Recent Results from RENO

TAUP 2015

7-11 September 2015, Torino, Italy

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on behalf of the RENO Collaboration

Seoul National University

KNRC

Korea Neutrino Research Center

RENO Collaboration

Reactor Experiment for Neutrino Oscillation

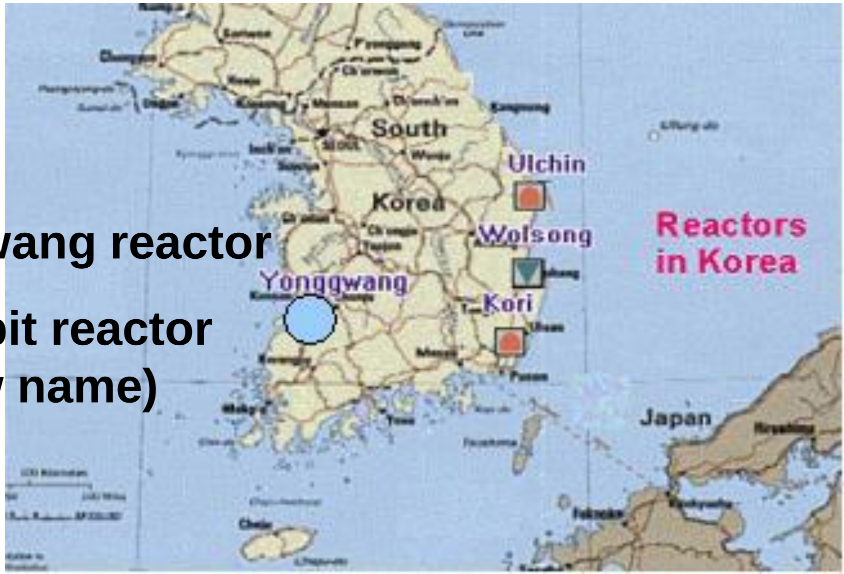
10 institutions and 40 physicists

- Chonnam National University
- Chung-Ang University
- Dongshin University
- GIST
- Gyeongsang National University
- Kyungpook National University
- Sejong University
- Seoul National University
- Seoyeong University
- Sungkyunkwan University

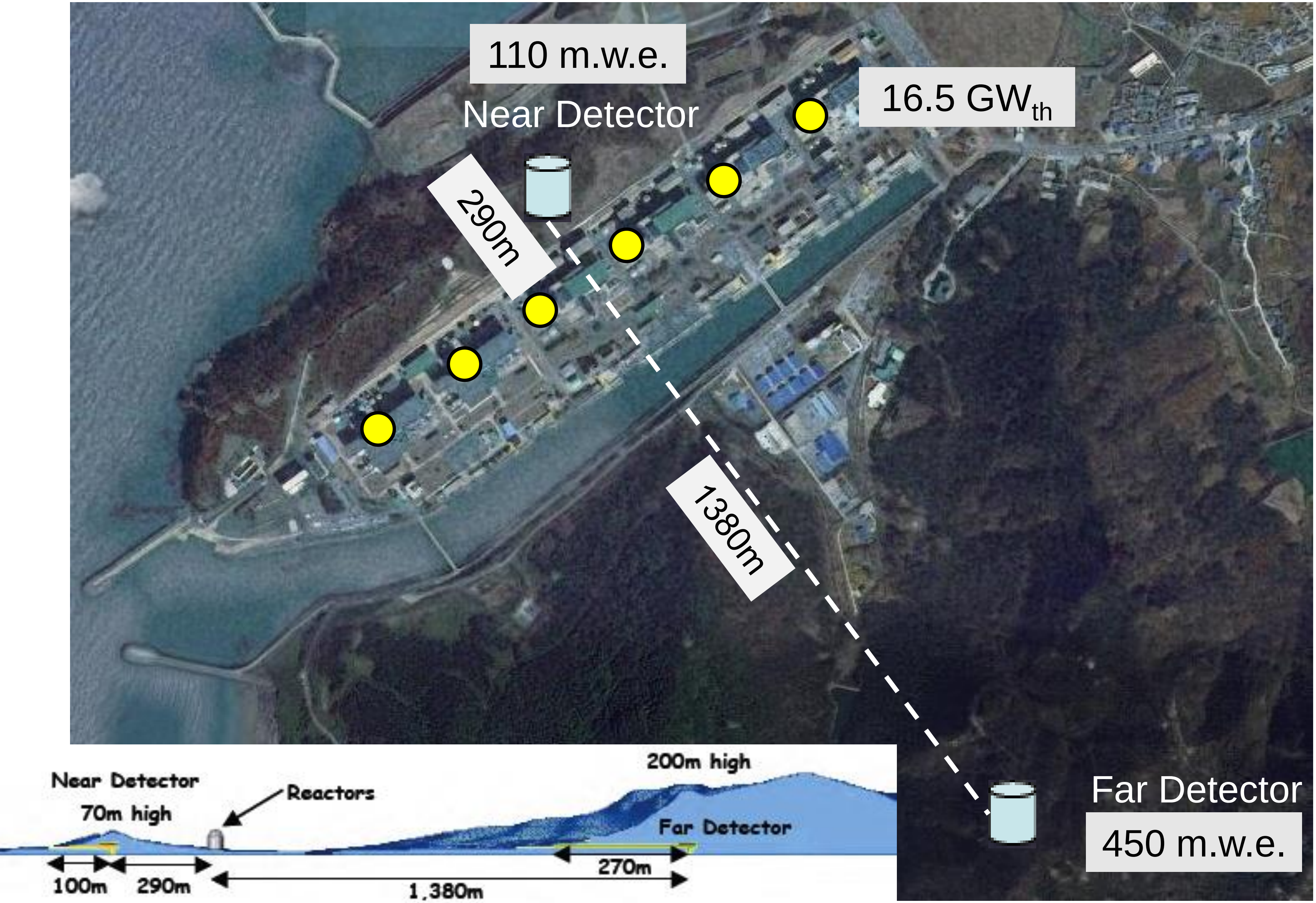
- Total cost : $10M
- Start of project : 2006
- The first experiment running with both near & far detectors from Aug. 2011

Yonggwang reactor

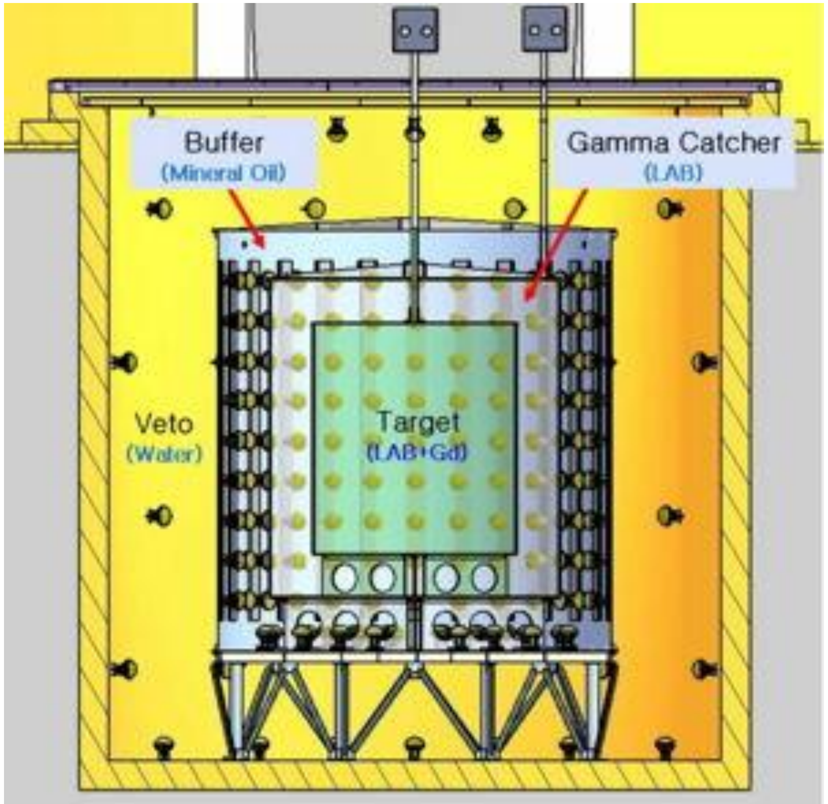
→ Hanbit reactor (new name)

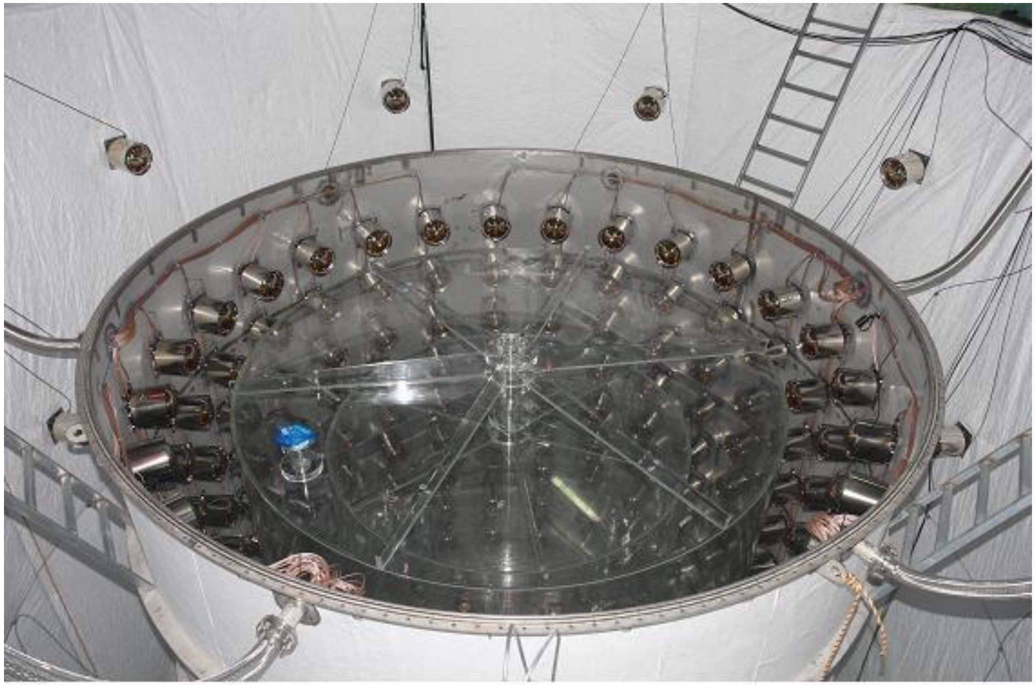


RENO Experimental Setup



RENO Detector





- 354 ID +67 OD 10” PMTs
- Target : 16.5 ton Gd-LS,   R=1.4m, H=3.2m
- Gamma Catcher : 30 ton LS,   R=2.0m, H=4.4m
- Buffer : 65 ton mineral oil,   R=2.7m, H=5.8m
- Veto : 350 ton water,   R=4.2m, H=8.8m

RENO Status

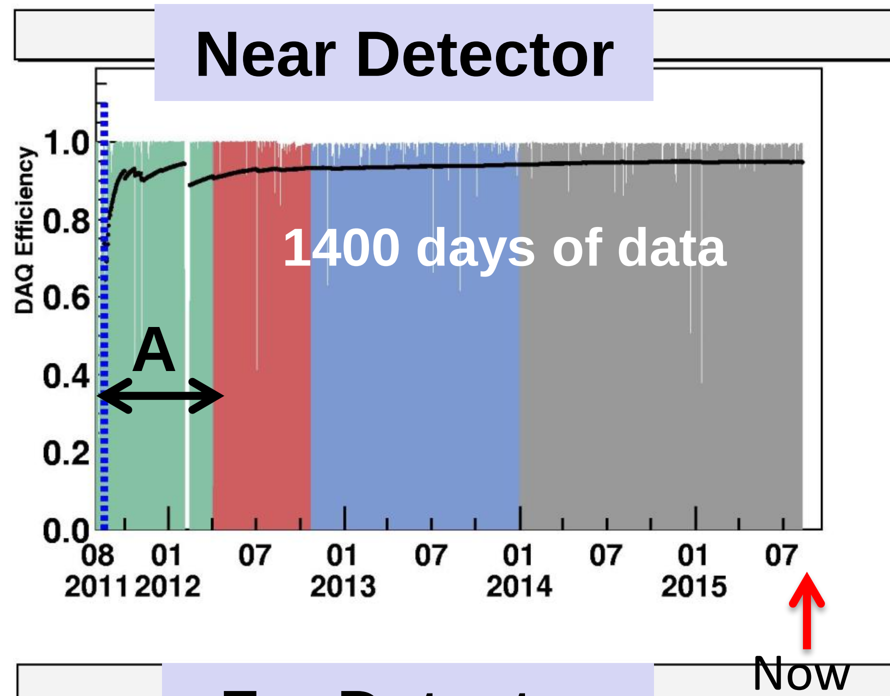
- Data taking began on Aug. 1, 2011 with both near and far detectors.
  (DAQ efficiency : ~95%)

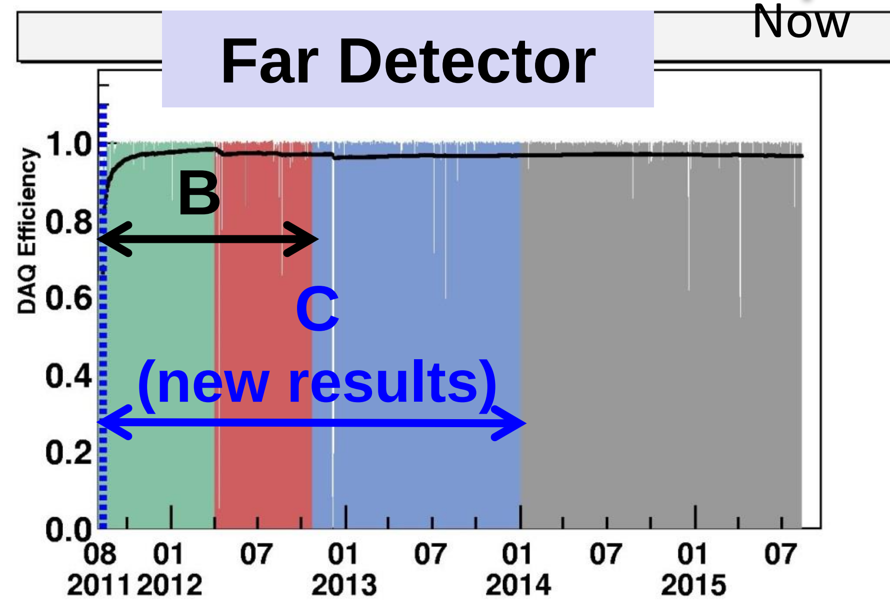
- **A** (220 days) : **First θ_{13} result**
  [11 Aug, 2011~26 Mar, 2012]
  PRL 108, 191802 (2012)

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

- **C** (~800 days) : New **result**
  Shape+rate analysis (**θ_{13} and Δm_{ee}^2**)
  [11 Aug, 2011~31 Dec, 2013]

- Total observed reactor neutrino events as of today : **~ 1.5M** (Near), **~ 0.15M** (Far)
  → Absolute reactor neutrino flux measurement in progress
  [reactor anomaly & sterile neutrinos]





Recent Results from RENO

- New measured value of θ_{13} from rate-only analysis using ~800 days of data

- Observation of an excess at ~5 MeV in reactor neutrino spectrum

- Observation of energy dependent disappearance of reactor neutrinos to measure Δm_{ee}^2 and θ_{13} (work in progress)

- Rate-only analysis with neutron capture on Hydrogen using ~400 days of data

Improvements after Neutrino 2014

- Relax Q_{max}/Q_{tot} cut : 0.03 → 0.07

  - allow more accidentals to increase acceptance of signal and minimize any bias to the spectral shape

- More precisely observed spectra of Li/He background

  - reduced the Li/He background uncertainty based on an increased control sample

- More accurate energy calibration

  - best efforts on understanding of non-linear energy response and energy scale uncertainty

- Elaborate study of systematic uncertainties on a spectral fitter

  - estimated systematic errors based on a detailed study of spectral fitter in the measurement of Δm_{ee}^2

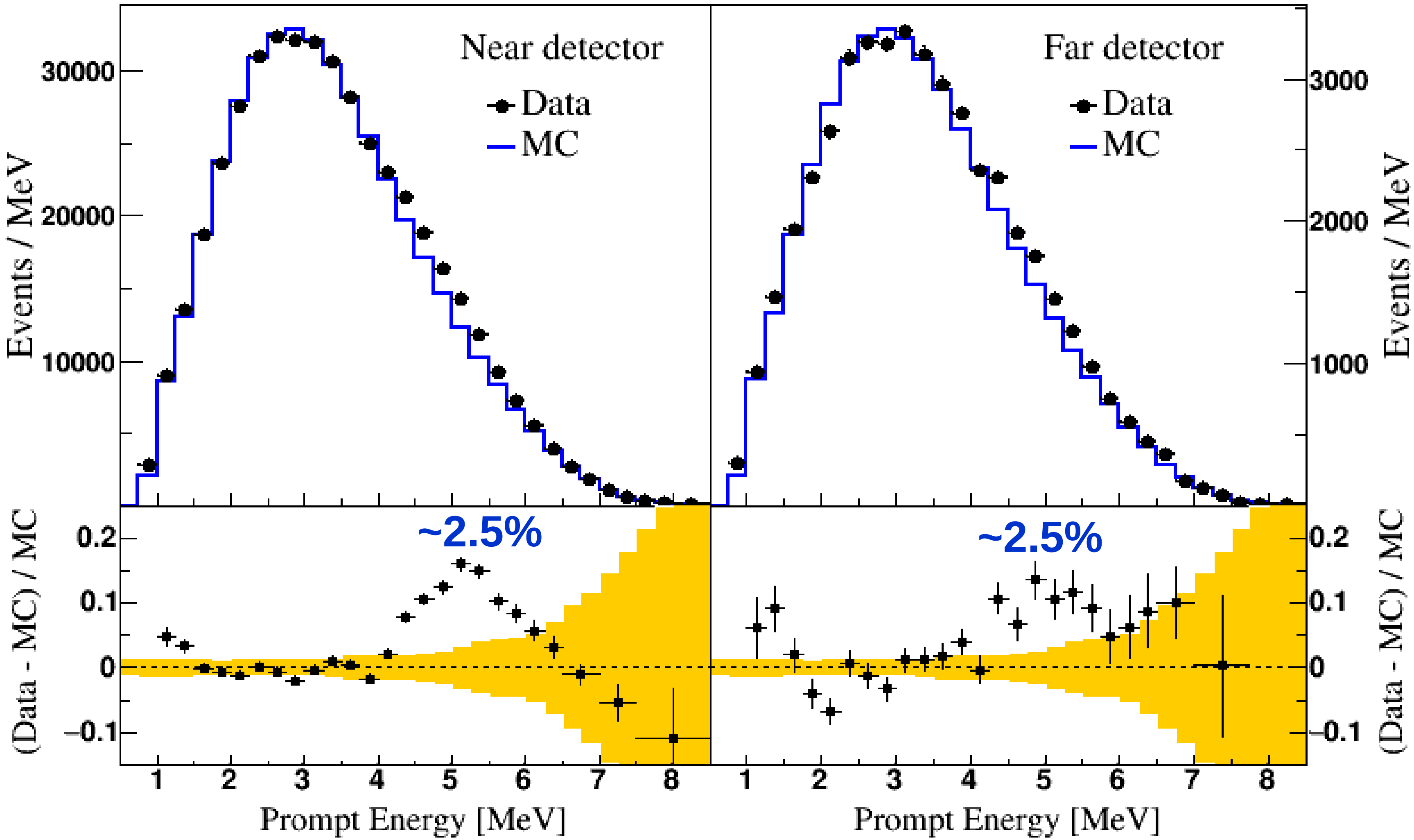
New θ_{13} Measurement by Rate-only Analysis

(Preliminary)

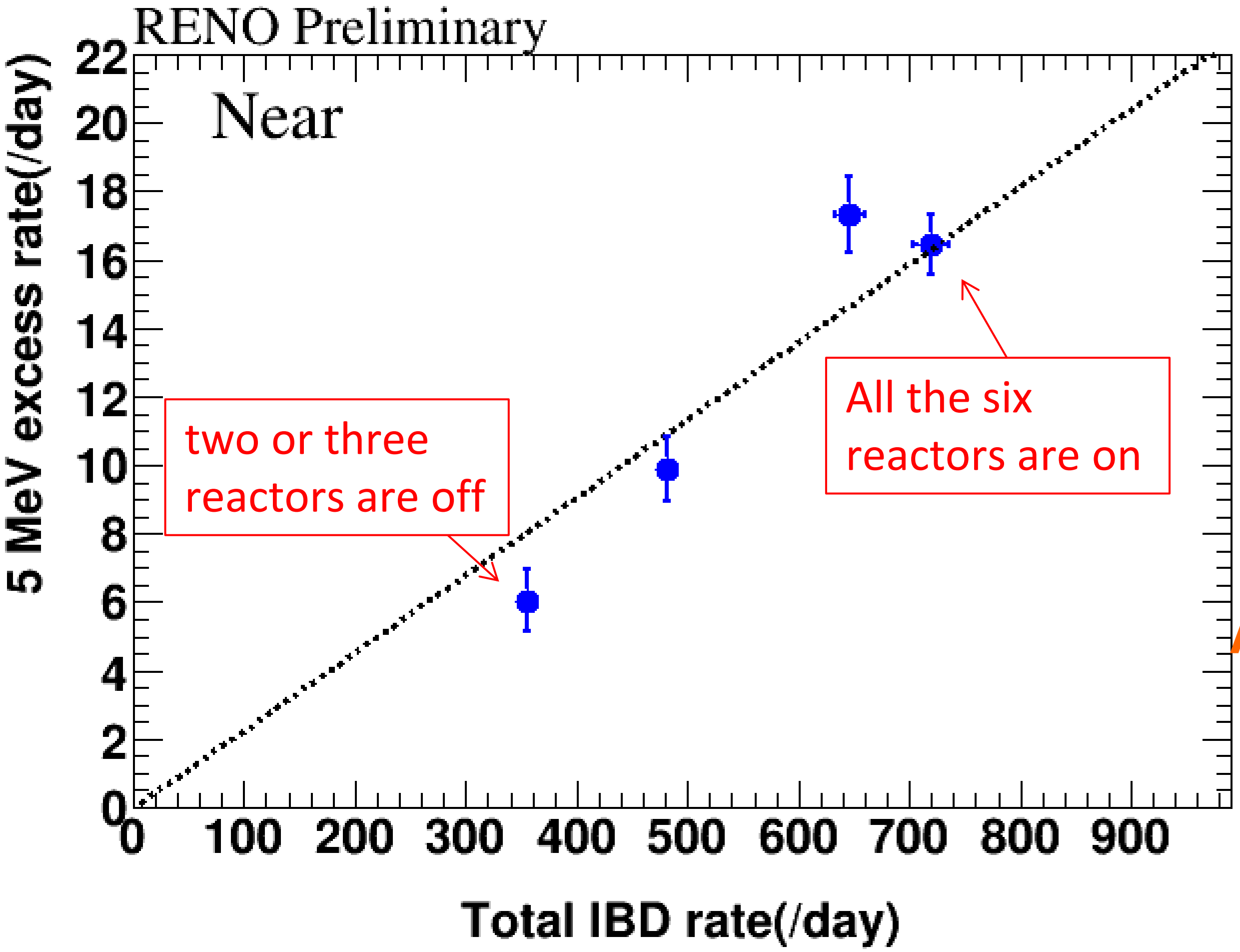
$$\sin^2 2\theta_{13} = 0.087 \pm 0.008(\text{stat.}) \pm 0.008(\text{syst.})$$

Uncertainties sources	Uncertainties (%)	Errors of $\sin^2 2\theta_{13}$ (fraction)
Statistics (near) (far)	0.21 % 0.54 %	**0.0080**
Systematics (near) (far)	0.94% 1.06%	**0.0081**
Reactor	0.9 %	0.0032 (39.5 %)
Detection efficiency	0.2 %	0.0037 (45.7 %)
Backgrounds (near) (far)	0.14 % 0.51 %	0.0070 (86.4 %)

Observation of an excess at 5 MeV



Correlation of 5 MeV Excess with Reactor Power



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

A new reactor neutrino component !!

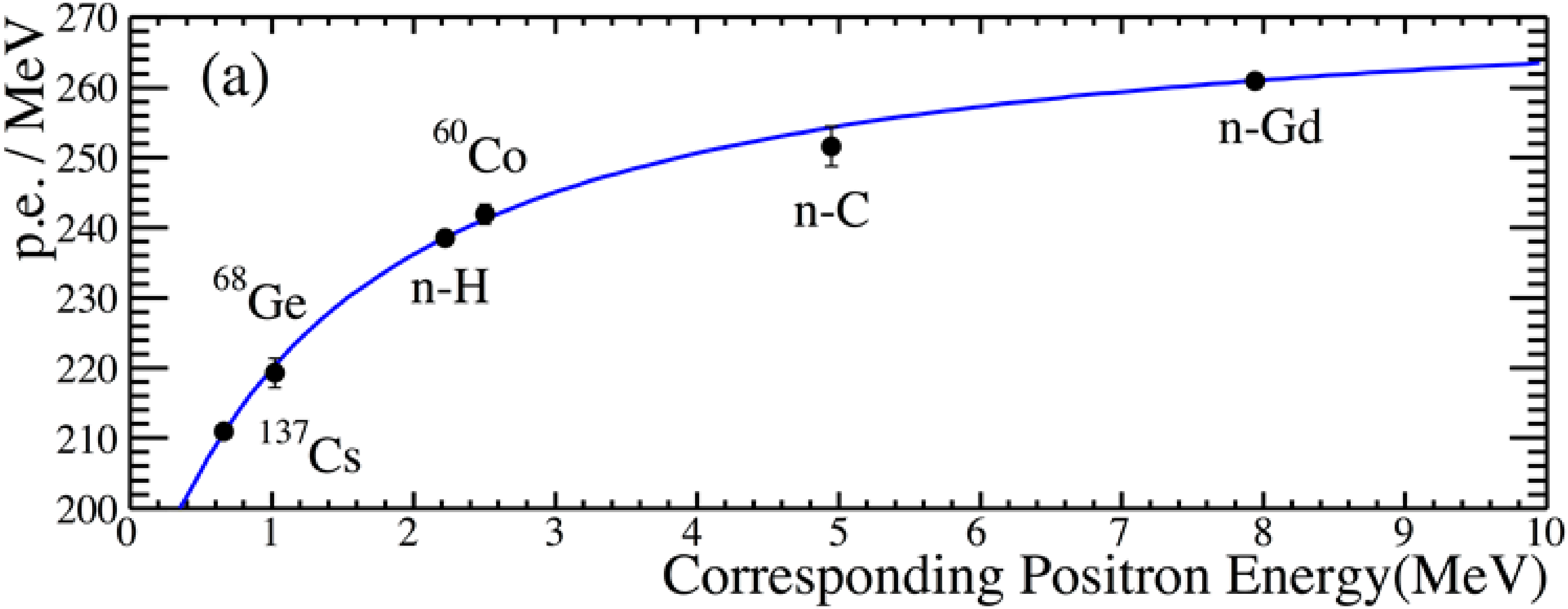
** Recent ab initio calculation [D. Dwyer and T.J. Langford, PRL 114, 012502 (2015)] :

- The excess may be explained by addition of eight isotopes, such as ^{96}Y and ^{92}Rb

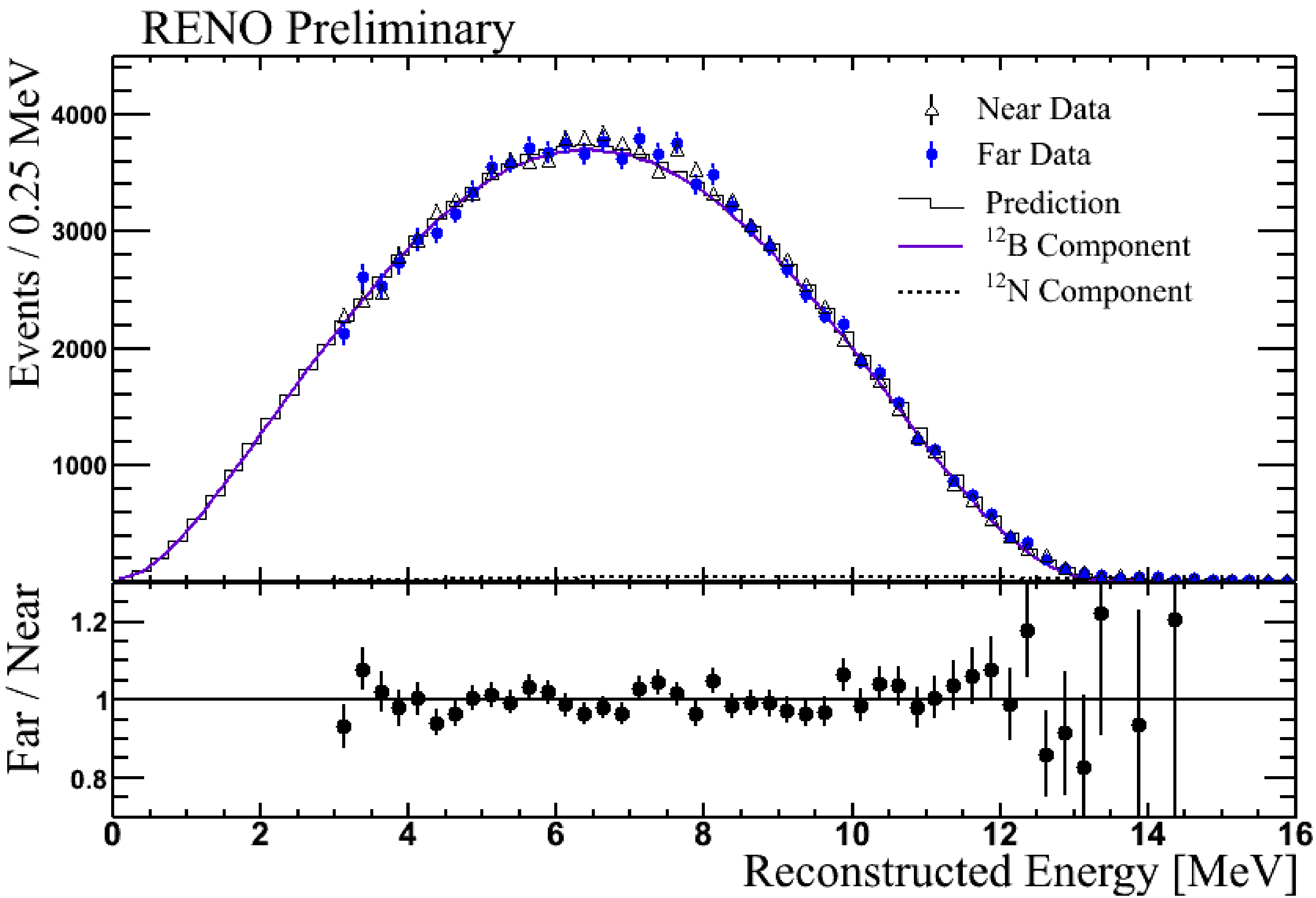
Spectral Analysis for Δm_{ee}^2

- Observation of energy dependent disappearance of reactor neutrinos to measure Δm_{ee}^2 and θ_{13} (work in progress)

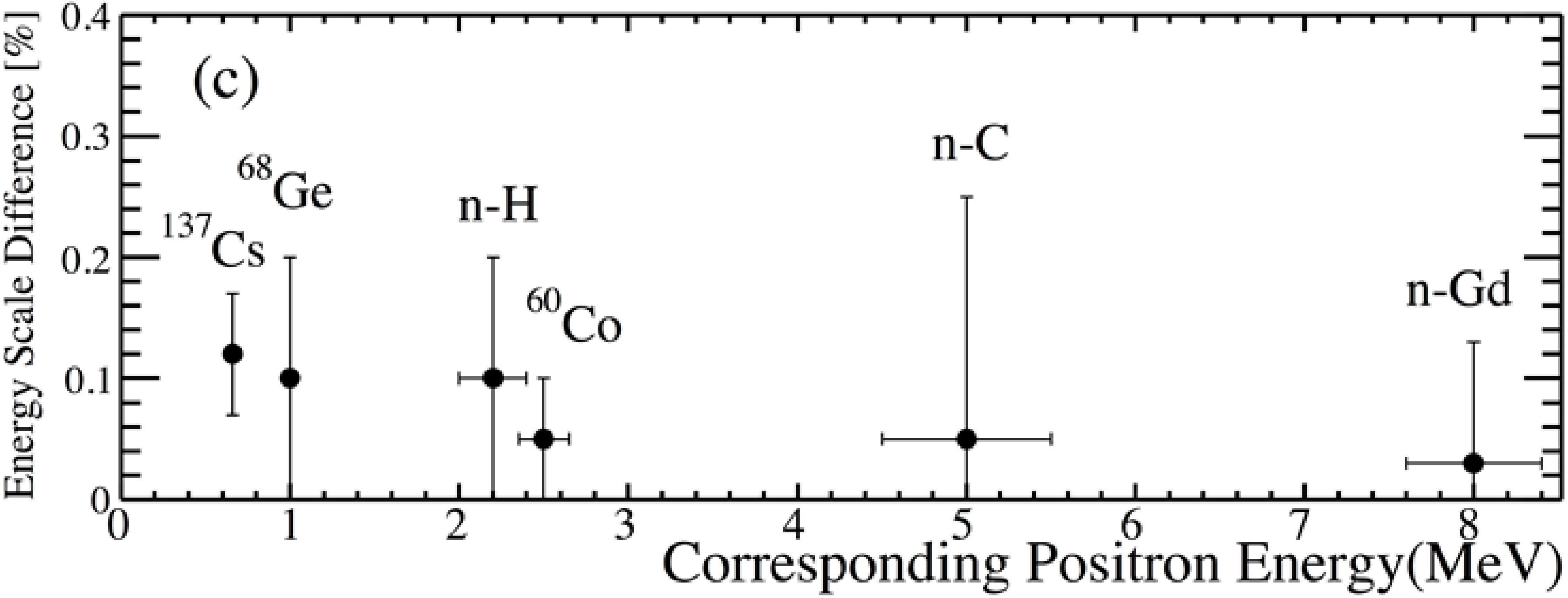
Energy Calibration from γ-ray Sources



B12 Energy Spectrum (Near & Far)



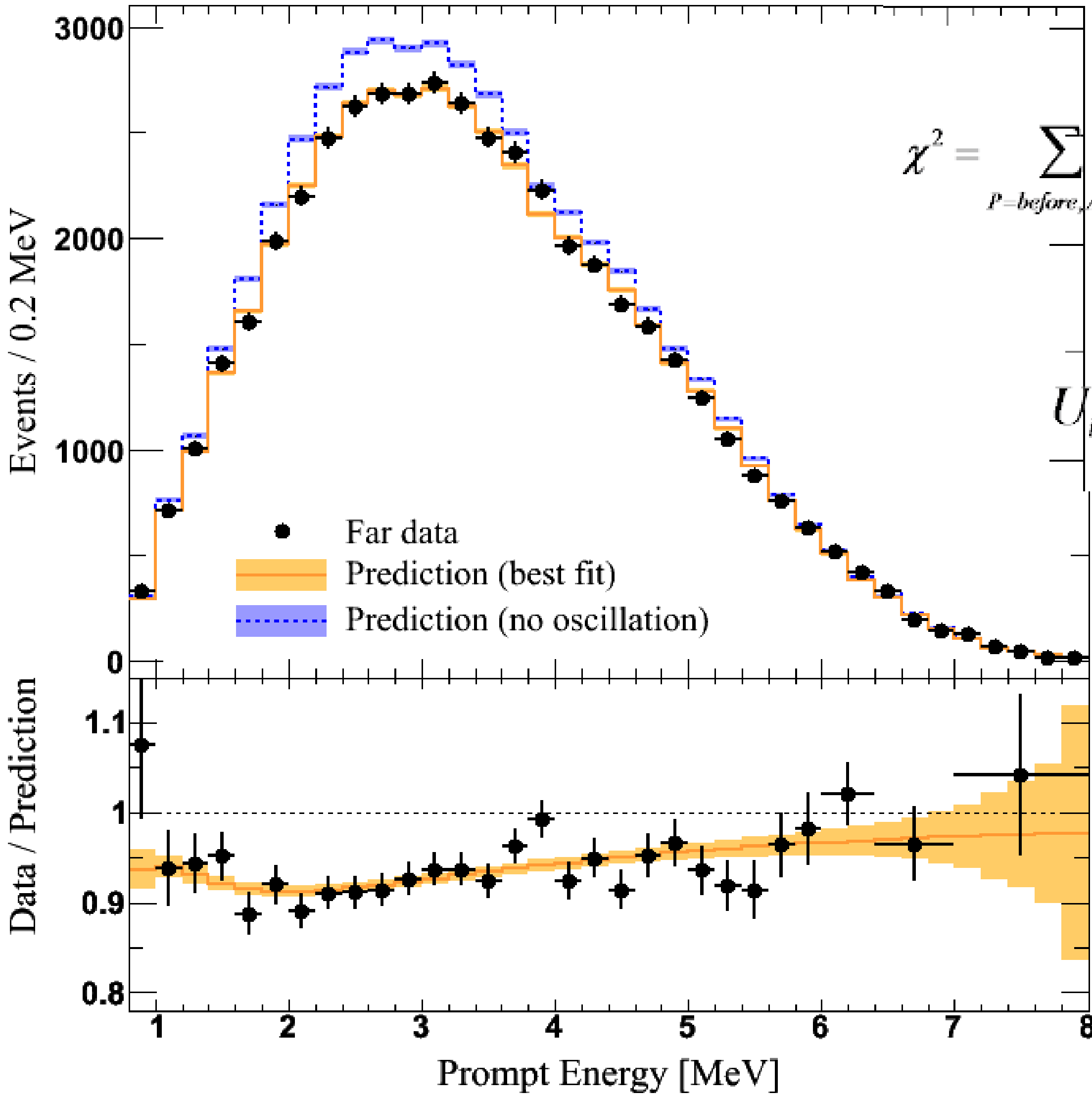
Energy Scale Difference between Near & Far



Energy scale difference < 0.15%

Far/Near Shape Analysis for Δm_{ee}^2

(work in progress)

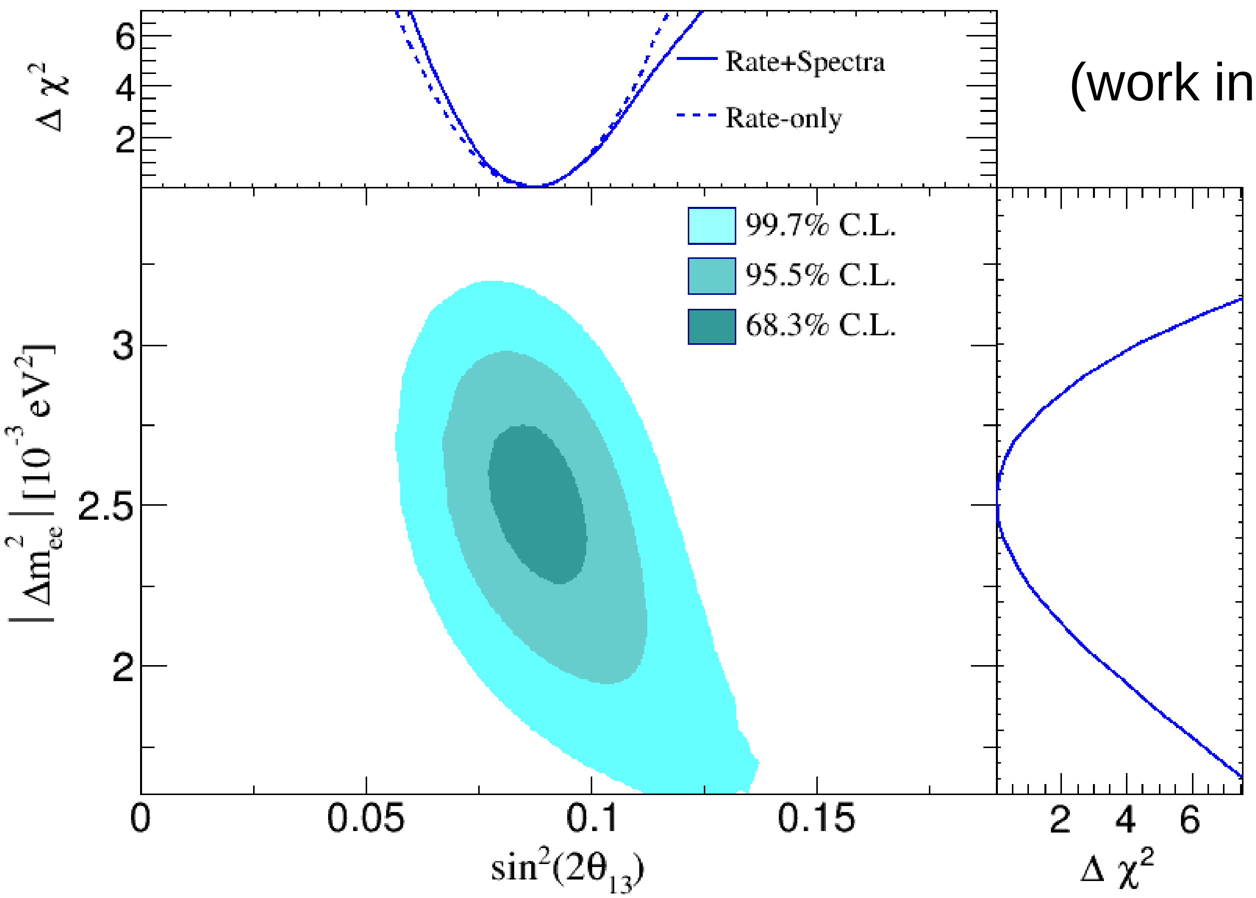


Minimize X^2 Function

$$\chi^2 = \sum_{P=before,After} \left\{ \sum_{i=1 \sim N_b} \frac{\left(\frac{N_{obs}^{F,P,i}}{N_{obs}^{N,P,i}} - \frac{N_{Exp}^{F,P,i}}{N_{Exp}^{N,P,i}} \right)^2}{(U_i)^2} \right\} + Pull\_Terms$$

$$U_i = \frac{N_{obs}^{F,i}}{N_{obs}^{N,i}} \cdot \sqrt{\frac{N_{obs}^{F,i} + N_{bkg}^{F,i}}{(N_{obs}^{F,i})^2} + \frac{N_{obs}^{N,i} + N_{bkg}^{N,i}}{(N_{obs}^{N,i})^2}}$$

Results from Spectral Fit



(work in progress)

$$\Delta m_{ee}^2 = [2.52 \pm 0.19(\text{stat}) \pm 0.17(\text{syst})] \times 10^{-3}\ \text{eV}^2$$

$$\sin^2 2\theta_{13} = 0.088 \pm 0.008(\text{stat}) \pm 0.007(\text{syst})$$

Systematic Errors of θ_{13} & Δm_{ee}^2

(work in progress)

$$\sin^2 2\theta_{13} = 0.088 \pm 0.008(\text{stat}) \pm 0.007(\text{syst})$$ (± 11 %)

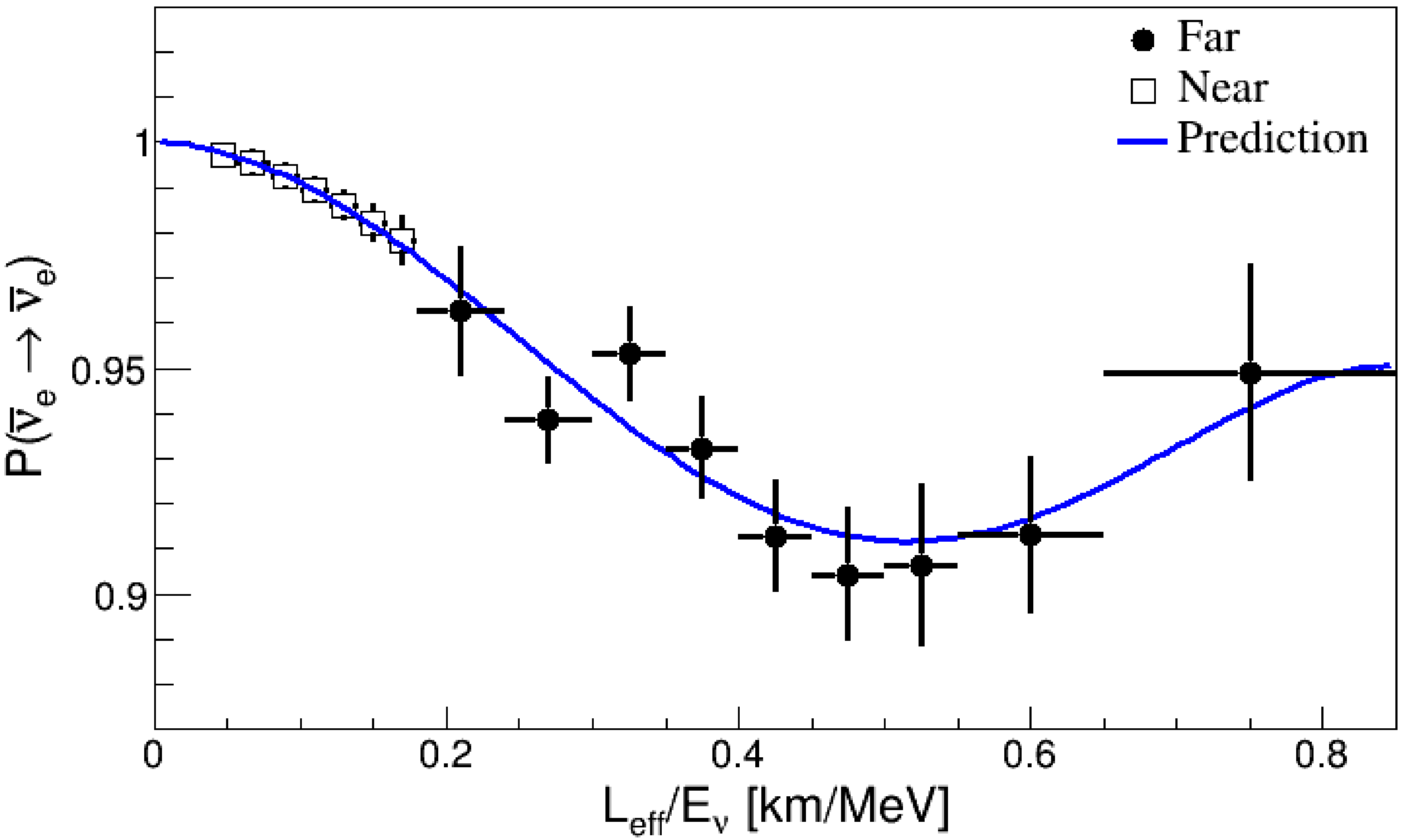
$$\Delta m_{ee}^2 = [2.52 \pm 0.19(\text{stat}) \pm 0.17(\text{syst})] \text{x} 10^{-3} \text{ eV}^2$$ (± 10 %)

Uncertainties sources	Uncertainties (%)	Errors of $\sin^2 2\theta_{13}$	Errors of Δm_{ee}^2 (x 10^{-3} eV^2)
Statistics (near) (far)	0.21 % 0.54 %	**0.008**	**0.19**
Total Systematics	0.94 % 1.06 %	**0.007**	**0.17**
Reactor	0.9 %	0.0025 (34.2 %)	-
Detection efficiency	0.2 %	0.0025 (34.2 %)	-
Energy scale diff.	0.15 %*	0.0015 (15.6 %)	0.07
Backgrounds (near) (far)	0.14 % 0.51 %	0.0060 (82.2 %)	0.15

(* tentative)

Observed L/E Dependent Oscillation

(work in progress)



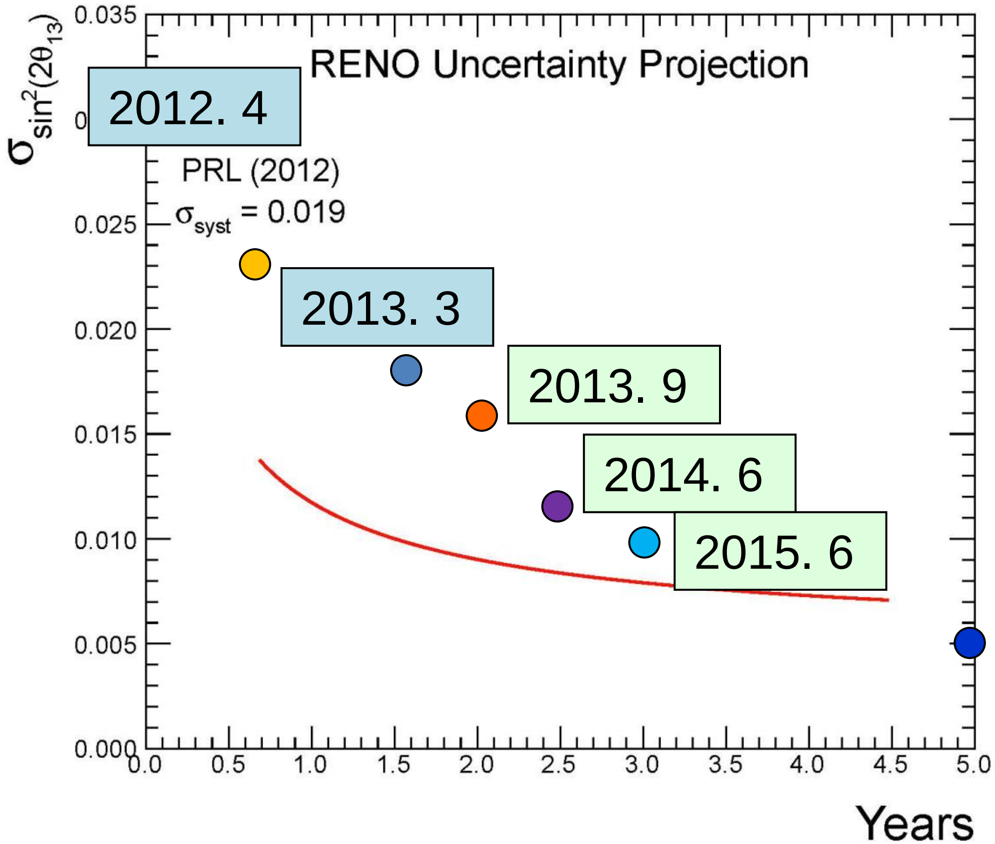
Projected Sensitivity of θ_{13} & Δm_{ee}^2

NDM 2015 $\sin^2 2\theta_{13} = 0.088 \pm 0.011$ (~800 days)

± 0.005 (5 % precision) (5 years of data)

* Expected precision of Δm_{ee}^2 : $\sim 0.1 \times 10^{-3}\ \mathrm{eV}^2$

(~ 4% precision)



(5 % precision)

(sensitivity goal of θ_{13})

Results from n-H IBD sample

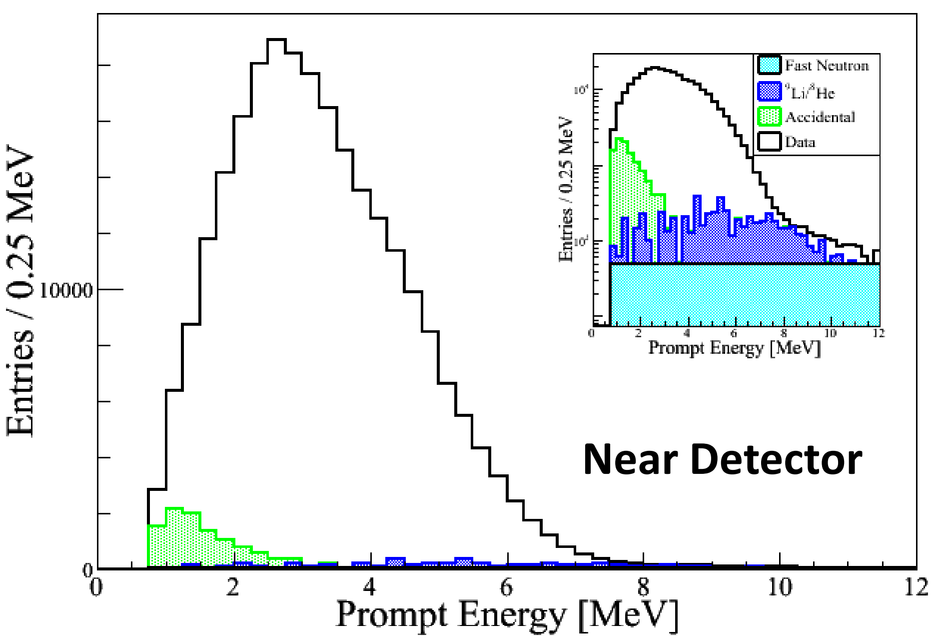
Very preliminary
Rate-only result (B data set, ~400 days)

$$\sin^2 2\theta_{13} = 0.103 \pm 0.014(\text{stat.}) \pm 0.014(\text{syst.})$$

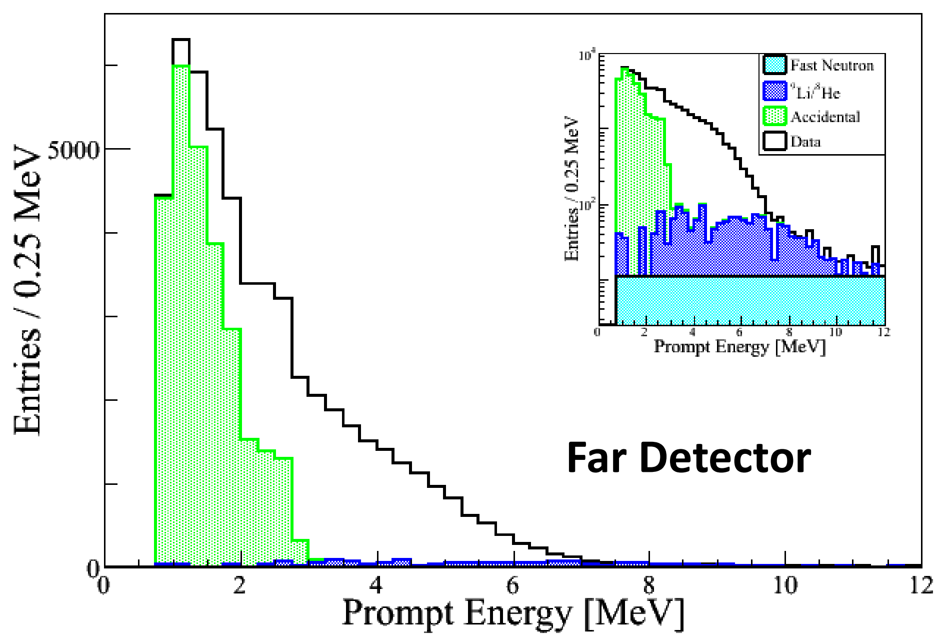
(Neutrino 2014) $\sin^2 2\theta_{13} = 0.095 \pm 0.015(\text{stat.}) \pm 0.025(\text{syst.})$

← Significant reduction in the uncertainty of the accidental background and new results coming soon.

preliminary



preliminary



Summary

- New measurement of θ_{13} by rate-only analysis

$$\sin^2 2\theta_{13} = 0.087 \pm 0.008(\text{stat}) \pm 0.008(\text{syst})$$

(preliminary)

- Observed an excess at 5 MeV in reactor neutrino spectrum

- Observation of energy dependent disappearance of reactor neutrinos and our first measurement of Δm_{ee}^2

$$\sin^2 2\theta_{13} = 0.088 \pm 0.008(\text{stat}) \pm 0.007(\text{syst})$$

($\pm$11 %)

(work in progress)

$$\Delta m_{ee}^2 = [2.52 \pm 0.19(\text{stat}) \pm 0.17(\text{syst})] x 10^{-3}\ \text{eV}$$

($\pm$10 %)

- Measurement of θ_{13} from on n-H IBD analysis

$$\sin^2 2\theta_{13} = 0.103 \pm 0.014(\text{stat}) \pm 0.014(\text{syst})$$

(preliminary)

- sin($2\theta_{13}$) to 5% accuracy
  Δm_{ee}^2 to 0.1×10^{-3} eV^2 (4%) accuracy within 2 years

Thank you for your attention !