Reactor Antineutrino Spectrum and Flux Measurement at Daya Bay

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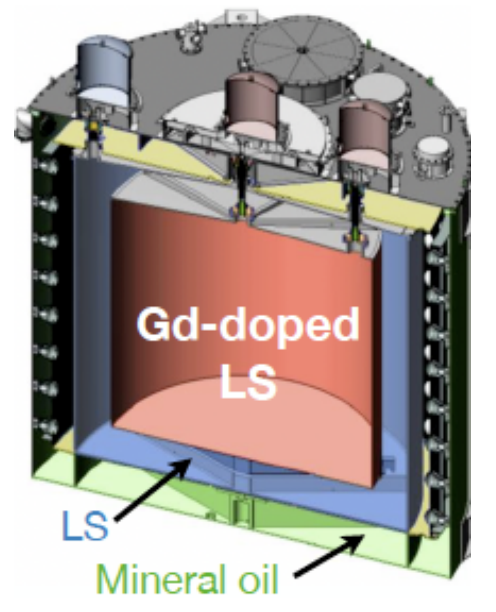
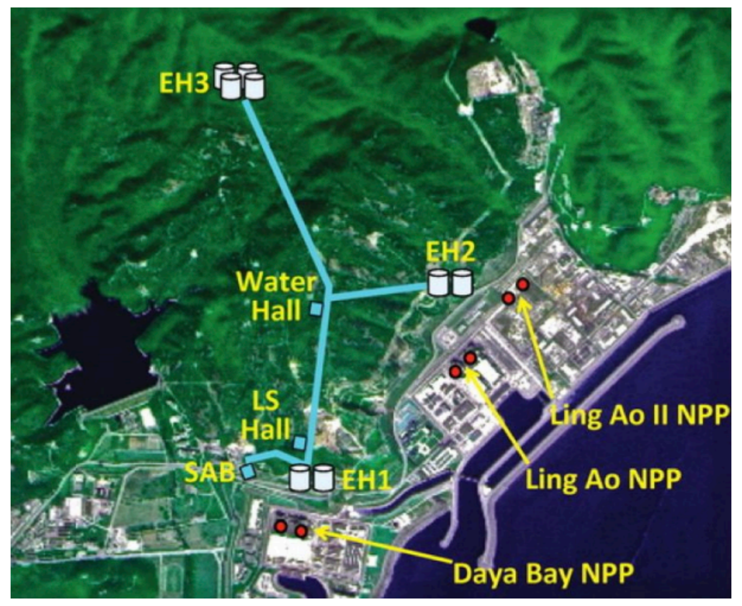
(on behalf of the Daya Bay collaboration)

1. Daya Bay Reactor Neutrino Experiment [1]

- Located in Southern China next to 6 x 2.9 GW_{th} reactors providing large $\bar{\nu}_e$ flux
- Primarily designed to precisely measure neutrino mixing angle θ_{13}
- 8 identically-designed antineutrino detectors (ADs) distributed in three experimental halls (EHs) up to 330 m underground for cosmic ray attenuation



Daya Bay AD cross section



Daya Bay EHs and power plant locations

2. Antineutrino Production and Detection [1,2]

- Reactor antineutrinos come from beta decays, product of mainly ^{235}U, ^{239}U, ^{239}Pu, ^{241}Pu fissions
- $\bar{\nu}_e$ detected through Inverse Beta Decay (IBD): $\bar{\nu}_e + p \rightarrow e^+ + n$
- e^+ loses energy then quickly annihilates with e^- providing the prompt signal
- n gets captured on Gd or H, when nucleus de-excites we see the delayed signal
- IBD signature is the coincidence of the two signals
- Poster results include capture on Gd IBD sample only
- $E_{\bar{\nu}_e} \approx E_{prompt} + 0.78 MeV$

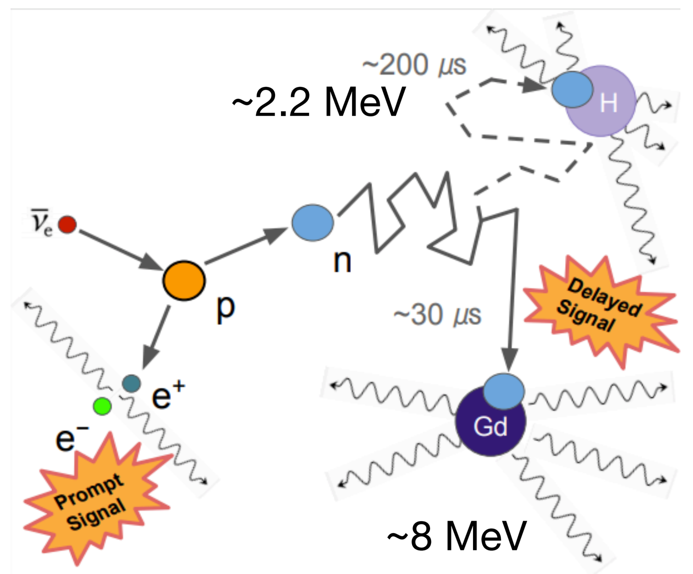


Figure of IBD detection process

$$N_{IBD}(1 - c^{SNF}) = \sigma_f \sum_{d=1}^{4} \sum_{r=1}^{6} \frac{N_d^P \epsilon_{IBD} P_{sur}^{rd} N_r^f}{4\pi L_{rd}^2}$$

IBD detection efficiency; Survival Probability; Sum over 4 detectors and 6 reactors; Number of fissions in core r; IBD yield per nuclear fission; Number of protons in detector; Distance to detector

- Largest uncertainty on previous yield measurement was ϵ_{IBD} (1.69% out of 2.1% total relative uncertainty)

Neutron Detection Efficiency

$$\epsilon_{IBD} = \epsilon_n \times \epsilon_{other}$$

3. Neutron Detection Efficiency Improvement [2]

- ϵ_n dominates total yield uncertainty, factors contributing to ϵ_n can be constrained using neutron source measurements
- Special calibration campaign deploying different sources in detector performed in late 2016

Relative Uncertainties on Yield

Source	Previous	This Work
statistic	0.1%	0.1%
oscillation	0.1%	0.1%
target proton	0.92%	0.92%
reactor	0.89%	0.89%
ϵ_n	1.69%	0.74%
ϵ_{other}	0.16%	0.16%
total	2.1%	1.5%

ϵ_n reduced by a factor of 2!

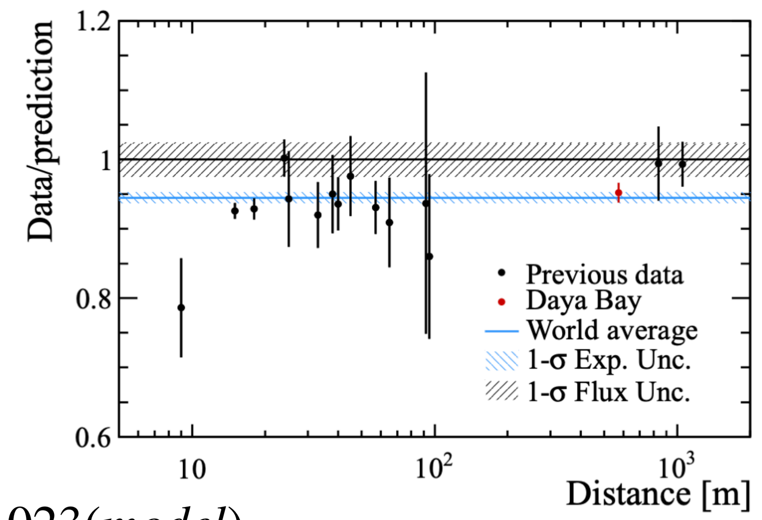
4. Yield Results [2,3]

- Total antineutrino yield

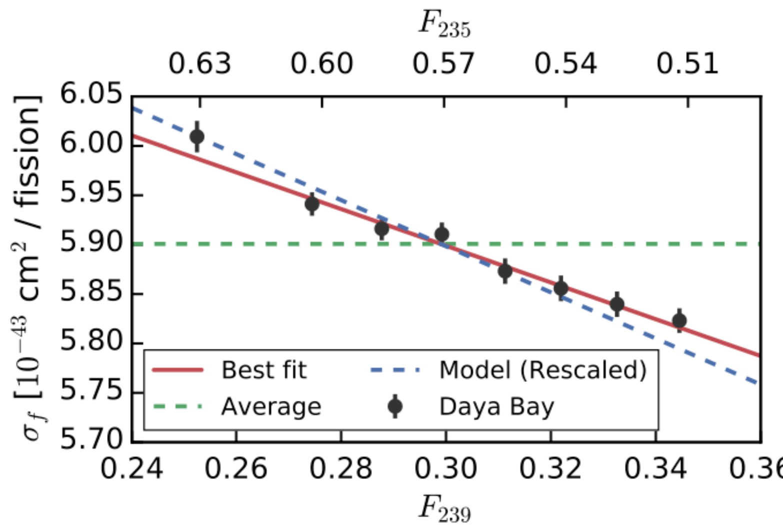
$$\sigma_f = (5.91 \pm 0.09) \times 10^{-43} \frac{\text{cm}^2}{\text{fission}}$$

from 1230 day data set agrees with world average, and deviates from Huber-Mueller (H-M) [4,5] model prediction

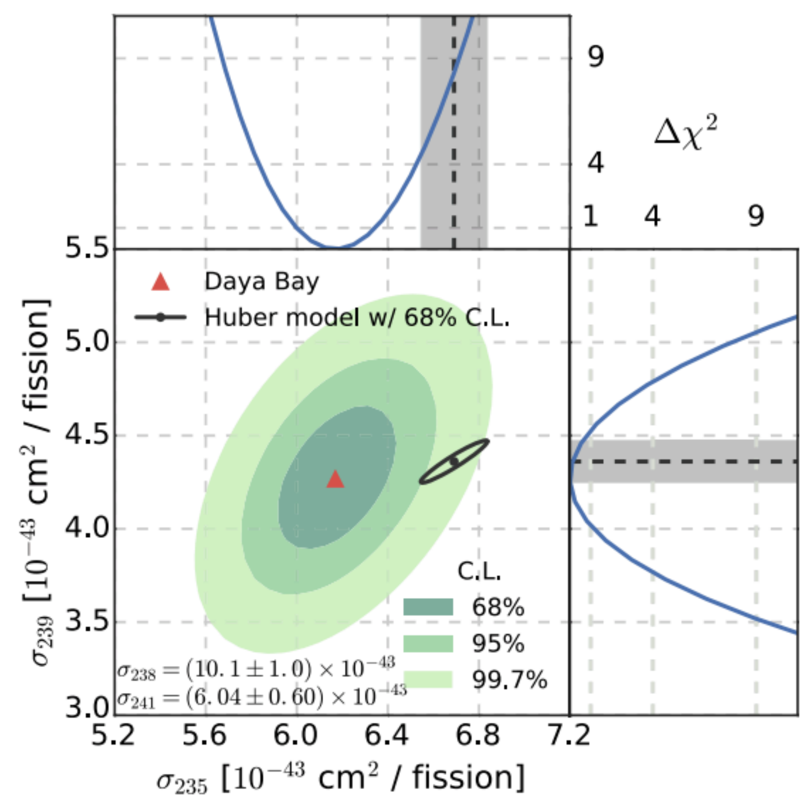
$$\frac{\text{data}}{\text{prediction}} = 0.952 \pm 0.014(exp) \pm 0.023(model)$$



- ^{235}U and ^{239}Pu isotopic yields are extracted from measurement of total yield as a function of effective fission fraction



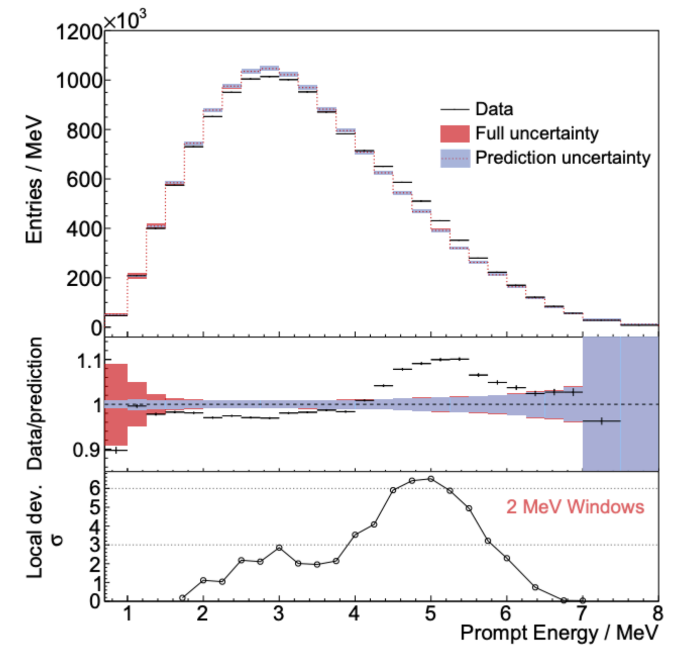
- Data favors ^{235}U as main contributor to reactor antineutrino anomaly
- Equal isotope deficit hypothesis, needed for sterile neutrino, disfavored at 2.8σ



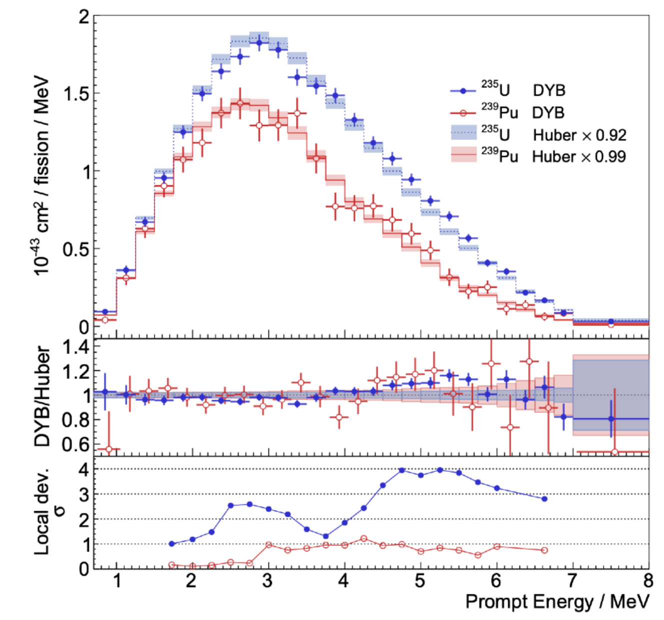
^{235}U , ^{239}Pu and H-M yields with allowed regions

5. Spectrum and Data-based Predictions [2,6,7]

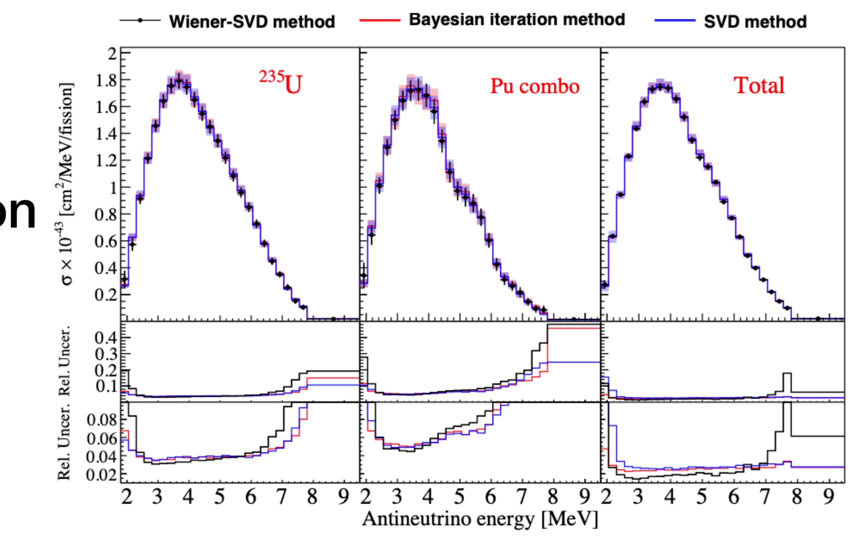
- Full spectral shape from 1958 days data deviates from H-M model
- Main feature is a ~5 MeV "bump"
- Local disagreement of 6.3σ between 4-6 MeV
- Global discrepancy significance of 5.3σ



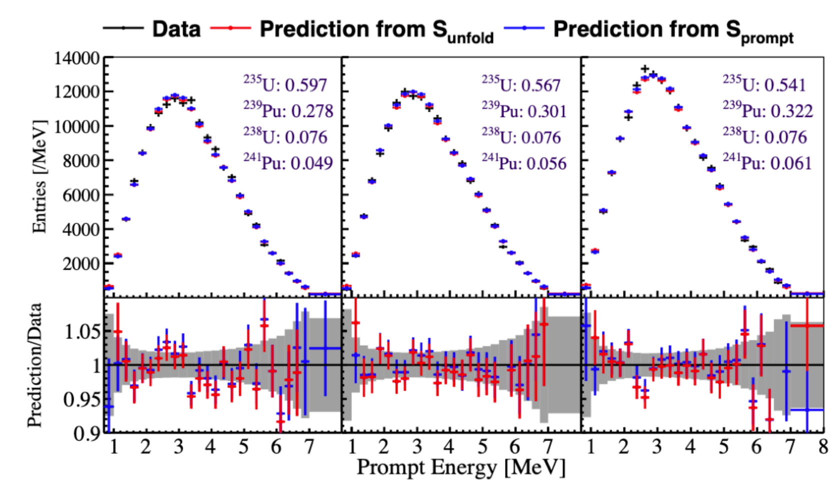
- ^{235}U and ^{239}Pu spectra are extracted from evolution of total spectrum as a function of effective fission fraction
- First extraction of isotopic spectra from a commercial reactor
- Both spectra exhibit ~5 MeV bump



- Unfolding the spectra removes detector response and allows direct comparison with other experiments
- Converts spectra from prompt energy to $\bar{\nu}_e$ energy



- Isotopic spectra uncertainties dominated by statistics and model uncertainties
- Data-driven prediction for other experiments with different fission fractions to 2% precision



References

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