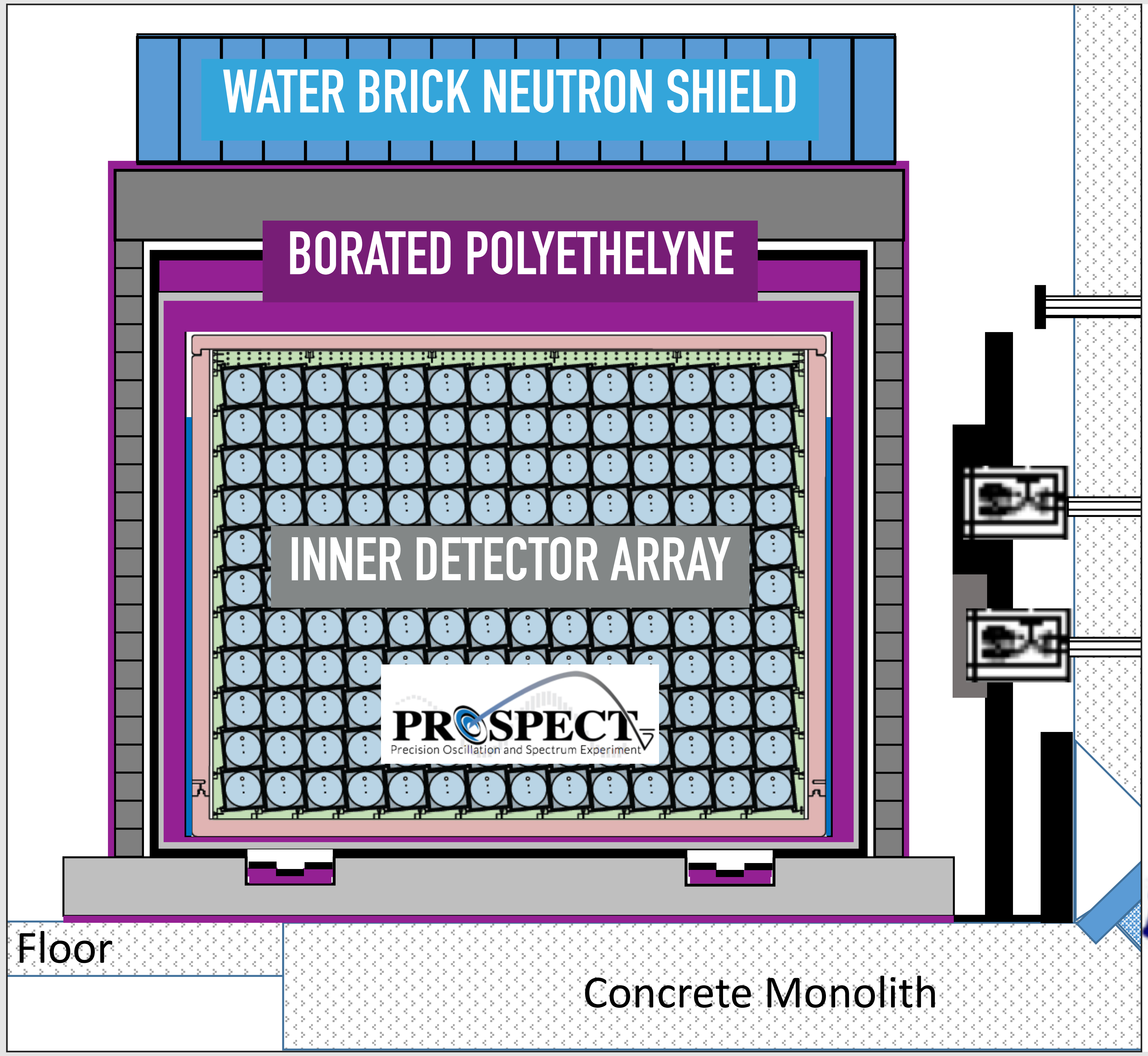
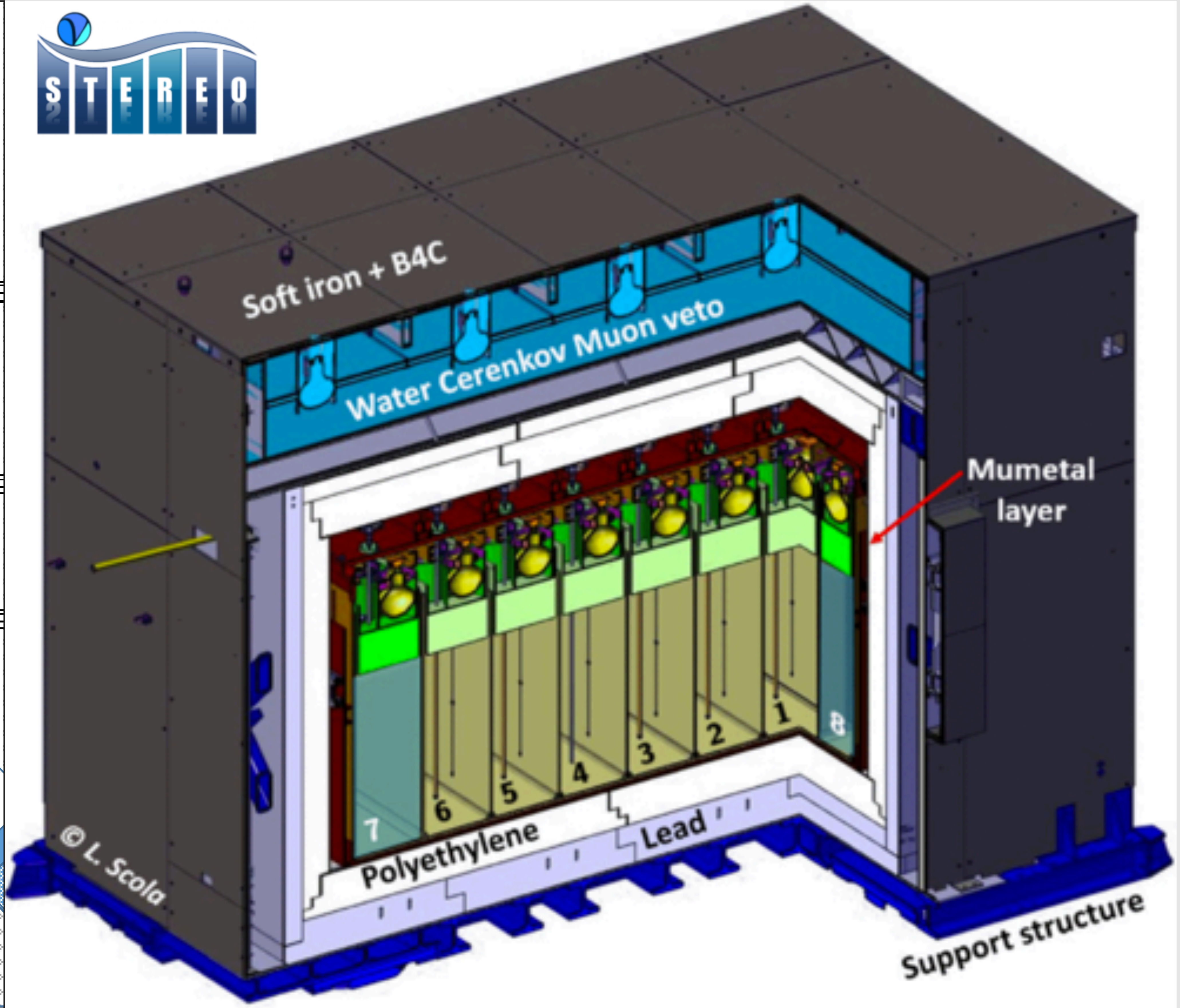
JOINT MEASUREMENT OF THE ^{235}U ANTINEUTRINO ENERGY SPECTRUM BY PROSPECT AND STEREO



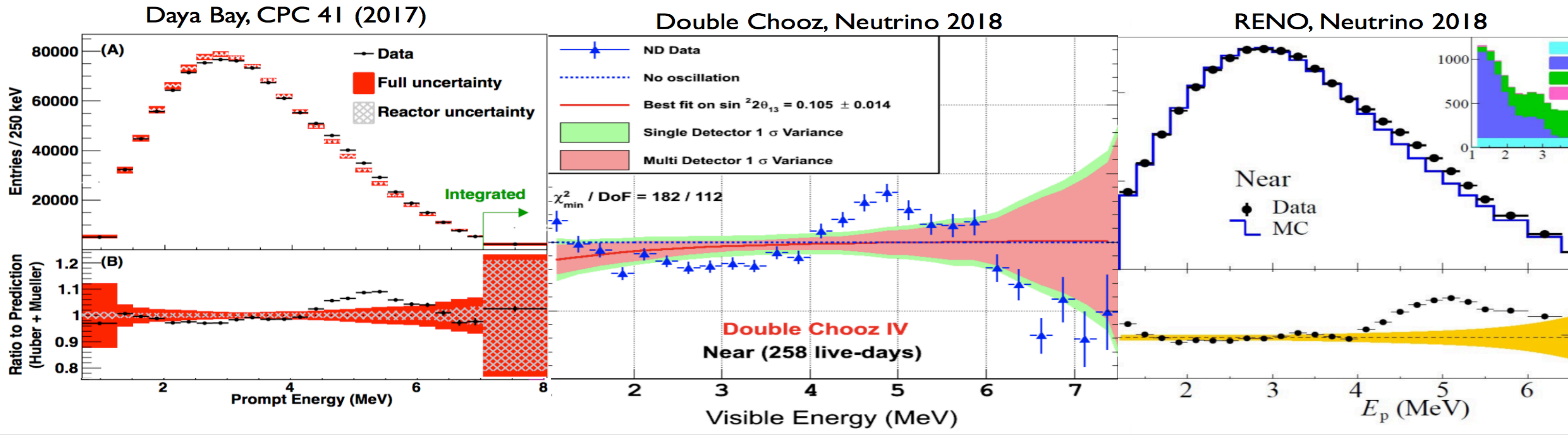


BEN FOUST
YALE UNIVERSITY
ON BEHALF OF THE PROSPECT COLLABORATION

Wright Laboratory

NEUTRINO SPECTRUM MEASUREMENTS FROM POWER REACTORS

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

GOALS OF THE JOINT ANALYSIS

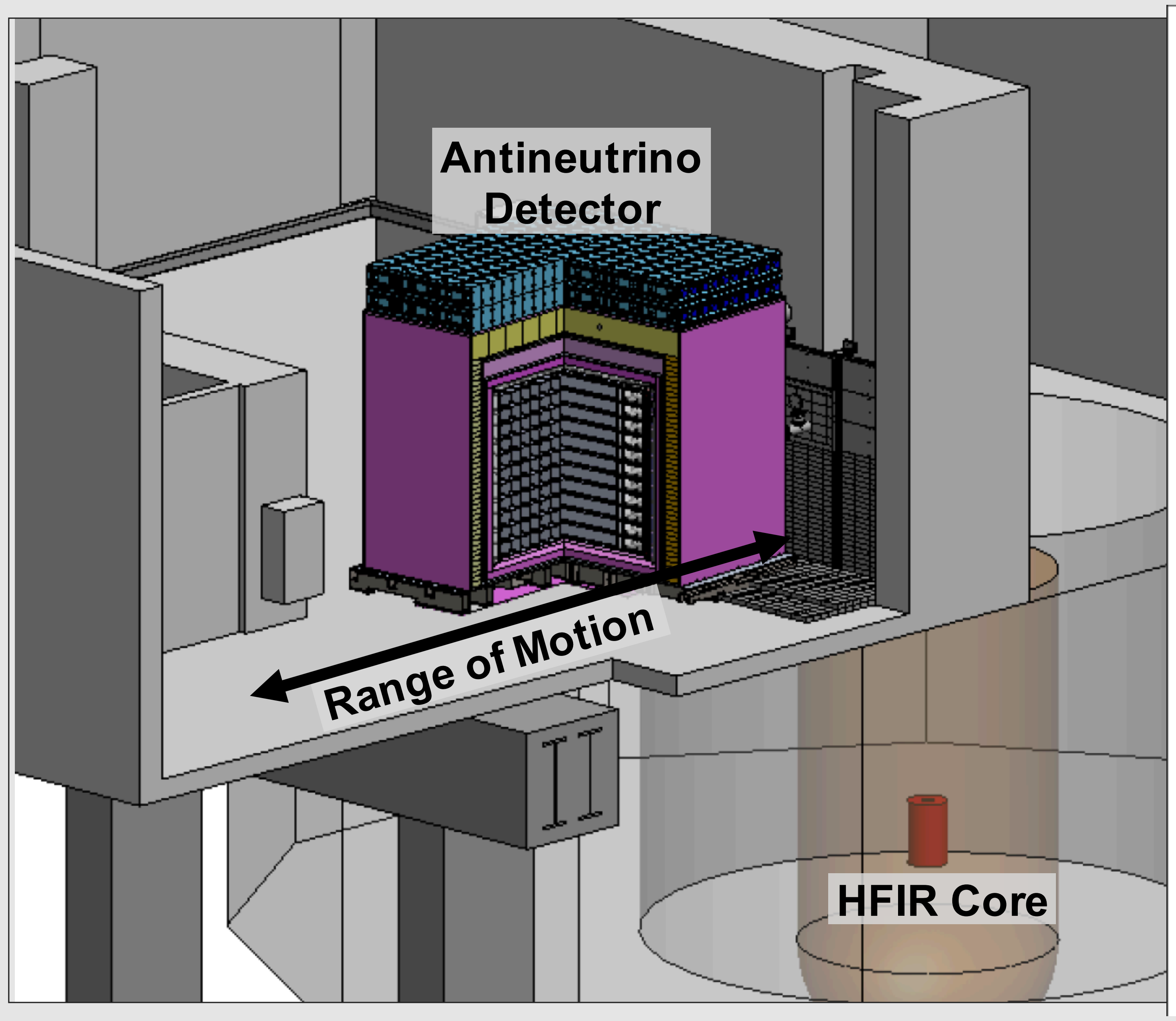
- Demonstrate Compatibility - We must show that the two experiments have measurements that are consistent with each other, and quantify their compatibility

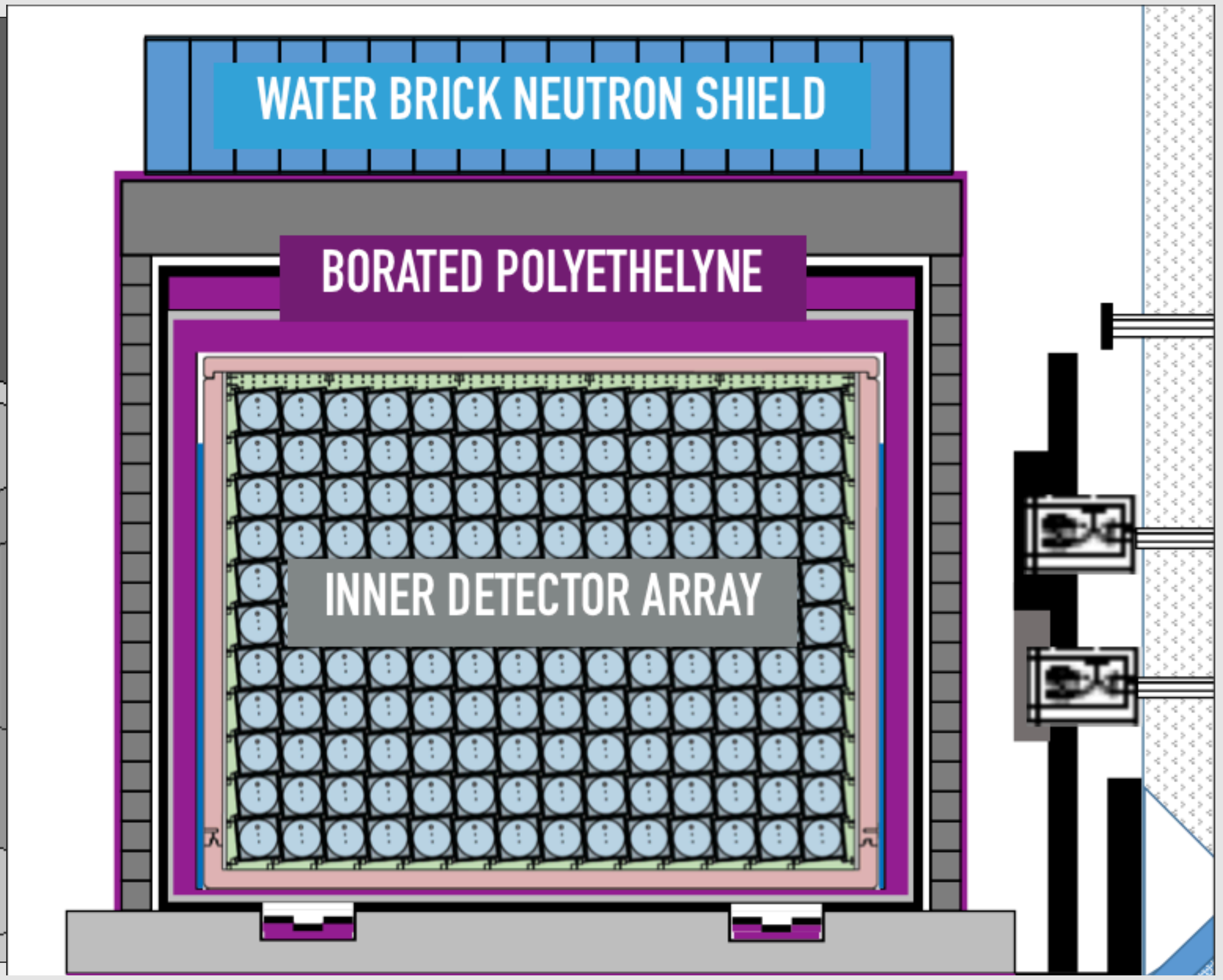
- Provide ^{235}U Antineutrino Spectrum - We must remove detector/site effects from the measurement by converting from the prompt space of each experiment to antineutrino energy, and provide a combined ^{235}U spectrum for reference by the community

- Compare Joint Spectrum to Model and Estimate Excess - We must quantify how the joint measurement compares to leading reactor model, and relate this to previous reactor measurements

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



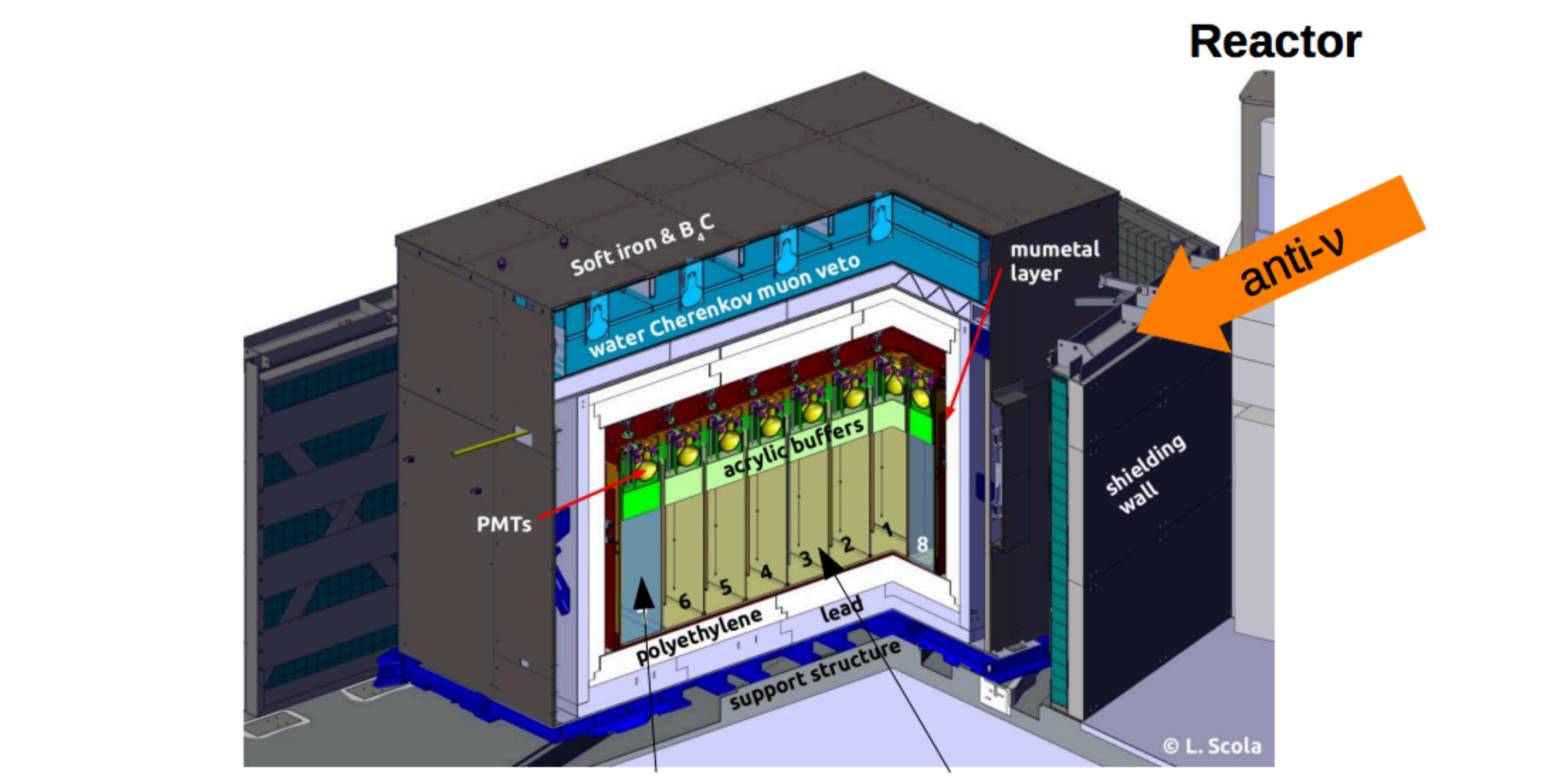


J. Ashenfelter et al., NIM A 2018.12.079

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



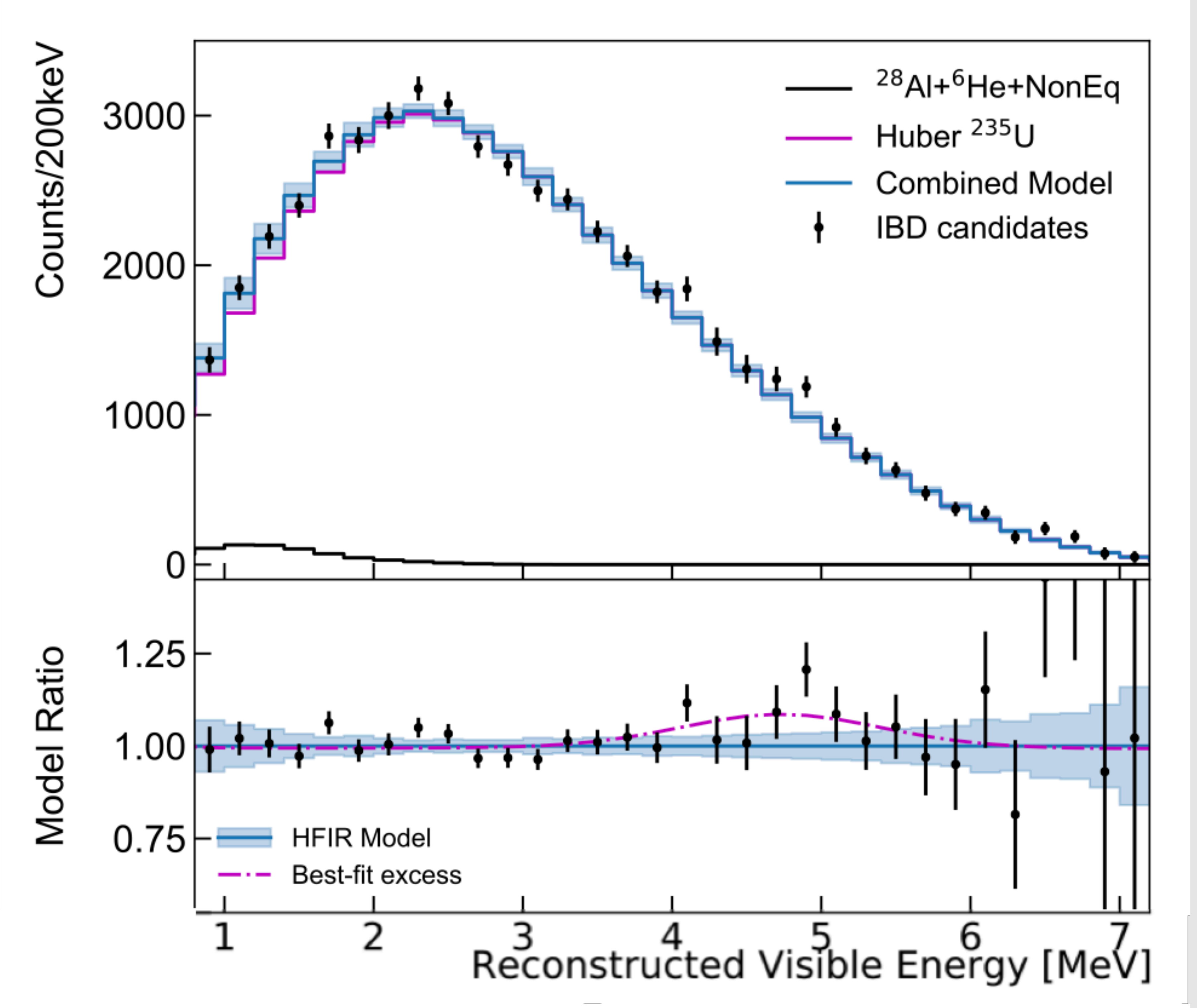
Gamma-Catcher: unloaded liquid scintillator **Target**: Gd-loaded liquid scintillator

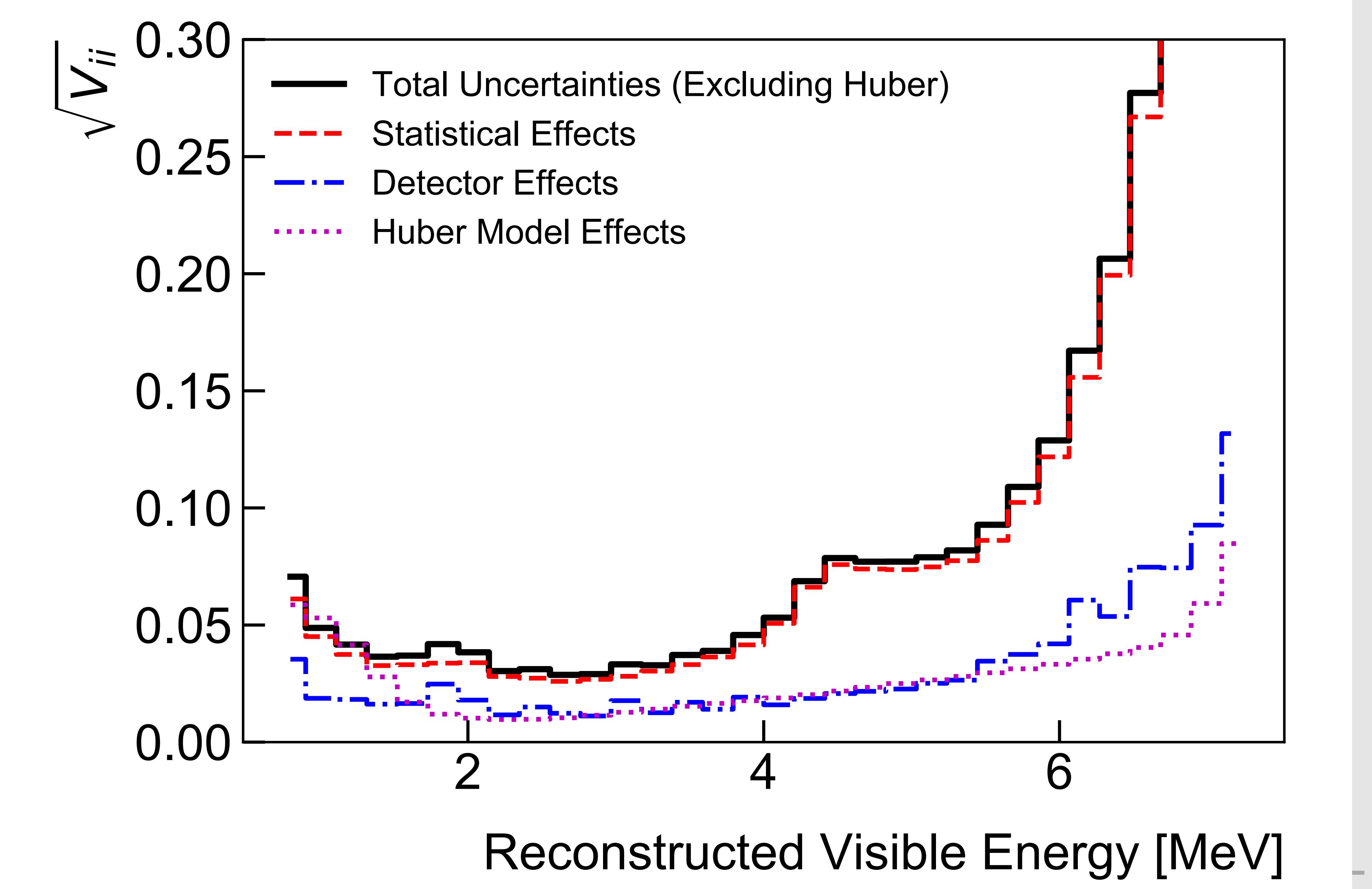
arxiv:2010.01876

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

PROSPECT PROMPT SPECTRUM

- 50560 +/- 406 IBD signal events
- S:B of 1.4:1 in signal energy range (0.8-7.2 MeV)
- Best fit bump size relative to Daya Bay: 84% +/- 39%
- Disfavor both 'No ^{235}U Contribution' and 'Only ^{235}U Contributes' LEU bump cases at $>2\sigma$
- Still statistics limited





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

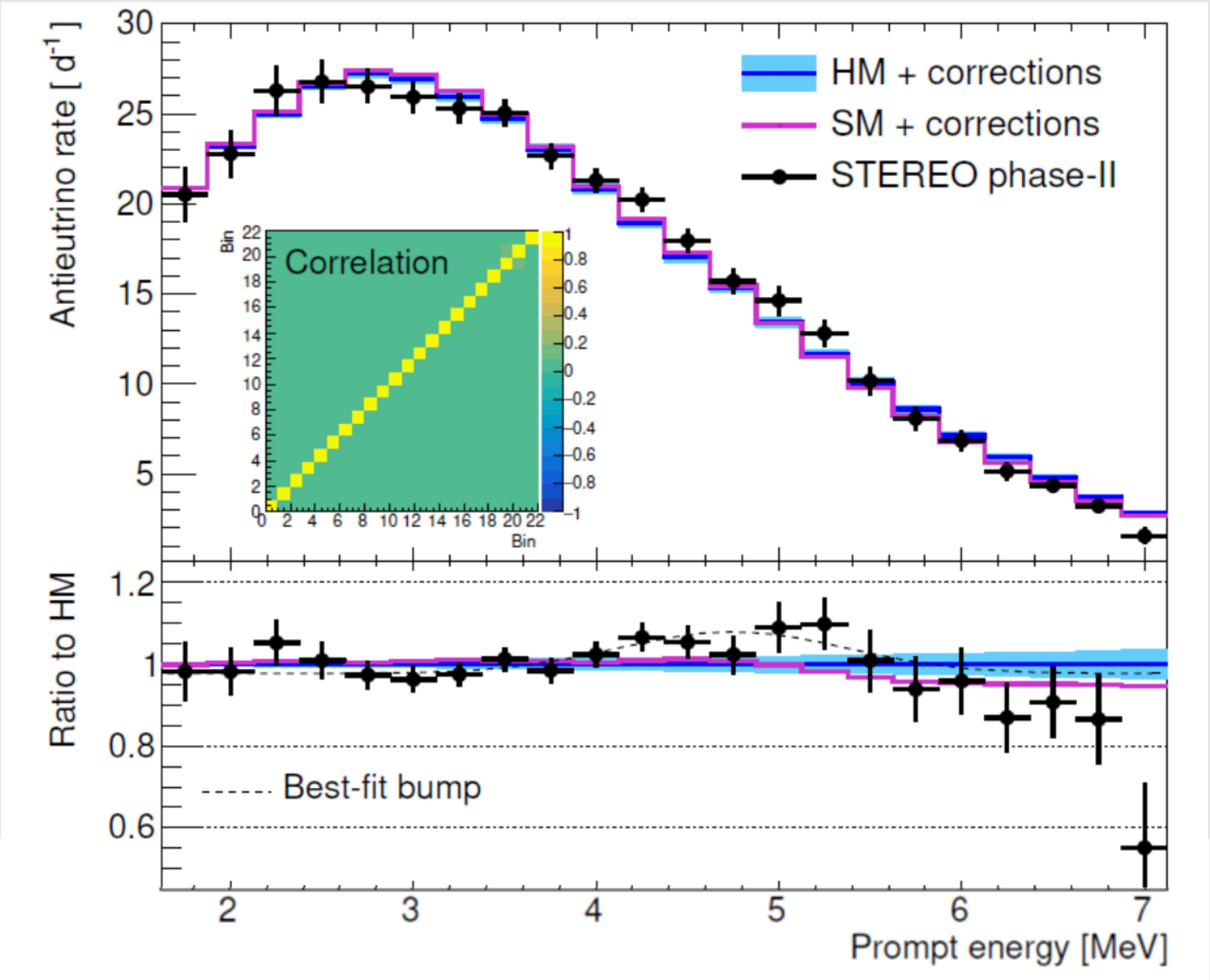
https://prospect.yale.edu/

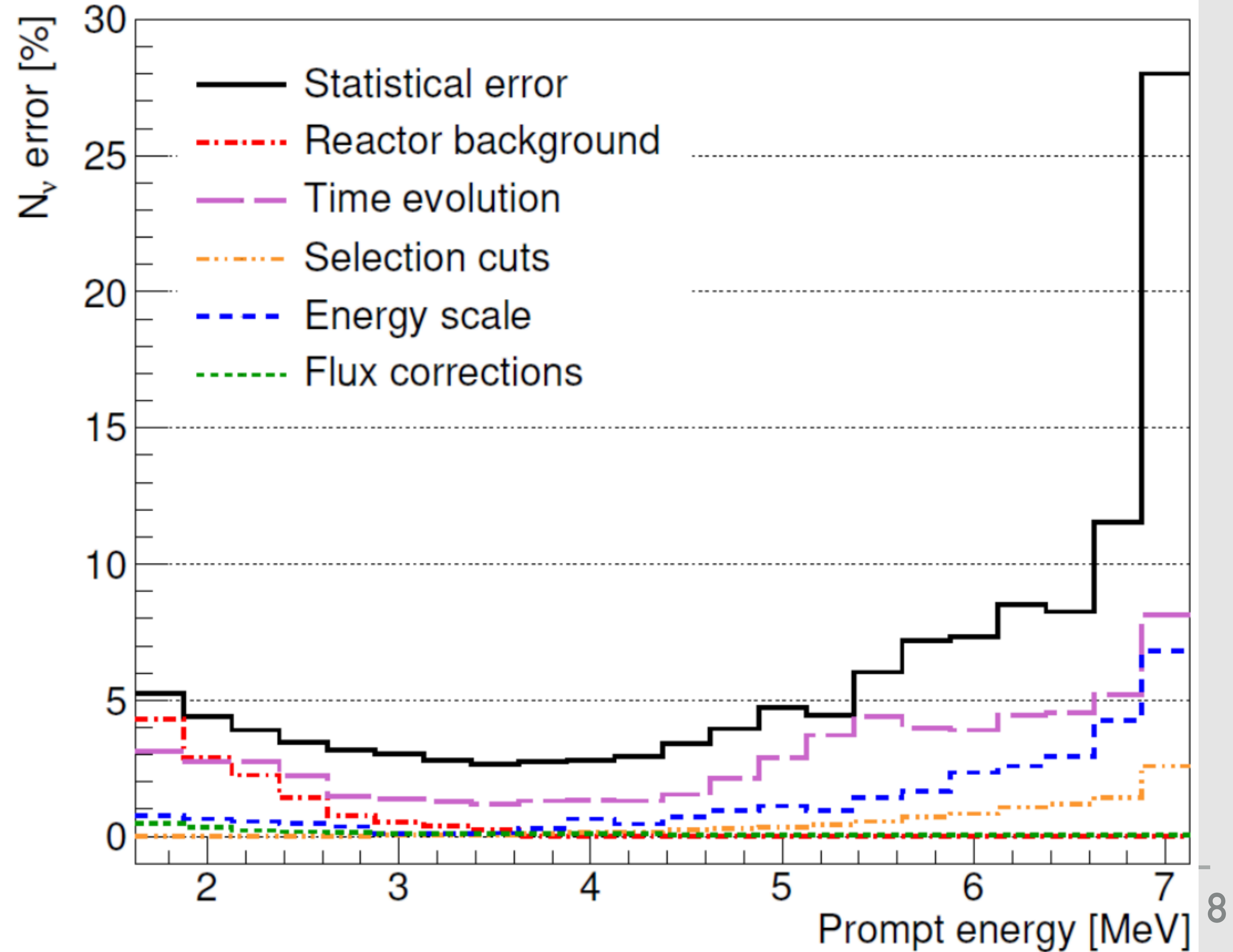
STEREO'S PROMPT SPECTRUM

- 43,000 Antineutrinos detected
- Significant bump observed in antineutrino energy: $A = 12.1 \pm 3.4\,\%$ (3.5σ) of spectrum at peak
- Findings between all isotope equal contribution (~9%) and only ^{235}U contributes (~16%)
- Still statistics limited

[arxiv:2010.01876]

[https://www.stereo-experiment.org/]



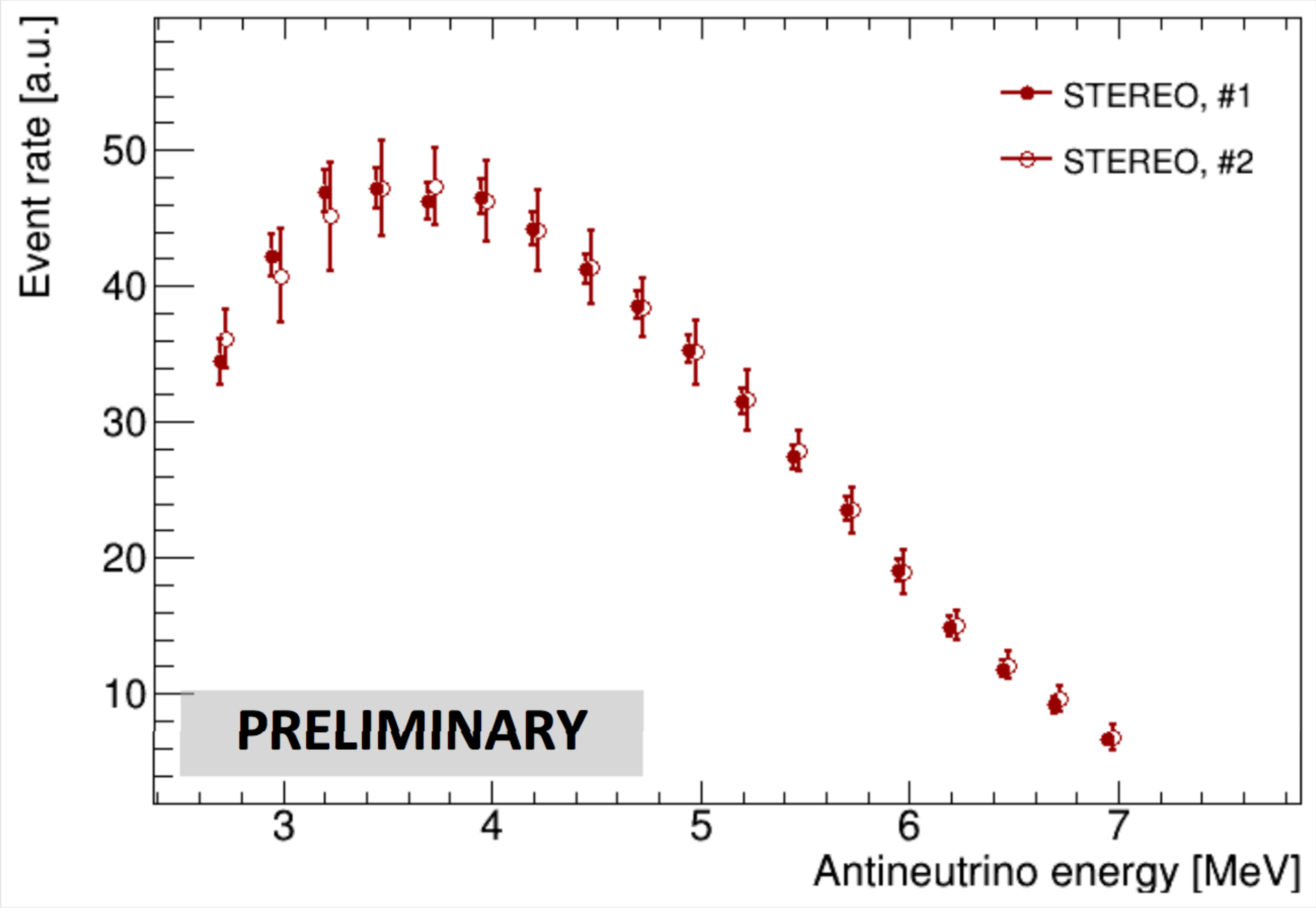


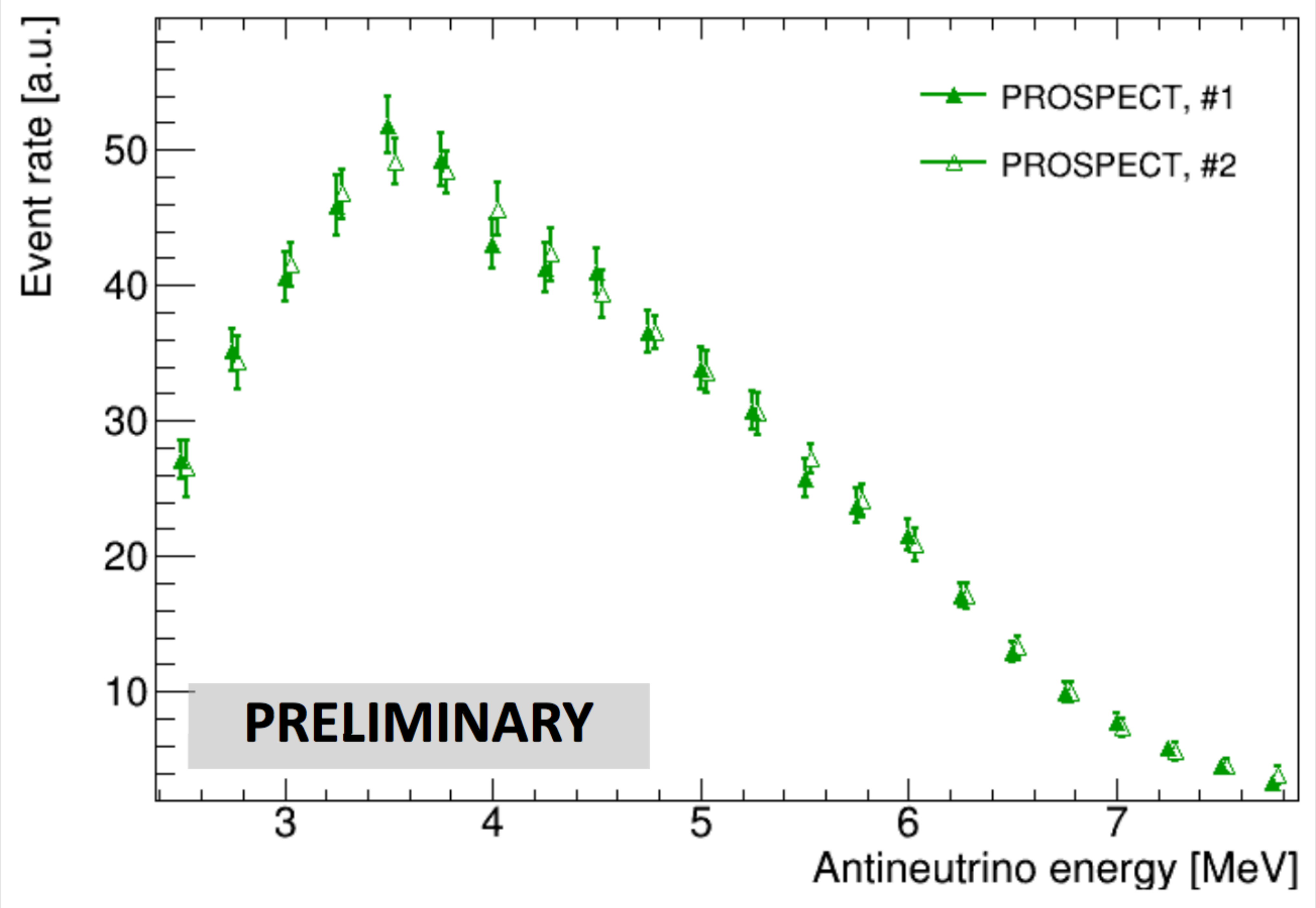
COMPARISON OF FRAMEWORKS

- Framework Validation:

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

Consistent Results





EXPERIMENTAL COMPATIBILITY

- Framework Validation:

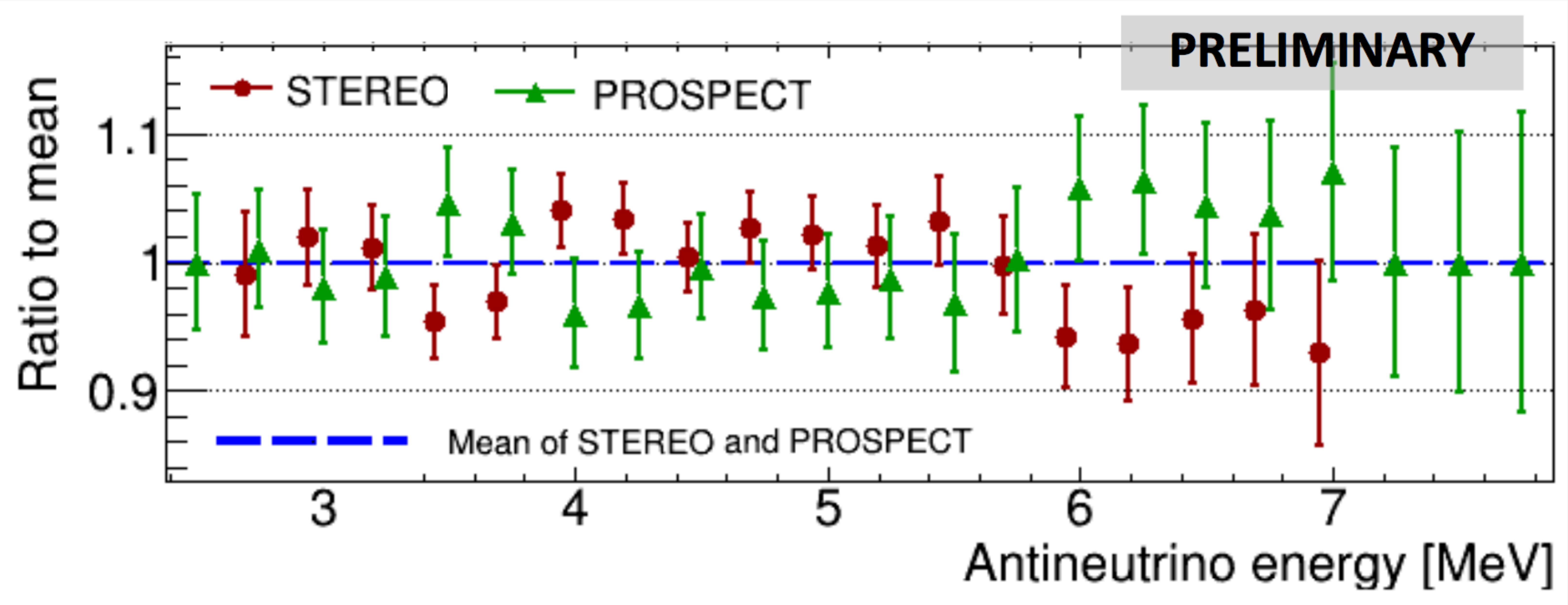
    1. STEREO's Tikhonov regularization

    2. PROSPECT's WienerSVD unfolding method

- Comparison of PROSPECT and STEREO Datasets:

    - $\chi^2 = 22.3/17$

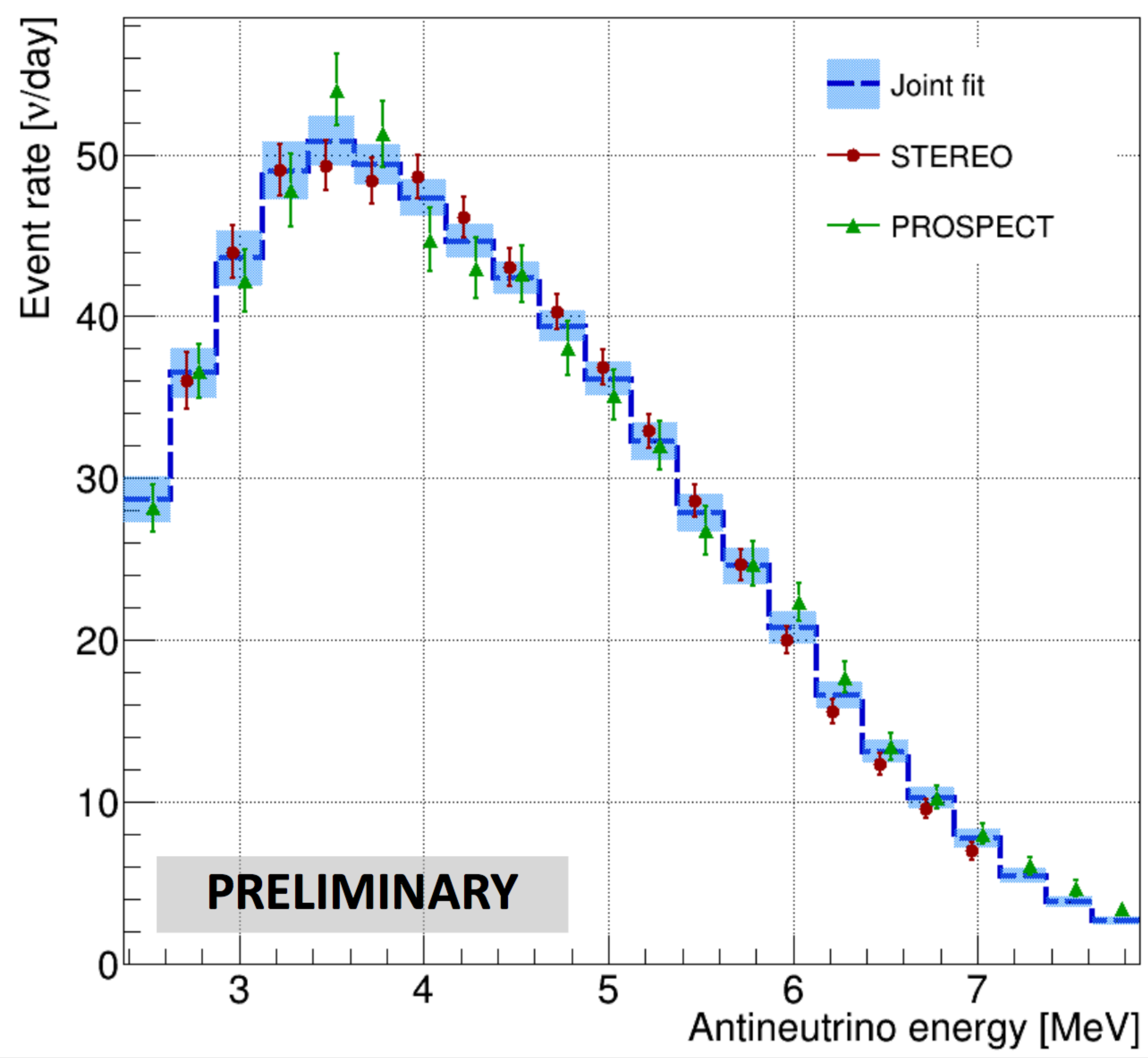
Statistically Compatible



UNFOLDED SPECTRUM

- Framework Validation:
    1. STEREO's Tikhonov regularization
    2. PROSPECT's WienerSVD unfolding method
- Comparison of PROSPECT and STEREO Datasets:
    - $\chi^2 = 22.3/17$
- Joint fit:

- To be published with smearing matrix
- Can be directly compared to ^{235}U model predictions



CLOSING STATEMENTS

- Modern measurements from HEU reactors can investigate the LEU spectrum anomaly
- PROSPECT and STEREO have separately measured the ^{235}U spectrum at high precision, and can be further improved by combining
- PROSPECT and STEREO datasets are found to be statistically compatible
- Finalized results coming soon!

PROSPECT TALKS AT APS

- Saturday, April 17
  - C. Roca: PROSPECT-II Detector Upgrade Design and Expanded Physics
  - J. Gaison: Joint Analysis of the Daya Bay and PROSPECT Spectra
  - X. Lu: PROSPECT-II Calibration System
  - B. Heffron: Machine Learning Analysis for PROSPECT
- Tuesday, April 20
  - C. Cappiello: Cosmic Ray Boosted DM at PROSPECT Theory
  - M. Andriamirado: Cosmic Ray Boosted DM at PROSPECT Analysis
  - J. Palomino: PROSPECT Latest Results
  - X. Zhang: Improving PROSPECT Neutrino Measurements


PROSPECT
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BACKUP SLIDES

SMEARING MATRIX

- The Ac, or smearing, matrix is used to apply the bias and smoothing effect from unfolding to a given spectrum in antineutrino energy
- This can and should be applied to models in true antineutrino energy to allow for an accurate comparison with the unfolded data
- The Ac matrix for the WienerSVD is:

$$D_{jnt} = \underbrace{C^{-1} V_C W_C V_C^T C}_{A_{C\,jnt}} (R^T (R R^T)^{-1} M_{jnt})$$

- For more information, please refer to arxiv:1705.03568