



ROAD TO PROSPECT-II

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on behalf of the  Collaboration

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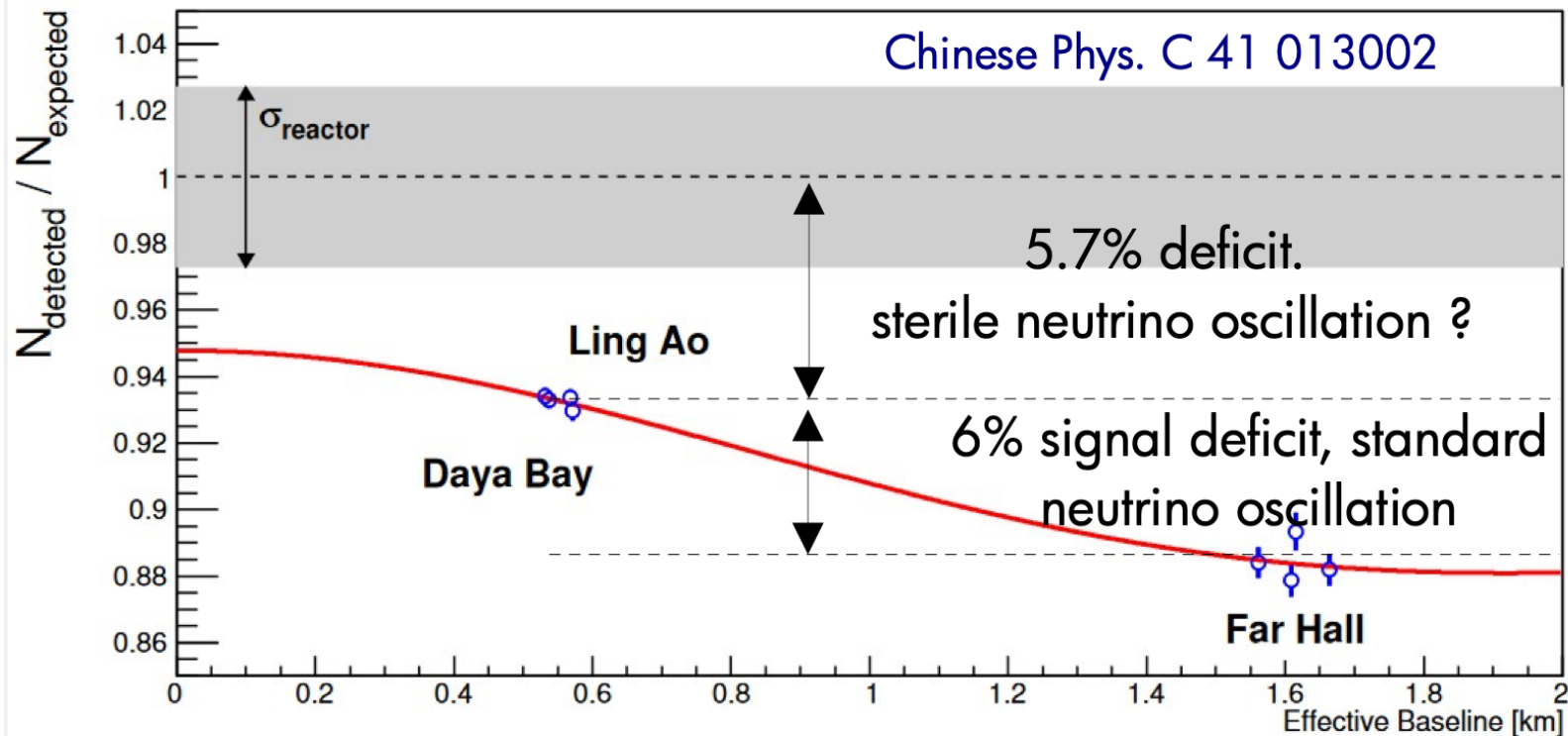


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PROSPECT Motivation: Reactor Antineutrino Anomaly (RAA)



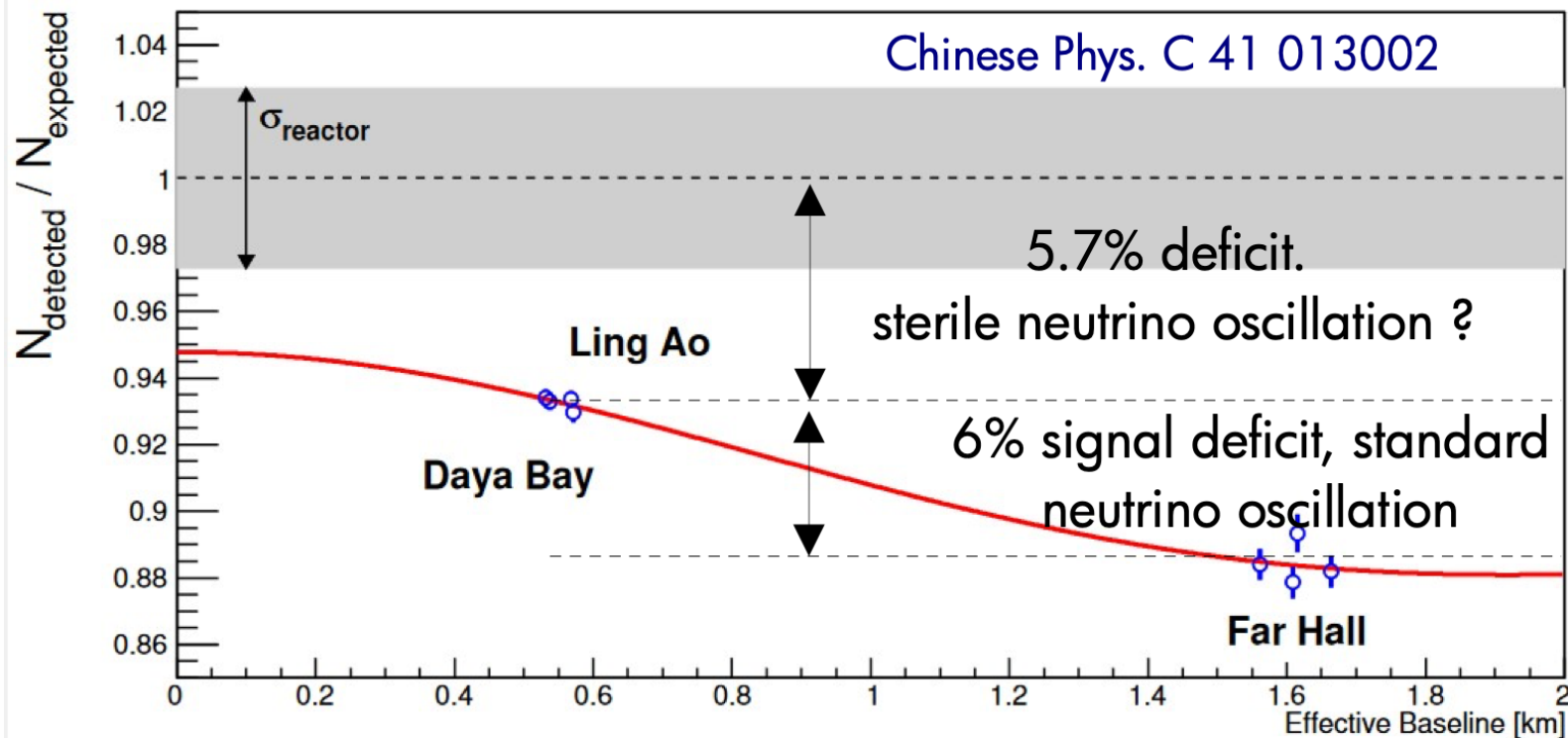
- Antineutrino flux predictions differs from precision measurements



PROSPECT Motivation: Reactor Antineutrino Anomaly (RAA)



- Antineutrino flux predictions differs from precision measurements
- Possible explanations:
 - Flux misprediction
 - Oscillation of active antineutrinos into sterile states

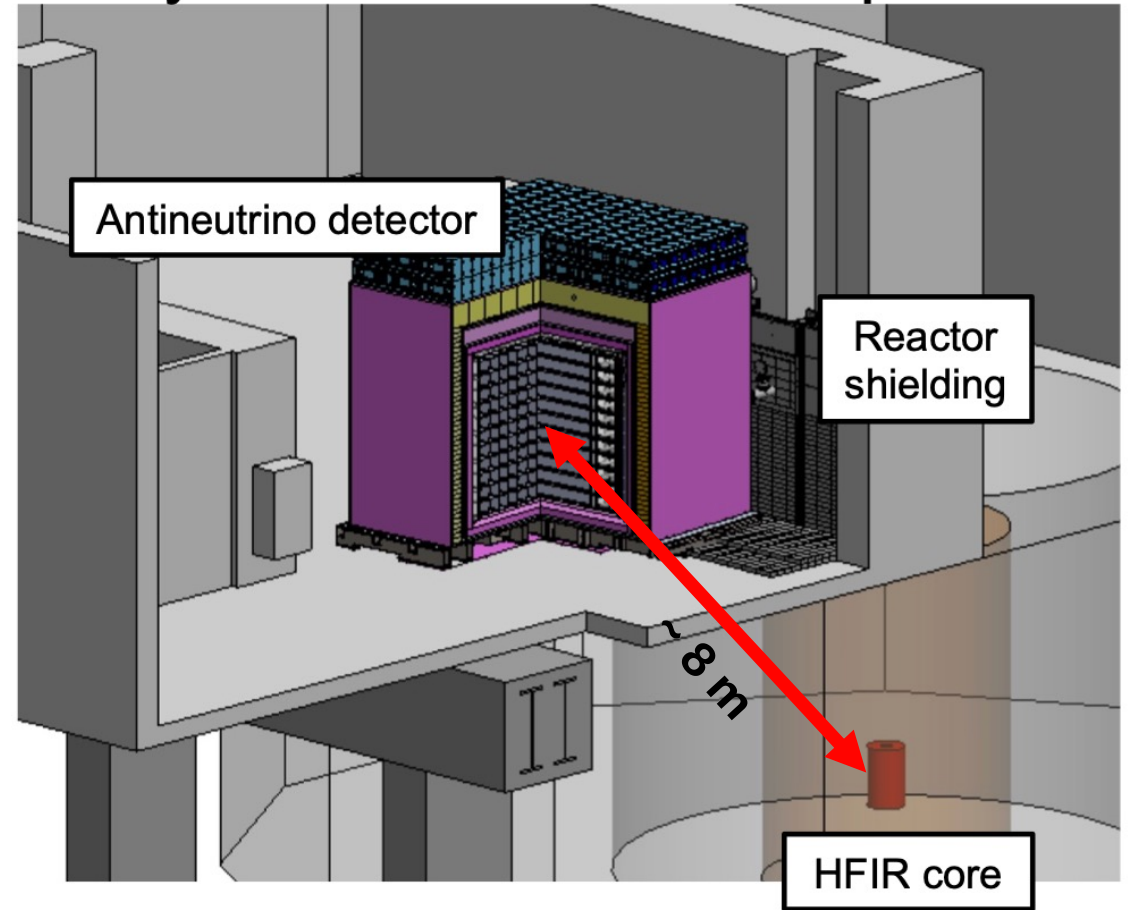


PROSPECT-I Design



- A 4-ton, segmented detector designed to search for sterile neutrino oscillation and ^{235}U spectrum measurement.

Layout of PROSPECT experiment

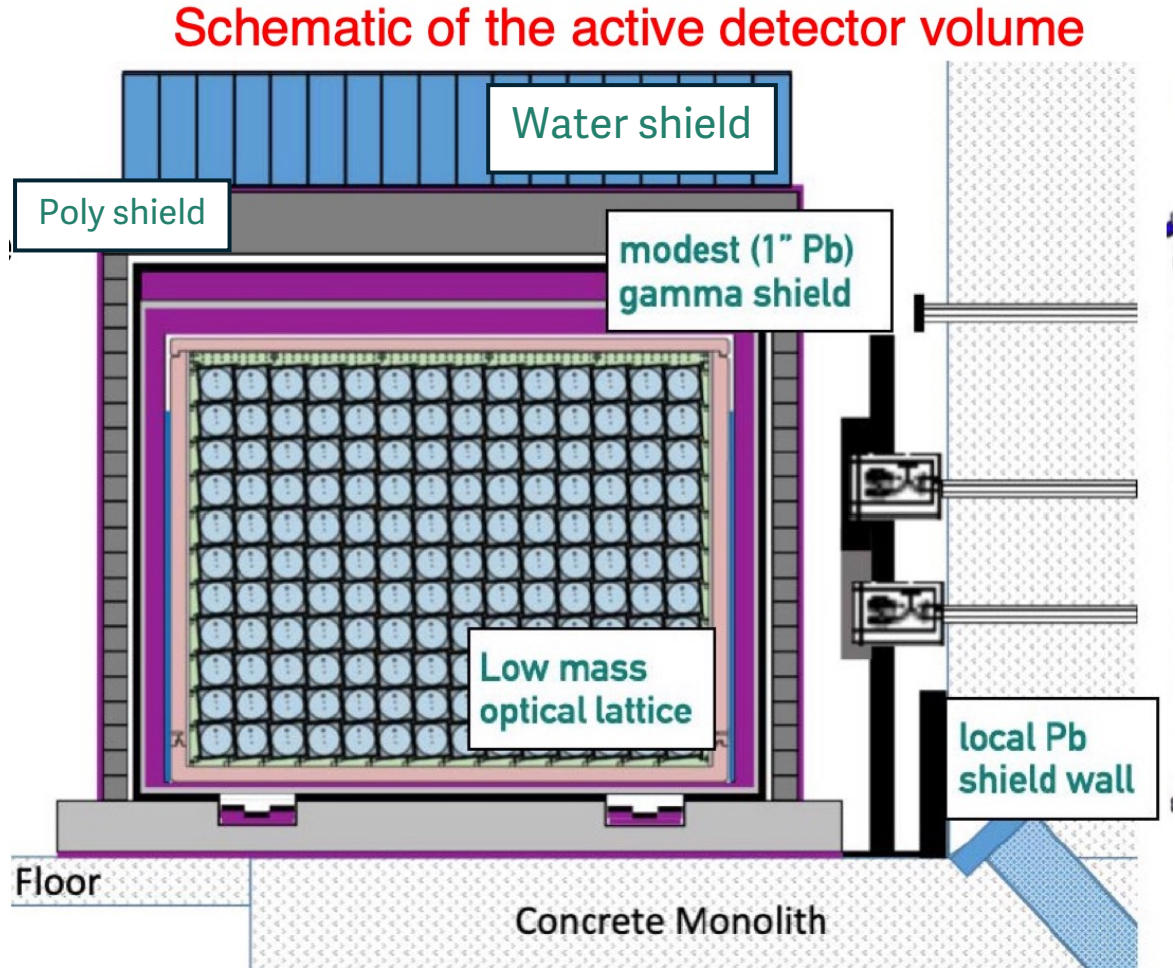


[NIMA 922 \(2018\) 287](#)

PROSPECT-I Design



- A 4-ton, segmented detector designed to search for sterile neutrino oscillation and ^{235}U spectrum measurement.
- Reactor on data from Mar - Oct 2018
- 6.7 – 9.2m from HFIR

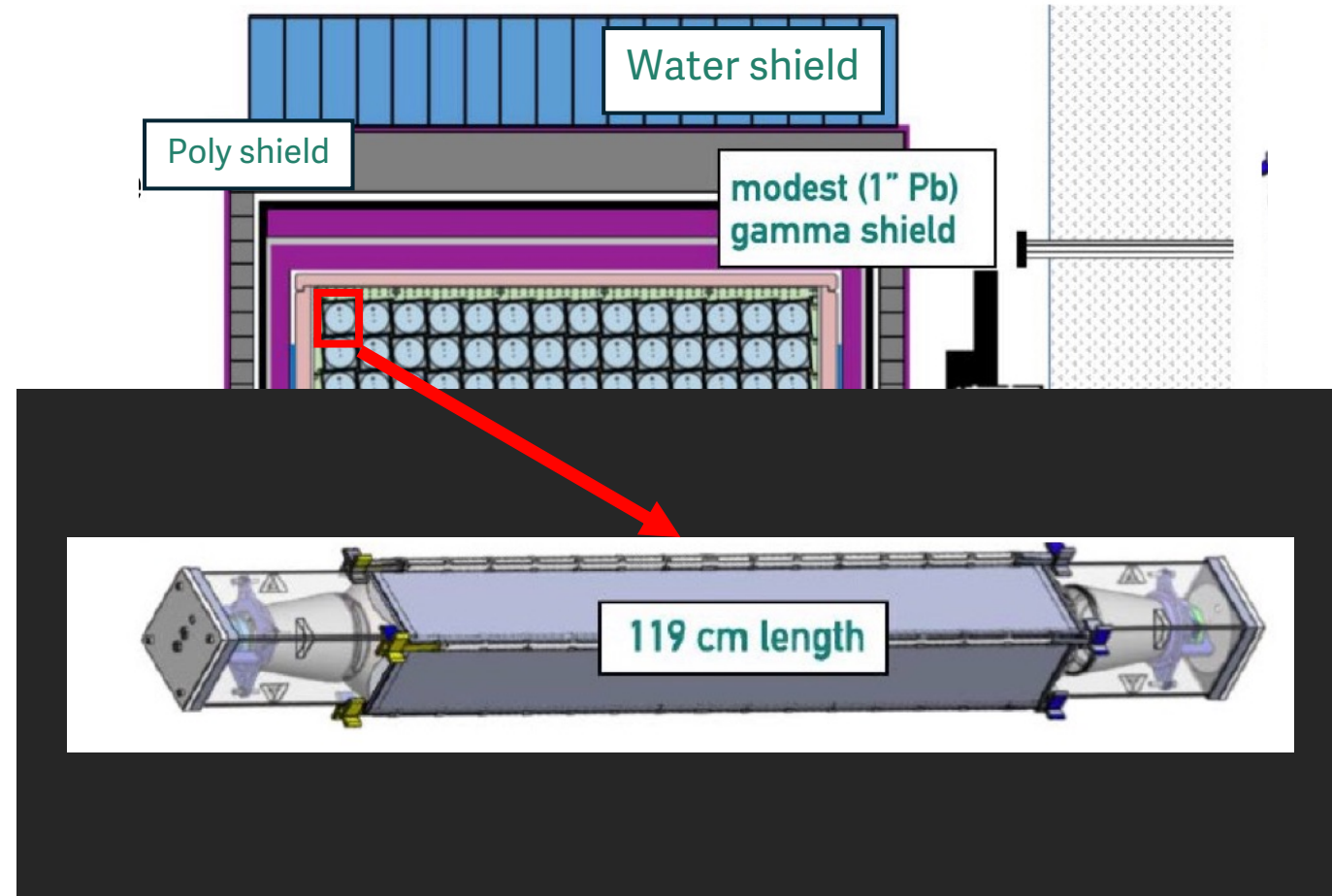


PROSPECT-I Design

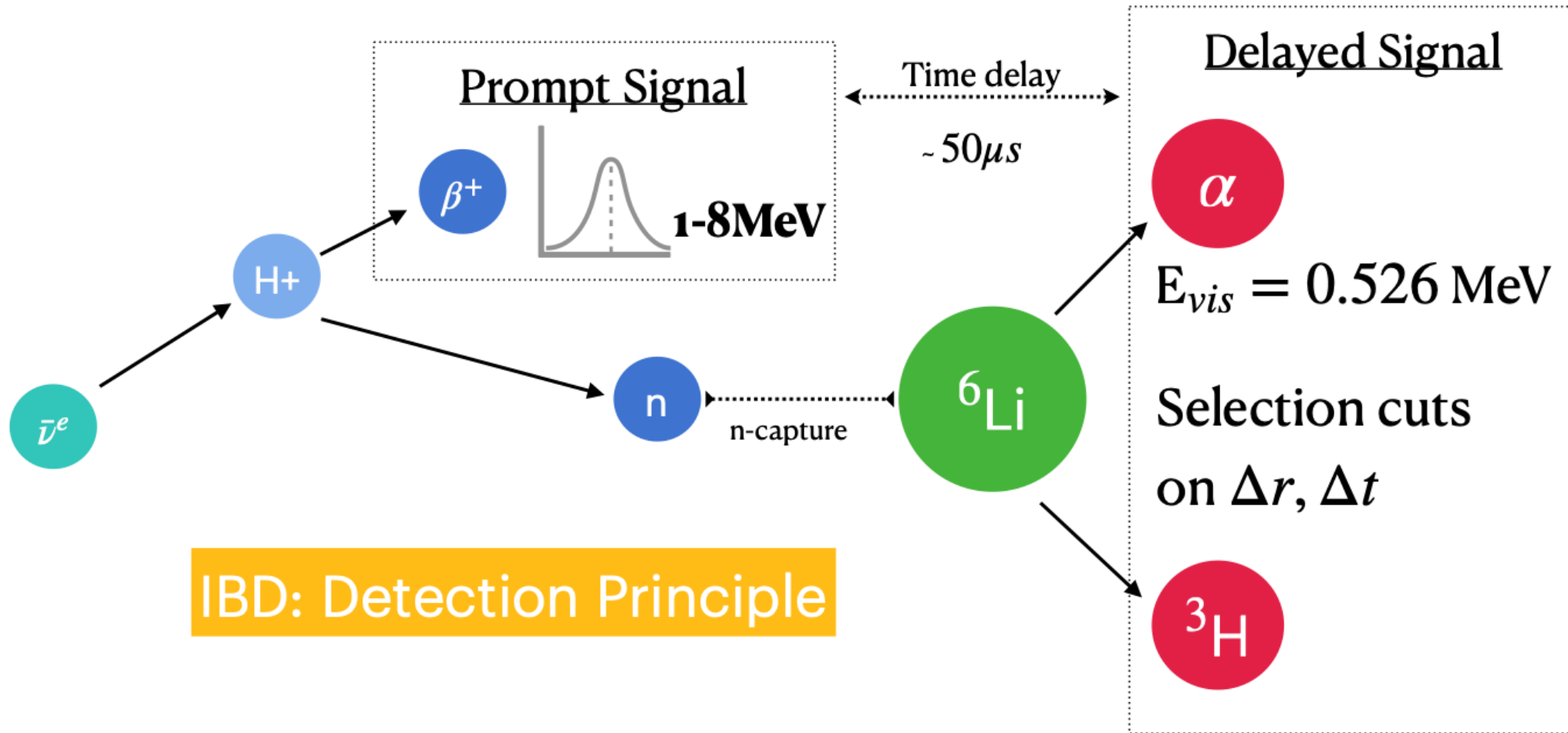


- A 4-ton, segmented detector designed to search for sterile neutrino oscillation and ^{235}U spectrum measurement.
- Reactor on data from Mar - Oct 2018
- 6.7 – 9.2m from HFIR
- 154 segments - 14 x 11 grid
- Each segment:
 - 2 PMTs
 - Filled with ^6Li -doped LS (LiLS)
 - Pulse Shape Discriminator

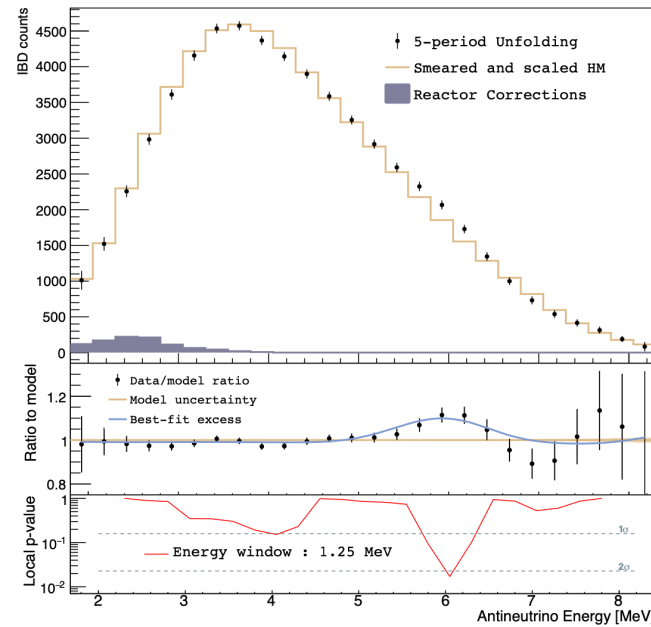
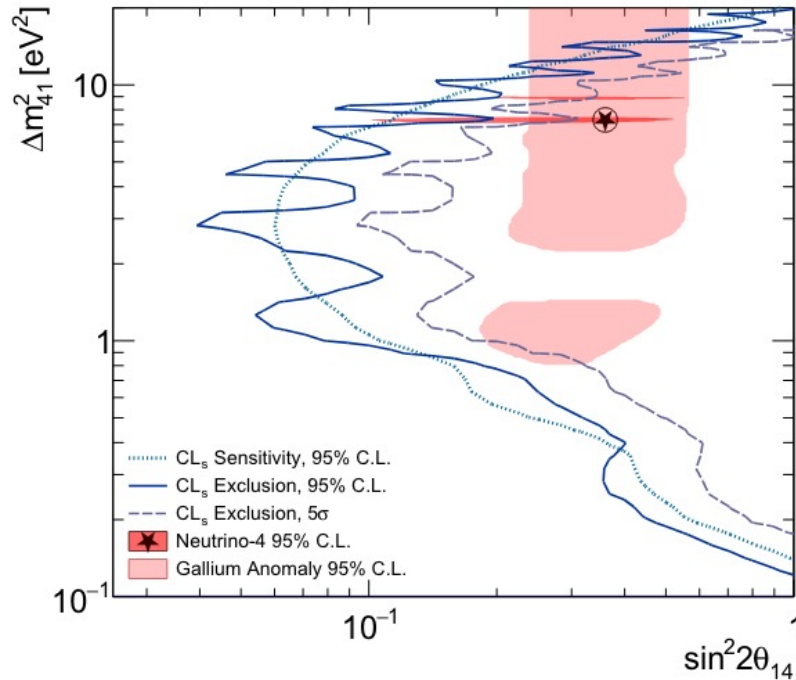
Schematic of the active detector volume



PROSPECT-I Design: IBD Detection Principle



PROSPECT-I Physics Results



- Limits on Sub-GeV Dark Matter from the PROSPECT Reactor Antineutrino Experiment – [arXiv:2104.11219](https://arxiv.org/abs/2104.11219)
- Joint analysis:
 - (2022) Daya Bay – [Phys. Rev. Lett. **128**, 081801](https://arxiv.org/abs/2104.11219)
 - (2022) STEREO – [Phys. Rev. Lett. **128**, 081802](https://arxiv.org/abs/2104.11219)
- Final Oscillation Analysis – [arXiv:2406.10408](https://arxiv.org/abs/2406.10408)
- Neutrino Directionality – [arXiv:2406.08359](https://arxiv.org/abs/2406.08359)
- Final Spectrum analysis – [Phys. Rev. Lett. **131**, 021802](https://arxiv.org/abs/2104.11219)
- Coming out soon:
 - Absolute flux measurement
 - Joint-Search for Light Sterile Neutrino Oscillations by PROSPECT, STEREO, and Daya Bay

Great signal to background ratio (4:1) and energy resolution.

Oscillation analysis: Neutrino-4 best-fit point is ruled out at $>5\sigma$ CL

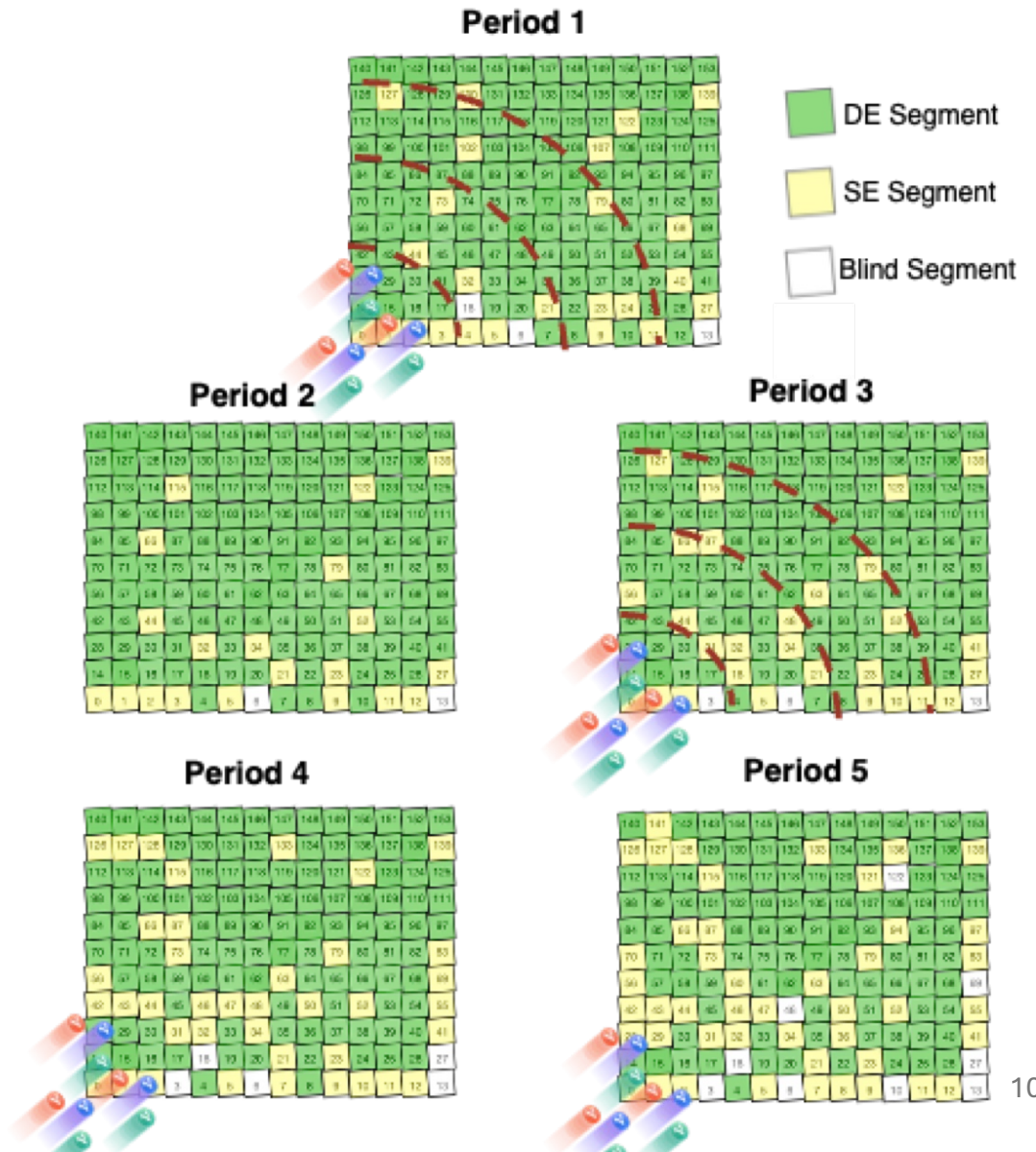
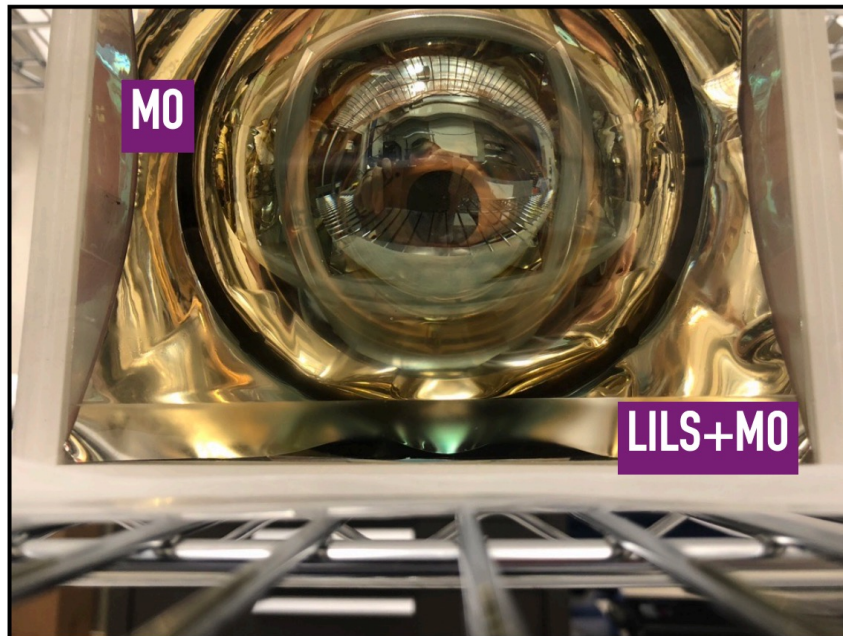
Spectrum measurement: Observation of excess at ~ 5 MeV

From PROSPECT-I to PROSPECT-II



• PROSPECT-I

- LiLS ingress into PMT housing caused **PMT degradation**
- **LiLS degradation** caused effective attenuation length and light collection degradation



From PROSPECT-I to PROSPECT-II



- LiLS ingress into PMT housing caused **PMT degradation**

- **LiLS degradation**

• PROSPECT-II

- Maintain PROSPECT-I **performance**

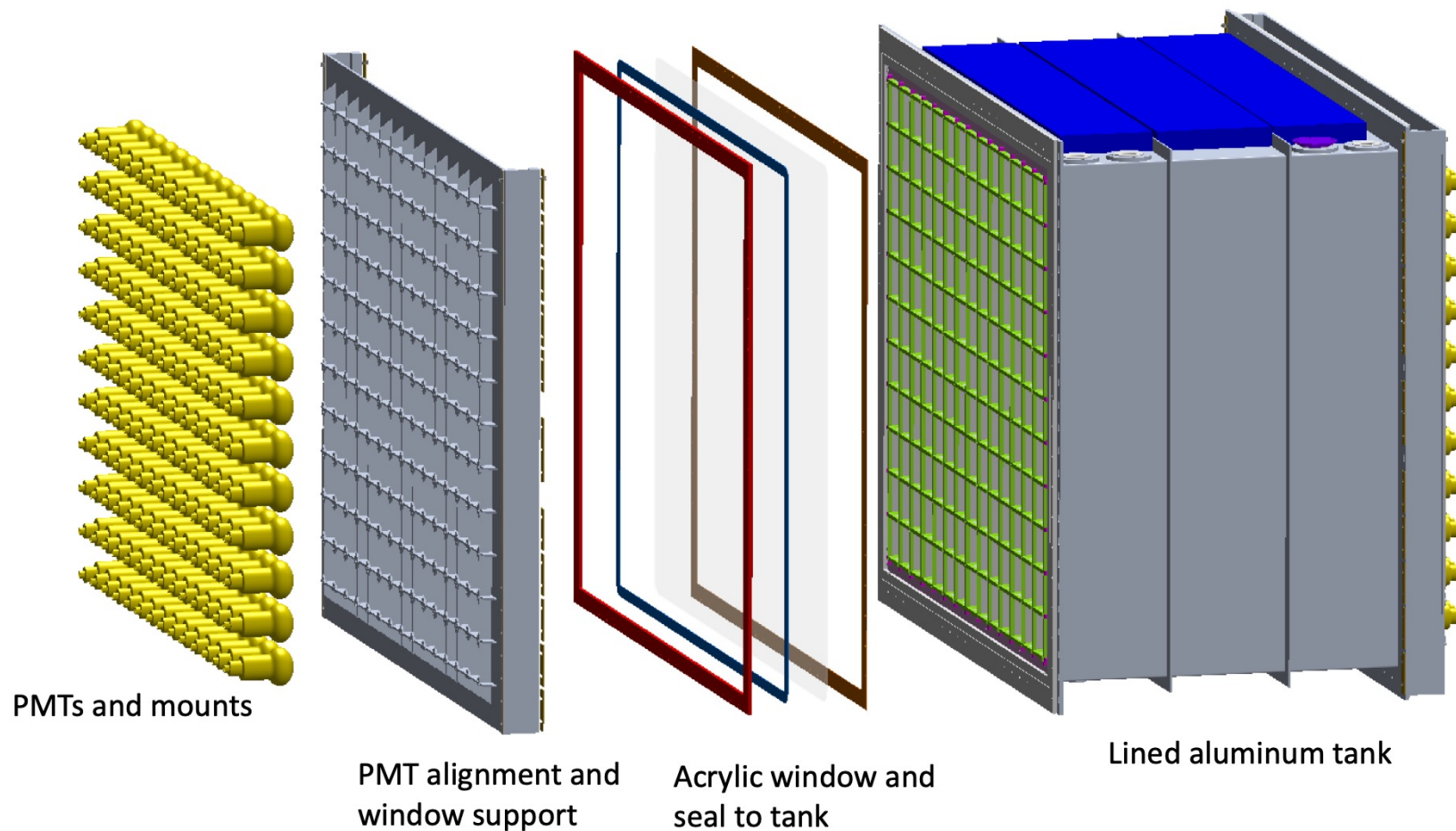
- Improve **stability**

- Remove PMTs from active volume

- Minimize LiLS contact with other materials

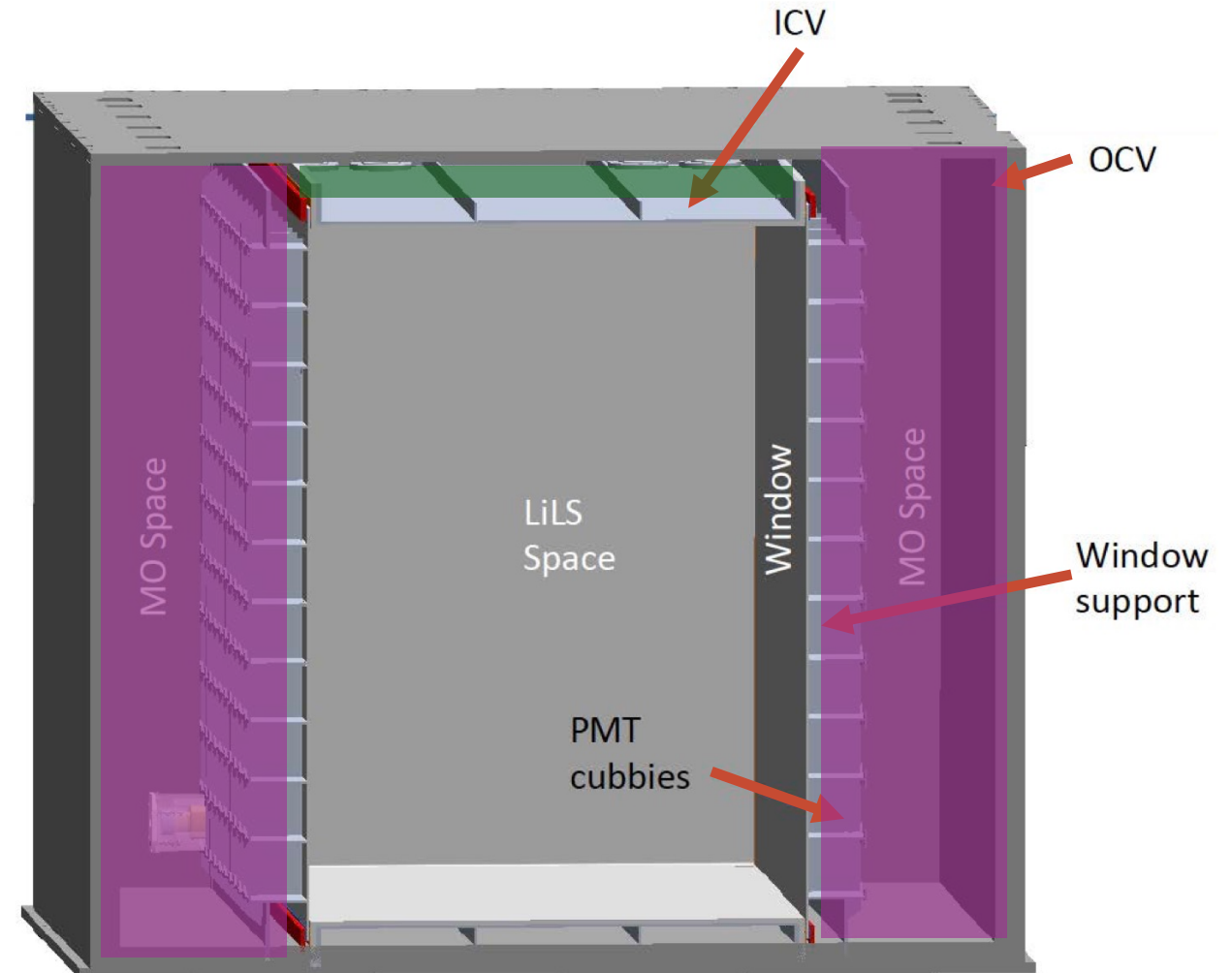
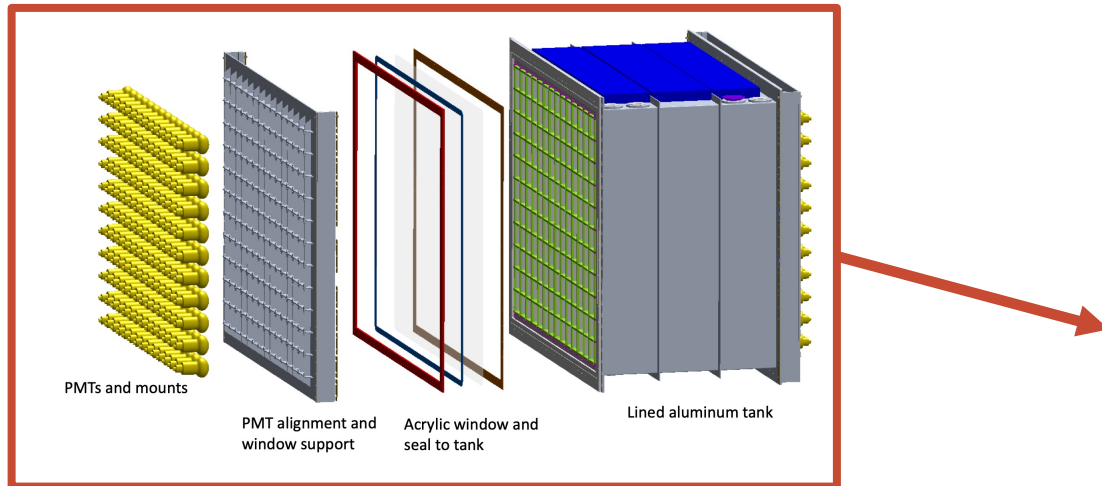
- Optimize LiLS isolation

PROSPECT-II Detector Design



Slimmer design → allows 20% more active volume, keeping the vessel size the same

PROSPECT-II detector design



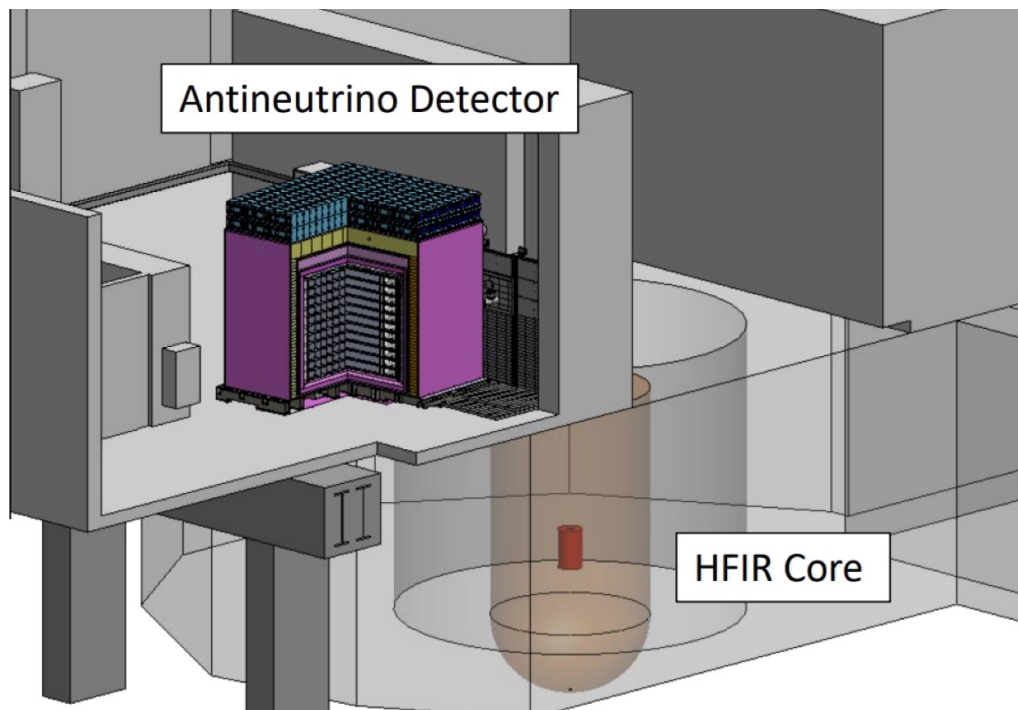
Mineral oil between ICV and OCV provides optical coupling and shielding

LiLS overflow system

Active cooling

Cabling out of LiLS volume

PROSPECT-II Deployment



HFIR remains as our target operation site for HEU measurements

Aiming for 14 cycles recorded over a 2-3 year run period

Detector is **movable → LEU site?**

Benefits described at [arXiv: 2301.13123](https://arxiv.org/abs/2301.13123)

Oak Ridge National Laboratory Neutron Production Overview

FY24												
	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24
SNS	FY24A									PPU 2MW Target Ramp to 1.7 MW @ 1.3 GeV for 1250 hr KPP		
HFIR	EOC 503	504	EOC 504	505	EOC 505	506	EOC 506	507	EOC 507	508	EOC 508	509

FY25													
	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	
SNS	FY25A			1.7 MW Operations						FY25B		1.8 MW Operations	
HFIR	EOC 509	510	EOC 510			511	EOC 511	512	EOC 512	513	EOC 513	514	EOC 514

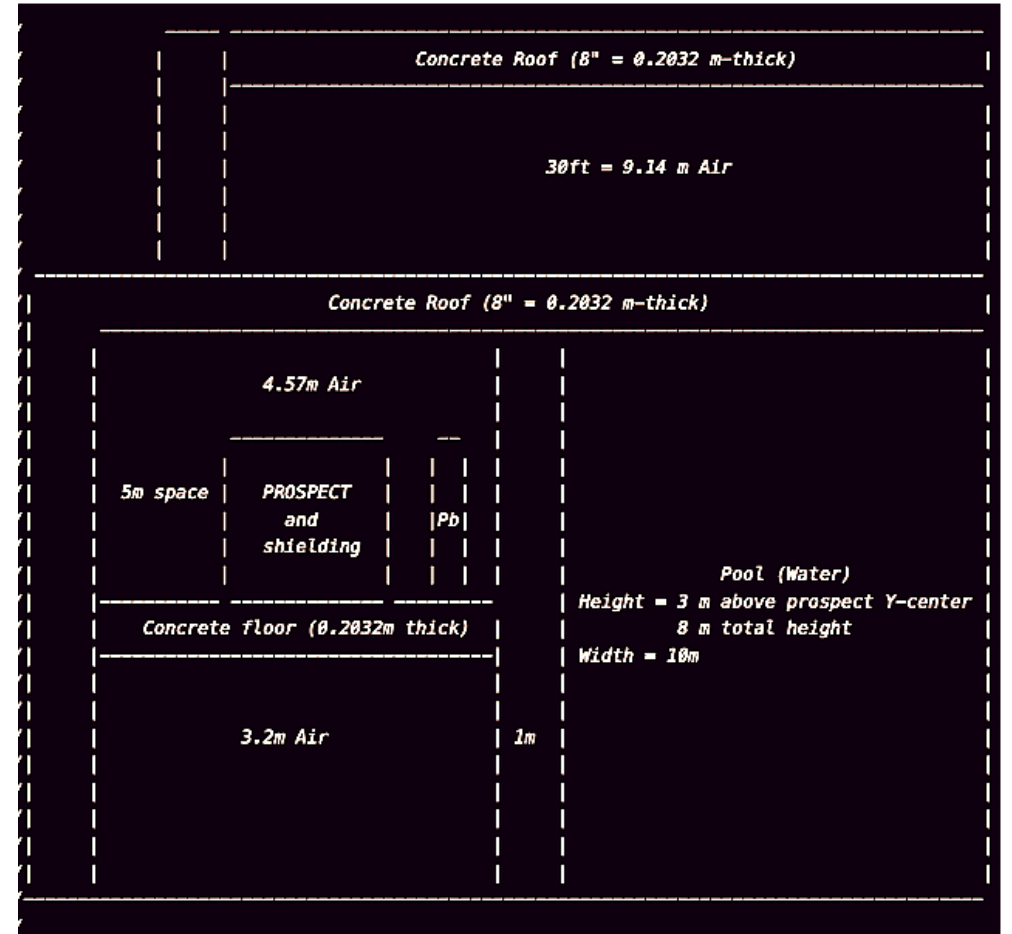
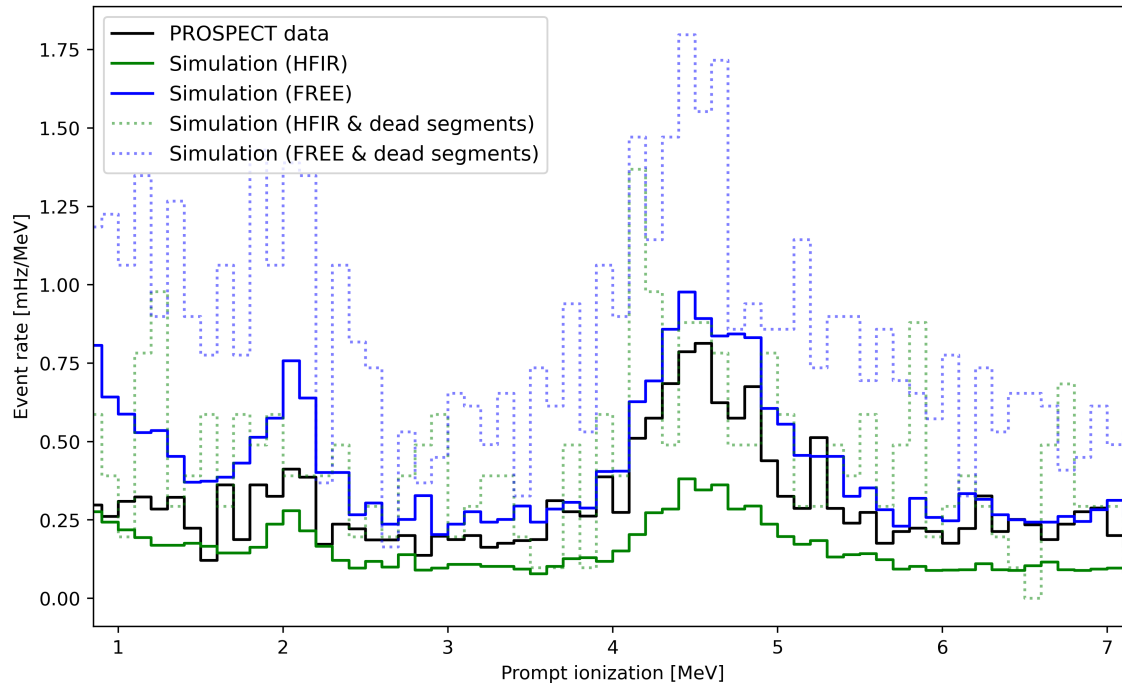
FY26														
	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26	Apr-26	May-26	Jun-26	Jul-26	Aug-26	Sep-26		
SNS	1.8 MW Operations		FY26A			1.9 MW Operations				FY26B		1.9 MW Operations		
HFIR	EOC 514	515	EOC 515	516	EOC 516	517	EOC 517	518	EOC 518		519	EOC 519	520	EOC 520

FY27													
	Oct-26	Nov-26	Dec-26	Jan-27	Feb-27	Mar-27	Apr-27	May-27	Jun-27	Jul-27	Aug-27	Sep-27	
SNS	2MW Operations		FY27A			2MW Operations				FY27B		2MW Operations	
HFIR	521	EOC 521 Cold Source - Helium Refrigerator Upgrade							522	EOC 522	523	EOC 523	524

FY28														
	Oct-27	Nov-27	Dec-27	Jan-28	Feb-28	Mar-28	Apr-28	May-28	Jun-28	Jul-28	Aug-28	Sep-28		
SNS	2MW Operations		FY28A			2MW Operations				FY28B		2MW Operations		
HFIR	EOC 524 Beam Room Cleanout							525	EOC 525	526	EOC 526	527	EOC 527	528

Legend: ■ Neutron Production, ■ Outage
 Revised 6/20/23. The working schedule for the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR) is subject to change in response to evolving operational and project needs. The community will be notified as soon as possible if changes occur.

PROSPECT Background Studies



Simplified side view of HFIR site

Here we can see the effects of different background scenarios, a better understanding of those is necessary to accomplish better projected results. **Longer segments** have an impact in background estimates too

PROSPECT-II Projected Results



- Oscillation: Extended sensitivity!!

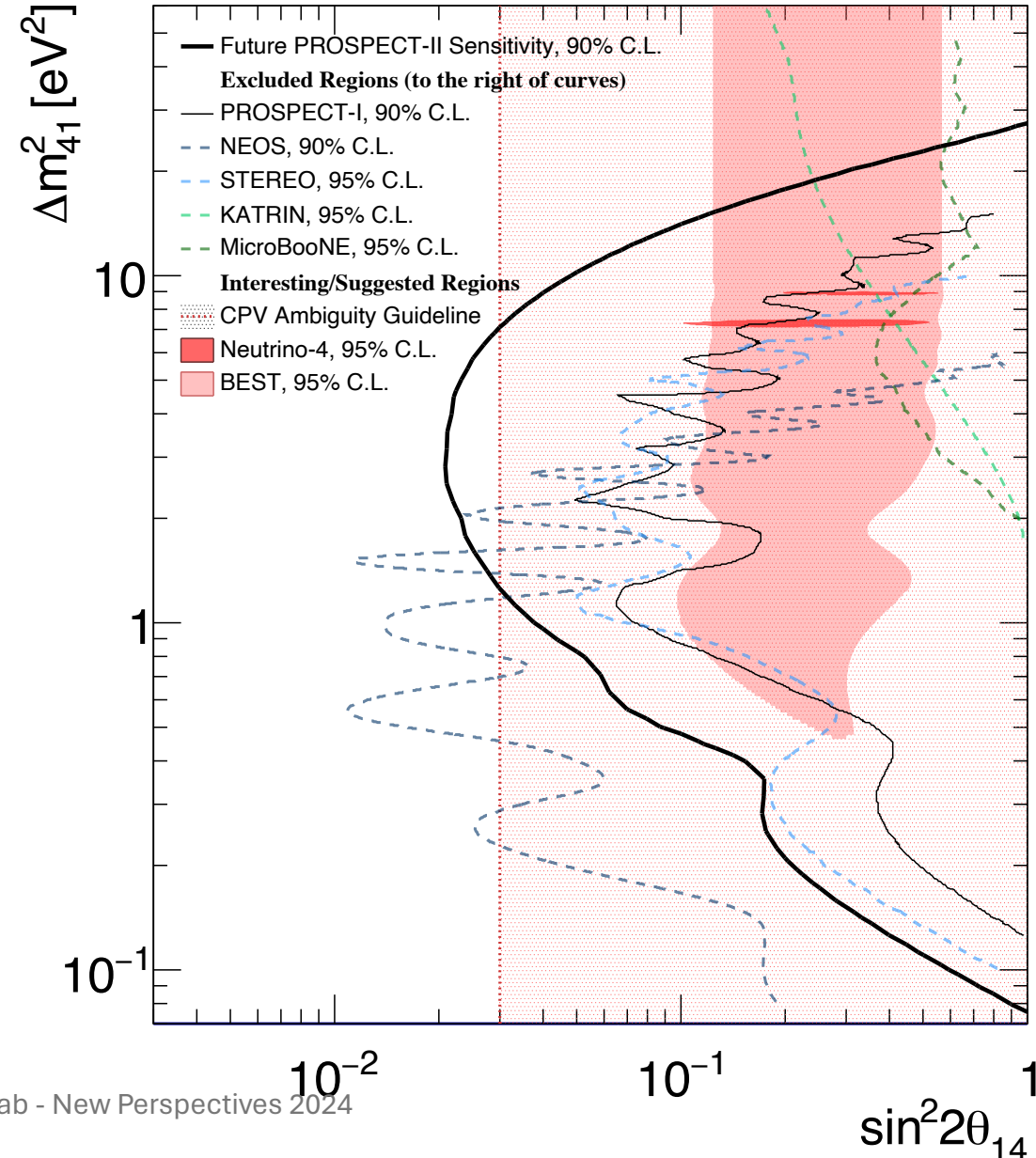
Parameter		P1	P2 at HFIR	P2 at LEU
Exposure	Average Baseline (m)	7.9	7.9	25
	Reactor-On Days (d)	105	336	548
	Reactor-Off Days (d)	78	360	61
	Signal:Background	1.4	4.3	19.3
	IBD Statistics (N_{IBD})	50560	3.74×10^5	2.72×10^6
	Effective Statistics (N_{eff})	15195	2.08×10^5	1.79×10^6

PROSPECT-II Projected Results

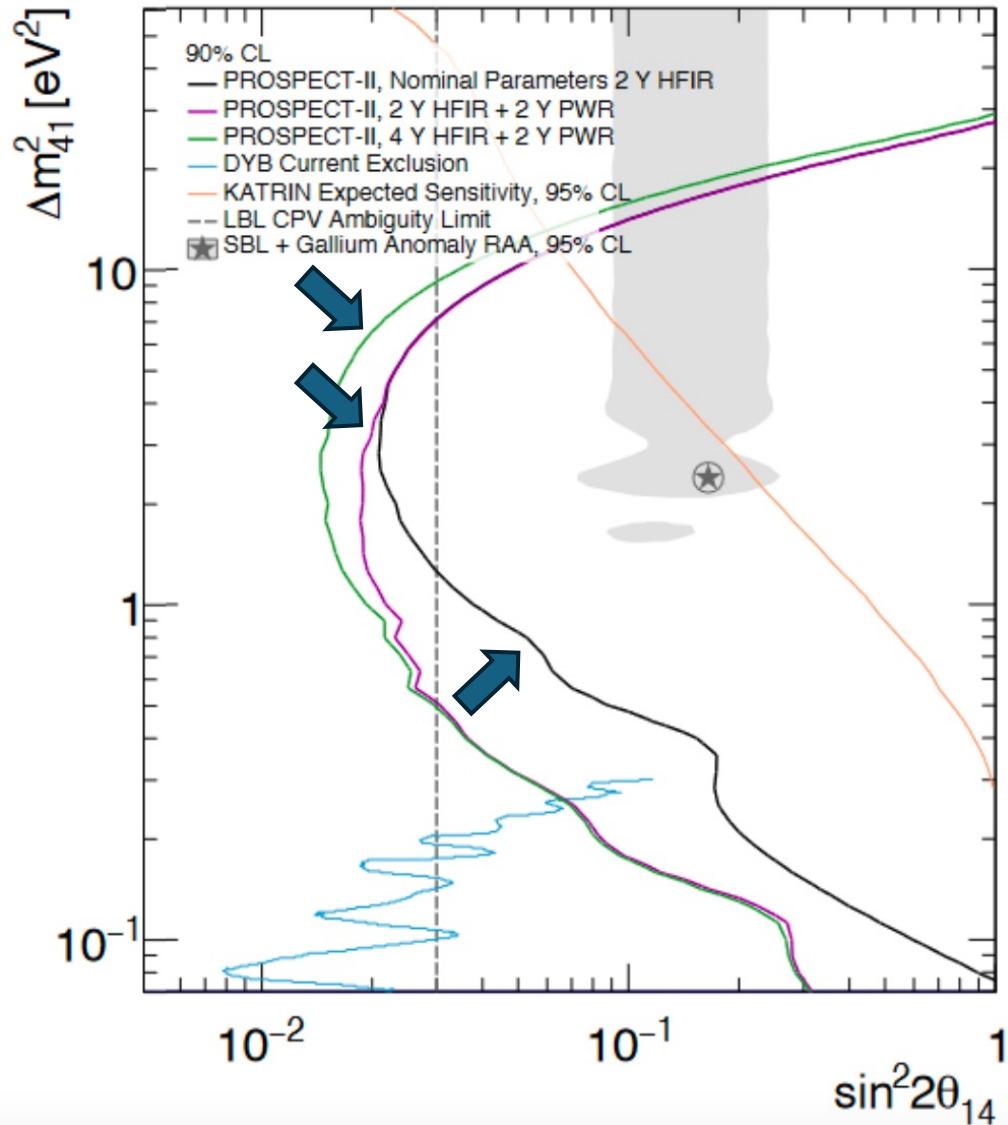


• Oscillation:

- More phase-space coverage, specially at higher Δm_{41}^2
- Addresses Neutrino-4
- Better coverage at higher Δm_{41}^2 than beam experiments
- Help us have a clearer picture on the Long Baseline CP Violation



PROSPECT-II Projected Results



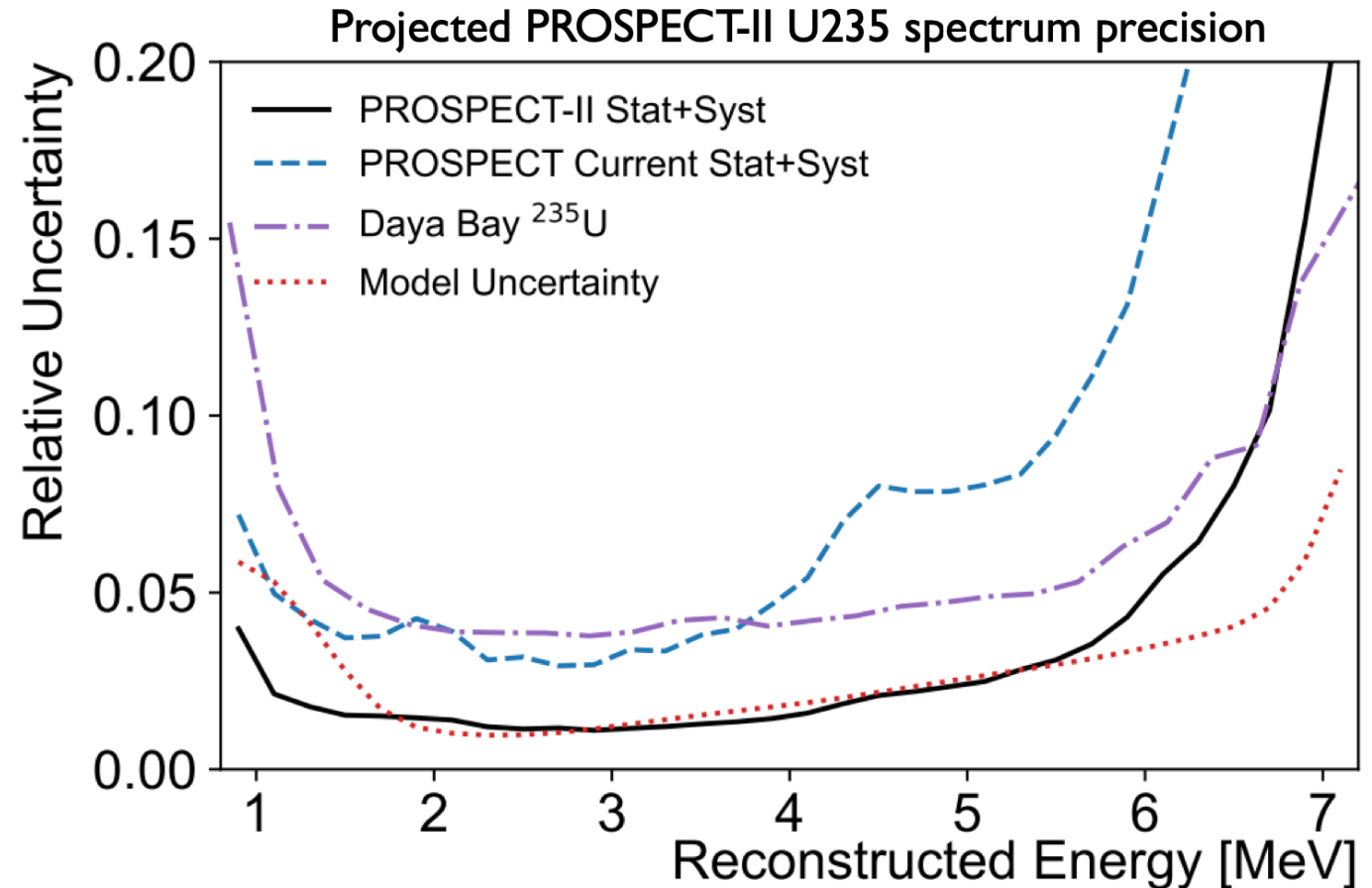
- HEU + LEU deployment:
 - Oscillation sensitivity extended to lower Δm_{41}^2 from longer baseline

PROSPECT-II Projected Results



- Spectrum:

- Double the precision, exceeding the model uncertainties for the majority of the antineutrino spectrum



PROSPECT-II Projected Results



- HEU + LEU deployment:

- Oscillation sensitivity extended to lower Δm_{41}^2 from longer baseline
- Flux measurements at both reactors yield unambiguous measure of the isotopic antineutrino yield

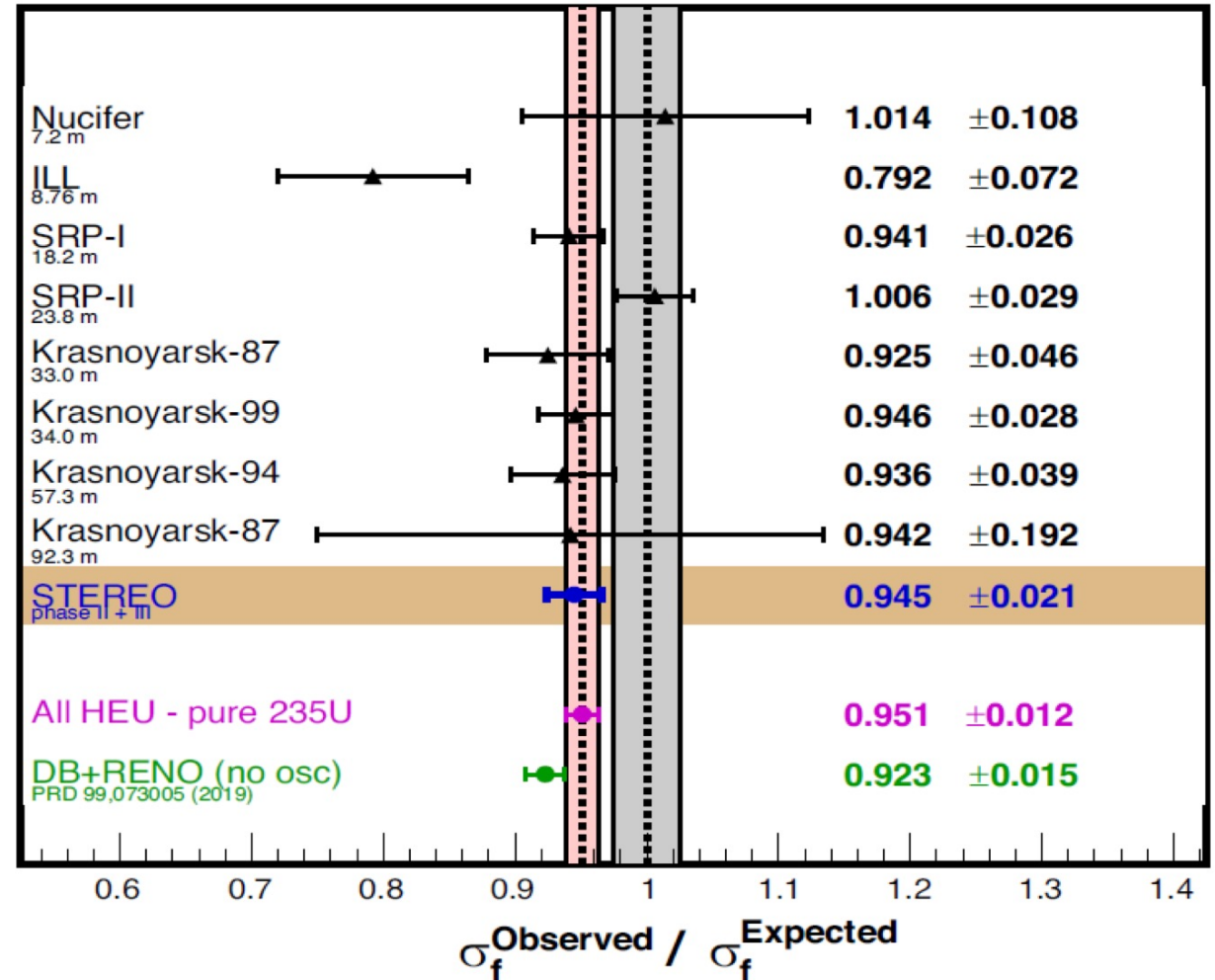
Case	Description	Precision on σ_i (%)		
		^{235}U	^{239}Pu	^{238}U
1	Daya Bay LEU	3.7	8.2	30
2	Daya Bay LEU + P-II HEU	2.4	6.3	21.3
3	P-II LEU + P-II HEU+	1.4	3.4	15.9
4	P-II LEU + P-II HEU+, Correlated	1.4	3.0	8.7
-	Model Uncertainty [66]	2.1	2.5	11.2

J. Phys. G: Nucl. Part. Phys. **49** 070501

PROSPECT-II Projected Results



Overview of ^{235}U Flux Measurements (by STEREO Collaboration)¹



Phys. Rev. Lett. **125**, 201801

• Flux:

- Fundamental for reactor CEvNS experiments
- Provide better limits on BSM phenomena
- Current best measurement is STEREO's
- P2 absolute flux measurement can be best: potential for lower HFIR thermal power uncertainty

Conclusion



- PROSPECT-I was a successful experiment with a number of valuable analysis
- PROSPECT-II robustness give us the chance to push even further the borders of knowledge we currently have in the field
- The collaboration is actively engaged on the design of P2

Thank you!



prospect.yale.edu

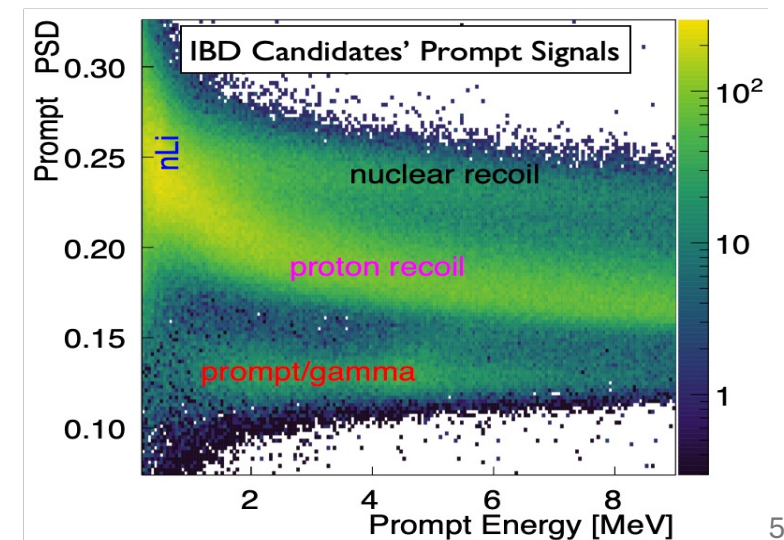
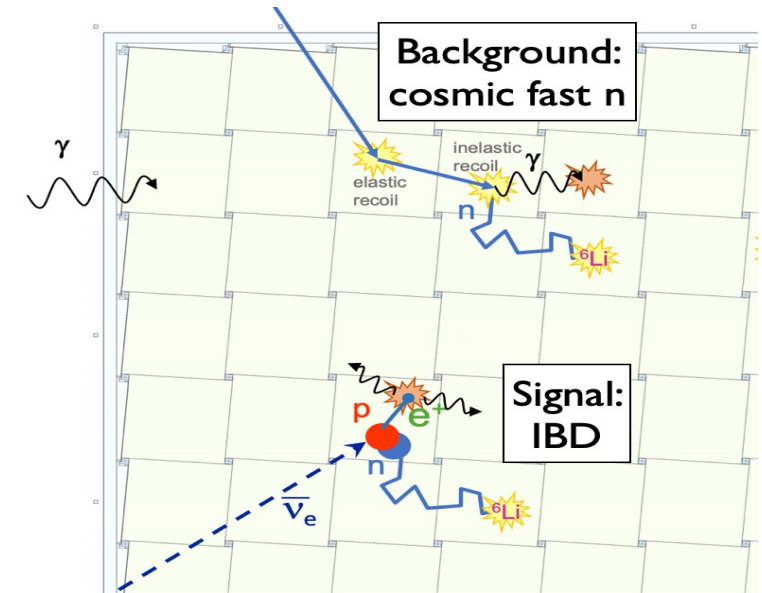


BACKUP SLIDES

Key Detector Features



- Prompt e^+ gives $\bar{\nu}_e$ energy estimate (>400 pe/MeV)
- Fully-contained, single-cell delayed n - ${}^6\text{Li}$ signal
- Prompt, delayed PSD differ from common background classes
- Double-end PMT readout and segmentation allows XYZ reco and topology cuts

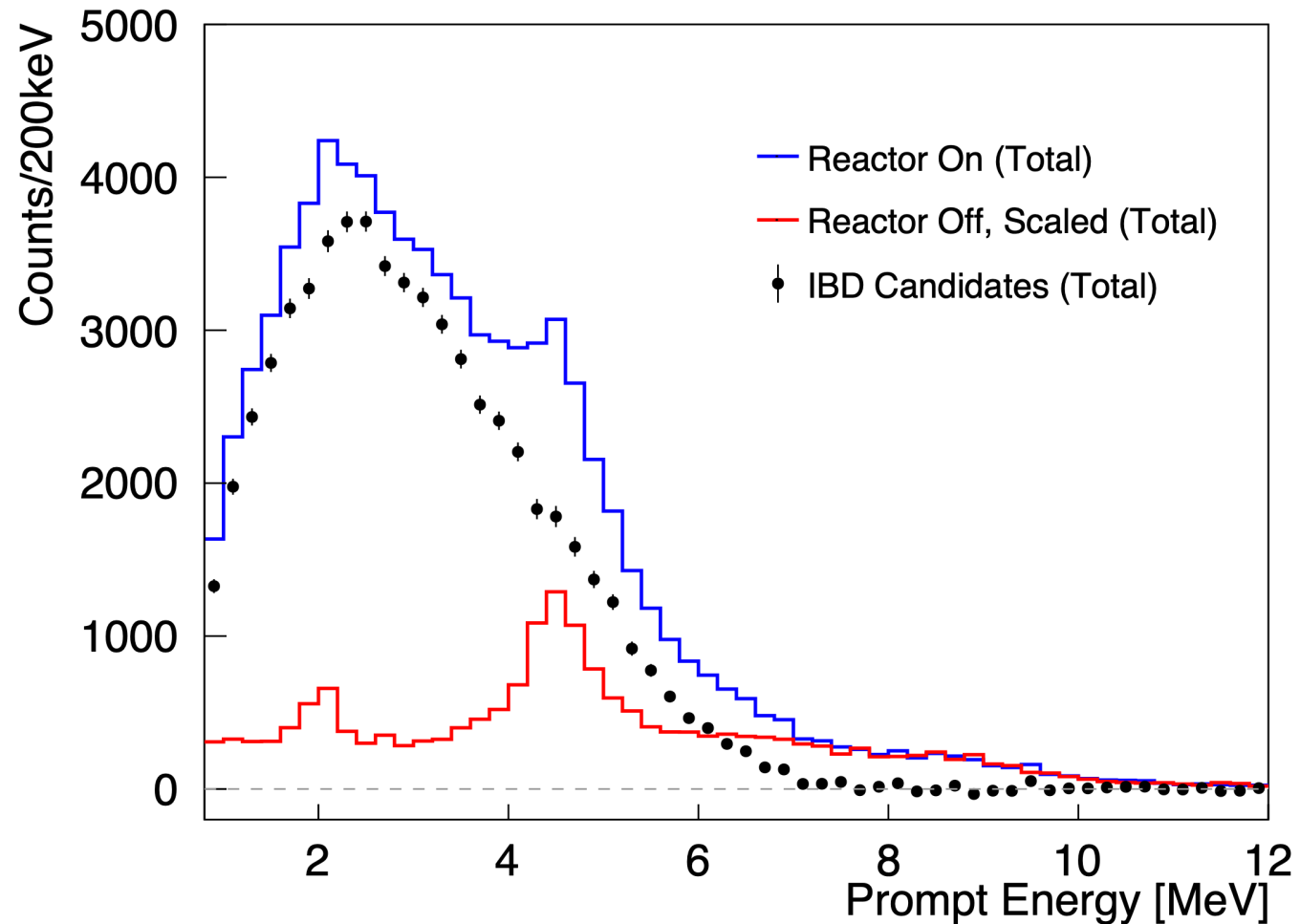


PROSPECT-I Physics Results



Great signal to background ratio and energy resolution!

S:B of 4:1

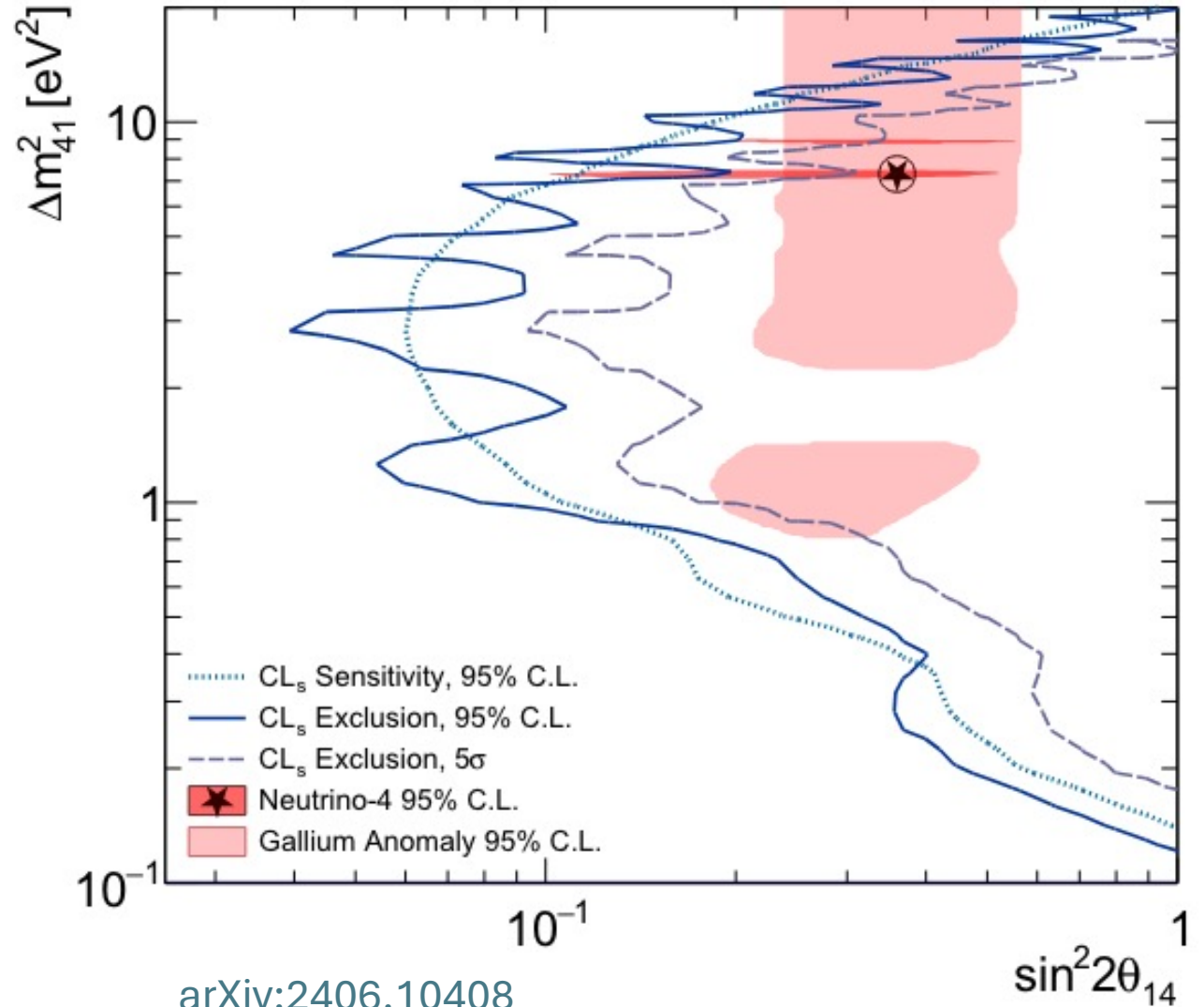


PROSPECT-I Physics Results



Oscillation analysis:

- No indication of sterile neutrino and rejected neutrino-4 best-fit point at 5σ in **final** analysis



[arXiv:2406.10408](https://arxiv.org/abs/2406.10408)

PROSPECT-I Physics Results



Spectrum measurement:

- Observation of excess at ~ 5 MeV
- Isotopic composition of ‘The Bump’:
 - Equal Isotope hypothesis preferred:
 - No ^{235}U disfavored at 3.2σ
 - All ^{235}U disfavored at 2.2σ

Check this values with the source

