θ_{13} measurement using data with neutron captured on hydrogen at RENO

Neutrino 2020

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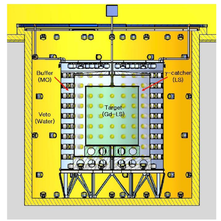
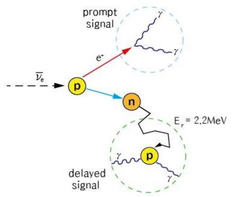
on behalf of the RENO collaboration

Principle and motivation





Inverse Beta Decay (IBD)

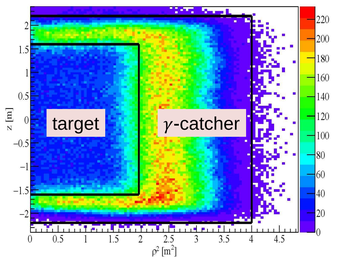
$\bar{\nu}_e + p \rightarrow e^+ + n$

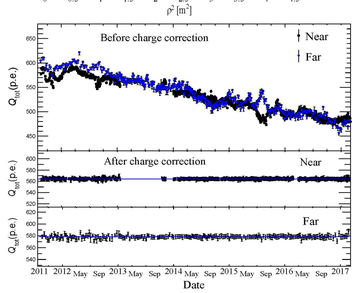
H capture	or	Gd capture
Delayed signal		Delayed signal
~200 μs		~30 μs
~ 2.2 MeV		~ 8 MeV
Target + γ catcher		Target only

- Independent measurement of θ_{13} value
- Consistency and systematic check on reactor neutrinos

Charge correction and vertex reconstruction

- Reconstruction of vertex and energy
- Vertex reconstructed by calculating a charge weighted average using hit PMTs
- The reconstructed vertex is checked by source data and matches well
- Correct the vertex and energy because of detector degradation and decreasing of active PMTs

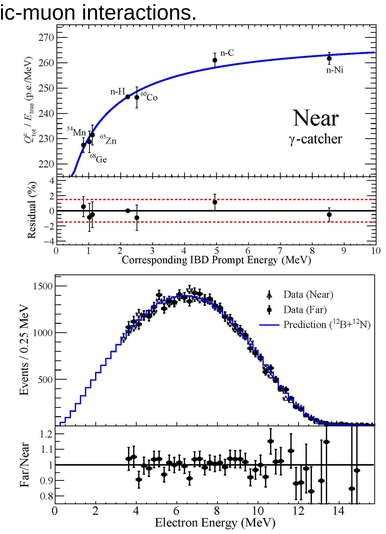




<corrected vertex distribution(top) and charge distribution of delayed signal(bottom)>

Energy calibartion

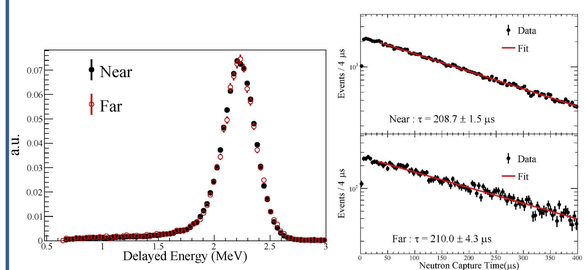
- Non-linear response of the scintillation energy is calibrated using γ-ray source
- Electron energy spectrum from β–decays from ^{12}B and ^{12}N which are produced by cosmic-muon interactions.



<energy conversion function (top) and energy spectrum of Boron(bottom))>

Neutron capture on hydrogen and event selection

The nH performance of two detector match very well

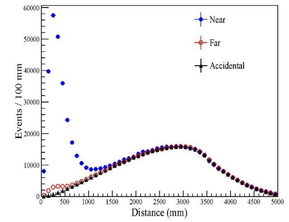


<Energy distribution of delayed energy> <neutron capture time>

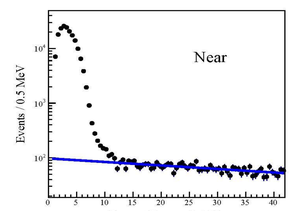
Cut criteria of nH capture			
Muon veto time (ms)	1	Prompt energy (MeV)	1.2 < E < 8.0
Shower muon veto time (ms)	700	Delayed energy (MeV)	-2σ < E < $+2\sigma$
Q_{max}/Q_{tot} of prompt signal	0.07	Time coincidence (μs)	2 < ΔT < 400
Q_{max}/Q_{tot} of delayed signal	0.06	ΔR (Distance of s1 and s2) (mm)	450

IBD candidates and backgrounds

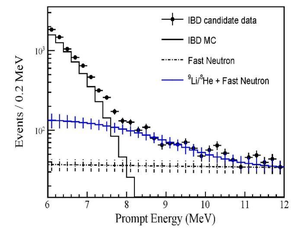
- **Accidental background**
  - dominant background of n-H analysis
  - the random association of prompt-like event and delayed-like neutron capture
  - Estimated by extrapolating from background dominant region of ΔR > 2000 mm



- **Fast Neutron background**
  - Produced by energetic muon from surrounding rock and inside the detector
  - Distribute up to high energy region
  - Estimated by extrapolating from background dominant region assuming an exponential spectrum of the background



- **Cosmogenic Li/He background**
  - Produced by interaction of cosmic muon with carbon in LS
  - Make Li/He background spectrum using delayed time from muon
  - Estimated by extrapolating from background dominant region of E_p > 8 MeV using measured Li/He background spectrum and Fast Neutron and IBD MC expectation



- **Cf contamination background**
  - Small amount of Cf neutron source was accidentally introduced into the target since Oct 2012

backgrounds	Near	Far
Accidental rate	8.48 ± 0.01	21.76 ± 0.01
Fast Neutron rate	3.16 ± 0.12	0.80 ± 0.12
Li/He rate	6.49 ± 0.49	1.71 ± 0.21
Cf contamination rate		0.095 ± 0.018

	Near	Far
IBD rate	367.05 ± 0.49	64.92 ± 0.22
After background subtraction	348.92 ± 0.70	40.55 ± 0.33
Total background rate	18.13 ± 0.51	24.37 ± 0.24
DAQ live time(day)	1546.61	1397.72

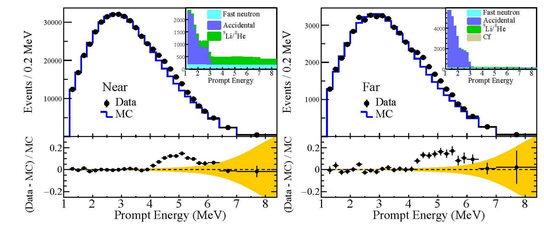
Results

Condition	Efficiency	Uncorrelated
H capture fraction	69.42 %	0.04 %
Trigger efficiency	78.79 %	0.02 %
Prompt energy cut	97.83 %	0.04 %
Delayed energy cut	87.71 %	0.15 %
Time coincidence	85.30 %	0.07 %
Spatial correlation cut	70.49 %	0.09 %
$Q_{max}^{prompt}/Q_{tot}^{prompt}$	92.22 %	0.08 %
$Q_{max}^{delayed}/Q_{tot}^{delayed}$	87.45 %	0.08 %
Total efficiency	**32.46 %**	**0.24%**

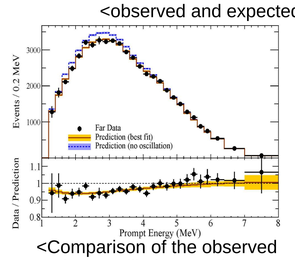
	Uncertainty	Fraction (%)
Reactor	0.003	4.9
Detection efficiency	0.010	54.2
Backgrounds	0.009	40.7
Δm^2_{ee}	0.001	0.2
Combined	0.014	

<Systematic uncertainty>

<detection efficiency>



<observed and expected prompt energy spectra>



<Comparison of the observed and no-oscillation predicted>

	Uncertainty fraction (%)	Correlation
Statistical	38.0	0
Reactor	19.7	1
Detector	21.3	0.1
Total background	22.8	0
Combined	101.8	0.1

<Fractional contribution of uncertainty source to combined>

Combined with n-Gd result of RENO

	n-Gd[1]	n-H	combined
$sin^2 2\theta_{13}$	0.0896 ± 0.0068	0.086 ± 0.008 ± 0.014	0.089 ± 0.006

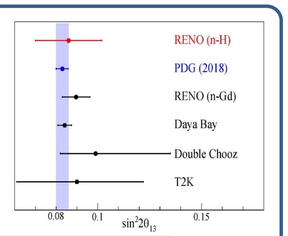
$$\left(\frac{n-H}{n-Gd}\right)_{sin^2 2\theta_{13}} = 0.960 \pm 0.188$$

Good consistency between n-H and n-Gd

[1] RENO collaboration, Measurement of Reactor Antineutrino Oscillation Amplitude and Frequency at RENO, Phys. Rev. Lett. 121 (2018) 201801 [arXiv:1806.00248]

summary

- We have performed an independent measurement of $sin^2 2\theta_{13}$ via neutron capture on hydrogen using 1500 live days data



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

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