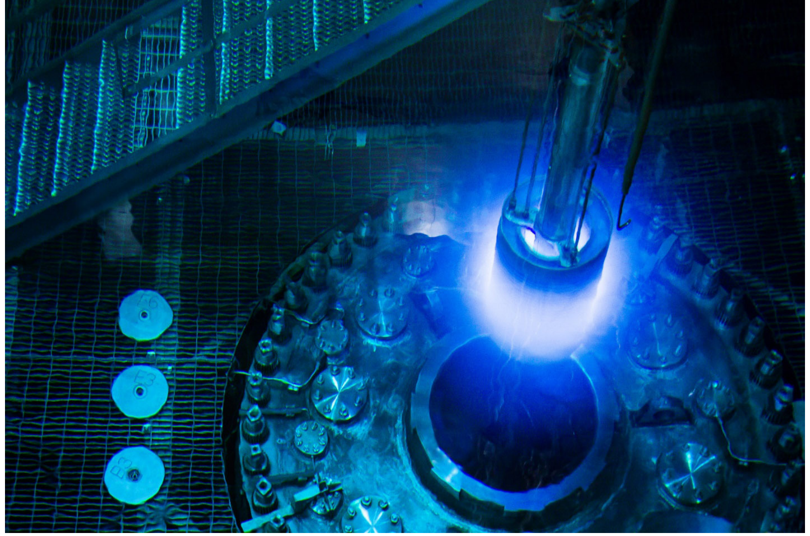
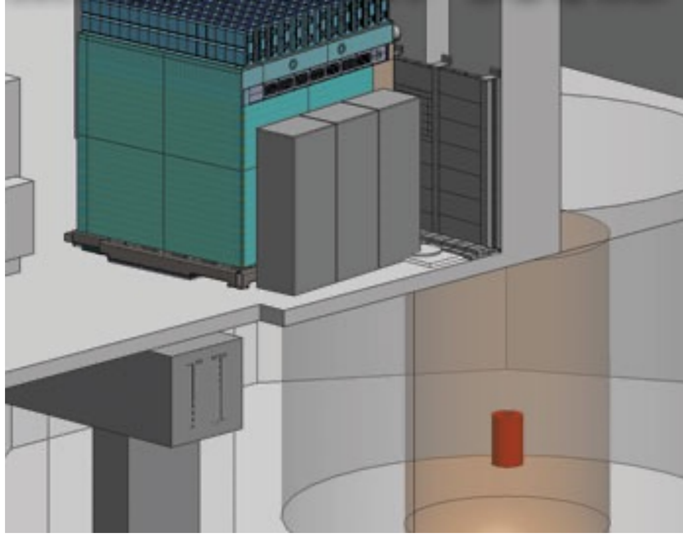




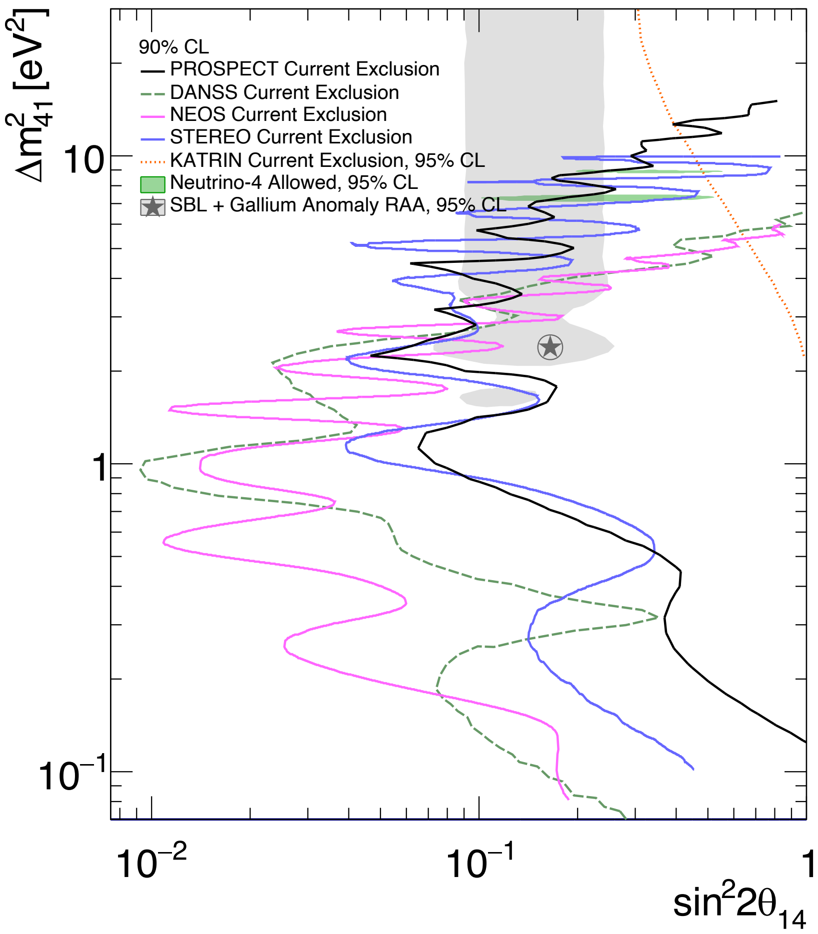
Physics Opportunities with a PROSPECT Upgrade

Rachel Carr (MIT), on behalf of the PROSPECT Collaboration | DPF | July 13, 2021

Reference: arXiv:2107.03934 (PROSPECT Collaboration, 2021)

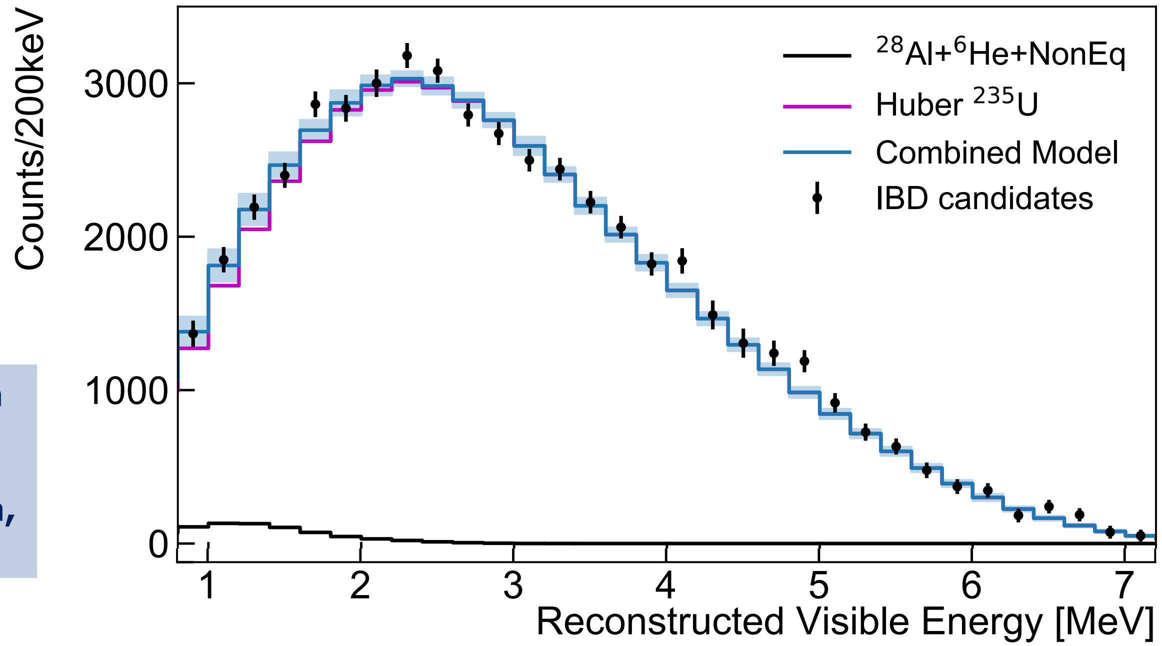
First phase of PROSPECT

Limits on eV-scale sterile neutrinos
→ progress on Reactor Antineutrino Anomaly



...in only **83 days** of data-taking → still **statistics-limited!**

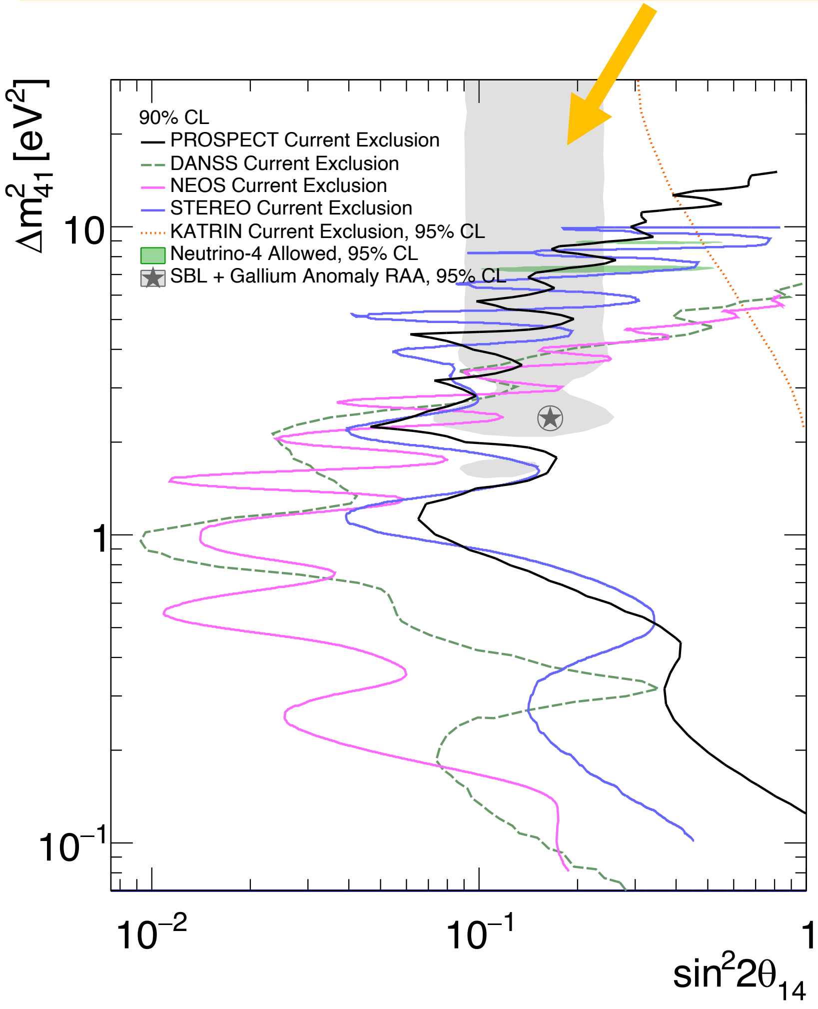
Antineutrino spectrum from ^{235}U
→ progress on understanding spectrum



See DPF talks from **P. Weatherly, D. C. Venegas-Vargas, J. Gaison, B. Foust**

More questions to answer!

Could **sterile neutrinos** be hiding in unexplored parameter space?



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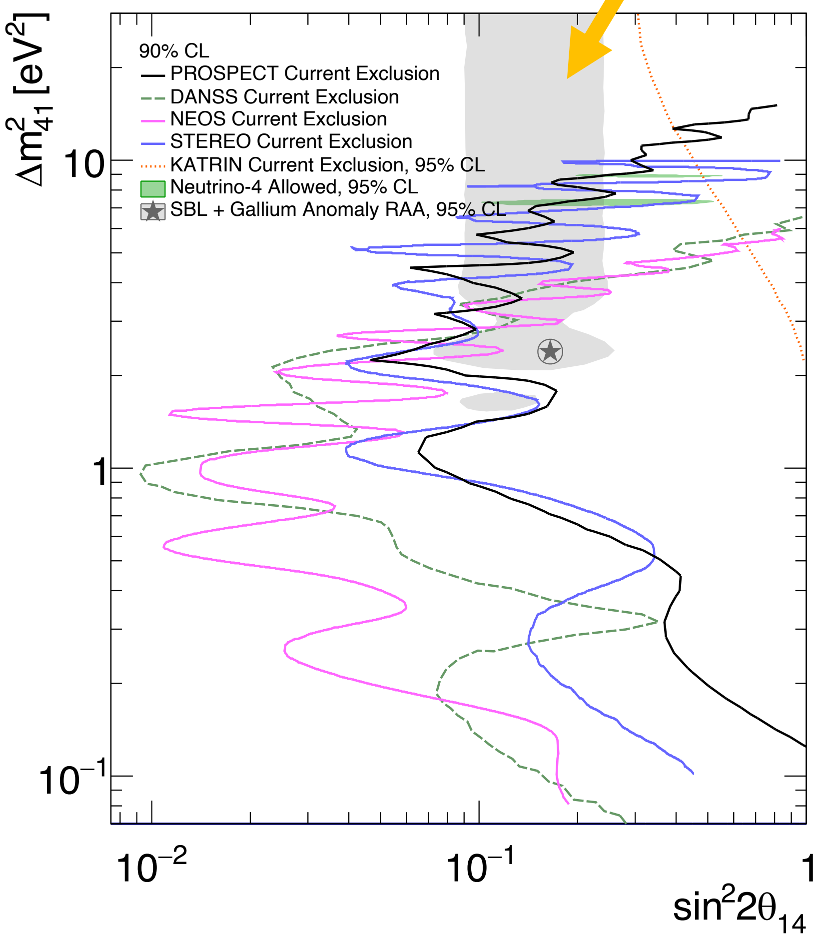
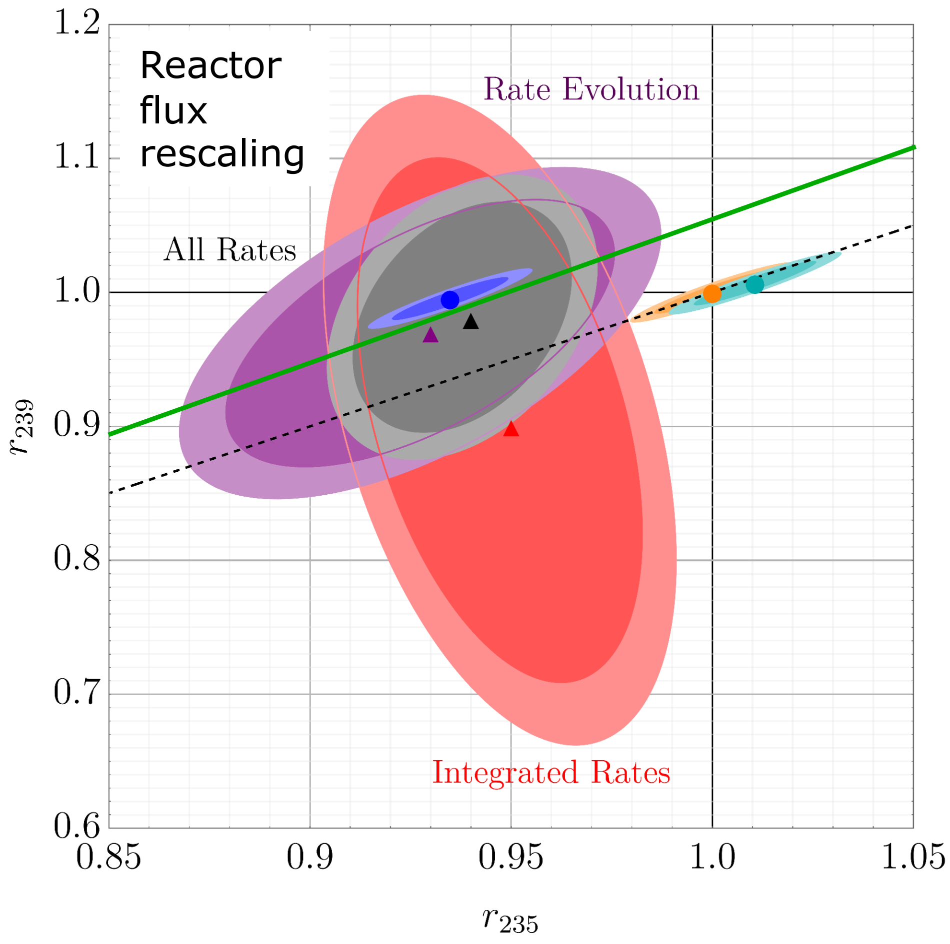


What is the full explanation of the **Reactor Antineutrino Anomaly?**



Adapted from J.M. Berryman and P. Huber, JHEP 01 167, arXiv:2005.01756 (2021)

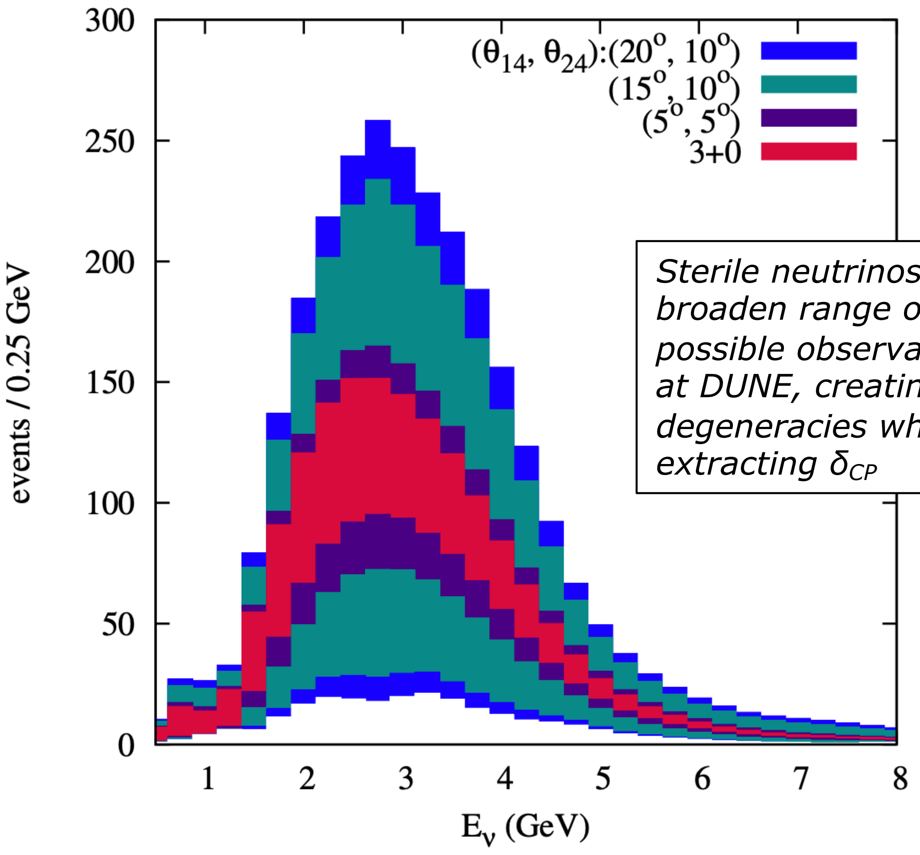
Large ellipses: 95% and 99% CL regions from global reactor antineutrino data (using fuel cycle evolution, or only total rate)

Small ellipses: ab initio and summation predictions

Green line: *new beta yield measurement by Kopeikin et al., arXiv:2103.01684 (2021)*

More questions to answer!

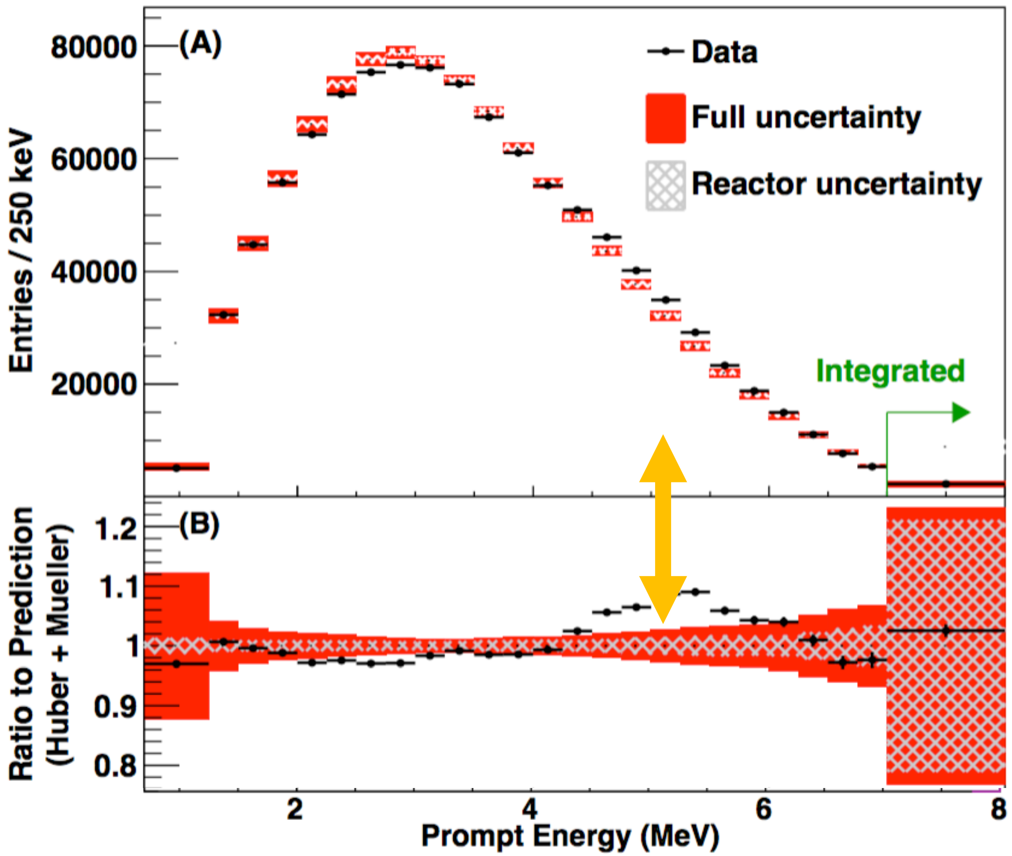
Are there sterile neutrinos that could complicate **long-baseline CPV results**?



Sterile neutrinos can broaden range of possible observations at DUNE, creating degeneracies when extracting δ_{CP}

R. Gandhi, B. Kayser, M. Masud and S. Prakash, JHEP 11 039, arXiv:1508.06275 (2015)

What explains the **reactor antineutrino spectrum shape**, including the "bump"?



Daya Bay Collaboration, Chin. Phys. C 41 013002, arXiv:1607.05378 (2017)

More questions to answer!

Could **sterile neutrinos** be hiding in unexplored parameter space?

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What explains the **reactor antineutrino spectrum shape**, including the "bump"?

PROSPECT II

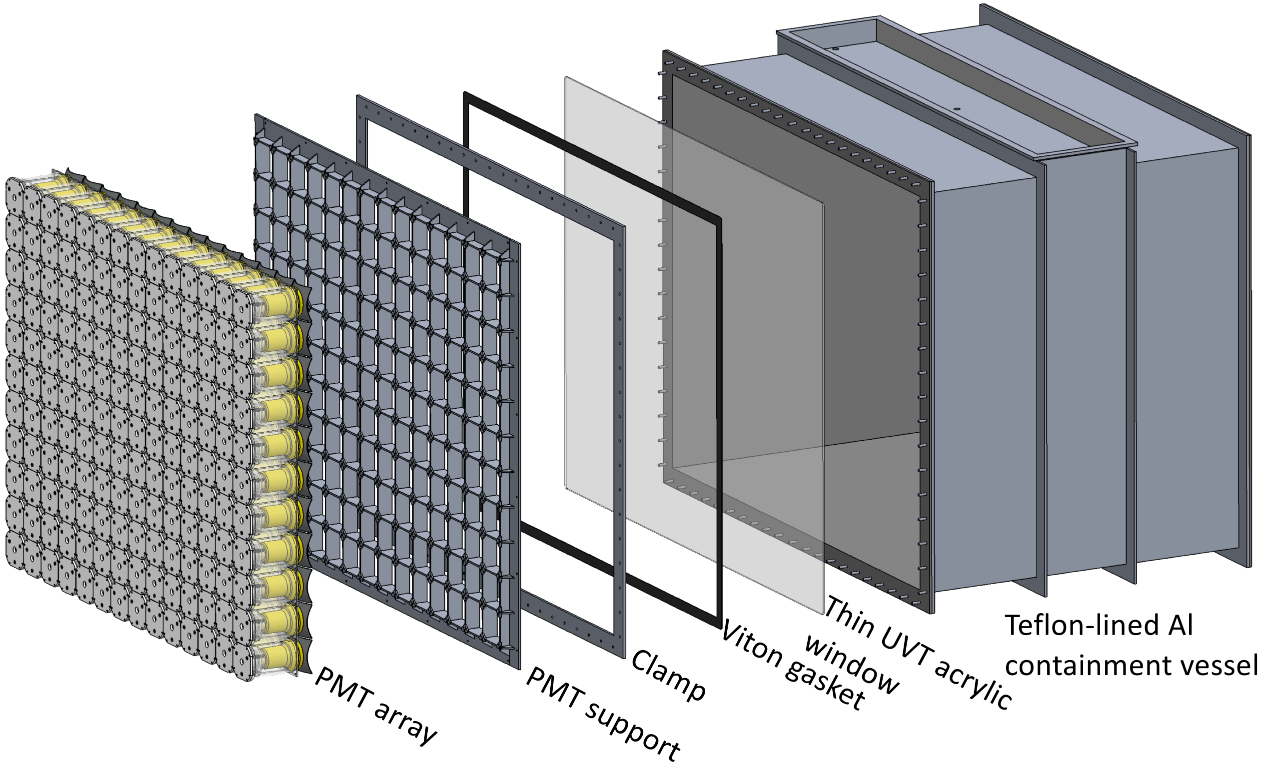
will address these questions by collecting **10x effective statistics** of PROSPECT-I at HFIR, plus potential for LEU deployment

Upgraded detector design

- Retains successful elements of PROSPECT-I: **segmented ^{6}Li-doped liquid scintillator with minimal shielding, located 7-9m from HEU core of HFIR** (+ possible LEU site)
- **Moves PMTs out of liquid scintillator volume**
- **Uses external calibration system** instead of calibration tubes inside active volume
- **Increases signal collection capacity** with 25% longer segments, 20% increased ^{6}Li fraction, longer data-taking period

PROSPECT II

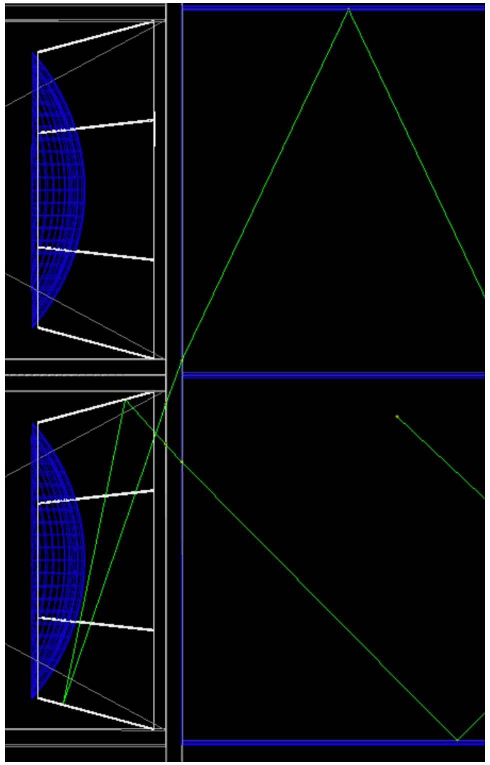
Inner detector



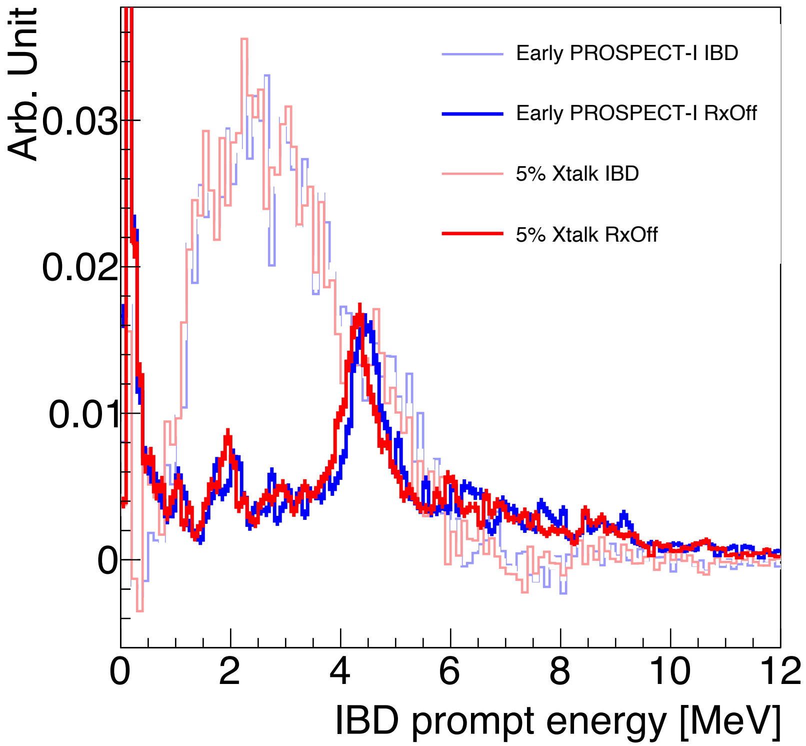
Validation of redesigned PMT interface

PROSPECT II

Redesigned interface between PMTs and scintillator volume, showing cross-talk event

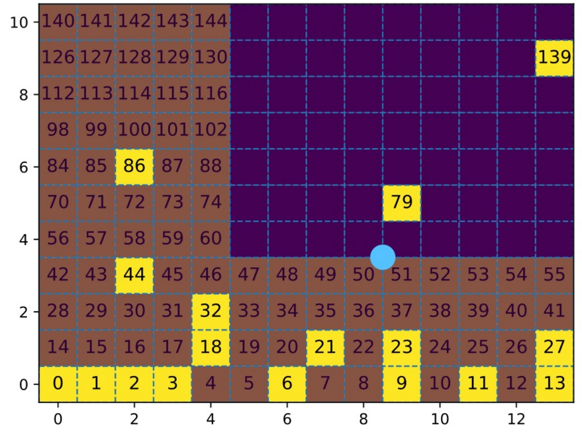


Simulation validates that **moving PMTs out of scintillator introduces minimal cross-talk between segments,** with minimal impact on signal selection.

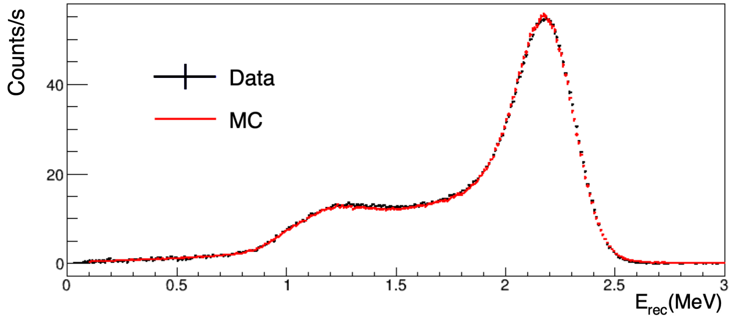


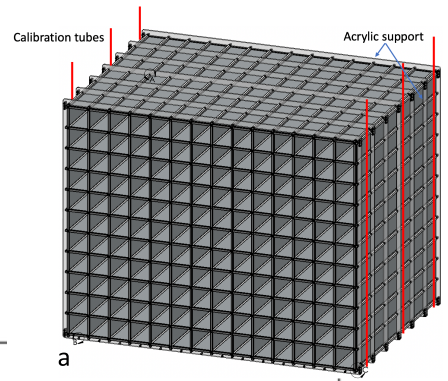
Validation of external calibration approach

Calibration data from PROSPECT-I (^{60}Co)

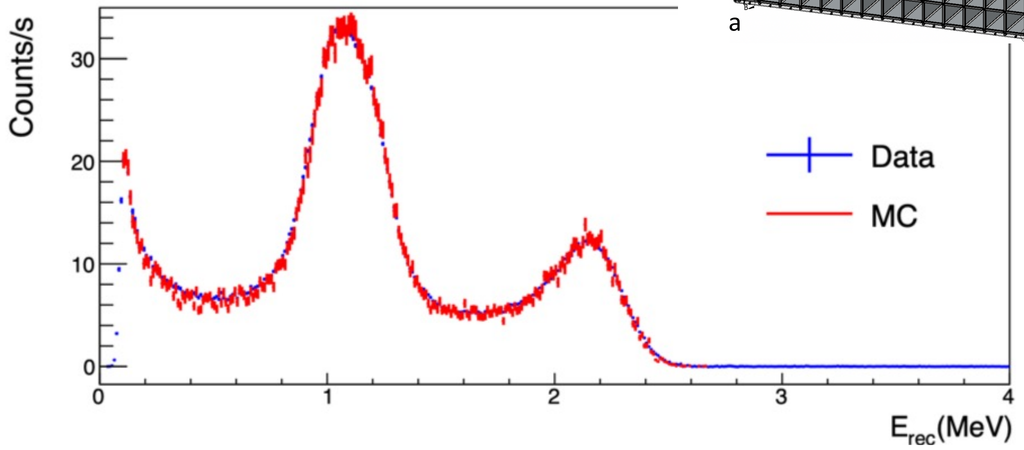


→ Analyzed as internal source for PROSPECT-I energy scale
(purple inner + brown outer segments; excluding yellow inoperative segments)





→ Analyzed to mimic external source, as in PROSPECT-II design (purple inner segments only)



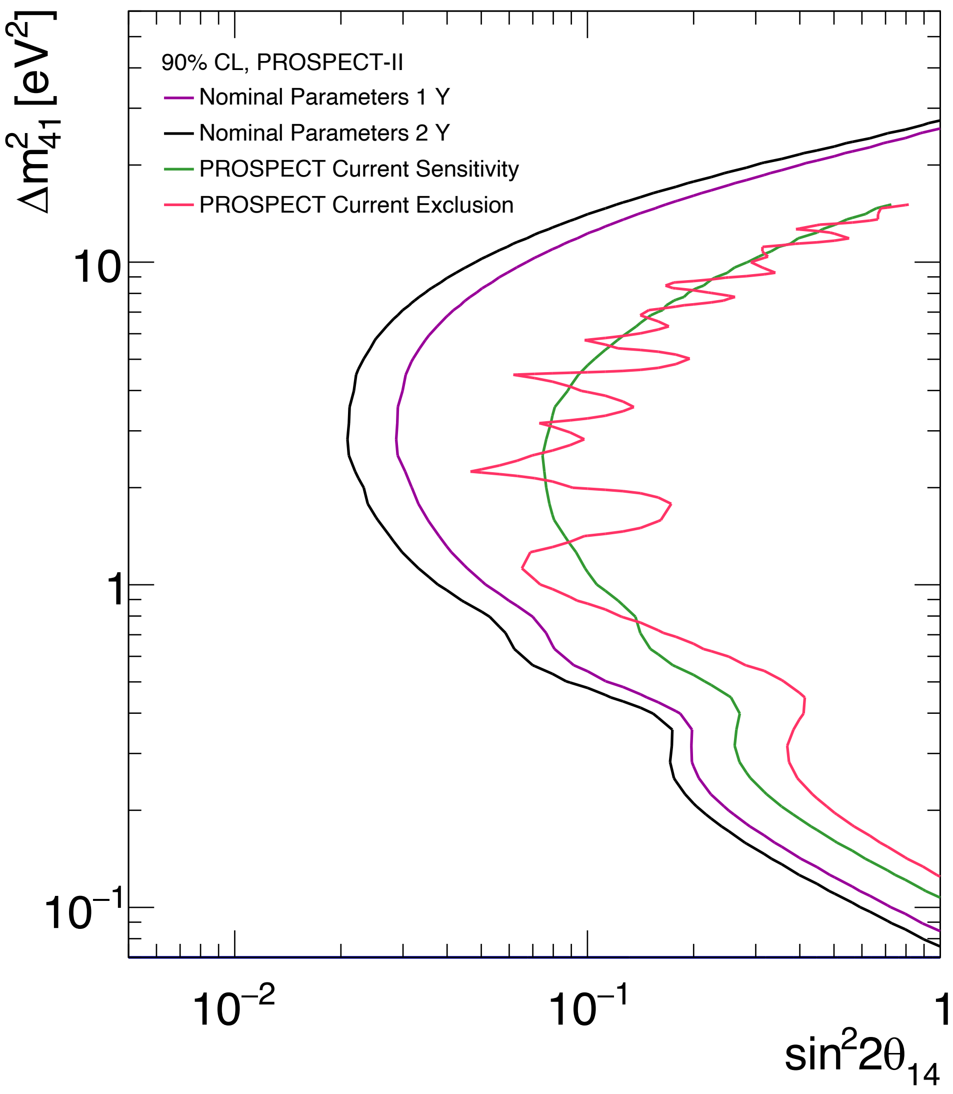
→ Externally deployed gamma sources can provide energy scale calibration for full detector.

Oscillation sensitivity

PROSPECT II

Nominal parameters:

Target mass = 4.8 tons
Average baseline = 7.9 m
Reactor-on days (for 2-year run) = 336
Reactor-off days (for 2-year run) = 360
Signal:background = 4.3
Effective signal statistics = 2.08 x 10^5



Oscillation sensitivity

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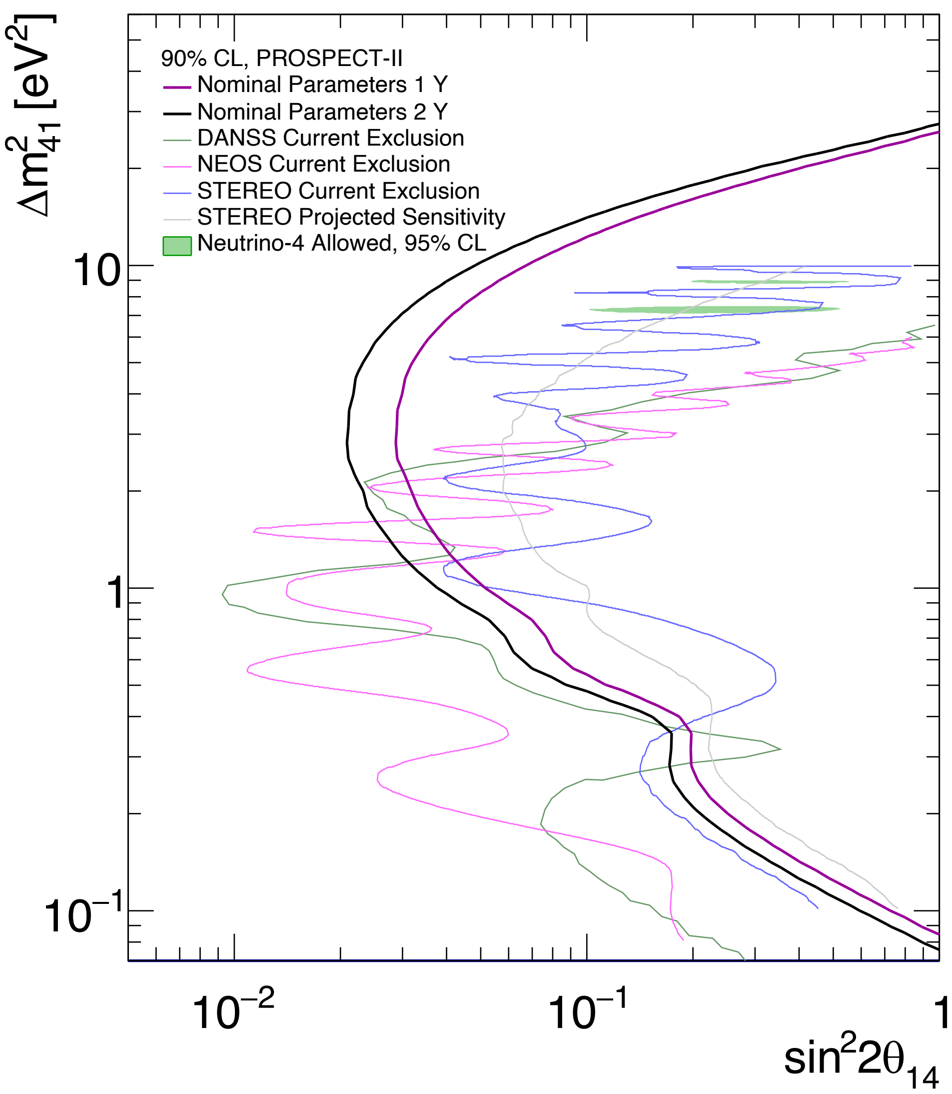
Effective signal statistics = 2.08 x 10^5

PROSPECT-II:

- Conclusively addresses Neutrino-4 signal claim within 1 year
- Covers phase space at high mass splittings beyond reach of other reactor experiments



Oscillation sensitivity

PROSPECT II

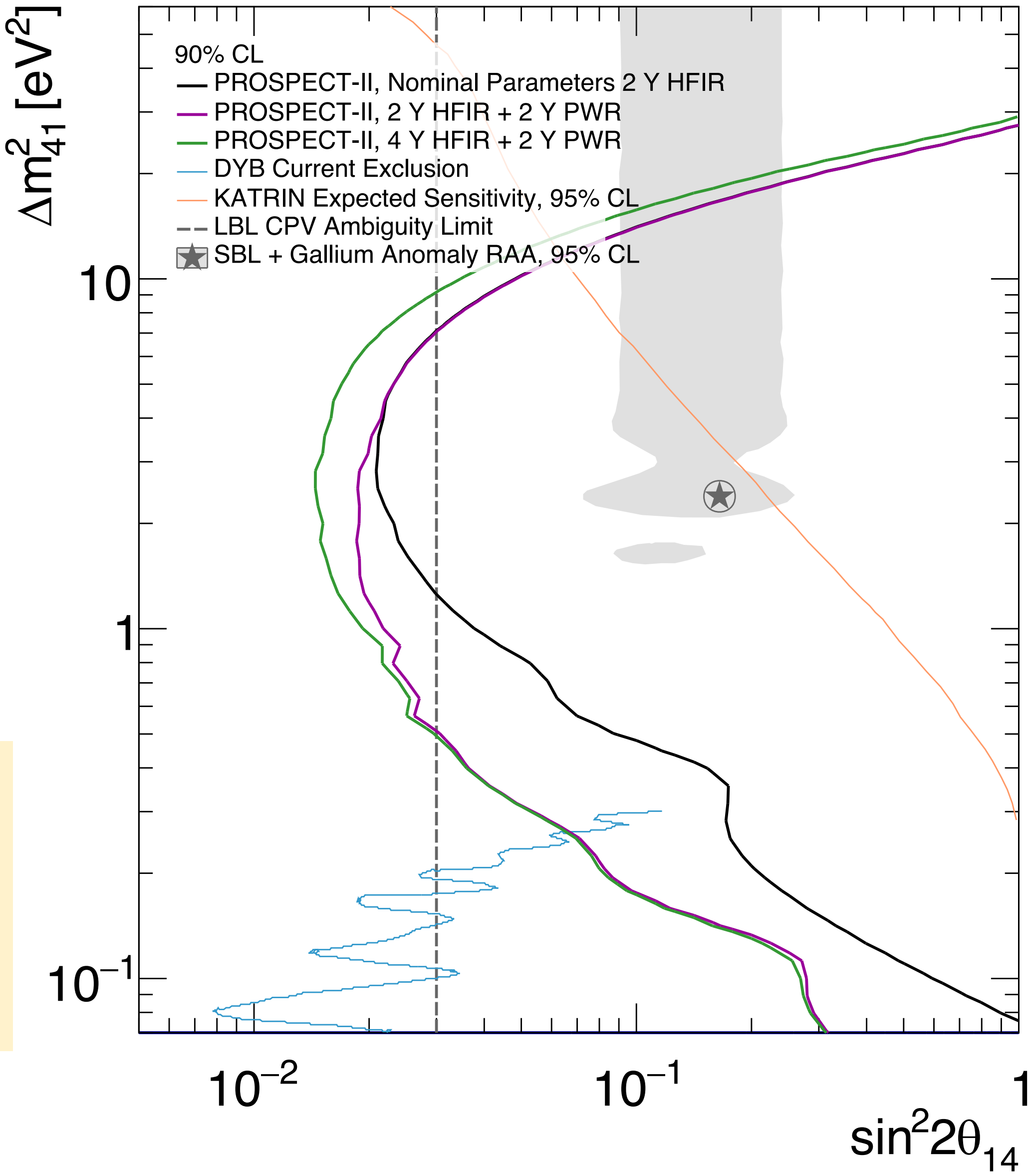
Nominal parameters at HFIR:

Target mass = 4.8 tons
Average baseline = 7.9 m
Reactor-on days (for 2-year run) = 336
Reactor-off days (for 2-year run) = 360
Signal:background = 4.3
Effective signal statistics = 2.08 x 10^5

(Slide 15: parameters for possible PWR deployment)

PROSPECT-II:

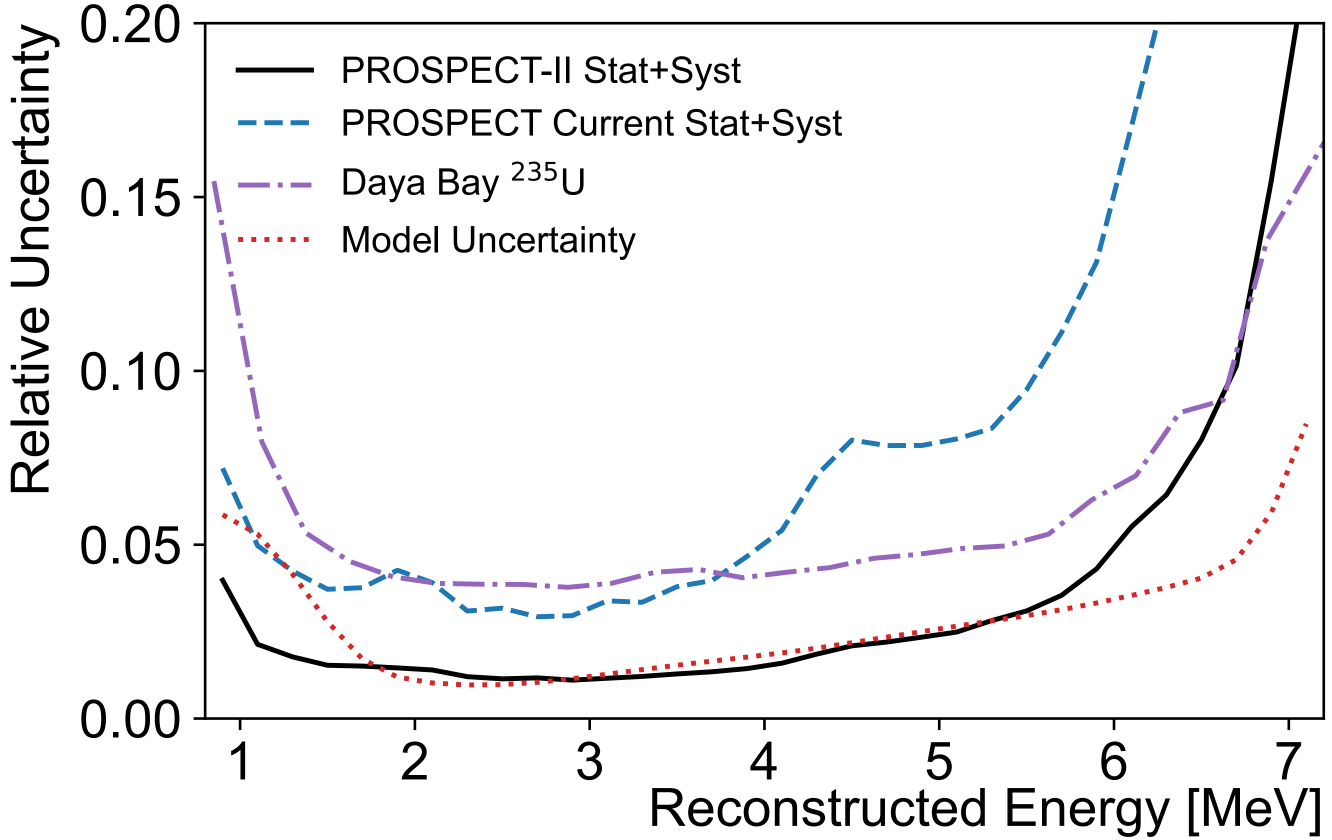
- Together with future KATRIN data, covers full "RAA phase space"
- Reaches $\sin^2 2\theta_{14}=0.03$ benchmark for CPV interpretation in 0.5-10 eV^2 range



Spectrum & flux sensitivity

PROSPECT II

- Increased precision on ^{235}U spectrum shape →
- ^{235}U flux measurement, with anticipated precision of ~2.5%



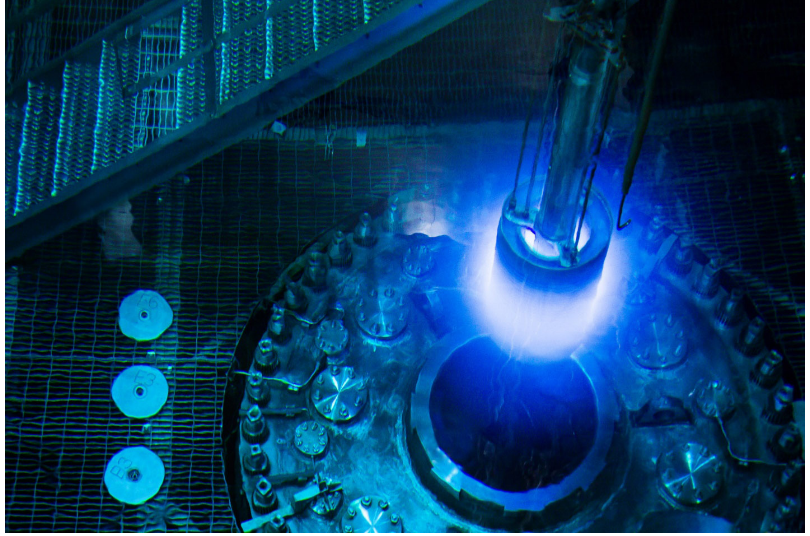
PROSPECT-II:
- Pushes precision on ^{235}U spectrum shape measurement below claimed model uncertainties
- Provides a new ^{235}U flux measurement

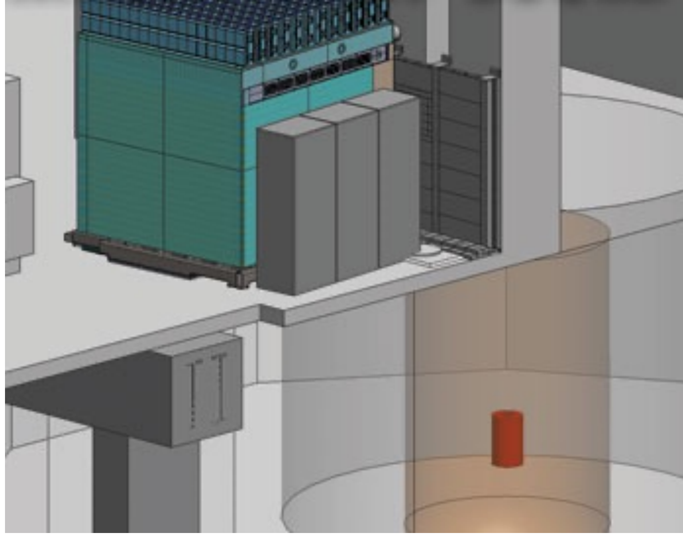
Conclusions

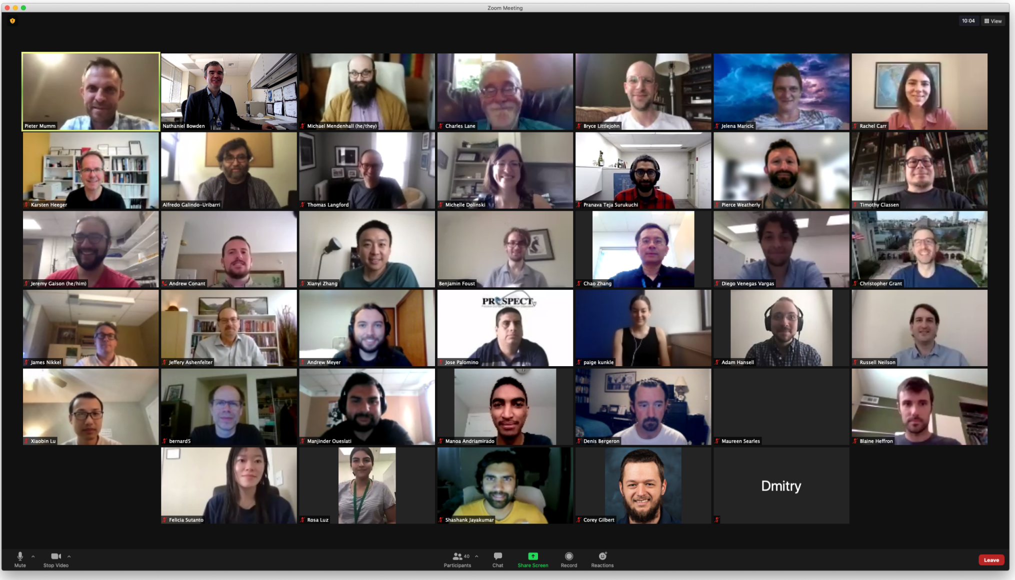
PROSPECT II

An evolutionary upgrade of the PROSPECT detector, in a 2-year run at HFIR, will:

- Search for mixing between active and sterile neutrinos in the mass-splitting range of 1-20 eV^2, covering a region beyond the reach of other reactor experiments;
- Extend sensitivity to the sterile mixing angle $\sin^2 2\theta_{14}$ below 0.03 in the ~1-10 eV^2 mass splitting range, to inform the interpretation of long-baseline CP violation experiments;
- Reduce ^{235}U spectrum uncertainties below 5%, uniquely constraining reactor predictions;
- Perform an absolute measurement of the ^{235}U neutrino yield and improve the robustness of the global yield picture for the three dominant fission isotopes ^{235}U, ^{239}Pu , and ^{238}U;
- Enable a future program with highly correlated detector systematics at an LEU reactor to strengthen oscillation, spectrum, and flux measurements.







PROSPECT

New this summer from PROSPECT:

PROSPECT-II Physics Opportunities
arXiv:2107.03934

Joint Measurement of the ^{235}U Antineutrino Spectrum by Prospect and Stereo
arXiv:2107.03371

Joint Determination of Reactor Antineutrino Spectra from ^{235}U and ^{239}Pu Fission by Daya Bay and PROSPECT
arXiv:2106.12251

Parameters for sensitivity projections

Parameter		P1	P2 at HFIR	P2 at LEU
Reactor	Power (MW_{th})	85		3000
	Cylinder Size ($d \times h$, m^2)	0.4×0.5		3×3
	Fuel	HEU		LEU
	Cycle Length	24 d		1.5 y
Detector	Segmentation	11×14	11×14	
	Segment Area (cm^2)	14.5×14.5	14.5×14.5	
	Segment Length (m)	1.17	1.45	
	Target Mass (ton)	~4.0	4.8	
	Light collection (PE/MeV)	~380	500	
	Detection Efficiency	~40%	40%	
Exposure	Average Baseline (m)	7.9	7.9	25
	Reactor-On Days (d)	105	336	548
	Reactor-Off Days (d)	78	360	61
	Signal:Background	1.4	4.3	19.3
	IBD Statistics (N_{IBD})	50560	3.74×10^5	2.72×10^6
	Effective Statistics (N_{eff})	15195	2.08×10^5	1.79×10^6

P-1: Parameters realized in PROSPECT-I, as analyzed in arXiv:2006.11210

P2 at HFIR: Parameters anticipated for the PROSPECT-II run at the High Flux Isotope Reactor (HFIR), Oak Ridge National Laboratory

P2 at LEU: Parameters estimated for a PROSPECT-II deployment at a commercial pressured water reactor (PWR) using low-enriched uranium (LEU) fuel

Table from arXiv:2107.03934