Wright Laboratory

Joint Isotope-Dependent Analysis of the Daya Bay and PROSPECT Reactor Antineutrino Spectra

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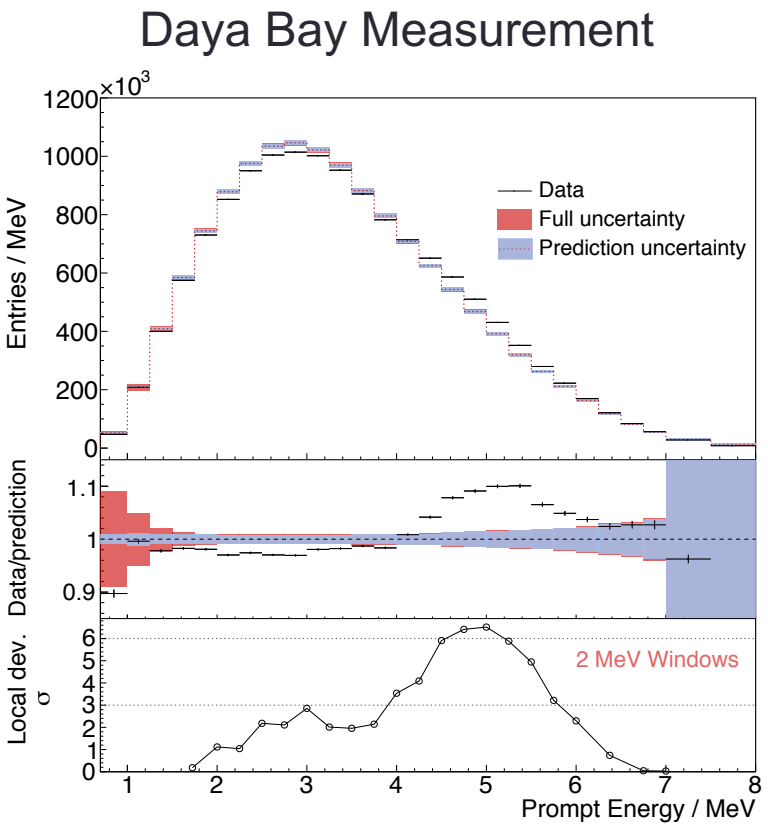
Model - Measurement Disagreements

- 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**

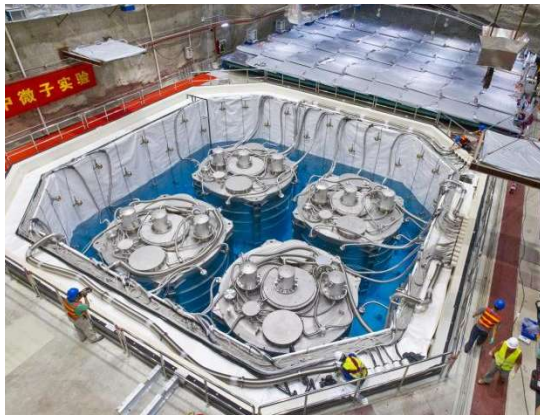


D. Adey et al., Phys Rev Lett 123, 111801

Reactor Measurements

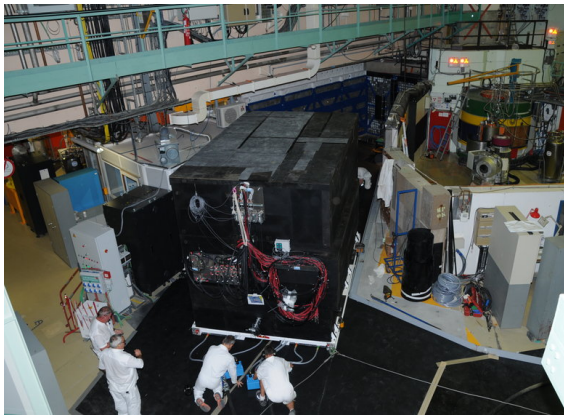
- Neutrinos identified via inverse beta decay (IBD)
- Detect positron events in coincidence with neutron events as tagged by neutron capture agent to determine neutrino energies
- Multiple recent experiments have measured ^{235}U neutrino energy spectra

Daya Bay



PROSPECT

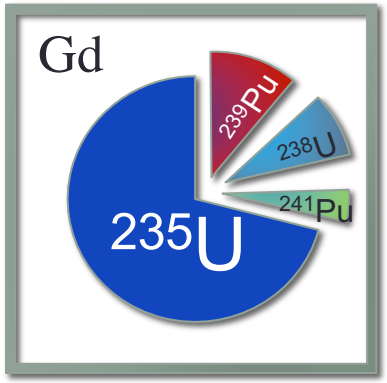
STEREO*

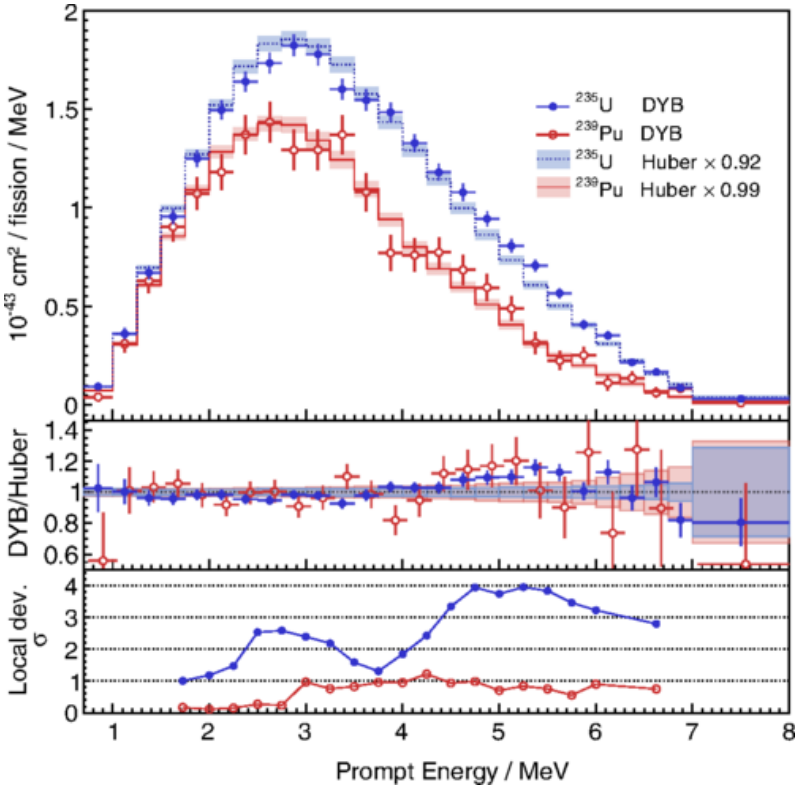


*More information on joint PROSPECT + STEREO analysis in next talk by B. Foust

Daya Bay

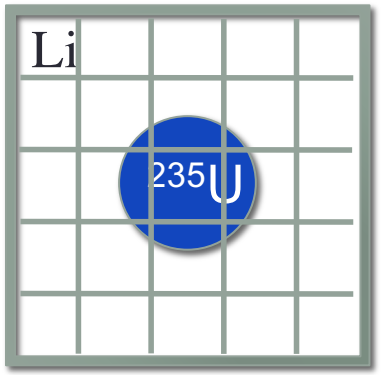
- Gd-loaded scintillator
- Multiple monolithic detectors
- Hundreds of meters from source
- 3.5 million antineutrinos detected
- Measurement of Low Enriched Uranium (LEU) power reactors with evolving fuel composition
- ^{235}U spectrum extracted from full measured spectrum using isotope fission fraction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



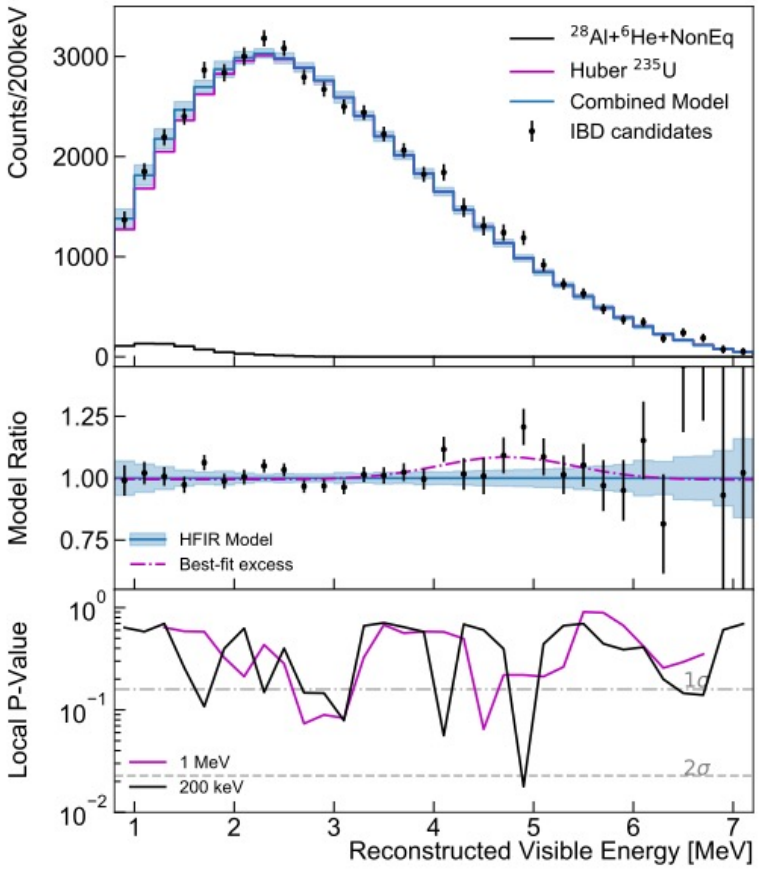


D. Adey et al., Phys Rev Lett 123, 111801

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



M. Andriamirado et al., Phys Rev D 103, 032001

Prompt Energy Definitions

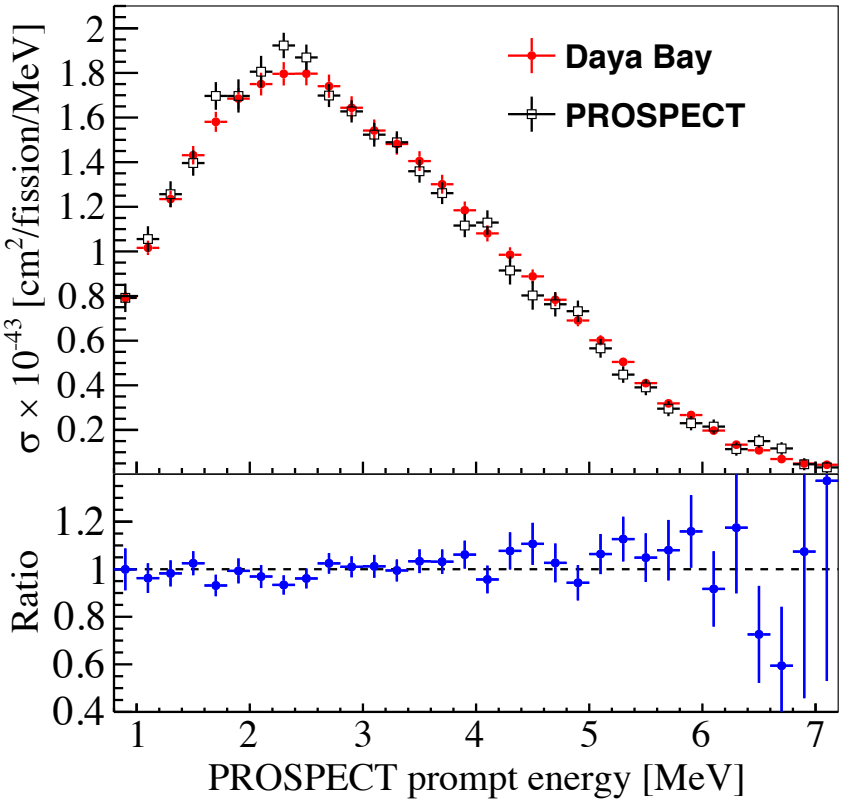
- Published neutrino spectra are in different energy spaces, and must be transformed in order to compare and combine
  - Daya Bay: positron energy
  - PROSPECT: visible energy in detector

- Measurements cannot be directly compared as is, but can be mapped from one energy space into the other through detector response functions

$$\boldsymbol{R}^{\mathrm{map}} = \boldsymbol{R}^{\mathrm{PRO}}\left(\boldsymbol{R}^{\mathrm{DYB}}\right)^{-1}$$

Prompt Shape Compatibility

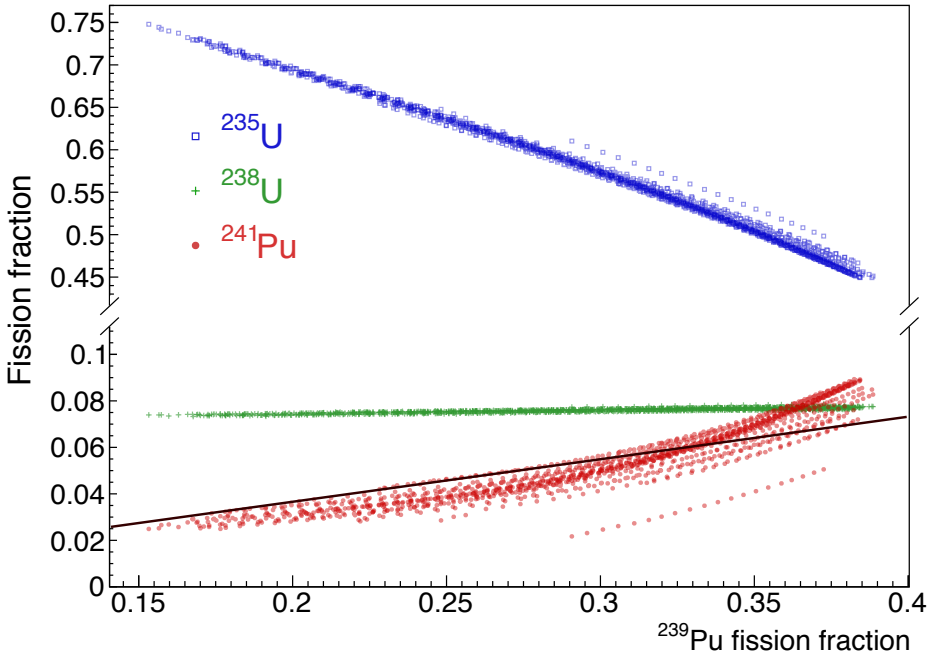
- PROSPECT rate scaled to match Daya Bay
- χ^2/dof = 25.4/31
- p-value of 0.75
- Daya Bay and PROSPECT ^{235}U measurements in good agreement



e-Print: arXiv:2106.12251

Power Reactor Deconvolution

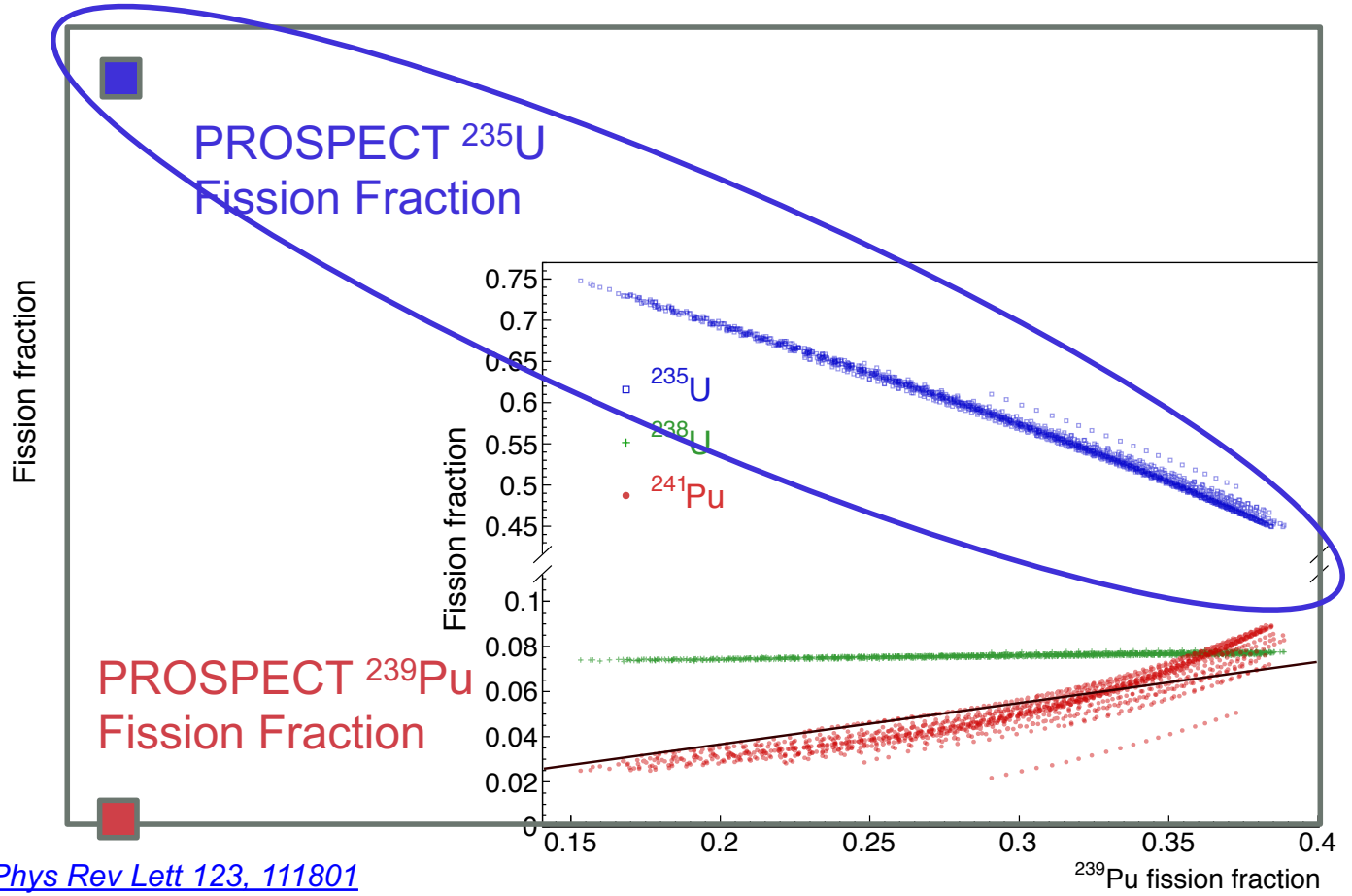
- Daya Bay total spectrum grouped by fission fraction and used to deconvolve ^{235}U and ^{239}Pu contributions



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

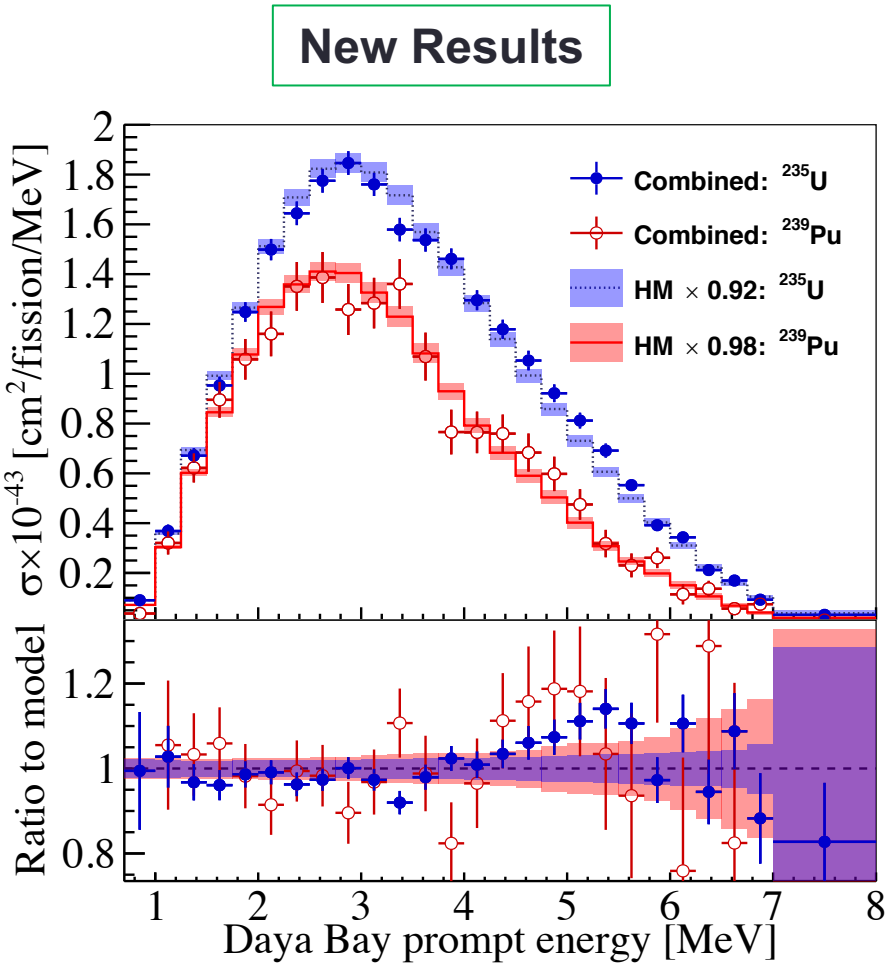
Power Reactor Deconvolution

- Pure ^{235}U measurement from PROSPECT constrains Daya Bay isotopic deconvolution



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

Power Reactor Deconvolution

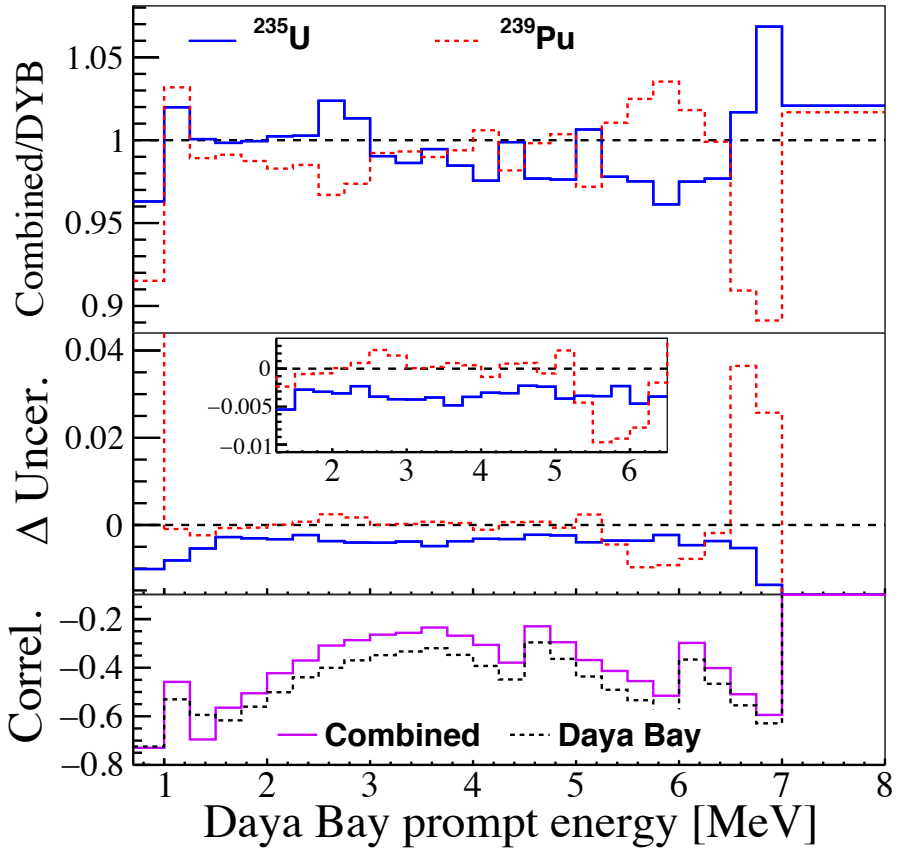


- New results consistent with previous results
- Local deviations from scaled model (2 MeV wide windows) increase by 0.2-0.5σ at all energies for ^{235}U
- No significant change for ^{239}Pu

e-Print: arXiv:2106.12251

Power Reactor Deconvolution

Difference from Previous Results

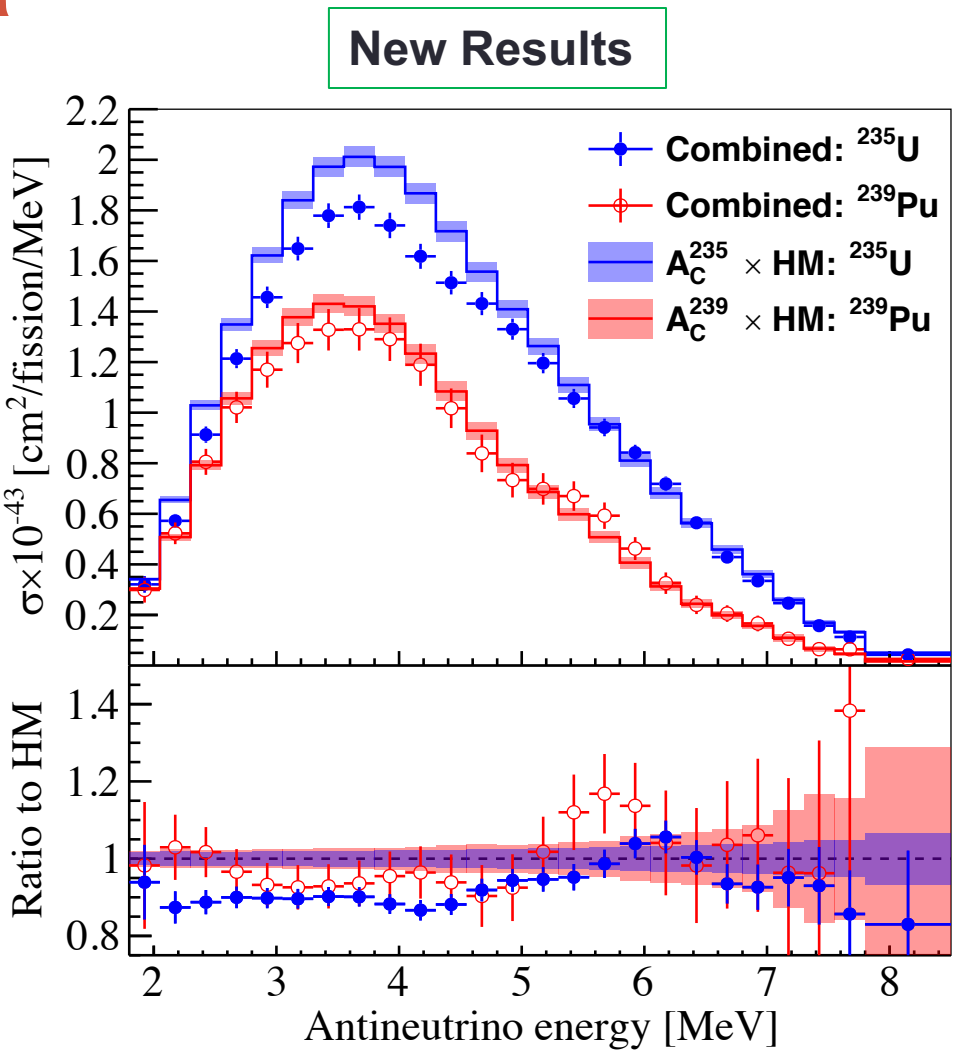


- Relative shape uncertainty of ^{235}U improves to 3%, no significant change to ^{239}Pu shape uncertainty
- Isotopic degeneracy improved by ~20%

e-Print: arXiv:2106.12251

Unfolded Spectra

- Deconvolved spectra unfolded and regularized via Wiener-SVD* technique
- A_c smearing matrix encodes effect from unfolding regularization into any model
- Rate constraint from Daya Bay



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

e-Print: arXiv:2106.12251

Conclusions

- Precision measurements needed to resolve tension between current models and measurements of reactor neutrino spectra.
- Daya Bay and PROSPECT ^{235}U measurements are compatible with each other.
- A jointly deconvolved reactor antineutrino spectrum improves both ^{235}U shape uncertainty to 3% and ^{235}U-^{239}Pu correlations are reduced by ~20% from Daya Bay-only results.

Thanks!

See Other PROSPECT Talks:

Latest Reactor Antineutrino Spectrum and Boosted Dark Matter Results: P. Weatherly
Reactor Position Reconstruction Study: D. C. Venegas-Vargas
Joint Analysis by PROSPECT and STEREO: B. Foust
Physics Opportunities with a PROSPECT Upgrade: R. Carr

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