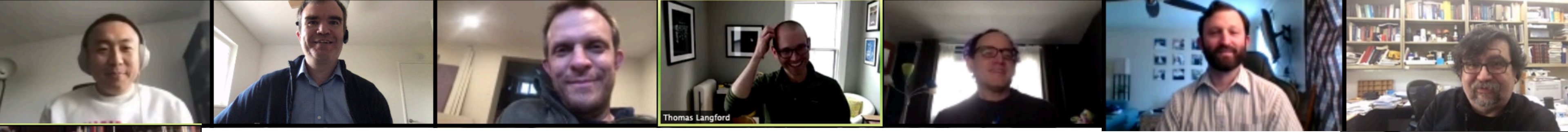
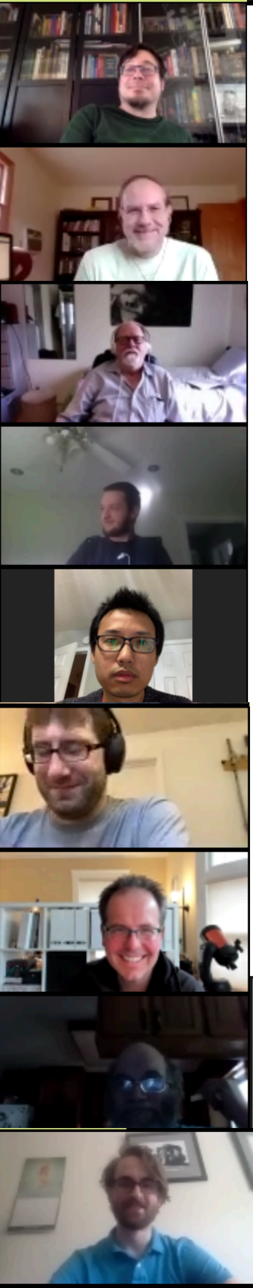
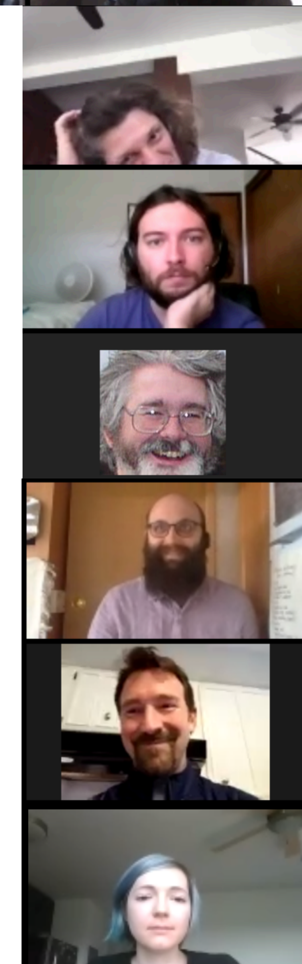






PROSPECT-II: Extending Scientific Reach through Upgraded Performance

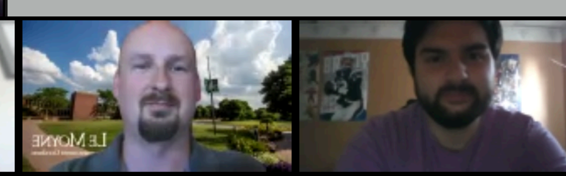
October 30 2020

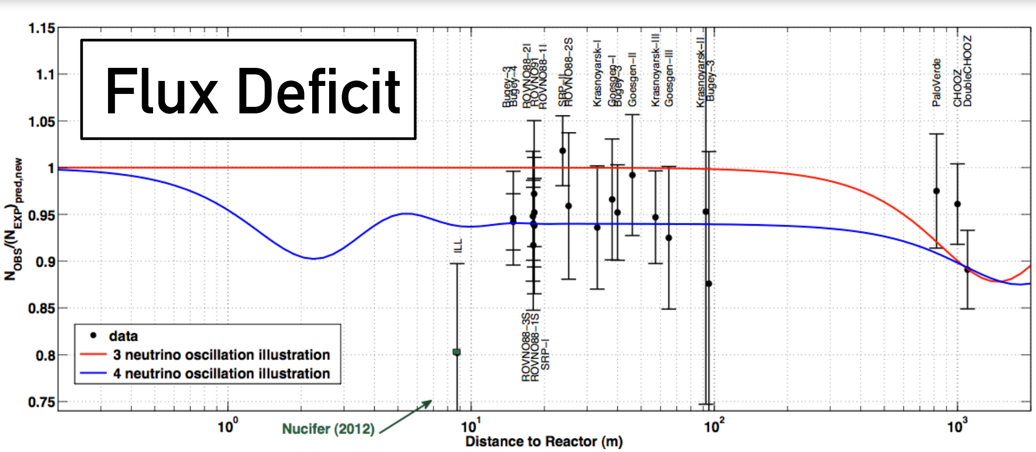
Pieter Mumm

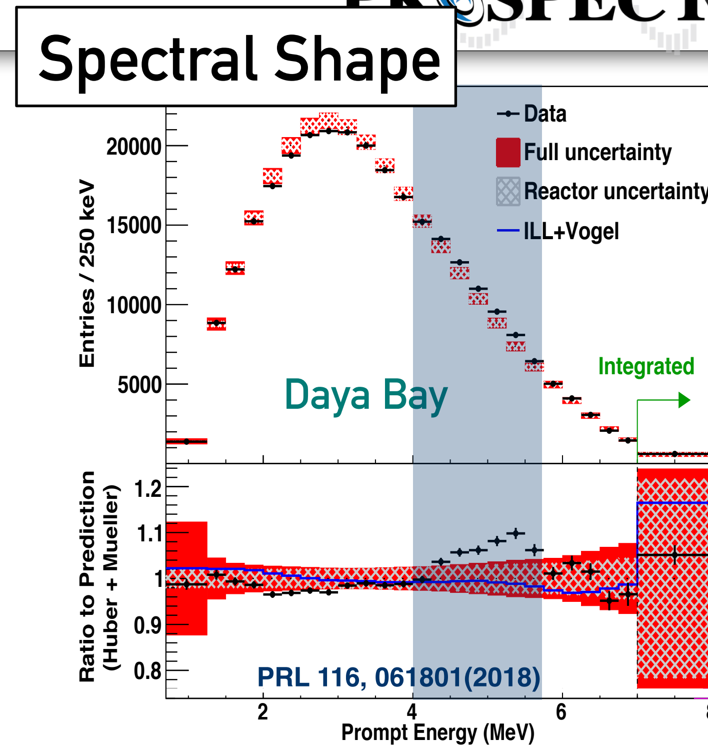
National Institute of Standards and Technology

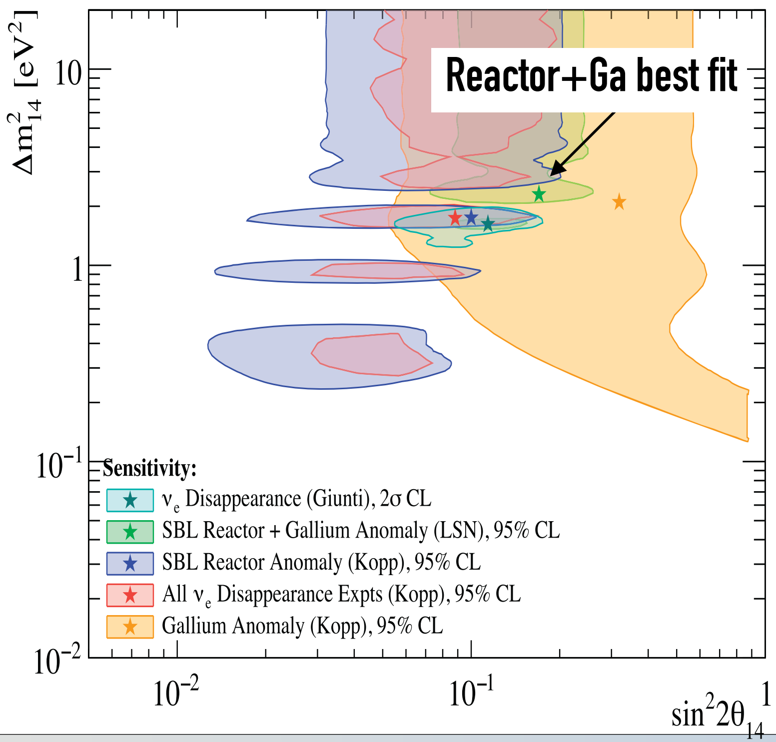
On Behalf of the PROSPECT Collaboration

PROSPECT April 2020
Collaboration Meeting Photo





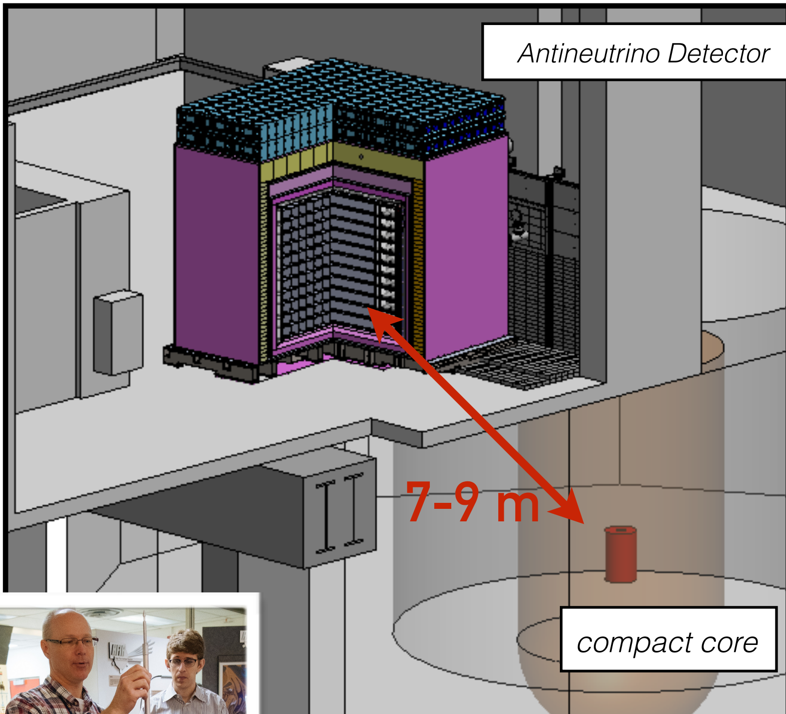


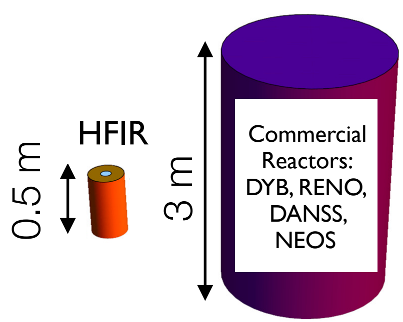


PROSPECT-I GOALS:

1. Search for short-baseline sterile-neutrino oscillations independent of reactor models
2. Measure antineutrino spectrum due to ^{235}U
3. Demonstrate near-field surface operation

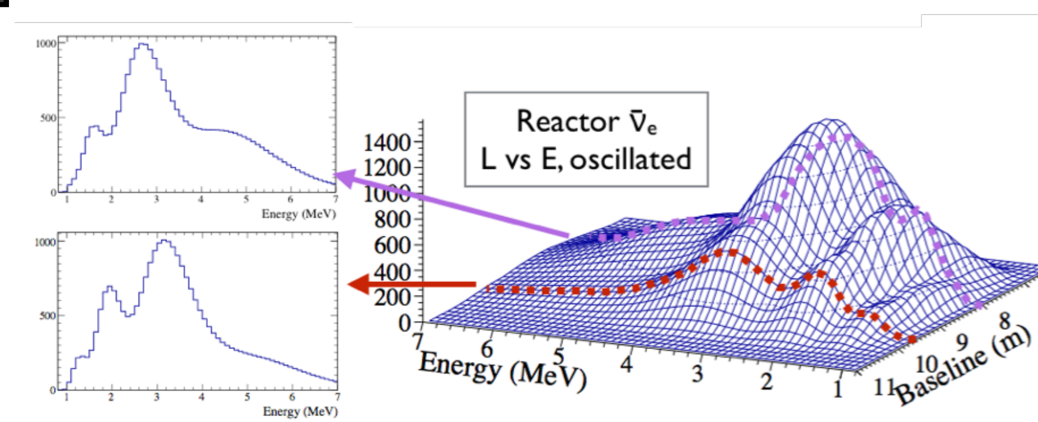
Experimental Strategy: PROSPECT





Experimental Strategy:

- Compact HEU research reactor (all 235U)
- Segmented detector localizes events and supports background rejection
- Measure high-resolution spectrum at a range of baselines (7-9m in current position)
- Search for characteristic relative spectral distortions within detector volume
- 46% reactor up time, allows equal stats for detailed study of cosmogenic backgrounds

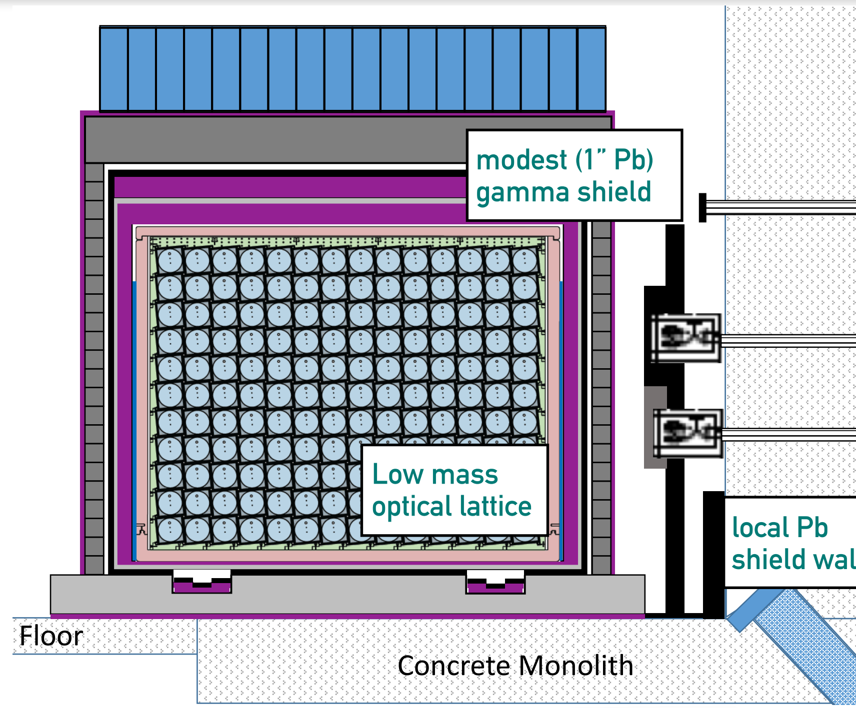


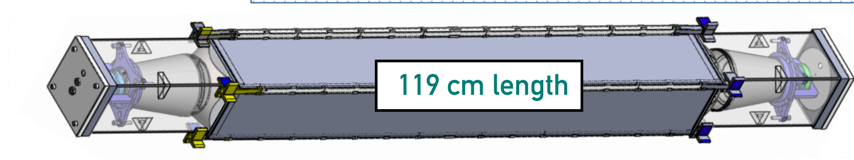
PROSPECT-I Detector overview

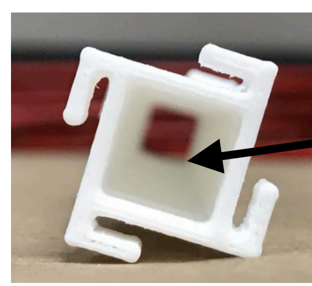
- Single 4,000 L ^{6}Li-loaded liquid scintillator,
- divided into 11 x 14 (154) array of optically separated segments
- 2D segmentation supports:
  - full X,Y,Z event reconstruction
  - fiducialization
  - event topology for signal selection
- Double ended PMT readout, with light concentrators
  - good light collection and energy response ~5%/$\sqrt{E}$ energy resolution
- Optimized shielding to reduce cosmogenic and local backgrounds

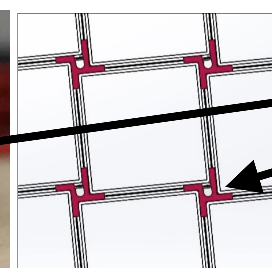
[PROSPECT, NIM A 922 (2018)](#)

[PROSPECT, JINST 14 P04014 (2019)](#)



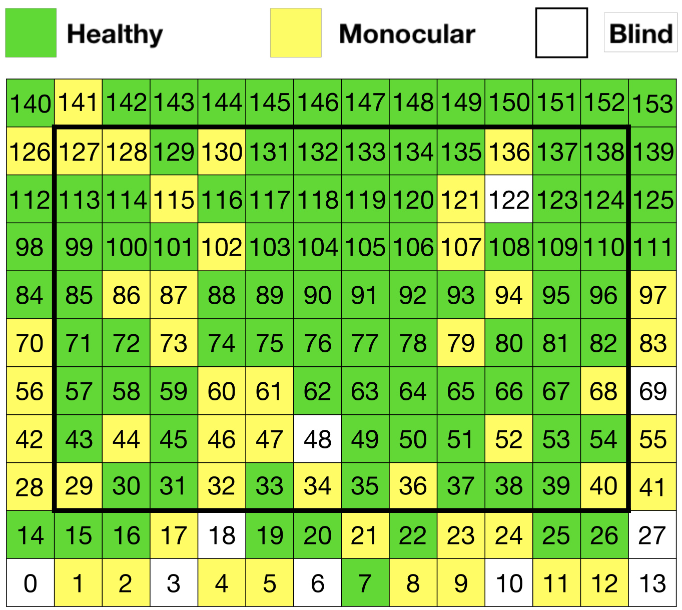




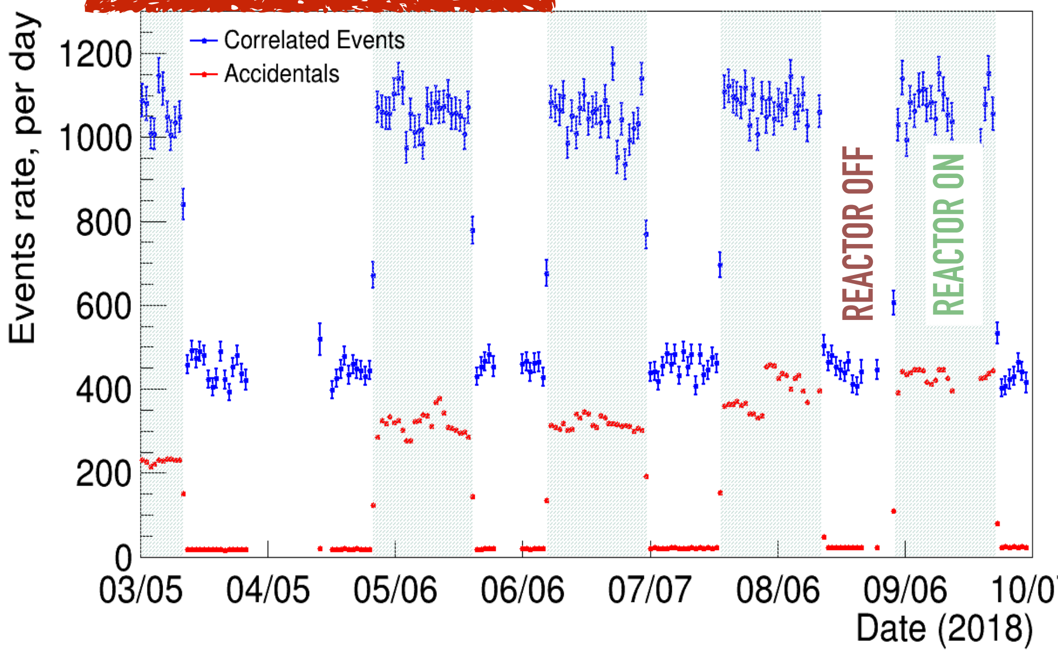


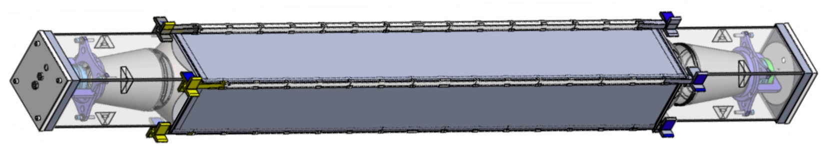
TILTED ARRAY FOR CALIBRATION ACCESS

PROSPECT-I Results



S:B ~ 1.36:1 (correlated)

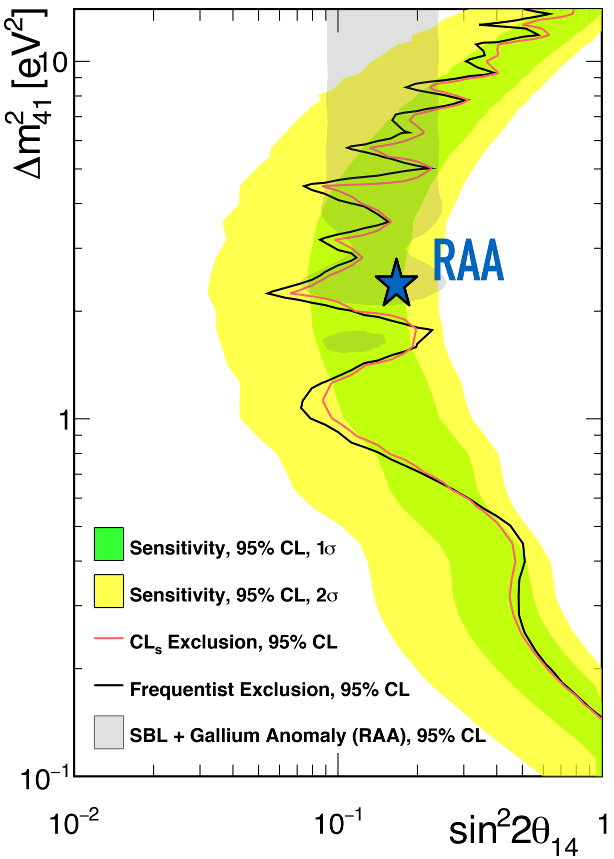


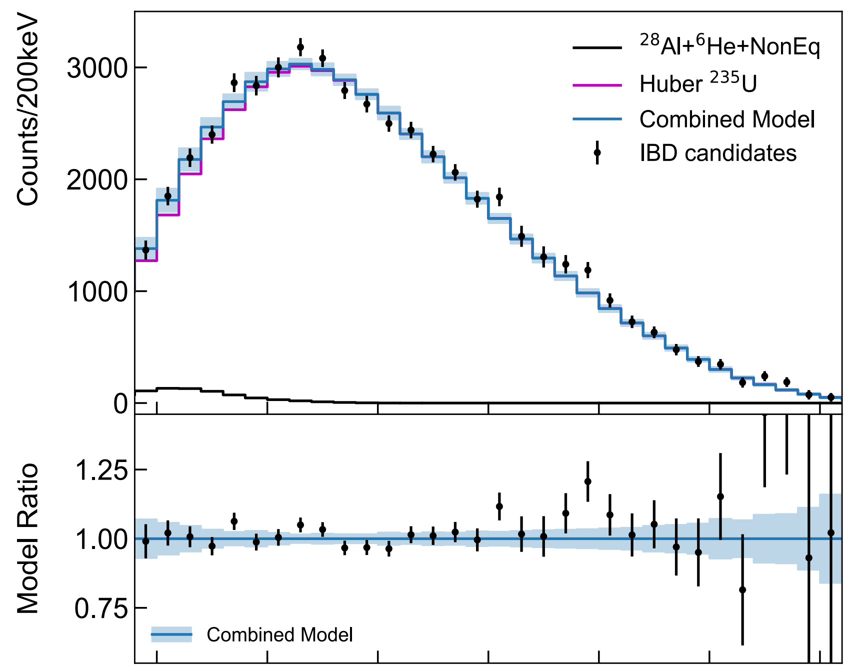


- 50,560 ± 406 IBD signal events
- 28,357 ± 18 accidental bkg events
- 36,934 ± 221 cosmic bkg events
- 530 IBD signal per calendar day

Excellent signal-to-background for a surface detector (< 1mwe overburden)

PROSPECT-I Results



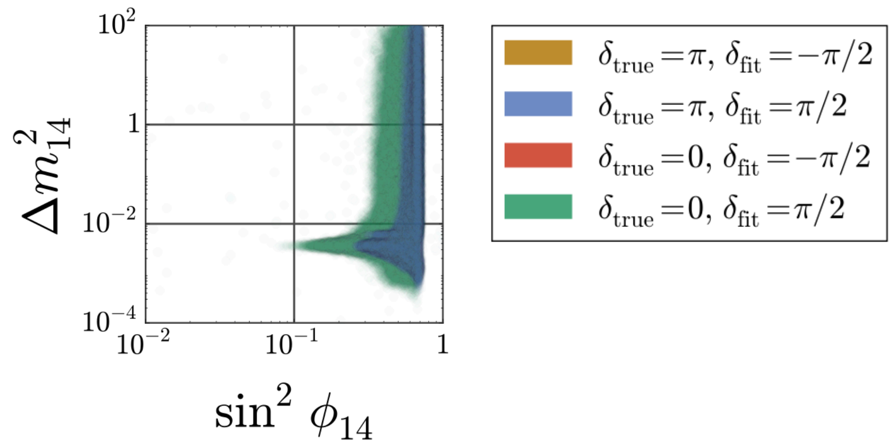


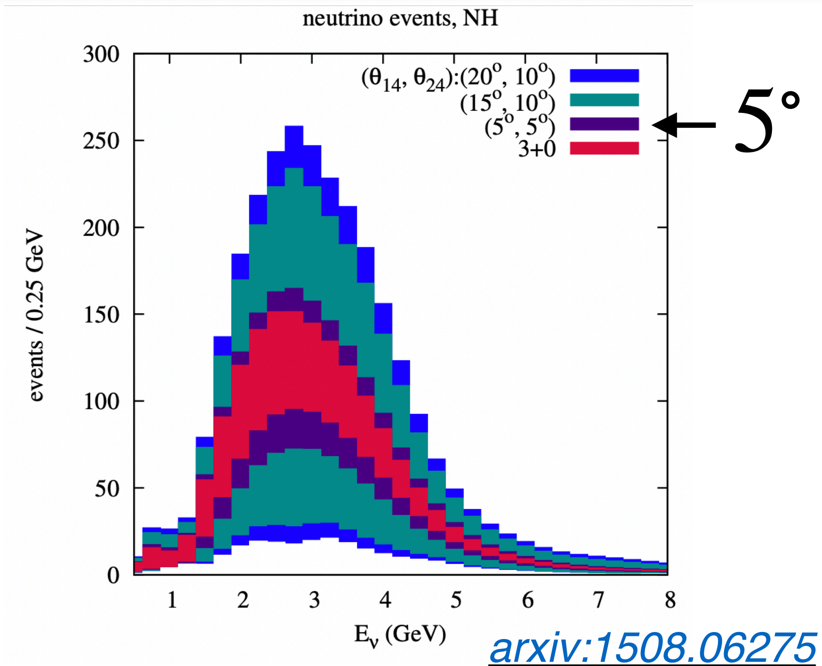
95.65 reactor-on calendar days, 73.09 reactor-off

- RAA best-fit excluded: 98.5% CL
- Data is compatible with null oscillation hypothesis (p=0.57)
- χ^2/NDF =30.79/31 for **shape-only** comparison with model
- PROSPECT feature size with respect to Daya Bay: 84% ± 39%. (No ^{235}U bump disfavored at 2.2σ CL, all ^{235}U is disfavored at 2.4σ CL)

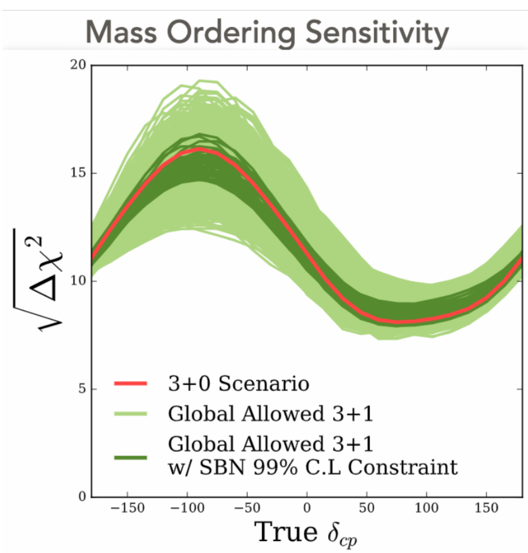
PROSPECT

- Can mimic CP violation in DUNE
  https://arxiv.org/pdf/1605.09376.pdf





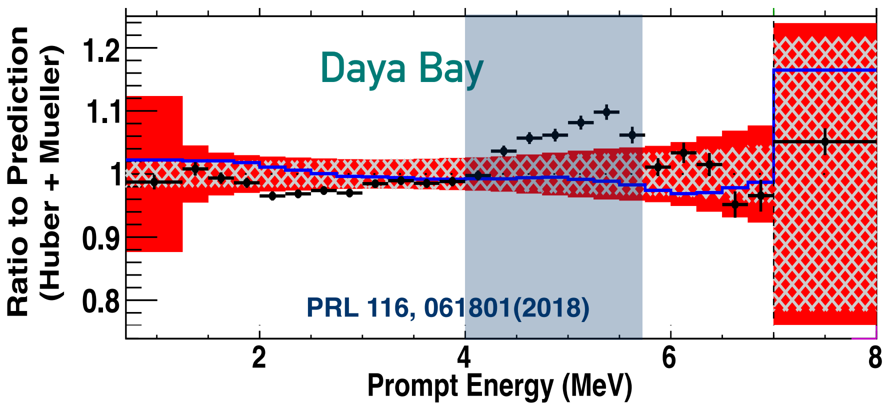
[arxiv:1508.06275](https://arxiv.org/abs/1508.06275)



Yeon-jae Jwa, ICHEP 2018
2018 allowed 3+1 space compared to constraint from a null SBN result

- Ambiguities in mass ordering
- Simple 3+1 models suffer strong tensions, more complex models add rich theoretical texture that short baseline expts. can help disentangle

Spectrum/flux Still Not Understood.

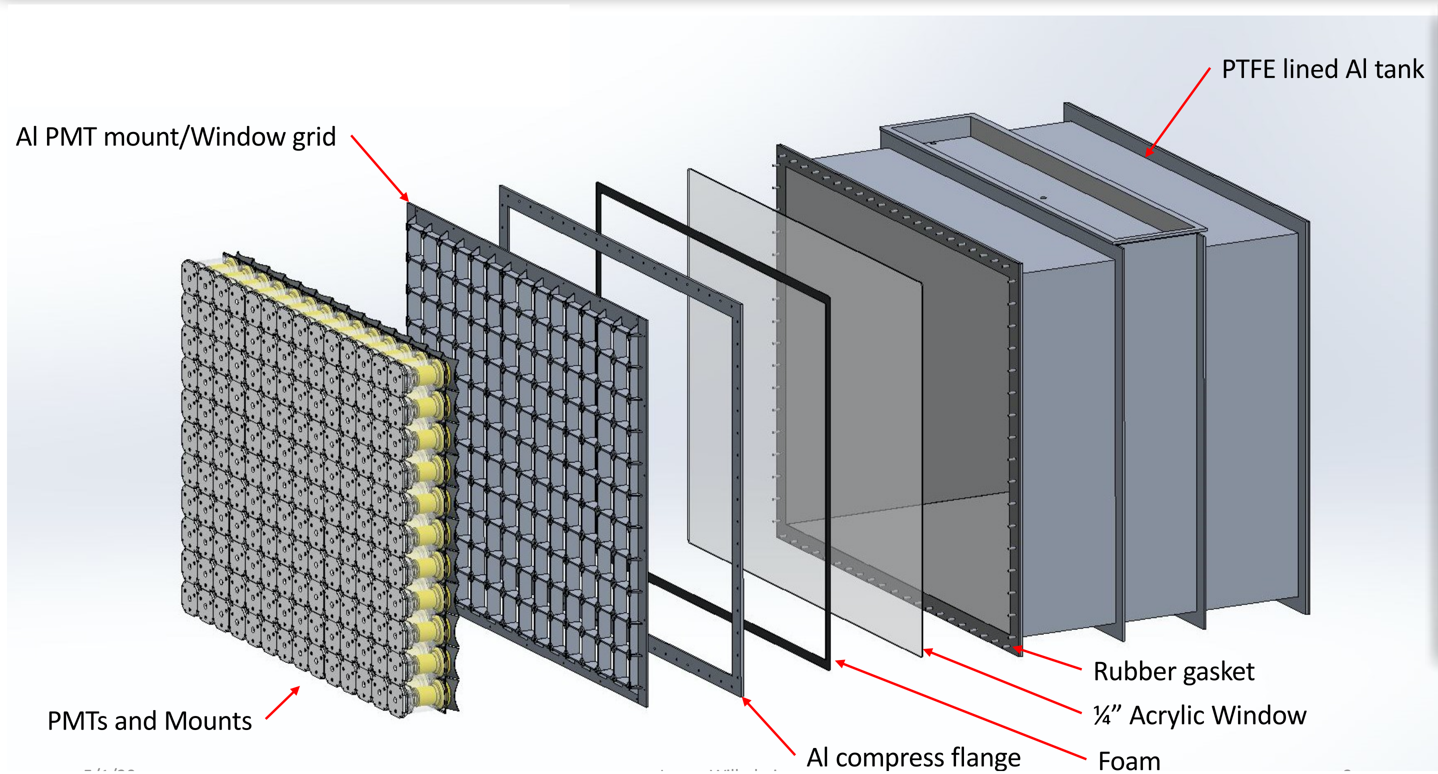


Description	Precision on σ_i (%)		
	^{235}U	^{239}Pu	^{238}U
Daya Bay LEU	3.7	8.2	30
Daya Bay LEU + P-II HEU	2.4	6.3	21.3
P-II LEU + P-II HEU+	1.4	3.4	15.9
P-II LEU + P-II HEU+, Correlated	1.4	3.0	8.7

- Spectral shape anomalies still unexplained, both in 4-6 MeV region and an very high and very low energies
- Reference spectrum needed for reactor-based hierarchy measurements, reactor CEvNS, and nuclear safeguards
- Systemically distinct input for joint spectrum analysis

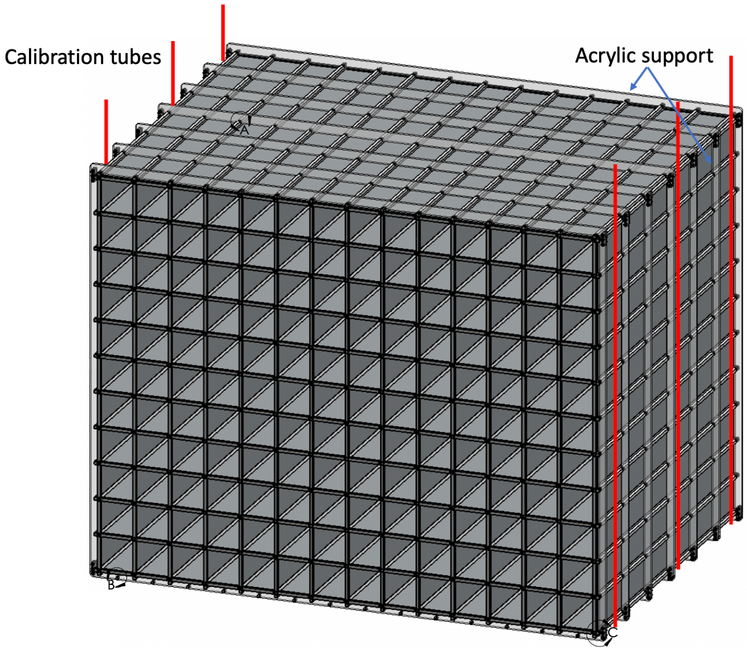
PROSPECT-II absolute flux measurement can:

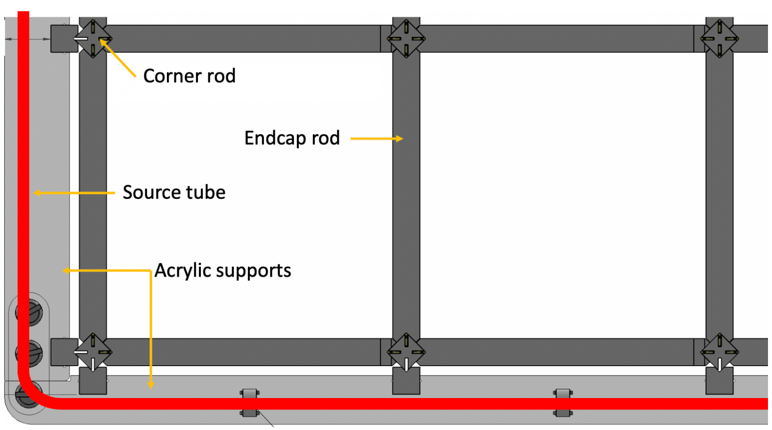
- Improve understanding of fission isotope yield
- Independent check of 5% deficit observed by STEREO (short-baseline experiment)



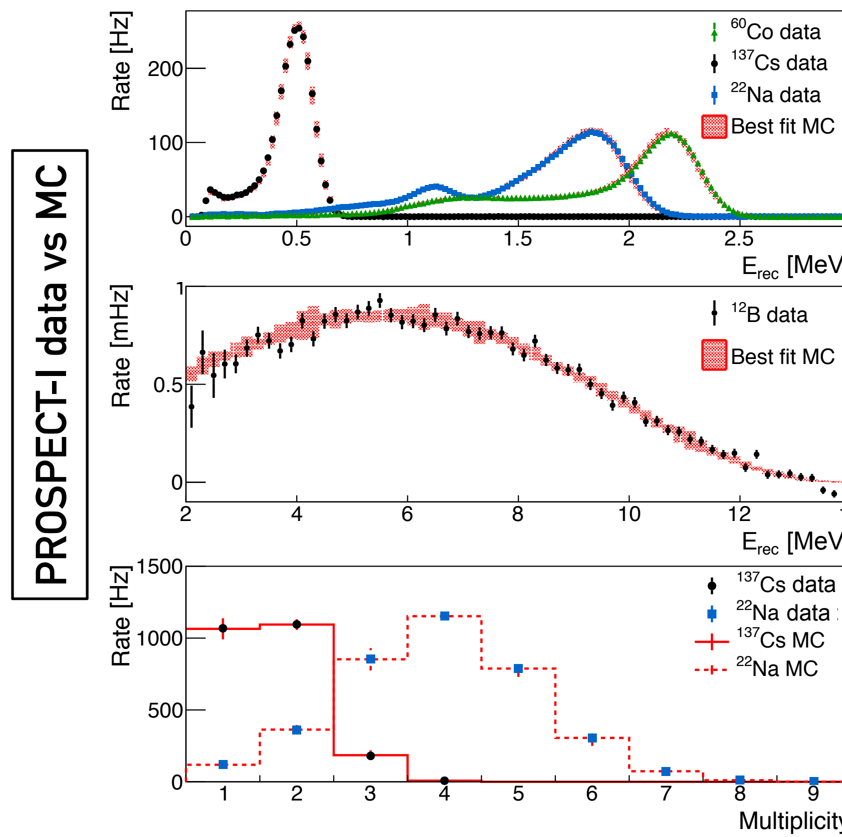
Match initial performance while improving stability (maintain similar segment pitch, same scintillator formulation, etc…) and facilitating redeployment

- Separate PMTs from LiLS volume, reduce exposure to materials, and improve cover gas
- Design approach facilitates operation at multiple sites
- Planned redeployment at HIFR ~ late 2021

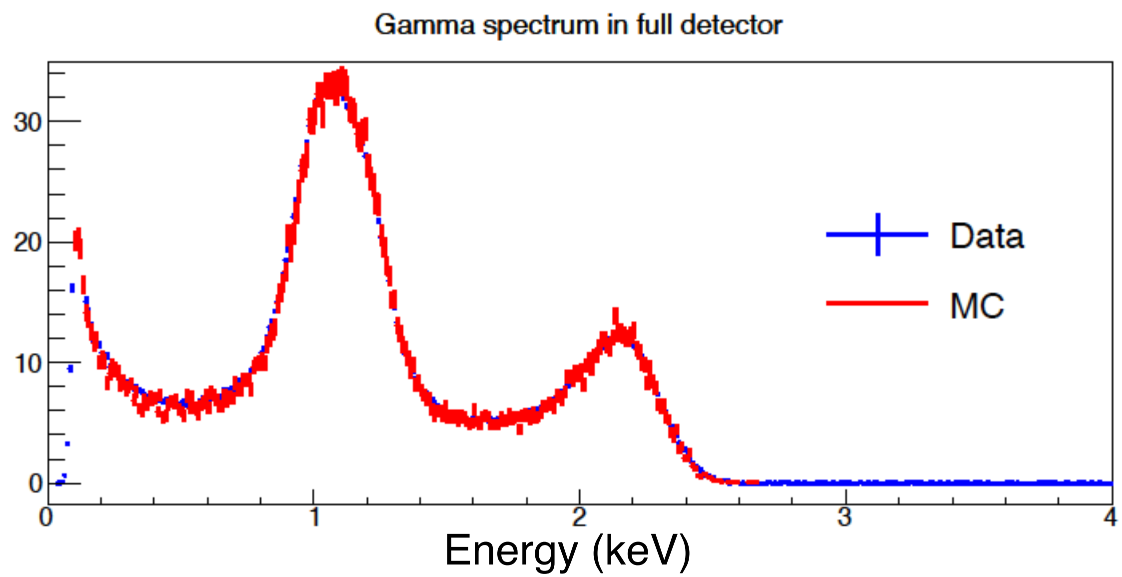


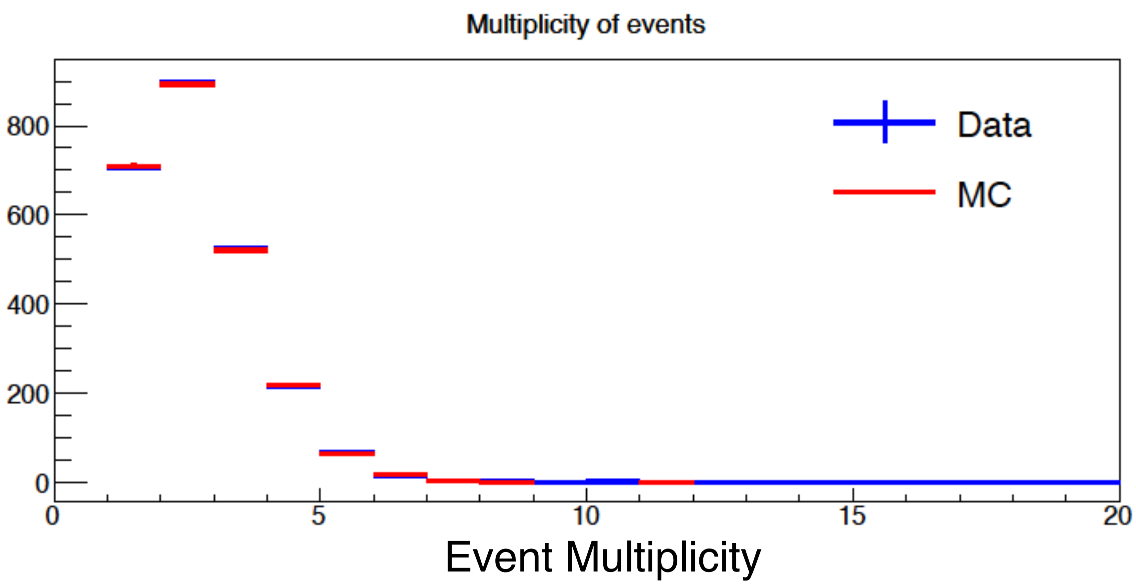


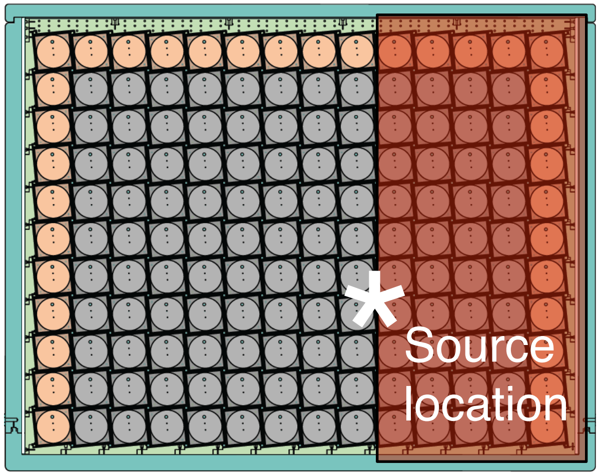
- Removing penetrations into central volume requires modification of calibration strategy
- Calibration source tubes will now feed around the outside of the detector



Validating Calibration Scheme





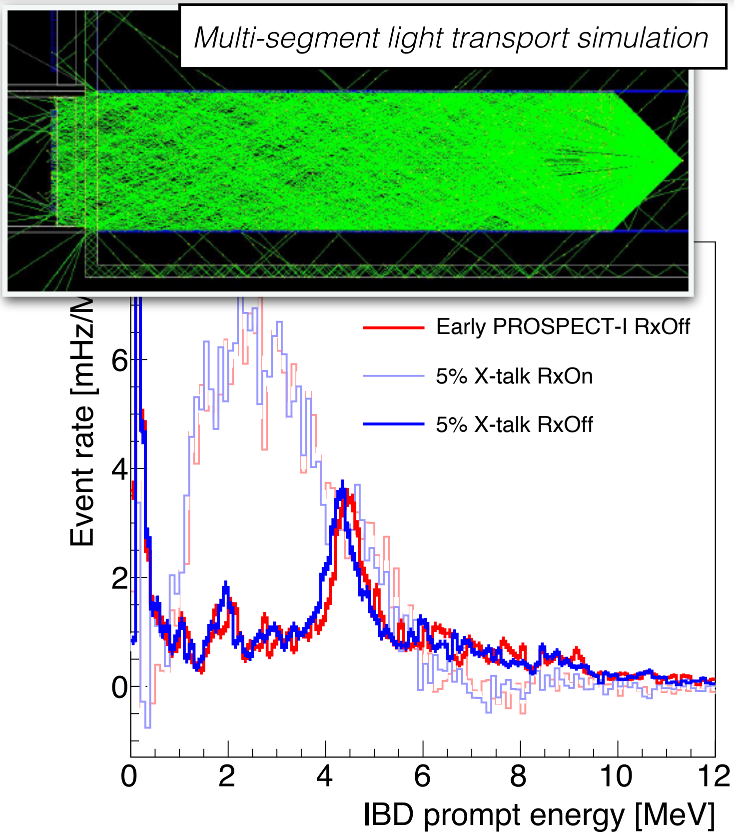


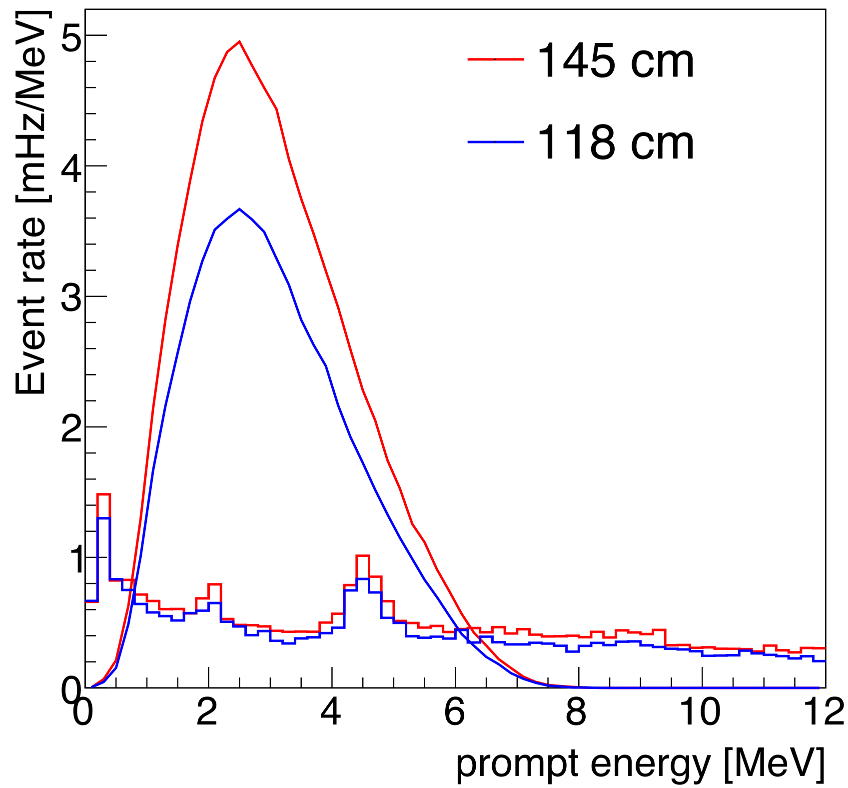
Using PROSPECT-I data simulate edge deployed source.

Energy and multiplicity data used to reconstruct detector (non-linear) response.

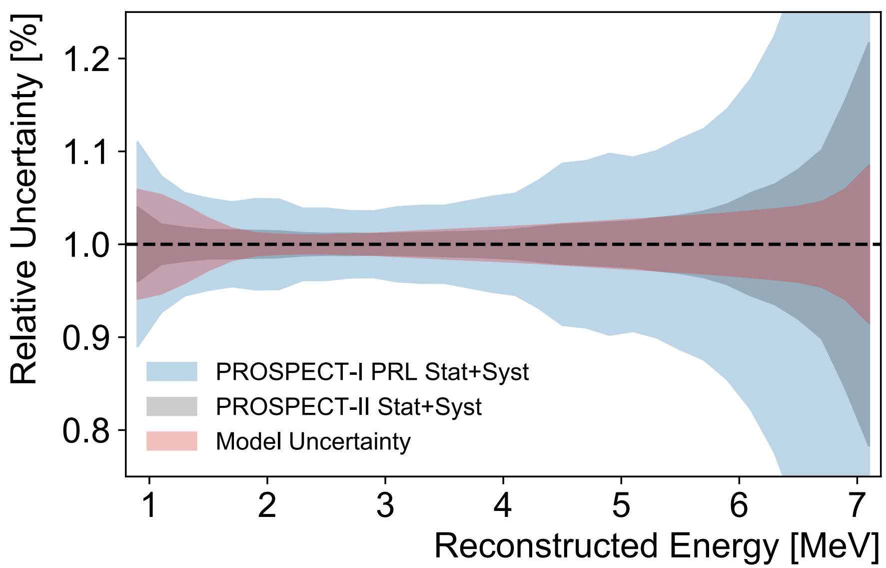
As before, features, e.g. capture on ^{6}Li and cosmogenic ^{12}B beta decays, constrain model and help determine energy scale

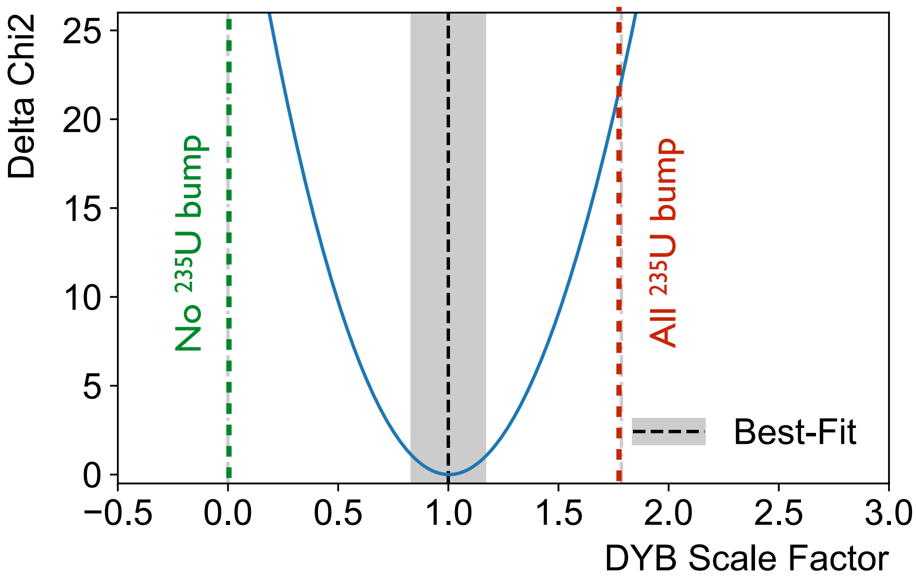
Cross-talk and signal to background





- Windows allow for communication between segments (Monte Carlo estimates ~ < 5%)
- Data-driven simulations suggest minimal impact of aground rejection
- Increased spatial efficiency allows larger fiducial volume (40% more signal)
- Projected signal to background ~ 3:1

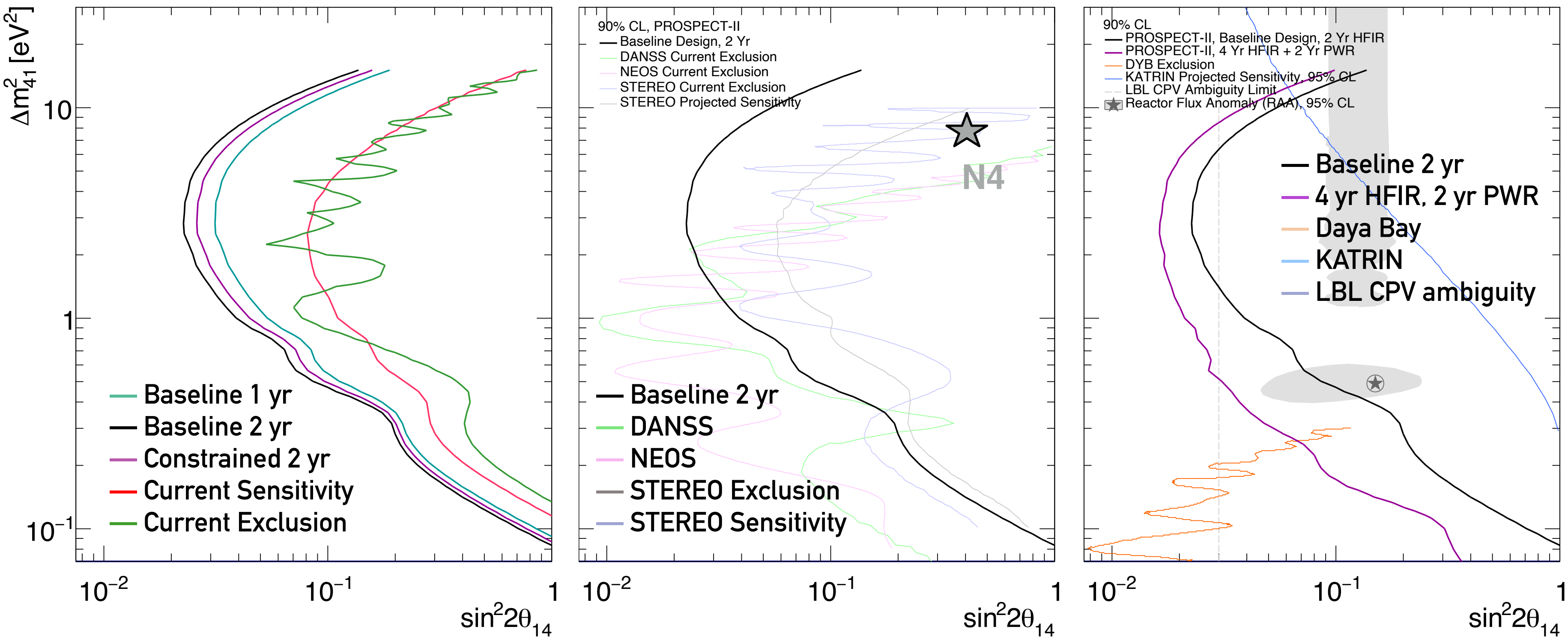




Assume similar performance with increased S:B ~ 3:1 and nominal 2 year and 4 year run times:

- Measurement uncertainties become comparable to model uncertainties
- Significant reduction in uncertainties in 4-6 'bump' region
- Significant increased precision in measuring the amplitude (n) of a bump-like feature in the 4-6 MeV prompt energy: PROSPECT will address hypothesis for the origin of this feature (n=0, no bump from ^{235}U; n=1.78, bump entirely from ^{235}UU) at high confidence level.

Oscillation Sensitivity



Global context:

- Significant gains over current sensitivity, covers below 5 deg over mid-Δm^2 phase space
- Addresses high-Δm^2 region with conflicting experimental results
- PROSPECT-II would continue to provide *unique* access to high m^2 region below Katrin
- Global effort is complementary, particularly if care is taken to support global analysis efforts

- PROSPECT has produced both impactful sterile oscillation and spectrum results (highest sensitivity at high-Δm^2) despite unplanned limitations to data collection (both due to PMT divider failure and a HFIR outage); yet the global picture remains unclear

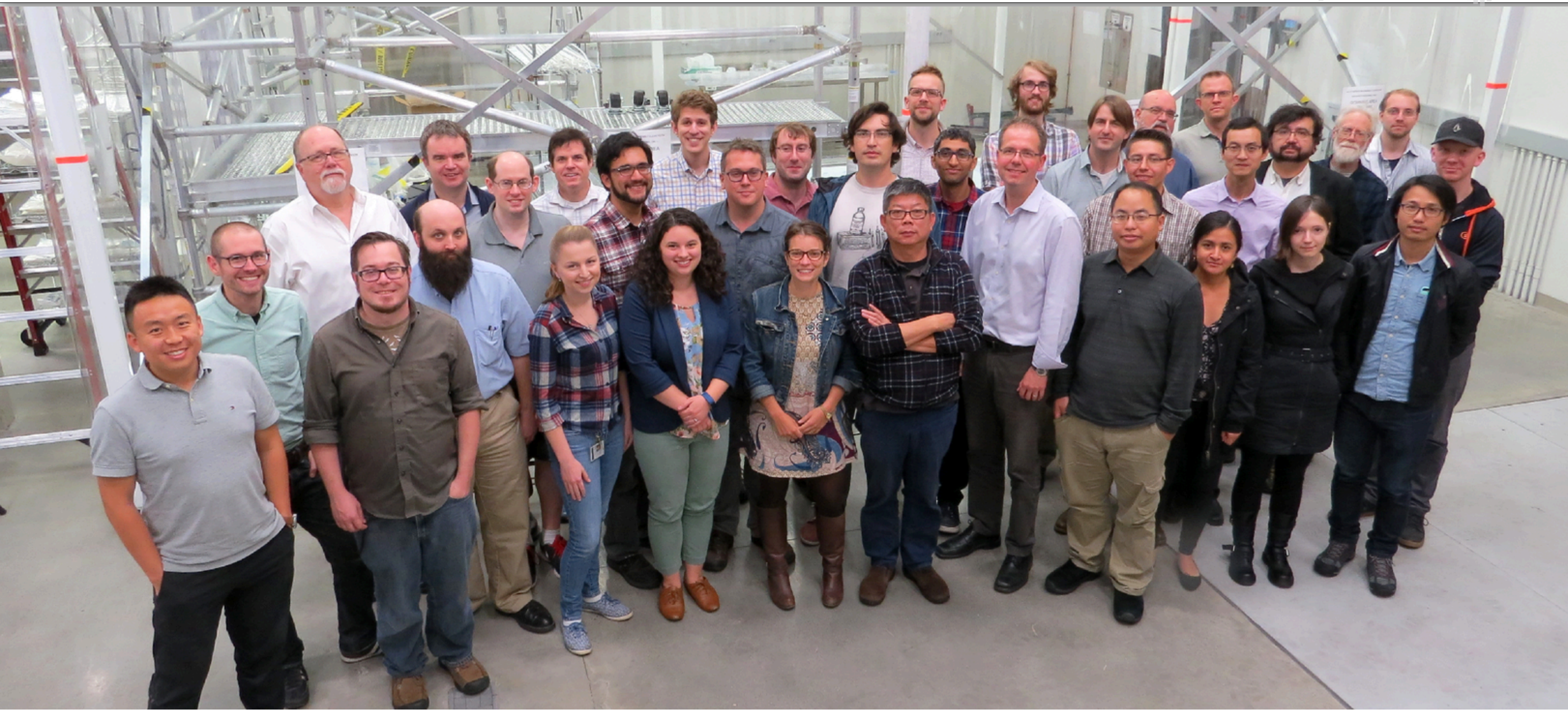
- PMT failure is understood. Will be eliminated through a robust design upgrade that is in progress; allows for extended running at HIFR with the option of additional deployments at other reactors, further improving sensitivity.

- Upgrade detector and continued data collection will enable:
    - *Definitively addressing the Reactor Anomaly and Neutrino-4*
    - *Eliminating possible ambiguities in long baseline experiments*
    - *High significance test of isotopic contributions to the shape anomaly*
    - *Absolute flux measurement*

SN.00002 Machine learning application to event reconstruction from single-ended PMT readout (Xiaobin Lu)

LK.00006 : Machine learning applications for Ortho-Positronium tagging in liquid scintillator for the PROSPECT experiment (Diego Venegas, Blane Heffron)

PROSPECT Collaboration



prospect.yale.edu

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