Joint Analyses of Reactor Antineutrino Spectra

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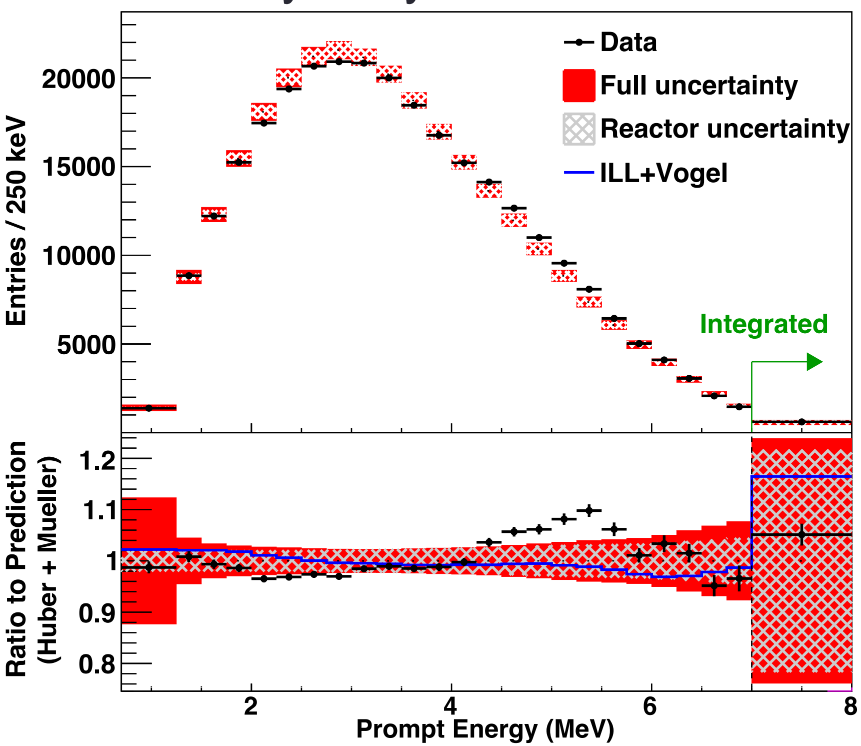
APS DNP Fall Meeting

Model - Measurement Disagreements

- Recent measurements of the neutrino energy spectrum from nuclear reactors deviates from model predictions
- What are the contributions from each fissile isotope?
- Deficiencies in the model prediction / input databases?
- **More precise spectral measurements are needed to help resolve these issues**

Daya Bay Measurement

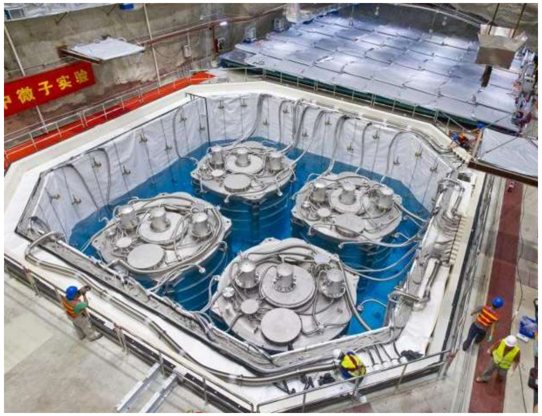


F. P. An et al., Ch Phys C 41, 1

Reactor Measurements

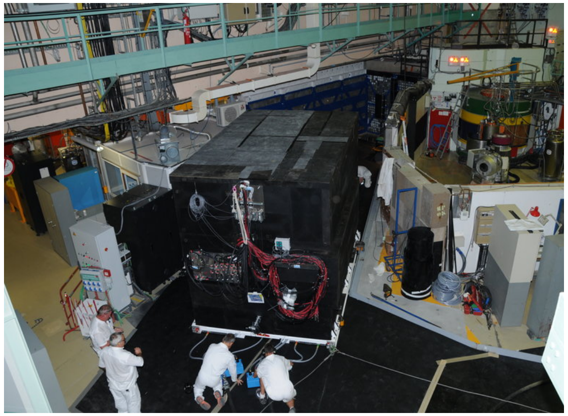
- Neutrinos identified via inverse beta decay (IBD)
- Detect positron events in coincidence with neutron events as tagged by some neutron capture agent to determine neutrino energies
- Multiple recent experiments have measured ^{235}U neutrino energy spectra

Daya Bay

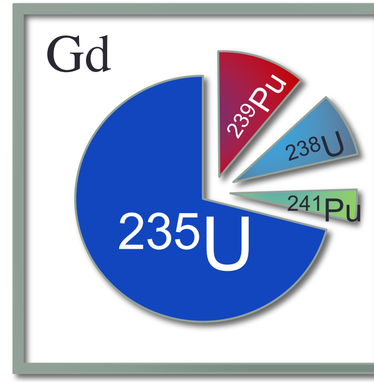


PROSPECT

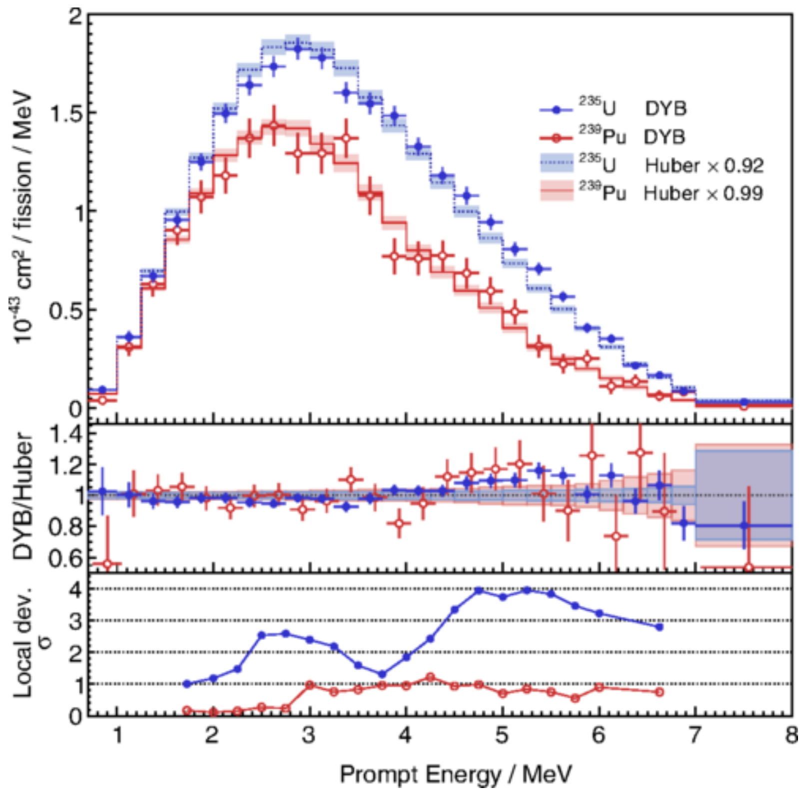
STEREO



Daya Bay



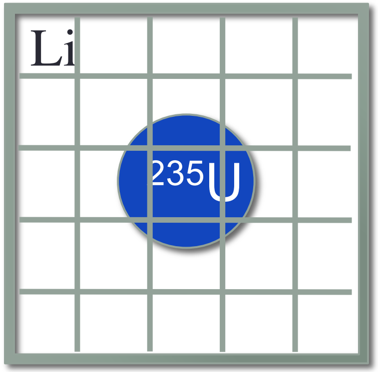
- Gd-loaded scintillator
- Multiple monolithic detectors
- Hundreds of meters from source
- 3.5 million antineutrinos detected
- Measurement of Low Enriched Uranium (LEU) power reactors with evolving fuel composition
- ^{235}U spectrum extracted from full measured spectrum using isotope fission fraction information and model constraints on ^{238}U and ^{241}Pu

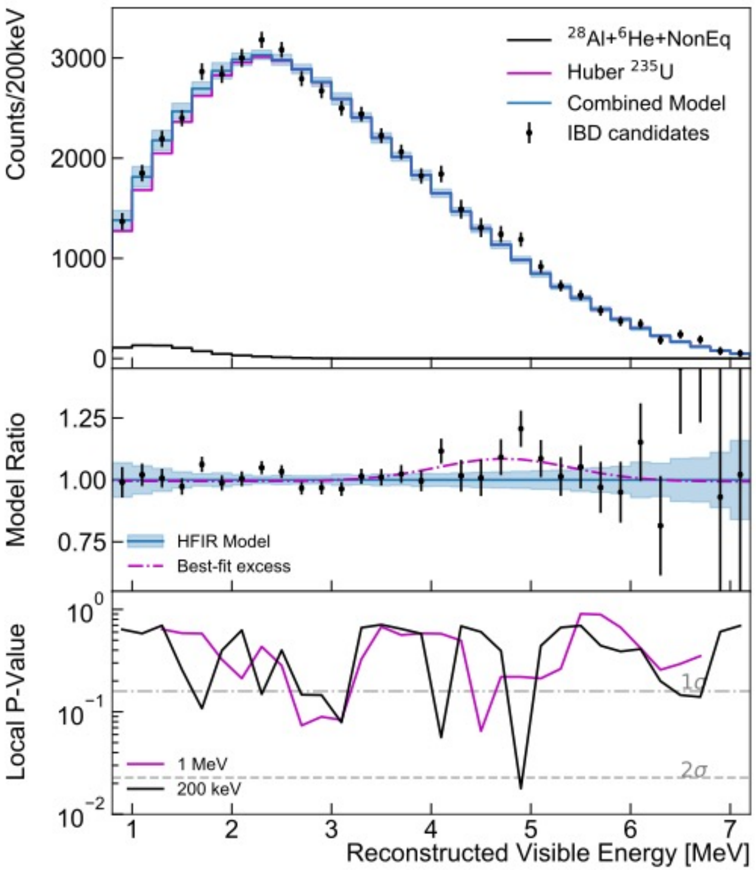


D. Adey et al., Phys Rev Lett 123, 111801

PROSPECT

- Li-loaded liquid scintillator
- Single, segmented detector
- 96 days of reactor-on data taking
- 50,000 antineutrinos
- ~10m from HEU reactor, direct measurement of ^{235}U

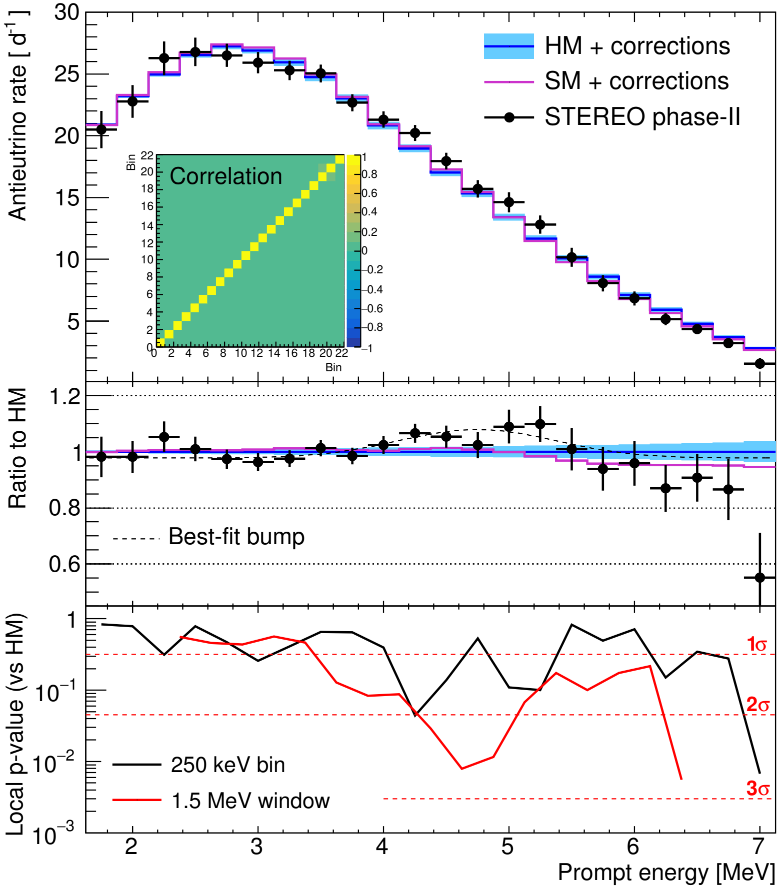




e-Print: arXiv:2006.11210

STEREO

- Gd-loaded liquid scintillator
- Single, segmented detector
- 118 full days equivalent of data taking
- 43,000 antineutrinos
- ~10m from HEU reactor, direct measurement of ^{235}U



e-Print: arXiv:2010.01876

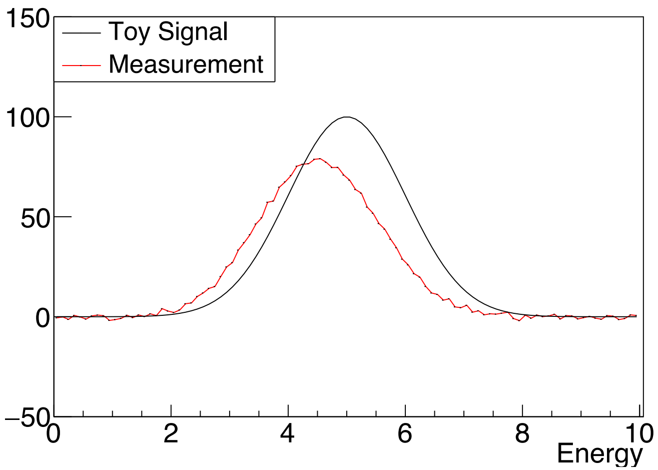
Prompt Energy Definitions

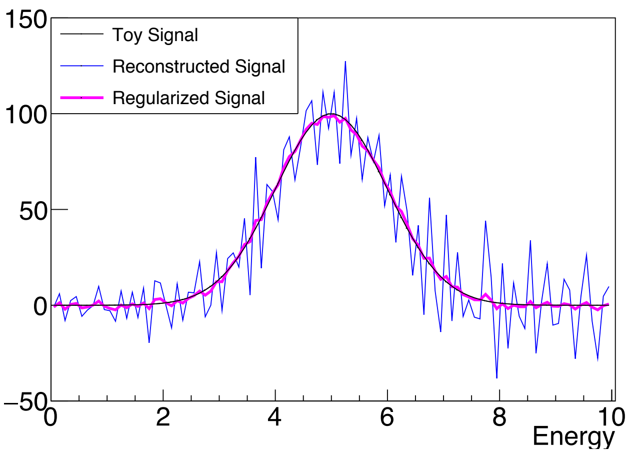
- Published neutrino spectra are in different energy spaces, and must be transformed in order to compare and combine
  - Daya Bay: positron energy
  - PROSPECT: visible energy in detector
  - STEREO: visible energy and unfolded neutrino energy

- One option is to unfold all measured spectra and uncertainties into true neutrino energy (as done by STEREO)

Unfolding into Neutrino Energy

- Using detector response function, measured energy can be unfolded into true neutrino energy
- Some regularization term needed to suppress noise in unfolded energy space





- Wiener-SVD* technique regularizes by optimizing the signal-to-noise ratio

*W. Tang et al, JINST 12, P10002 (2017)

Joint Fit

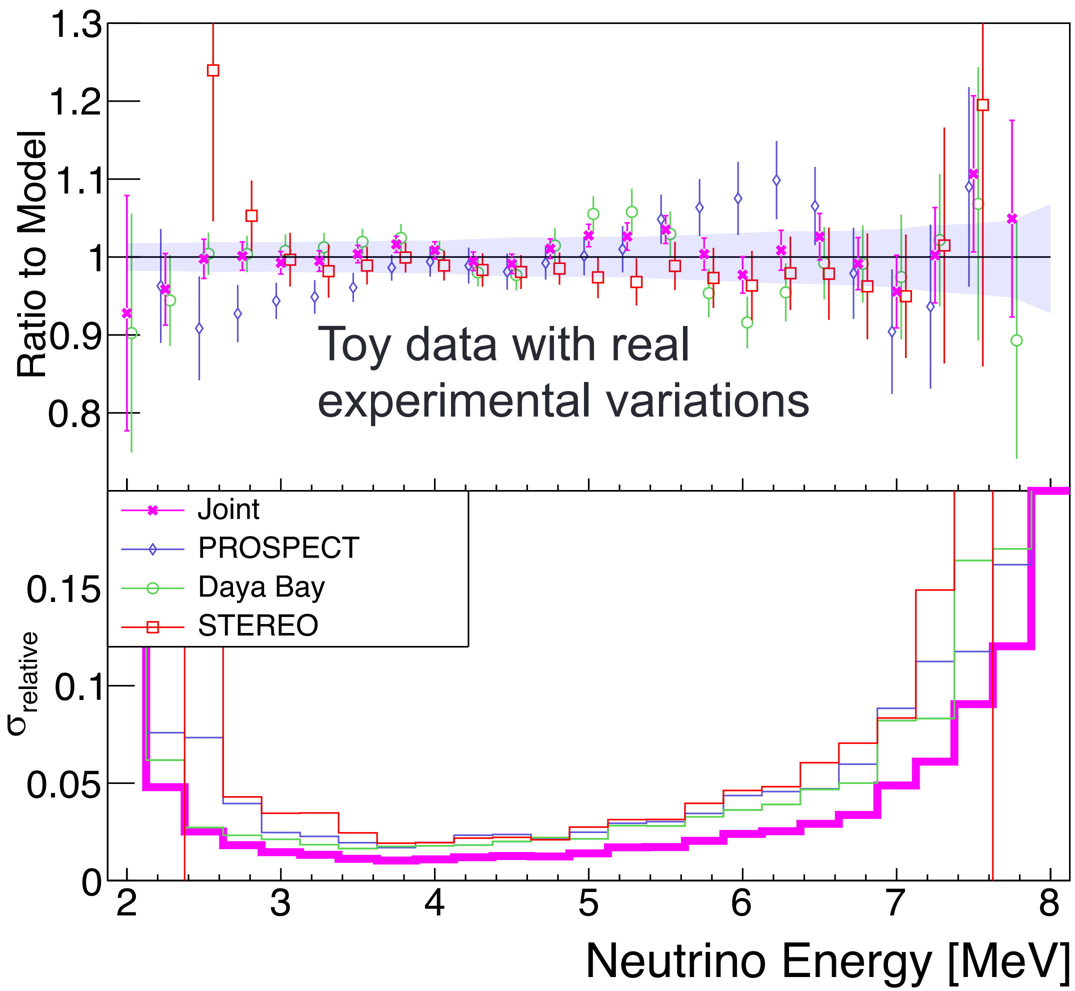
- Treating each experiment independently, a jointly constrained ^{235}U spectrum can be fit minimizing:

$$\chi^2 = \sum_{i=1}^{3} (\alpha_i \vec{S} - \vec{M}_i)^T V_i^{-1} (\alpha_i \vec{S} - \vec{M}_i)$$

$$\vec{S}_j = \vec{S}_j^{Model}(1 + \epsilon_j)$$

- Covariance matrix V_i and unfolded measurement $\vec{M}_i$
- Minimizing over all energy bins ϵ_j and relative normalizations α_i

Toy Study



Significant increase in precision when combining measurements

Conclusions

- Precision measurements needed to resolve tension between current models and measurements of reactor neutrino spectra
- ^{235}U measurements from Daya Bay, PROSPECT, and STEREO can be unfolded and combined into a jointly constrained measurement
- Combined spectrum leverages advantages of each experiment and makes a more precise spectrum than any individual measurement
- Joint analyses are underway, look for results soon!

Thanks!

Other PROSPECT Talks:

- Latest Sterile Neutrino Analysis (EG.00001 J Palomino Gallo)
- Latest Spectrum Results (EG.00002 B. Foust)
- Future analysis improvements (EG.00004 X. Zhang / M. Mendenhall)
- Detector Upgrade (EG.00005 H. P. Mumm)
- Background Characterization at HFIR (EG.00009 B. Heffron/ C. Gilbert / A. Galindo-Uribarri)
- Machine Learning Antineutrino Detection (EG.00007 A. Delgado)
- Machine Learning Tagging of Ortho-Positronium (LK.00006 D. Venegas / B. Heffron)
- Machine Learning for Event Reconstruction (SN.00002 X. Lu)

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