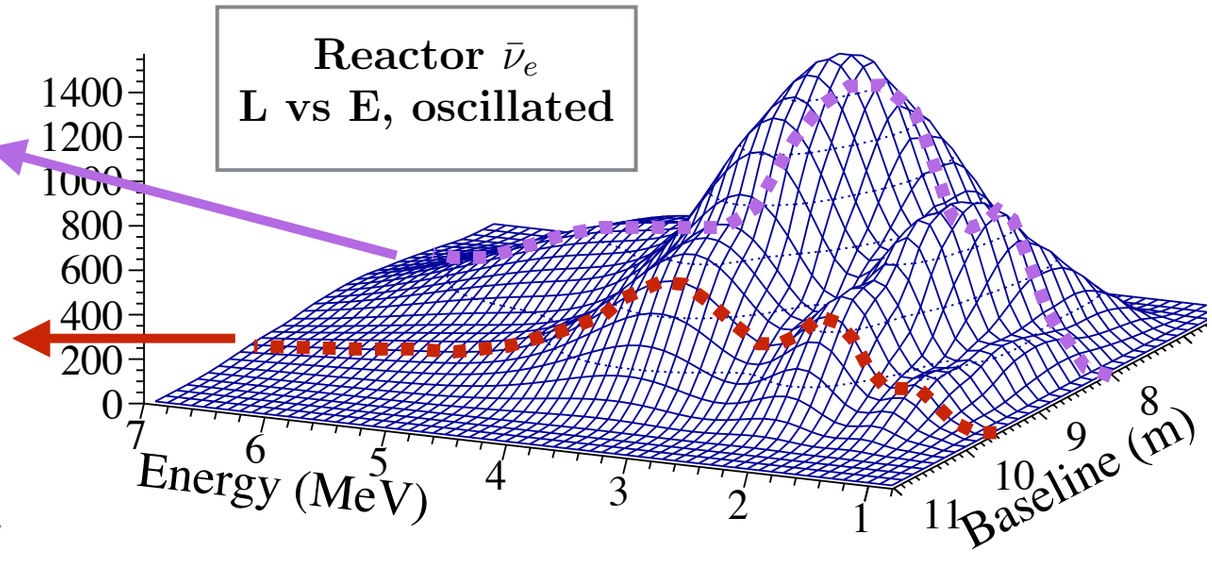


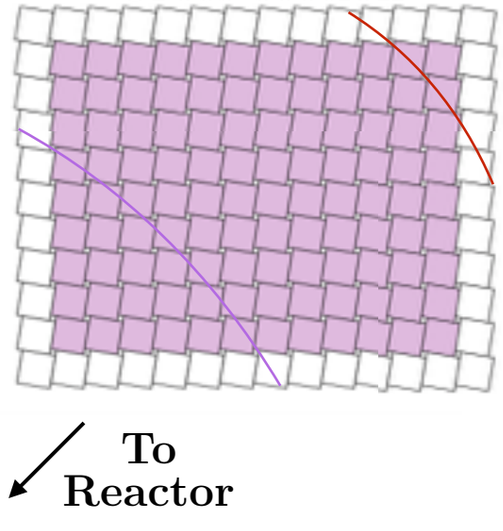
Sterile Neutrino Search

- Relative spectral measurement between 154 independent detectors (segments)
- Independent of underlying reactor flux and spectrum models.
- Relative measurement and movement minimize systematic errors
- **PROSPECT will be able to exclude sterile neutrino best fit at 4σ in one year!**





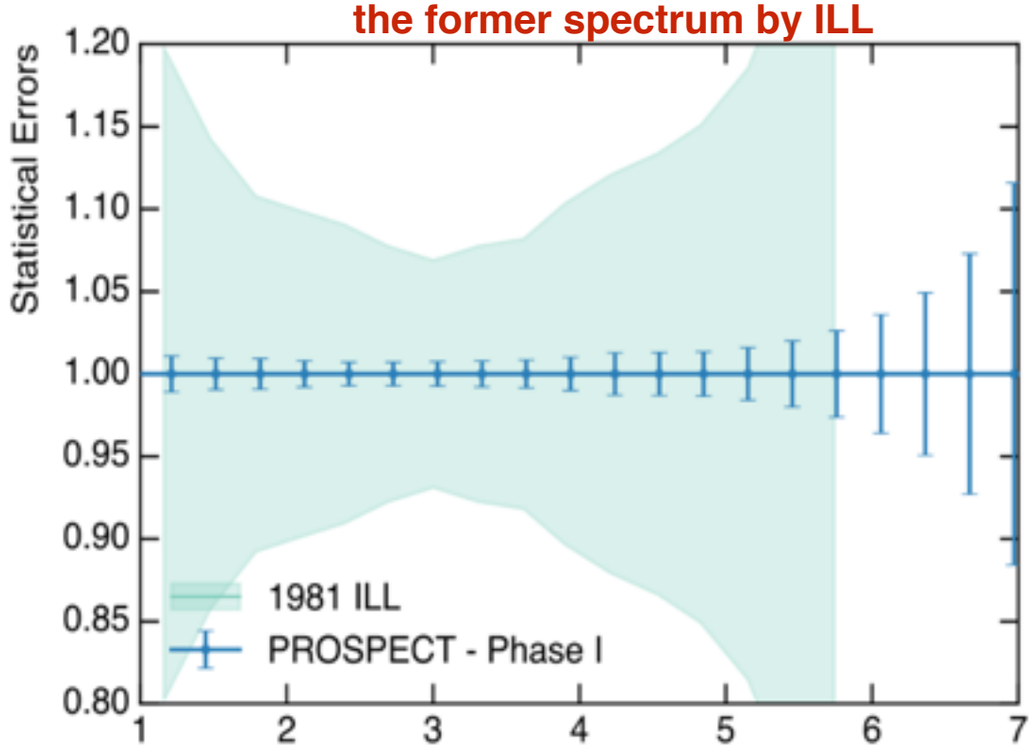


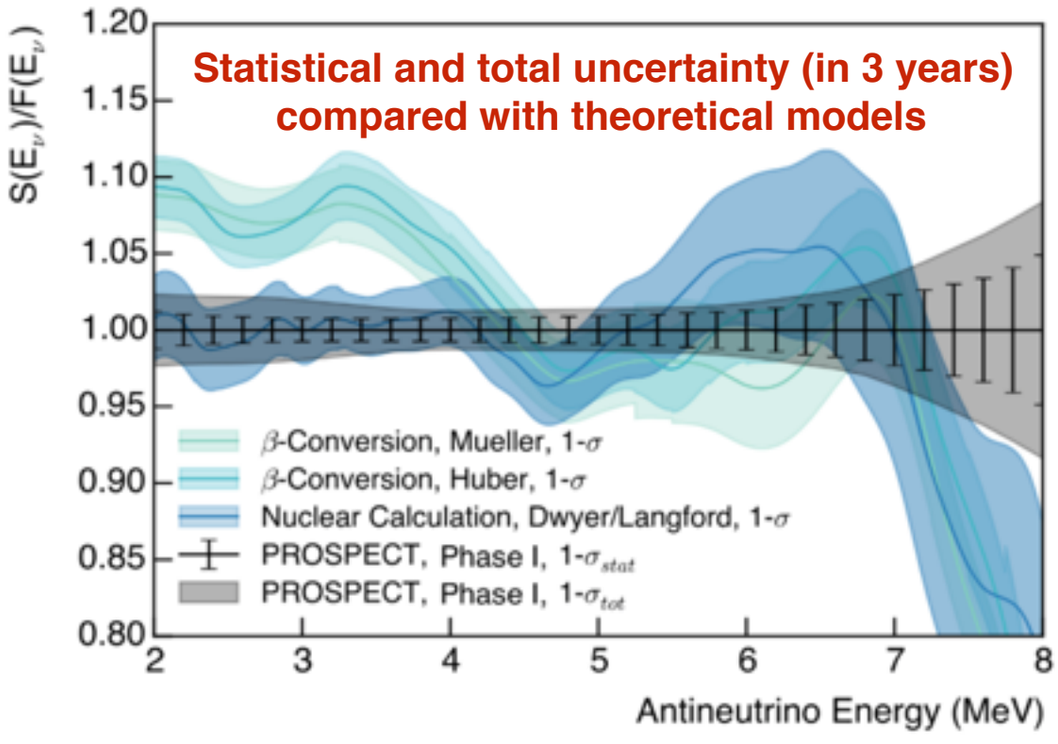


PROSPECT HEU antineutrino spectrum measurement

- Constraint different reactor models using the information from the HEU reactor
- HFIR HEU: only 1 isotope, no time dependence (Daya Bay, RENO, Double Chooz multiple isotopes)
- Antineutrino spectrum energy resolution: 4.5%/sqrt(E)
- Statistical uncertainty <1.5% per energy bin in interested range (0.2 MeV energy bins)
- Produce a benchmark spectrum for future reactor experiments

Statistical uncertainty of PROSPECT compared with the former spectrum by ILL





PROSPECT development status

PROSPECT-0.1
Characterize LS
Aug 2014-Spring 2015

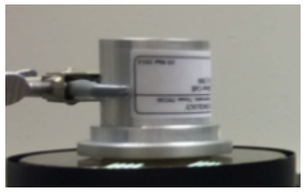
PROSPECT-2
Background studies
Dec 2014 - Aug 2015

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

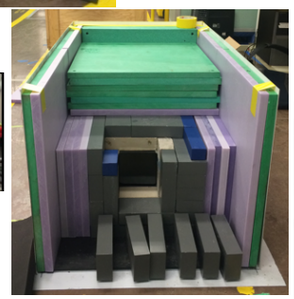
PROSPECT-50
Validation of design
Simulation benchmark
2016

PROSPECT AD-I
Physics measurement
2017

5cm length
0.1 liters
LS, ^{6}LiLS



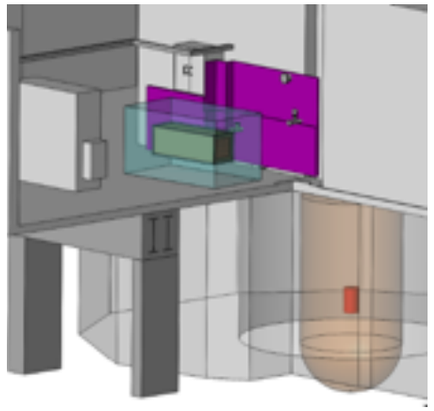
12.5 length
1.7 liters
^{6}LiLS



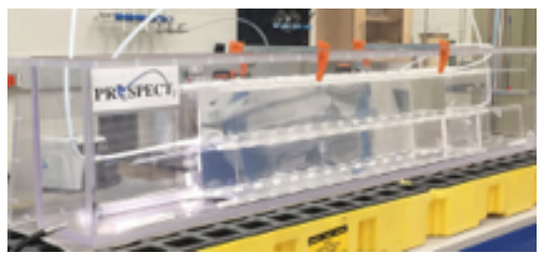
multi-layer
shielding

1m length
23 liters
LS, ^{6}LiLS

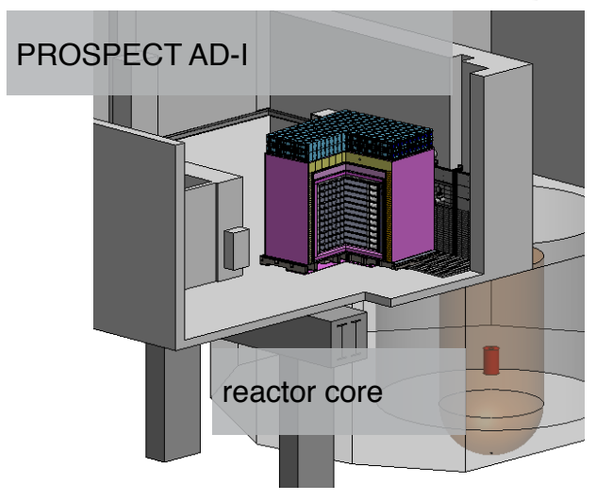
local reactor shielding



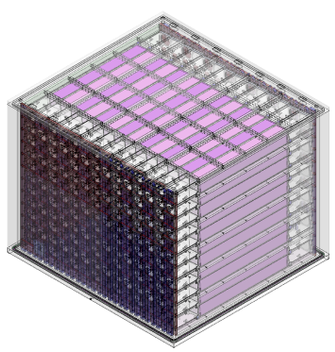
1x2 segments
1.2m length
50 liters
LS,^{6}LiLS



PROSPECT AD-I



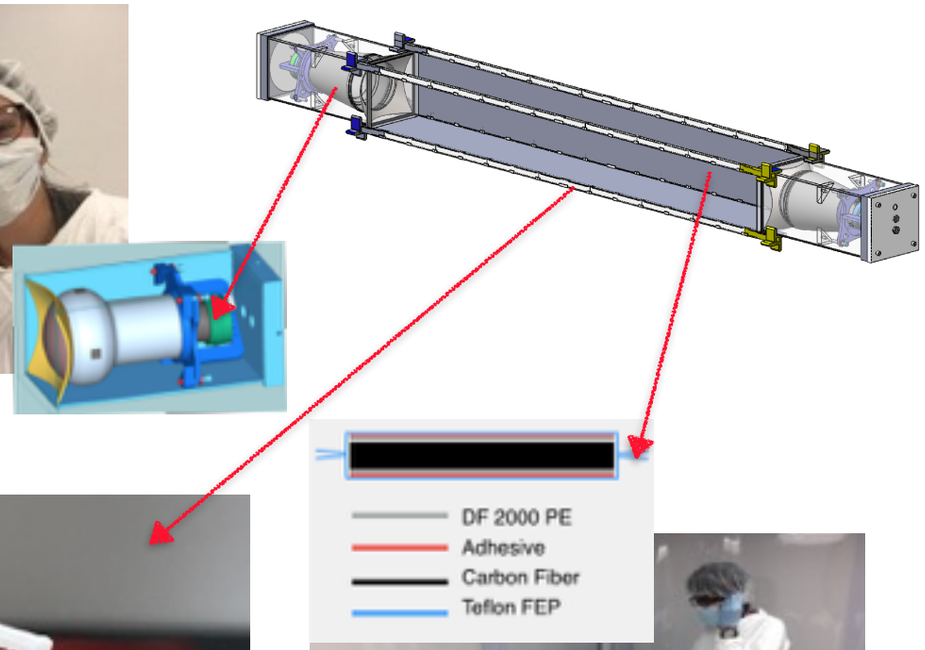
11x14 segments
1.2m length
~4 tons
^{6}LiLS



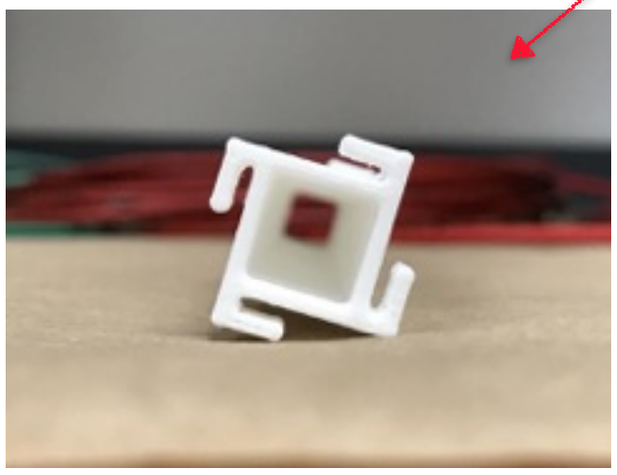
Current construction status

- Construction of components moving forward.
- Expected deployment at HFIR: by the end of 2017

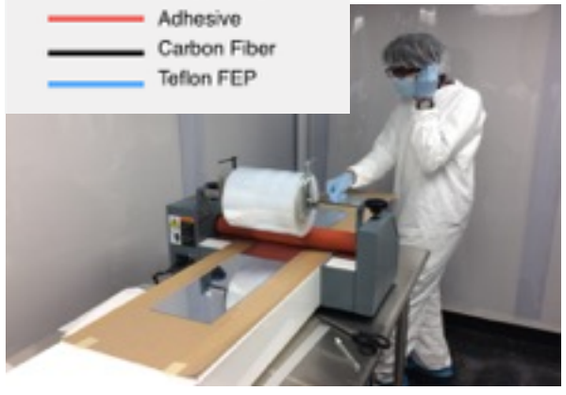
PMT housing



Making LiLS



3-D printed rods



Multilayer reflector laminating

Summary

- SBL reactor measurements at HEU cores are essential for probing the nature of the spectral anomaly, and for making conclusive, model-independent tests for sterile neutrinos.

- We need more data to constrain the “Reactor Antineutrino Anomaly” further!

- Commissioning of PROSPECT by the end of 2017 at HFIR

- PROSPECT will provide a unique measurement of the ^{235}U reactor antineutrino spectrum for use in improving reactor flux predictions.

- PROSPECT will be able to exclude current global sterile neutrino best fit points at 4σ CL in 1 year.

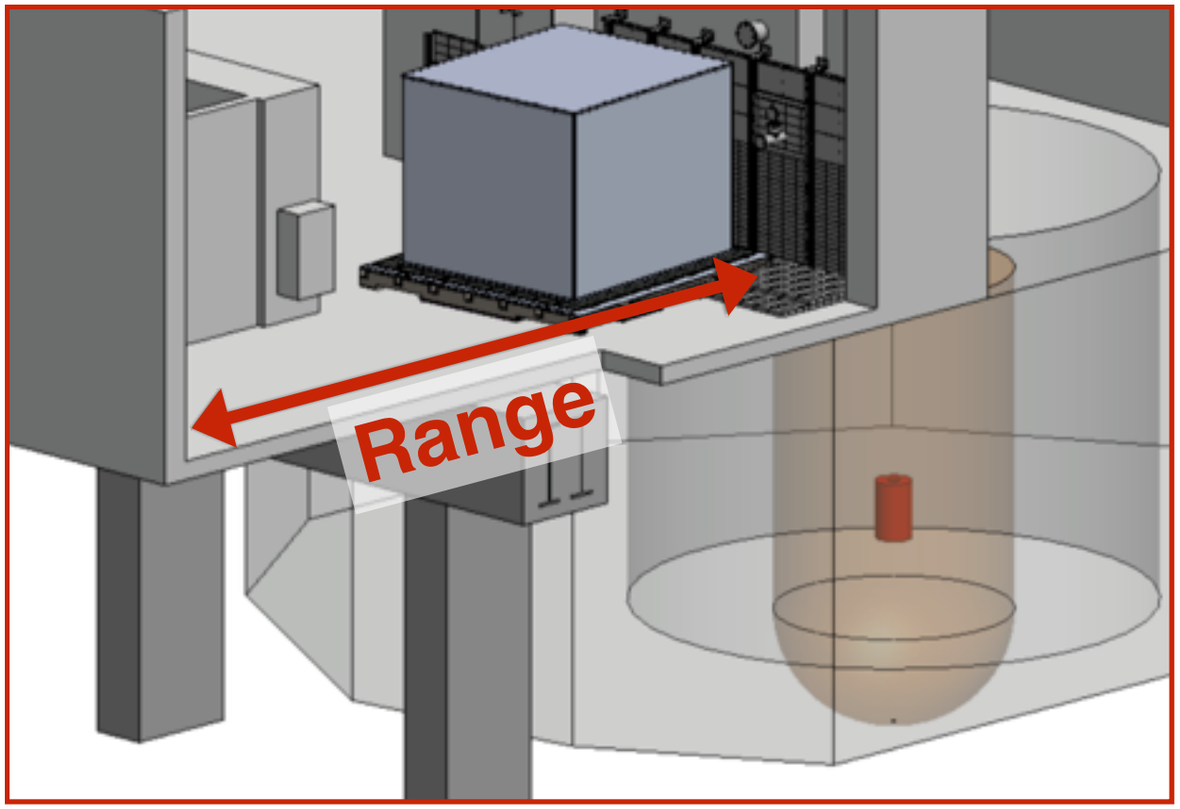
PROSPECT Collaboration

prospect.yale.edu

arXiv:1309.7647
Nucl. Instru. Meth. Phys. Res. A 806 (2016) 401
Journal of Phys. G 43 (2016) 11
JINST 10 (2015) P11004

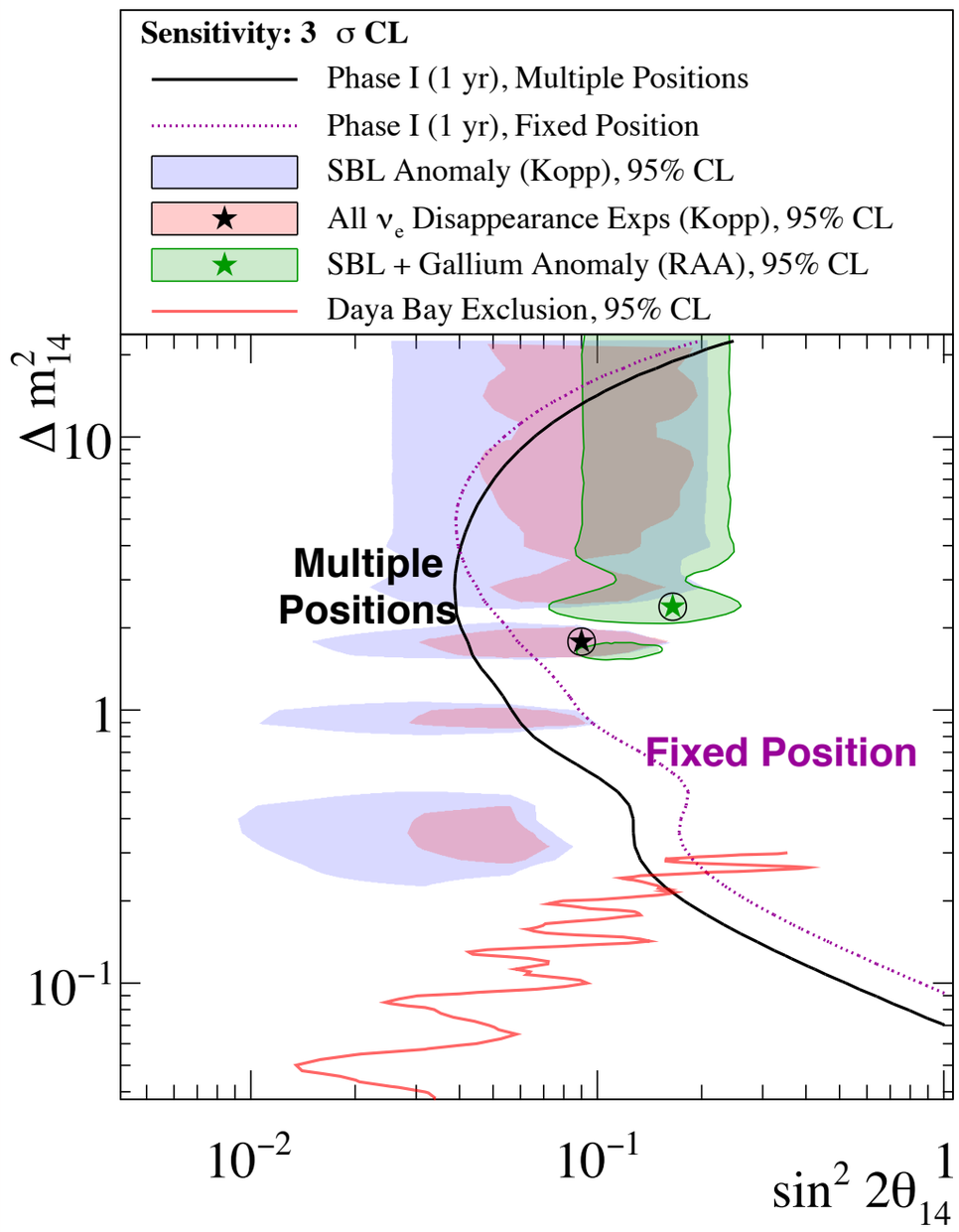
BACKUP

Movable PROSPECT Phase-I Detector



- Movable detector allows an expanded investigation into the lower Δm^2 parameter space
- Systematic effects are also reduced with a movable detector

Oscillation sensitivity with One year of data



Movable PROSPECT detector enables coverage of desired (Δm^2,θ_{14}) parameter space