PROSPECT

Precision Reactor Oscillation and Spectrum Experiment

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On behalf of the PROSPECT Collaboration

A sterile neutrino search and reactor spectrum measurement at very short baselines

Lawrence Livermore National Laboratory

LLNL-PRES-681674

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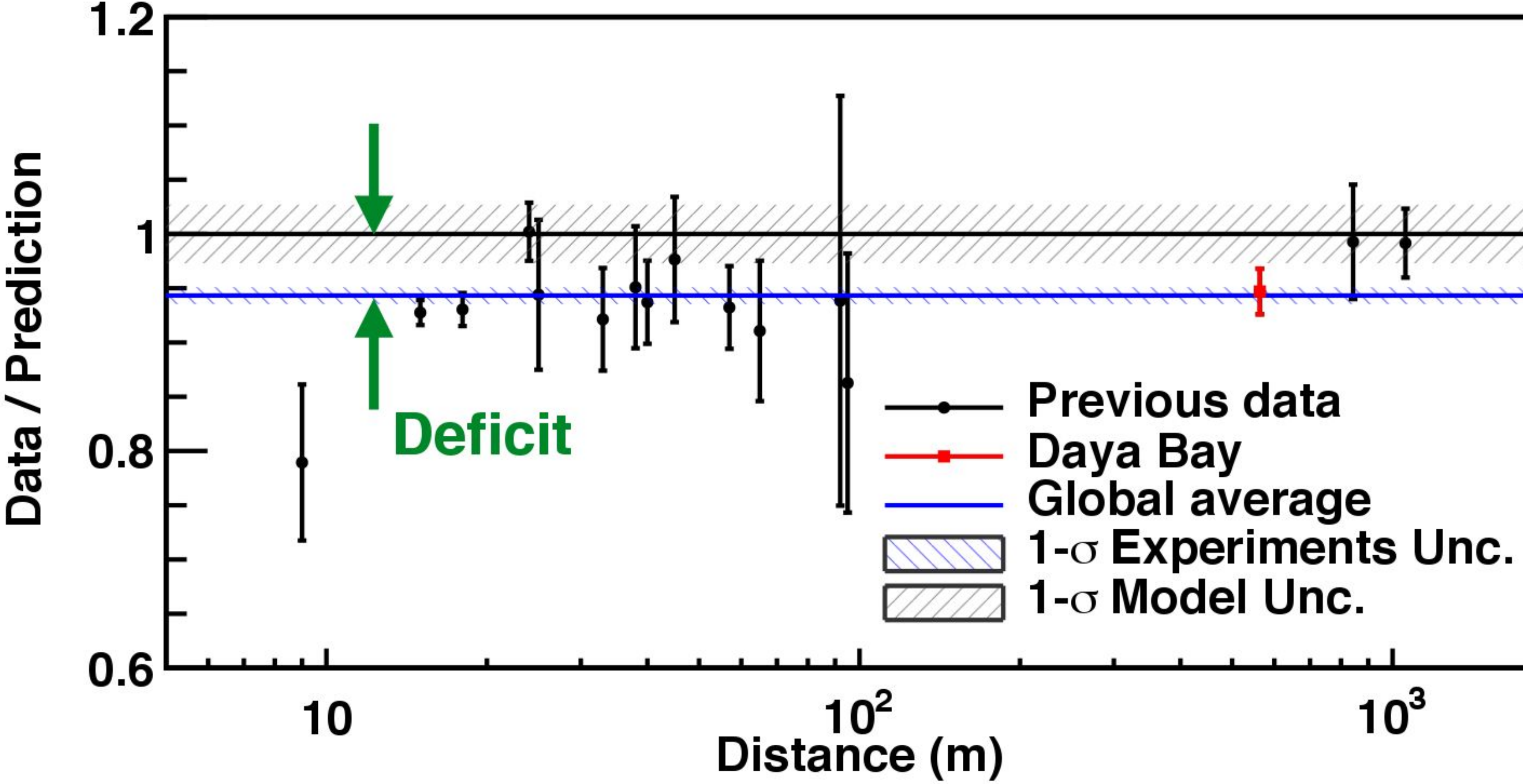
Reactor Antineutrino Flux Anomaly

arXiv:1508.04233 (Daya Bay)



Is this deficit evidence of oscillation to a fourth neutrino?
Yes: Evidence outside the reactor context. **No**: Could be flaws in reactor predictions

The history of the solar & atmospheric anomalies says we should look!

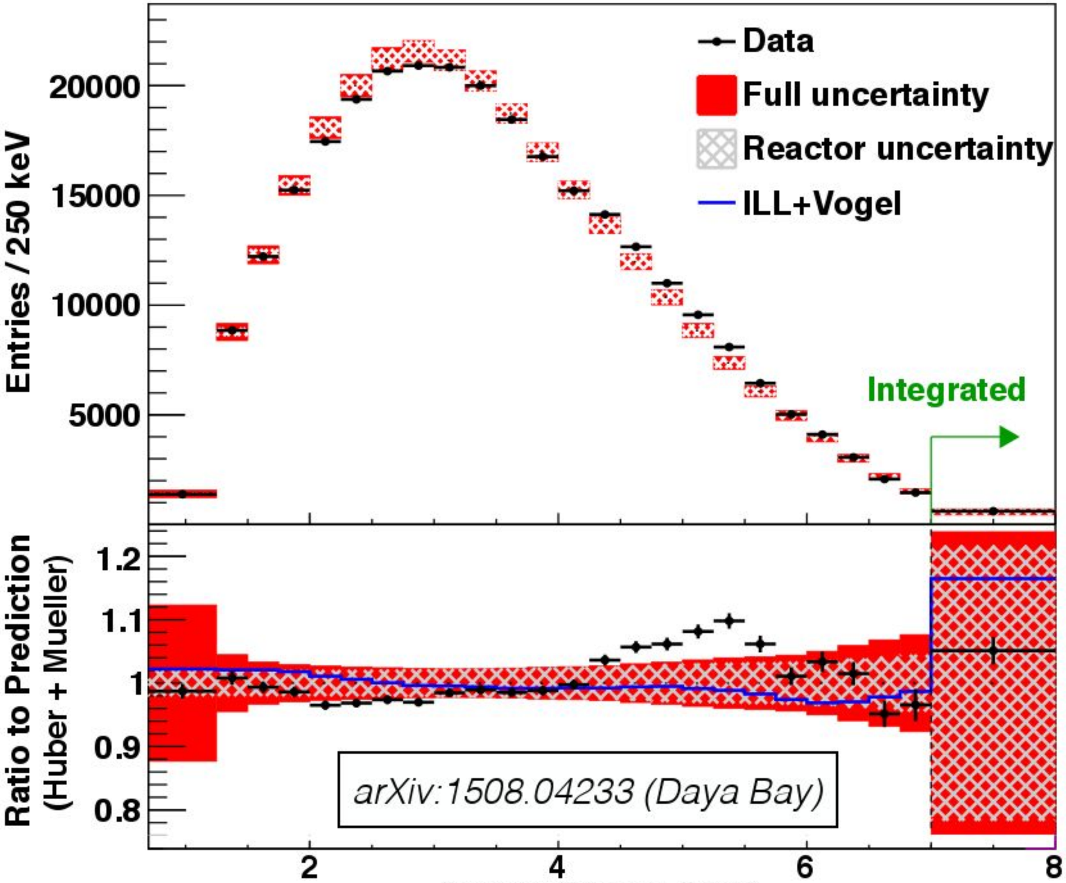
Reactor Antineutrino Spectrum Anomaly

Definite evidence of deficiencies in reactor predictions

Motivates a precision, short-baseline reactor antineutrino detector

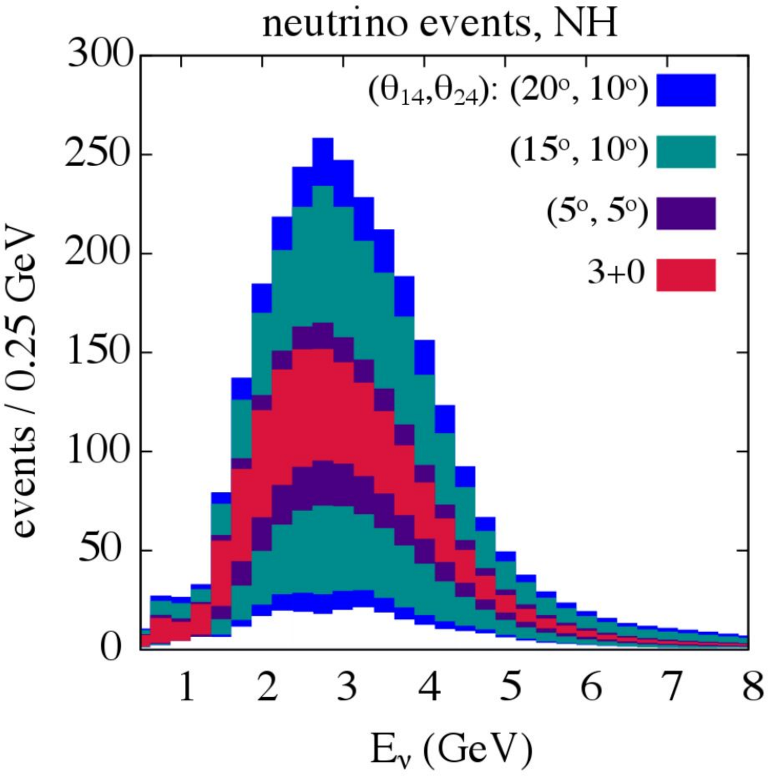
Perform a **prediction-independent** search for sterile neutrinos: find oscillations in data, without reference to prediction

Measure the reactor spectrum and flux to greater precision, constraining open questions in reactor predictions



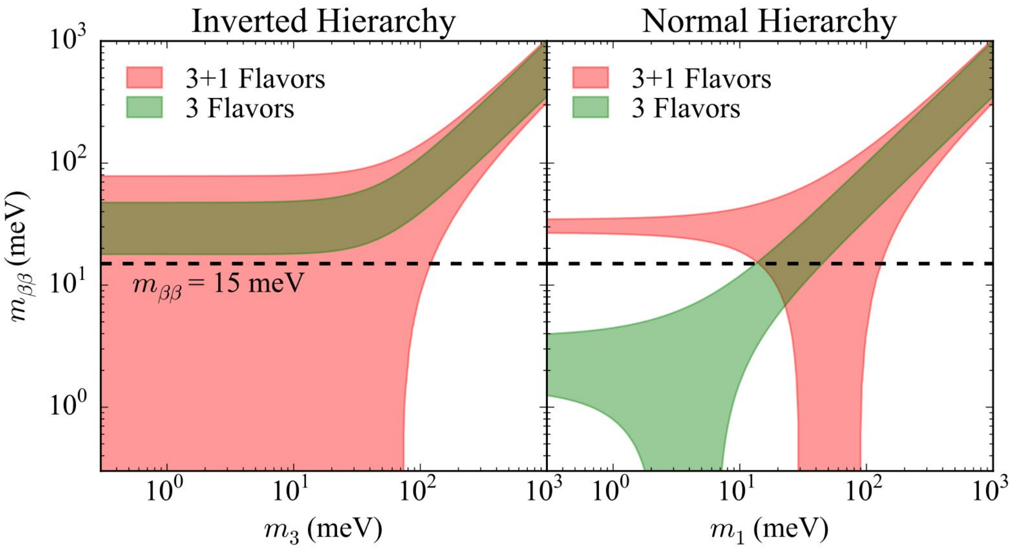
arXiv:1508.04233 (Daya Bay)

Experimental Implications



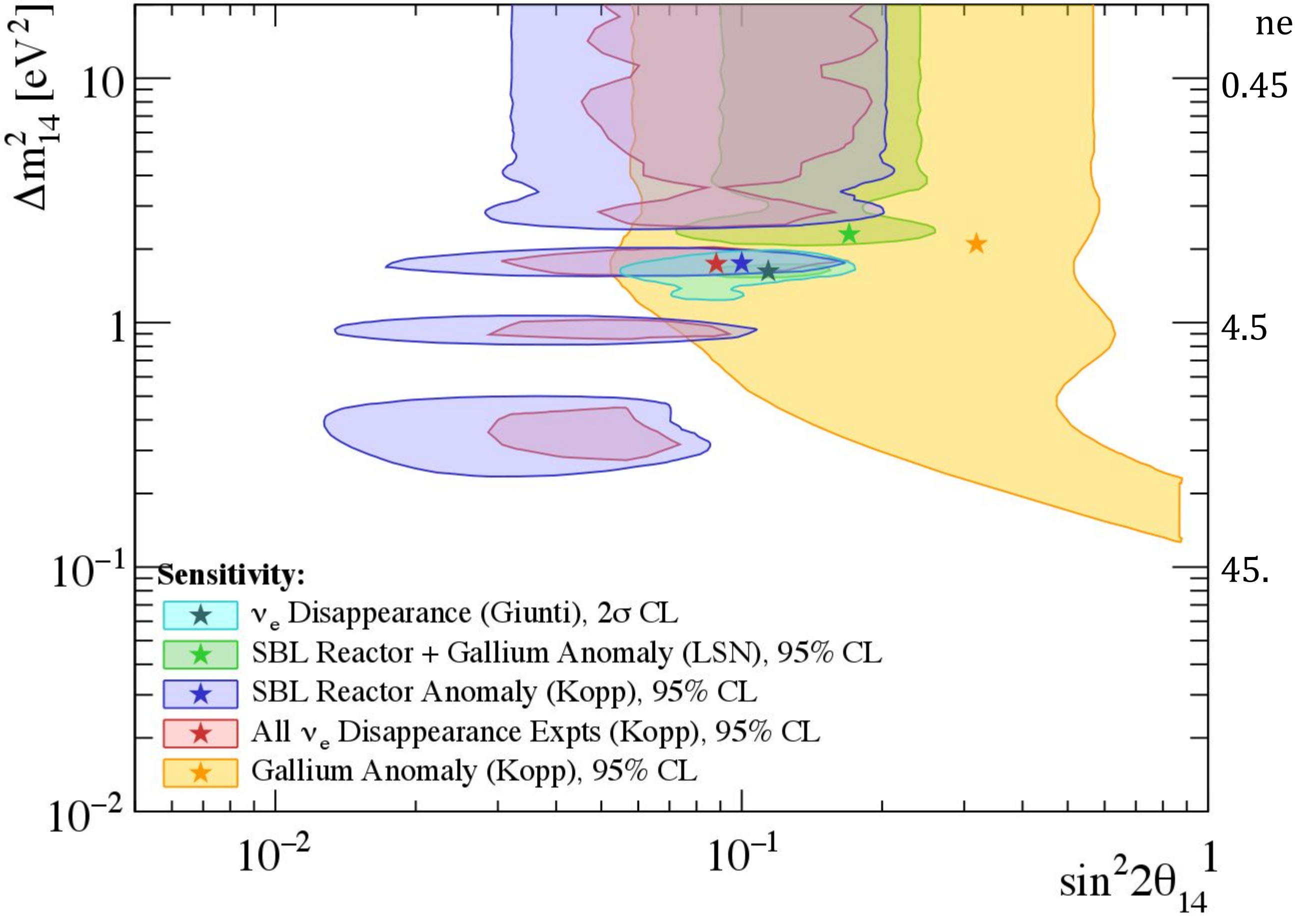
DUNE expected rates. Each colored band shows the range of possible rates varying the CP-violating phase.

Adding in a sterile neutrino, particularly at larger mixing angles, has a dramatic effect.
Giunti & Zavanin, JHEP1507 (2015)



0νββ allowed regions change greatly under sterile neutrino hypothesis
arXiv:1512.02202

3+1 Model Allowed Region



Mixing angle accessible to a detector small enough to place within meters of reactor core

The PROSPECT Antineutrino Detector

Very short baseline

Compact Core

Lithium-loaded, pulse shape discriminating liquid scintillator

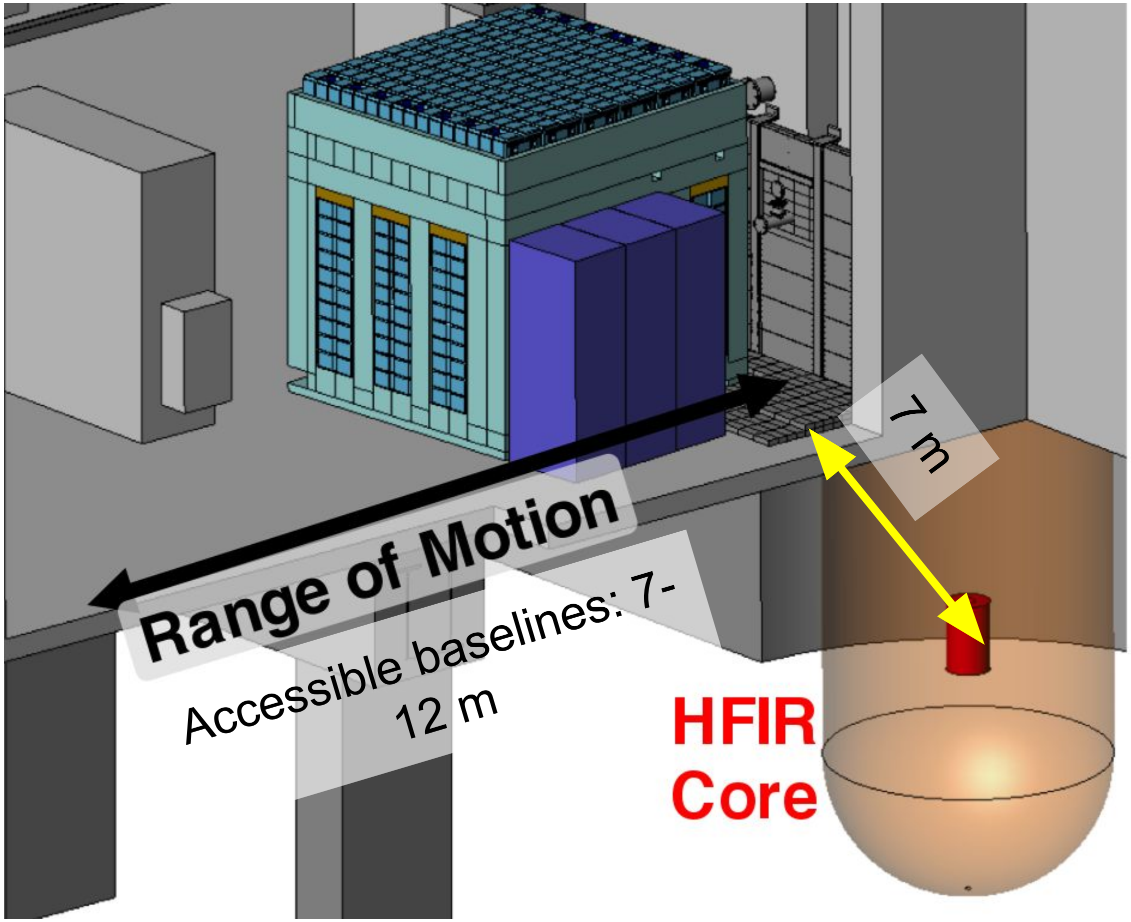
Segmented

Challenge: Surface environment, not a low-background environment

Requirement: powerful discrimination for antineutrinos

Solution: clear signature in specialized scintillator, electron recoil followed by nuclear recoil

arXiv:1512.02202



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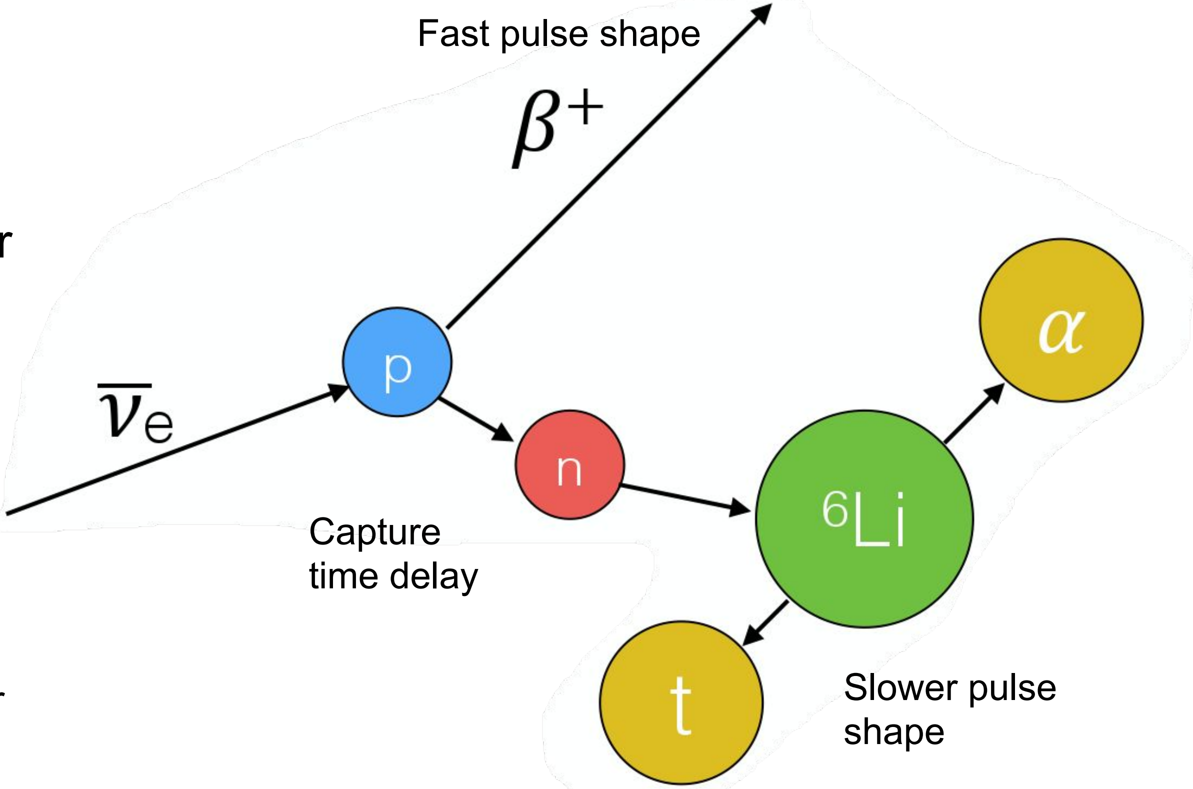

Challenge: Surface environment, not a low-background environment

Requirement: powerful discrimination for antineutrinos

Solution: clear signature in specialized scintillator, electron recoil followed by nuclear recoil

^{6}Li-loaded EJ309 scintillator

Nontoxic, high-flashpoint

light yield sufficient for 4.5% $/\sqrt{E}$ energy resolution in PROSPECT

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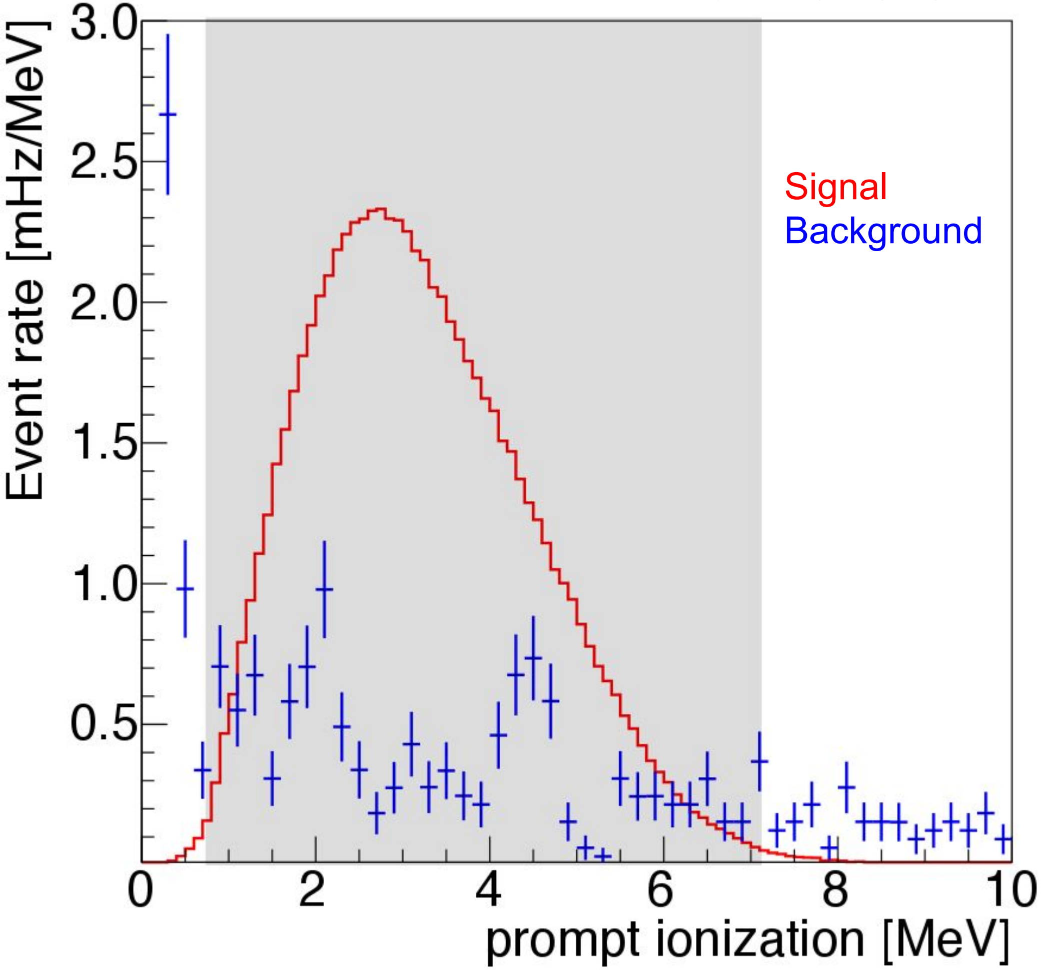
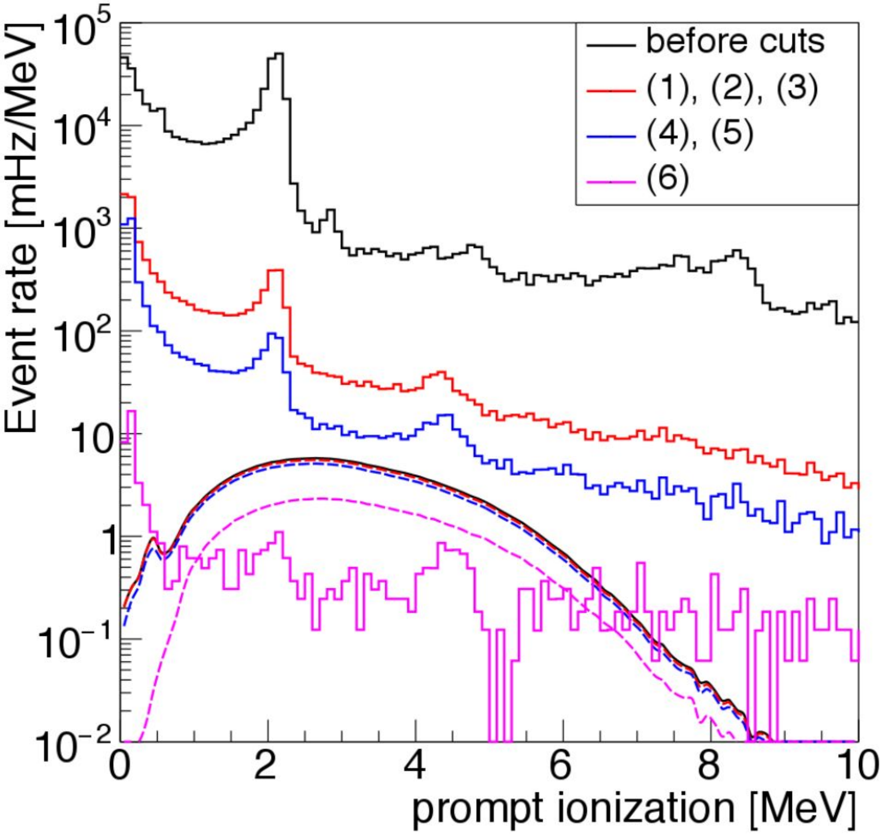
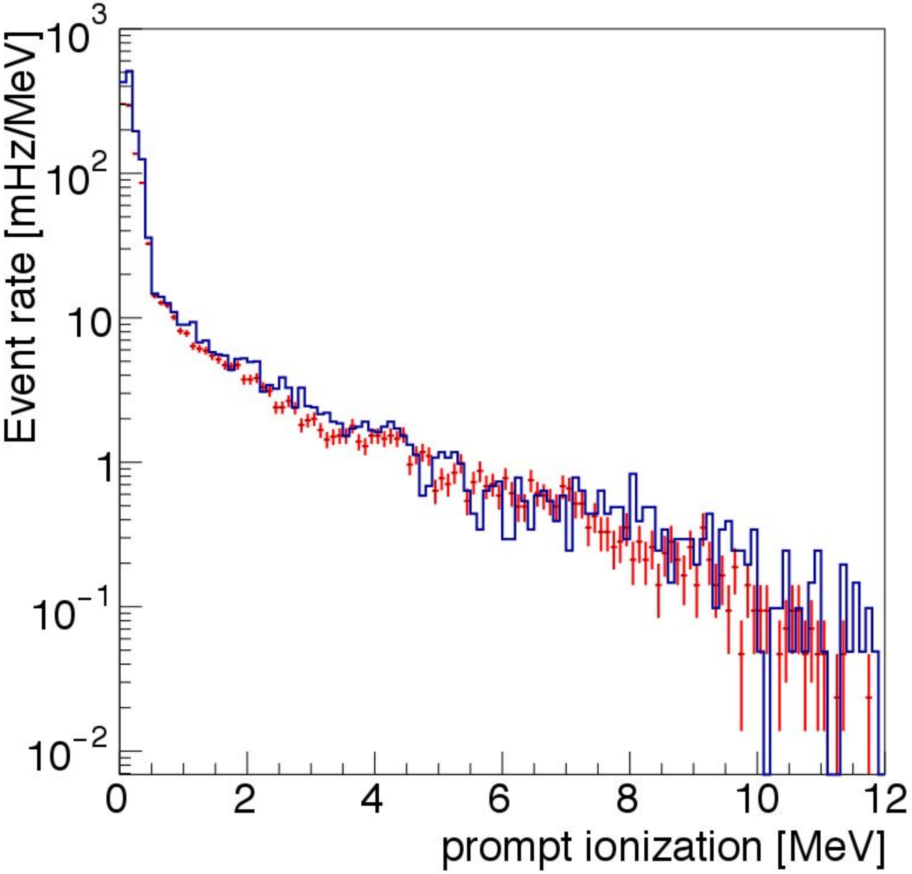


Simulation validated against on-site prototype data

Background discrimination





black line: coincident electron & nuclear recoil

1,2,3) Timing 4,5) topology

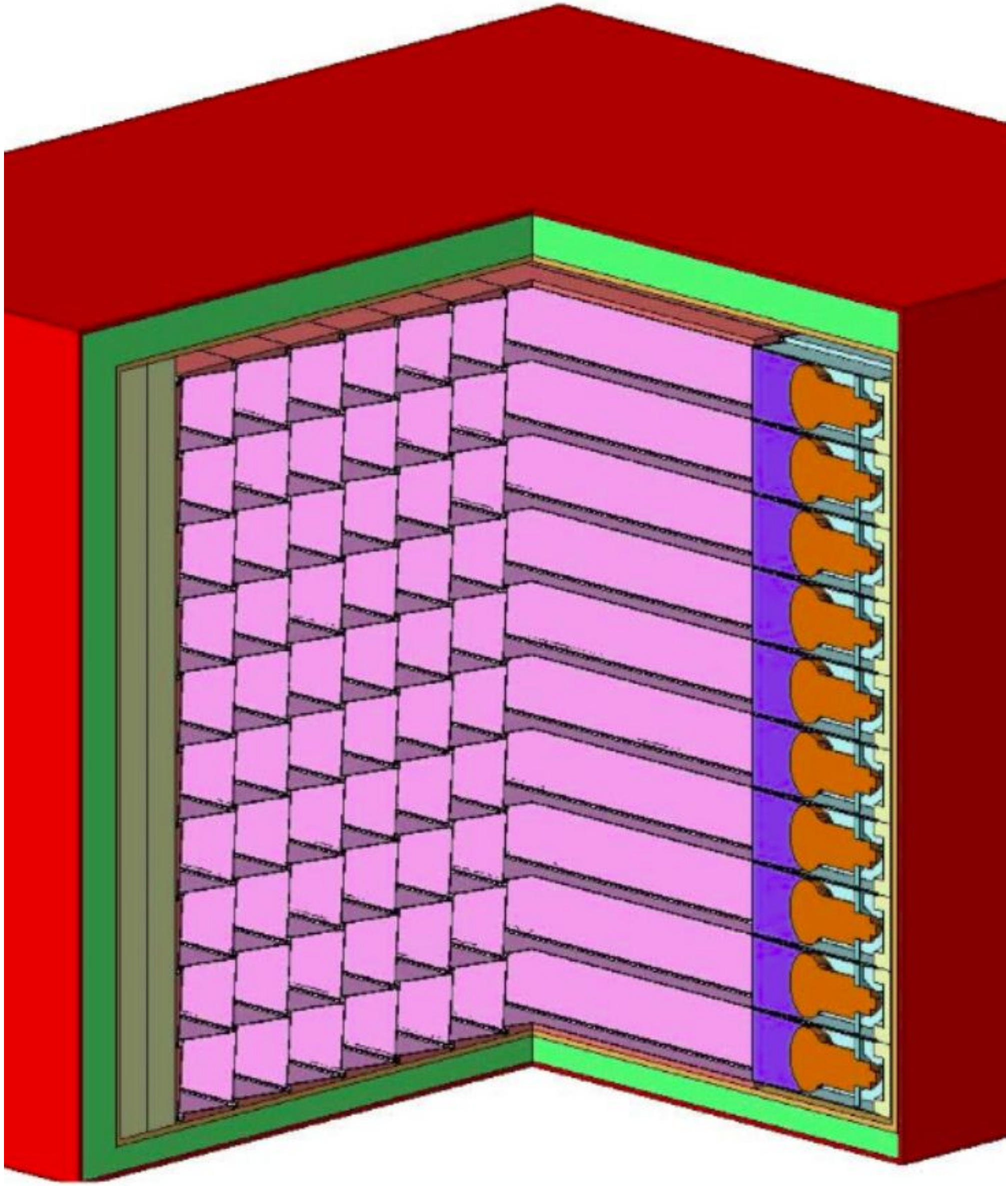
6) fiducialization

dotted: neutrino events

Prototype data

Simulation

The PROSPECT Antineutrino Detector



Very short baseline

Compact Core

Lithium-loaded, pulse shape discriminating liquid scintillator

Segmented

1.75m x 1.46m x 1.2m
10 x 12 segments
2940 kg target mass

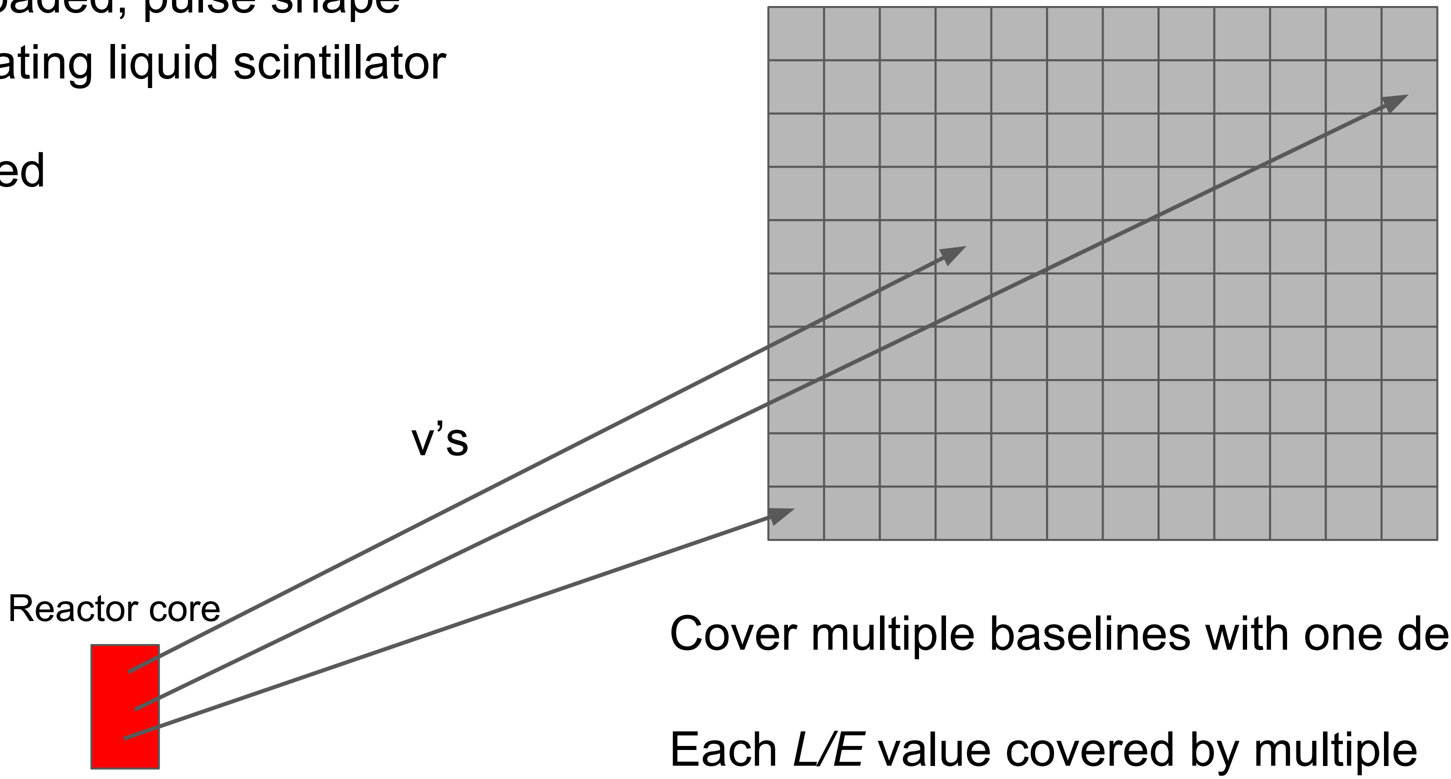
The PROSPECT Antineutrino Detector

Very short baseline

Compact Core

Lithium-loaded, pulse shape discriminating liquid scintillator

Segmented

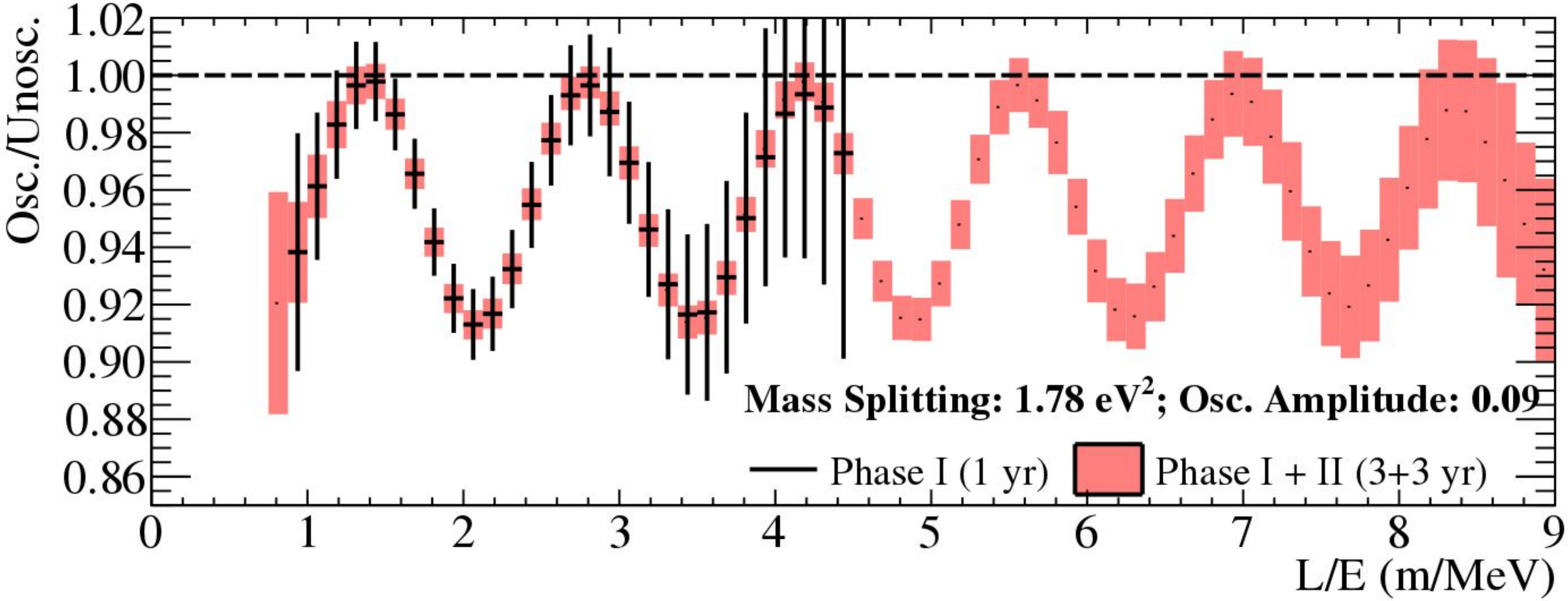


Cover multiple baselines with one detector

Each *L/E* value covered by multiple segments

Physics Reach

arXiv:1512.02202



Assuming best-fit 3+1 model, PROSPECT would see very clear evidence of oscillation to the sterile neutrino: multiple oscillations

No need to compare to any prediction: only compare different *L/E* bins to each other

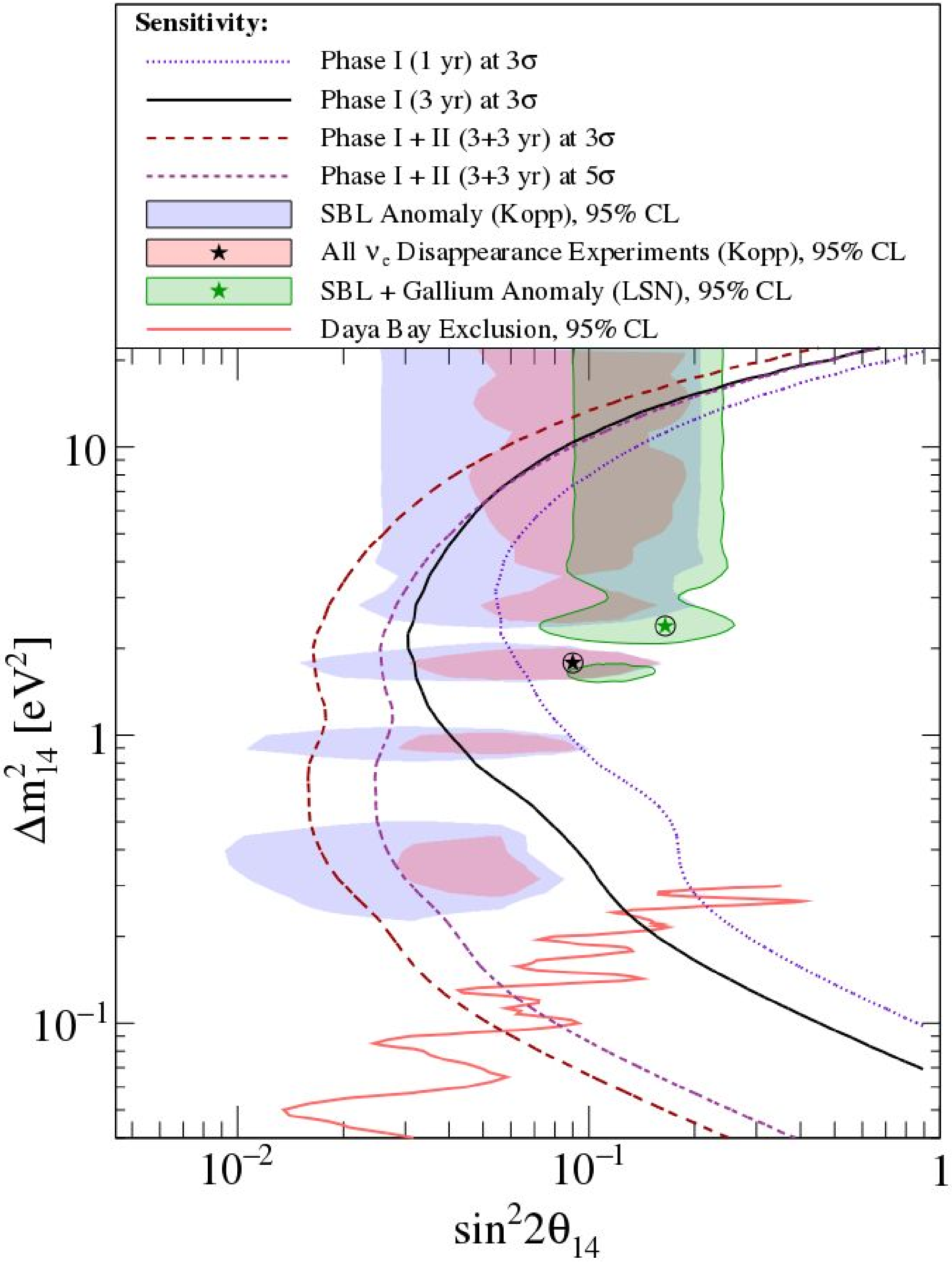
Phase II (larger detector at 15 m baseline) extends baseline reach

Physics Reach

Within 1 year, exclude or confirm "Kopp" best-fit for 3+1 (4σ)

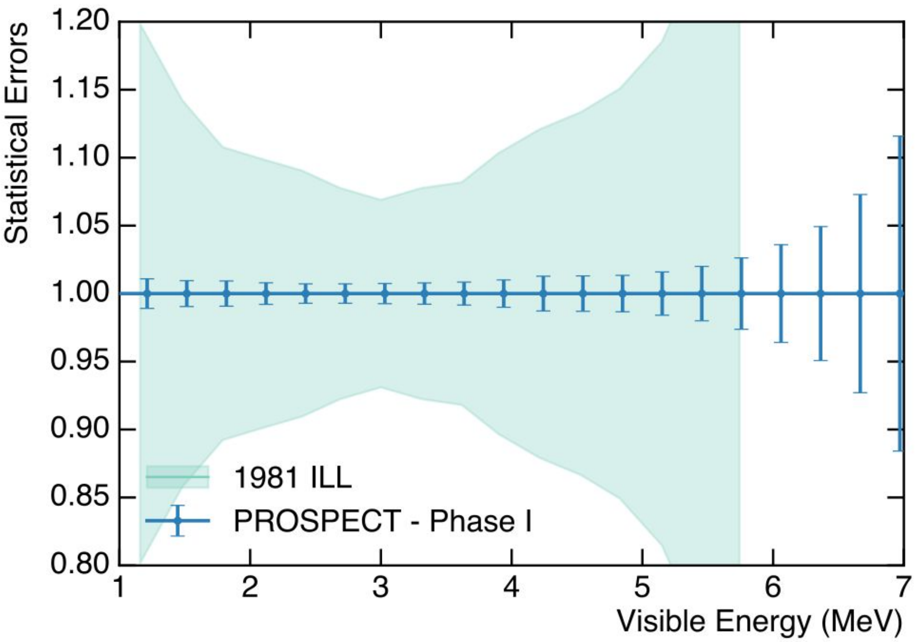
Within 3 years, exclude large portions of remaining parameter space (>3σ)

With Phase II extension, even further reach: 5σ over majority of allowed space with $\Delta m^2_{14} < 10$ eV^2

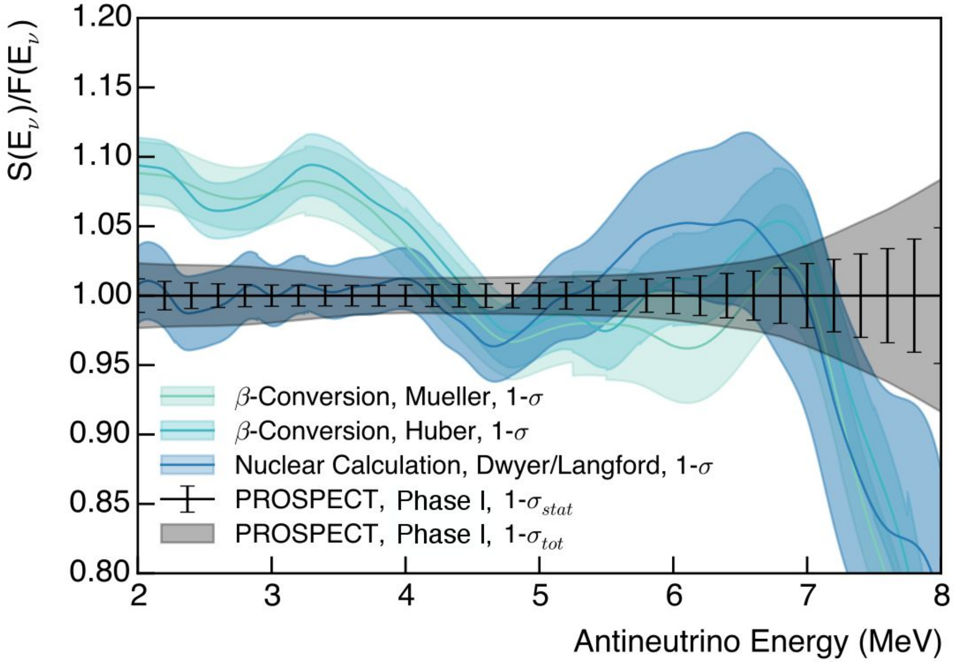


arXiv:1512.02202

Physics Reach: Reactor Neutrino Predictions



The last neutrino spectrum measurement of a HEU reactor was in 1981. PROSPECT will make a much more precise spectral measurement



Different reactor predictions and projected measurement, relative to a smooth approximation of the neutrino spectrum

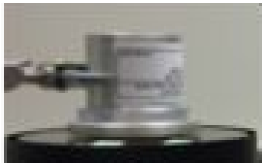
Easier to pick out the effect of prediction differences in the HEU context

PROSPECT will be able to differentiate between predictions

PROSPECT **Timeline**

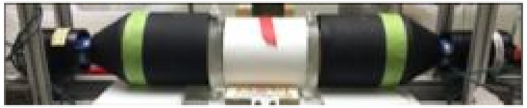
PROSPECT-0.1
Characterize LS
Aug 2014-Spring 2015

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



PROSPECT-2
Background studies
Dec 2014 - Aug 2015

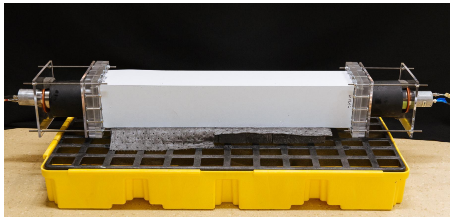
12.5 length
1.7 liters
^{6}LiLS



multi-layer shielding

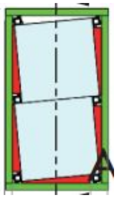
PROSPECT-20
ON SITE
Segment characterization
Scintillator studies
Background studies
Spring/Summer 2015

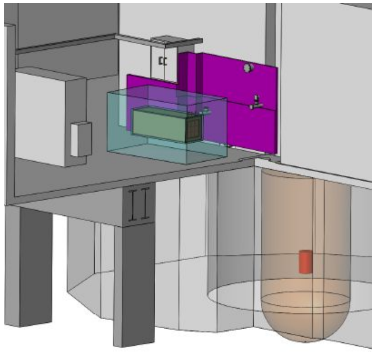
1m length
23 liters
LS, ^{6}LiLS



PROSPECT-50
Baseline design prototype
Currently under construction

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

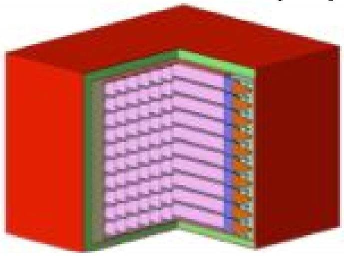


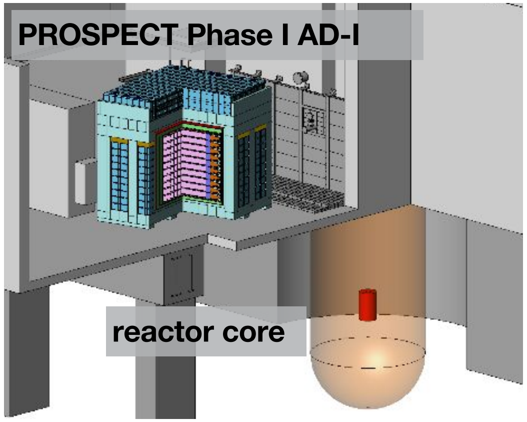


local reactor shielding

PROSPECT AD-I
Physics measurement
Late 2016

10x12 segments
1.2m length
~3 tons
^{6}LiLS





PROSPECT Phase-II
Extends Physics Reach

Conclusion

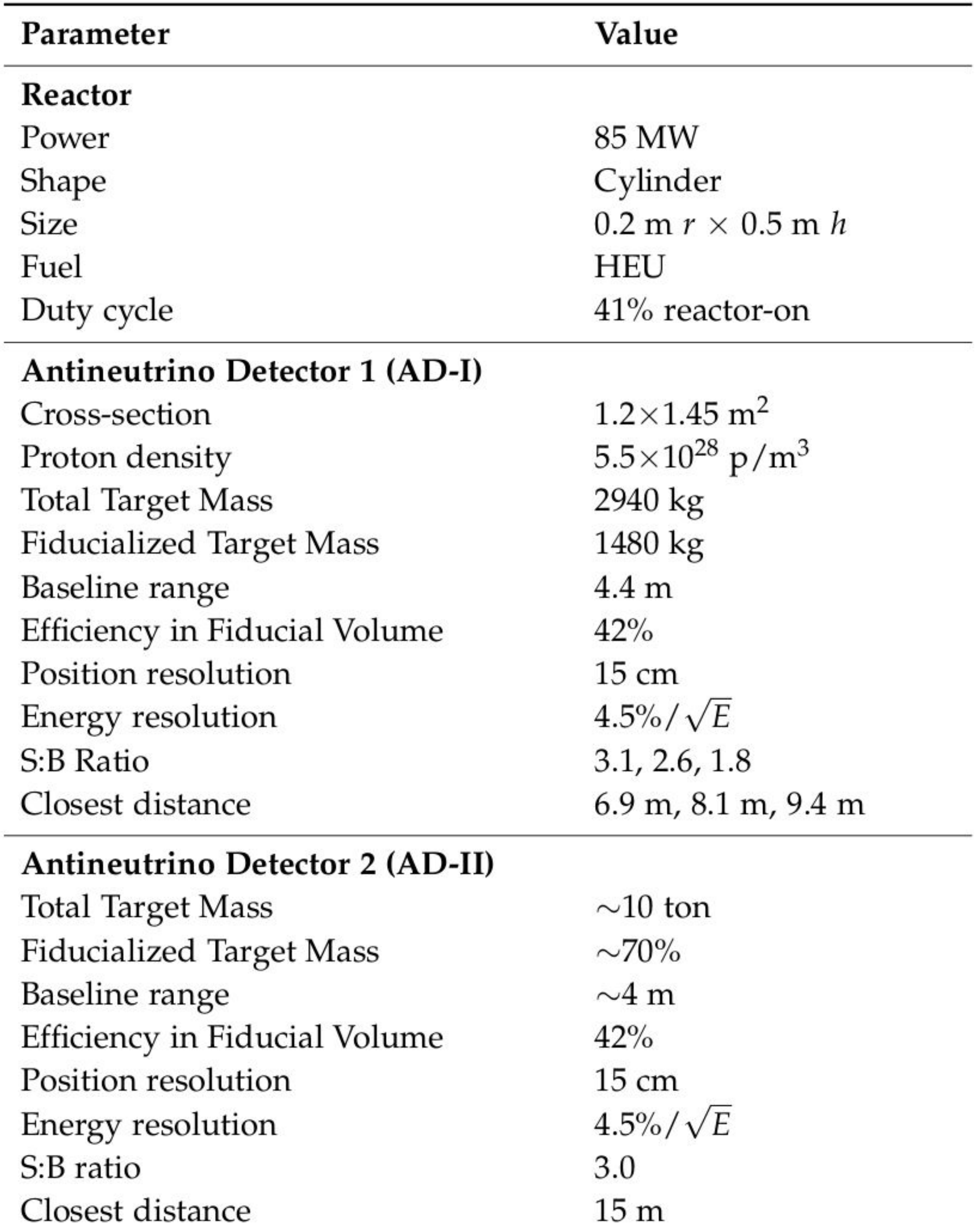
PROSPECT detects reactor antineutrinos at very short baselines

Excludes best-fit sterile neutrino model within one year

Ready to go: successful prototypes, can do full-scale this year

Resolving anomalies is how neutrino discoveries are made. Now’s the time to tackle the reactor anomaly.

prospect.yale.edu
arXiv:1512.02202
arXiv:1506.03547
arXiv:1508.06575
arXiv:1309.7647



Parameter	Value
Reactor	
Power	85 MW
Shape	Cylinder
Size	0.2 m $r \times$ 0.5 m h
Fuel	HEU
Duty cycle	41% reactor-on
Antineutrino Detector 1 (AD-I)	
Cross-section	1.2×1.45 m^2
Proton density	5.5×10^{28} p/m^3
Total Target Mass	2940 kg
Fiducialized Target Mass	1480 kg
Baseline range	4.4 m
Efficiency in Fiducial Volume	42%
Position resolution	15 cm
Energy resolution	$4.5\%/\sqrt{E}$
S:B Ratio	3.1, 2.6, 1.8
Closest distance	6.9 m, 8.1 m, 9.4 m
Antineutrino Detector 2 (AD-II)	
Total Target Mass	$\sim$10 ton
Fiducialized Target Mass	$\sim$70%
Baseline range	$\sim$4 m
Efficiency in Fiducial Volume	42%
Position resolution	15 cm
Energy resolution	$4.5\%/\sqrt{E}$
S:B ratio	3.0
Closest distance	15 m