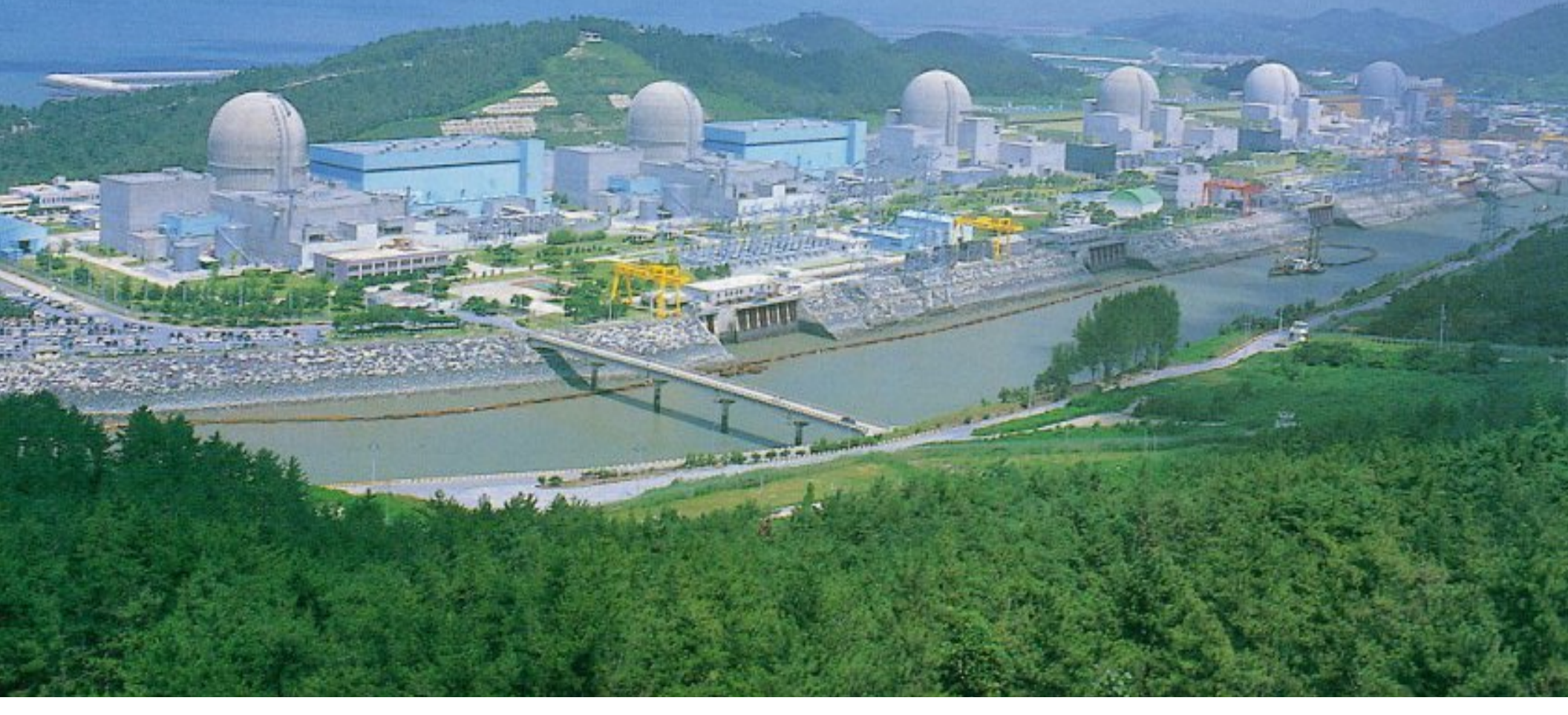
Recent Results from RENO Experiment

KAIST
Jonghee Yoo
on behalf of the RENO Collaboration

2020-06-25 Neutrino 2020, Chicago, USA



Reactor Experiment for Neutrino Oscillation

9 Institutions and 40 Physicists

Chonnam National University

Dongshin University

Gwangju Institute of Science and Technology

Gyeongsang National University

Korea Advanced Institute of Science and Technology

Kyungpook National University

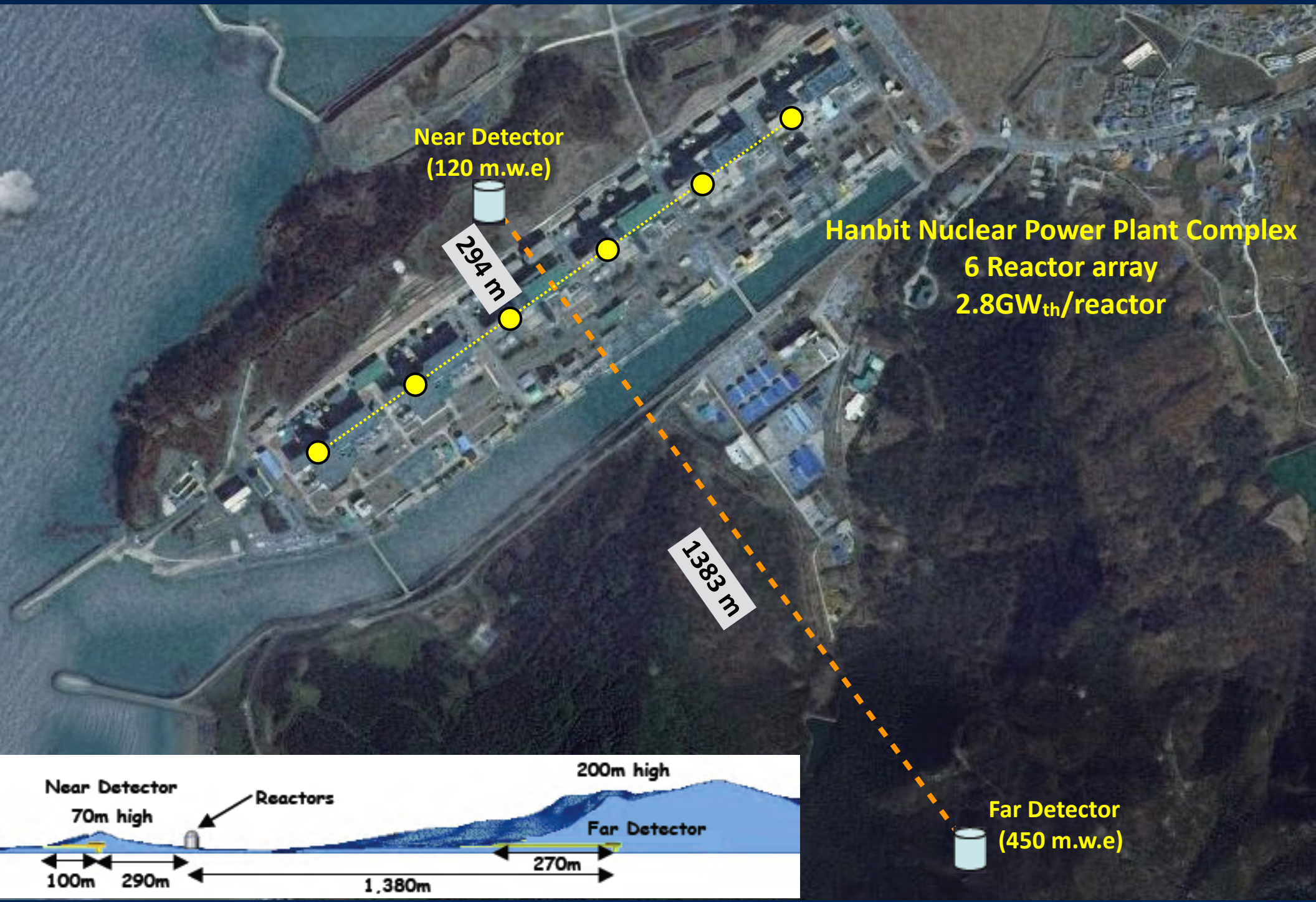
Seoul National University

Seoyeong University

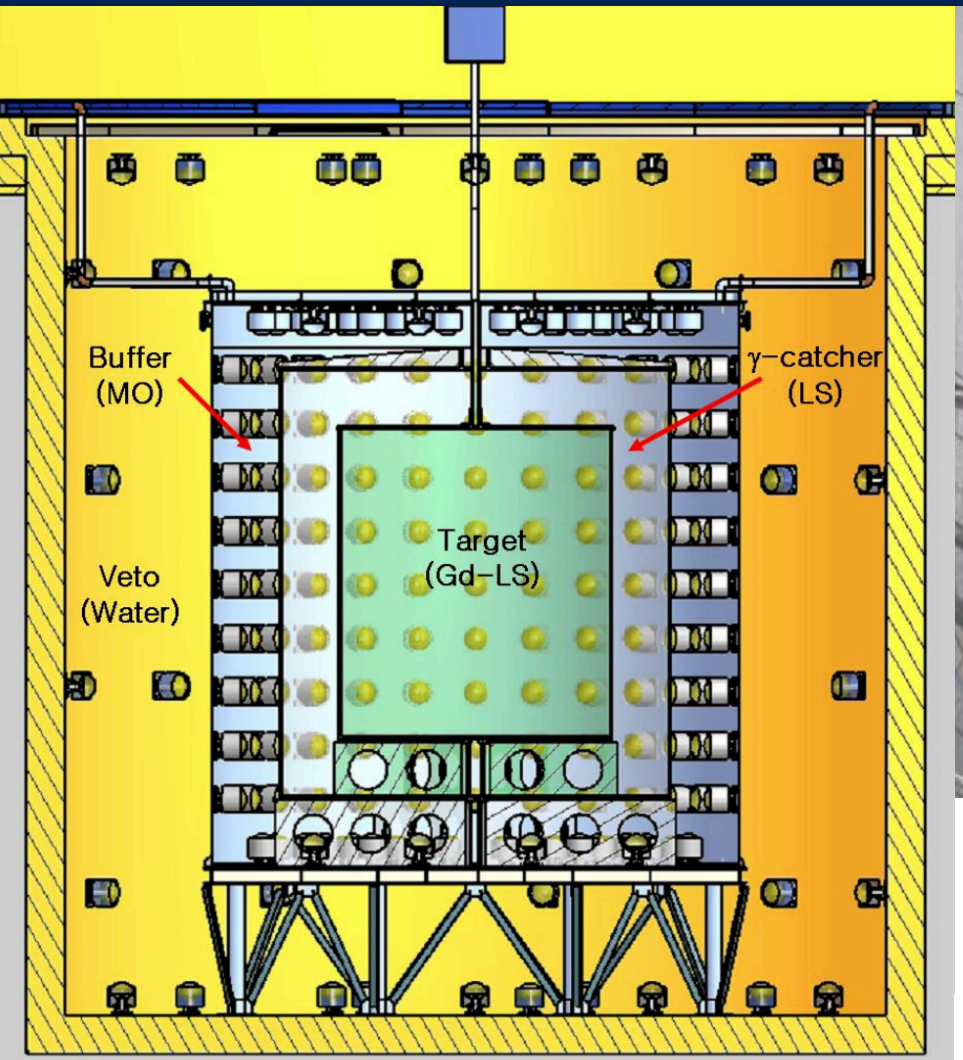
Sungkyunkwan University

- Start of project: 2006
- The first reactor experiment running with both near and far detectors since August 2011

RENO Experimental Setup



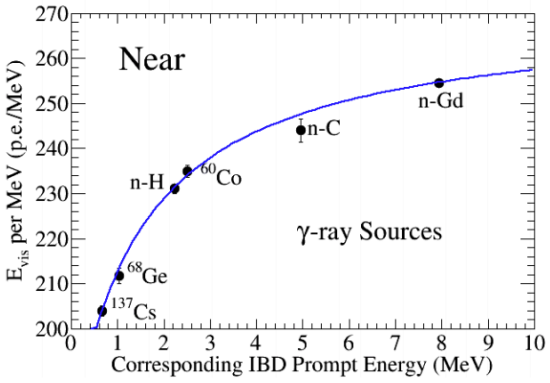
RENO Detectors

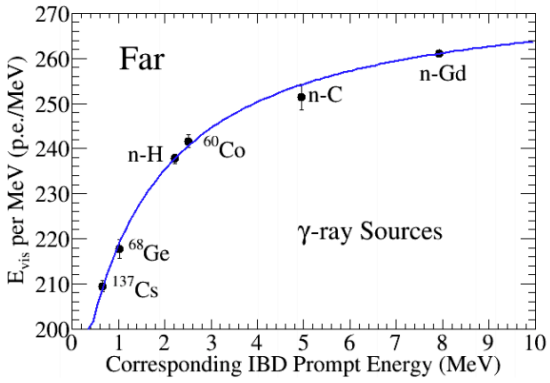


Two identical (near and far) detectors

354 (Buffer) + 67 (Veto) 10” PMTs

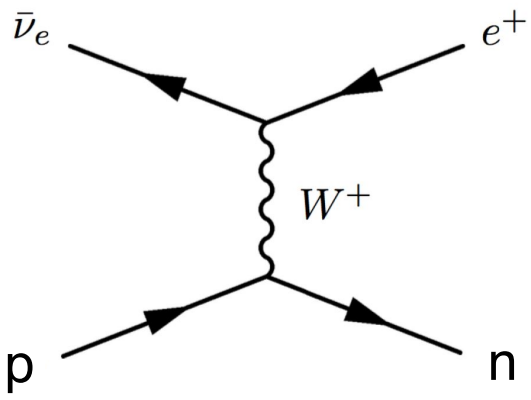
Detector Calibration





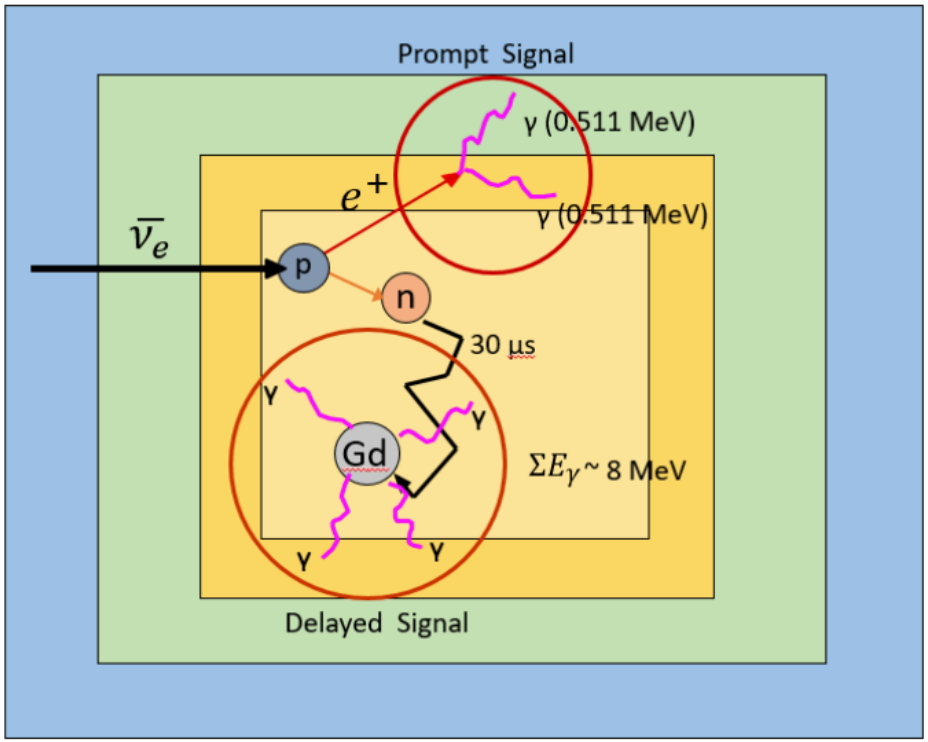
- Target (Gd-loaded LS) 16 tons
- Gamma catcher (LS) 29 tons
- Buffer (Mineral oil) 64 tons
- Veto (Water) 353 tons

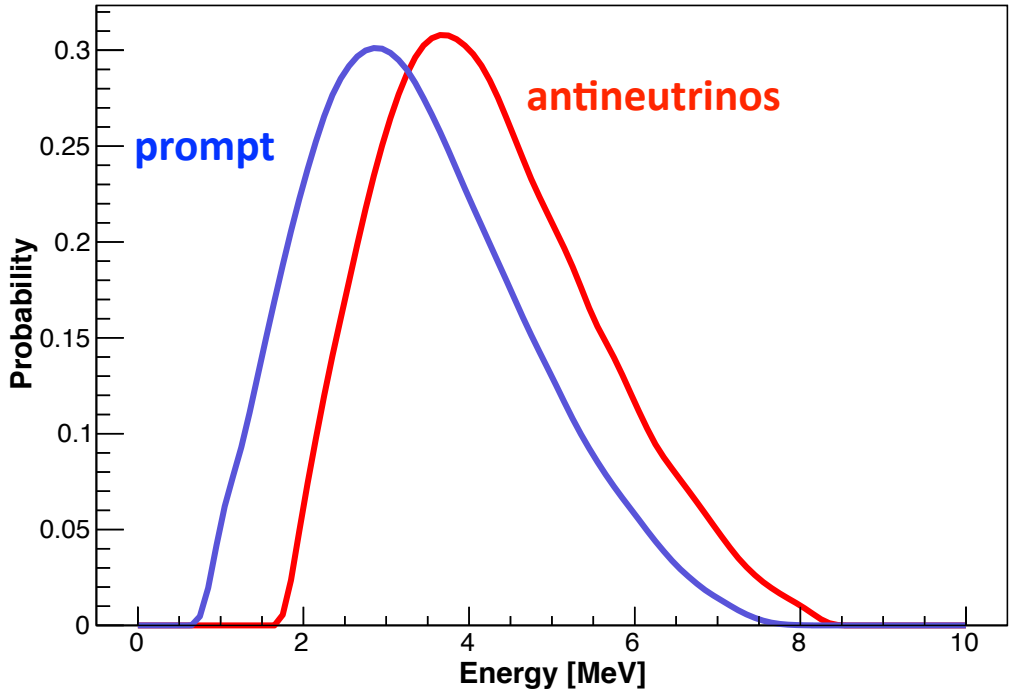
Inverse Beta Decay



$e^+e^- \rightarrow 2\gamma$ (prompt)

n-Gd $\rightarrow \gamma\ldots$ (delayed ~30μs)





$$E_\nu^{thr} = \frac{(m_n + m_p)^2 - m_p^2}{2m_p} = 1.806\,\mathrm{MeV}$$

$$E_{\mathrm{prompt}} = K.E.(e^+) + 2 \times (0.511)\,\mathrm{MeV}$$

$$\simeq E_\nu - 0.78\,\mathrm{MeV}$$

Recent Results from RENO

- "Fuel-composition dependent reactor antineutrino yield at RENO"
  Phys. Rev. Lett. 122, 232501 (2019)

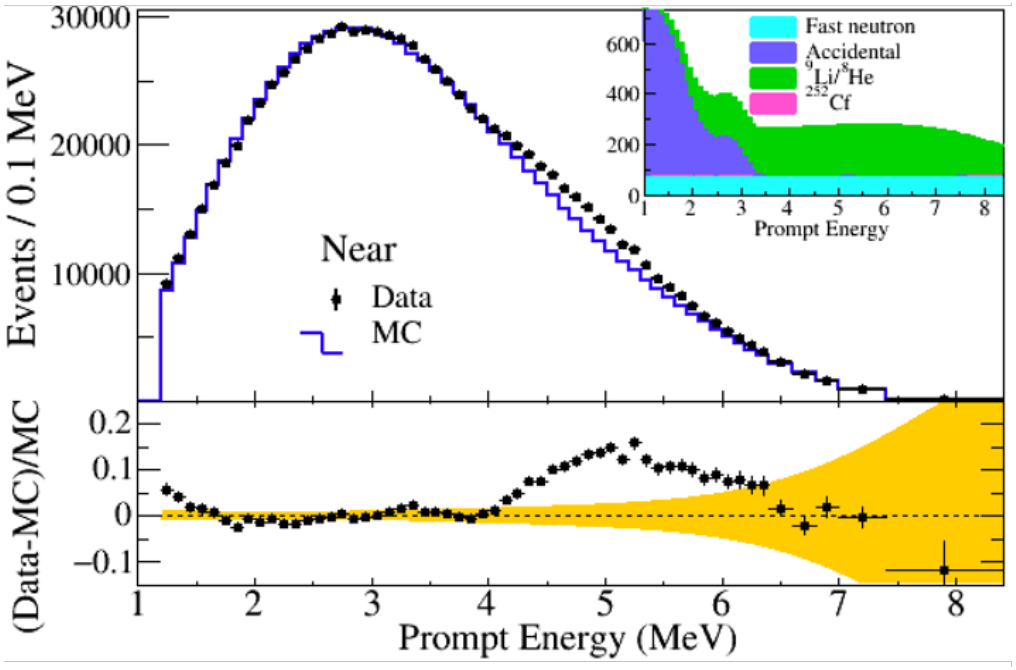
- "Observation of Reactor Antineutrino Disappearance Using Delayed Neutron Capture on Hydrogen at RENO" JHEP04 (2020) 029
  - Update of 1500 days data
  - The first θ_{13} measurement in n-H channel
  ➔ see poster session #56 by Dr. Eunhyang Kwon

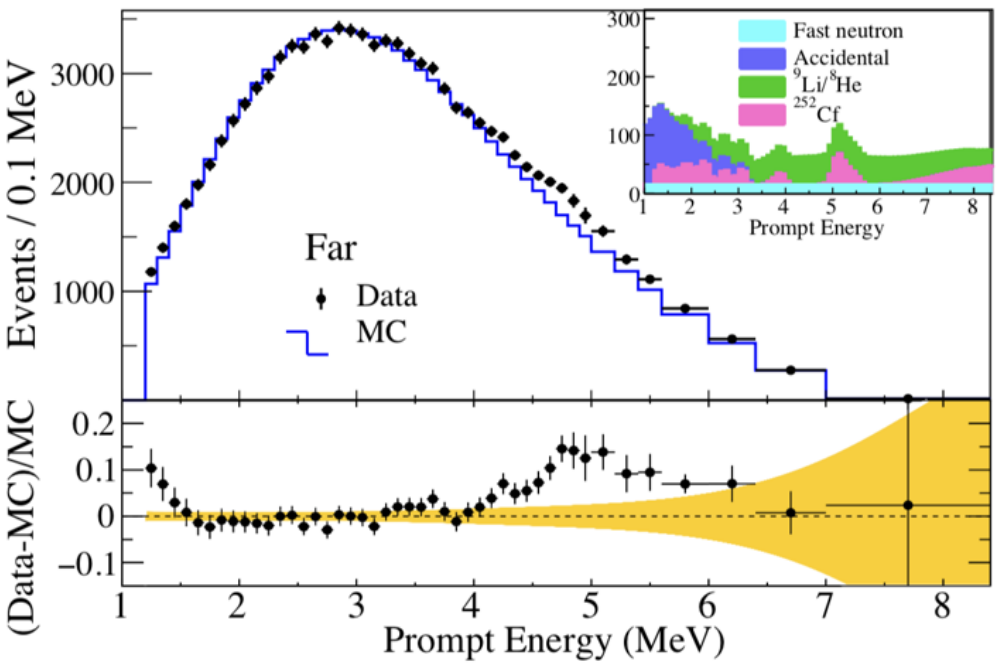
- "Search for Sub-eV Sterile Neutrino at RENO"
  arXiv:2006.07782 (2020) posted at online 14 June 2020
  ➔ see poster session #128 by Dr. Jiwoong Seo

- Updated analysis of 2900 days (Aug. 2011 – Feb. 2020) of RENO data
  - 2200 Days results published at PRL121 (2018) 20, 201801
  - Update on Reactor Antineutrino Anomaly (RAA)
  - Update on θ_{13} and Δm^2 from n-Gd channel
  - Update on 5 MeV excess (finer bin measurement)
  ➔ see poster session #62 by Dr. DongHa Lee

Measured Spectra of IBD Prompt Signal

RENO 2900 days (2200 + 700 days) : Aug. 2011 — Feb. 2020
- Clear excess at 5MeV compared to the Huber-Mueller prediction

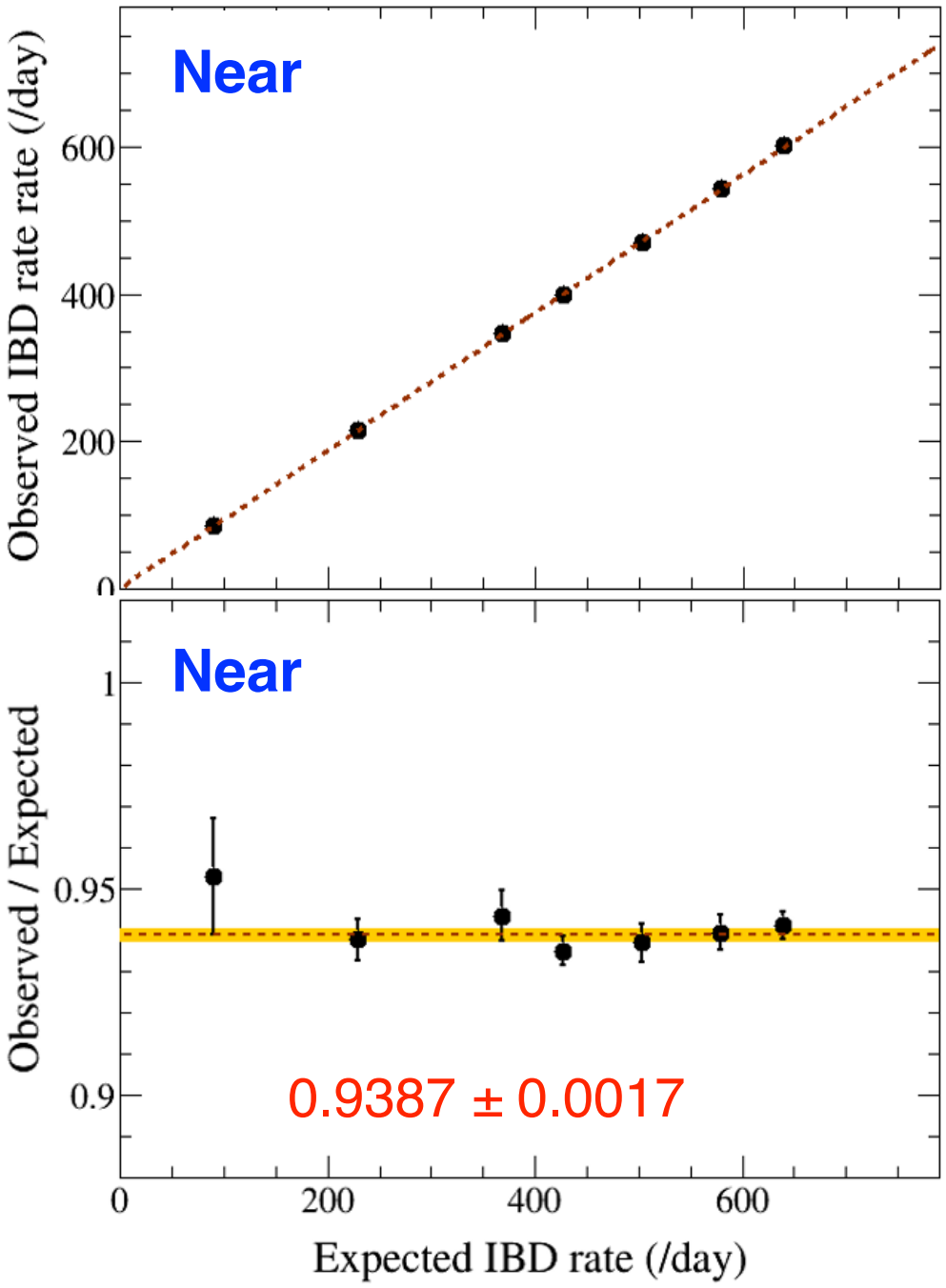


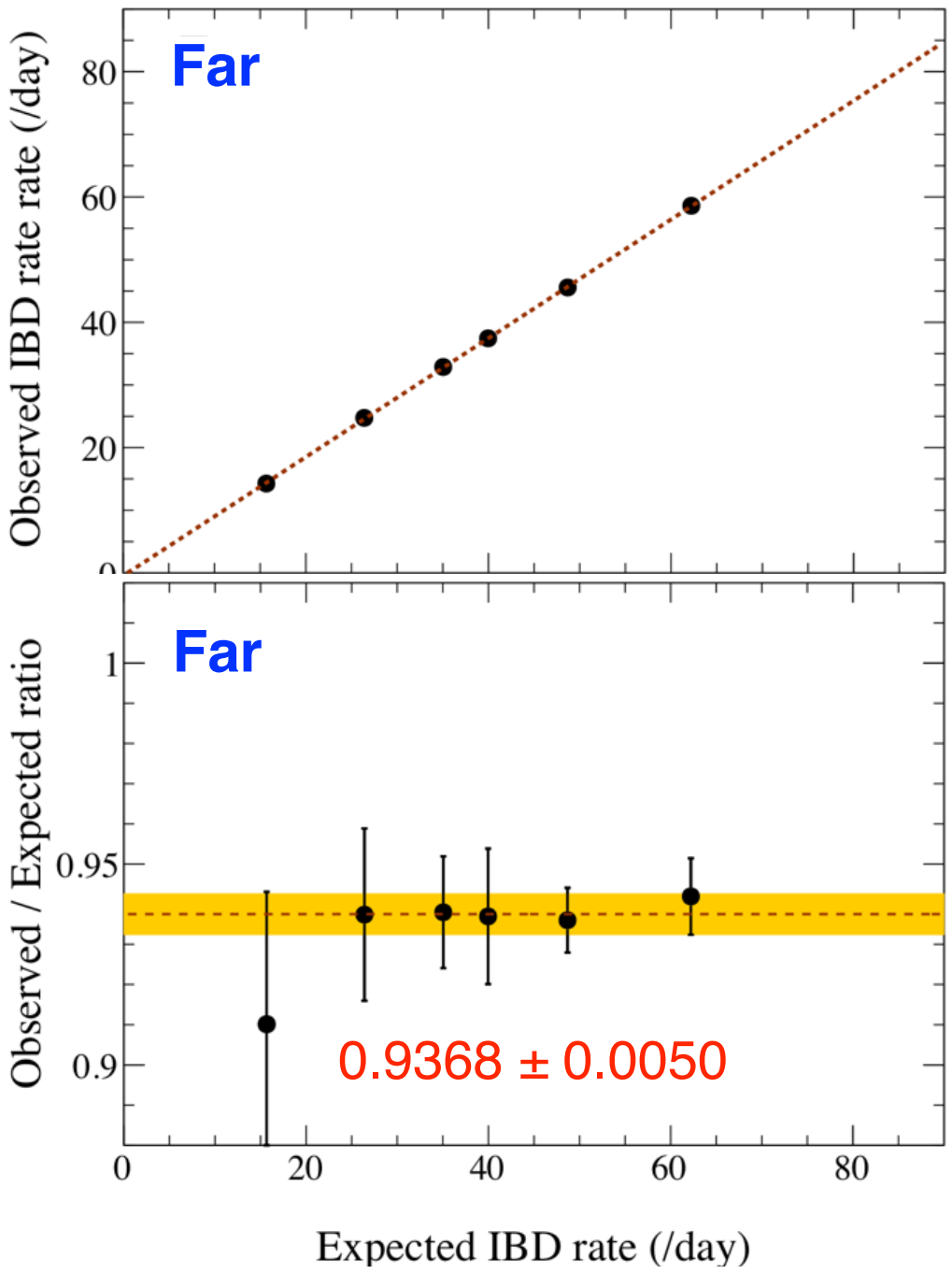


Near detector live time: 2509 days
#IBD candidates: 989,736
Background rate: 2.26 ± 0.05 %
5 MeV excess rate: 2.50 ± 0.06 %

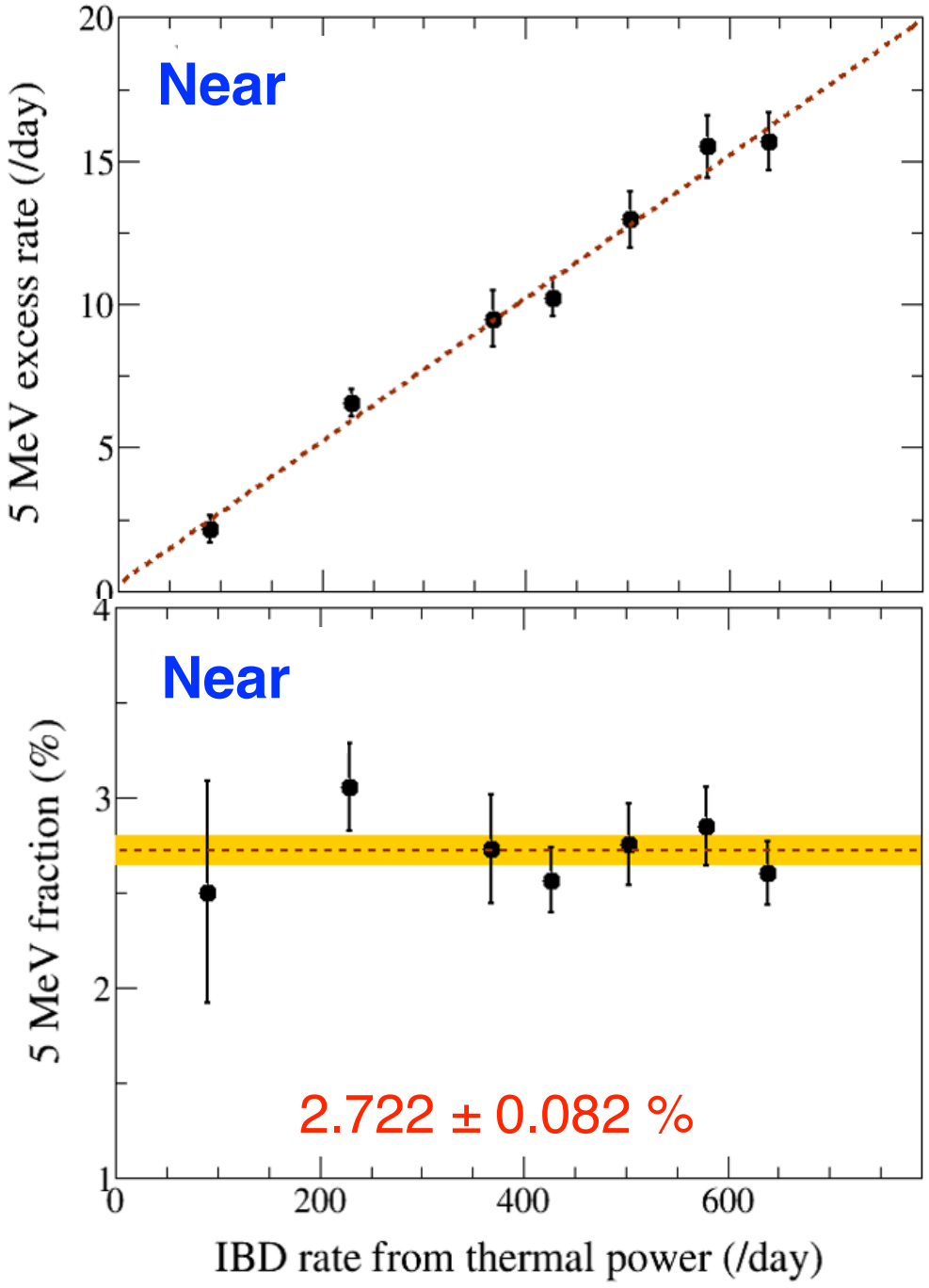
Far detector live time: 2908 days
IBD candidates: 120,383
Background rate: 4.77 ± 0.19 %
5 MeV excess rate: 2.26 ± 0.18 %

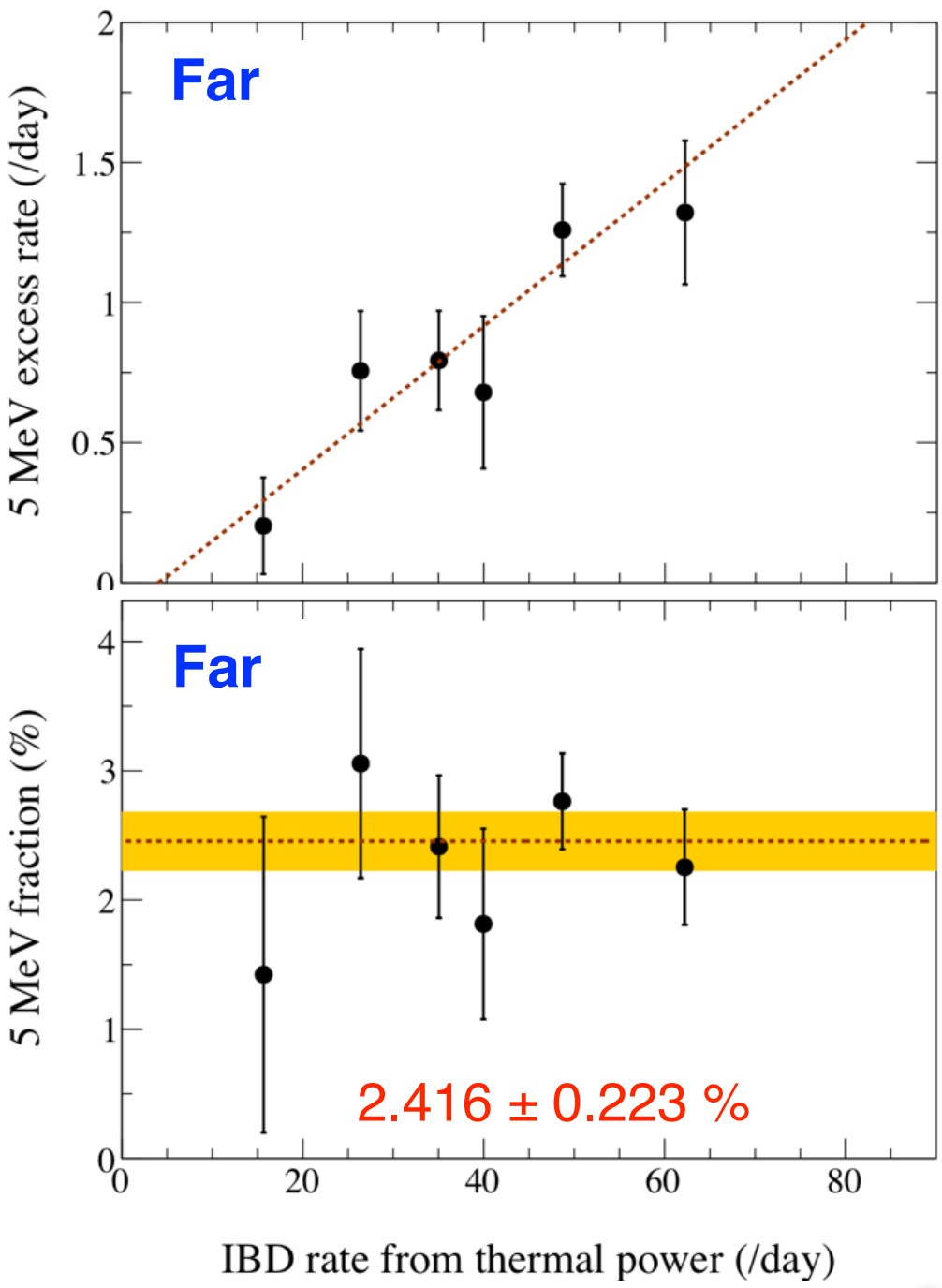
Observed IBD Rate VS Thermal Power



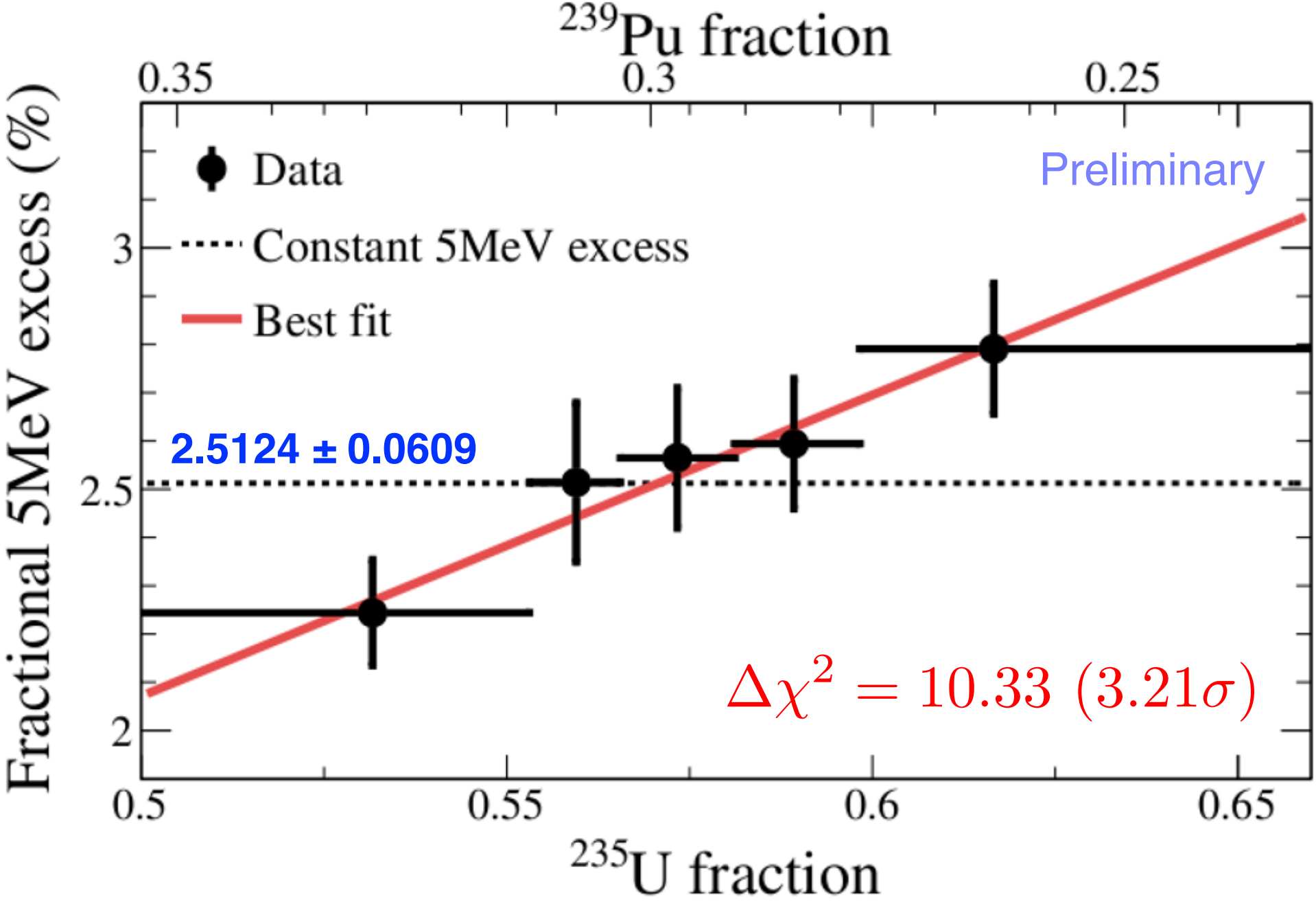


5 MeV Excess VS Thermal Power

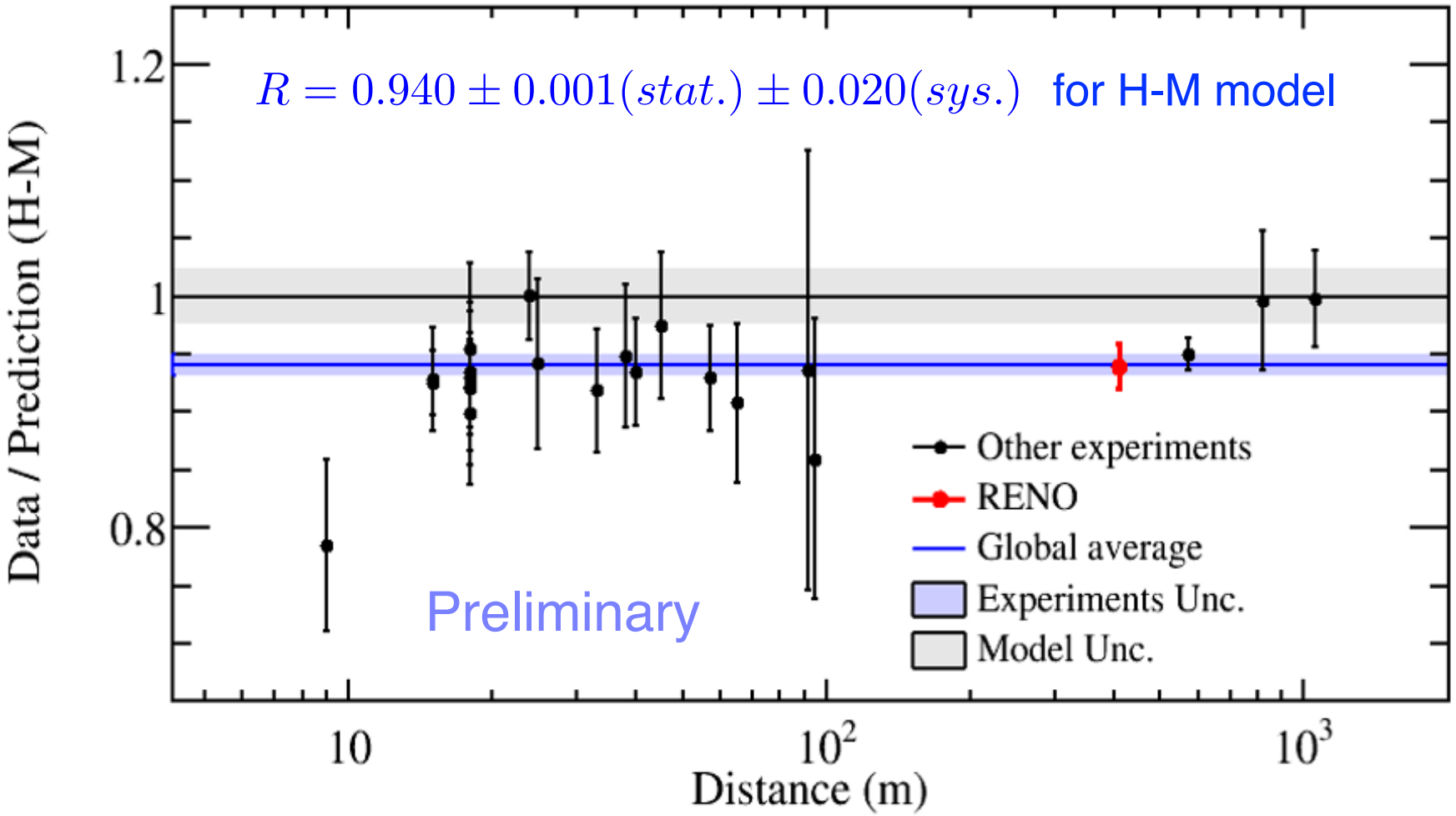




Fuel Dependence of the Fractional 5 MeV Excess (2900 Days)



Reactor Antineutrino Anomaly (RAA)



IBD yield: $\overline{y}_f = 5.8303 \pm 0.1249 (\times 10^{-43}\,\mathrm{cm}^2/\mathrm{fission})$

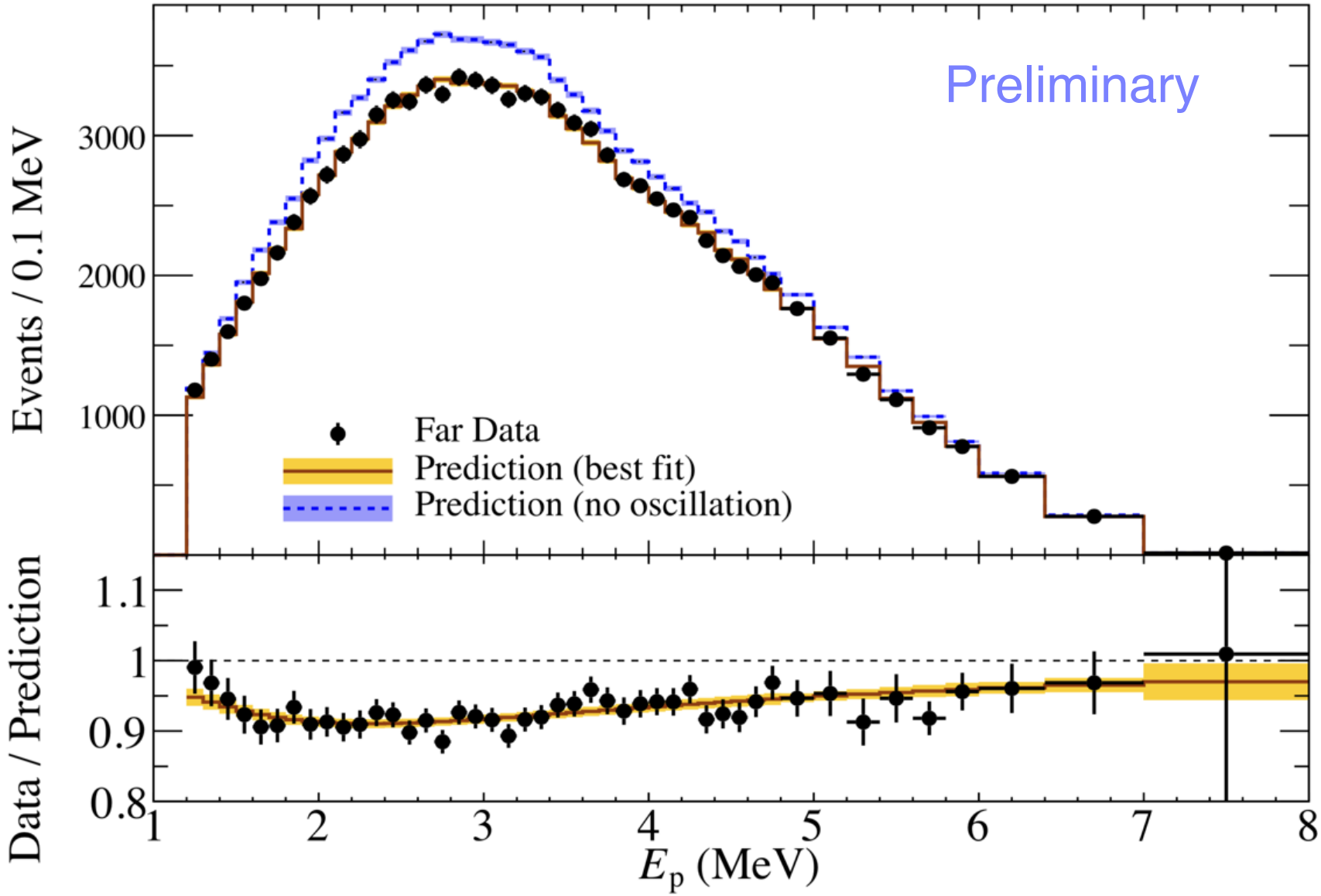
Data / Prediction: $R = 0.983 \pm 0.001(stat.) \pm 0.021(sys.)$ for ILL+Vogel model

Average fission fraction: $\overline{F}_{235} : \overline{F}_{238} : \overline{F}_{239} : \overline{F}_{241} = 0.571 : 0.073 : 0.300 : 0.056$

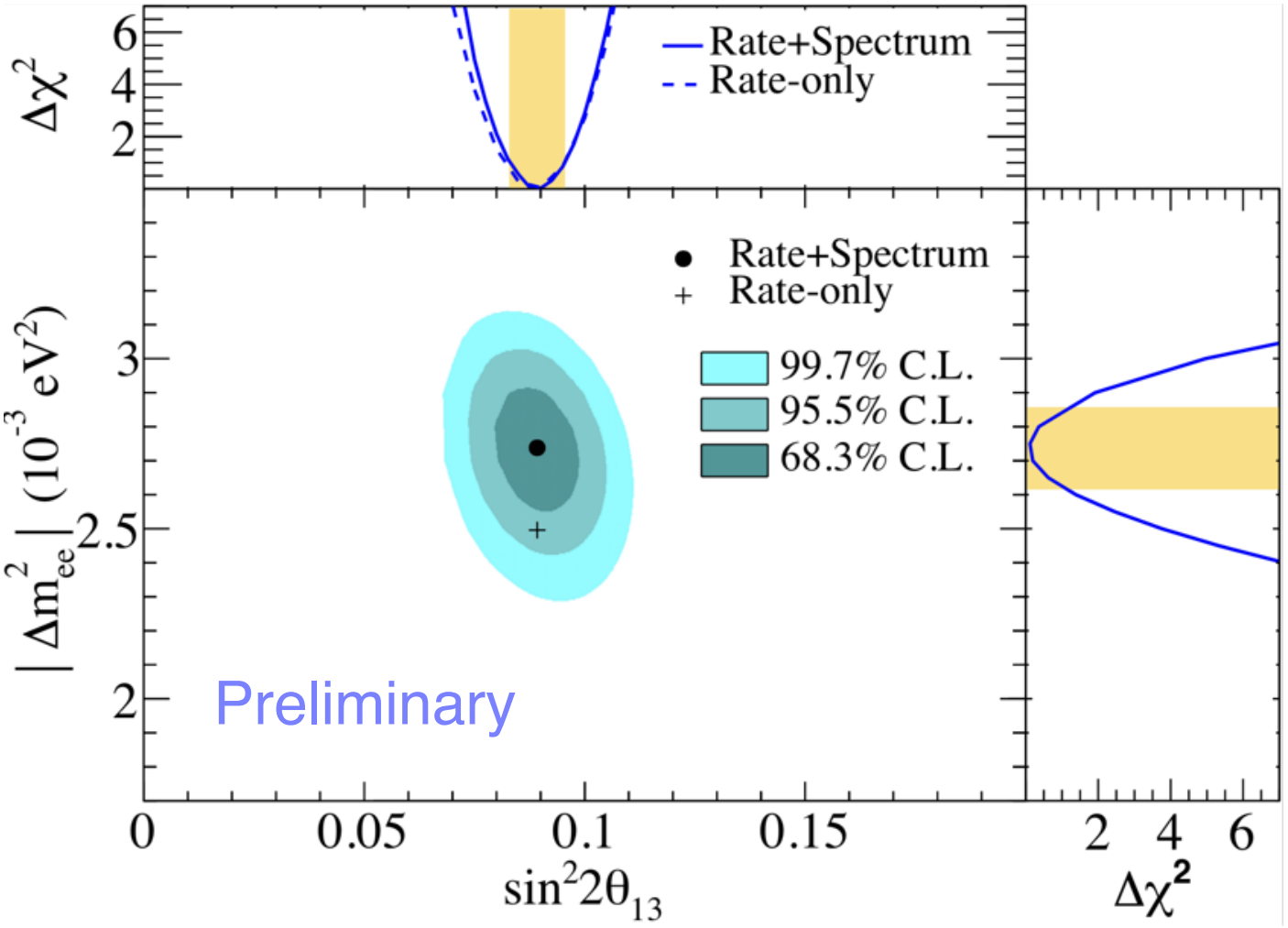
Far to Near Prompt Spectra Shape Comparison

RENO 2900 days (Aug. 2011 — Feb. 2019)

- Energy dependent disappearance of reactor antineutrinos



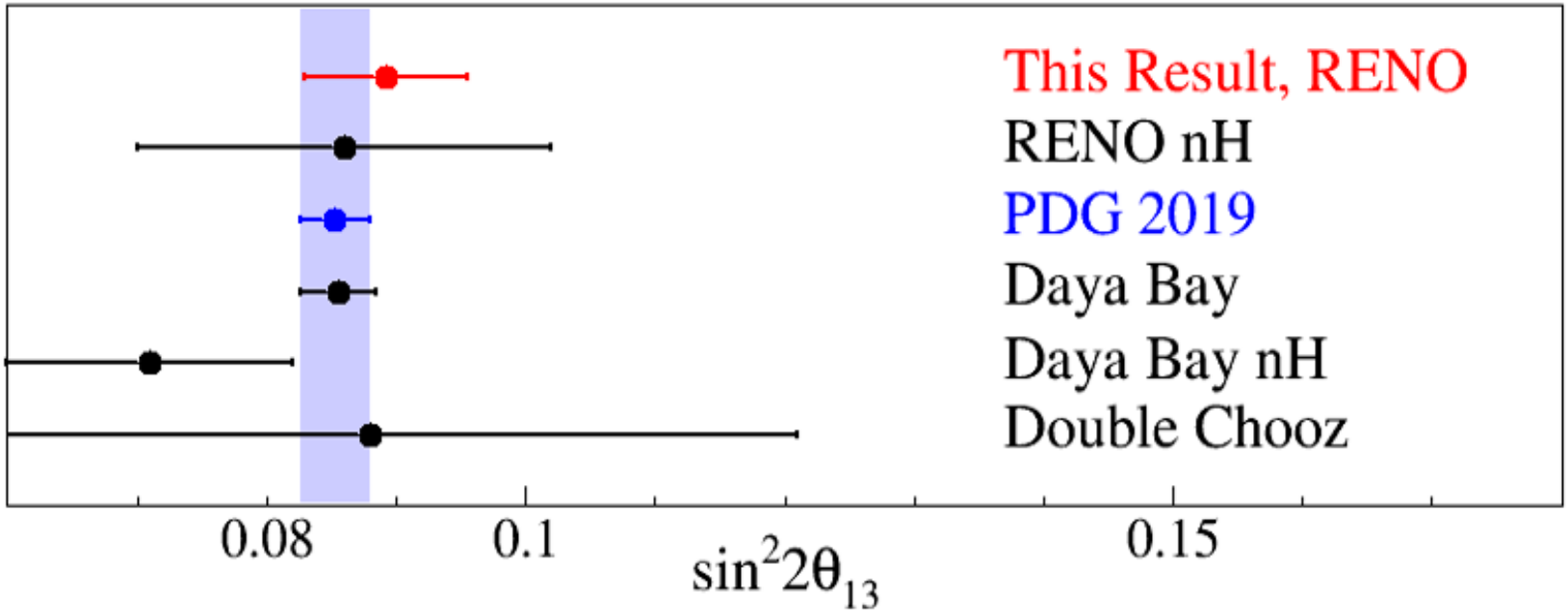
RENO 2900 days (Aug. 2011 — Feb. 2020)

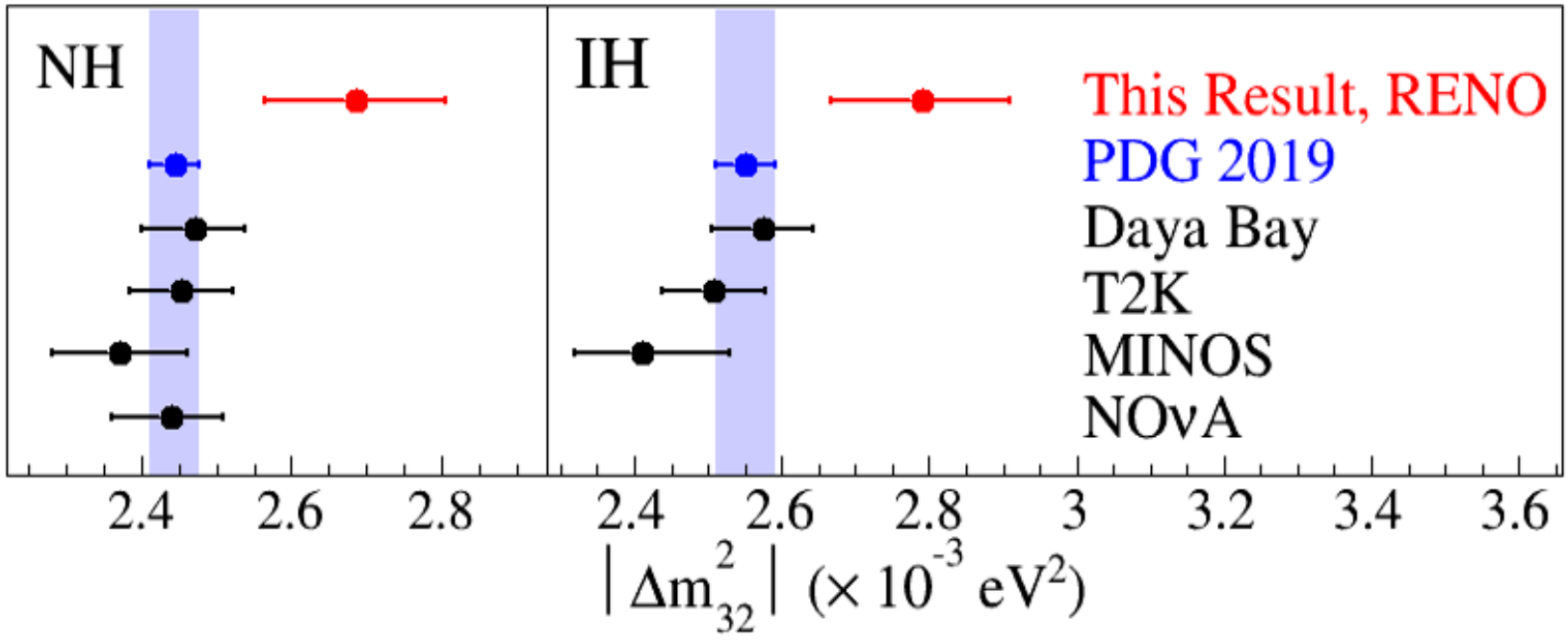


$$\sin^2 2\theta_{13} = 0.0892 \pm 0.0044(stat.) \pm 0.0045(sys.) \quad \pm 7.0\%$$

$$|\Delta m^2_{ee}| = 2.74 \pm 0.10(stat.) \pm 0.06(sys.)(\times 10^{-3}\mathrm{eV}^2) \quad \pm 4.4\%$$

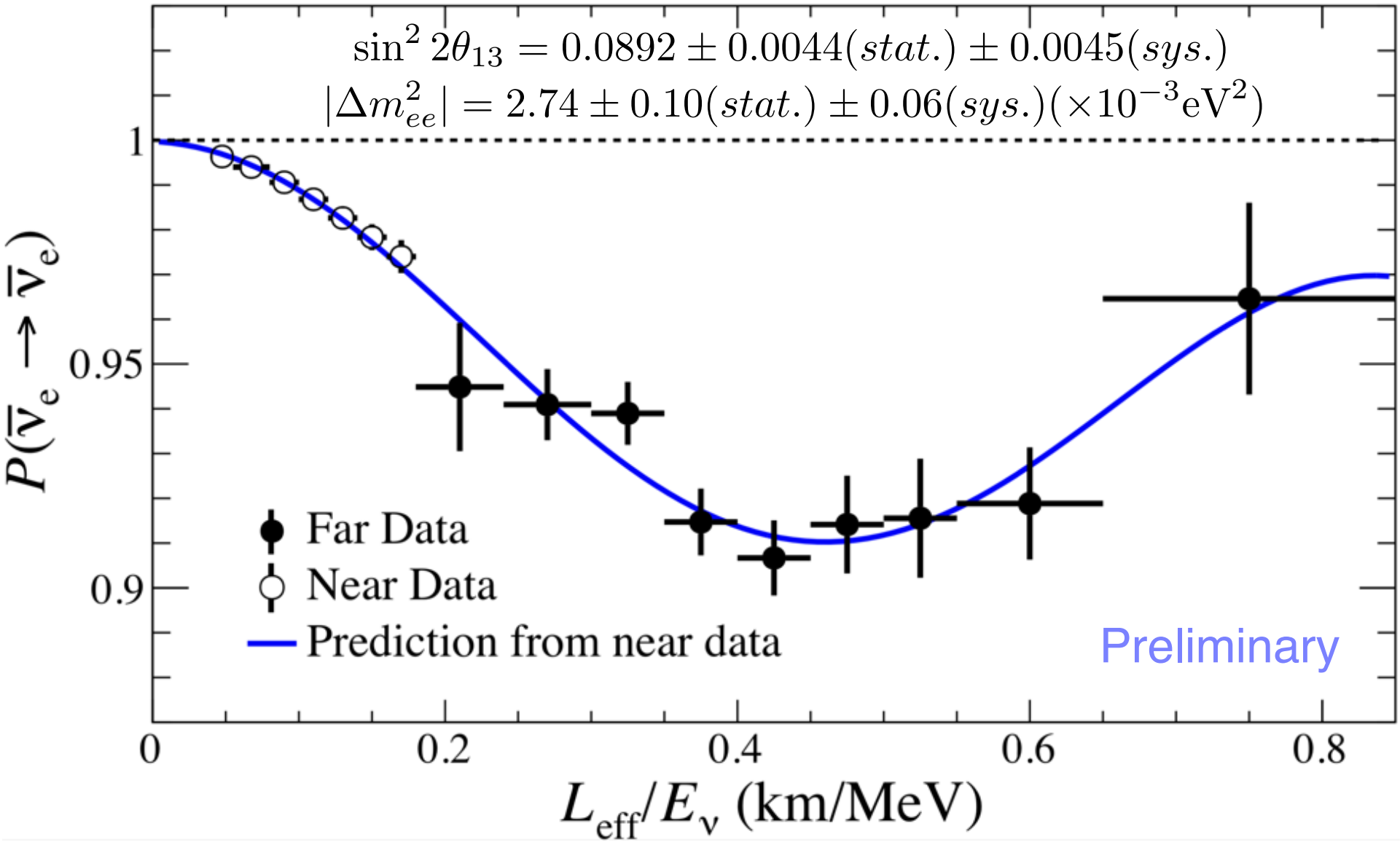
Neutrino Oscillation: θ_{13} and Δm^2_{32}



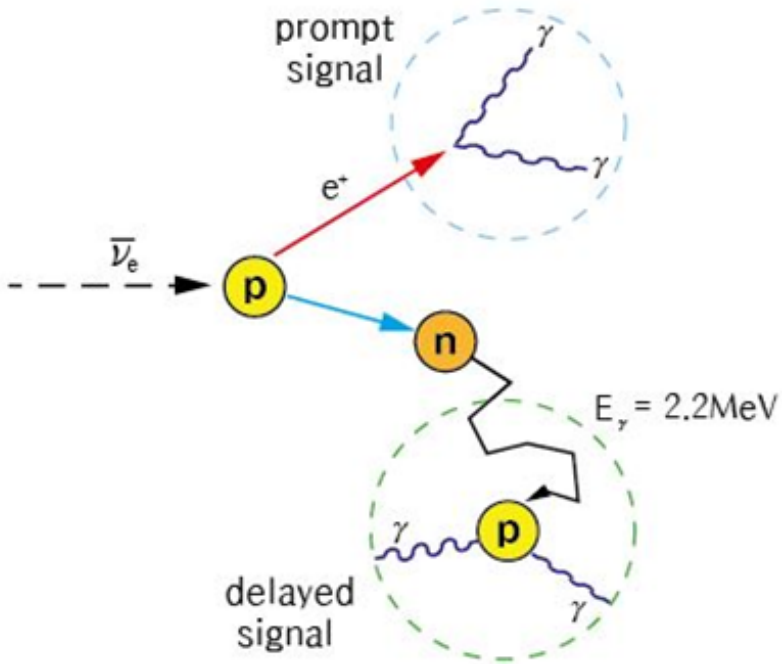


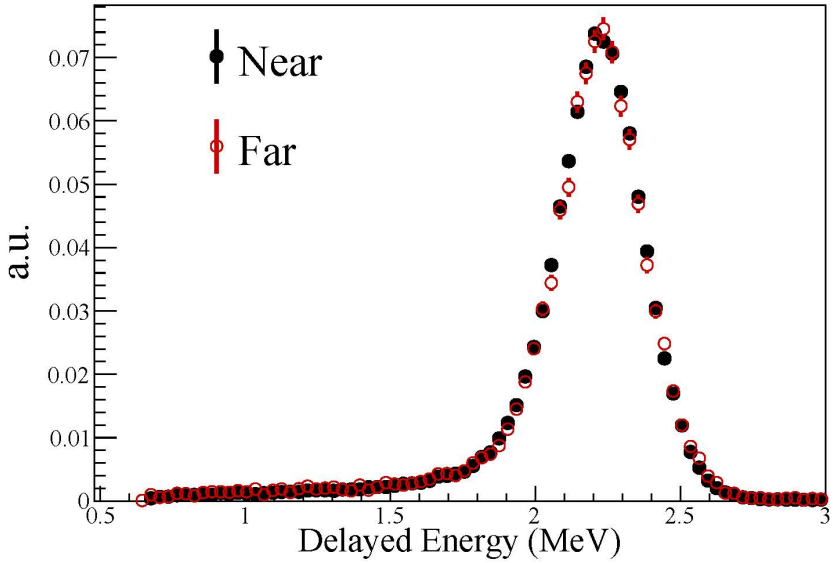
Neutrino Oscillation: L/E Dependence

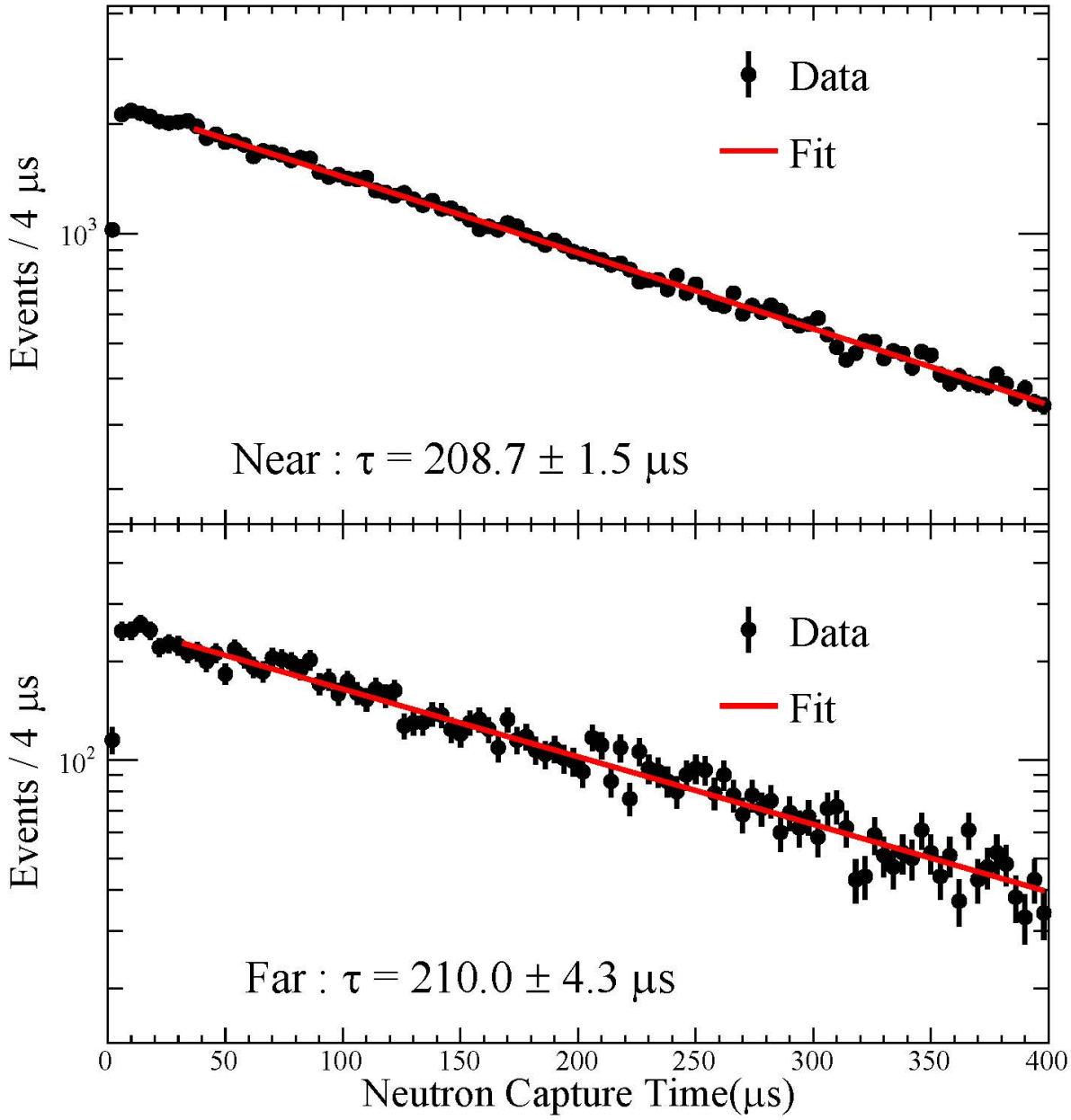
$$P(\overline{\nu}_e \to \overline{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2 \left(1.27 \Delta m^2_{ee} \frac{L}{E_\nu} \right)$$



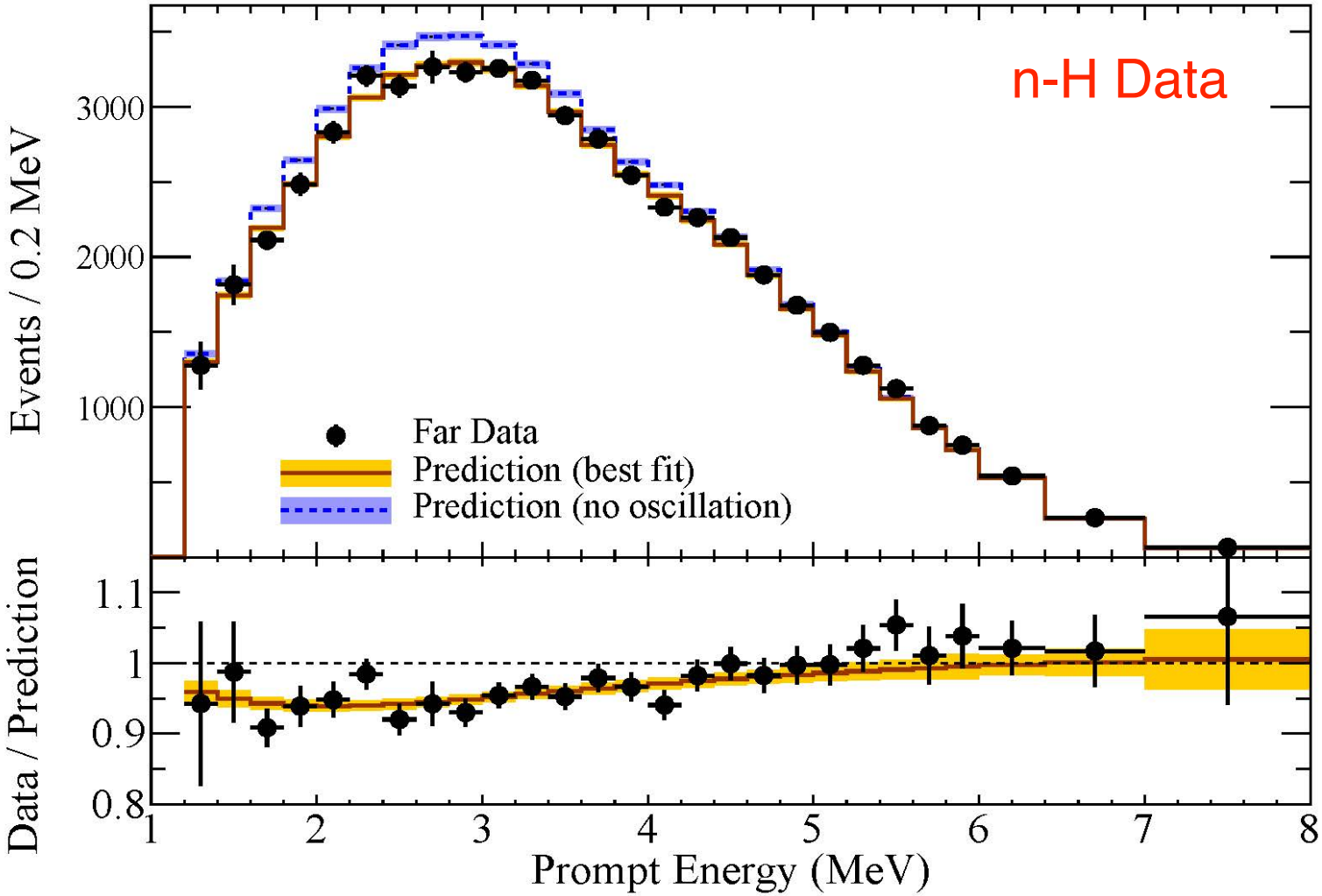
RENO 1500-Days Data n-H Analysis Results







Independent measurement of $\sin^2 2\theta_{13}$ using 1500 live days n-H data

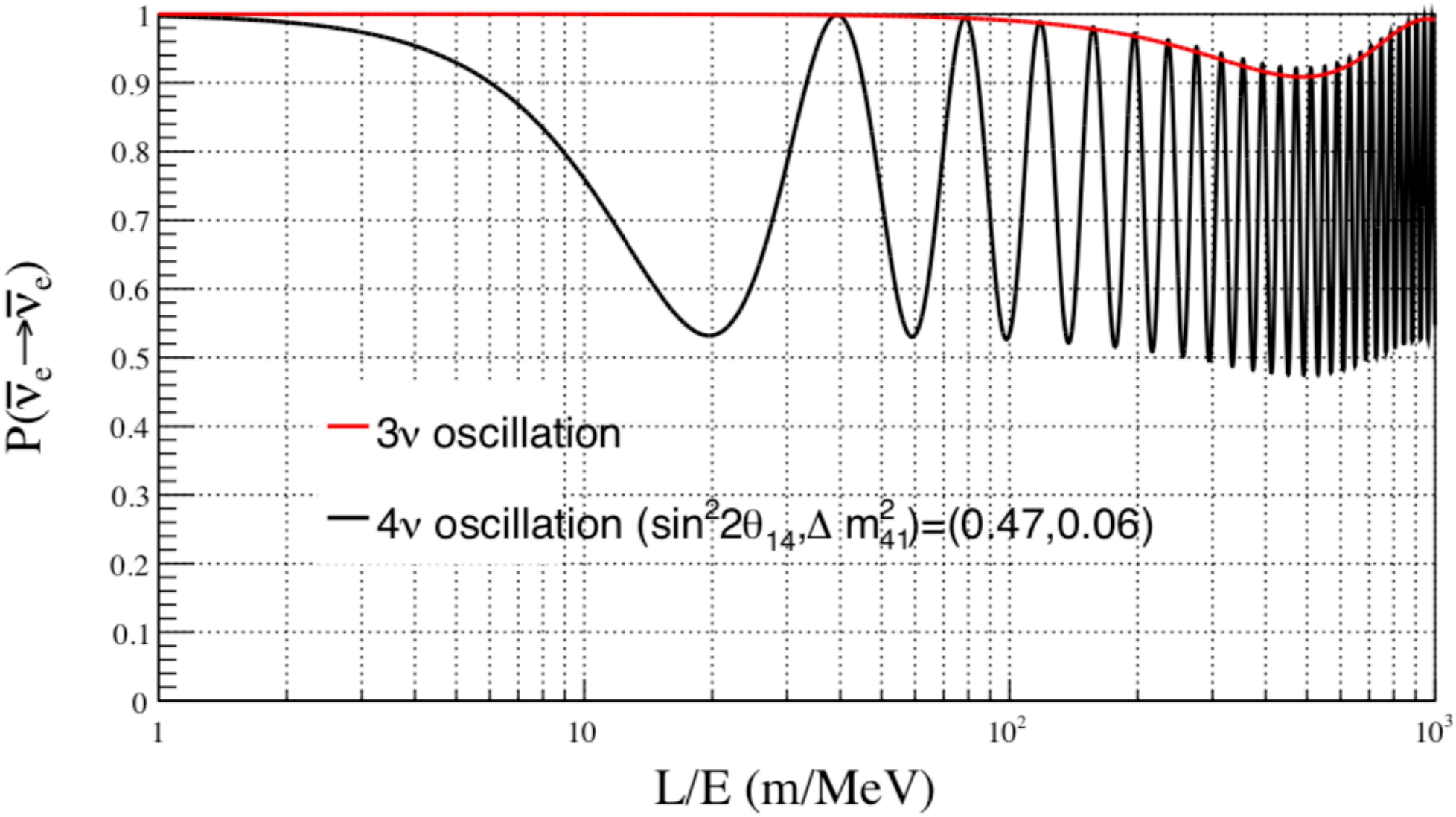


$$\sin^2 2\theta_{13} = 0.086 \pm 0.008(stat.) \pm 0.014(sys.)$$

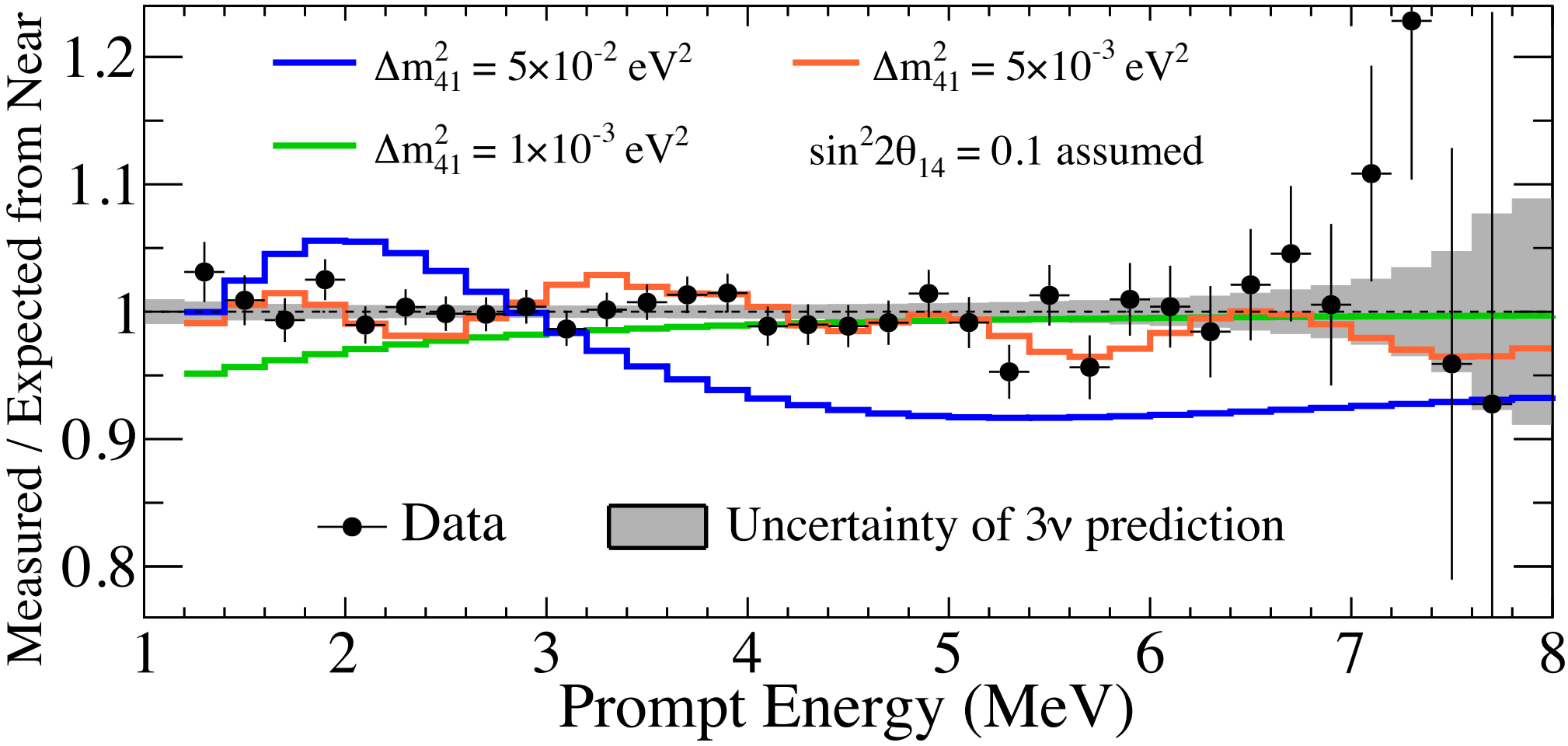
$$\left(\text{using PDG input: } |\Delta m^2_{ee}| = 2.562 \times 10^{-3}\,\text{eV}^2\right)$$

(3+1) Neutrino Model

$$P(\overline{\nu}_e \to \overline{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2\left(1.27\Delta m^2_{31}\frac{L}{E_\nu}\right) - \sin^2 2\theta_{14} \sin^2\left(1.27\Delta m^2_{41}\frac{L}{E_\nu}\right)$$

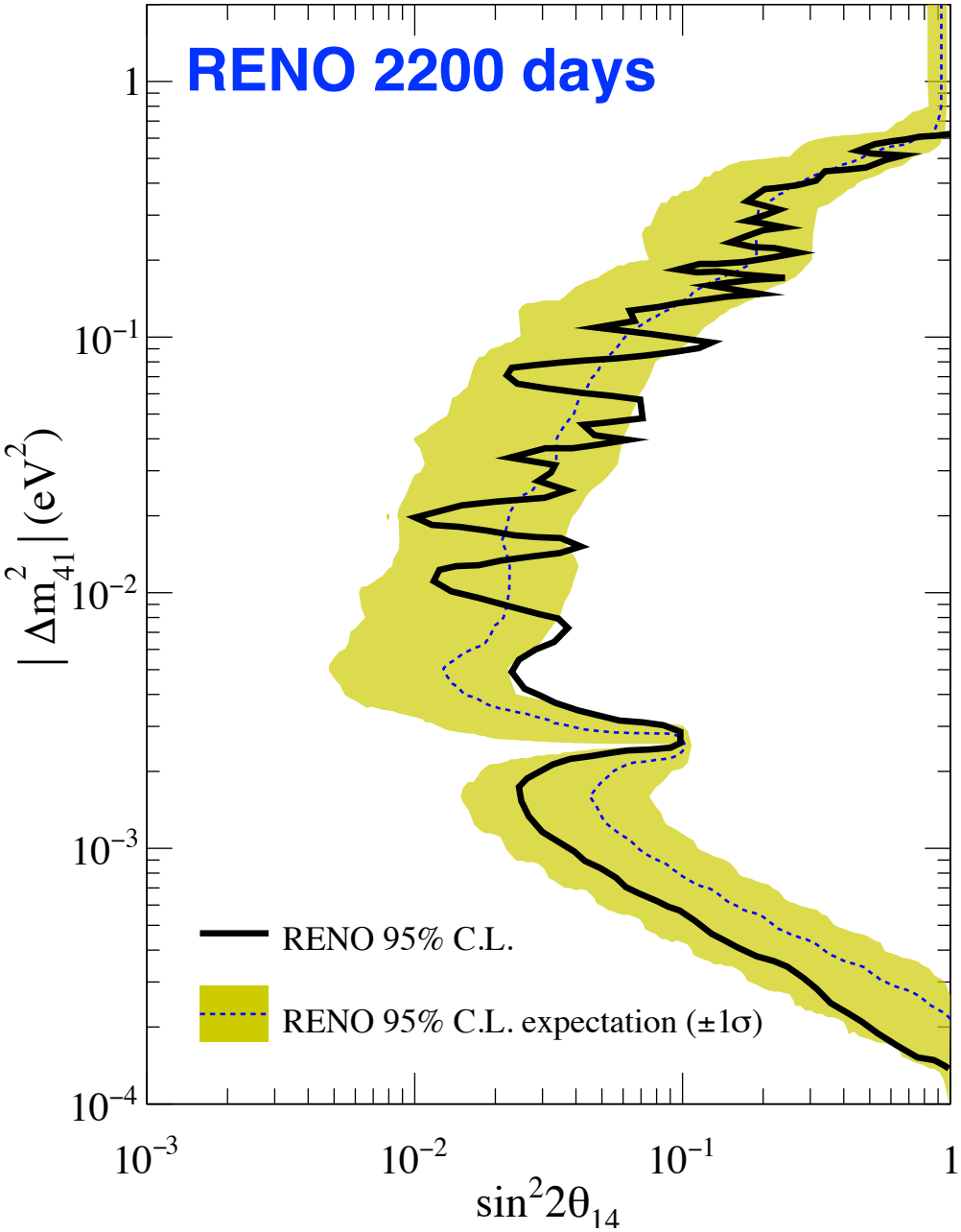


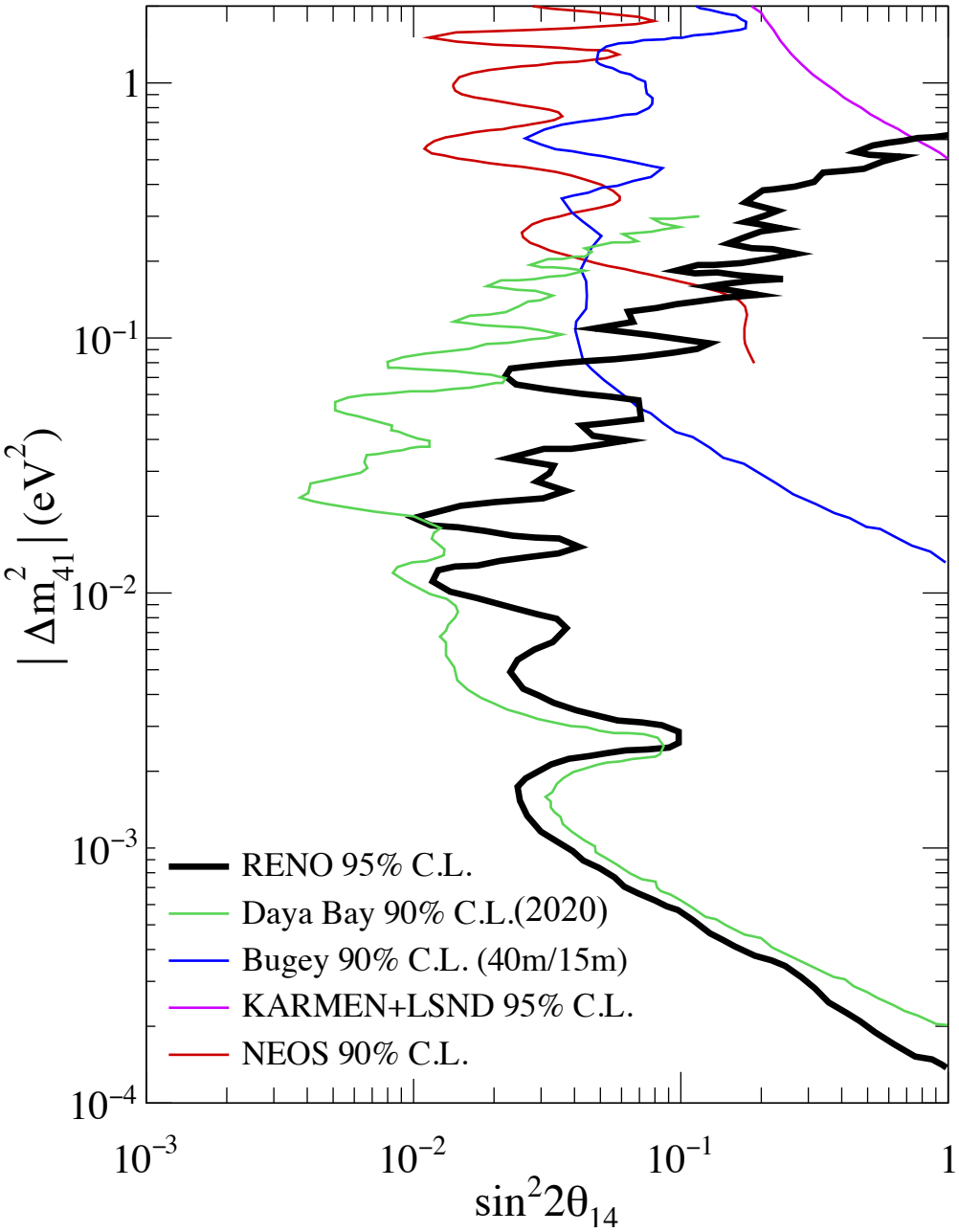
2200 Days of RENO Data



arXiv: 2006.07782 (posted on 14th June 2020)

RENO Sterile Neutrino Search





arXiv: 2006.07782 (posted on 14th June 2020)

Summary

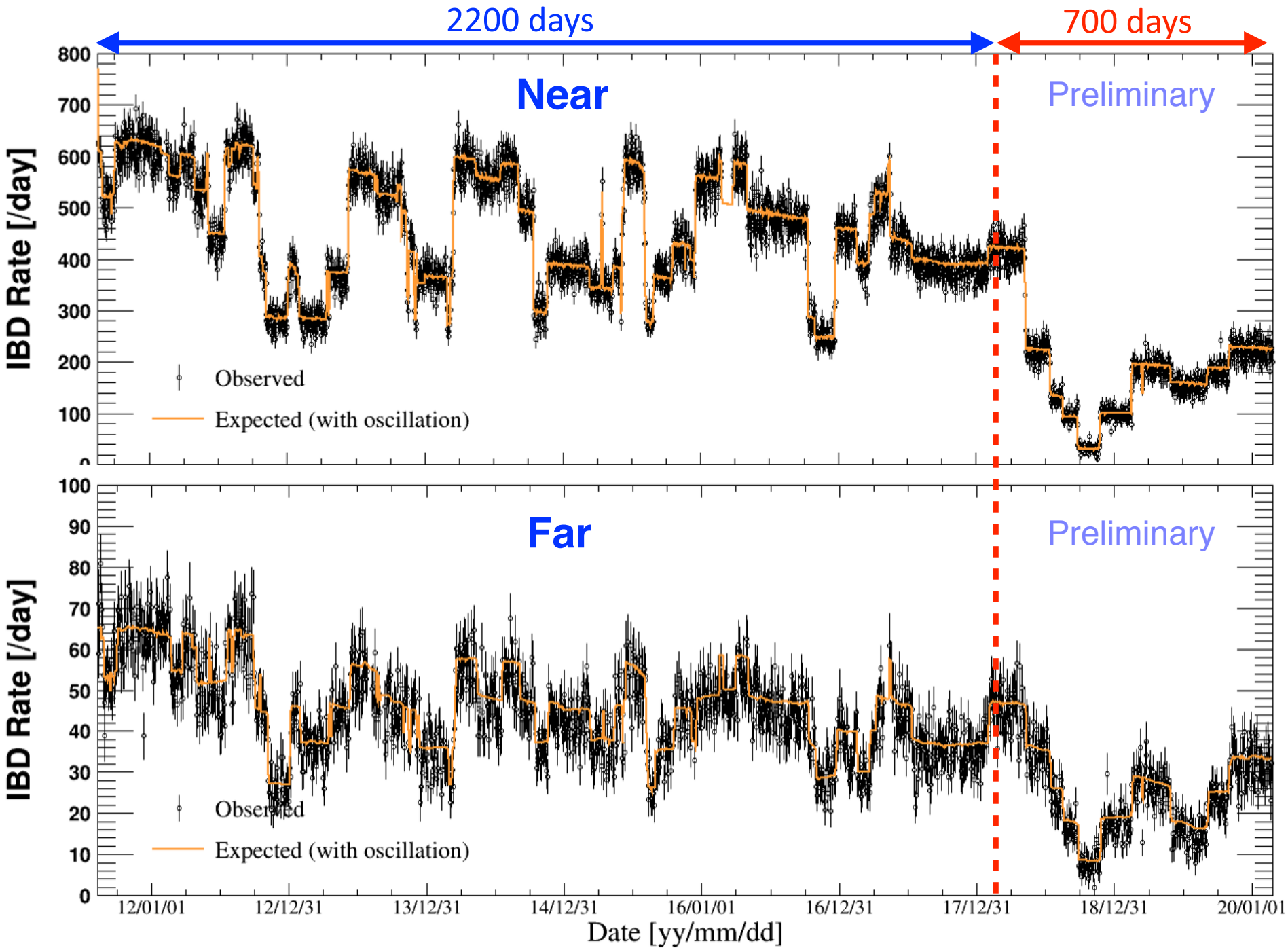
- Report updated results using **RENO 2900 days data**
- Precision measurement of θ_{13} and $|\Delta m^2_{ee}|$
- Absolute reactor neutrino flux : **R = 94.0±2.0 % (for HM)**
- Correlation between 5 MeV excess and ^{235}U fission **(3.2σ C.L.)**
- The first RENO sterile neutrino search results: **arXiv:2006.07782**

RENO Poster Presentations in Neutrino 2020

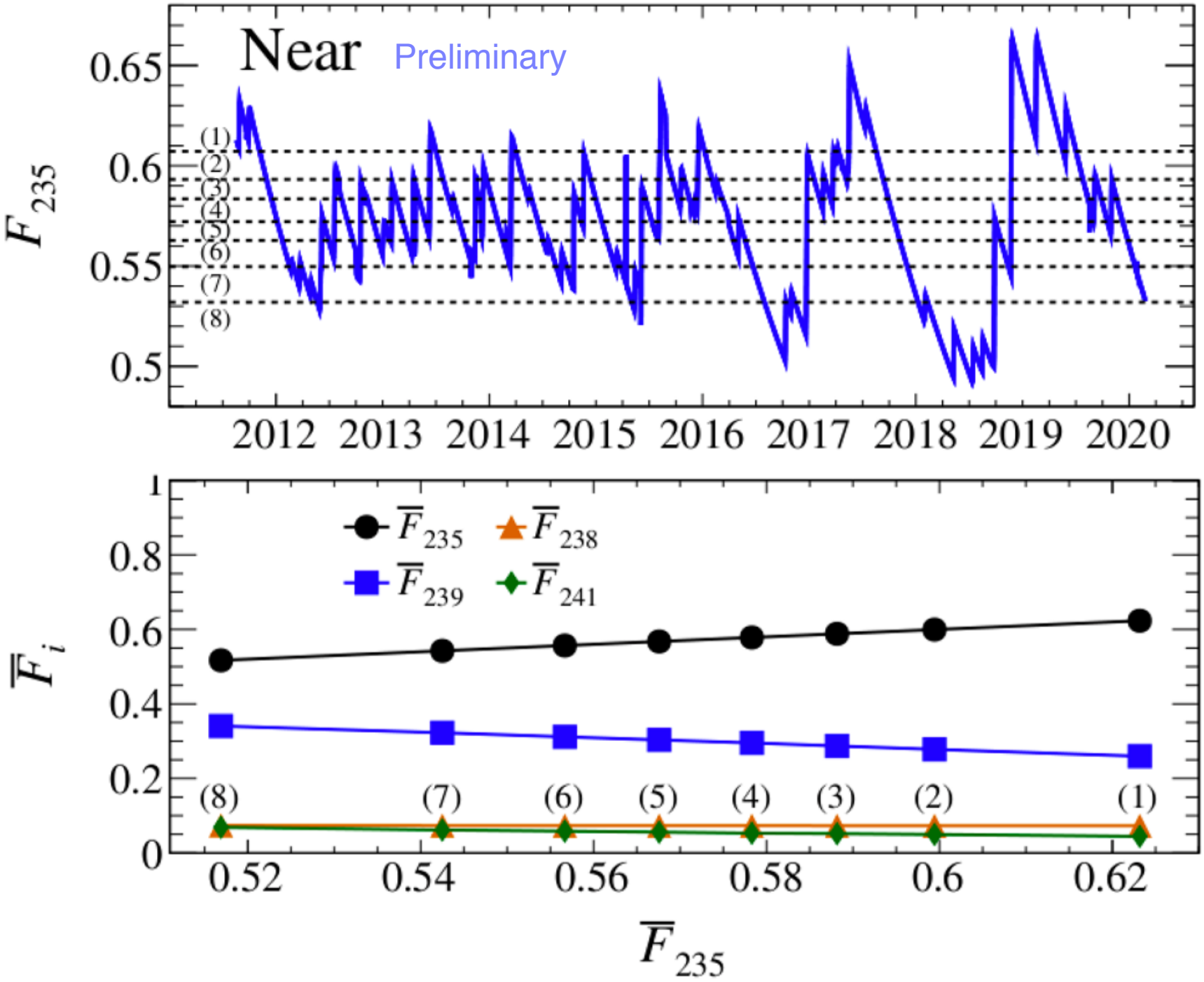
(1) **DongHa Lee**, "Updated results on reactor antineutrino oscillation amplitude and frequency for 2900 days at RENO" **(poster #62)**
(2) **Jiwoong Seo**, "Search for Sterile Neutrinos at RENO" **(poster #128)**
(3) **Eunhyang Kwan**, "θ_{13} measurement using data with neutron capture on hydrogen at RENO" **(poster #56)**

Backup Slides

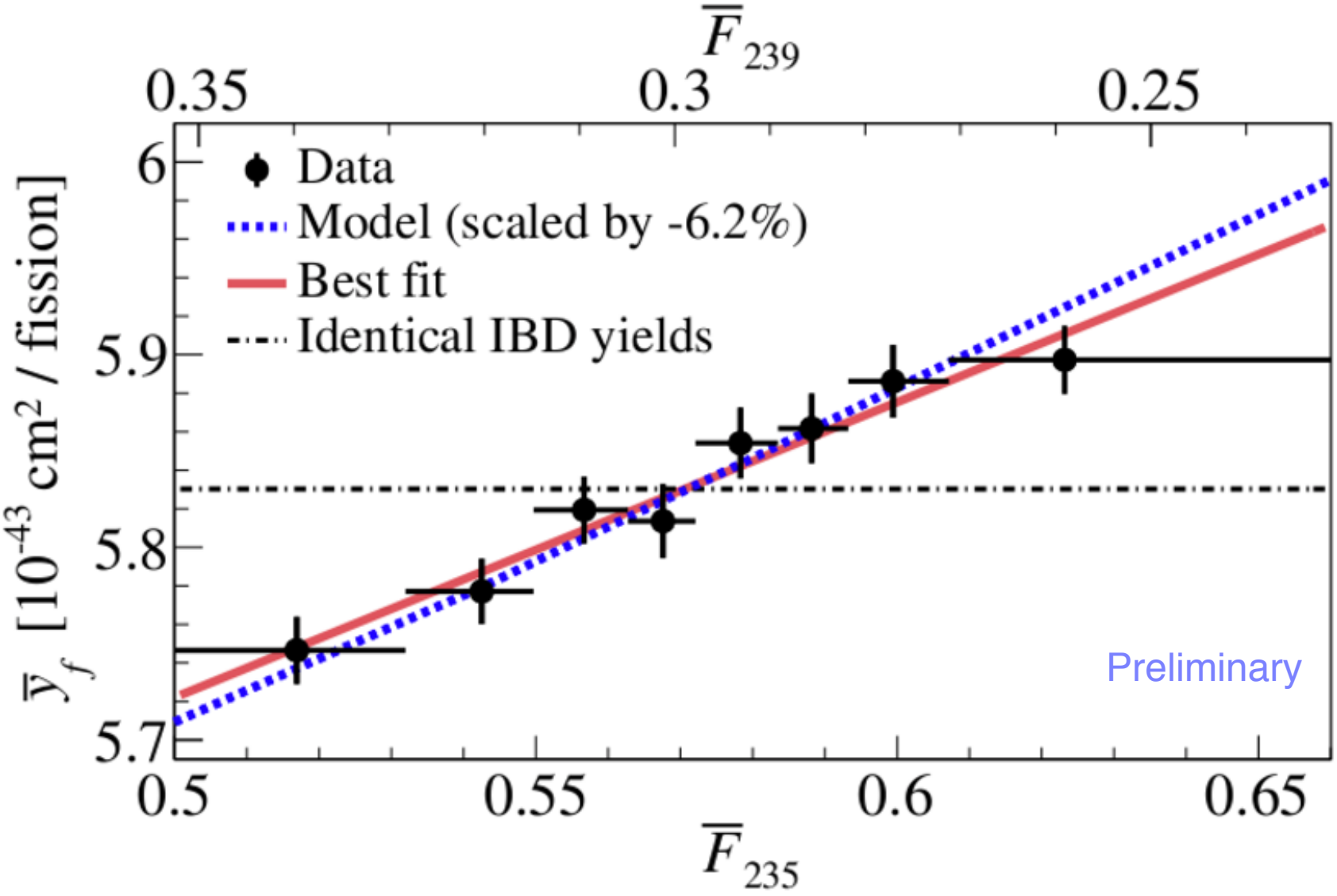
RENO 2900-Days Daily IBD Rate



RENO Fuel Fraction in the Reactor Core



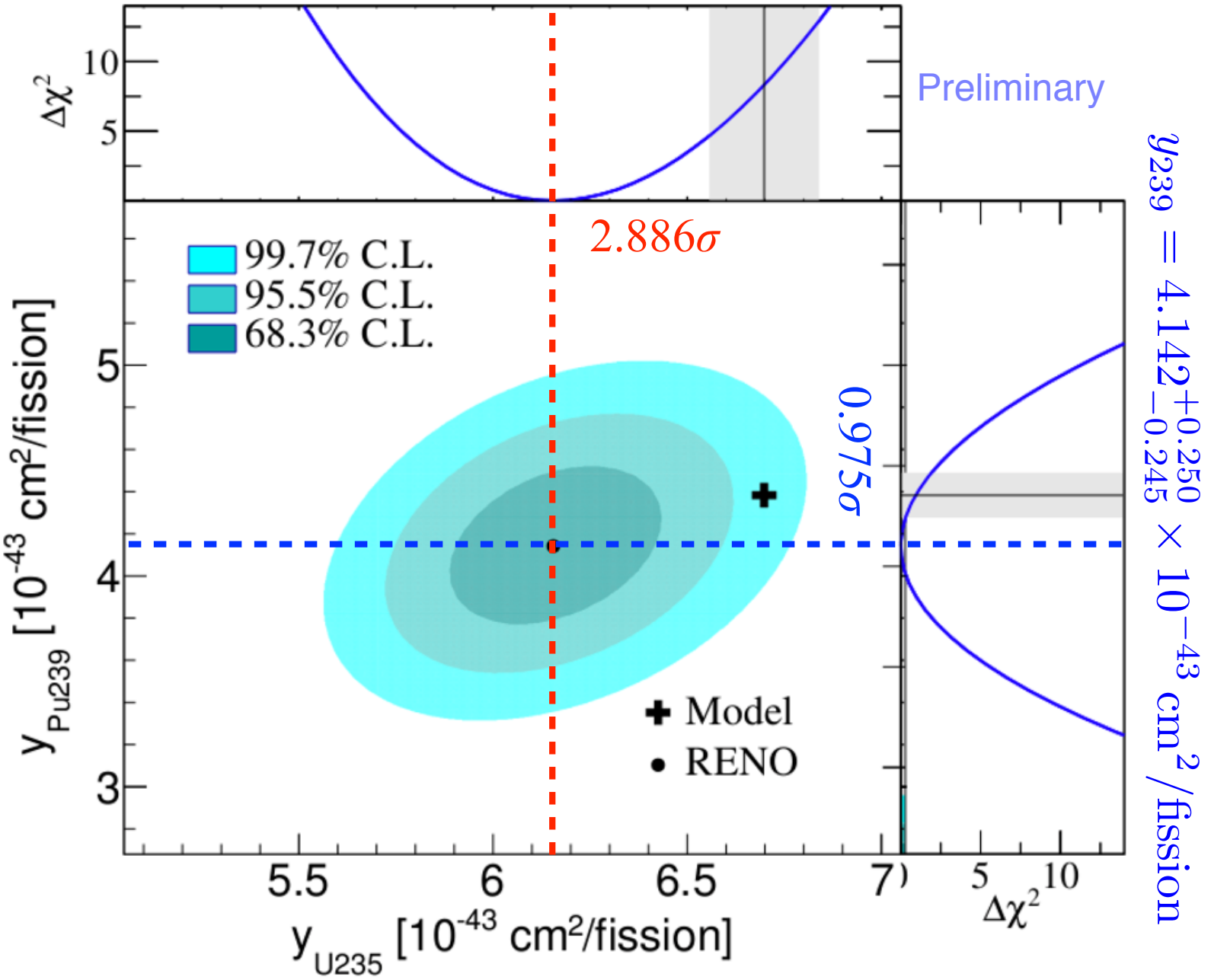
Fuel Dependence of IBD Yield



Identical yield $\overline{y}_f = 5.8303 \pm 0.0063 \times 10^{-43}\,\mathrm{cm}^2/\mathrm{fission}$

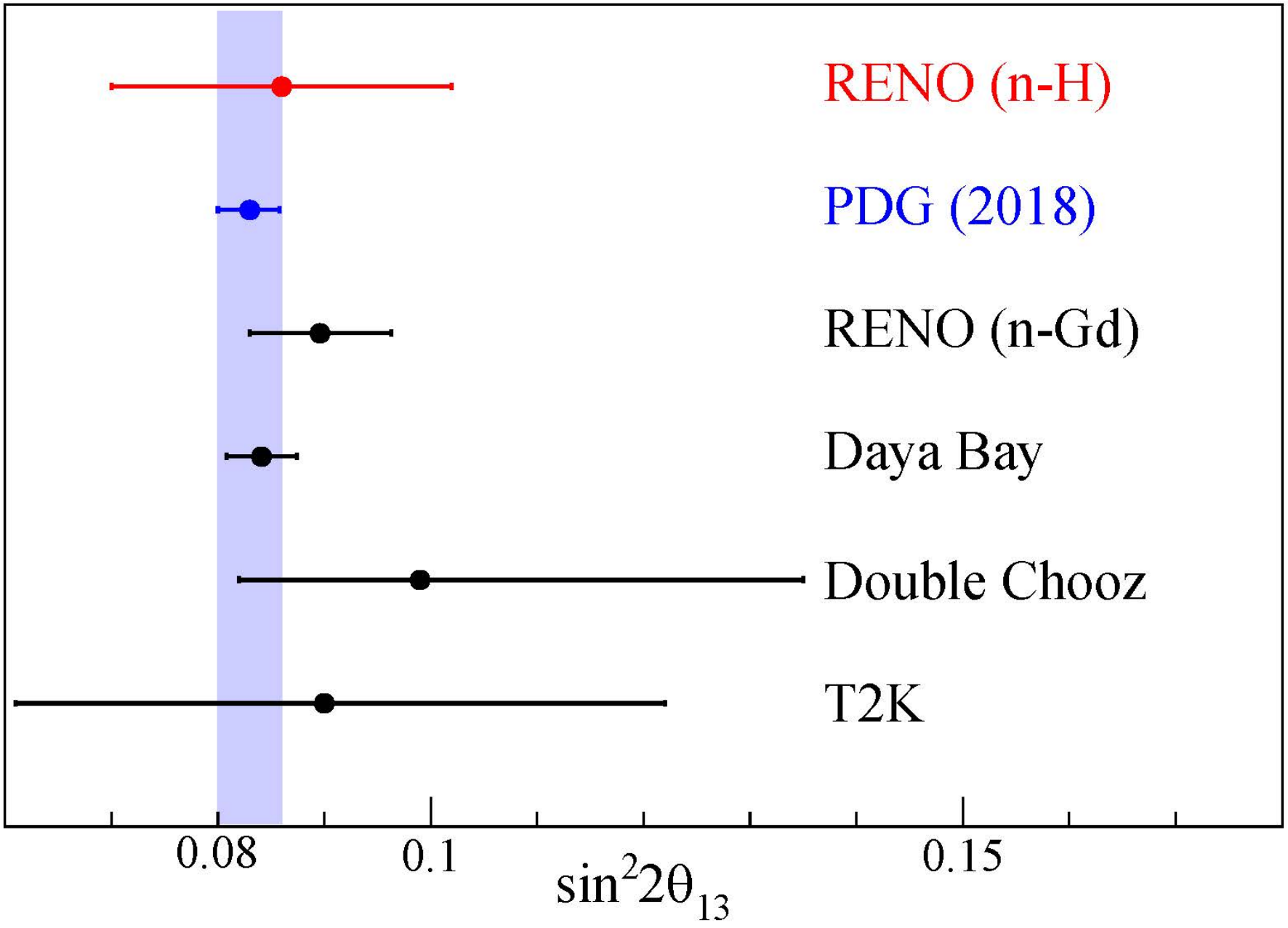
Null fuel dependence ruled out by 7.7σ

$$y_{235} = 6.155^{+0.183}_{-0.178} \times 10^{-43}\,\mathrm{cm}^2/\mathrm{fission}$$

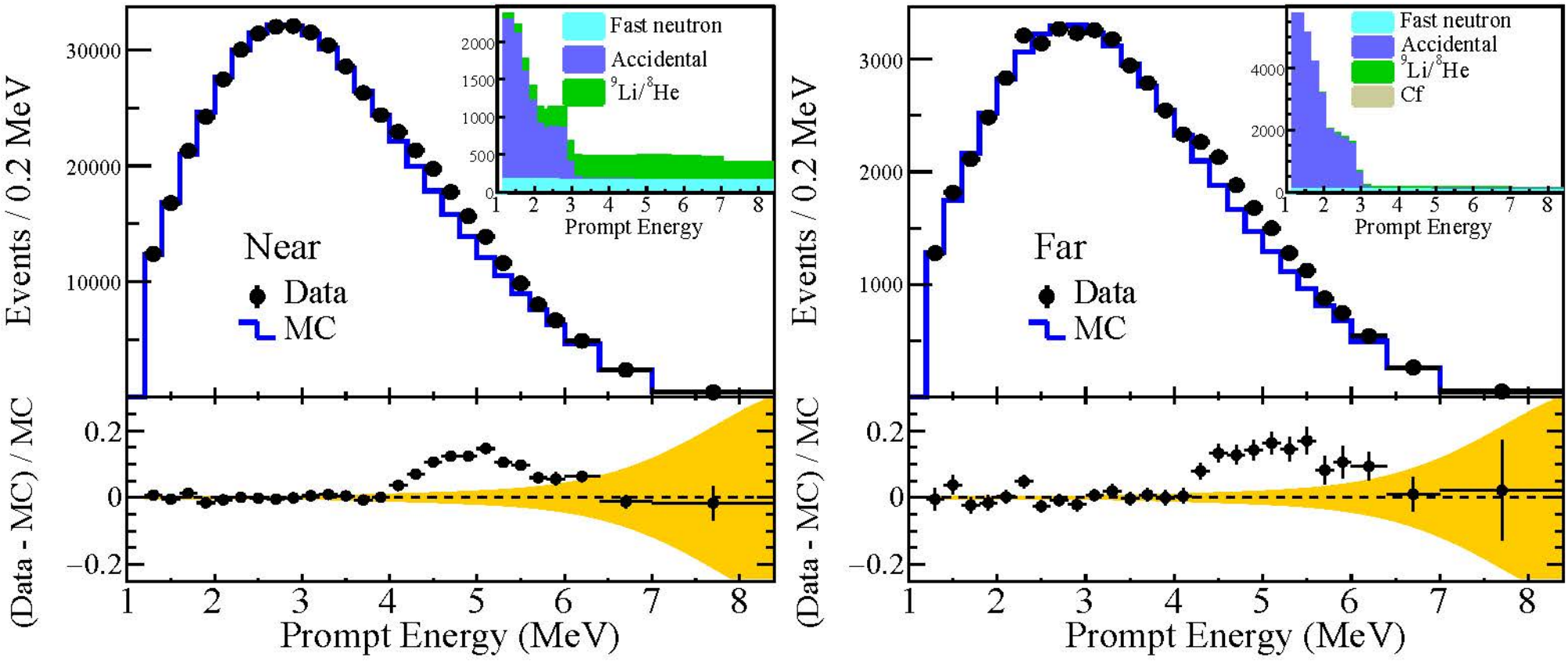


$$y_{239} = 4.142^{+0.250}_{-0.245} \times 10^{-43}\,\mathrm{cm}^2/\mathrm{fission}$$

RENO 1500-Days Data n-H Analysis Results



Independent measurement of $sin^2 2\theta_{13}$ using 1500 live days n-H data



$$\sin^2 2\theta_{13} = 0.086 \pm 0.008(stat.) \pm 0.014(sys.)$$

$$|\Delta m^2_{ee}| = 2.562 \times 10^{-3}\,\mathrm{eV}^2$$

RENO Sterile Neutrino Search (Additional Plots)