Latest Results of the Reactor Fuel Evolution Study at Daya Bay

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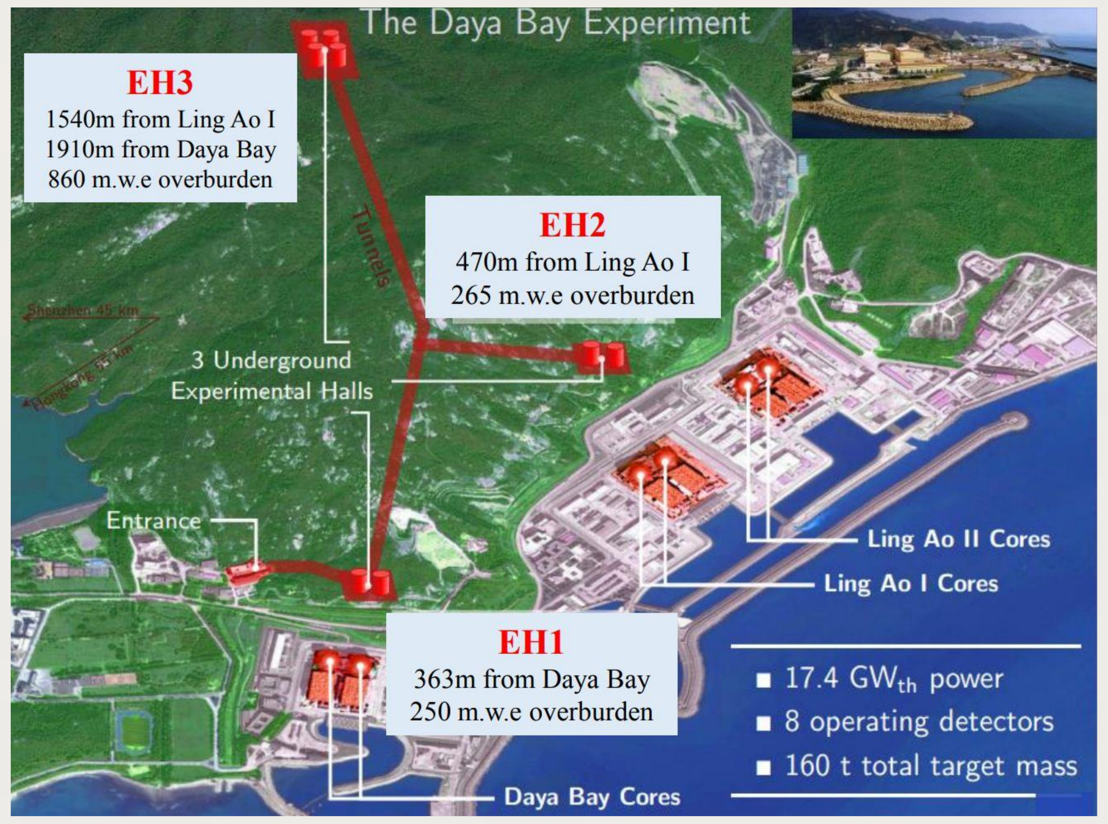
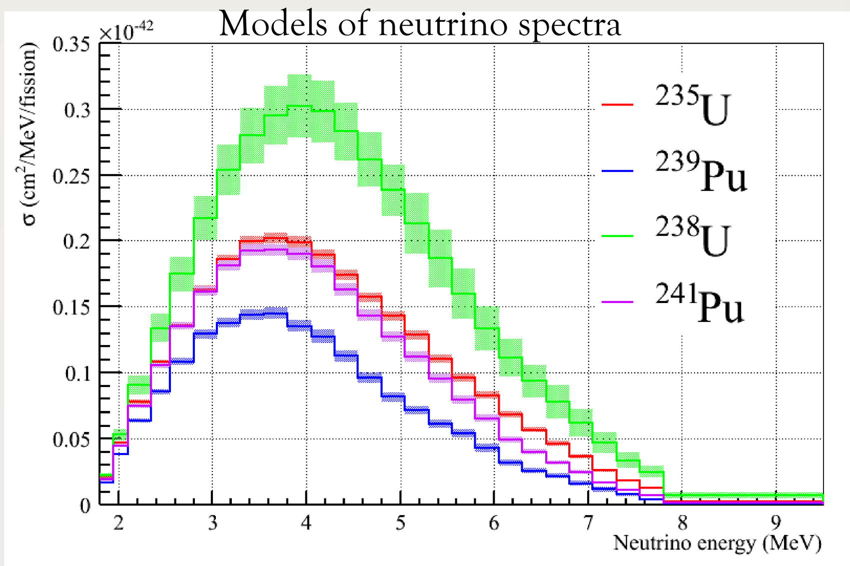
On behalf of the Daya Bay Collaboration

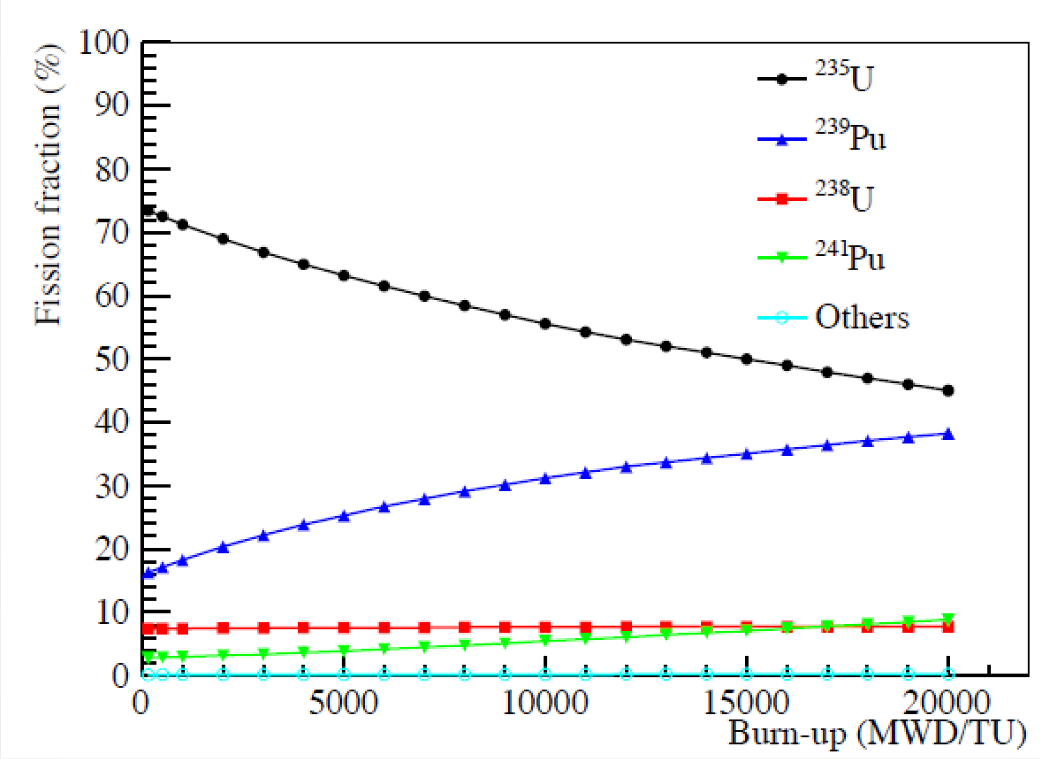
The Daya Bay Experiment



The most precise measurement of θ_{13} with 8 identically designed antineutrino detectors

Reactor antineutrinos





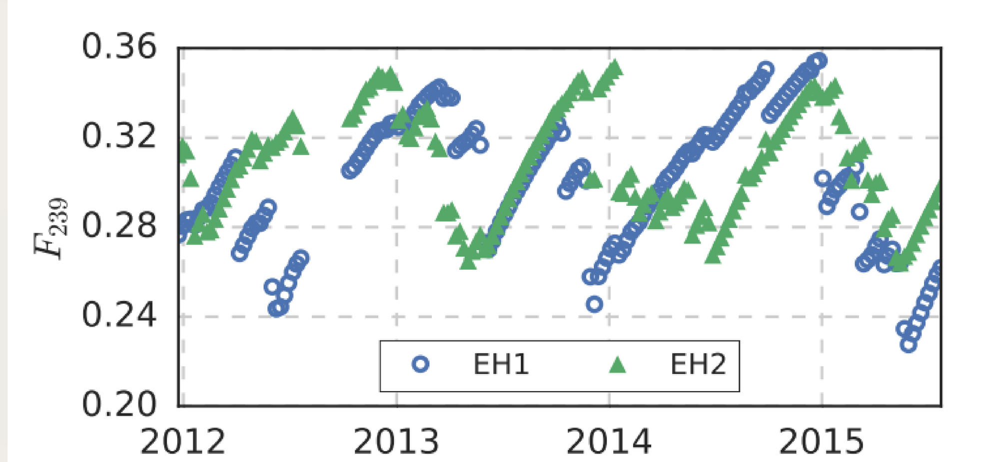
- Fission fraction: the fraction of fissions due to different isotopes.
- The neutrino yields can be extracted at Daya Bay due to:
  1) Fission fractions are evolving with respect to the fuel burning;
  2) Different neutrino yields of the two primary isotopes: ^{235}U and ^{239}Pu

Flux Evolution

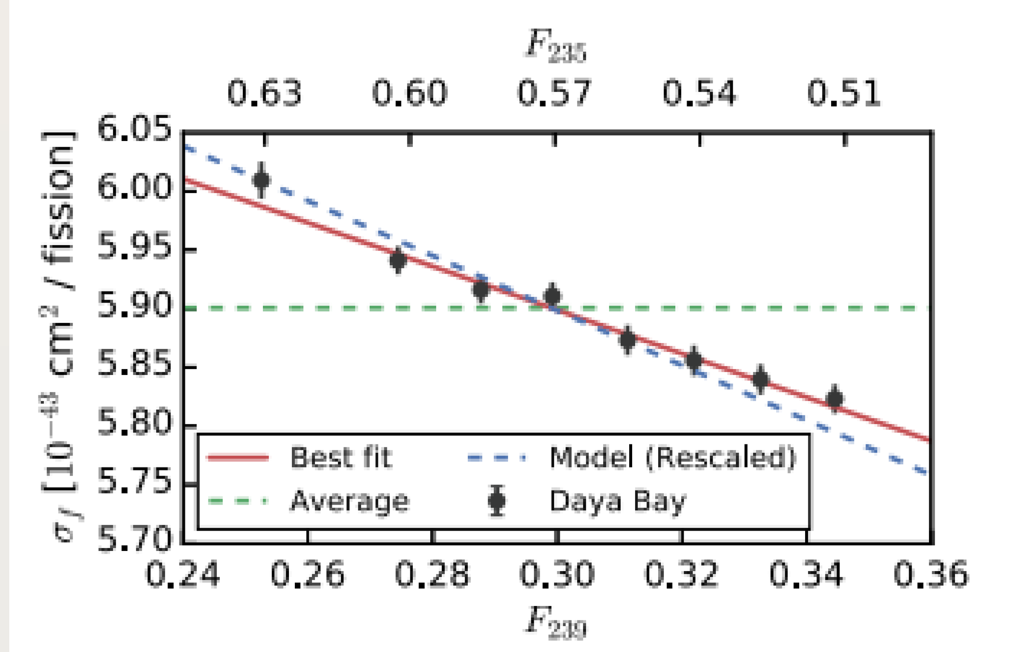
Phys. Rev. Lett. 118. (2017) 251801

$$F_i(t) = \sum_{r=1}^{6} \frac{W_{\mathrm{th},r}(t)\bar{p}_r f_{i,r}(t)}{L_r^2 \bar{E}_r(t)} \Big/ \sum_{r=1}^{6} \frac{W_{\mathrm{th},r}(t)\bar{p}_r}{L_r^2 \bar{E}_r(t)}$$

- Define 'effective fission fraction' observed by each detector.

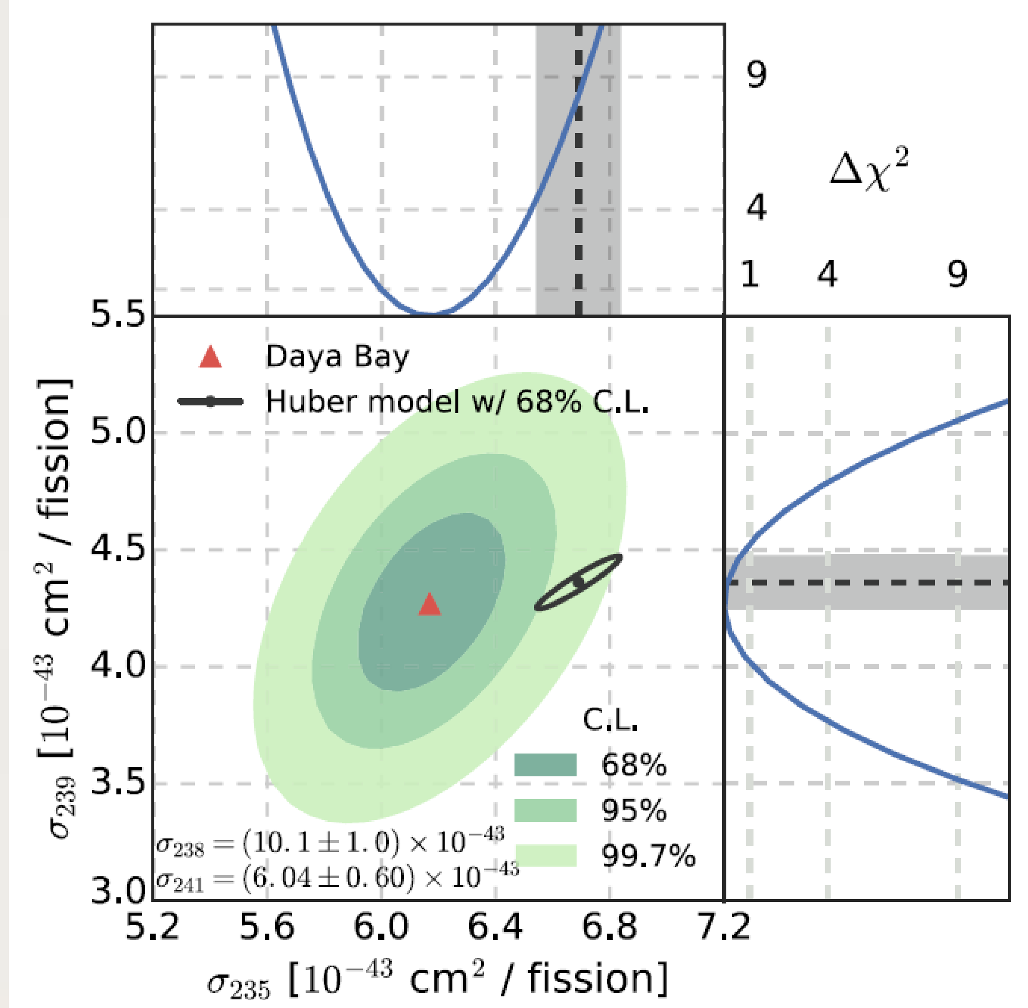


- The antineutrino reaction rate has an opposite trend to the effective fission fraction of ^{239}Pu.



- Extract the neutrino yields of ^{235}U and ^{239}Pu by constraining those of ^{238}U and ^{241}Pu

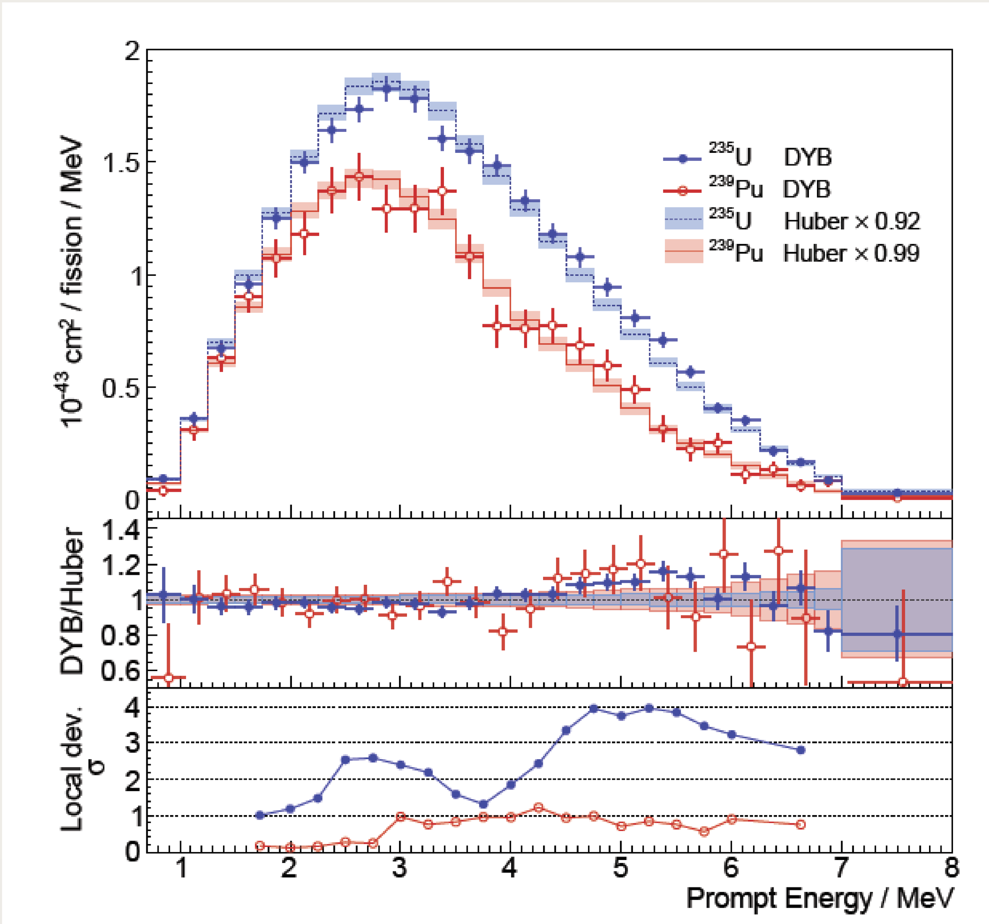
$$\chi^2 = (\sigma_f - F\sigma)^T V^{-1} (\sigma_f - F\sigma) + \sum_{^{238}\mathrm{U},\,^{241}\mathrm{Pu}} \frac{(\sigma_i - \bar{\sigma}_i)^2}{\varepsilon_i^2}$$



- Compared to the Huber model prediction:
  1) 7.8% deficit on ^{235}U flux
  2) Consistent ^{239}Pu flux.
- Prefer ^{235}U responsible for the Reactor Antineutrino Anomaly.
- Disfavor all isotopes with equal deficit (2.8σ) or ^{239}Pu solely responsible (3.2σ).
- Dominant uncertainty sources: statistics, detection efficiency

Spectrum Evolution

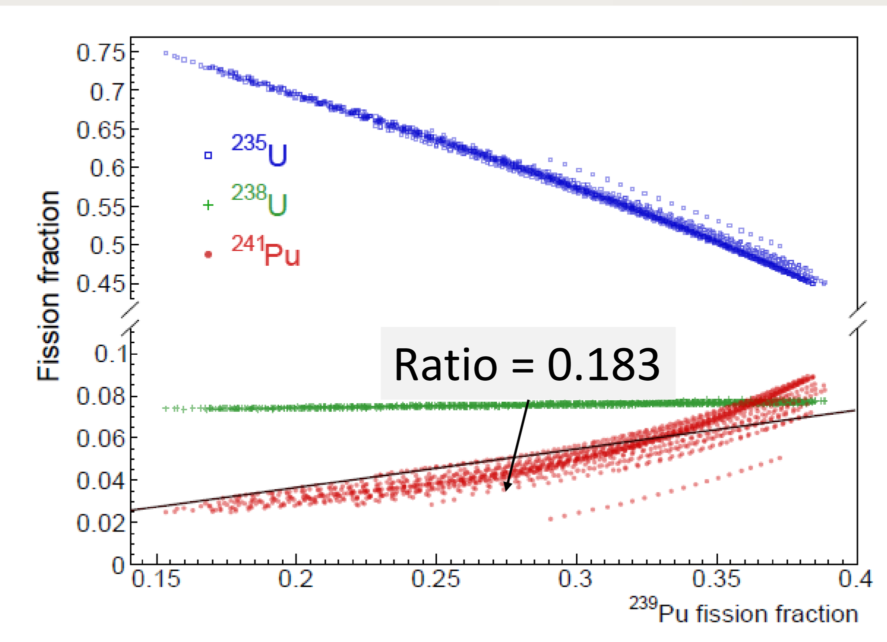
Phys. Rev. Lett. 123 (2019) 111801



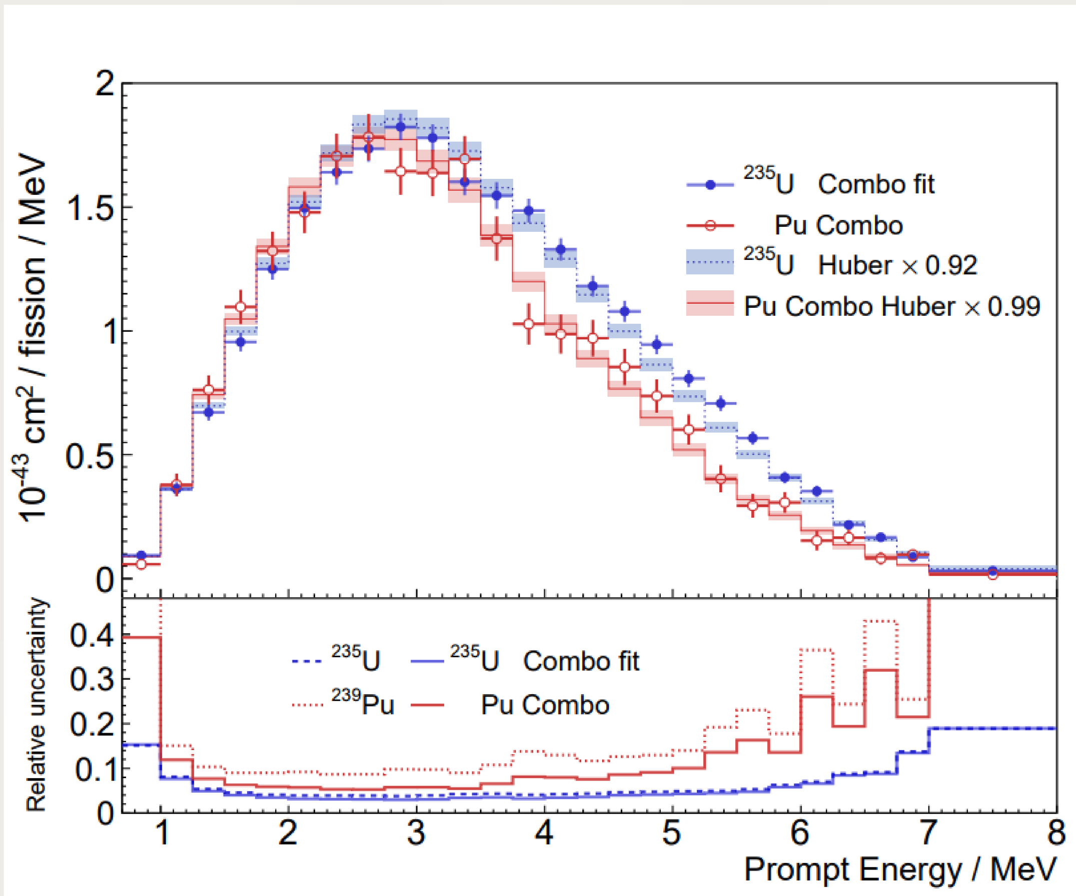
- Use 1958 days' data to extract the ^{235}U and ^{239}Pu neutrino spectra by constraining the spectra of ^{238}U and ^{241}Pu with model predictions.
- Comparison with the Huber model prediction after normalization
  - Similar bump excess for ^{235}U and ^{239}Pu in 4~6 MeV.
  - Significance of local deviations: 4σ for ^{235}U, 1.2σ for ^{239}Pu limited by larger uncertainty.
- First measurements of ^{235}U and ^{239}Pu neutrino spectra in commercial reactors.
- Dominant uncertainty sources: statistics (~60%), and systematics from ^{238}U and ^{241}Pu constraints (~35%).

- Reduce the systematic uncertainty by combining ^{239}Pu and ^{241}Pu according to their fission fraction ratio

$$S_{\mathrm{combo}} = S_{239} + 0.183 \times S_{241}$$



- Strong correlation between ^{239}Pu and ^{241}Pu fission fractions.
- Residual S241 is corrected when fission fraction ratio deviates from 0.183



- S_{combo} spectrum uncertainty: ~6% (~9% for ^{239}Pu-only)
- The extraction of the ^{235}U and ^{239}Pu spectra provide alternative reference for other reactor antineutrino experiments.

Reference

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