

Recent Results from RENO Experiment

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on behalf of the RENO Collaboration

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Reactor Experiment for Neutrino Oscillation

9 Institutions and 30 Physicists

Chonnam National University

Dongshin University

Gwangju Institute of Science and Technology

Gyeongsang National University

Korea Advanced Institute of Science and Technology

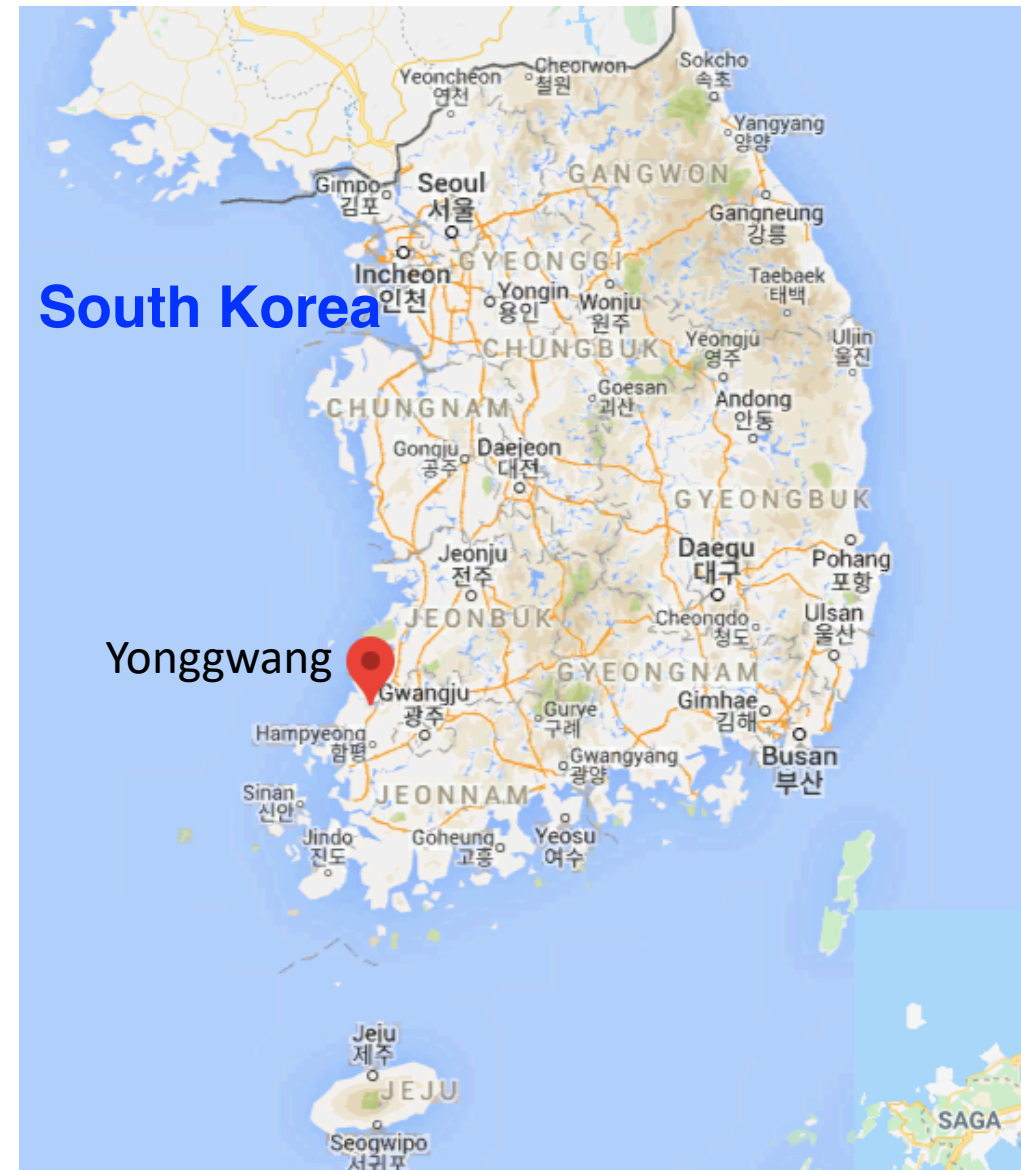
Kyungpook National University

Seoul National University

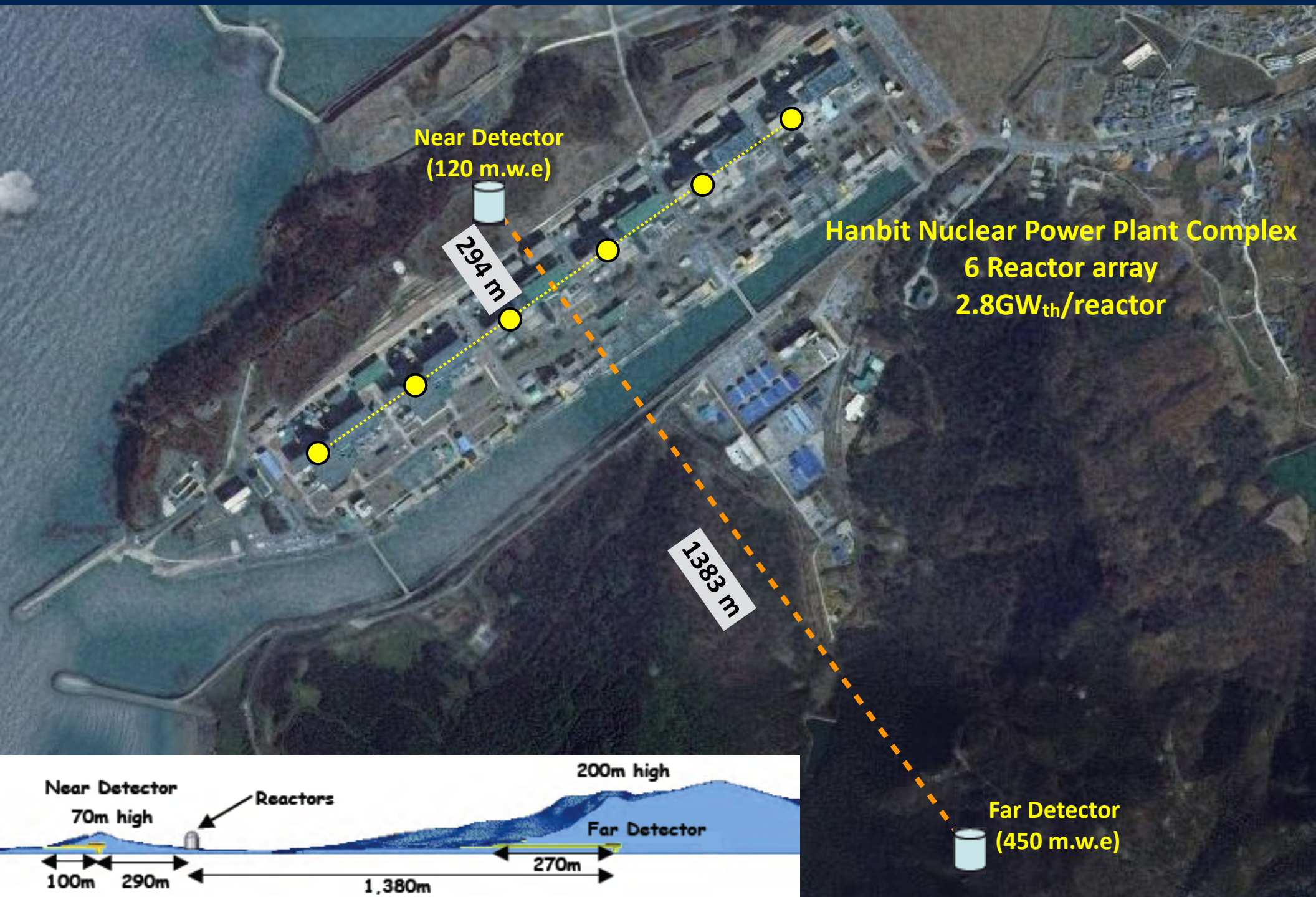
Seoyeong University

Sungkyunkwan University

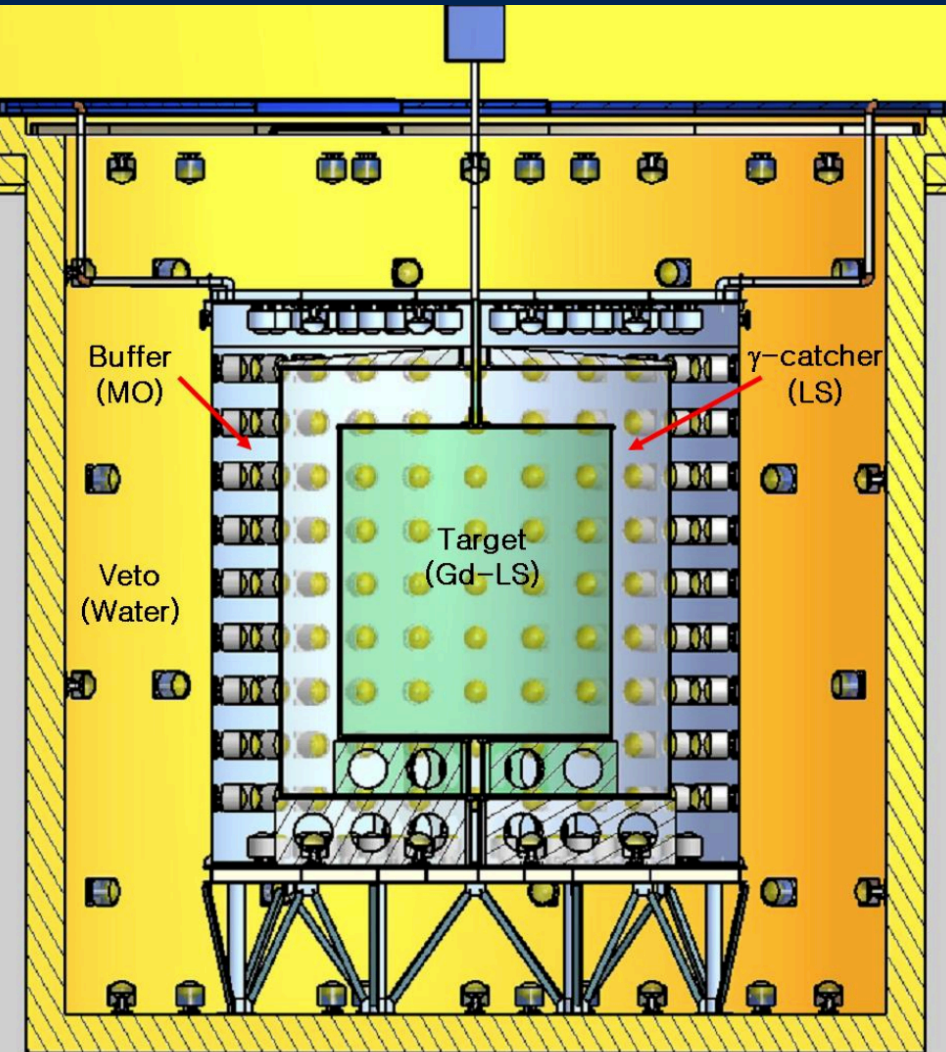
- Start of project: 2006
- The first reactor experiment running with both near and far detectors since August 2011



RENO Experimental Setup



RENO Detectors



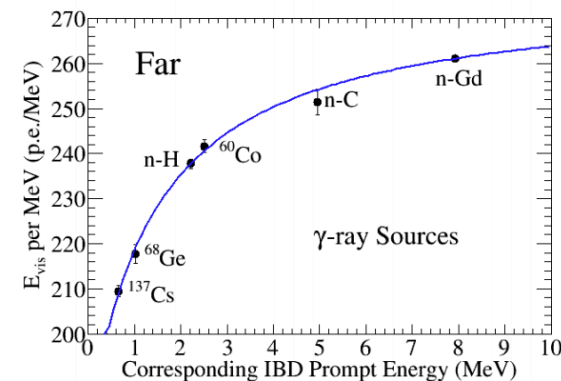
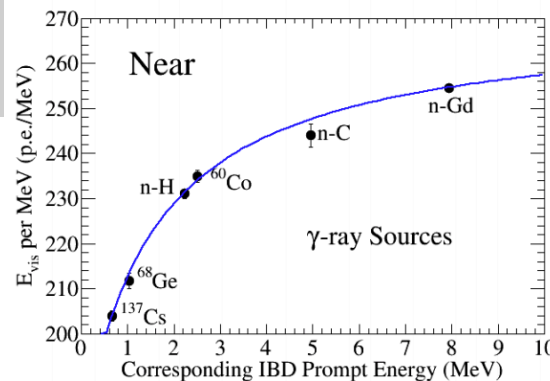
Two identical (near and far) detectors

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



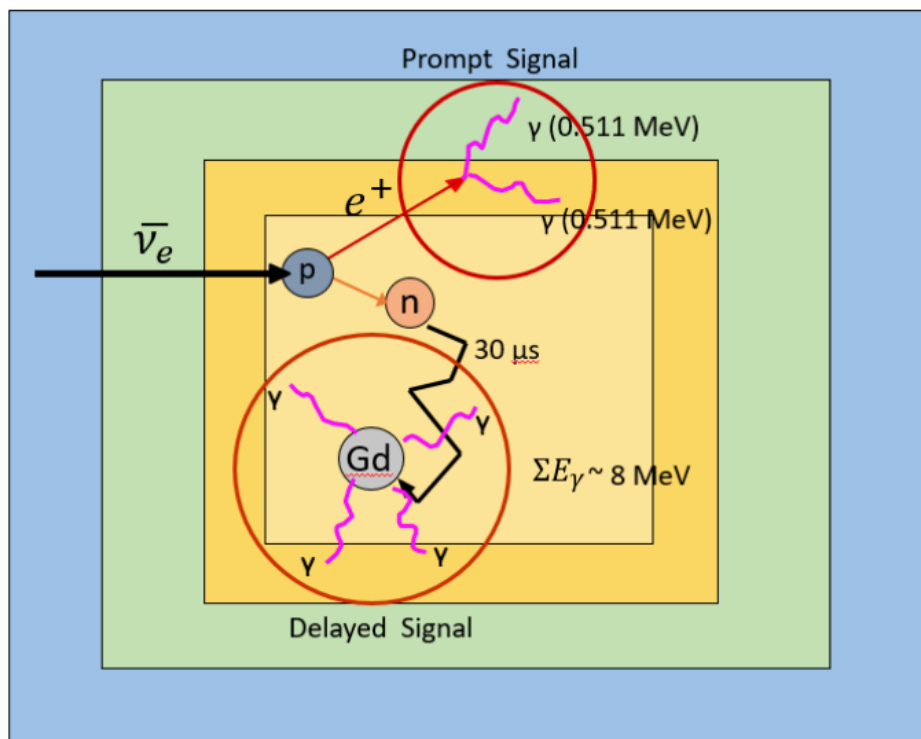
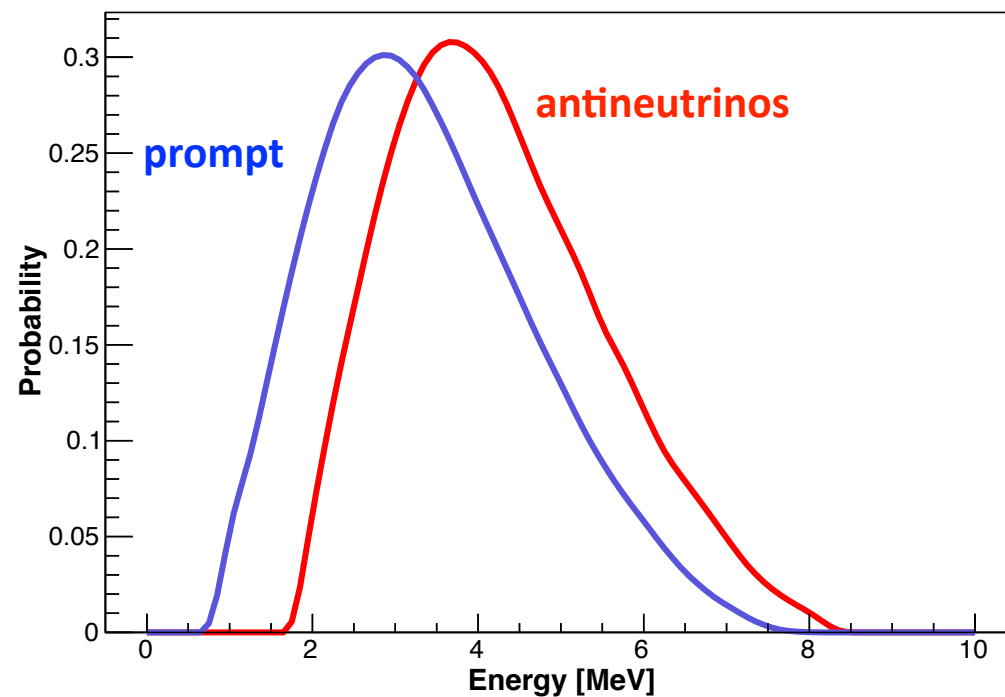
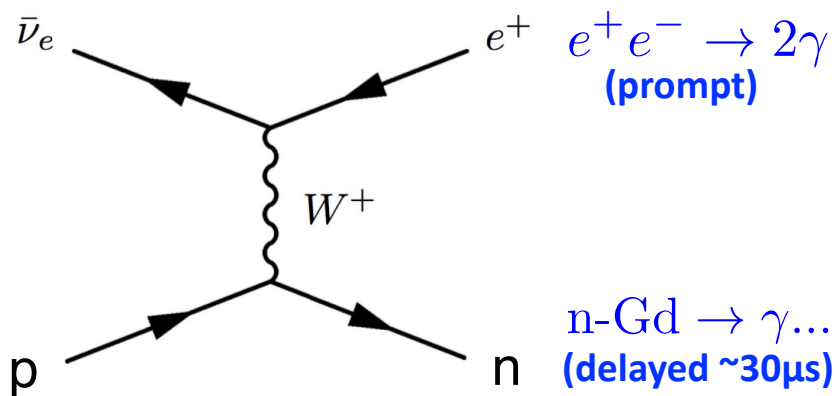
354 (Buffer) + 67 (Veto) 10" PMTs

Detector Calibration



RENO Antineutrino Detection Principle

Inverse Beta Decay



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

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

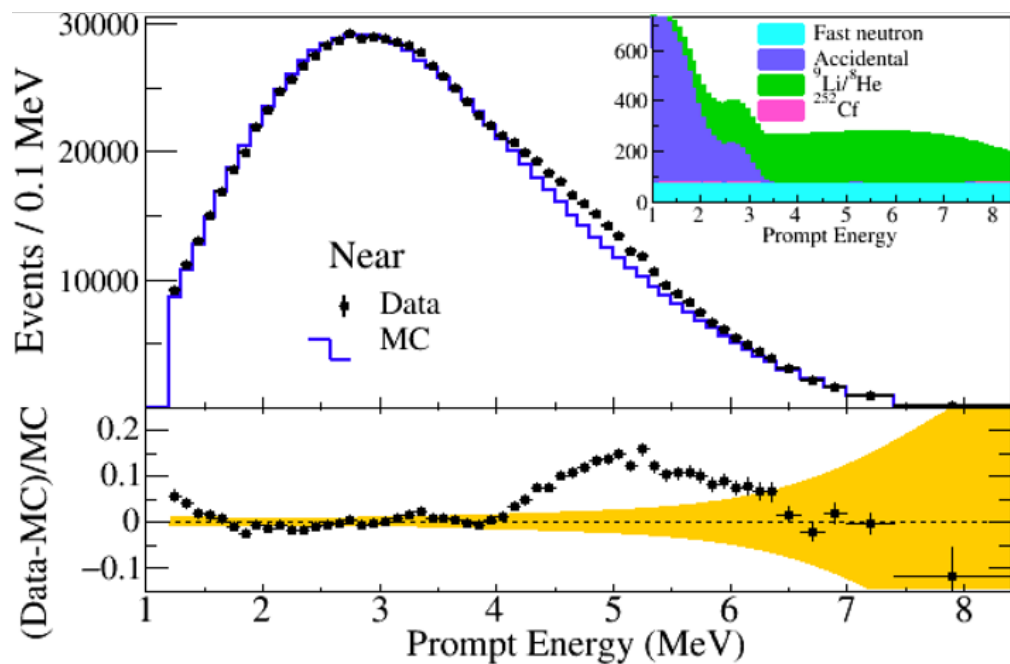
$$\simeq E_\nu - 0.78 \text{ MeV}$$

Measured Spectra of IBD Prompt Signal

RENO 2200 days results: PRL 121, 201801 (2018)

RENO 2900 days (2200 + 700 days) : Aug. 2011 — Feb. 2020

- Clear excess at 5MeV compared to the Huber-Mueller prediction

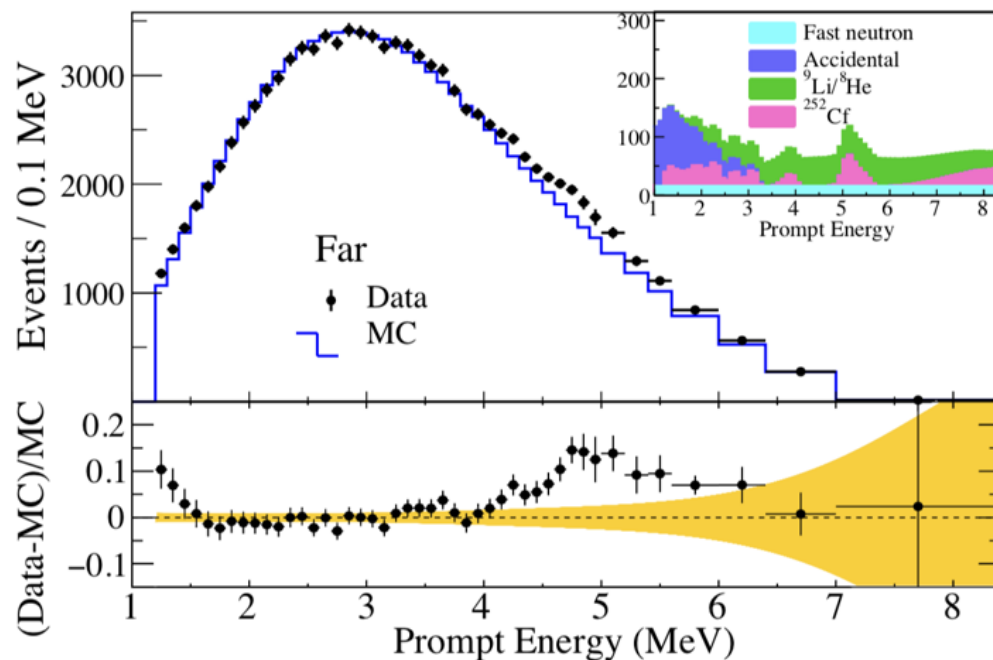


Near detector live time: 2509 days

#IBD candidates: 989,736

Background rate: $2.26 \pm 0.05 \%$

5 MeV excess rate: $2.50 \pm 0.06 \%$



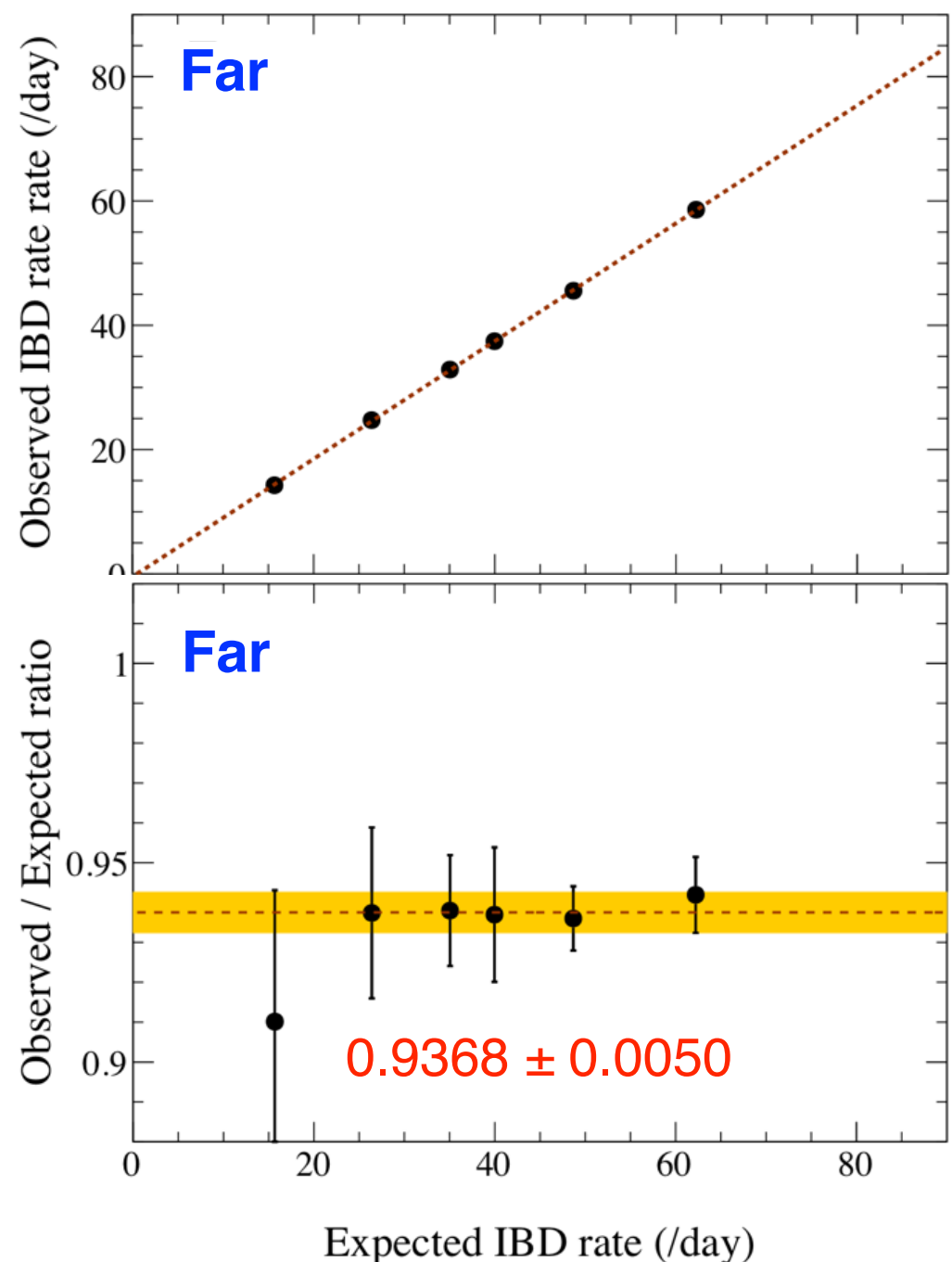
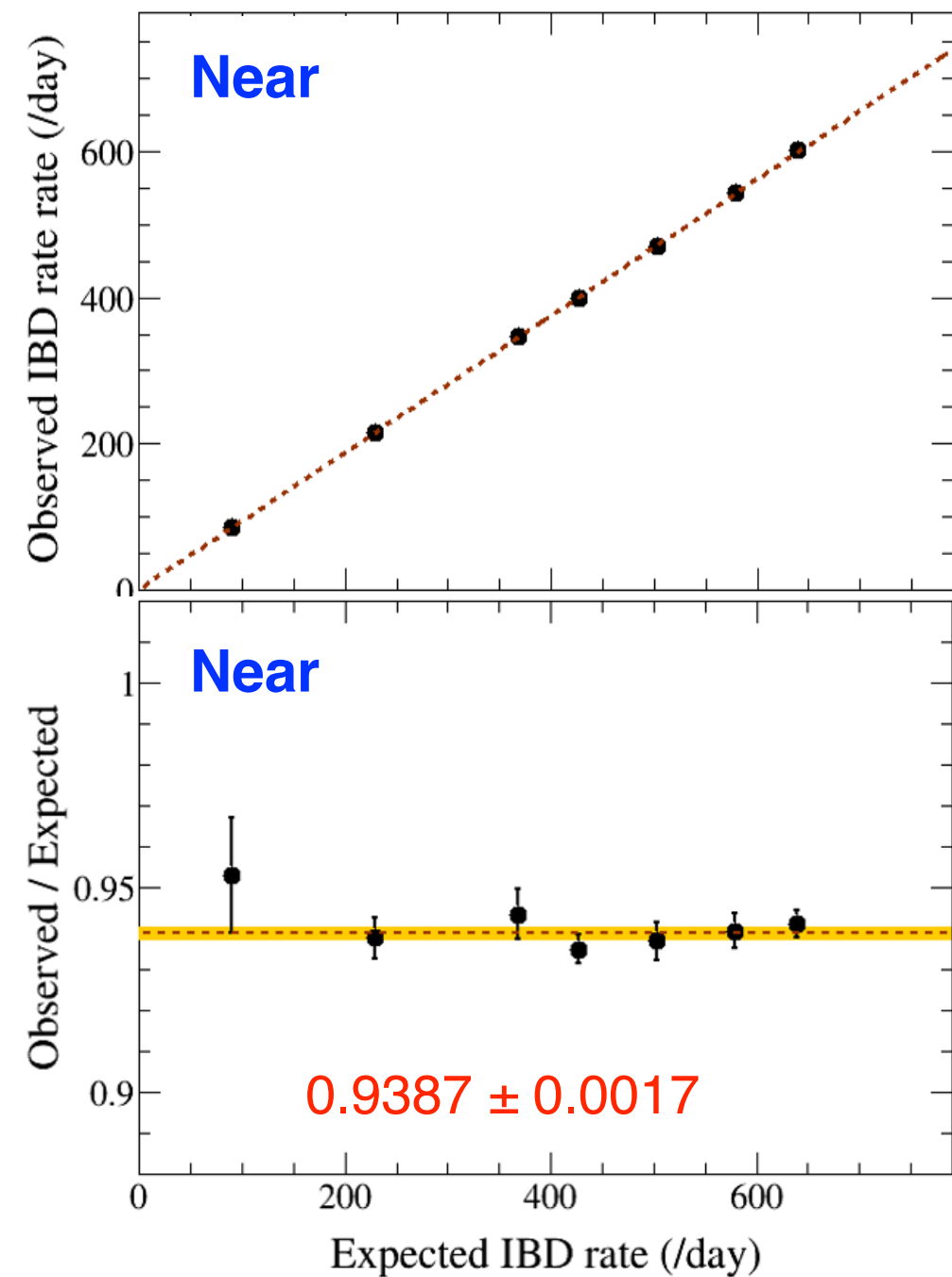
Far detector live time: 2908 days

IBD candidates: 120,383

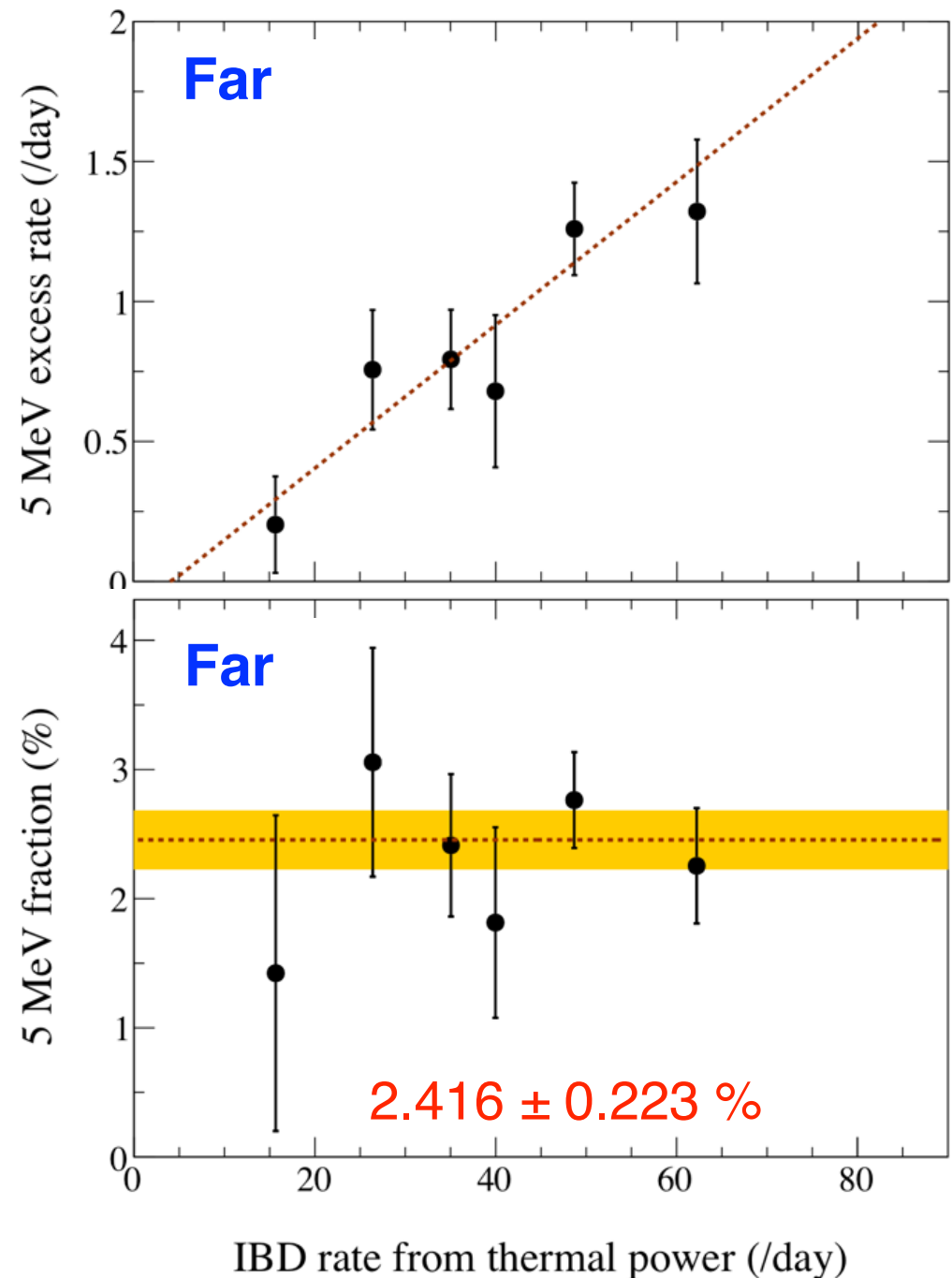
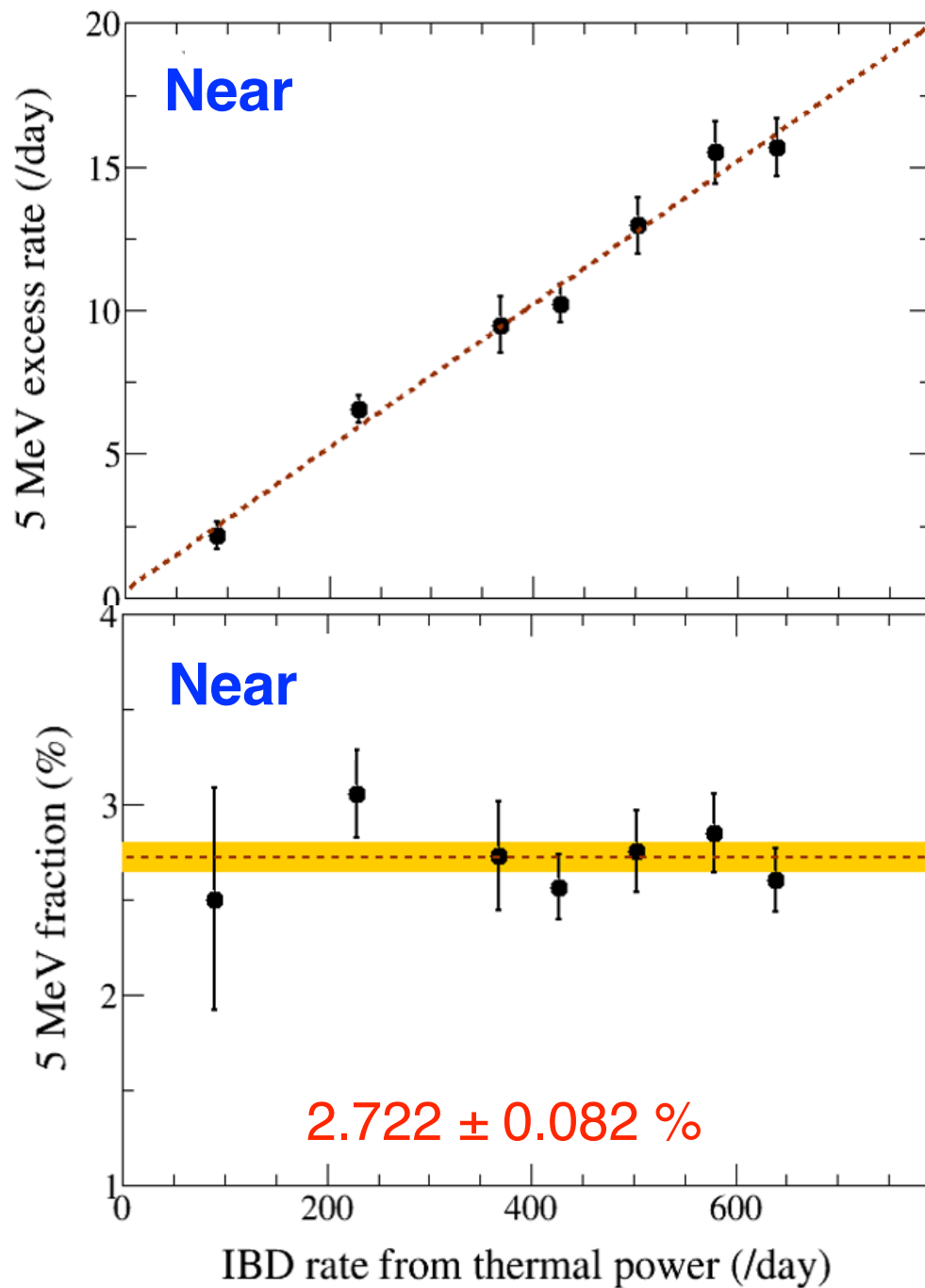
Background rate: $4.77 \pm 0.19 \%$

5 MeV excess rate: $2.26 \pm 0.18 \%$

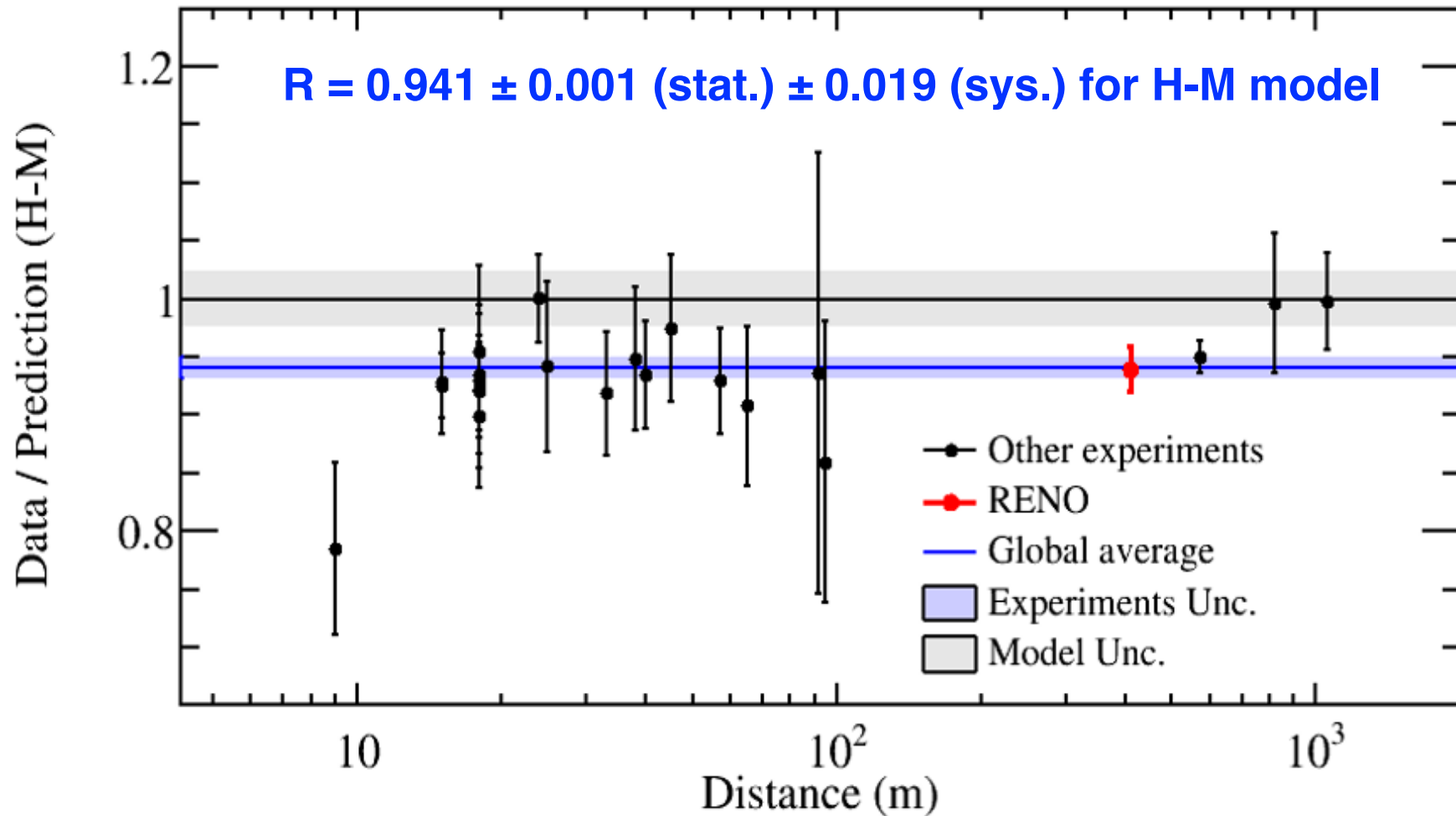
Observed IBD Rate VS Thermal Power



5 MeV Excess VS Thermal Power



Reactor Antineutrino Anomaly (RAA)



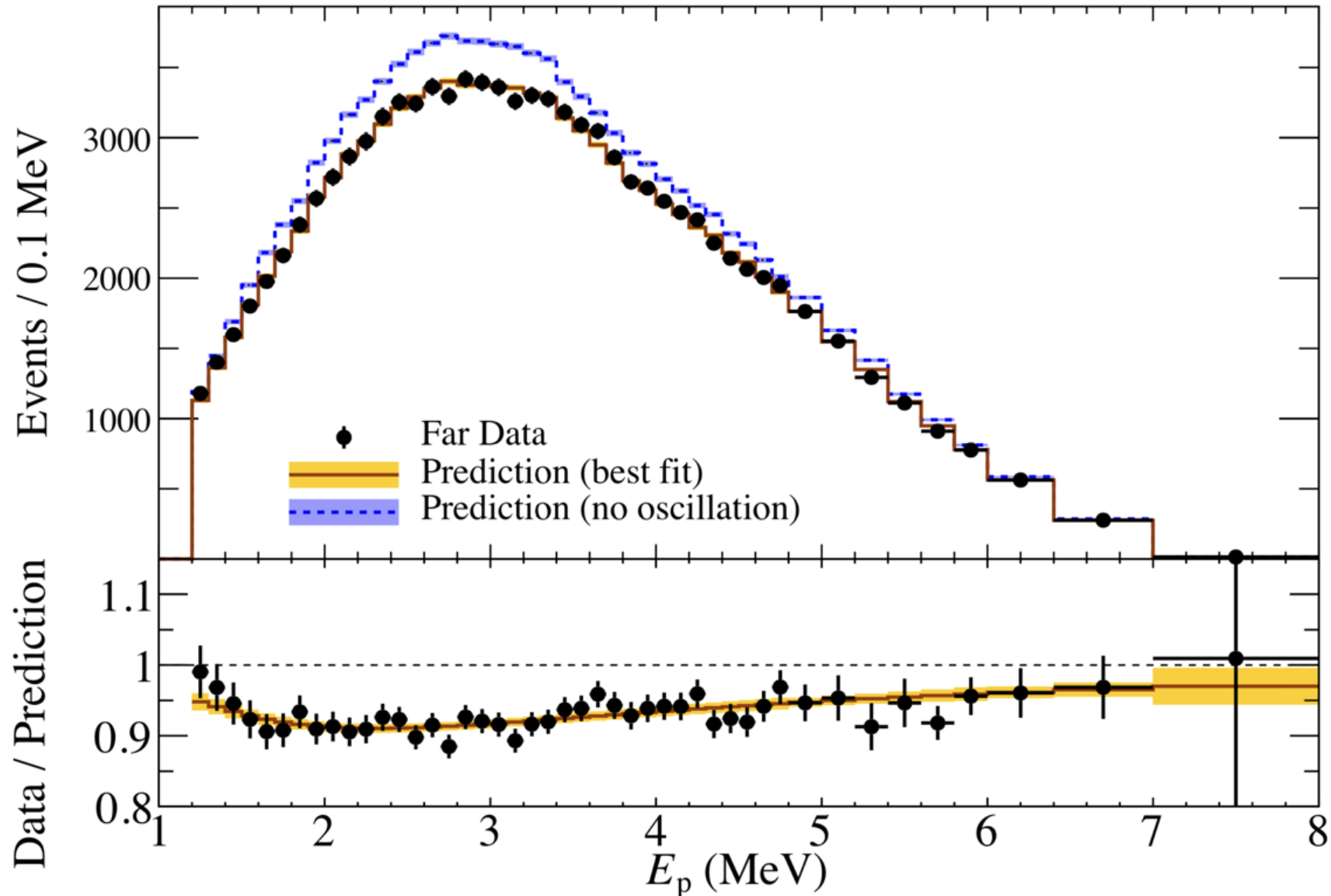
IBD yield: $\bar{y}_f = 5.852 \pm 0.124 (\times 10^{-43} \text{ cm}^2 / \text{fission})$

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

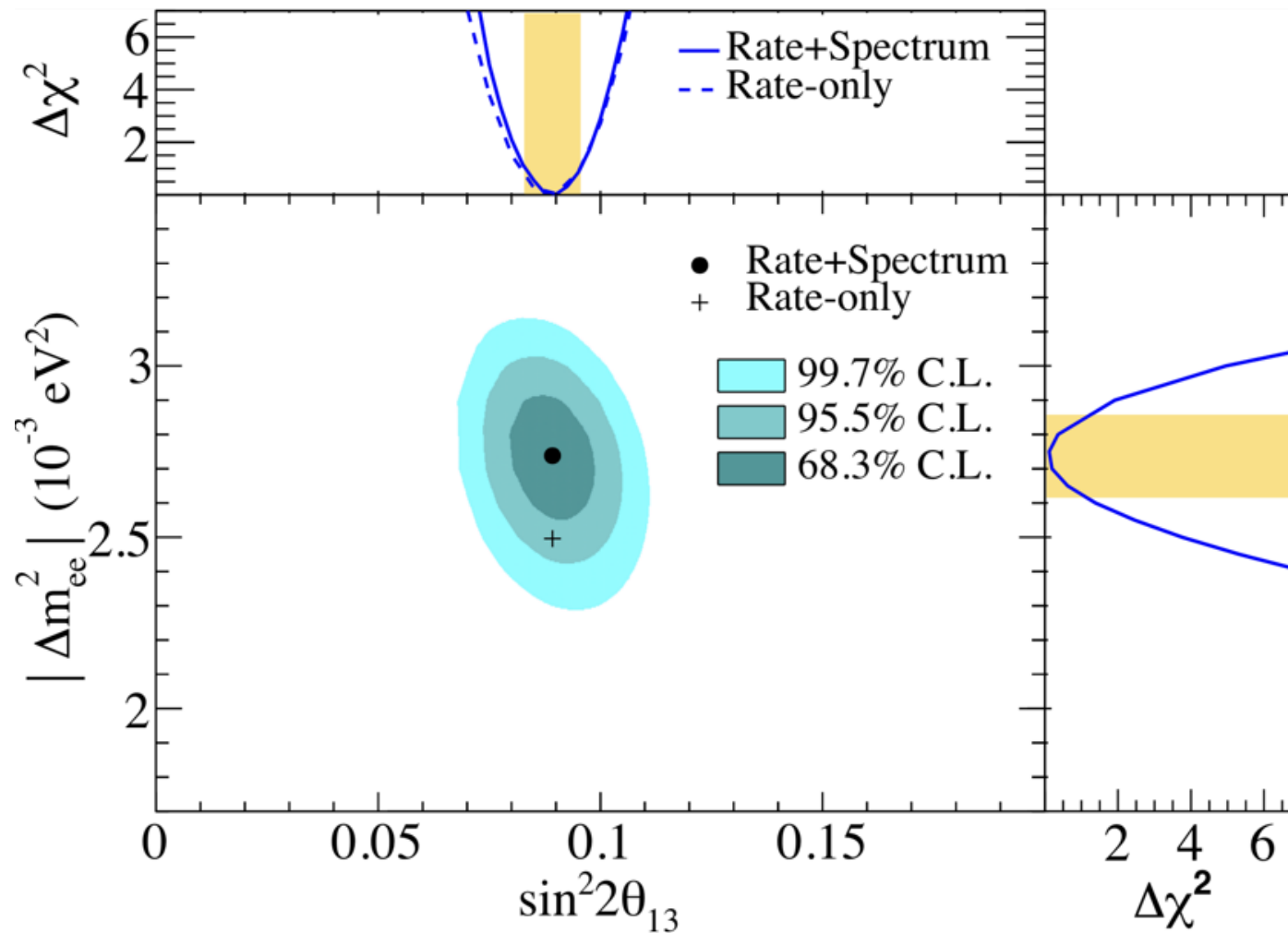
Far to Near Prompt Spectra Shape Comparison

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

- Energy dependent disappearance of reactor antineutrinos



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

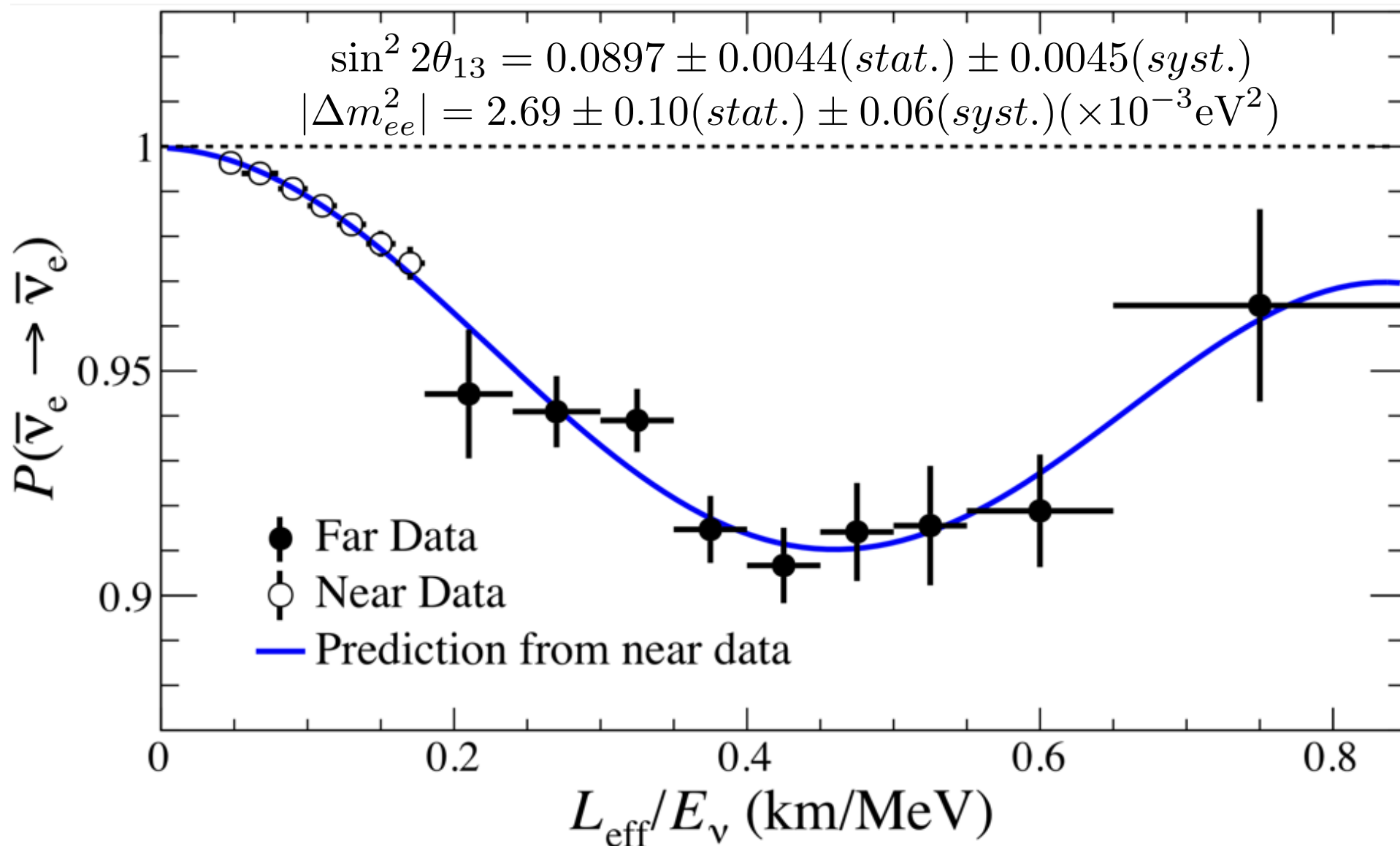


$$\sin^2 2\theta_{13} = 0.0892 \pm 0.0044(stat.) \pm 0.0045(sys.) \quad \pm 7.0\%$$

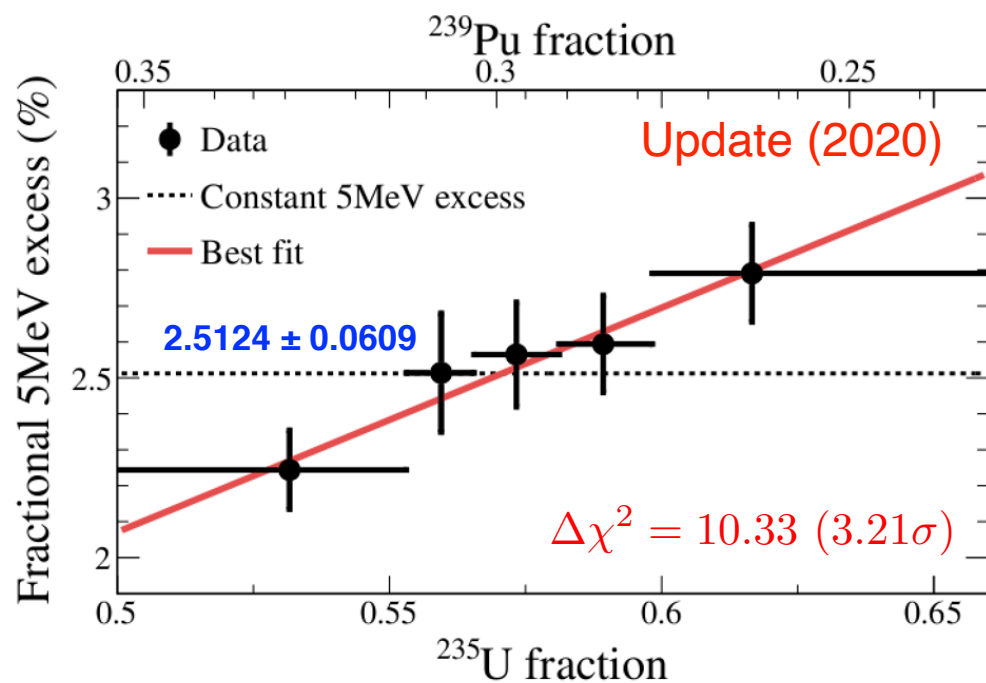
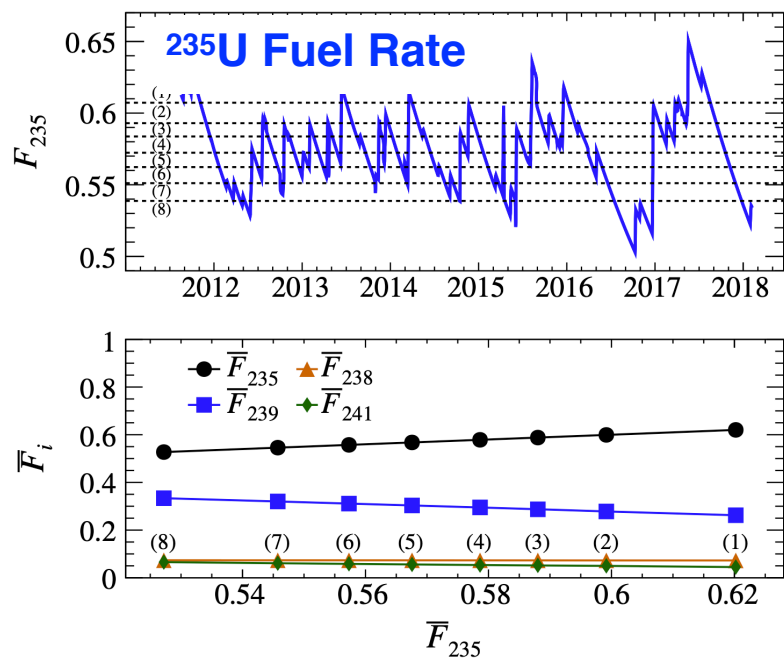
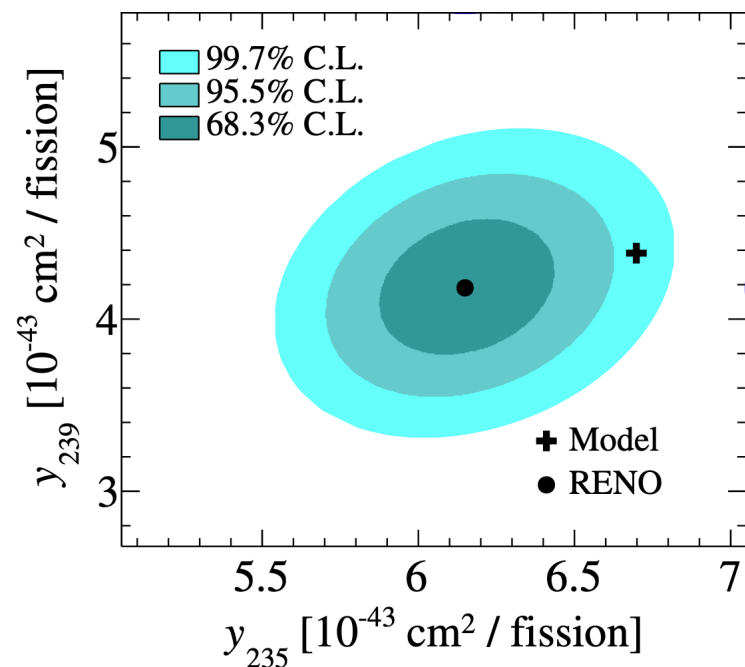
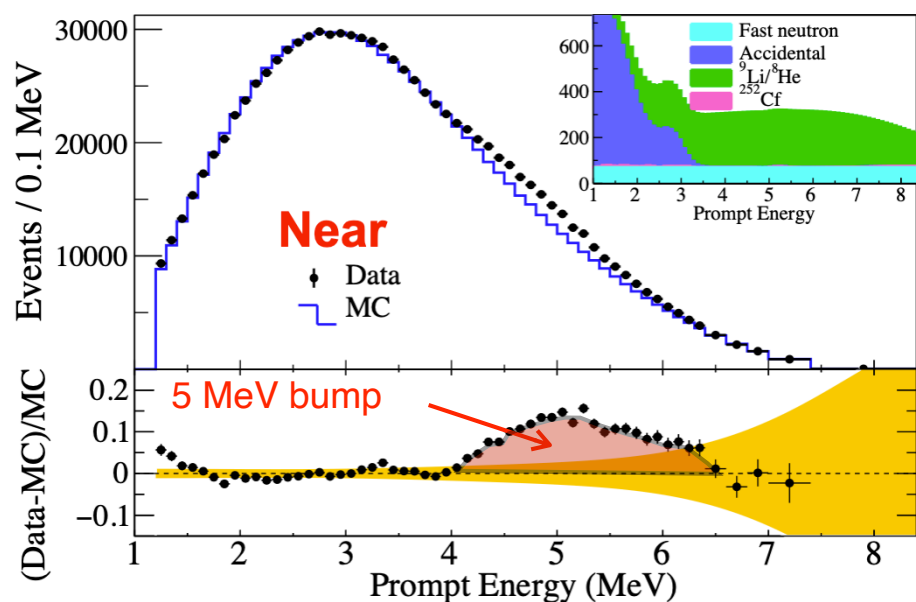
$$|\Delta m^2_{ee}| = 2.74 \pm 0.10(stat.) \pm 0.06(sys.) (\times 10^{-3} \text{eV}^2) \quad \pm 4.4\%$$

Neutrino Oscillation: L/E Dependence

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2 \left(1.27 \Delta m_{ee}^2 \frac{L}{E_\nu} \right)$$



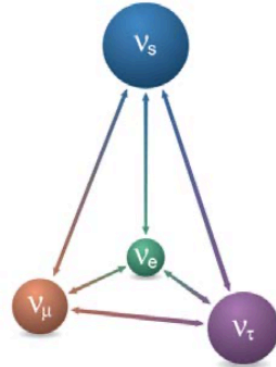
Fuel Dependence of the 5 MeV Excess: PRL 122, 232501 (2019)



Search Sterile Neutrinos (RENO Near/Far) : Sub-eV Scale

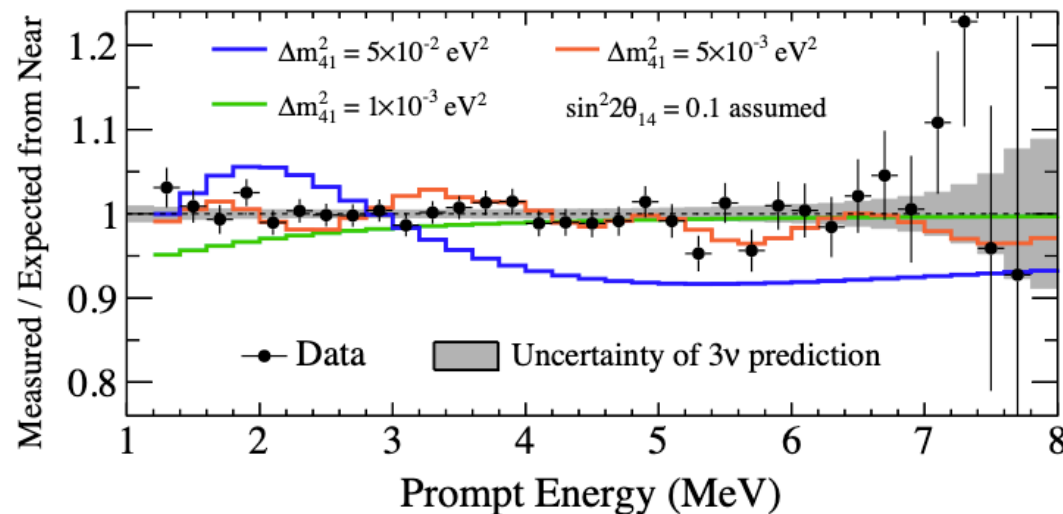
Phys. Rev. Lett. 125, 191801 (2020-11-06)

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} & U_{e4} \\ U_{\mu1} & U_{\mu2} & U_{\mu3} & U_{\mu4} \\ U_{\tau1} & U_{\tau2} & U_{\tau3} & U_{\tau4} \\ U_{s1} & U_{s2} & U_{s3} & U_{s4} \end{pmatrix}$$

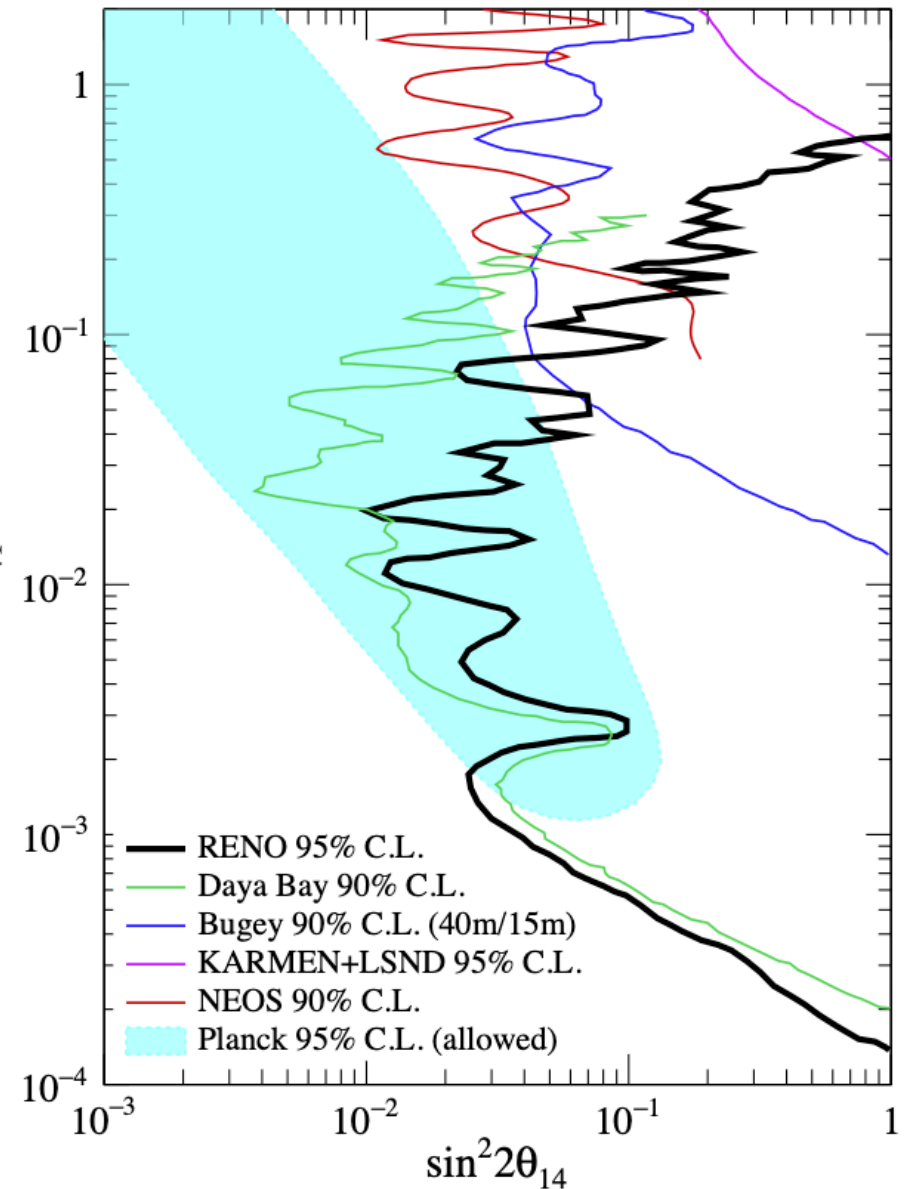


Using RENO Far to Near spectral ratio

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2 \left(1.27 \Delta m_{31}^2 \frac{L}{E_\nu} \right) - \sin^2 2\theta_{14} \sin^2 \left(1.27 \Delta m_{41}^2 \frac{L}{E_\nu} \right)$$

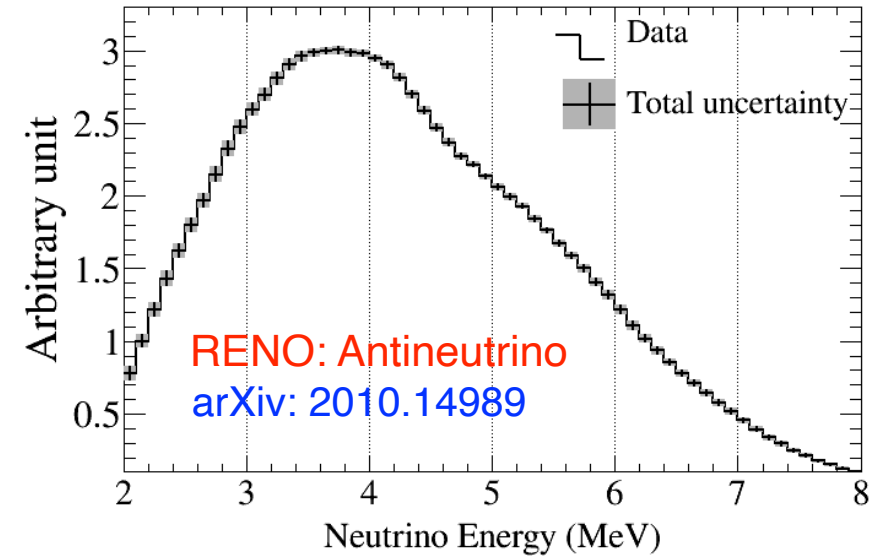
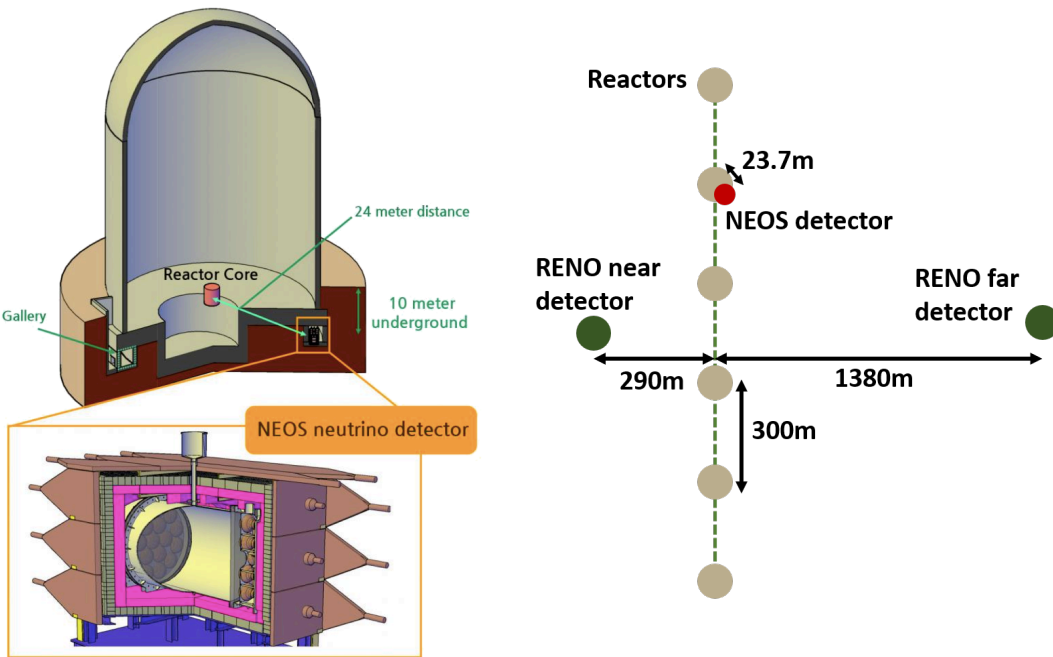


$|\Delta m_{41}^2| (\text{eV}^2)$

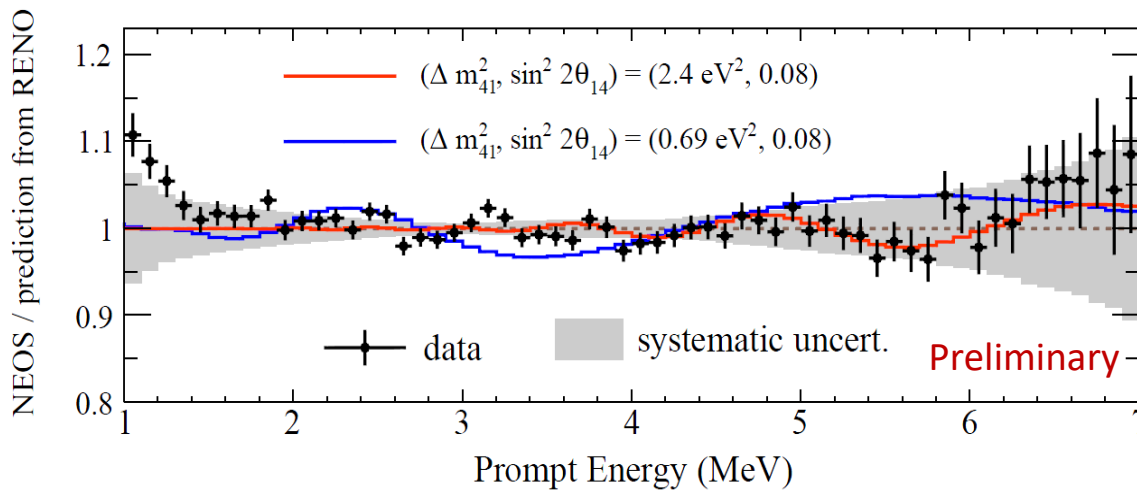
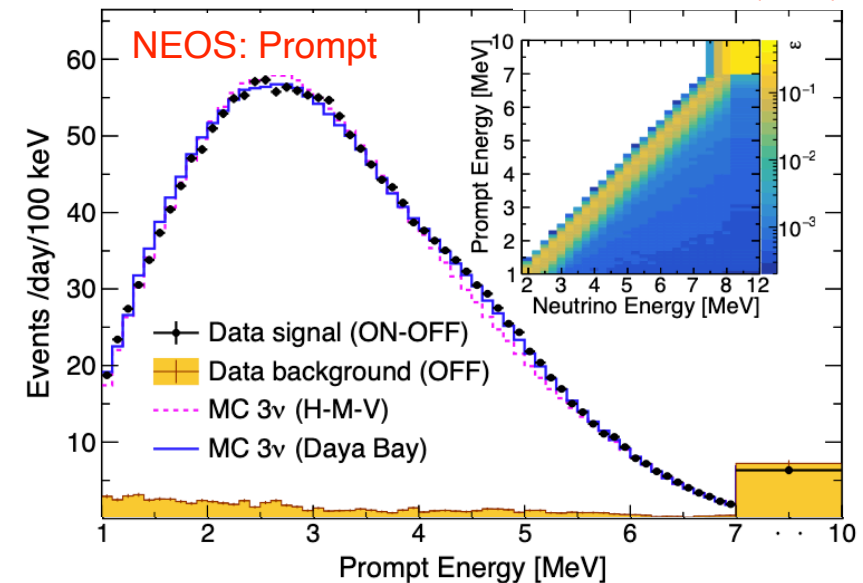


Sterile Neutrino Search (RENO + NEOS) : eV Scale

NEOS at Reactor



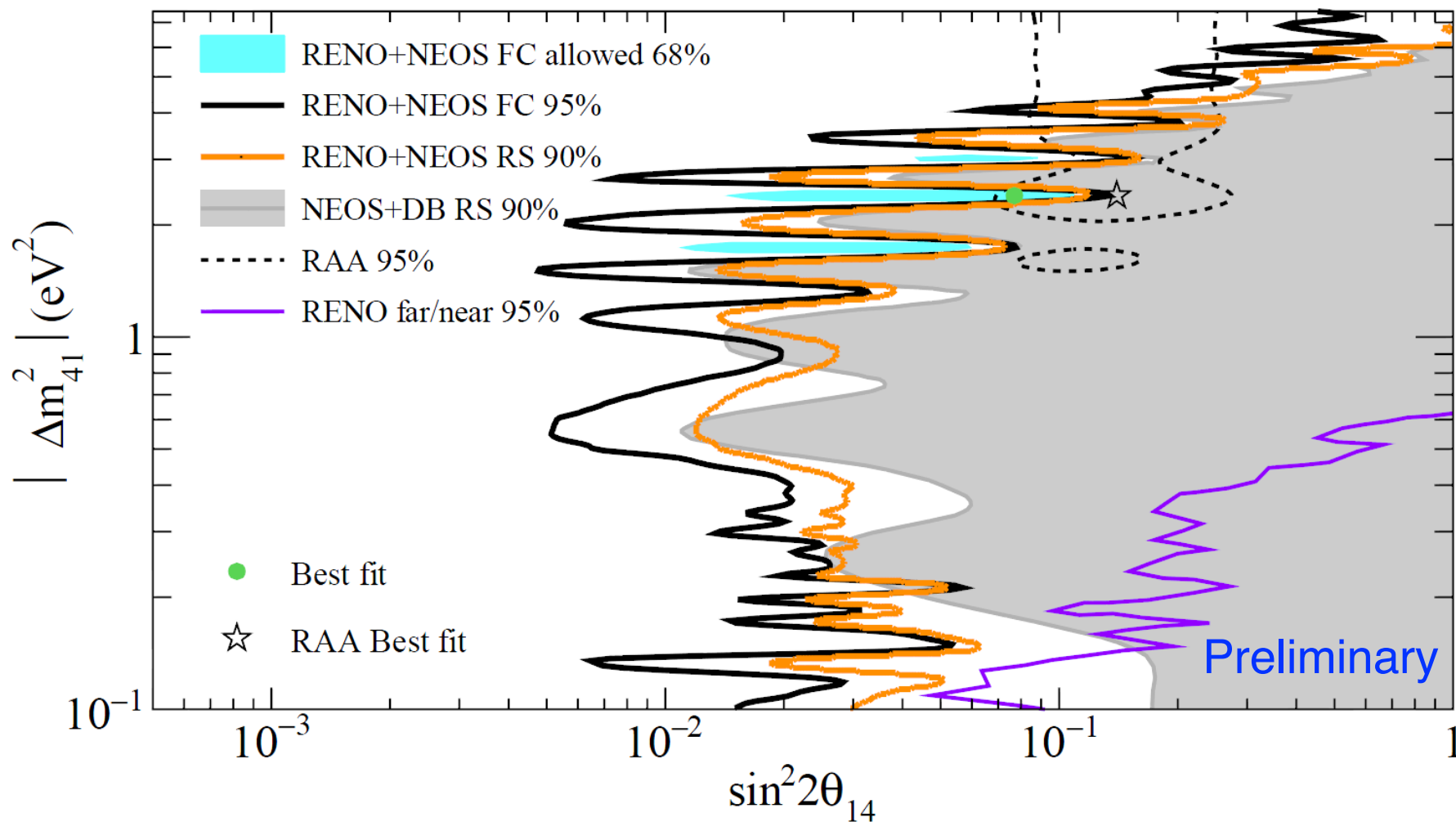
PRL118 121802 (2017)



→ See S. G. Yoon's talk (2021-02-25) and arXiv: 2011.00896

Sterile Neutrino Search (RENO + NEOS) : eV Scale

RENO+NEOS collaboration: joint analysis in progress



RENO+NEOS best fit at (0.08, 2.4 eV²)

4ν min $\chi^2/\text{DOF} = 47.45/58$ (3ν $\chi^2/\text{DOF} = 56.24/60$) $\Delta\chi^2 = 8.8$, $p=8.5\%$

→ See S. G. Yoon's talk (2021-02-25)

- Report updated results using **RENO 2900 days data**
- Precision measurement of θ_{13} and $|\Delta m_{ee}^2|$
- Absolute reactor neutrino flux : **$R = 94.1 \pm 1.9 \%$ (for HM)**
- Correlation between 5 MeV excess and ^{235}U fission **(3.2σ C.L.)**
- The first RENO sterile neutrino search: **PRL 125, 191801 (2020)**
- RENO antineutrino spectrum: **arXiv: 2010.14989**
- Sterile neutrino search (RENO + NEOS) : **arXiv: 2011.00896**