New Results from RENO

Sunny (Seon-Hee) Seo

Seoul National University

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Sudbury, ON, Canada

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KNRC

Korea Neutrino Research Center

RENO Collaboration

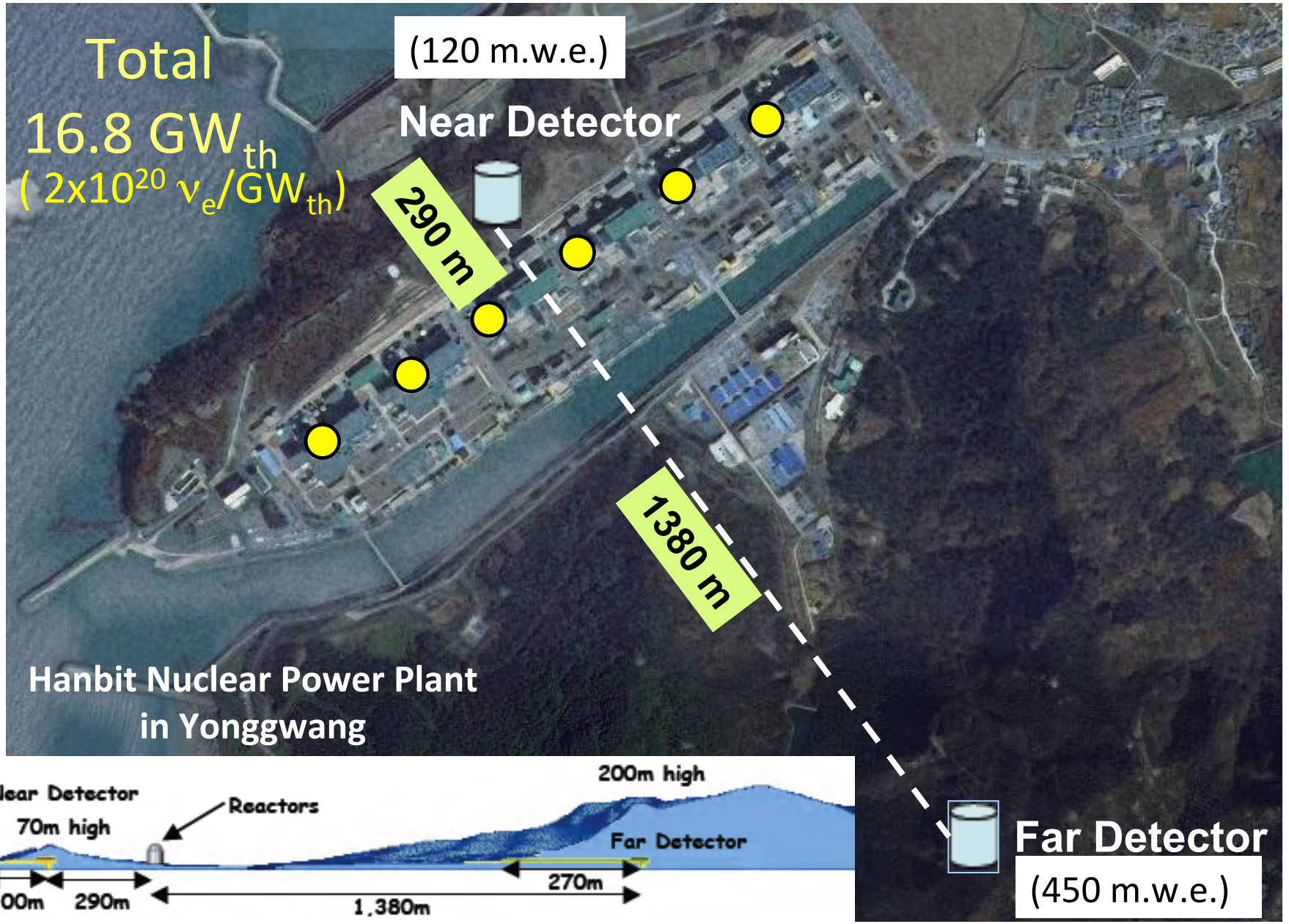
Reactor Experiment for Neutrino Oscillation

(~40 members in 8 institutions)

- Chonnam National University
- Dongshin University
- GIST
- Gyeongsang National University
- Kyungpook National University
- Seoul National University
- Seoyeong University
- Sungkyunkwan University

- Total cost : **$10M**
- Start of project : **2006**
- The first reactor experiment running with both near & far detectors from **Aug. 2011**

RENO Experimental Setup



RENO Data-taking Status

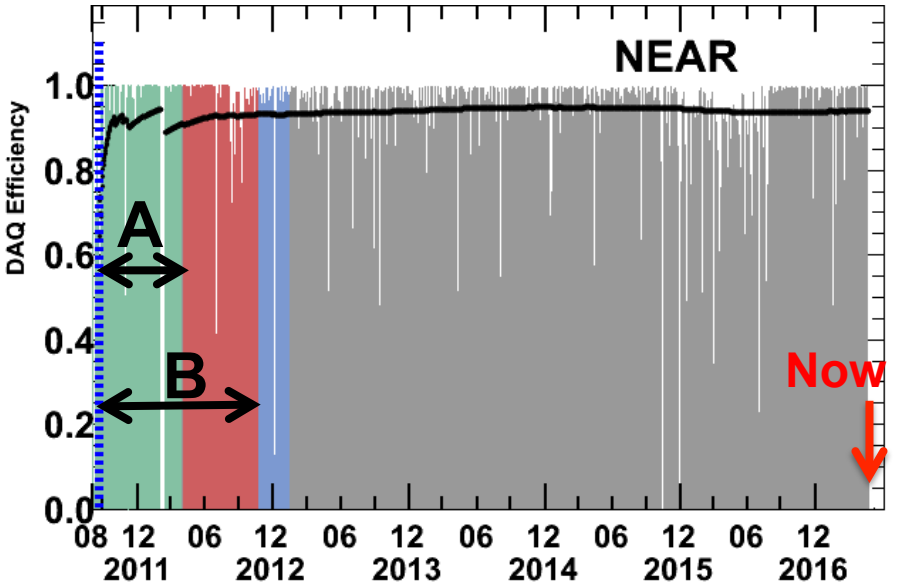
- Data taking began on Aug. 1, 2011 with both near and far detectors.
  (DAQ efficiency : ~95%)

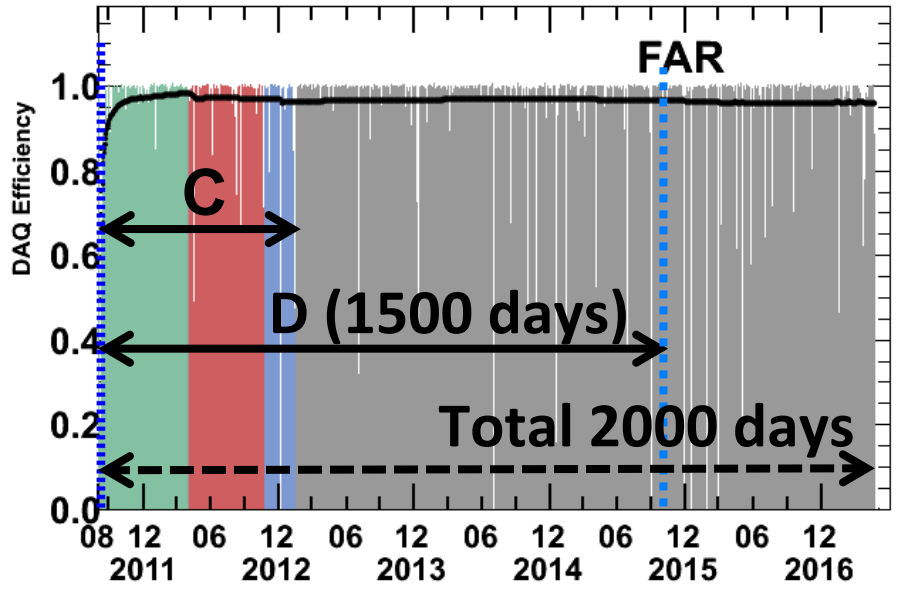
- **A (220 days)** : **First θ_{13} result**
  [11 Aug, 2011~26 Mar, 2012]
  PRL 108, 191802 (2012)

- **B (403 days)** : **Improved θ_{13} result**
  [11 Aug, 2011~13 Oct, 2012]
  NuTel 2013, TAUP 2013, WIN 2013

- **C (500 days)** : **First $|\Delta m^2_{ee}|$ result**
  Rate+shape analysis (θ_{13} and $|\Delta m^2_{ee}|$)
  [11 Aug, 2011 ~ 21 Jan,2013]
  PRL 116, 211801 (2016)
  submitted to PRD (arXiv:1610.04326)

- **D (1500 days)** : **New results**
  [11 Aug, 2011 ~ Sep, 2015]





New Results from RENO

We updated the following measurements
using 1500 live days of data (Aug. 2011 ~ Sept. 2015).

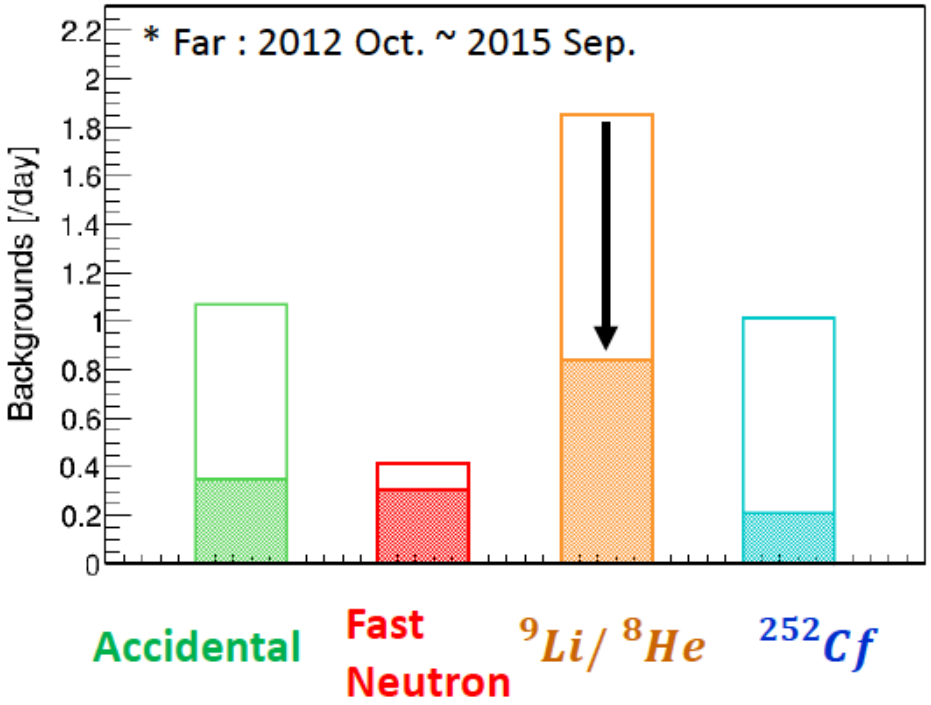
1. $\sin^2(2\theta_{13})$ and $|\Delta m_{ee}^2|$ spectral measurements

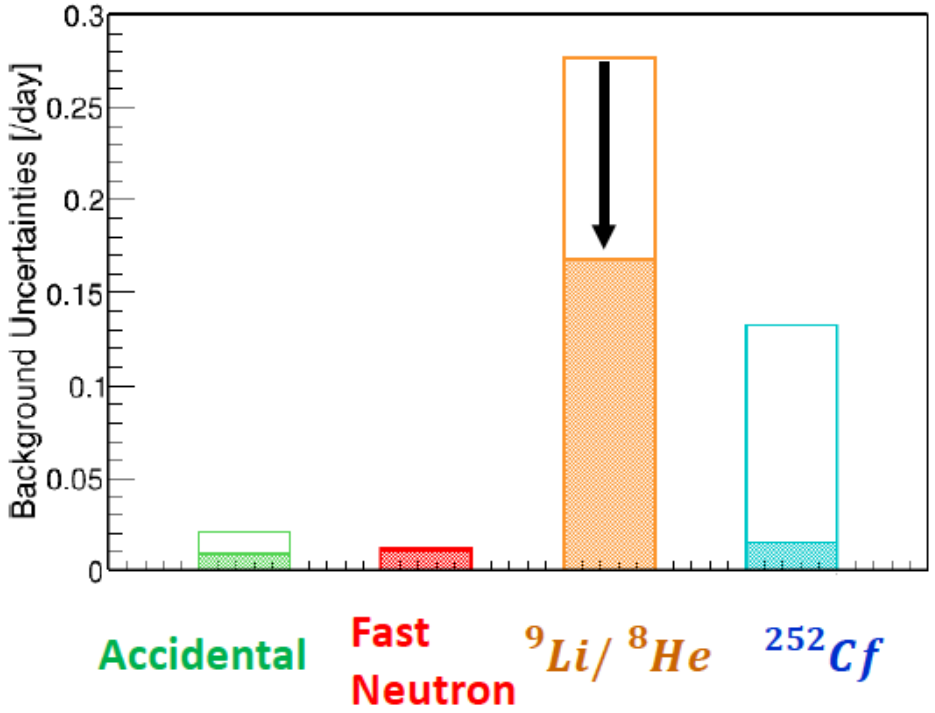
2. Measurement of 5 MeV excess of the reactor neutrino spectrum

3. Measurement of an absolute reactor neutrino flux

Reduction of Background Rates & Uncertainties

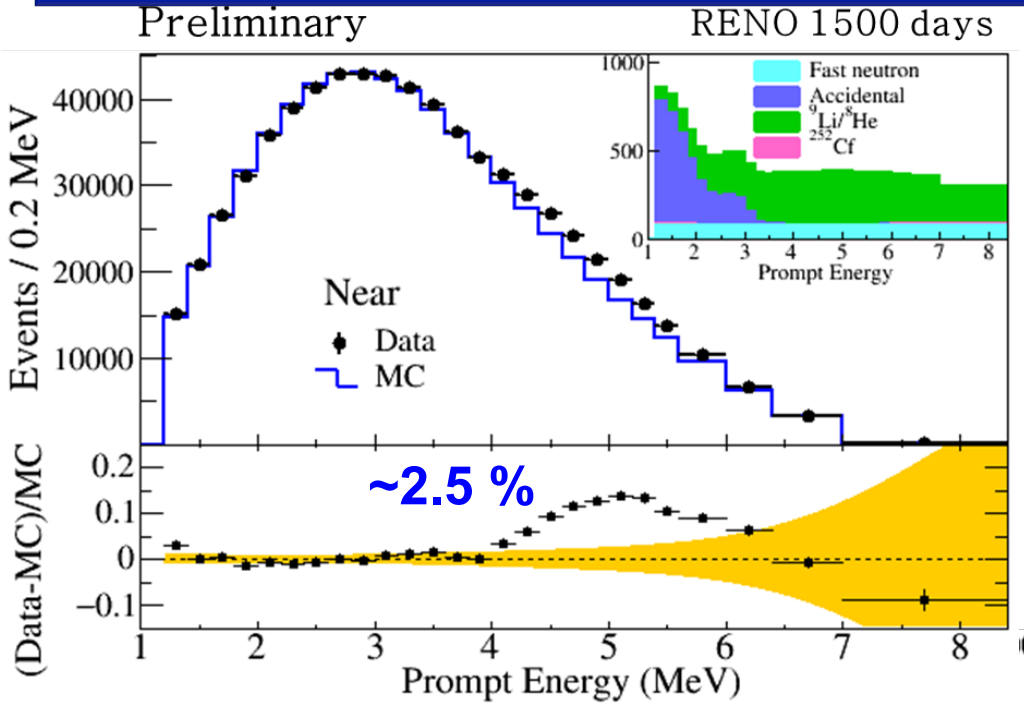
→ Allows precise measurements of $\sin^2(2\theta_{13})$ and $|\Delta m_{ee}^2|$.





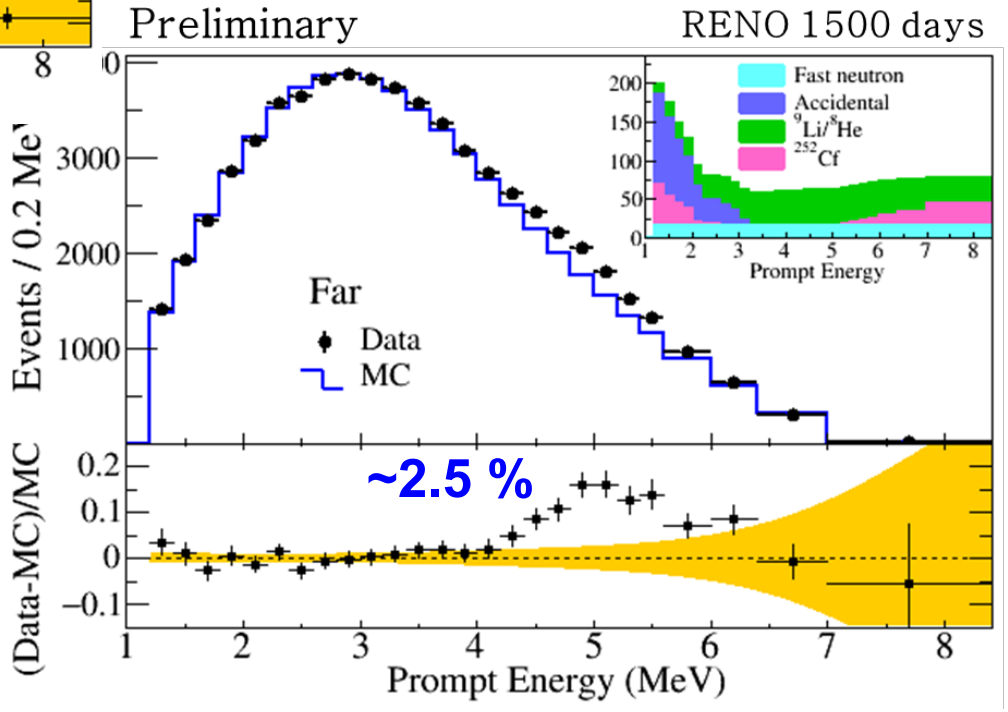
- Accidentals : Additional cuts and improved flashing-PMT removal algorithms
- Cosmogenic $^9Li/\ ^8He$: Optimized muon veto criteria
- ^{252}Cf contamination : Improved multiple-neutron removal algorithms

Measured Spectra of IBD Prompt Signal

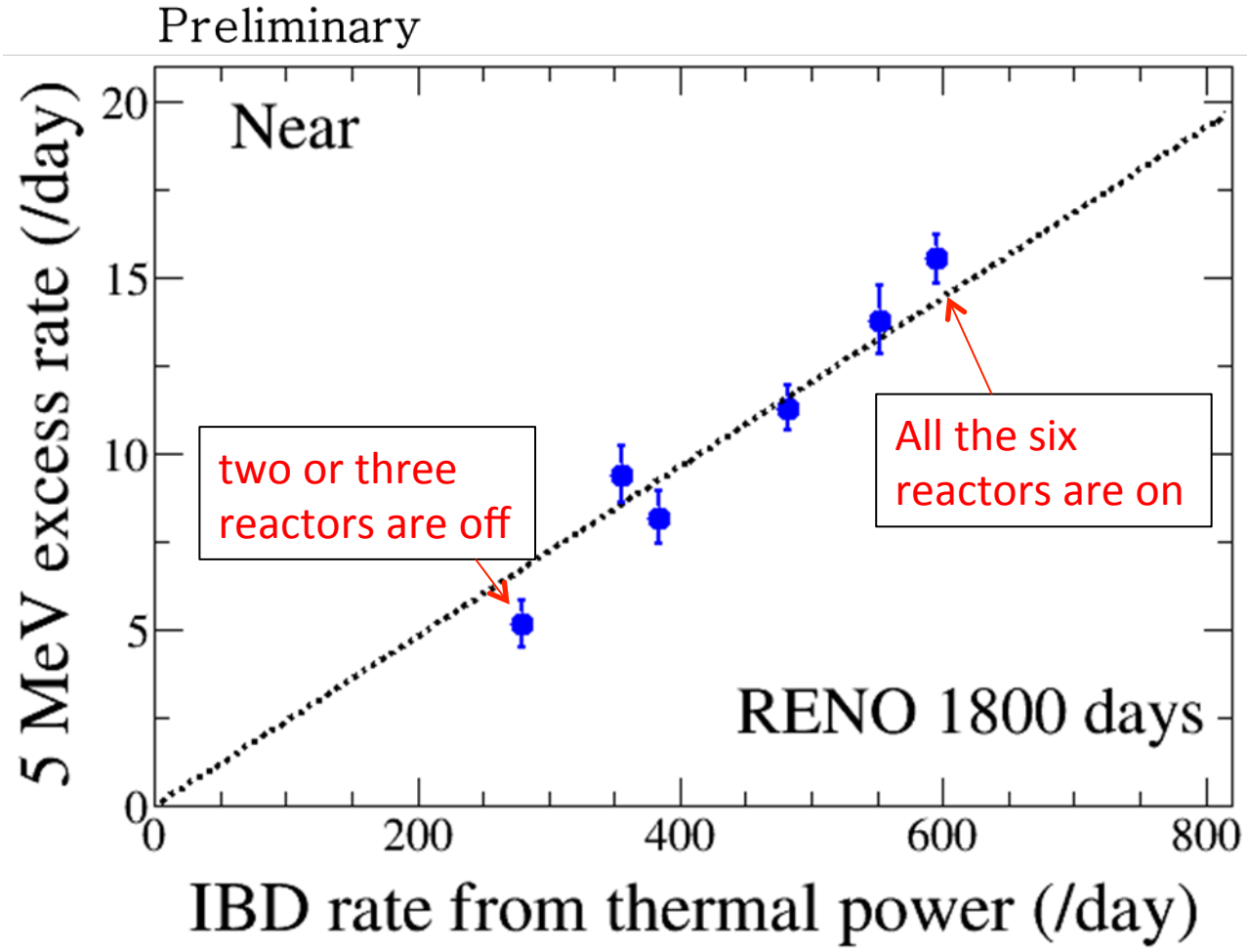


RENO's observation of 5 MeV excess with 1500 days data

Clear excess at 5 MeV



Correlation of 5 MeV Excess with Reactor Power

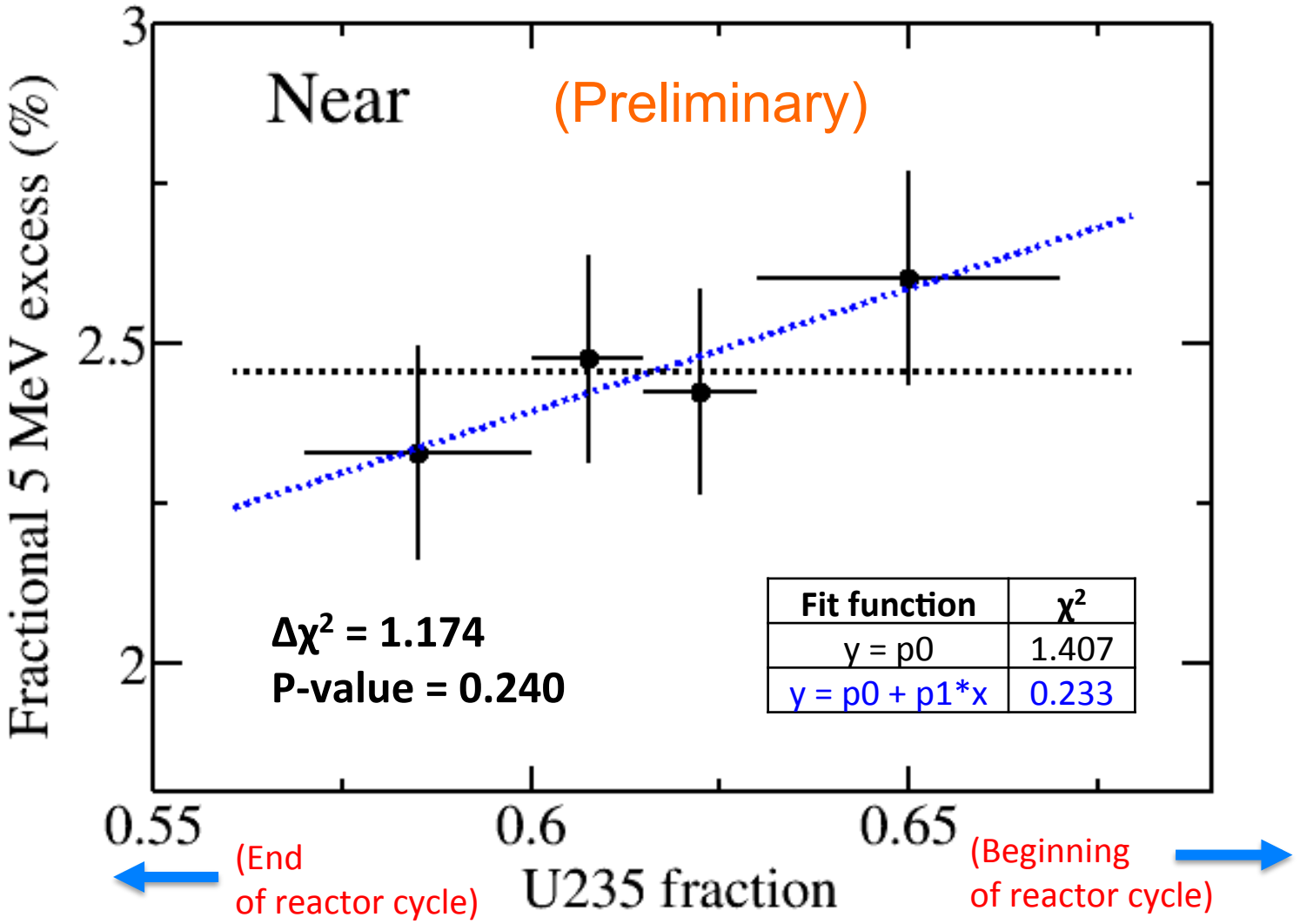


5 MeV excess has a clear correlation with reactor thermal power !

The 5 MeV excess comes from reactors!

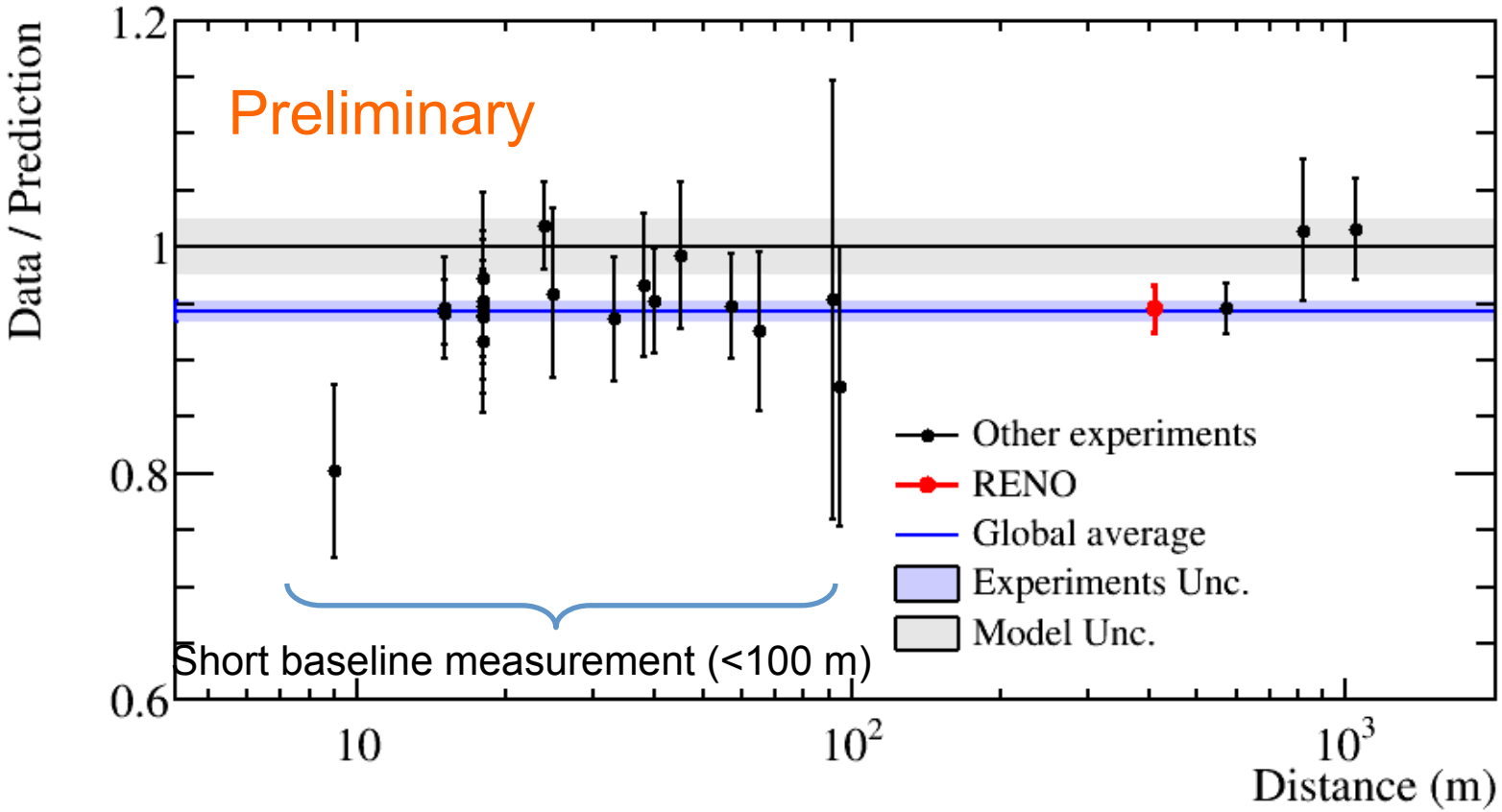
Correlation of 5 MeV Excess with ^{235}U

^{235}U fraction corresponds to freshness of reactor fuel



Absolute Reactor Neutrino Flux Measurement

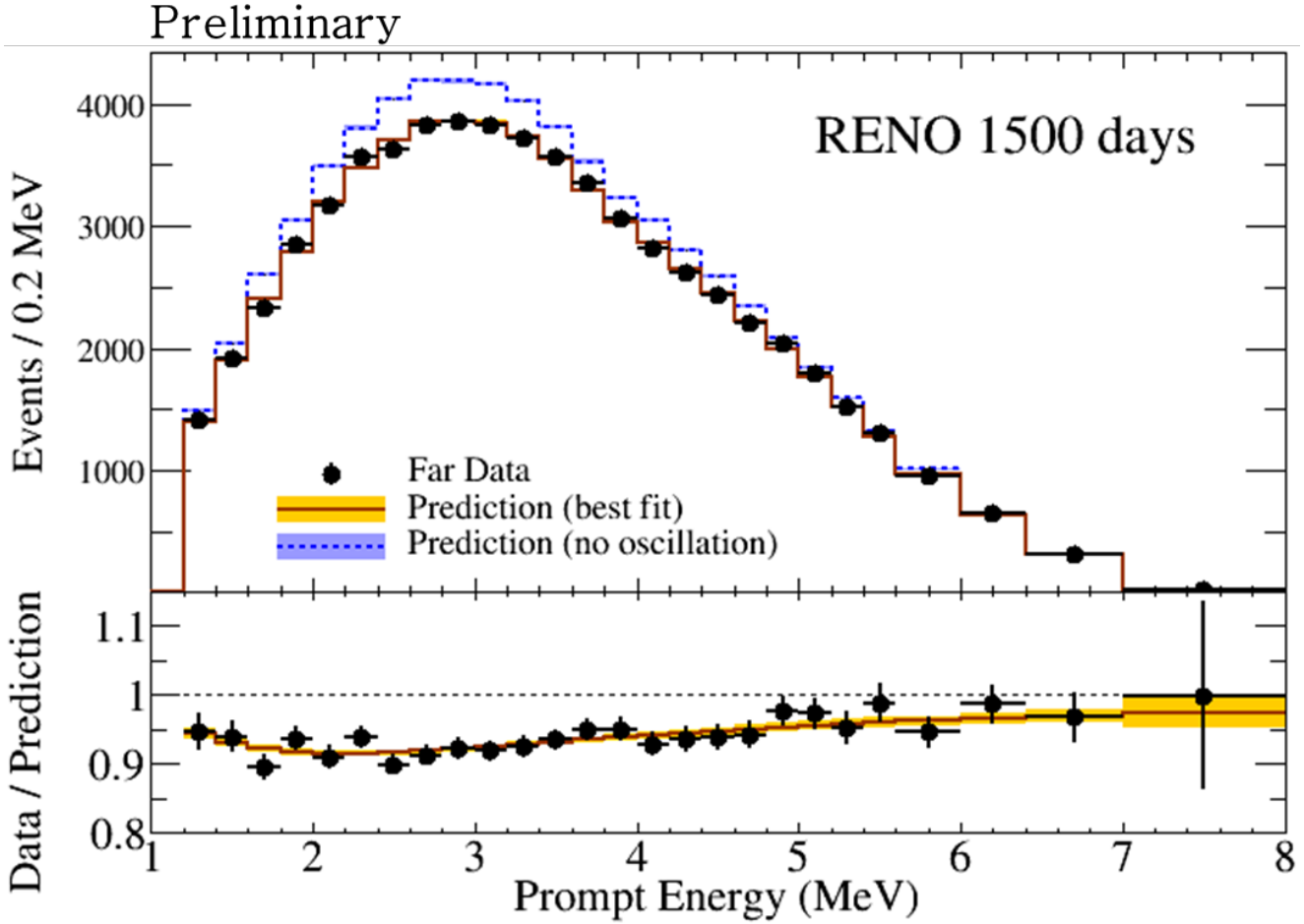
RENO 1500 days at near (411 m)	Data / Prediction (Huber + Mueller)
	0.946 +- 0.021



→ Deficit of observed reactor neutrino fluxes relative to the prediction (Huber + Mueller model) indicates an overestimated flux or possible oscillation to sterile neutrinos

Results from Spectral Fit (I)

Energy-dependent disappearance of reactor antineutrinos

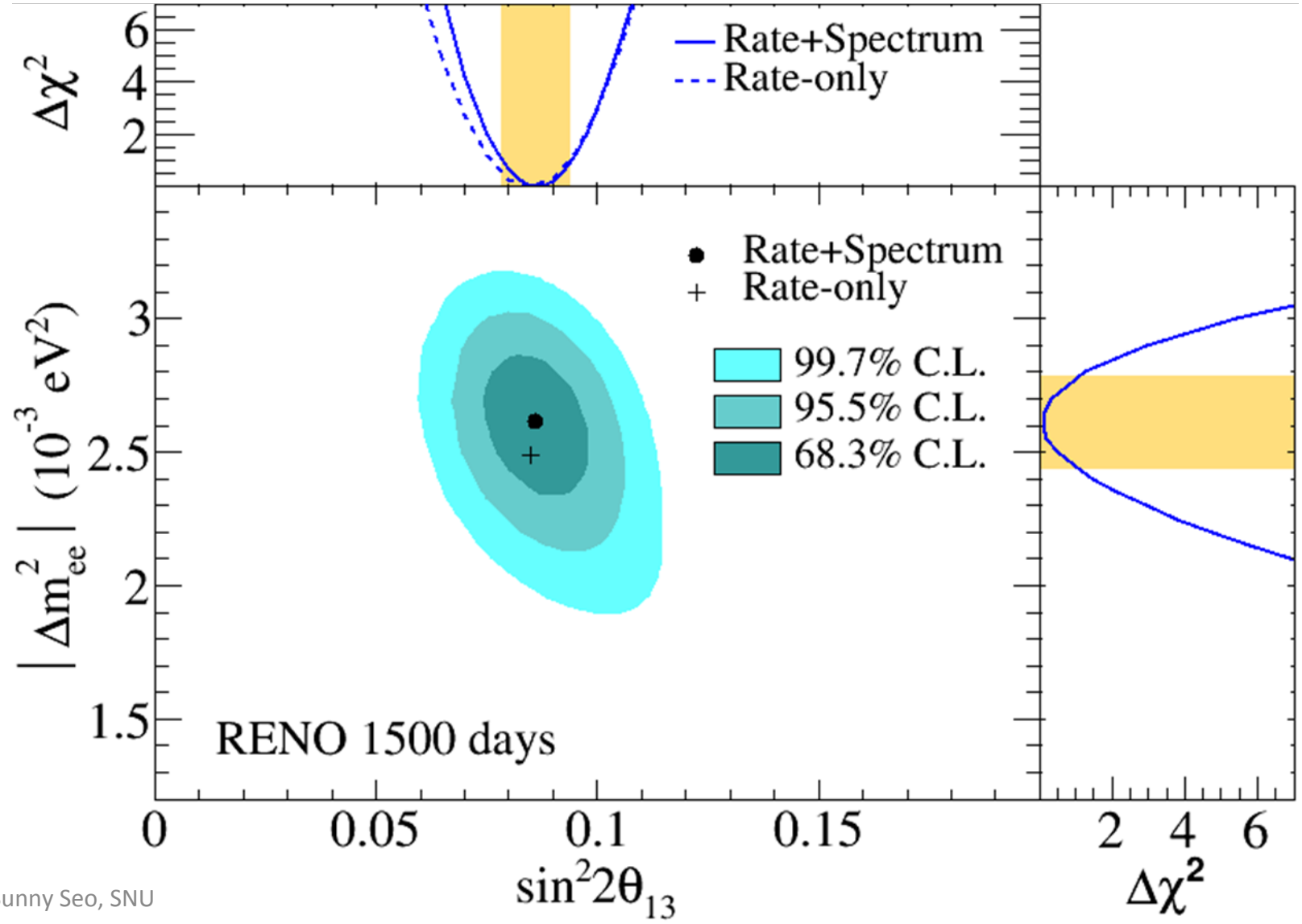


$$\sin^2 2\theta_{13} = 0.086 \pm 0.006(\text{stat.}) \pm 0.005(\text{syst.})$$ (± 9 %)

$$\left|\Delta m^2_{ee}\right| = 2.61^{+0.15}_{-0.16}(\text{stat.})^{+0.09}_{-0.09}(\text{syst.}) \ (\times 10^{-3}\,\text{eV}^2)$$ (± 7 %)

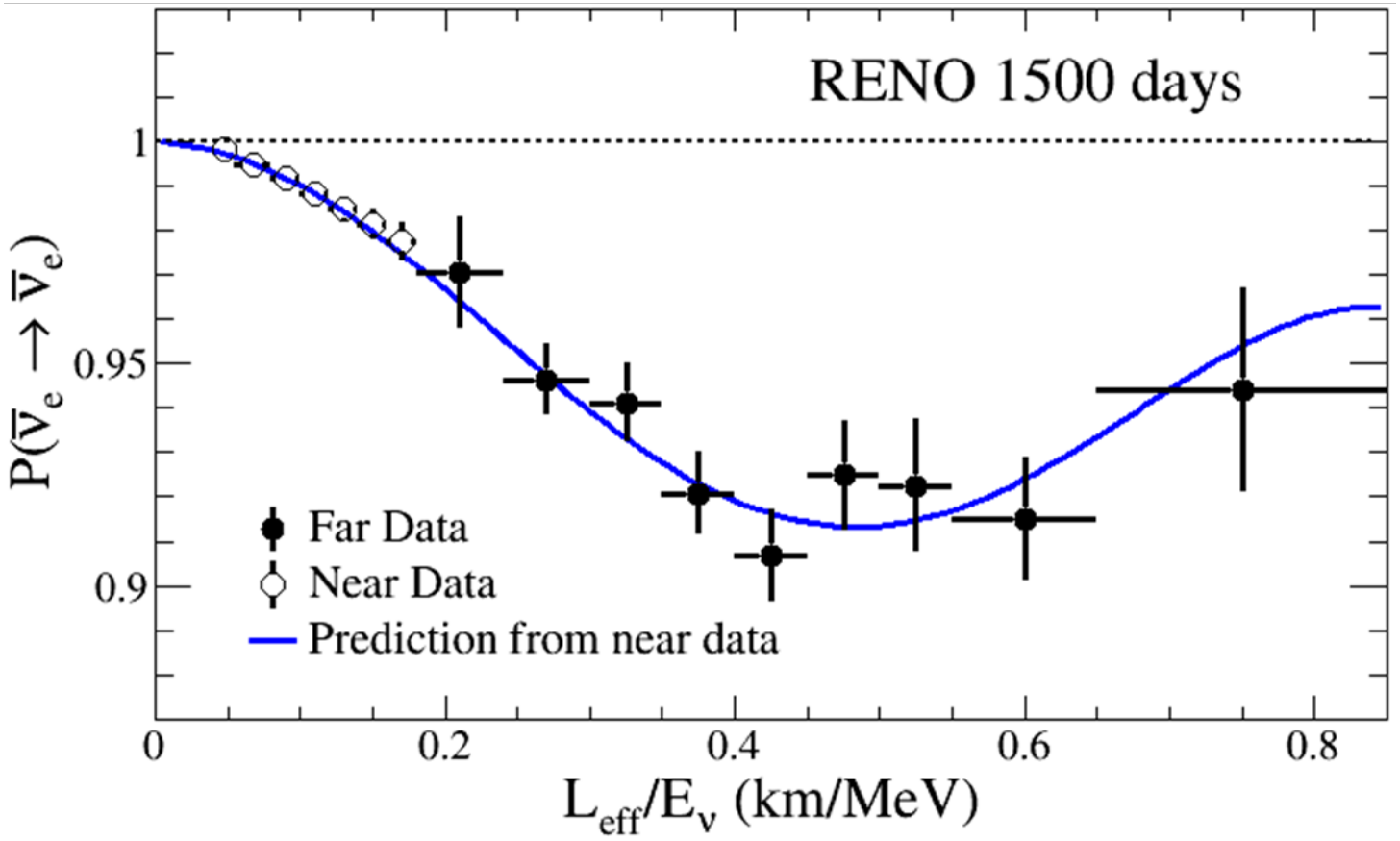
Results from Spectral Fit (II)

Preliminary result



Observed L/E Dependent Oscillation

Preliminary result



$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) \approx 1 - \sin^2 2\theta_{13} \sin^2\left(\Delta m^2_{ee} \frac{L}{4E_\nu}\right)$$

More Precise Measurements

500 days	Mean	Stat.	Sys.	Precision
$\sin^2(2\theta_{13})$	0.082	+0.009 -0.009	+0.006 -0.006	12 %
$\lvert\Delta m_{ee}^2\rvert$ ($\times 10^{-3}$ eV^2)	2.62	+0.21 -0.23	+0.12 -0.13	10 %

PRL 116, 211801 (2016), Submitted to PRD (arXiv:1610.04326)

New results (preliminary)

1500 days	Mean	Stat.	Sys.	Precision
$\sin^2(2\theta_{13})$	0.086	+0.006 -0.006	+0.005 -0.005	9 %
$\lvert\Delta m_{ee}^2\rvert$ ($\times 10^{-3}$ eV^2)	2.61	+0.15 -0.16	+0.09 -0.09	7 %

→ Systematic errors are reduced due to background reduction and larger statistics of control samples.

RENO: Plan & Prospects

Plan for RENO data taking

RENO data will be taken until early 2019 and it will take 3 additional years for the data analysis.

Possible extension of additional 2~3 years

According to our recent study, the systematic error of $|\Delta m_{ee}^2|$ is smaller than the statistical error.

$\sin^2 2\theta_{13}$ will approach to ~**6% precision** (our design goal).

	Y2012	Y2015	Y2017	Y2021
	500 days Measured	1500 days Measured	~2000 days Expected	~3500 days Expected
$\sin^2(2\theta_{13})$	12%	9%	~9%	6~7%
$\lvert\Delta m^2_{ee}\rvert$	10%	7%	~7%	4~5%

RENO Summary

- More precise measurements of θ_{13} and Δm_{ee}^2 energy dependent disappearance of reactor neutrinos with **1500 days** data

(Preliminary)

$$\sin^2 2\theta_{13} = 0.086 \pm 0.006(\text{stat.}) \pm 0.005(\text{syst.})$$ ±0.008 (9 %)

$$\left|\Delta m^2_{ee}\right| = 2.61^{+0.15}_{-0.16}(\text{stat.})^{+0.09}_{-0.09}(\text{syst.})\ (\times 10^{-3}\,\text{eV}^2)$$ ±0.18 (7 %)

(Preliminary)

- Measured absolute reactor neutrino flux: R= 0.946±0.021

- Updated an excess at 5 MeV in reactor neutrino spectrum

- $\sin^2(2\theta_{13})$ and Δm_{ee}^2 to ~6% accuracy by using data until early 2019

- Additional 2~3 years of data taking under consideration to improve Δm_{ee}^2 accuracy

Thank you very much
for your attention !