PROCEEDINGS OF SCIENCE

Recent Results from RENO

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The Reactor Experiment for Neutrino Oscillation (RENO) started data-taking from August 2011 and has successfully measured the smallest neutrino mixing angle θ_{13} by observing the disappearance of reactor electron antineutrinos. Electron antineutrinos from the six reactors at Hanbit Nuclear Power Plant in Korea are detected and compared by the two identical near-and-far detectors. RENO has published precise values of θ_{13} and its measurement of Δm^2_{ee} based on energy dependent disappearance probability. In this paper, we present an updated measurement of θ_{13} and Δm^2_{ee} based on roughly 3000 days of data, an independently measured value of θ_{13} based on 1500 days of data with neutron capture on hydrogen as a delayed signal, and a sterile neutrino search result.

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1. Introduction

RENO has published the measurement result of the smallest neutrino mixing angle θ_{13} in 2012 [1]. The value of θ_{13} and $|\Delta m^2_{ee}|$ were also measured by energy dependent analysis [2]. Currently, other analyzes are ongoing using data of 3000 days and published [3, 4].

2. RENO experiment

RENO detectors are located at Hanbit nuclear power plant in Yonggwang, Korea. As show in Fig. 1, there are six reactors with $\sim 16 GW_{th}$. The far and near detectors are placed at 294 m and 1383 m from the reactor array, respectively. RENO measured the oscillation parameters by observing the oscillation effect from far-to-near ratio of anti-neutrino fluxes. In the RENO experiment, various systematic uncertainties correlated with reactor and detector can be canceled out because of two identical detectors.

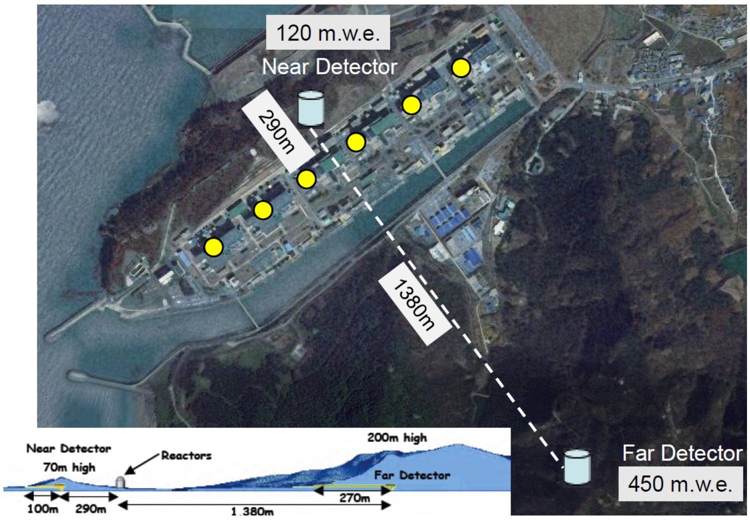

Figure 1: Experimental set-up of RENO

Each RENO detector consists of a main inner detector (ID) and an outer veto detector (OD) as shown in Figure 2. The main detector is contained in a cylindrical stainless steel vessel that houses two nested cylindrical acrylic vessels. The innermost acrylic vessel holds 18.6 m^3 (16.5 t) ~0.1% Gadolinium (Gd) doped liquid scintillator (LS) as a neutrino target. An electron antineutrino is detected via the inverse beta decay (IBD) reaction, $\overline{\nu}_e + p \rightarrow e^+ + n$. The coincidence of a prompt positron signal and a delayed signal from neutron capture by Gd provides the distinctive signature of IBD events.

The central target volume is surrounded by a 60 cm thick layer of LS without Gd, useful for catching γ-rays escaping from the target region and thus increasing the detection efficiency. Outside this γ-catcher region, a 70 cm thick buffer-layer of mineral oil provides shielding from radioactivity from the surrounding rocks and the 354 10-inch Hamamatsu R7081 photomultiplier tubes (PMTs) that are mounted on the inner wall of the stainless steel container, and provide 14% surface coverage. The outermost veto layer of OD consists of 1.5 m of highly purified water in order to identify events coming from outside by their Cherenkov radiation and to shield against ambient γ-rays and neutrons from the surrounding rocks. The OD is equipped with 67 10-inch R7081 water-proof PMTs mounted on the wall of the veto vessel. The detail of detection methods and setup of the RENO experiment can be found elsewhere [6].

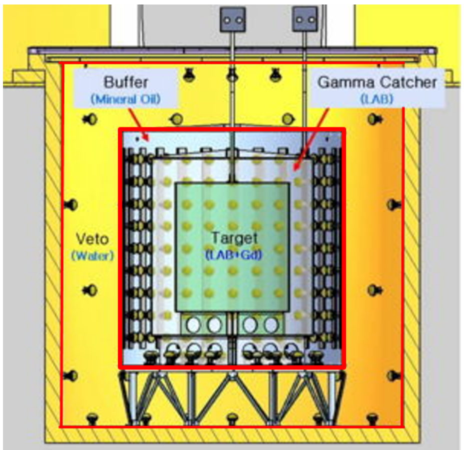

Figure 2: RENO detector

3. θ_{13} measurement using n-H events

The motivation of (n-H) analysis is independent measurement of θ_{13} value and consistency and systematic check on reactor neutrinos. While longer capture time and low energy of the delay signal create challenges in this analysis, high statistics can be achieved as events in the gamma catcher region, which is twice as much as the target volume, can be used. We obtained the results of rate only analysis using n-H data after cut optimization.

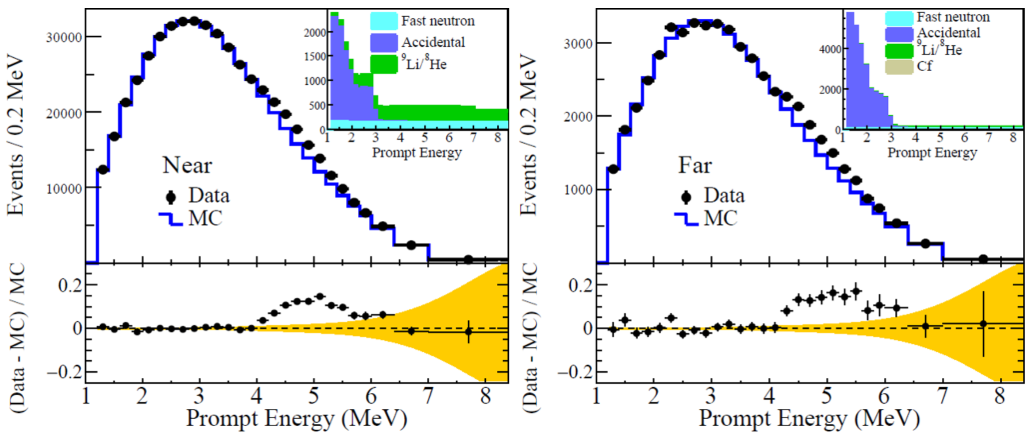

Figure 3: Energy spectra of prompt signal in n-H analysis

Figure 3 shows the energy spectrum of prompt signal after background subtraction. In case of far detector, the rate of accidental background is ~30% of IBD candidates. Our current result is a rate only analysis, and we need to reduce the background further to get energy dependent analysis results. The best fit value of neutrino mixing angle is

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

where the world average value of $|\Delta m^2_{ee}| = (2.562 \times 10^{-3}\ \text{eV}^2)$ is used. Even though the systematic uncertainty is higher than in the n-Gd results, the mean value matches well with that from other experiments within uncertainty [3].

4. Sterile neutrino search

The analysis of sterile neutrino search is based on the spectral shape comparison between near and far detector, and uses ~2200 live days of data with n-Gd events. Figure 4 shows the comparison of exclusion limit from other experiment. The black solid line indicates the exclusion curve at the 95% confidence level from RENO. The region on the right side is ruled out for sterile neutrinos. Since each experiment uses different confidence level, we can not compare the result accurately. However, RENO result rules out a little more region at low Δm^2 level [4] .

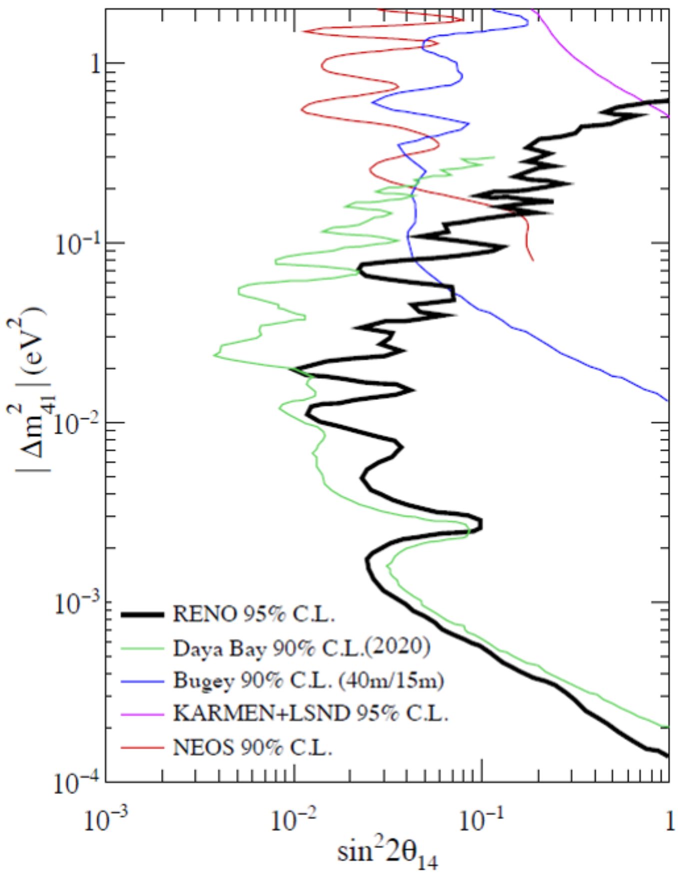

Figure 4: Comparison of exclusion limit

5. Updated results of RENO

The (n-Gd) analysis uses data of 2900 days. IBD candidates of near (far) detector is obtained to be 989,736 (120,383), background fraction is measured to be 2.26% (4.77%). In RENO data, clear excess with ~2.5% at 5MeV also was measured in both detectors. As shown in Fig. 5, there are allowed regions in $|\Delta m^2_{ee}|$ and $\sin^2 2\theta_{13}$. The best fit values with energy dependent analysis are

$$\sin^2 2\theta_{13} = 0.0892 \pm 0.0044 \text{ (stat.)} \pm 0.0045 \text{ (syst.)}$$

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

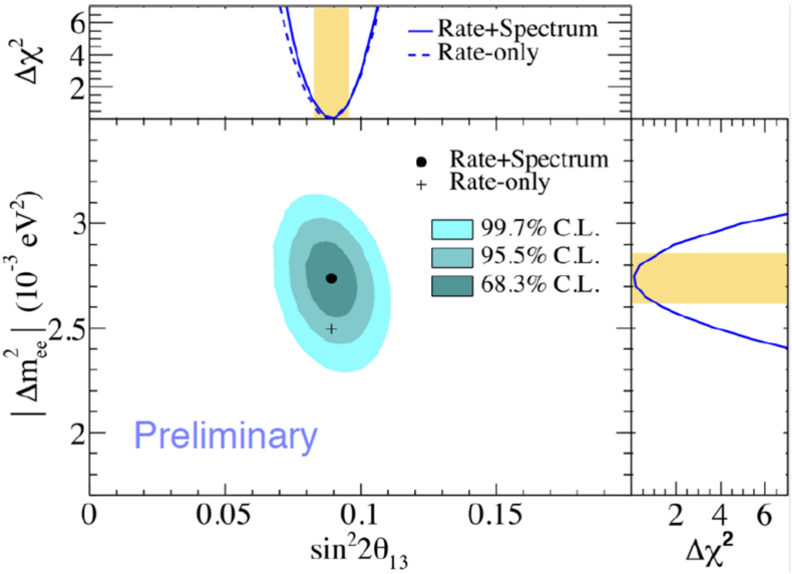

Figure 5: Spectral measurement of (n-Gd) analysis

Figure 6 shows the global average of oscillation parameters. The result of RENO experiment for $\sin^2 2\theta_{13}$ is consistent with global average, and that for $|\Delta m^2_{ee}|$ is slightly larger than the global average in both normal and inverted hierarchy.

6. Summary

RENO has updated the results using data of 2900days. The measurement results from both the n-Gd and the n-H analysis match well with the global average. We are also investigating for the reactor neutrino flux and sterile neutrinos. These results will also be published soon.

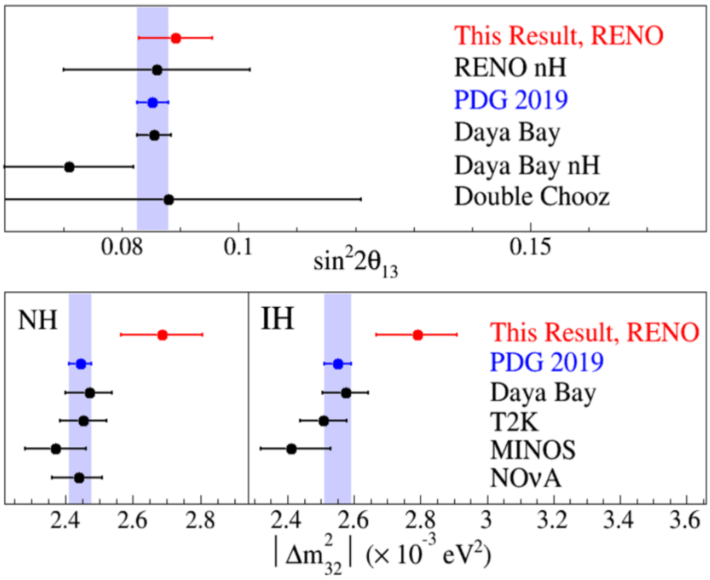

Figure 6: Global average of oscillation parameters

References

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