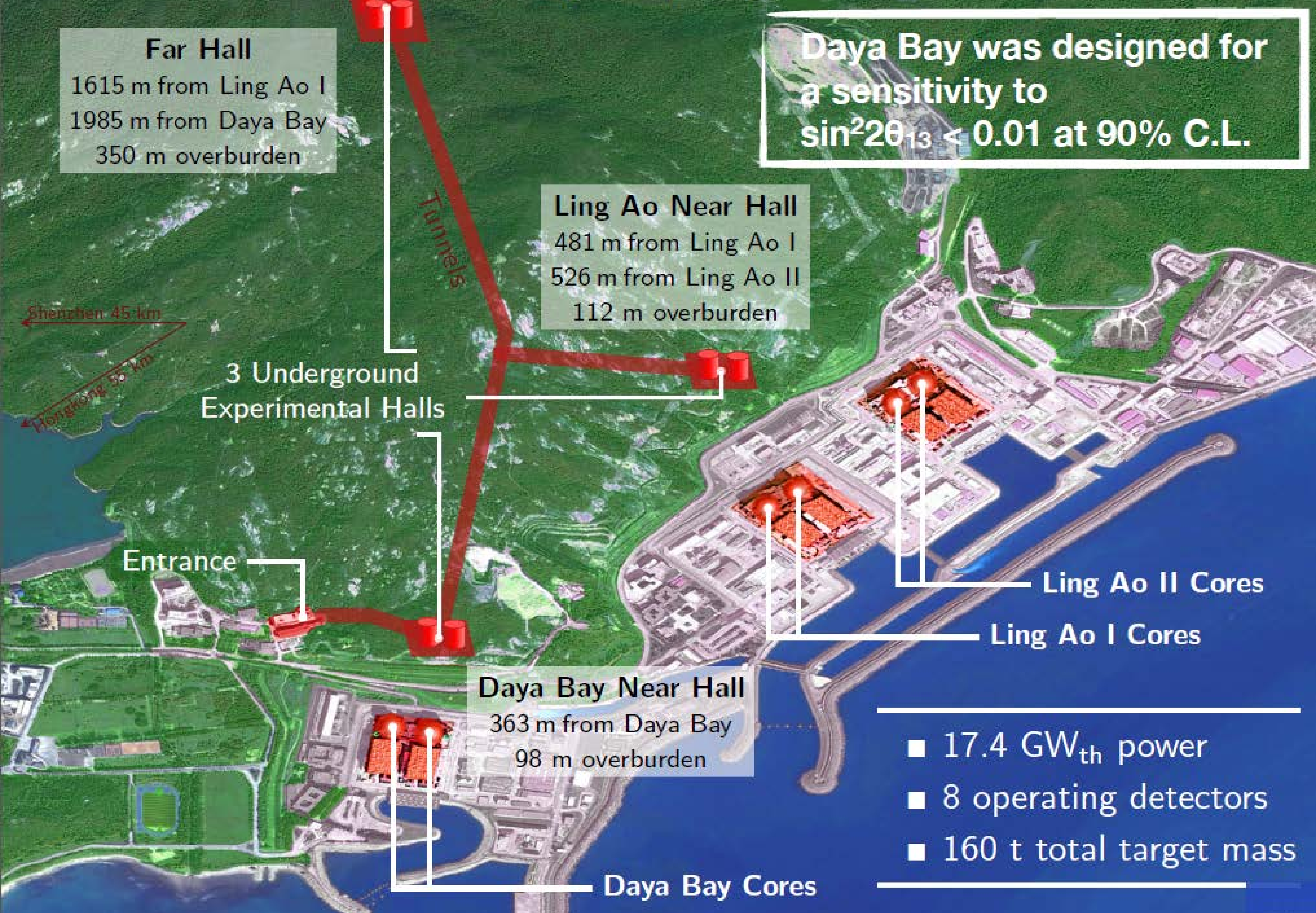
The Latest Daya Bay Results

Chao Zhang

On behalf of the Daya Bay Collaboration

BROOKHAVEN NATIONAL LABORATORY

The Daya Bay Experiment



Daya Bay was designed for a sensitivity to $\sin^2 2\theta_{13} < 0.01$ at 90% C.L.

- 17.4 GW_{th} power
- 8 operating detectors
- 160 t total target mass

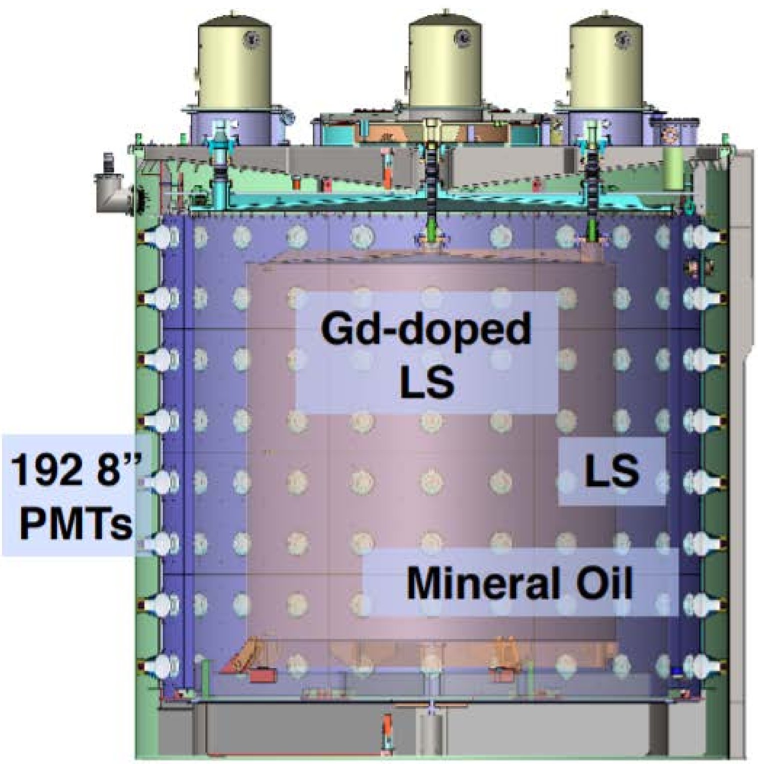
Daya Bay Detectors

Inverse Beta Decay (IBD):

$$\overline{\nu}_e + p \rightarrow e^+ + n$$

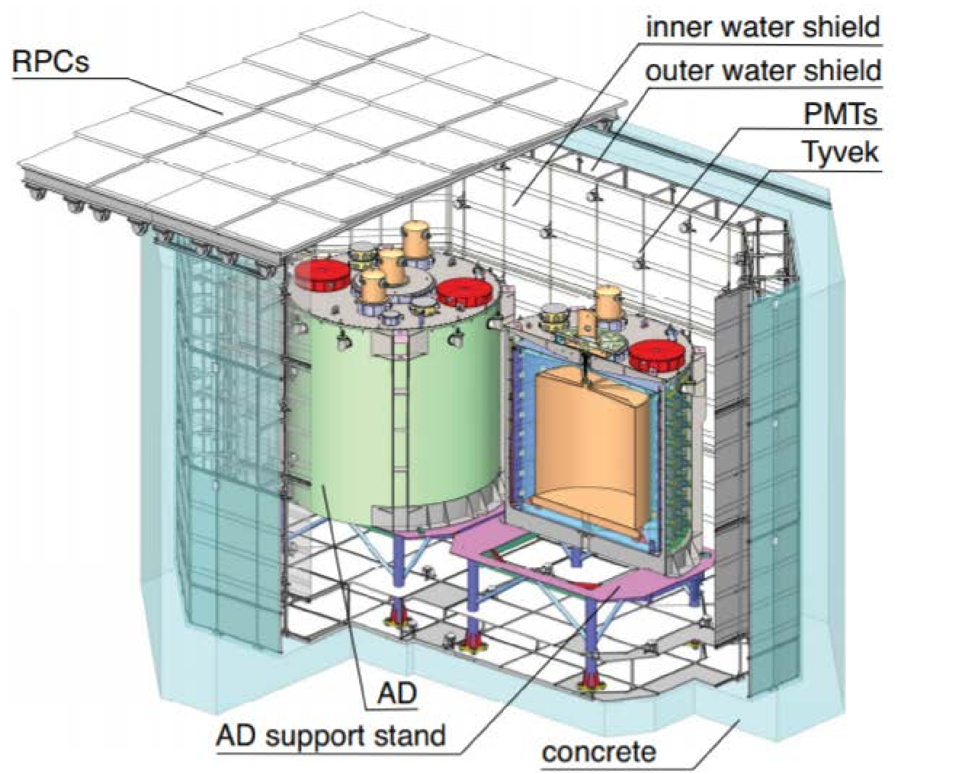
$$n + p \rightarrow D + \gamma$$ 2.2 MeV

$$n + Gd \rightarrow Gd^* \rightarrow Gd + \gamma s$$ 8/8.5 MeV 30 μs



Energy resolution:
$\sigma_E/E \cong 8.5\%/\sqrt{E}$

NIM A811, 133 (2016)

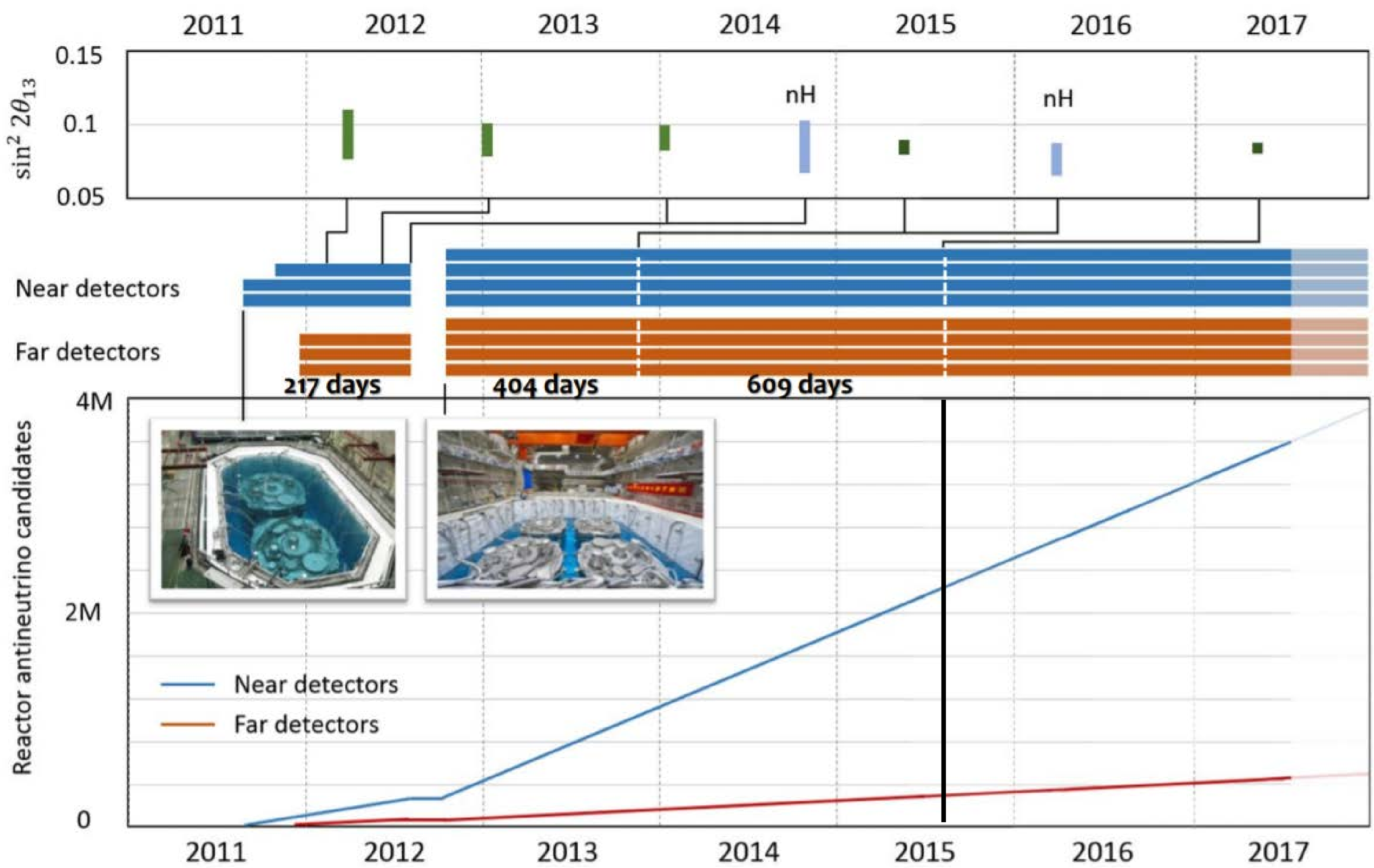


Double purpose: shield the ADs and veto cosmic ray muons

NIM A773, 8 (2015)

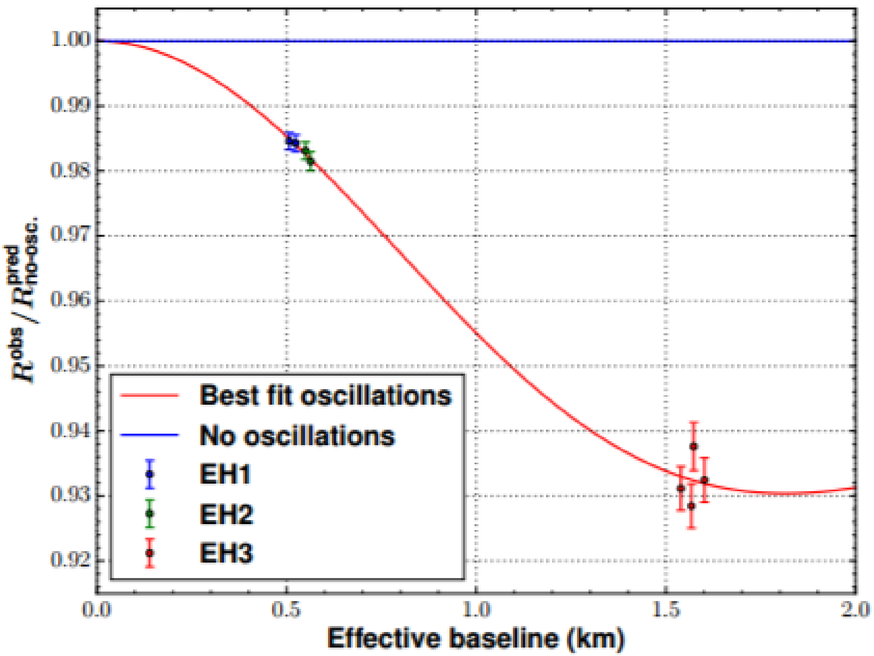
Data Taking Status

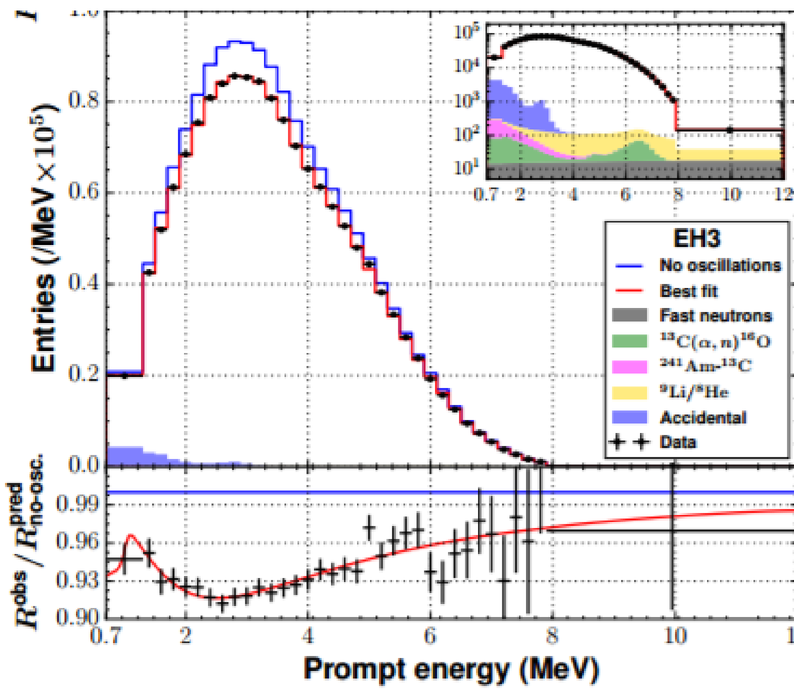
- Latest data set: **2011/12 – 2015/7, 1230 days**
  - Near site: **2.2 M events**
  - Far site: **300 K events**



Standard Oscillation Analysis

$$P(\bar{\nu}_e \to \bar{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2(\Delta m^2_{ee} \frac{L}{4E}) - \cos^4 \theta_{13} \sin^2 2\theta_{12} \sin^2(\Delta m^2_{21} \frac{L}{4E})$$

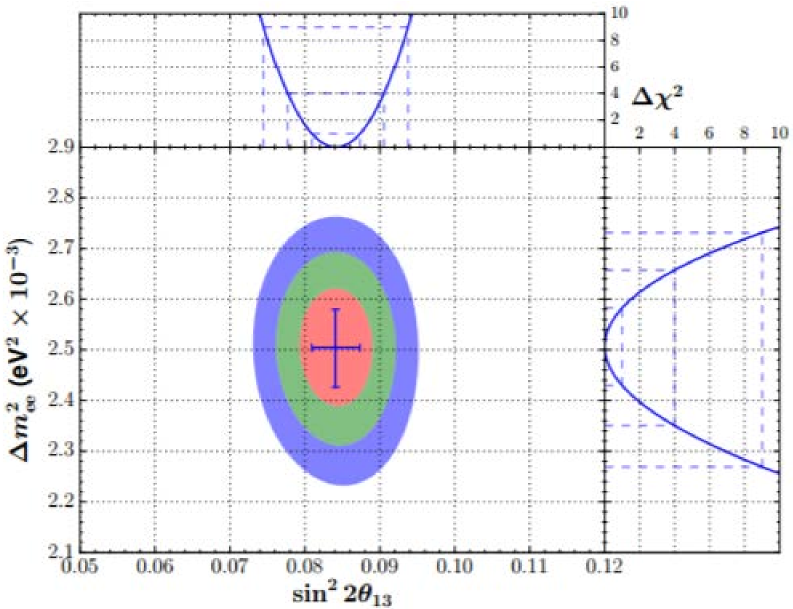




1230 days
PRD 95, 072006 (2017)

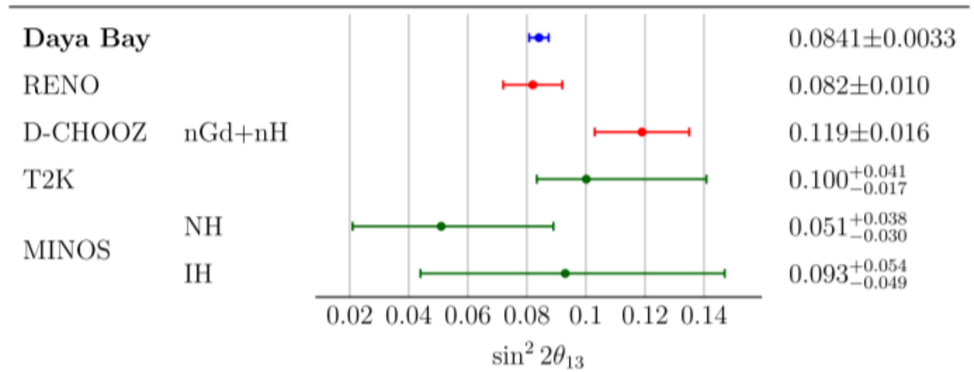
Standard Oscillation Analysis

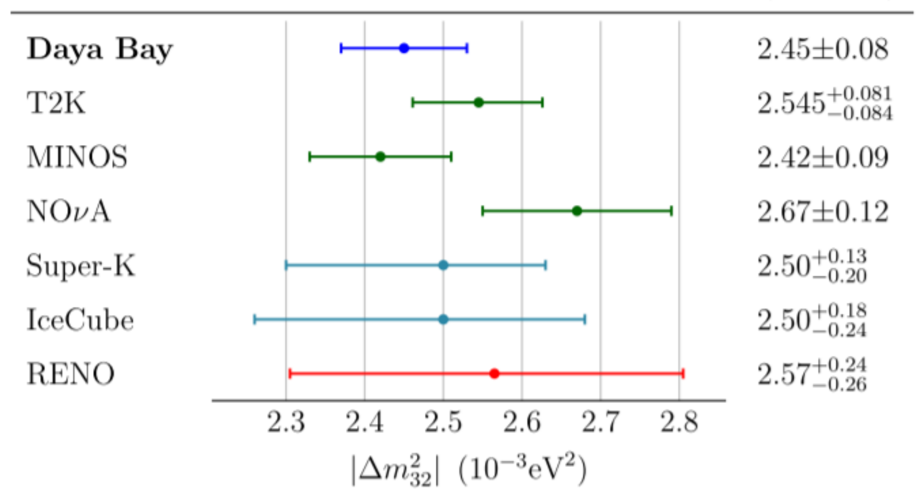
$$\sin^2 2\theta_{13} = [8.41 \pm 0.27(\text{stat.}) \pm 0.19(\text{syst.})] \times 10^{-2}$$
$$|\Delta m^2_{ee}| = [2.50 \pm 0.06(\text{stat.}) \pm 0.06(\text{syst.})] \times 10^{-3}\ \text{eV}^2$$
$$\chi^2/\text{NDF} = 234.7/263$$



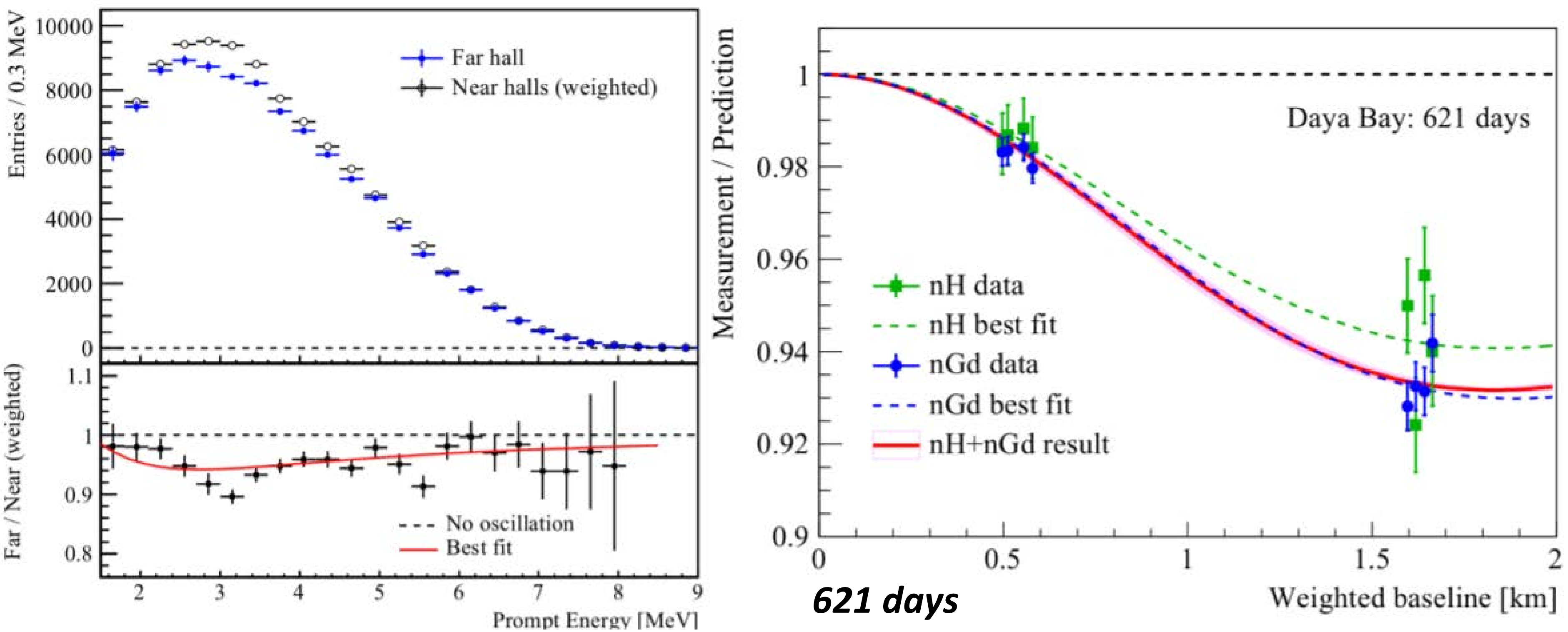
PRD 95, 072006 (2017)

Most precise θ_{13} and $|\Delta m_{32}^2|$ (<4%) measurements to date .





nH Oscillation Analysis

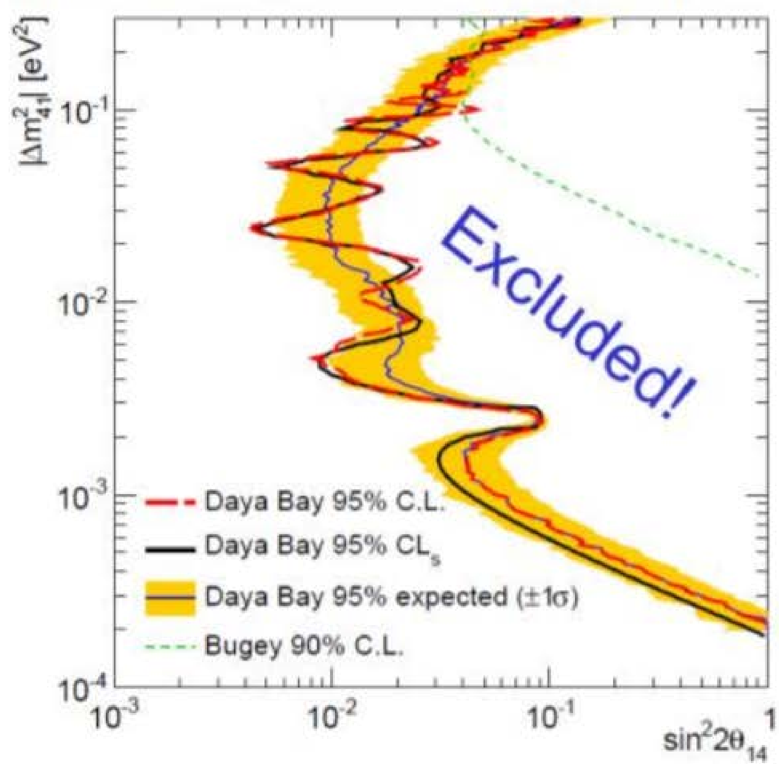


621 days
PRD 93, 072011 (2016)

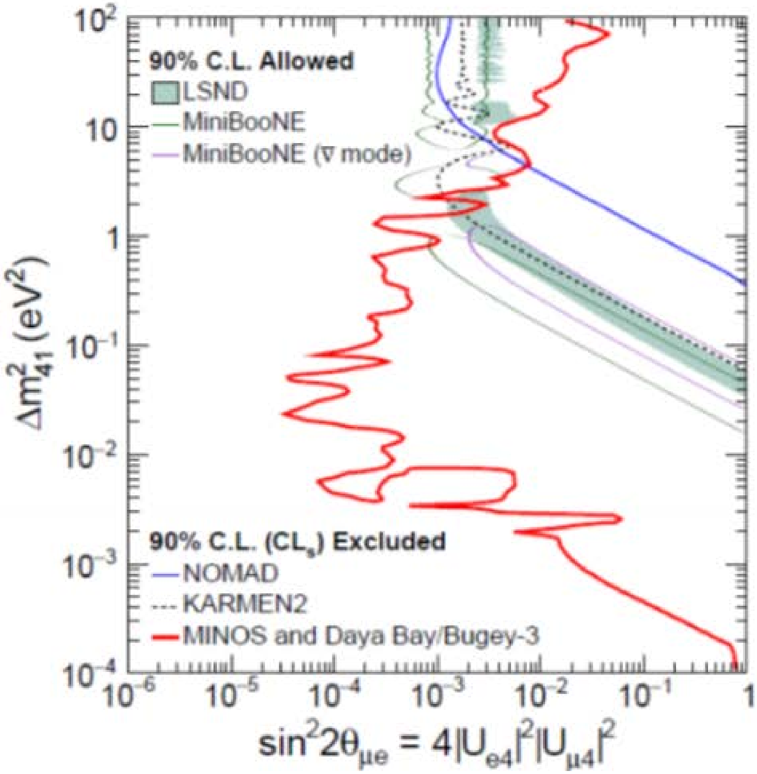
- Independent sample of neutron capture on Hydrogen with different systematics
- Consistent result: $\sin^2 2\theta_{13} = 0.071 \pm 0.011$ $\chi^2/NDF = 6.3/6$

Sterile Neutrino Search

Phys. Rev. Lett. 117 ,151802(2016)



Phys. Rev. Lett. 117, 151801 (2016)



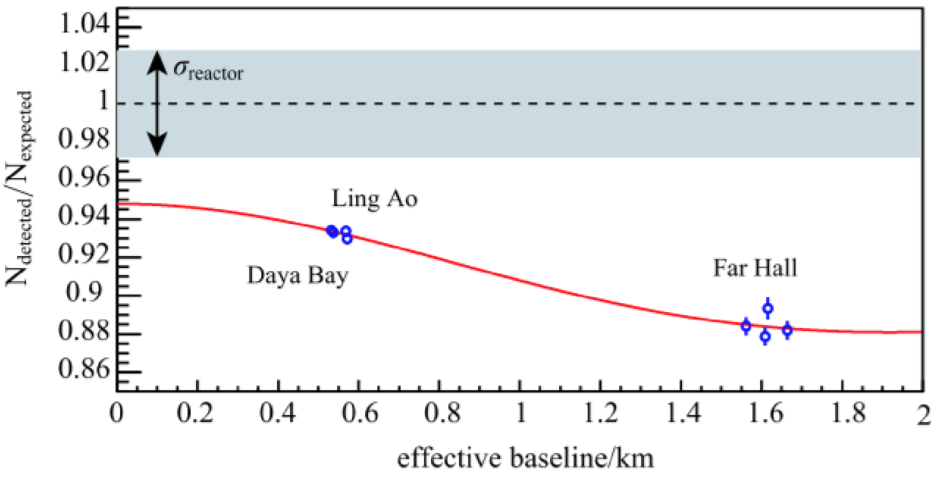
- No hint of light sterile neutrinos
- Combining with MINOS and Bugey-3, excluded a large parameter space allowed by LSND/MiniBooNE anomalies

Absolute Reactor Antineutrino Flux

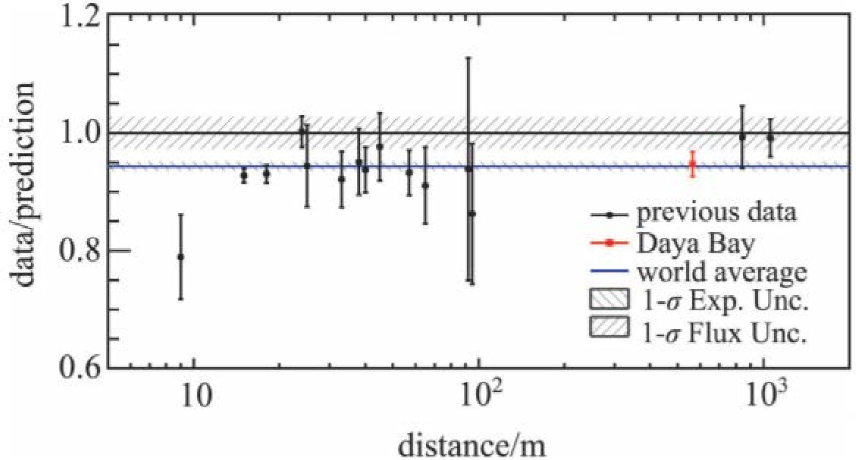
- Daya Bay's blind analysis of absolute flux agrees with previous experiments

$$\frac{Data}{Model\ (\text{Huber} + \text{Muller})} = 0.946 \pm 0.020\ (exp.)$$

- 5.4% deficit compared with the recent Huber (^{235}U, ^{239}Pu, ^{241}Pu) plus Muller (^{238}U) model



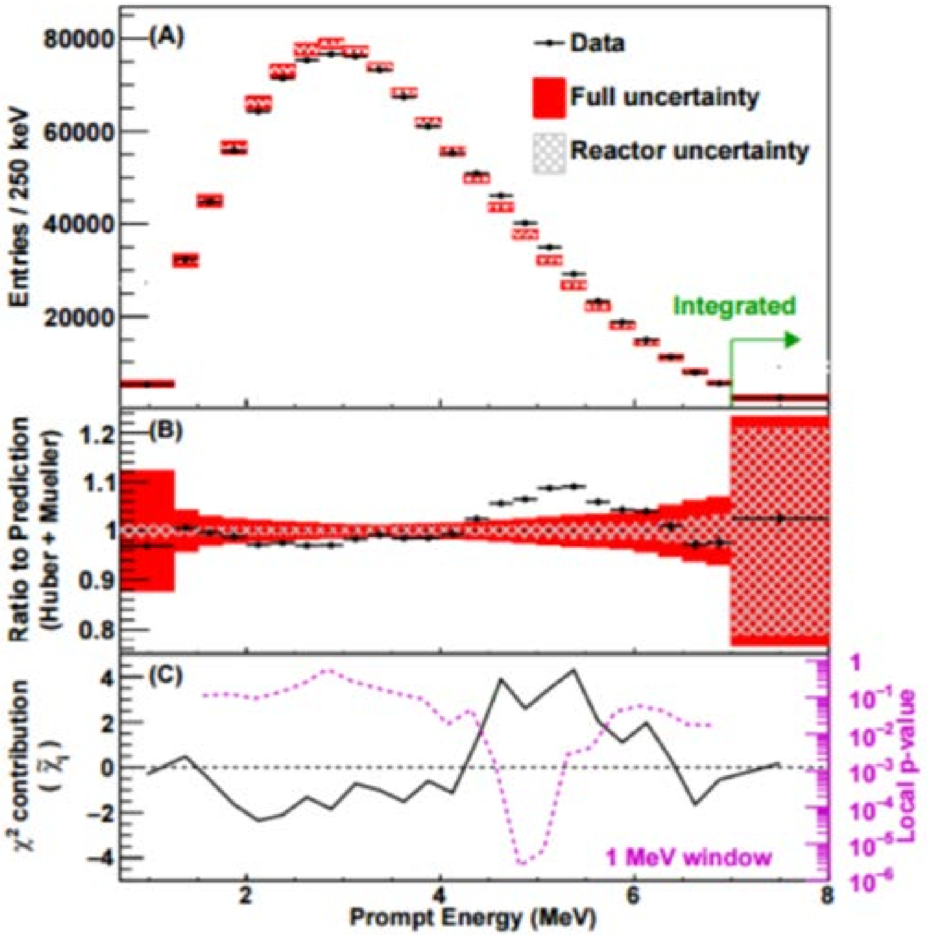
Chin. Phys. C41, 1 (2017)



Flux anomaly unlikely due to experimental bias

Reactor Antineutrino Spectrum

- Bump in (4 – 6 MeV, 4.4σ local significance) prompt energy region when compared to the model predictions
  - Cannot be explained by detector effects such as energy response
  - Cannot be explained by sterile neutrino oscillations
  - Also observed by RENO, Double Chooz, NEOS

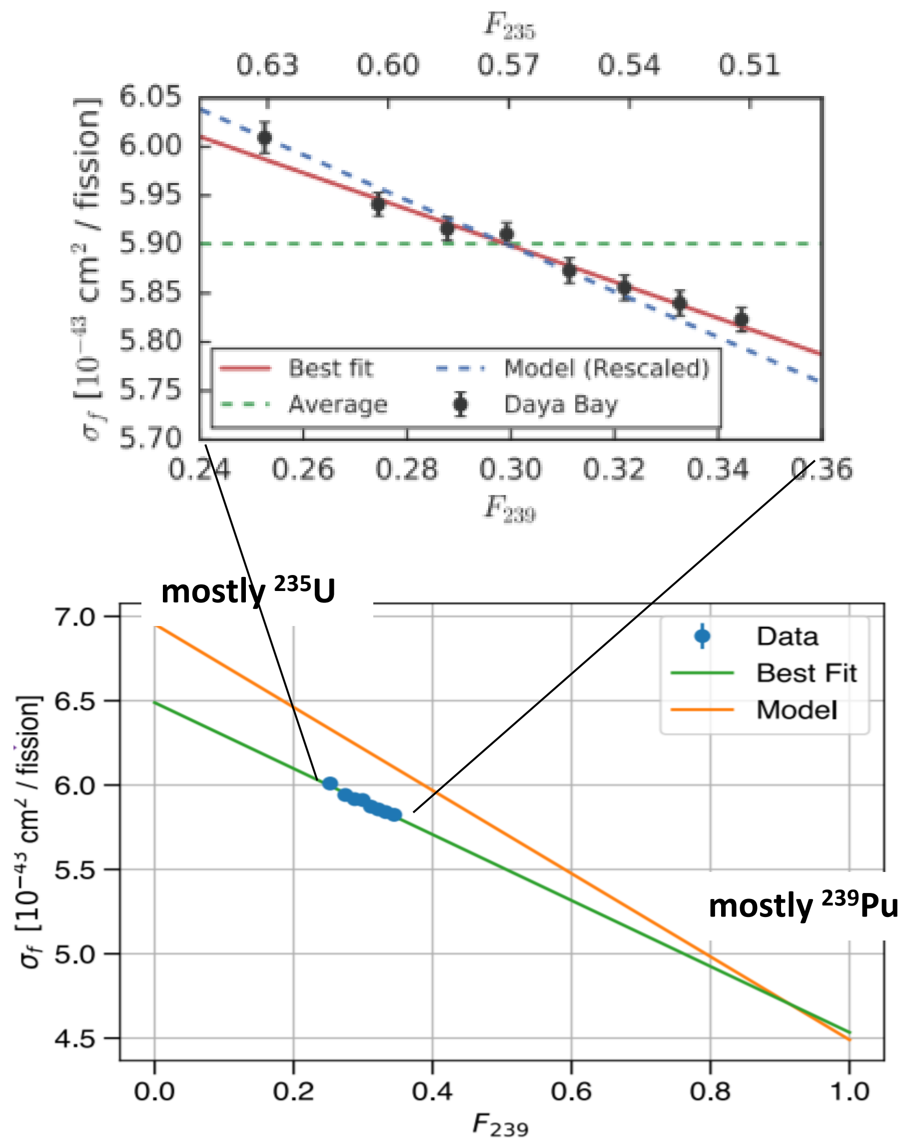


Chin. Phys. C41, 1 (2017)

Reactor Fuel Evolution

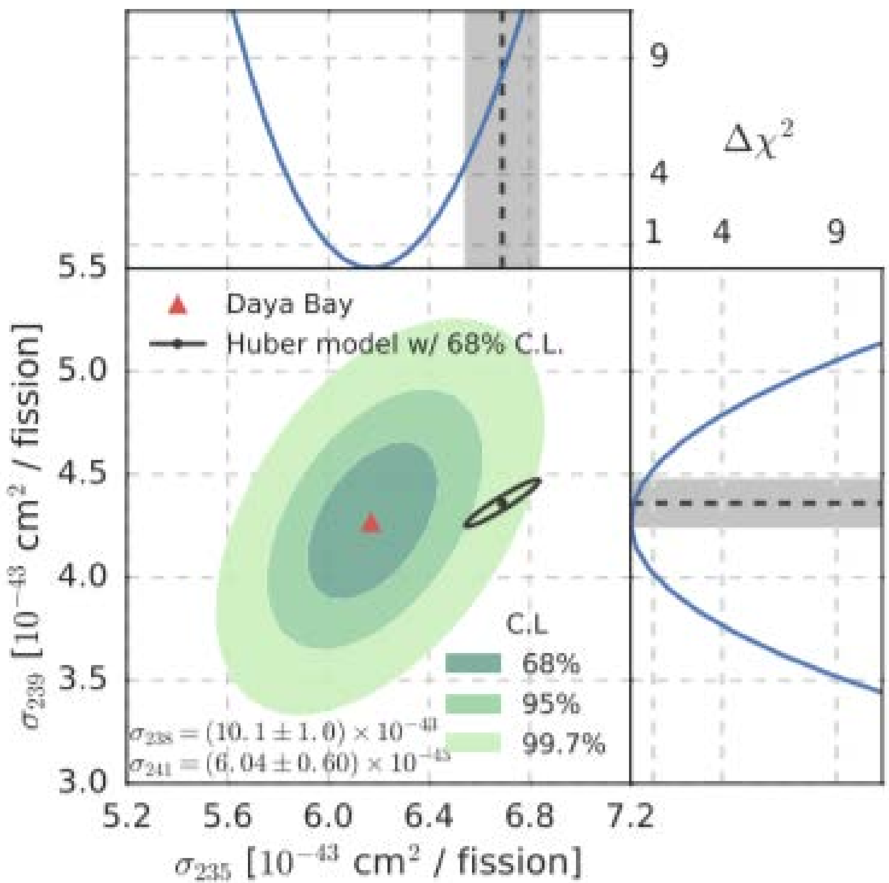
- Observed clear linear evolution of IBD yield vs. effective fission fraction of ^{239}Pu
  - 10σ demonstration that the yields between ^{235}U and ^{239}Pu are different
- However, the evolution slope does not agree with theory
  - Indication that the reactor flux anomaly is mostly coming from ^{235}U model prediction

PRL 118, 251801 (2017)



Extraction of ^{235}U and ^{239}Pu Yield

- Combined fit of the two major fission isotopes ^{235}U and ^{239}Pu
  - Assumed the yields of the two minor isotopes ^{238}U and ^{241}Pu from model prediction with an enlarged 10% error.
- Results suggest ^{235}U being the main contributor to the Reactor Antineutrino (Flux) Anomaly
  - ^{235}U is 7.8% lower than H-M model (2.7% meas. uncertainty)
  - ^{239}Pu is consistent with H-M model (6% meas. uncertainty)



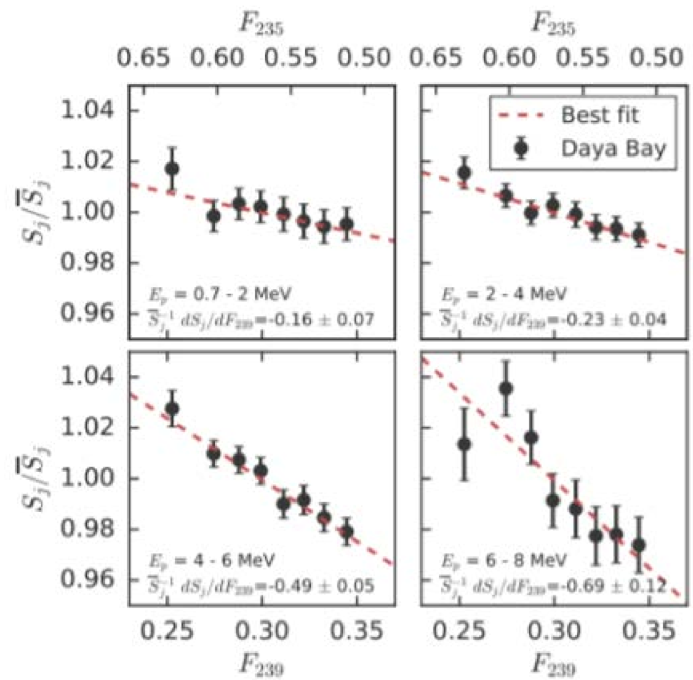
PRL 118, 251801 (2017)

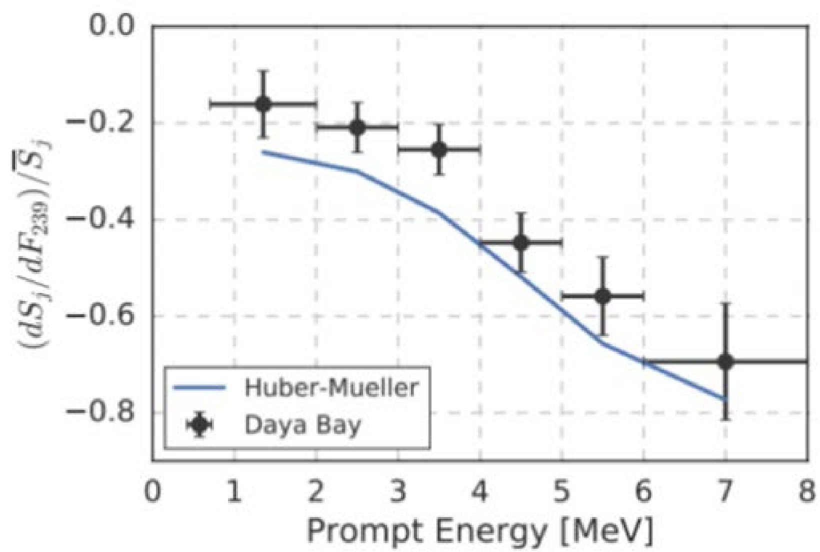
RAA cause	$\Delta\chi^2$/ndf	p-value
^{235}U	0.17/1	0.68
^{239}Pu	10.0/1	0.00016
All isotopes	7.9/1	0.0049

Sterile neutrino as the sole cause of RAA disfavored at 2.8σ

Spectrum Evolution

- The evolution slopes are different in different energy bins
  - First 5σ demonstration that the spectrum shape changes with fuel evolution
- The shape change is consistent with most models' predictions
- Need larger statistics and better efficiency estimates





Summary and Outlook

- Daya Bay has been continuously producing important results
  - Most precise measurement of $\sin^2 2\theta_{13}$ and $|\Delta m^2_{ee}|$
  - New limits on light sterile neutrinos
  - Updated measurement of reactor antineutrino flux and spectrum
  - New analysis of reactor fuel evolution
  - Other analyses: decoherence, muon modulation, etc.
- Future improvements
  - New FADC electronics implemented in one AD in 2016 to improve the understanding of the non-linearities in the energy response
  - New neutron calibration campaign in 2017 to reduce detection efficiency uncertainty
  - One AD in Daya Bay Hall was used for LS studies since 2017 to better understand the scintillator optical model
  - Plan to run till 2020, improve both $\sin^2 2\theta_{13}$ and $|\Delta m^2_{ee}|$ to below 3%