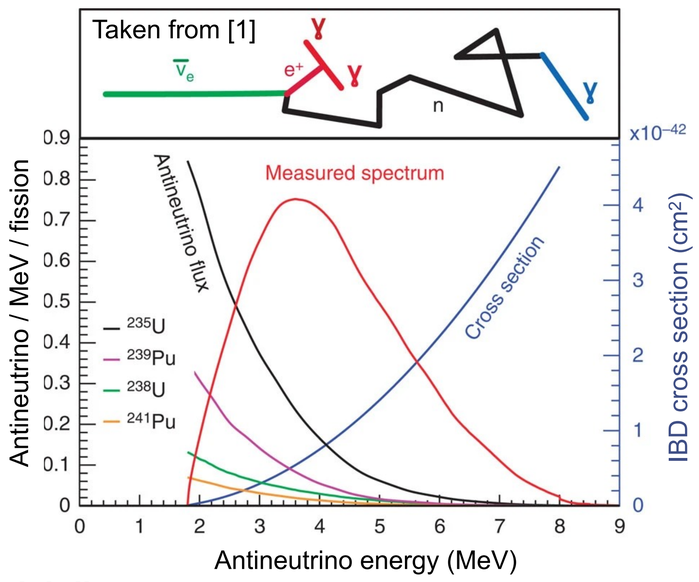
Reactor Neutrino Flux and Spectrum Measurements with Daya Bay Full Data Set

ID: 236

Yang HAN, Sun Yat-sen University, hany88@mail.sysu.edu.cn
Jinhao HUANG Institute of High Energy Physics, huangjinhao@ihep.ac.cn
on behalf of the Daya Bay collaboration

Reactor $\bar{\nu}_e$

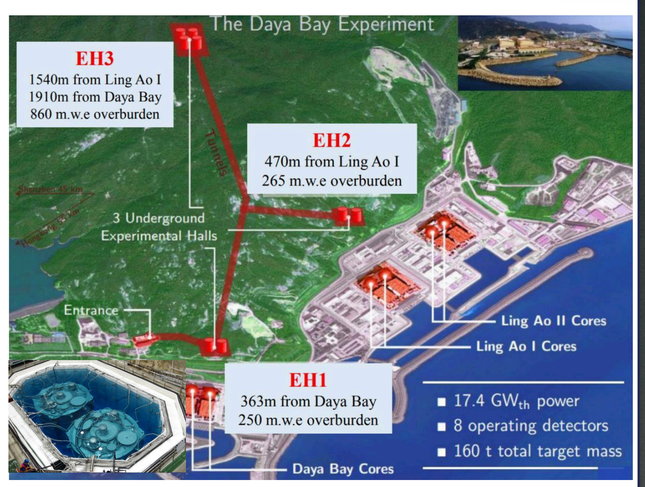
- **Nuclear reactor**: ~10^{20} $\bar{\nu}_e$'s / $\mathrm{GW_{th}}$ (production via $n \to p + e^- + \bar{\nu}_e$)
- **Fission isotopes:** ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu contributing >99% $\bar{\nu}_e$ in low enriched uranium reactors (commercial)
- **Detection:** inverse beta decay (IBD), $\bar{\nu}_e + p \to e^+ + n$ (mainly)
  Prompt Delay



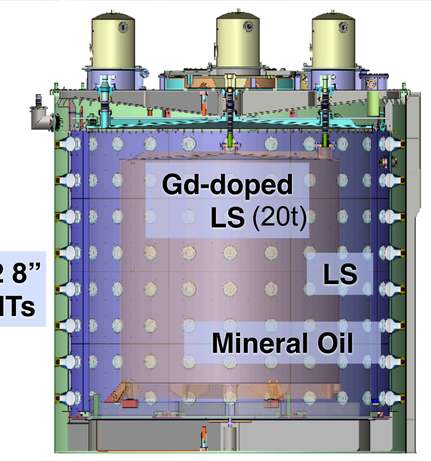
- **Data — Model discrepancy:**
  Rate discrepancy w.r.t. Huber-Mueller (HM) model [2,3]
  Shape discrepancy w.r.t. conversion and summation models

Daya Bay (DYB) Experiment [4]

- **Primarily for θ_{13} measurement** [5] (near-far relative measurement)
- **Source:** 6 reactor cores, 17.4 $\mathrm{GW_{th}}$
- **Detector:** 8 identical antineutrino detectors (ADs) at 3 sites
- **Operation:** Dec. 2011~ Dec. 2020 (3158 days)



- **Reactor $\bar{\nu}_e$ flux and spectrum measurement:** (absolute measurement)
  Precision measurement with complete data set of about 4.7 million IBD candidates collected at 4 near ADs.
  (Data with n-Gd as delay signals)



Reactor $\bar{\nu}_e$ flux at DYB

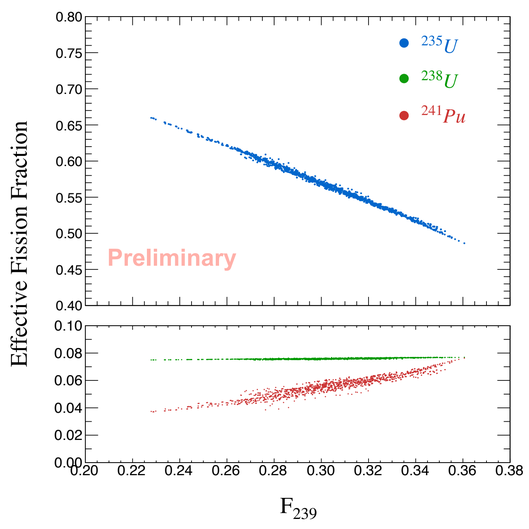
- **Flux in terms of IBD yield :** number of $\bar{\nu}_e$ per fission × IBD cross section
- **Overall flux σ_f :** combination of 4 isotopic fluxes according to their fractions
- **Average overall flux with DYB full data:**

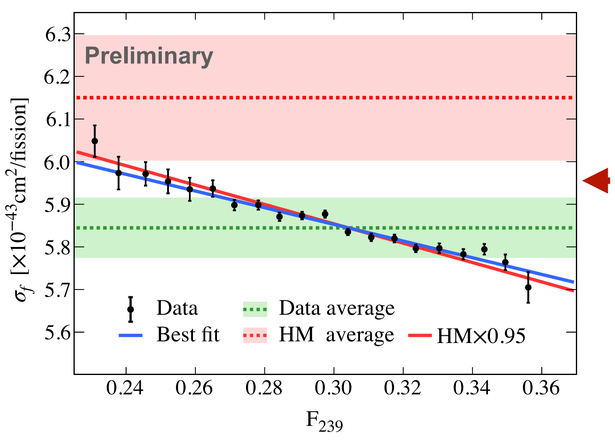
$$\bar{\sigma}_f = [5.84 \pm 0.07] \times 10^{-43}\mathrm{cm}^2/\mathrm{fission}$$ (syst. err. dominant)

- **Fuel evolution:** in one burning period

^{235}U ↓ ^{238}U — ^{239}Pu ↑ ^{241}Pu ↑

- **Effective fission fraction F_i:**
  frac. of fiss. isotopes viewd by detectors (weekly basis)
- **Fuel evolution in terms of F_{239}**





- **Overall flux evolution**

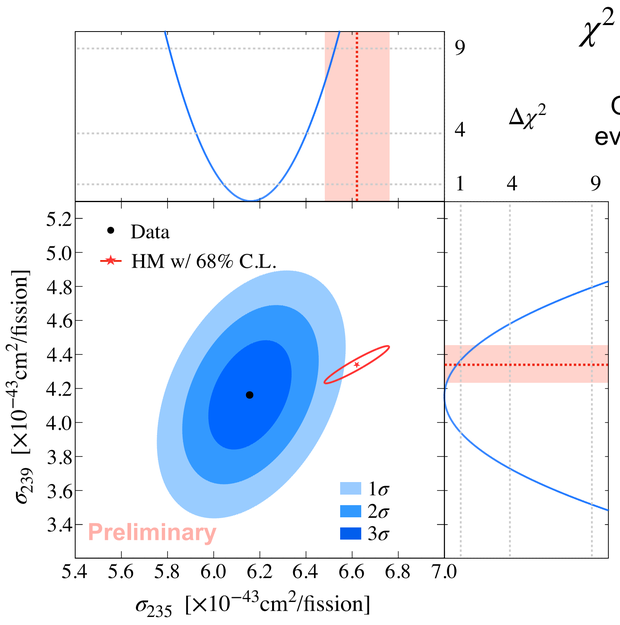
Enable

- **Extract ^{235}U and ^{239}Pu fluxes:**

eff. fiss. frac. systematics

$$\chi^2 = \chi^2(\sigma_f, F, \sigma_i, \epsilon) + \chi^2(\sigma_{238}, \sigma_{241})$$

Overall flux evolution data | Isotopic yields to be extracted | Constrain ^{238}U and ^{241}Pu with HM (10%)

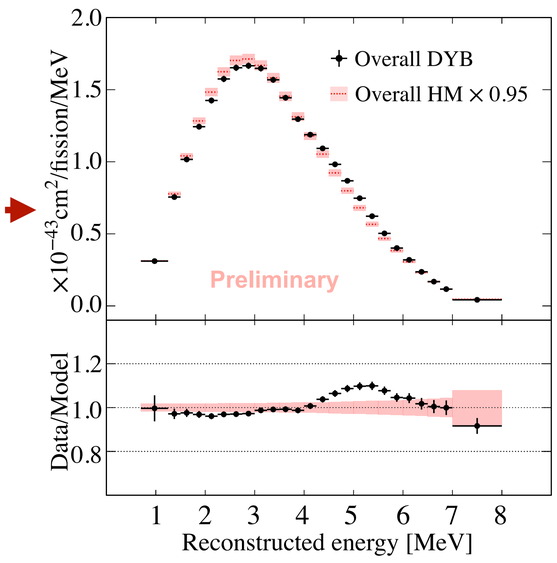


$$\sigma_{235} = [6.16 \pm 0.12] \times 10^{-43}$$
$$\sigma_{239} = [4.16 \pm 0.21] \times 10^{-43}$$
(unit: cm^2/fission)

(dominant errors from syst. and model)

Reactor $\bar{\nu}_e$ spectrum at DYB

- **Spectrum:**
  25 bins in 0.7~8 MeV reconstructed energy of IBD prompt signal
- **Overall spectrum:**



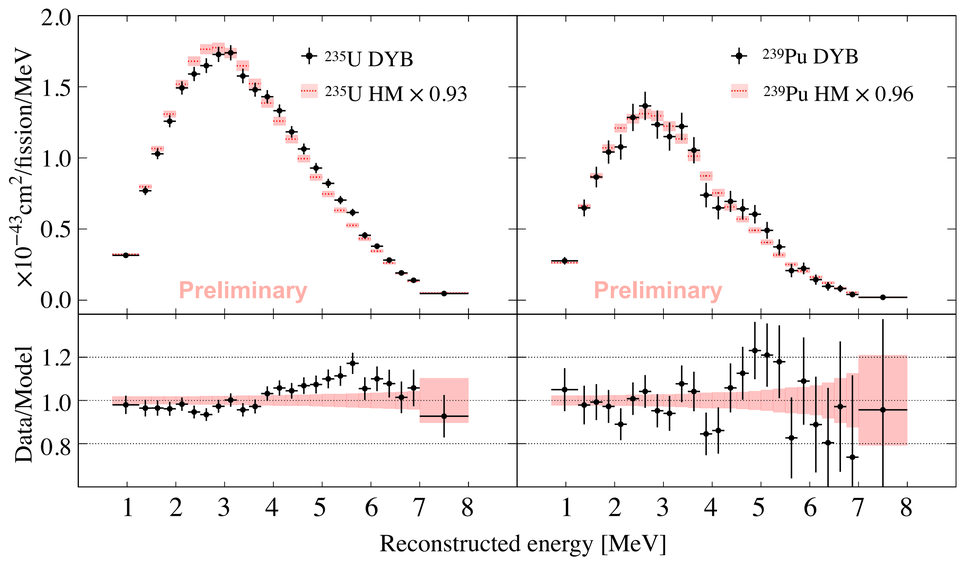
~1.4% precision in 2~5 MeV
Shape discrenpcy w.r.t. HM model
~10σ significance in 4~6 MeV
(syst. err. dominant)

- **Extract ^{235}U and ^{239}Pu spectra:**

eff. fiss. frac. systematics

$$\chi^2 = \chi^2(s_f, F, s_i, \epsilon) + \chi^2(s_{238}, s_{241})$$

Overall spectrum evolution data | Isotopic spectra to be extracted | Constrain ^{238}U and ^{241}Pu with HM (conservative setting with enlarged HM err.)



^{235}U: ~3% precision in 2~5 MeV,
shape dis. w.r.t. HM: ~4σ in 4~6 MeV

^{239}Pu: ~8% precision in 2~5 MeV,
shape dis. w.r.t. HM: ~1σ in 4~6 MeV

(stat. err. dominant)

Reference:

1. P. Vogel et al. Nature Commun. 6 (2015) 6935
2. T. A. Mueller et al., Phys.Rev. C83, 054615 (2011)
3. P. Huber, Phys.Rev. C84, 024617 (2011)
4. Daya Bay Collaboration, Nucl. Instrum .Meth. A811, (2016) 133–161
5. Daya Bay Collaboration, Phys.Rev.Lett. 130 (2023) 16, 161802