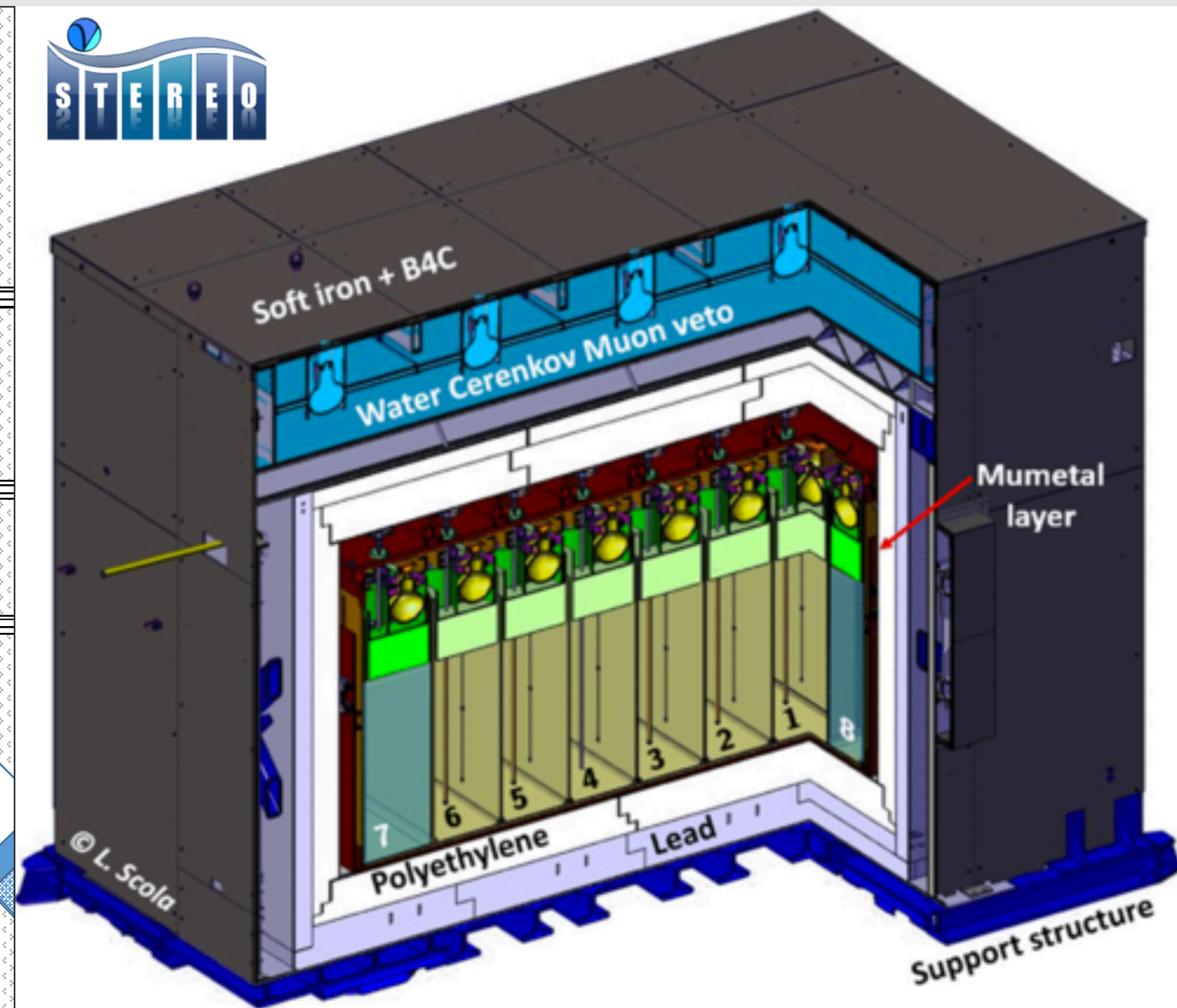
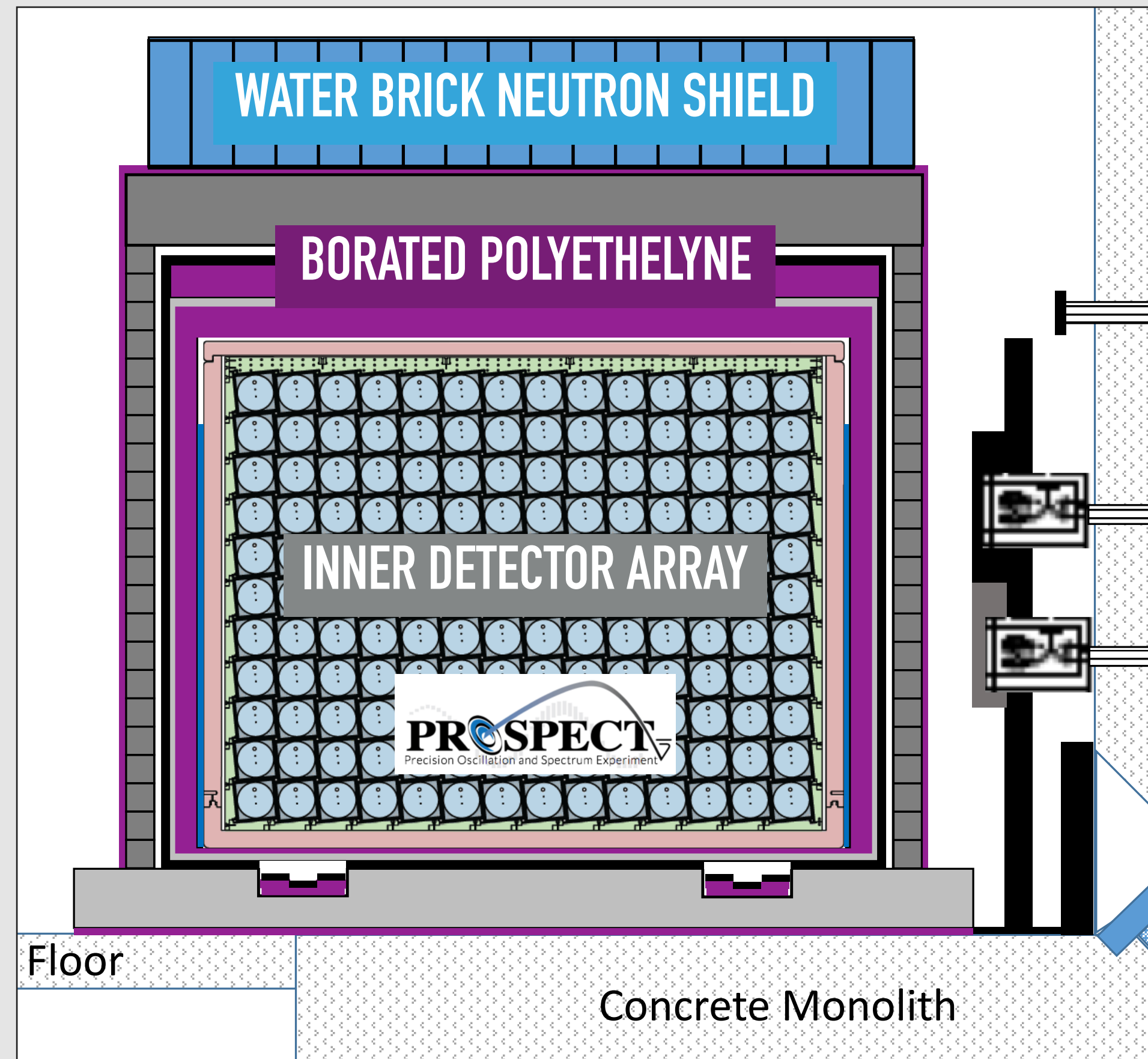
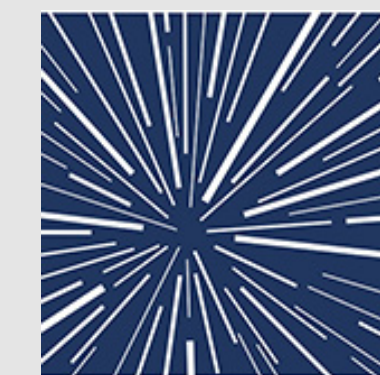


JOINT MEASUREMENT OF THE ^{235}U ANTINEUTRINO ENERGY SPECTRUM BY PROSPECT AND STEREO



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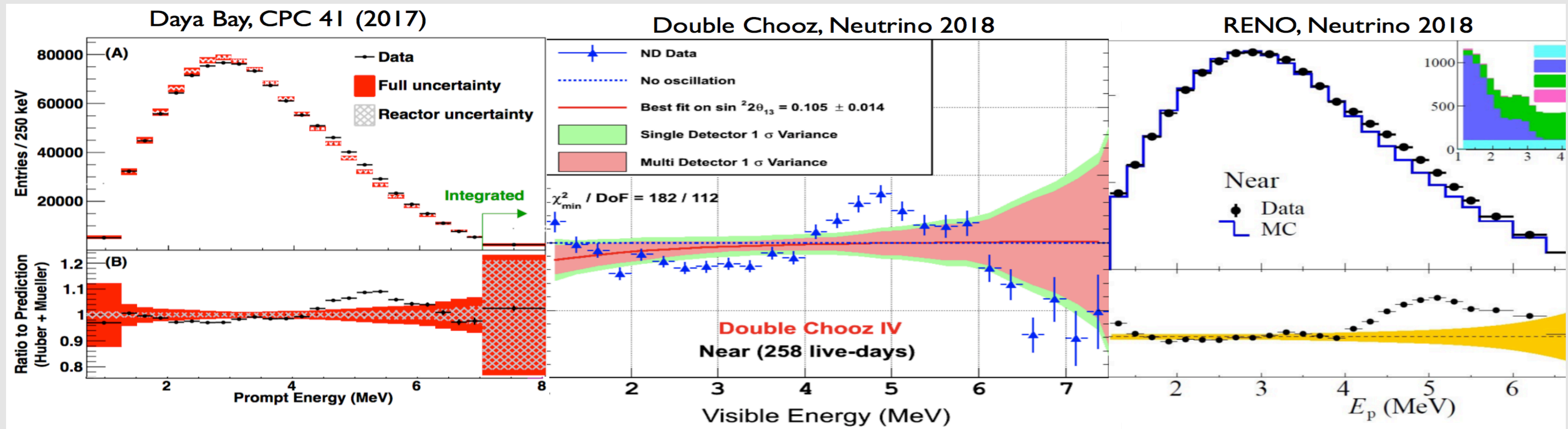
[arXiv:2107.03371](https://arxiv.org/abs/2107.03371)



Wright
Laboratory

NEUTRINO SPECTRUM MEASUREMENTS FROM POWER REACTORS

- ▶ Spectrum models don't match experimental data in low enriched uranium (LEU) power reactors
- ▶ Poor fit overall to leading reactor models (Huber/Mueller).
- ▶ 'Bump' in 4-6 MeV (prompt energy) range
- ▶ Neutrino events come from a mixture of fissile isotopes: ^{235}U , ^{238}U , ^{239}Pu , ^{241}Pu
- ▶ Need new reactor data to clarify source of deviations



WHY A JOINT MEASUREMENT

- ▶ Reactor models do not provide a sufficient prediction of the antineutrino spectrum
- ▶ PROSPECT and STEREO are the leading measurements of the pure ^{235}U spectrum without significant contributions from other isotopes
- ▶ Both experiments' spectrum measurements are still statistics limited with relatively low systematic uncertainties
- ▶ By combining the measurements, we can increase the statistical power and produce a reference spectrum of ^{235}U for use by the community

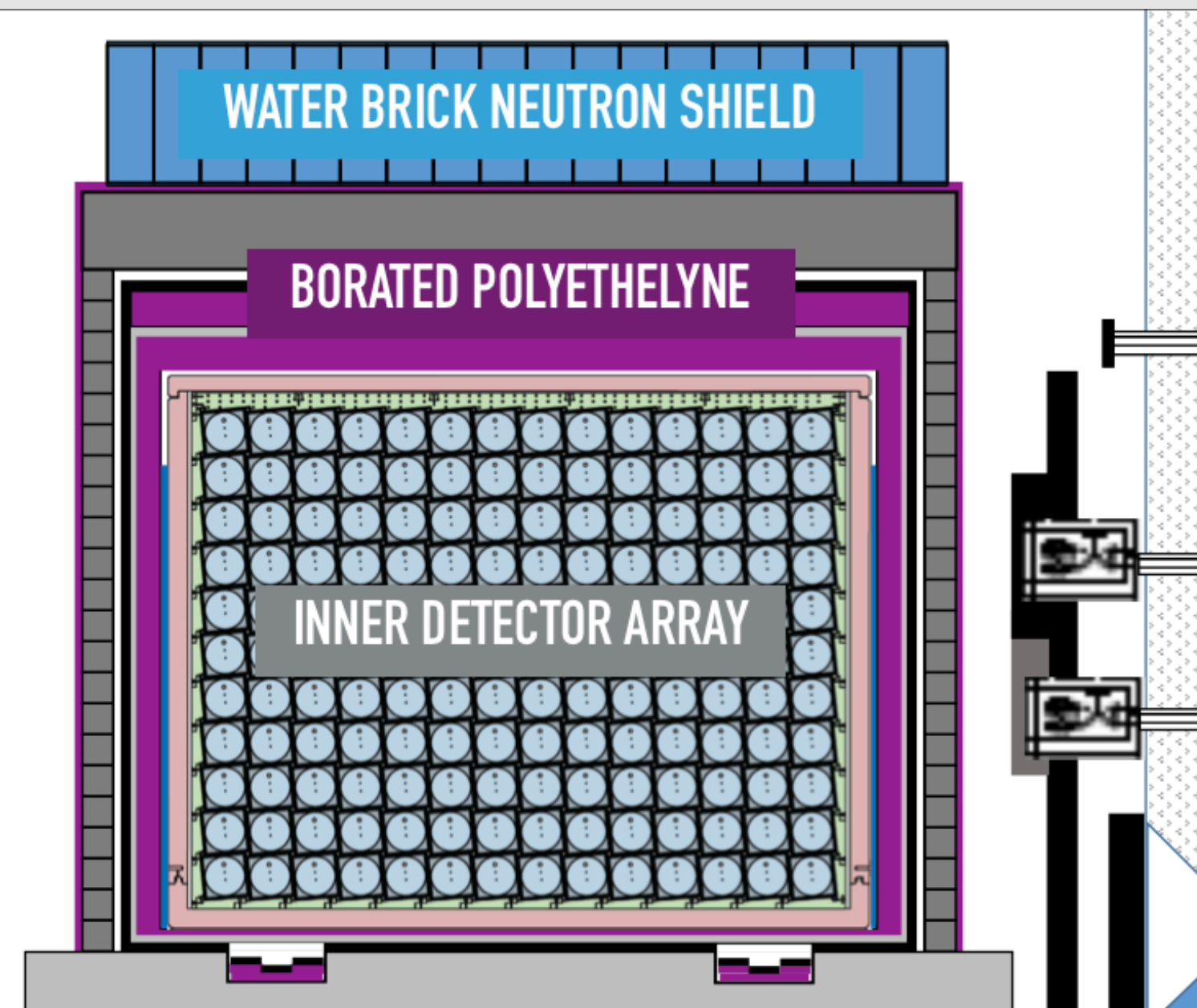
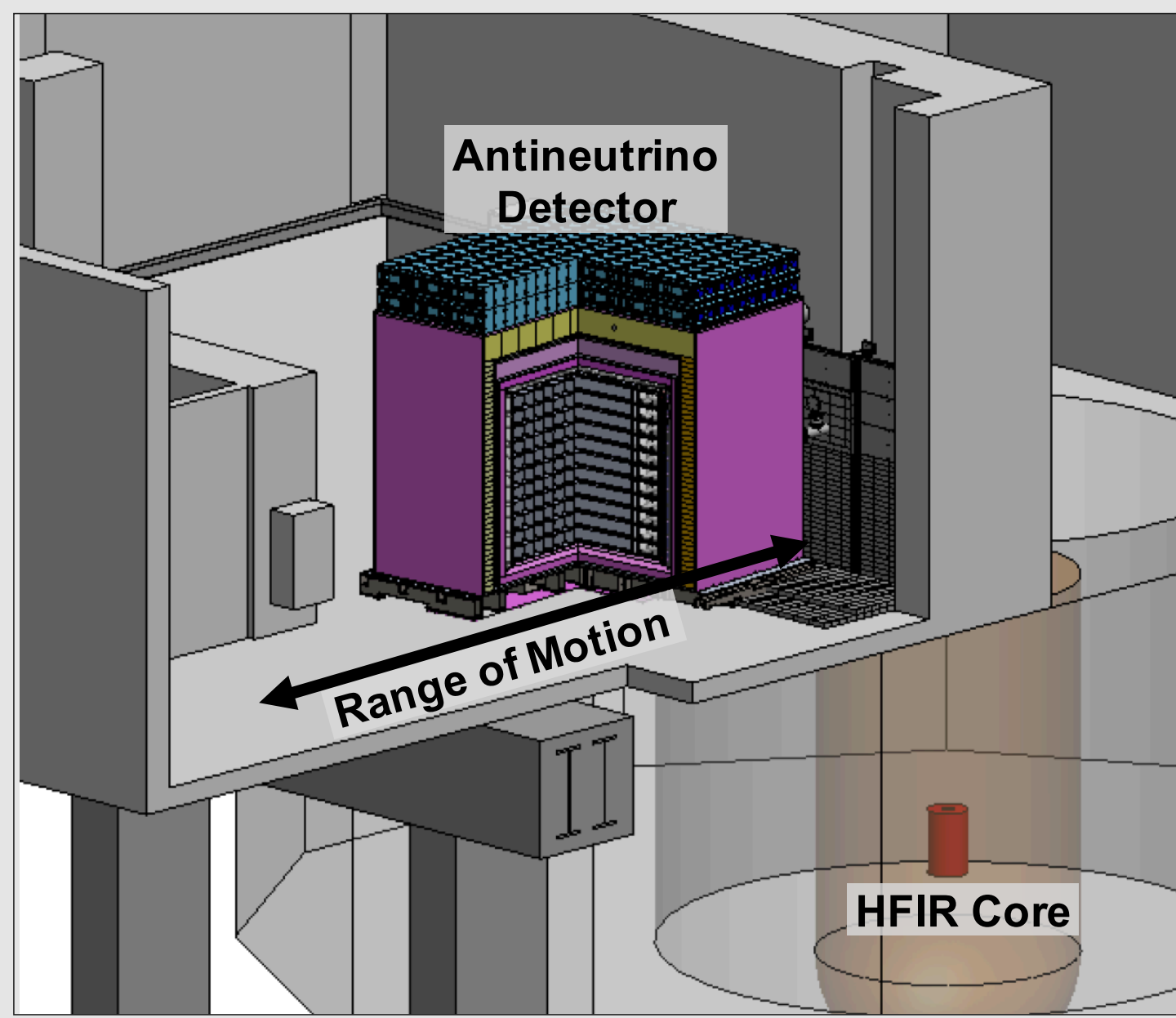
THE PROSPECT EXPERIMENT

▶ Experimental Site (HFIR, ORNL):

- ▶ 85 MW HEU reactor core with 46% duty cycle
- ▶ $>99\%$ of $\bar{\nu}_e$ flux from ^{235}U fissions

▶ Detector Design

- ▶ Segmented design for calibration access
- ▶ Optimized for background suppression
- ▶ Particle identification with pulse shape discrimination

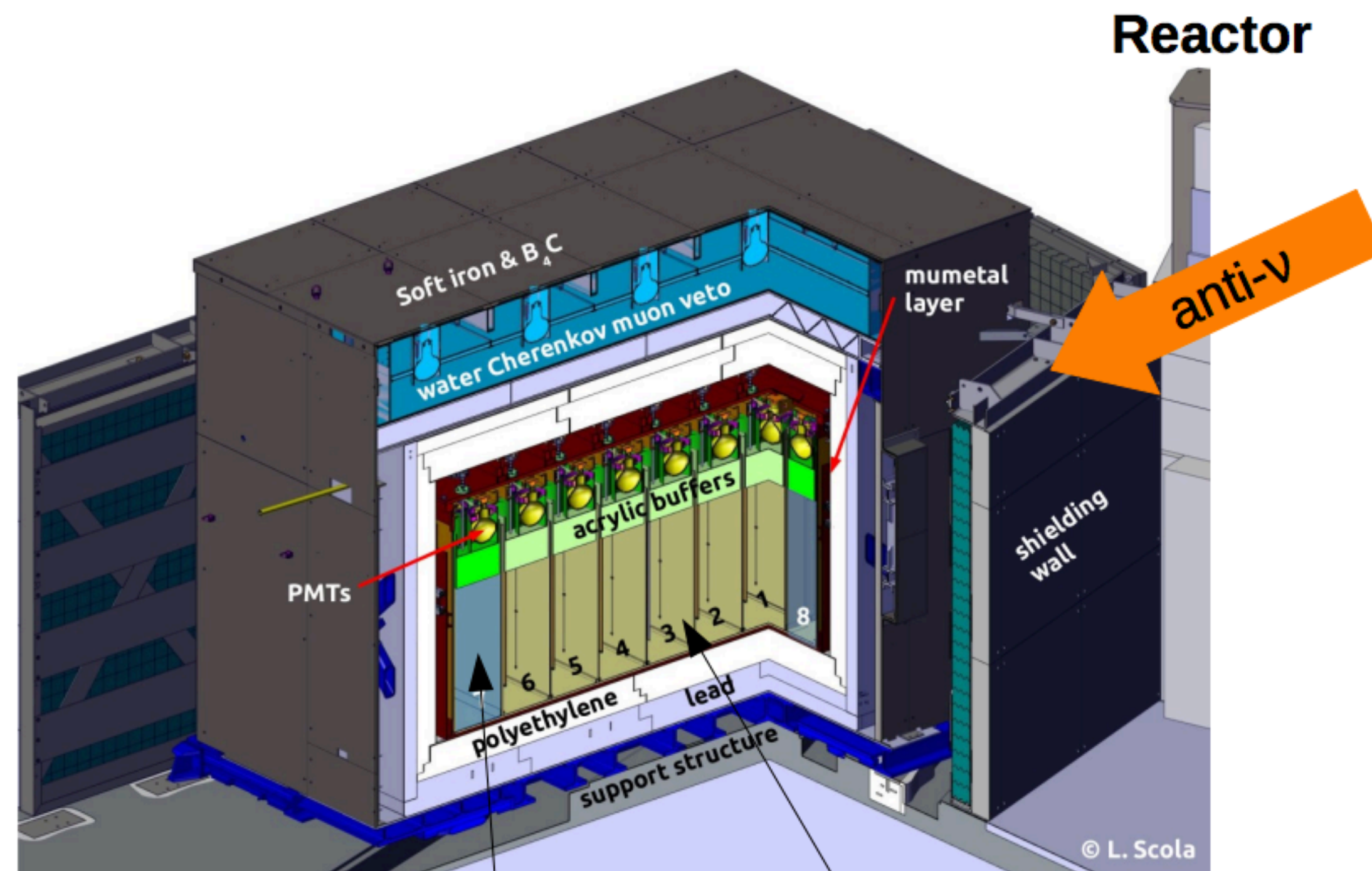


J. Ashenfelter et al., NIM A [2018.12.079](#)

<https://prospect.yale.edu/>

THE STEREO EXPERIMENT

- ▶ Experimental site (RHF, ILL):
 - ▶ 58 MW HEU reactor
 - ▶ Compact core
 - ▶ >99% of flux from ^{235}U fissions
- ▶ Detector Design:
 - ▶ 6 fiducial cells
 - ▶ Liq. Scintillator + Gd
 - ▶ Pulse shape discrimination



Gamma-Catcher: unloaded liquid scintillator **Target:** Gd-loaded liquid scintillator

[arxiv:2010.01876](https://arxiv.org/abs/2010.01876)

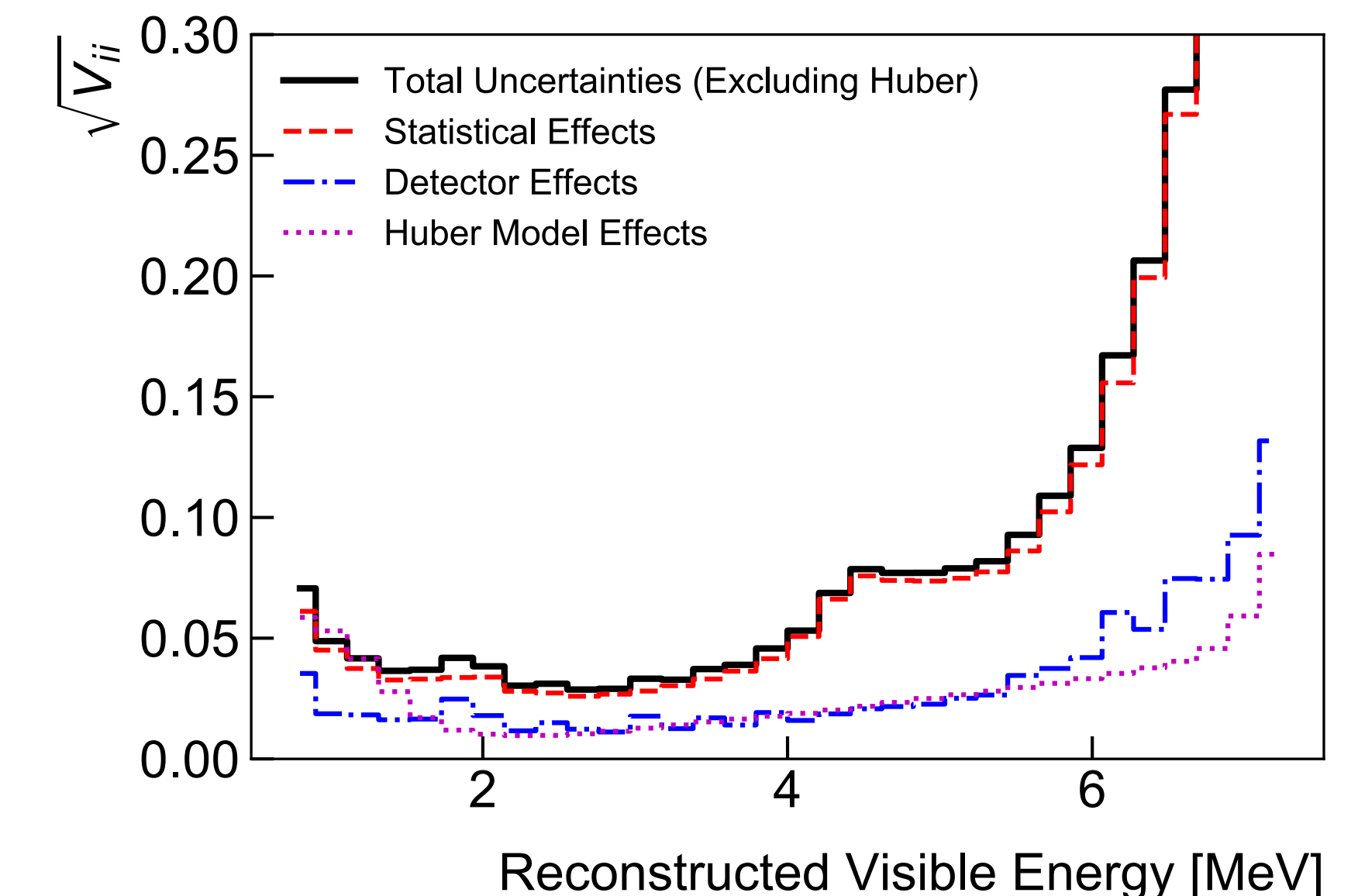
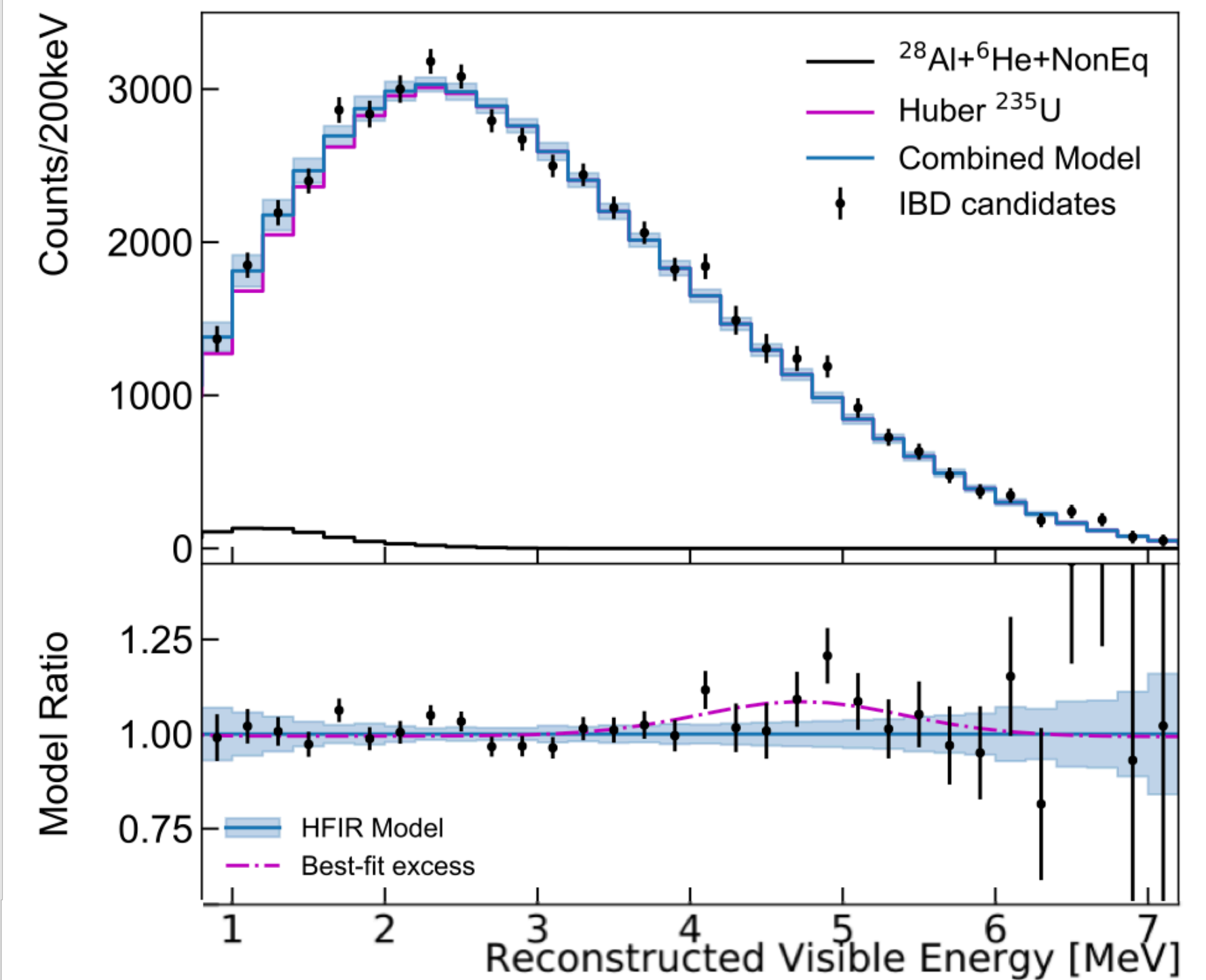
<https://www.stereo-experiment.org/>

PROSPECT PROMPT SPECTRUM

- ▶ 50560 +/- 406 IBD signal events
- ▶ Best fit bump size relative to Daya Bay: 84% +/- 39%
- ▶ Disfavor both 'No ^{235}U Contribution to' and 'Only ^{235}U Contributes to' LEU bump cases at $>2\sigma$
- ▶ Still statistics limited

[M. Andriamirado et al., Phys Rev D 103, 032001](#)

<https://prospect.yale.edu/>

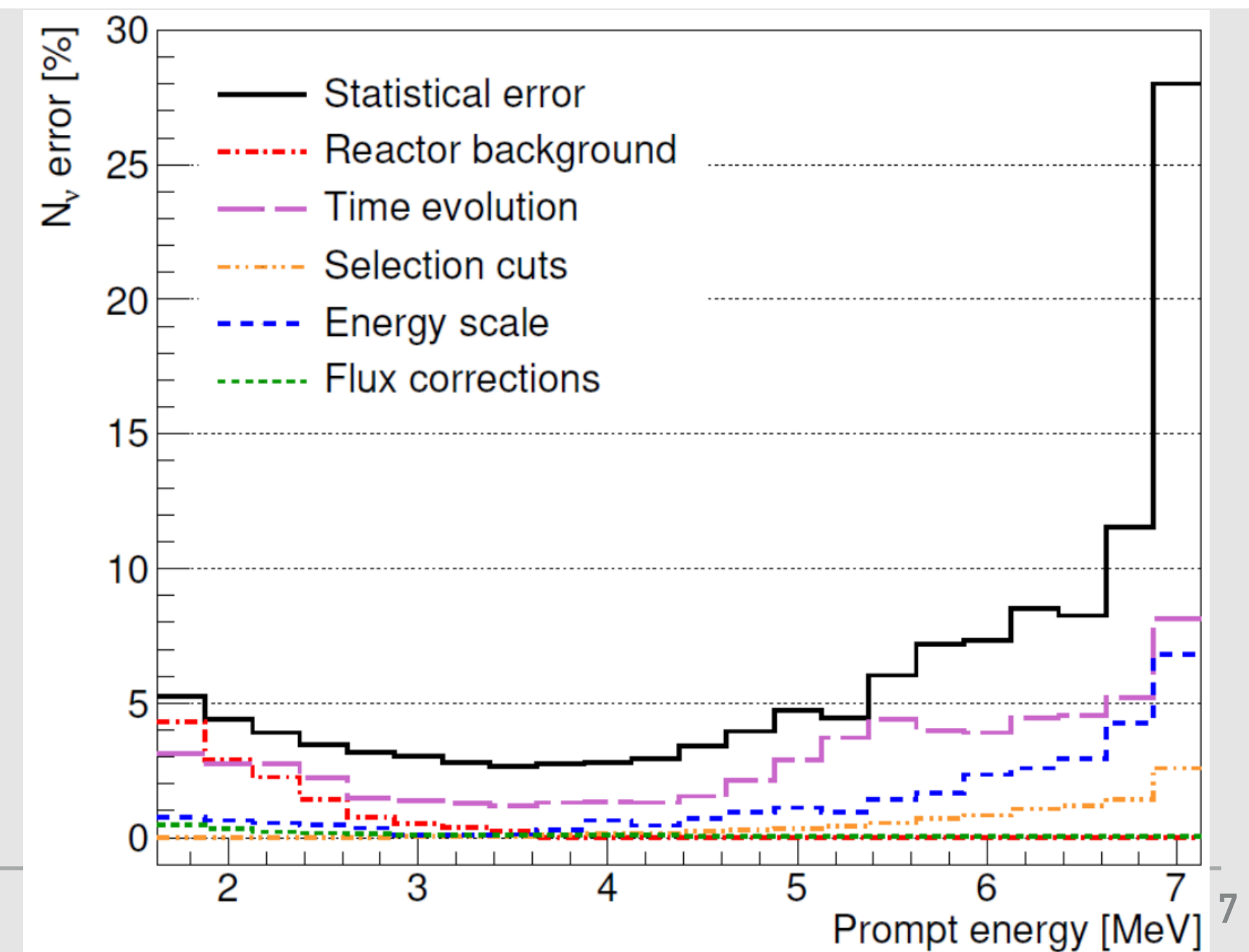
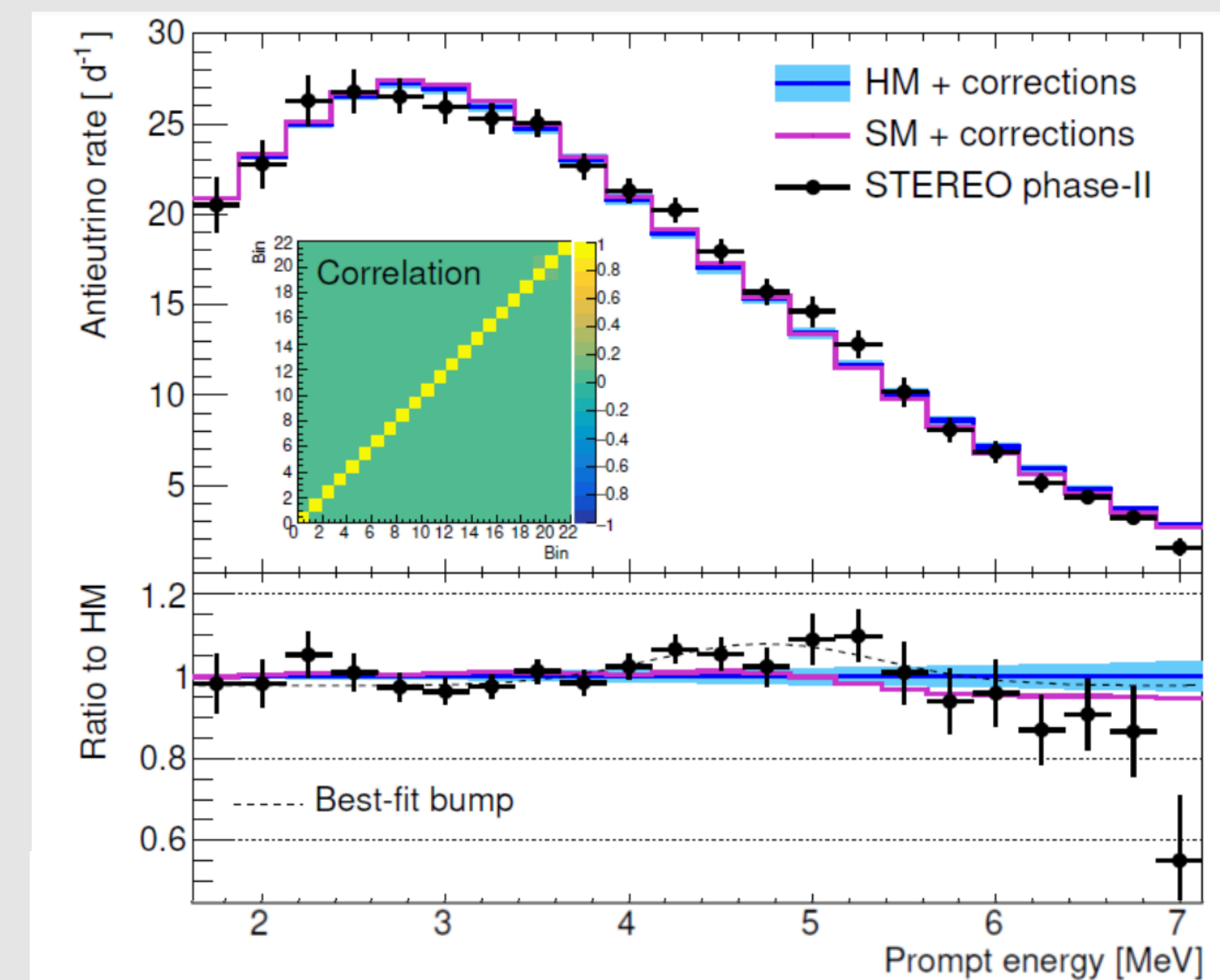


STEREO'S PROMPT SPECTRUM

- ▶ 43,000 Antineutrinos detected
- ▶ Significant bump observed in antineutrino energy: $A = 12.1 \pm 3.4 \%$ (3.5σ) of spectrum at peak
- ▶ Findings consistent with case of ^{235}U equally contributing to LEU bump
- ▶ Still statistics limited

[arxiv:2010.01876](https://arxiv.org/abs/2010.01876)

<https://www.stereo-experiment.org/>



PROMPT COMPATIBILITY

- ▶ Prompt comparison avoids uncertainties of filtered unfolding!
- ▶ Move one experiment's data into the prompt space of the other with unfiltered unfolding, then refolding with the other's response

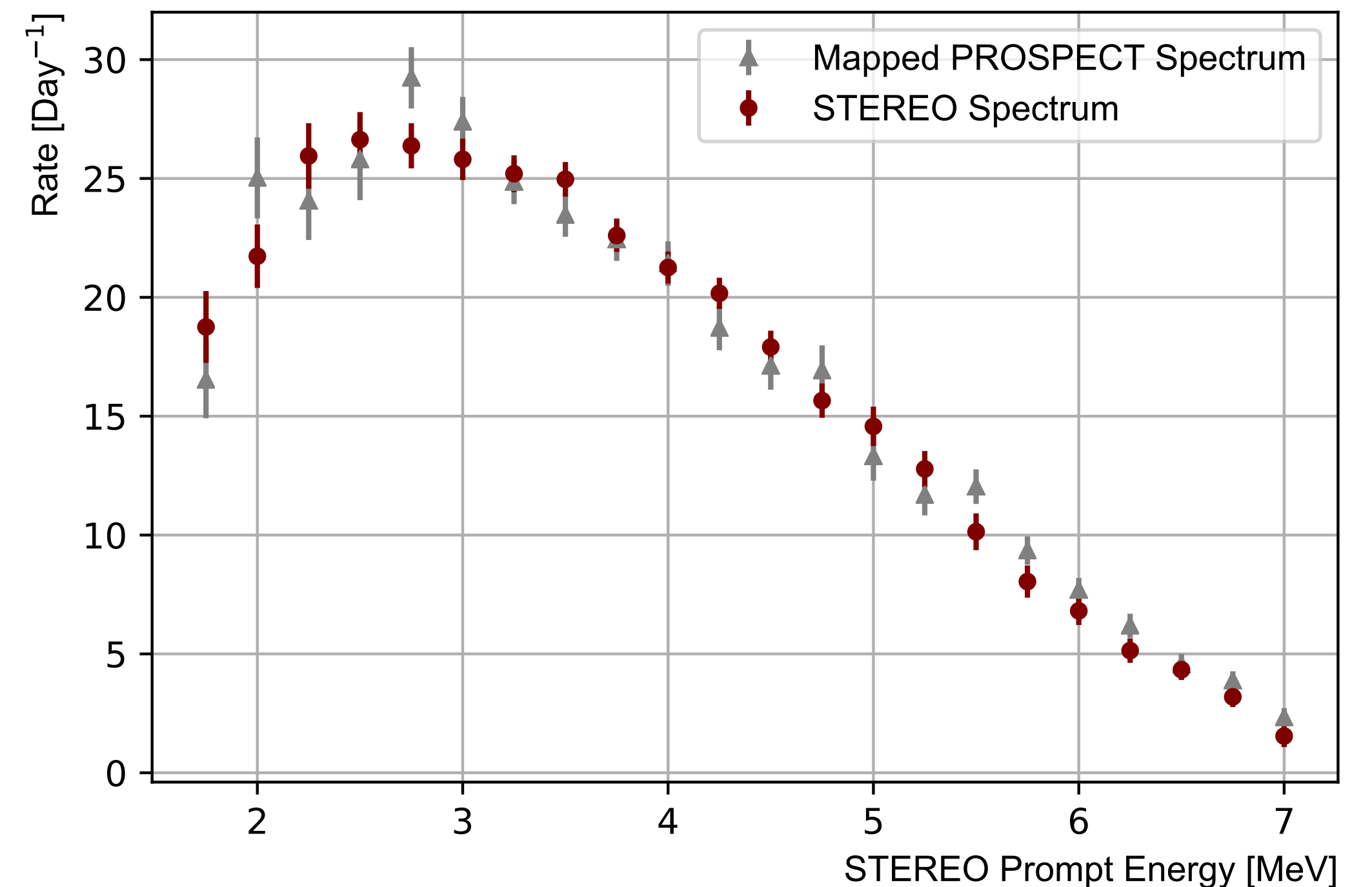
$$R_{map} = R_{STE} \cdot R_{PRO}^{-1}$$

$$M_{map} = R_{map} \cdot M_{PRO}$$

- ▶ Fit spectra with free floating normalization

$$\chi^2/ndf = 24.1/21$$

▶ Statistically Compatible Inputs



ANALYSIS METHOD: DATA UNFOLDING

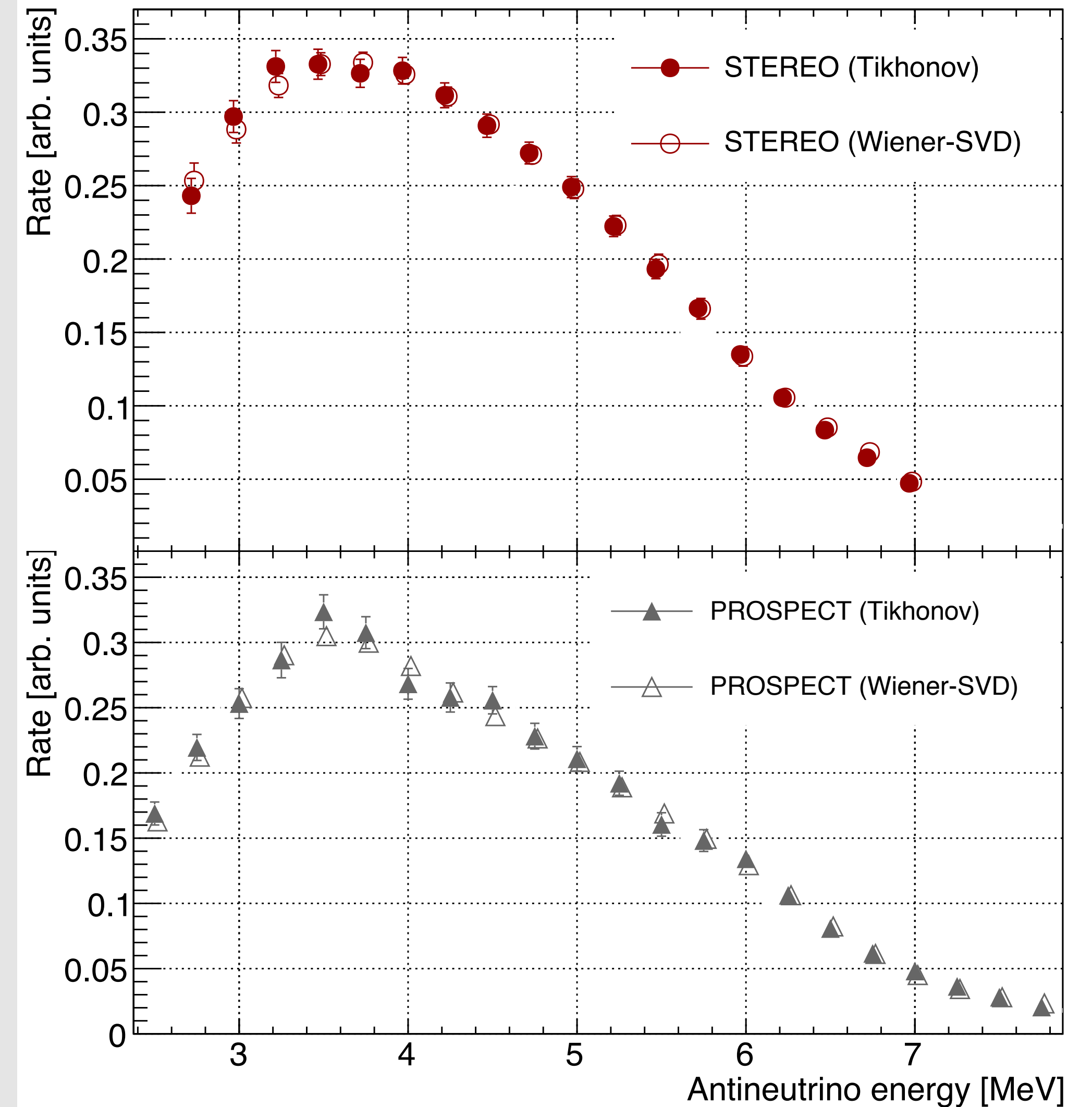
- ▶ To create a measurement independent of factors unique to each experiment, we must convert from the prompt space of each to true antineutrino energy space via 'unfolding'
- ▶ Ideal Case: $M = R \times S \Rightarrow S = R^{-1} \times M$
 - ▶ S = true signal in neutrino energy
 - ▶ R = response matrix
 - ▶ M = measured signal in prompt energy
- ▶ Realistically:
 - ▶ R not necessarily invertible
 - ▶ M has non-signal noise elements which are blown out of proportions by R^{-1}

COMPARISON OF FRAMEWORKS

► Framework Validation:

1. STEREO's Tikhonov regularization
2. PROSPECT's WienerSVD unfolding method

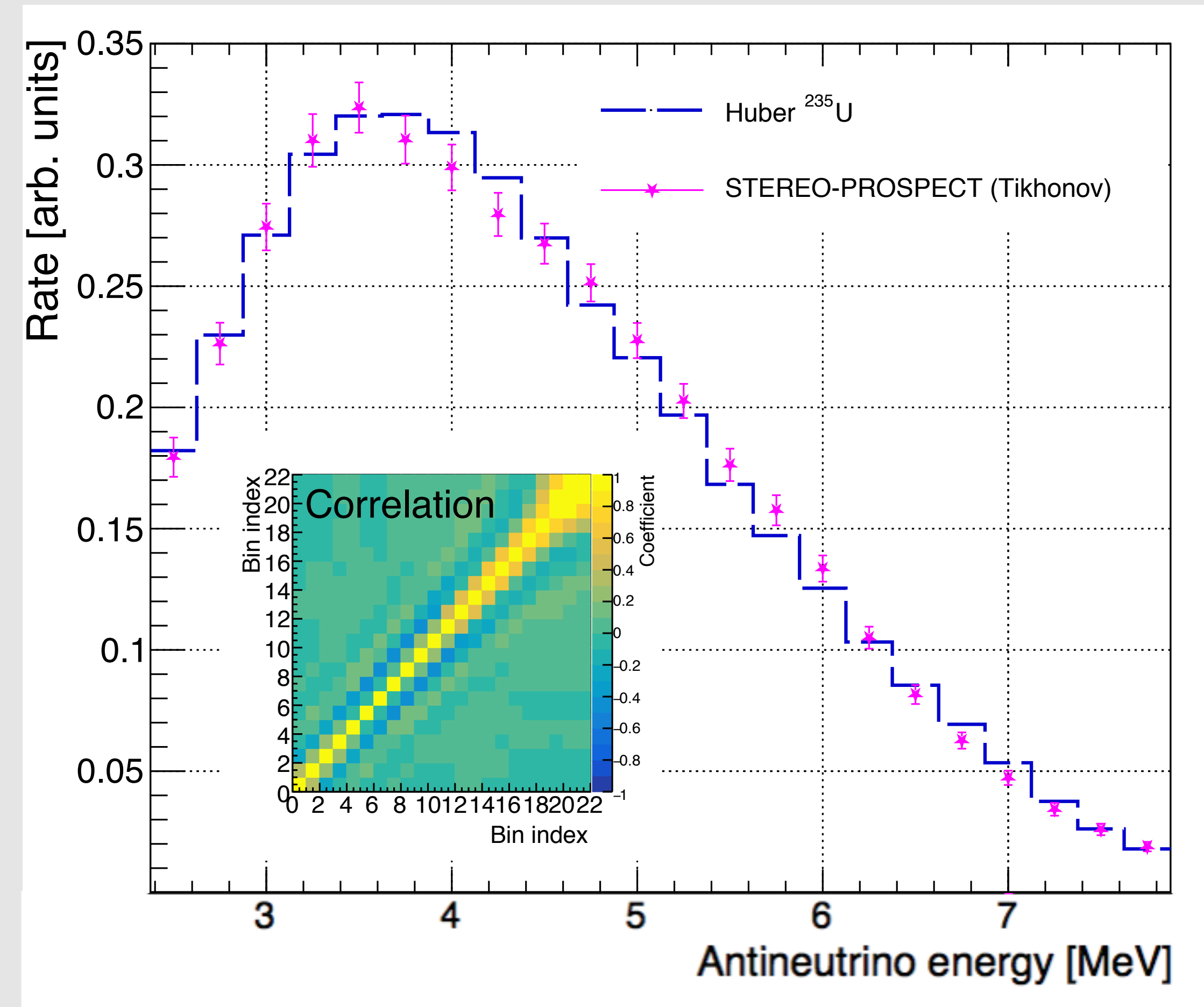
► Cross-checked and Consistent Results



UNFOLDED SPECTRUM

- ▶ Use the Tikhonov method to present result
- ▶ Using a free floating normalization, best fit to Huber model gives $\chi^2/ndf = 30.8/21$

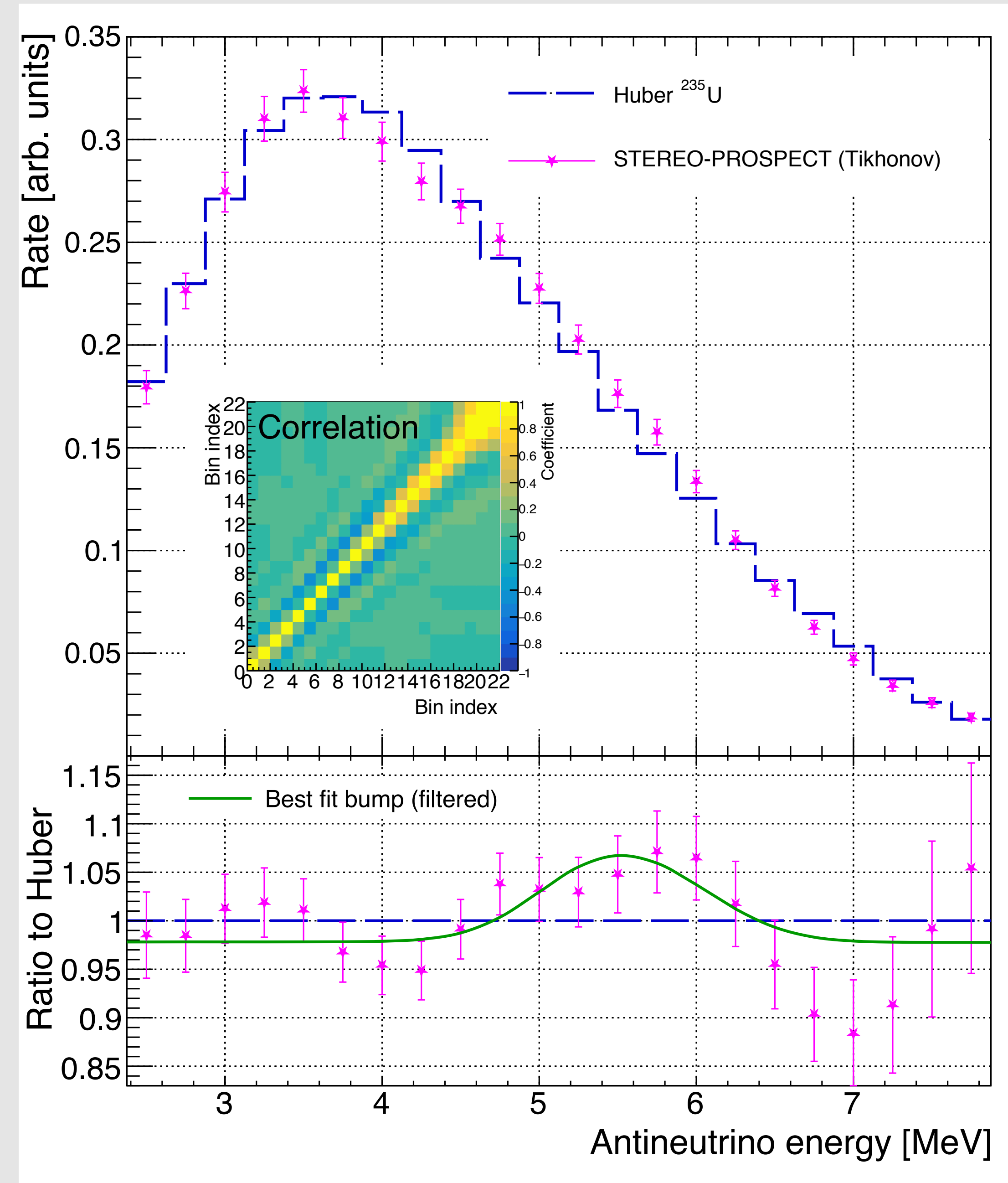
- ▶ Results available ([arXiv:2107.03371](https://arxiv.org/abs/2107.03371))
- ▶ Thorough supplemental materials, including filter matrix
- ▶ Can be directly compared to ^{235}U model predictions



BUMP SEARCH

- ▶ Find an excess in the 5-6 MeV range
- ▶ Fit a Gaussian with free amplitude, mu, and sigma values to the excess
- ▶ The addition of the best-fit Gaussian to the Huber model gives $\Delta\chi^2/\Delta ndf = 12.0/3$ (2.4σ significance)
- ▶ Consistent with the Daya Bay ^{235}U spectrum in shape-only comparison ($\chi^2/ndf = 21.0/21$)

- ▶ Find an excess with significance 2.4σ
- ▶ Consistent with ^{235}U equally contributing to LEU excess



CLOSING STATEMENTS

- ▶ New results posted to arxiv just last week!



[arXiv:2107.03371](https://arxiv.org/abs/2107.03371)

- ▶ PROSPECT and STEREO datasets found to be statistically compatible
- ▶ PROSPECT and STEREO have successfully combined their separately measured high precision ^{235}U spectra
- ▶ The publication of the jointly unfolded result includes filter matrix for comparing to ^{235}U antineutrino models, can be used as a reference spectrum by community
- ▶ Find an excess with 2.4σ significance in the 5-6 MeV energy range



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15 Institutions, 70 collaborators

