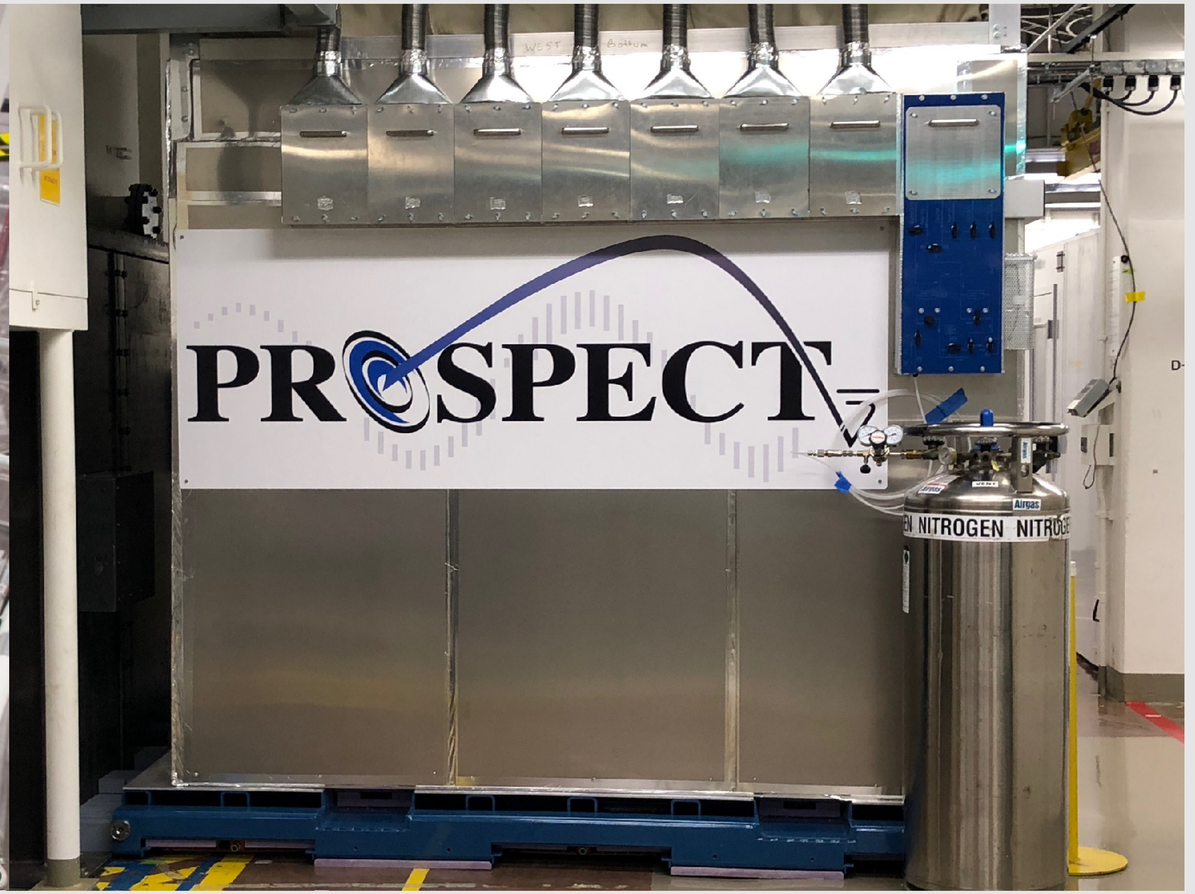
MEASUREMENT OF THE ^{235}U ANTINEUTRINO ENERGY SPECTRUM WITH PROSPECT



BEN FOUST
YALE UNIVERSITY
ON BEHALF OF THE PROSPECT COLLABORATION

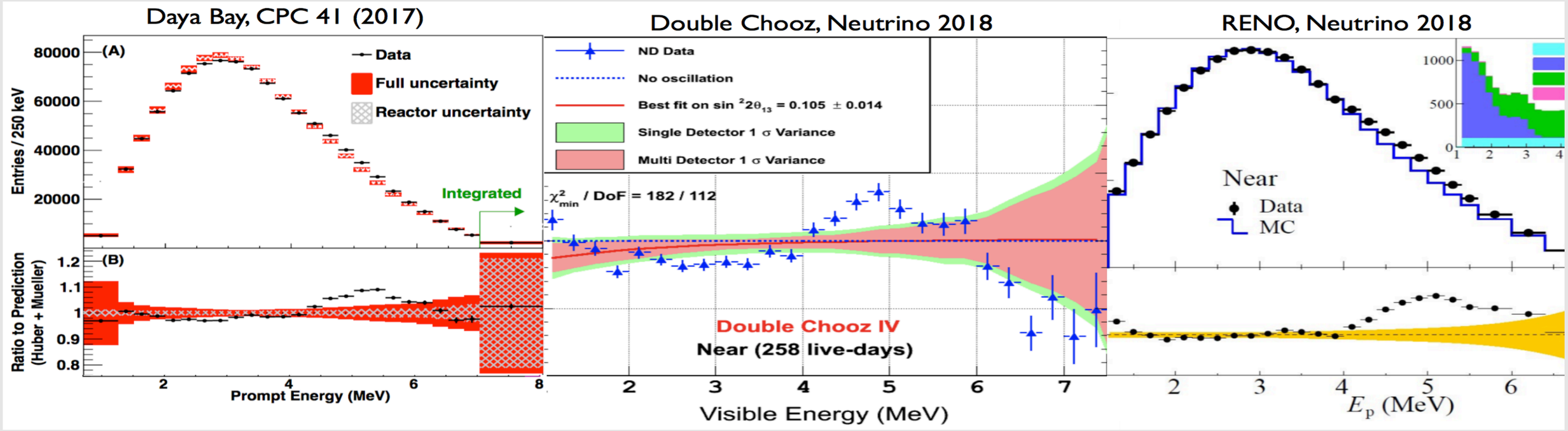
Wright Laboratory

PROSPECT TALKS AT DNP

- Latest Sterile Neutrino Analysis (E.G. 00001 J. Pallomino Gallo)
- Joint Analysis Prospects (E.G. 00003 J. Gaison)
- Future Analysis Improvements (E.G. 00004 X. Zhang/M. Mendenhall)
- Detector Upgrade (E.G. 00005 P. Mumm)
- Machine Learning Applications (E.G. 00007 A. Delgado)
- HFIR Background Characterization (E.G. 00009 B. Heffron, C. Gilbert, A. Galindo-Uribarri)
- Machine Learning Tagging of Ortho-Positronium (L.K. 00006 B. Heffron)
- Machine Learning for Event Reconstruction (S.N. 00002 X. Lu)

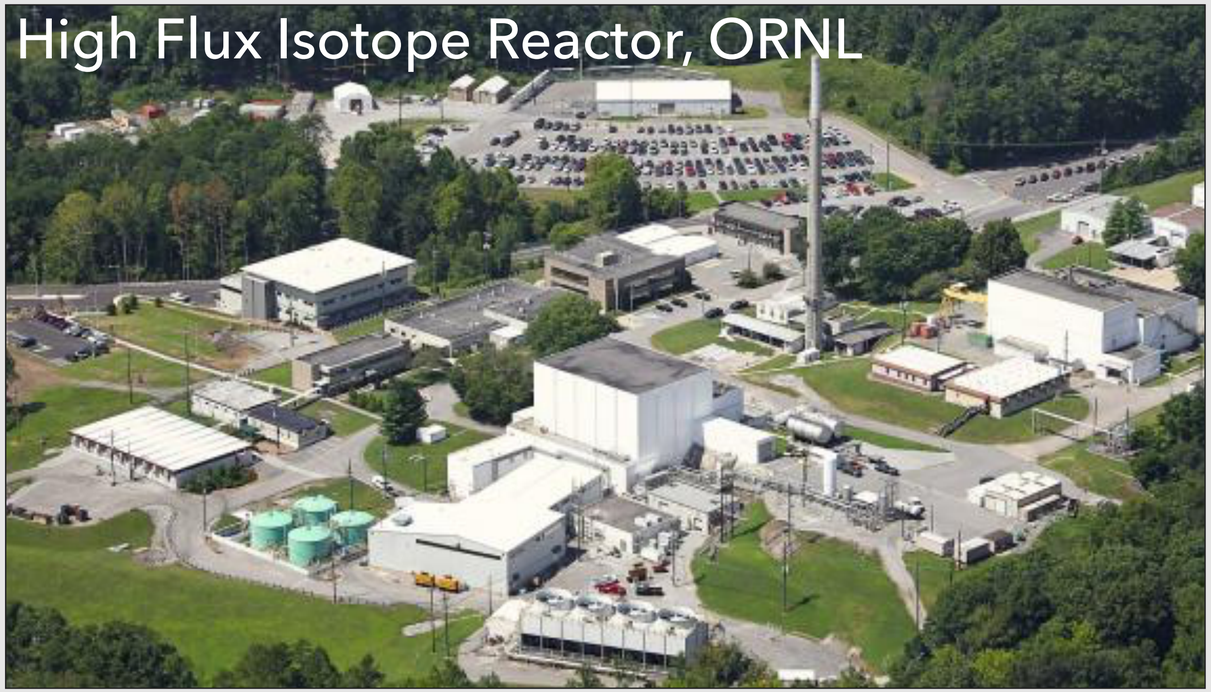
NEUTRINO SPECTRUM MEASUREMENTS FROM POWER REACTORS

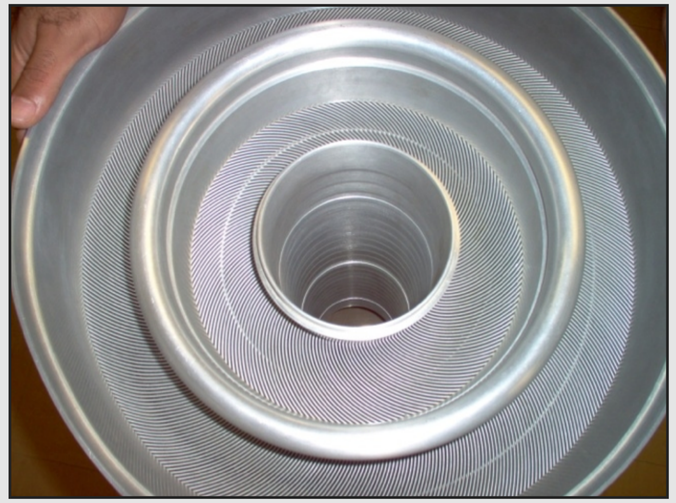
- Spectrum models don't match experimental data in low enriched uranium (LEU) power reactors
  - Neutrino events come from a mixture of fissile isotopes: ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu
  - 'Bump' in 4-6 MeV (prompt energy) range
  - Poor fit overall to leading reactor models (Huber/Mueller).
-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



HFIR: A UNIQUE EXPERIMENTAL SITE

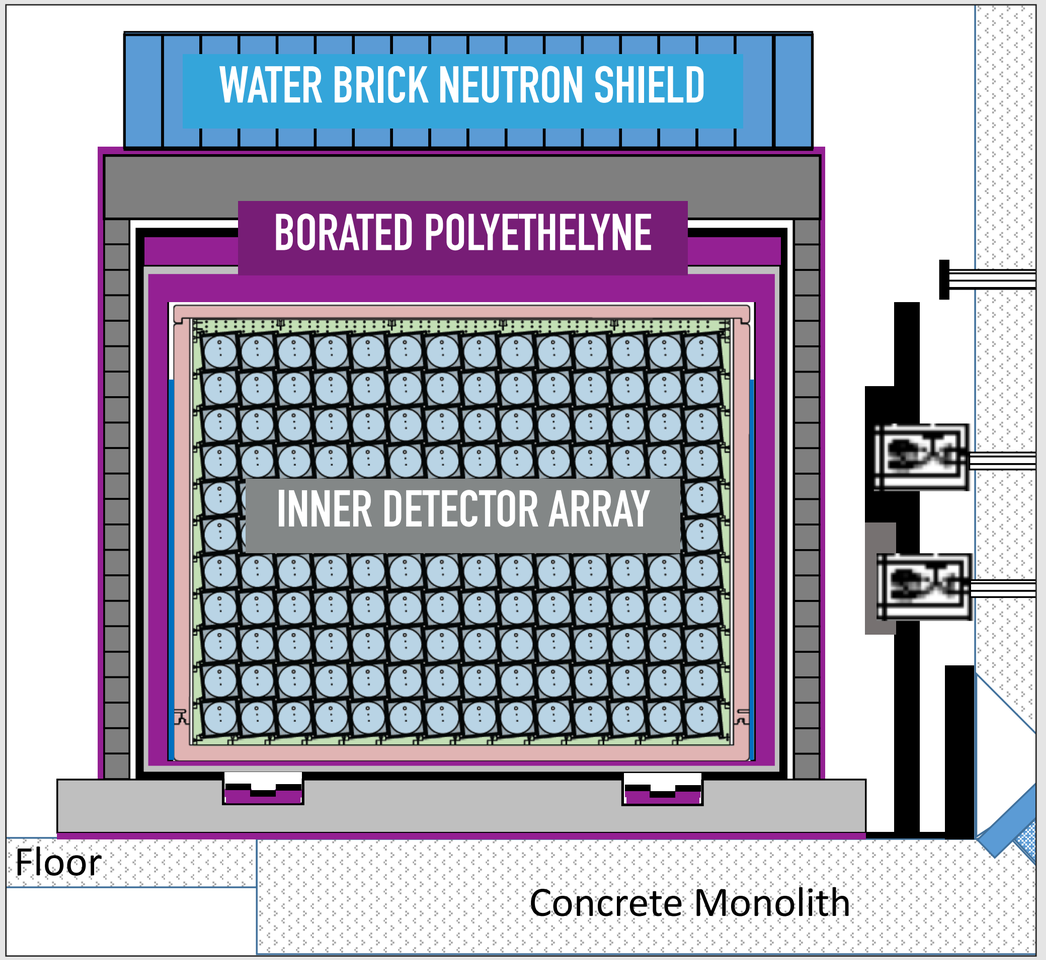
- 85 MW reactor core
- Highly Enriched Uranium (HEU) fuel (^{235}U)
- 46% duty-cycle, 7 cycles/yr, 24 day reactor-on periods
- >99% of $\overline{\nu}_e$ flux from ^{235}U fission
- Challenges:
  - Minimal overburden (<1 mwe)
  - high gamma background
  - limited space for shielding

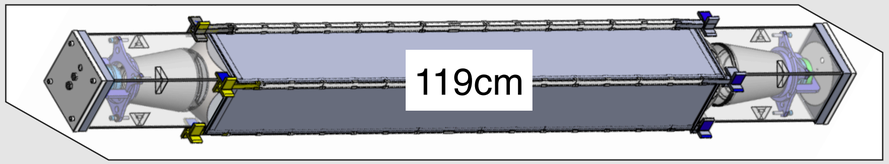




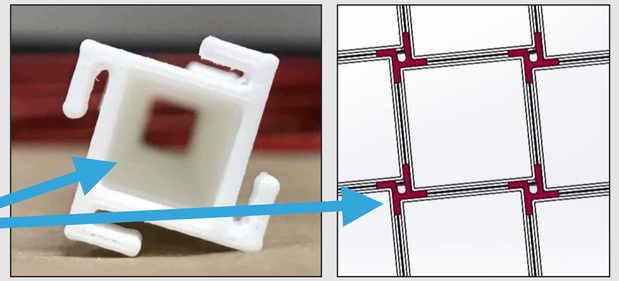
DETECTOR DESIGN

- Segmented detector with 154 optically separated segments
- Segmented design allows for:
  - Calibration access
  - Fiducialization
  - Position reconstruction in three dimensions
  - Event topology and particle ID

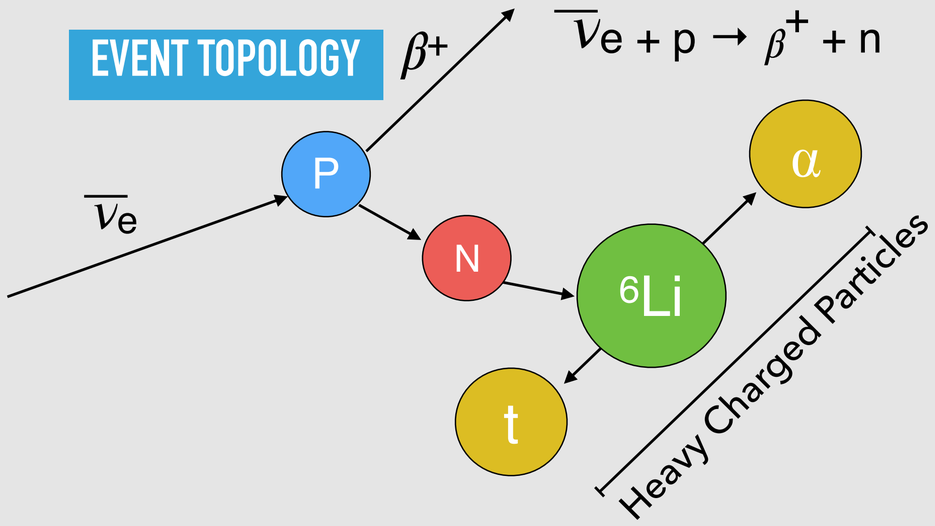




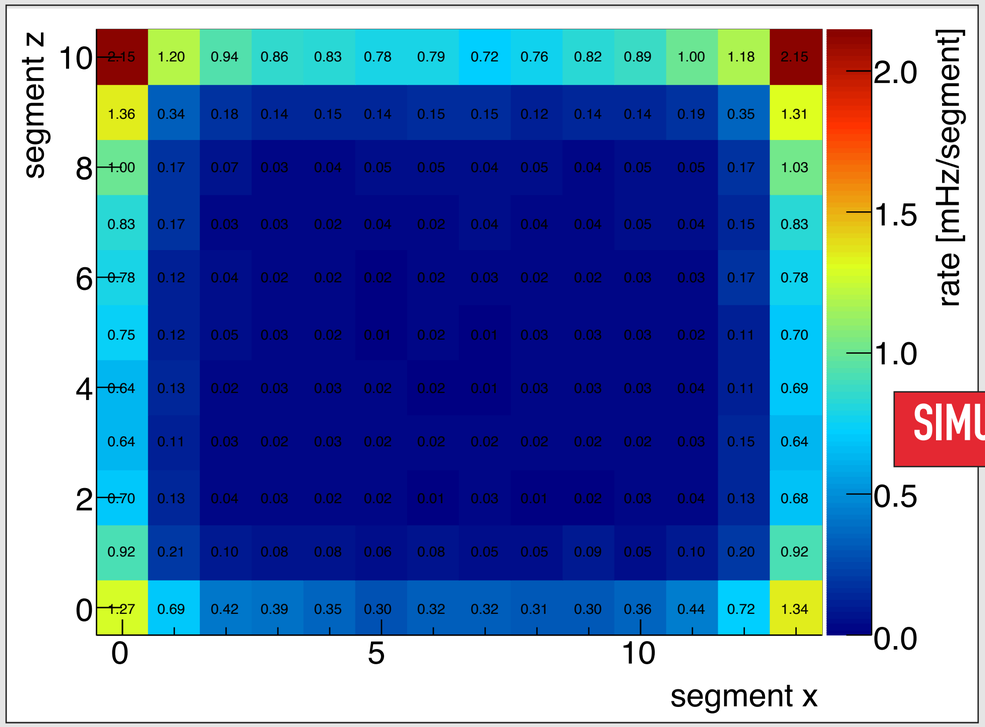
Tilted array allows calibration access

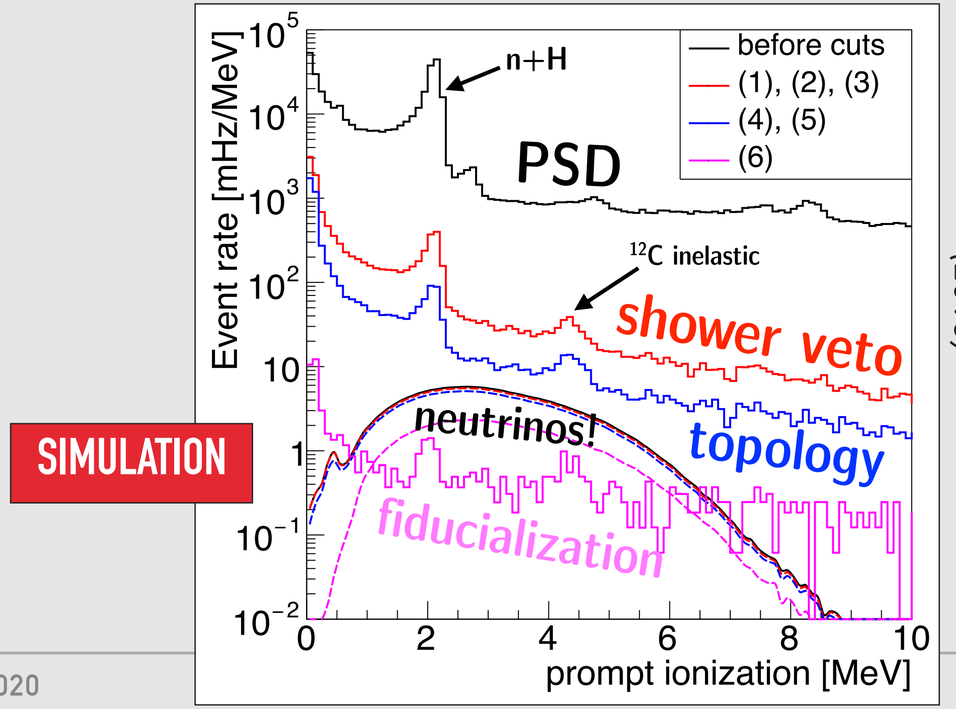


IBD SELECTION



- Clear, correlated signal signature
- Particle ID with pulse-shape discrimination
- Detector optimized for background suppression with shower veto, event topology, and fiducialization





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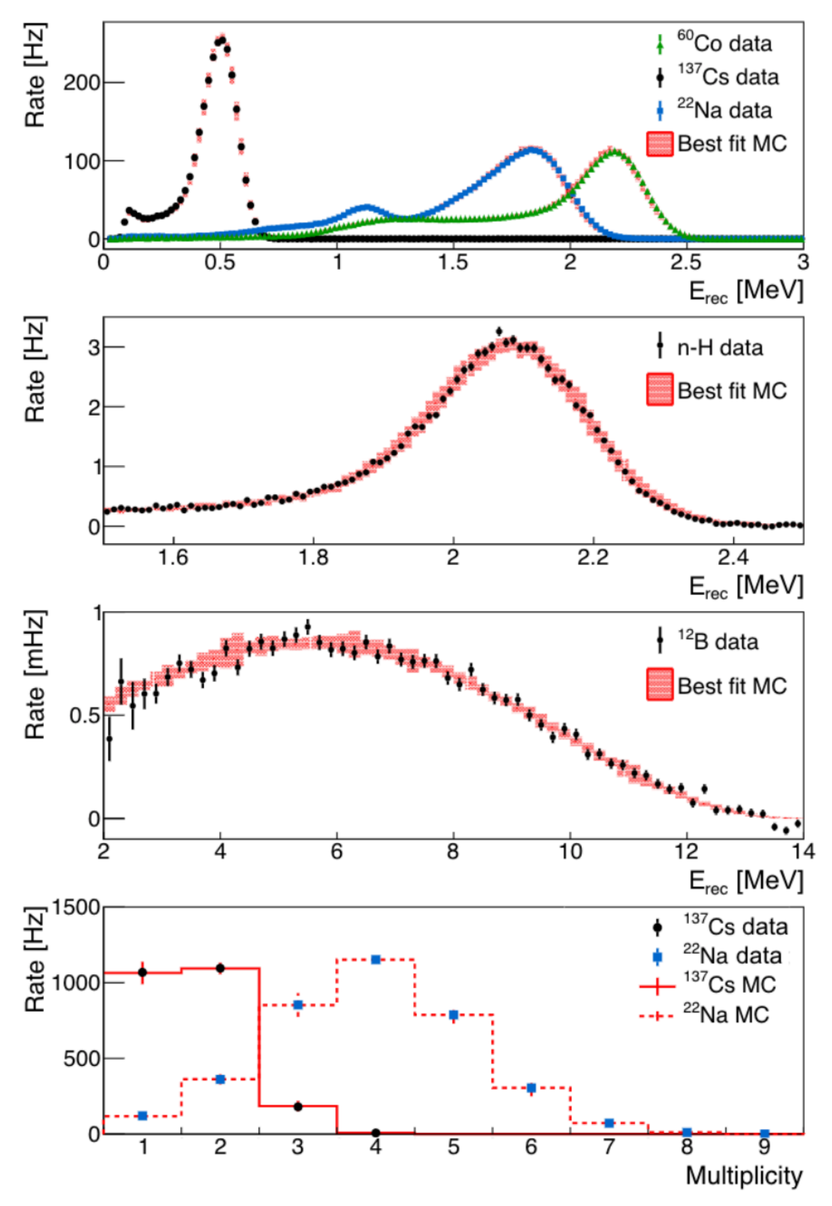
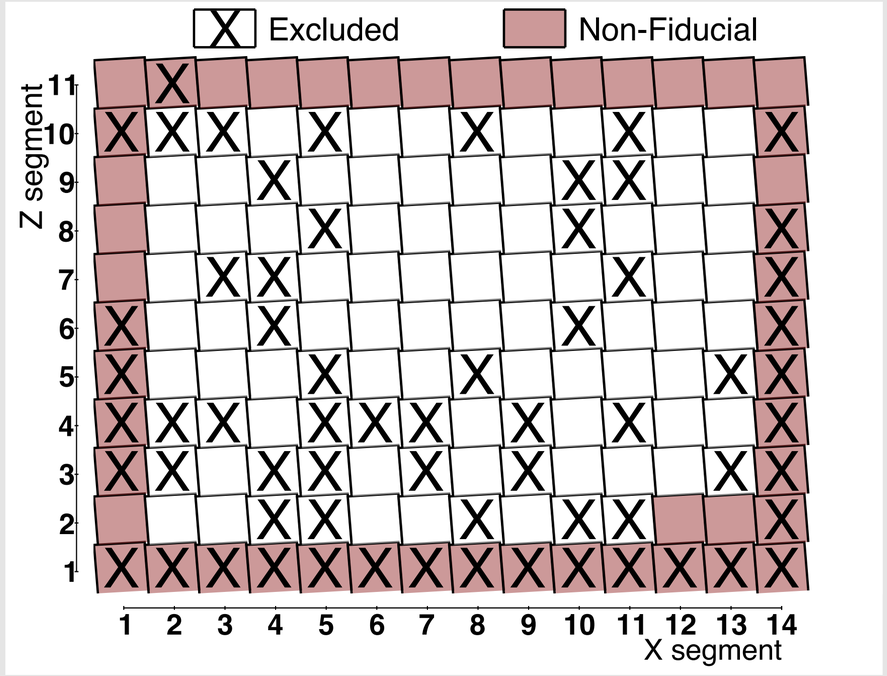
DETECTOR PERFORMANCE

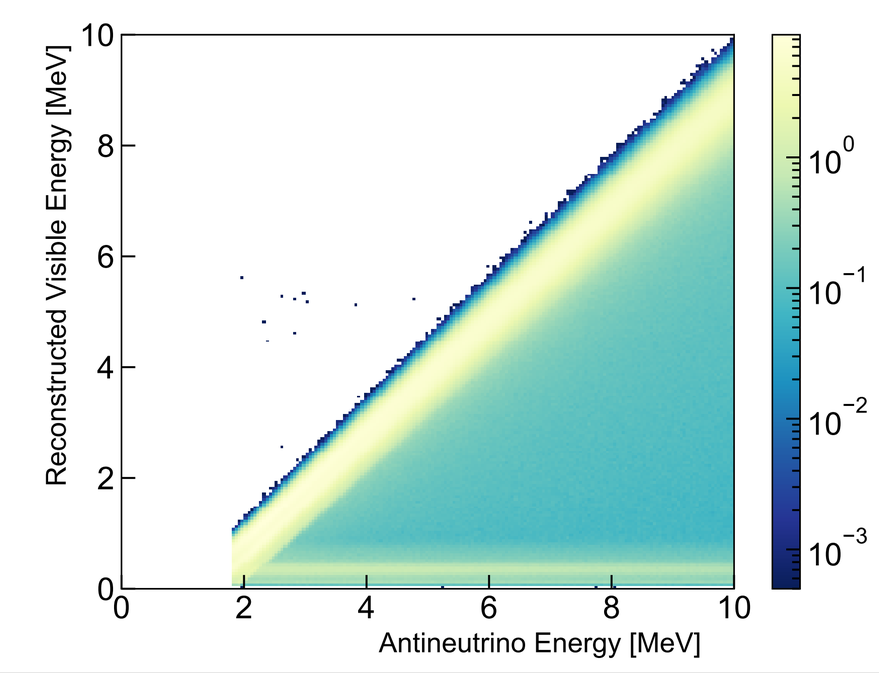


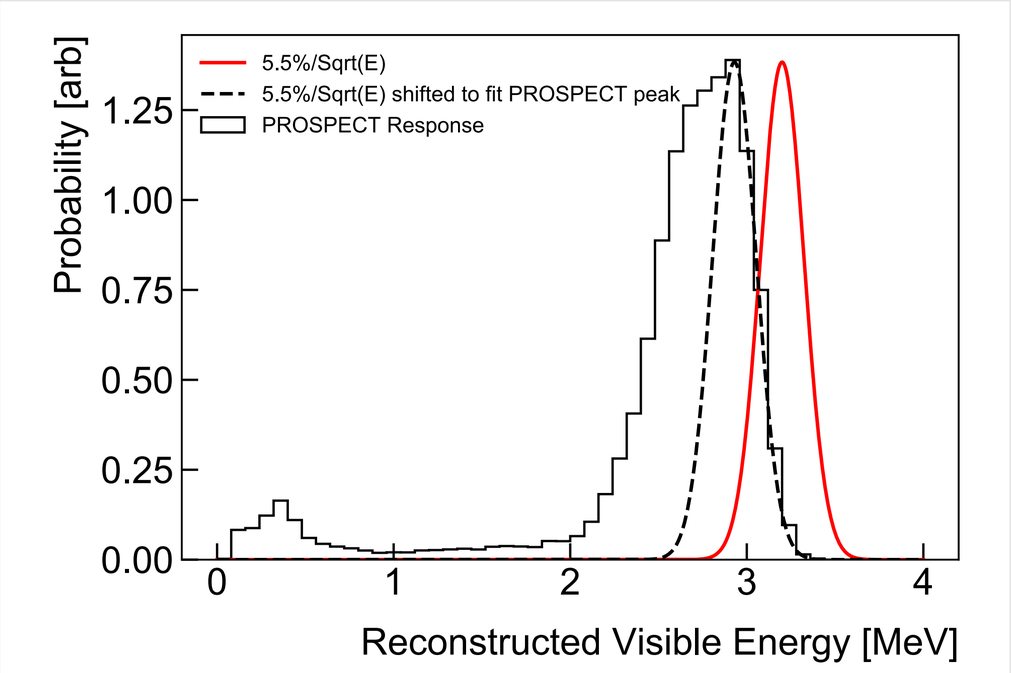


- Energy resolution of <5% at 1 MeV
- MC successfully tuned to agree with calibration data
- Reject candidates from 36 fiducial segments experiencing PMT current instabilities

DETECTOR MODELING

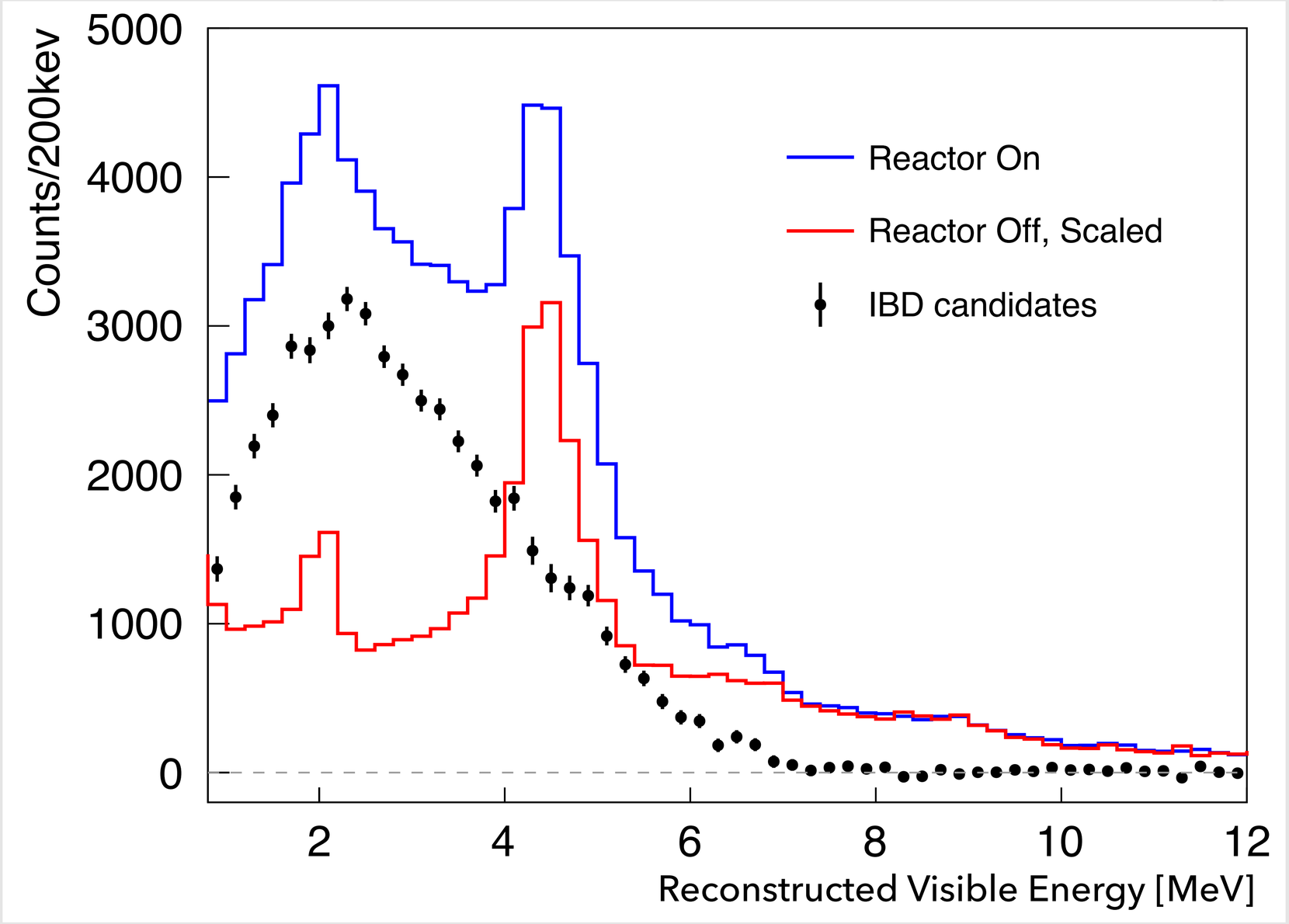
- Full-detector IBD prompt energy response modeled by calibration-tuned Geant4 MC
- Energy leakage into dead mass/non-fiducial segments cause substantial off-diagonal contribution
- Allows accurate comparison of hypotheses in true energy to the prompt space of the experiment (Reconstructed Visible Energy)





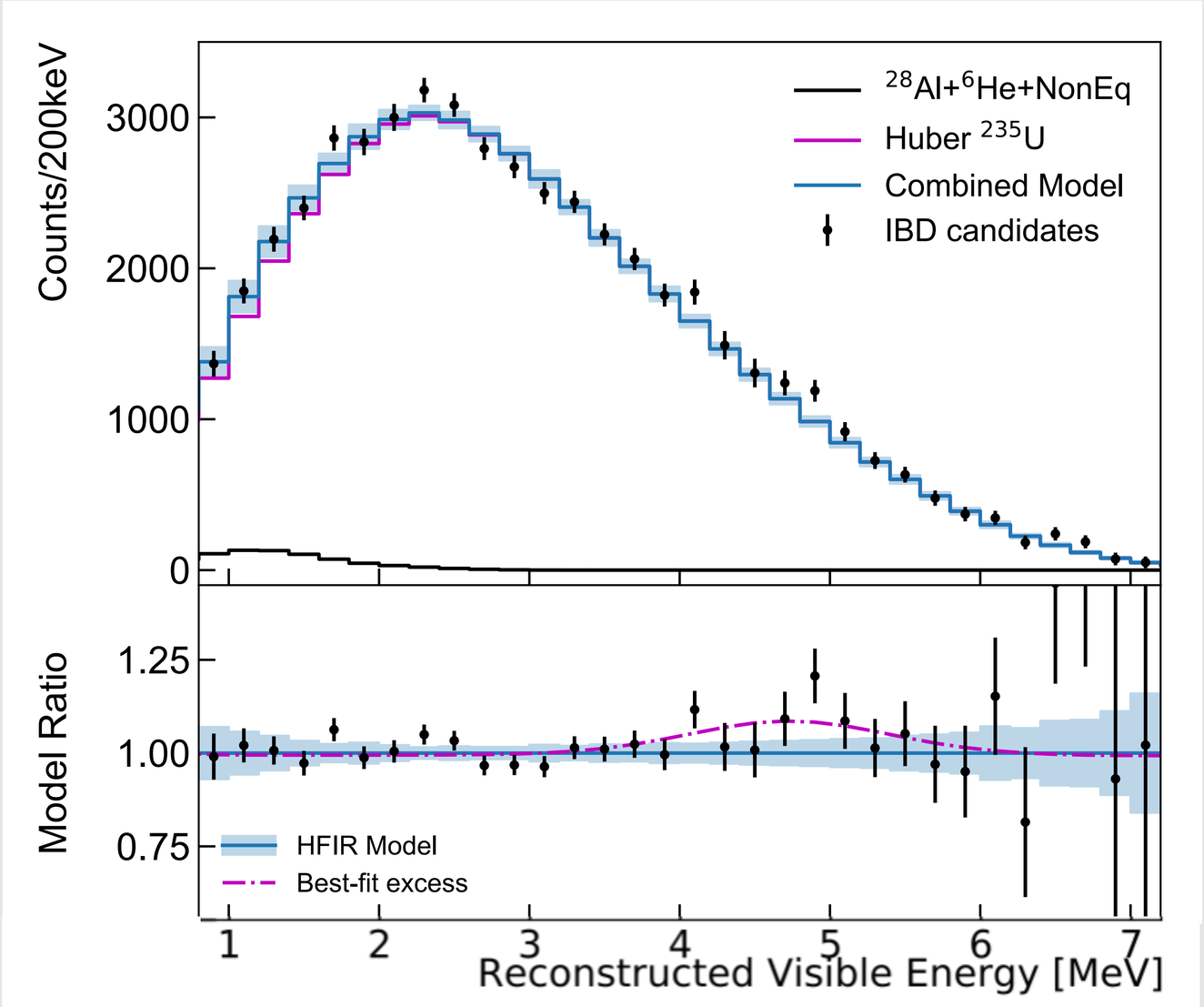
SPECTRUM MEASUREMENT

- 95.65 calendar days reactor-on, 73.09 reactor-off
- 50560 ± 406 IBD signal events
- S:B of 1.4:1 in signal energy range (0.8-7.2 MeV)



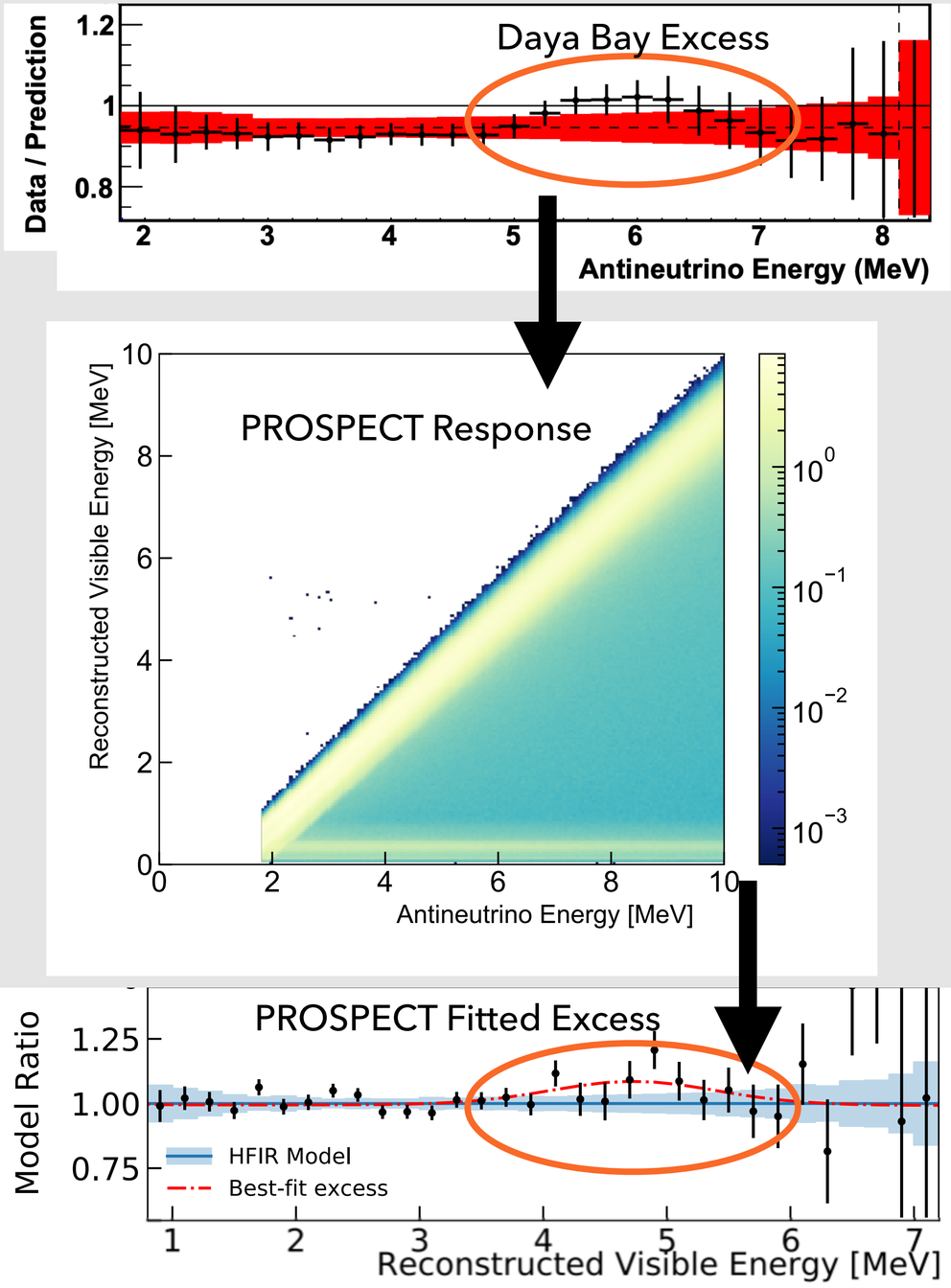
SPECTRAL INTERPRETATION

- We apply the PROSPECT response matrix to the Huber model to make a comparison in prompt space
- Find that the Huber model is in reasonable agreement with our data
  - X^2/ndf = 30.8/31, p-value = 0.48
  - Still statistics limited



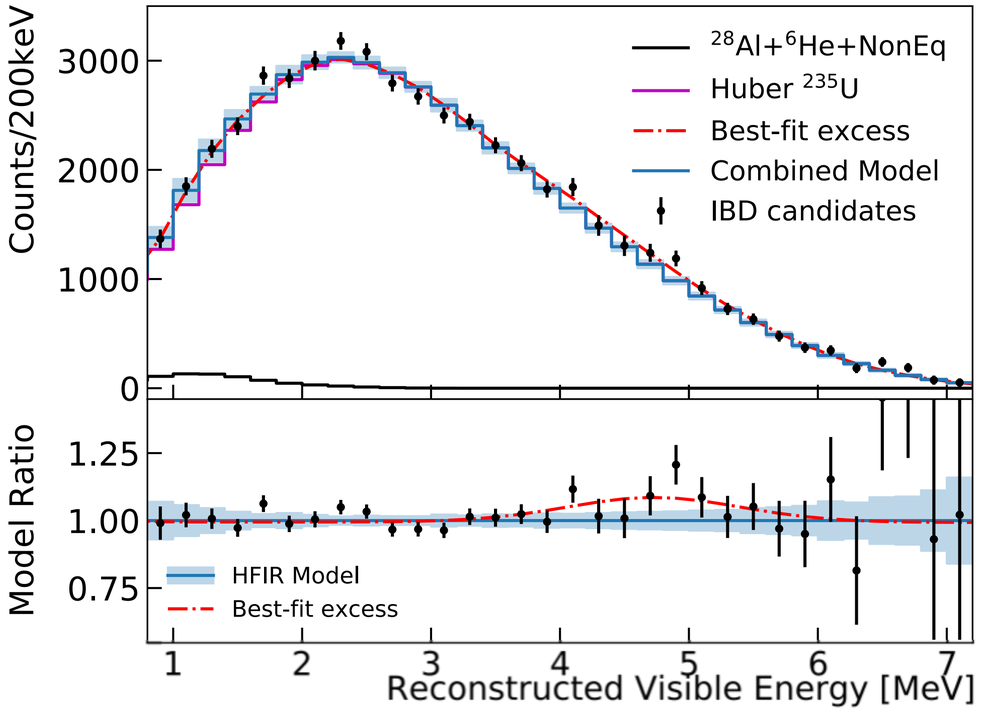
SEARCH FOR θ_{13}-LIKE EXCESS

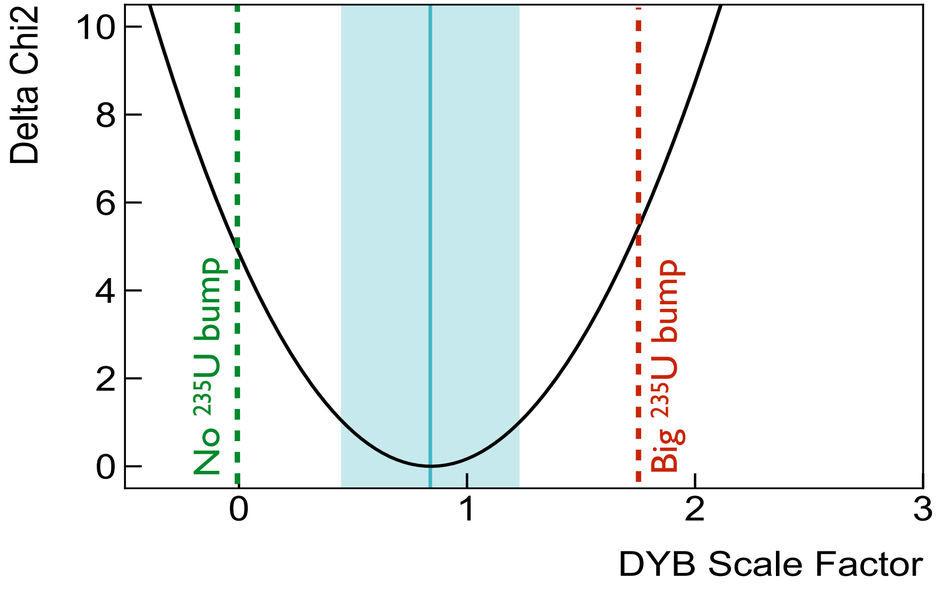
- Fit a gaussian with fixed mean and width to Daya Bay's excess in true energy
- Apply PROSPECT response and fit for amplitude in prompt space
- If ^{235}U has no contribution to Daya Bay's findings, expect no bump
- If ^{235}U is entirely responsible for Daya Bay's findings, expect a very large bump



BEST FIT EXCESS

- Best fit bump size relative to Daya Bay: 84%±39%
- Allowing a Daya Bay-like excess to be added to the Huber model improves the fit with $\Delta\chi^2$ of 4.84 (Δndf =1)
- Disfavor both 0% size 'No-Bump' and 178% size 'Big ^{235}U Bump' cases at >2σ





CLOSING STATEMENTS

- PROSPECT is a surface detector with minimal overburden, and has made an accurate measure of the ^{235}U spectrum and demonstrated new technology
- Have measured >50,000 IBD events from ^{235}U at the HFIR research reactor
- Achieve S:B of 1.4:1 in signal range
- Find the Huber model to be in reasonable agreement with data
  - Adding deviation similar to what is seen in θ_{13} experiments improves agreement significantly enough to disfavor no-bump case
  - Still statistics limited
- Joint efforts with other reactor experiments under way to improve sensitivity and allow further interpretation of spectrum

PROSPECT

prospect.yale.edu

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GRFP NSF GRADUATE RESEARCH FELLOWSHIP PROGRAM

15 Institutions, 70 collaborators

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