Status of RENO Experiment

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Abstract. The RENO (Reactor Experiment for Neutrino Oscillation) experiment is under construction to measure the smallest neutrino mixing angle θ_{13} using anti-neutrinos emitted from the Yonggwang nuclear power plant in Korea. The experiment is planning to start data-taking in early 2011 with two identical 16-ton Gadolinium loaded liquid scintillator detectors located near and far from the center of the reactor array. The estimated systematic uncertainty associated with the measurement is less than 0.6%. Based on three years of data, the expected statistical error is about 0.3% and it would be sensitive to measure the neutrino mixing angle in the range, $\sin^2(2\theta_{13}) > 0.02$. In this talk, the overview and status of RENO experiment are described.

Keywords: RENO, Reactor Neutrino Experiment, Neutrino Mixing Angle θ_{13}
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INTRODUCTION

Neutrino oscillations now have been established with experimental observations and the next step is to map out the parameters associated with neutrino masses and mixings [1]. There are three mixing angles (θ_{12}, θ_{23}, θ_{13}) and one phase angle (δ) to describe the neutrino oscillation. Reactor neutrino experiment can provide θ_{13} measurement without the ambiguities associated with matter effects and CP violation [2] [3].

THE RENO EXPERIMENT

The basic feature of RENO experiment is to search for energy dependent reactor anti-neutrino disappearance using two identical detectors, for comparison of neutrino fluxes at two different locations [4].

The Yonggwang nuclear power plant with world-second largest thermal power output of 16.4GW, is an intense source of low energy anti-neutrinos suitable for measuring neutrino oscillations due to θ_{13}. Each reactor core is generating about equal power. The average cumulative operating factors for all reactors are above 80%. These six reactors are lined up in roughly equal distances and spans ~1.3km as shown in FIGURE 1.

FIGURE 1. The layout of the Yonggwang experiment site. Red dots and yellow dots represent reactors and detectors, respectively.

RENO Detector

The experimental setup consists of two identical 16 ton liquid scintillator detectors with one at a near site, roughly 290m away from the reactor array center, and the other at a far site, roughly 1.4km away from the reactor array center as shown in FIGURE 1. The near detector is located below a 70 m high hill, and the far detector under a 260 m high mountain.

Detector

The RENO detector consists of a neutrino target, a gamma catcher, a buffer and a veto. FIGURE 2 shows the schematic view of RENO detector.

A neutrino target of Linear Alkyl Benzene (LAB) based liquid scintillator doped with 0.1% Gadolinium (Gd) is contained in a transparent acrylic vessel. It has a total volume of 18.7 m^3 and a target mass of 16.1 tons. This target is surrounded by a 60 cm thick gamma catcher unloaded liquid scintillator and a 70 cm thick non-scintillating buffer. The gamma catcher is contained in a cylindrical acrylic vessel, having transparency to the light of wavelengths above 400 nm, and the mineral oil of the buffer region is contained in a stainless steel vessel. This stainless steel vessel optically isolates the inner detector from the outer veto system. A total of 354 10-inch photomultipliers in a uniformly distributed array are mounted on the inner surface of the buffer vessel, providing 14 % photo-sensitive surface area coverage. A 1.5 m thick water layer of 353 tons surrounds the whole inner detector. A total of 67 10-inch PMTs are mounted on a cylindrical concrete tank. It is used for vetoing cosmic muons and reducing backgrounds coming from its surrounding rock.

Liquid Scintillator

Liquid scintillators(LS) are contained in the target and gamma catcher layers of the RENO detector. When the LS is loaded with Gd, which has a much larger thermal neutron capture cross section than a free proton, the delayed neutron capture signal is enhanced significantly over the radioactive background by producing photons with total energy of ~ 8 MeV. LS consists of aromatic organic solvent, flour, and wavelength shifter. RENO uses LAB based LS, and PPO and Bis-MSB as a wavelength shifter. The target is filled with 0.1% Gd, binding with carboxylate (CBX) ligands [5], loaded LS.

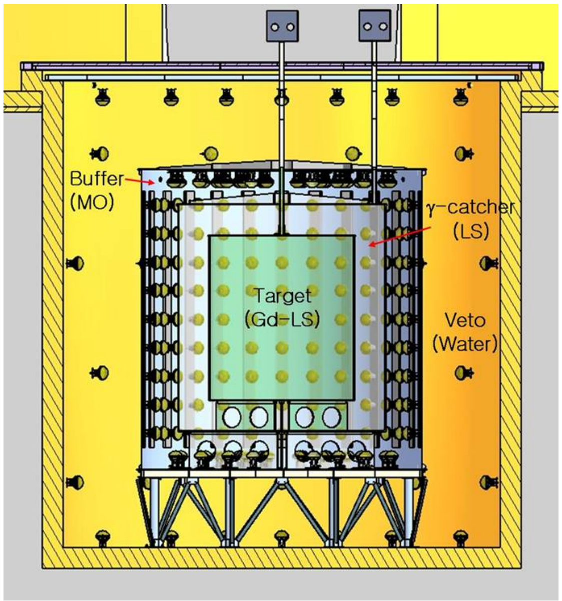

FIGURE 2. A schematic view of RENO detector.

DAQ System

The RENO DAQ employs a new front-end electronics QBEE (QTC [6] Based Electronics with Ethernet) developed for the Super-Kamiokande experiment (Super-K IV). The QBEE consists of 8 charge-to-time convertors (QTC) and 4 time-to-digital convertors (TDC) to process 24 analog inputs, and transfers the data via 100 Mbps Ethernet per board. The QTC has the large dynamic range of 2500 pC per channel and a time resolution of 0.52 nsec. This electronics records every hit with no dead time and the software triggers are applied to identify the events.

Systematic Uncertainties and Sensitivity

Systematic Uncertainties

The sources of systematic uncertainty are reactor related, detector related, and background related. By using two identical detectors, the detector related systematic uncertainties could be mostly canceled out and, in addition, the effects of reactor related uncertainties are greatly reduced. The systematic uncertainty goals for RENO are shown in TABLE 1.

TABLE 1. Reactor and detector related systematic uncertainties for RENO.

Uncertainty Source	RENO
Reactor Power	0.4
Energy Released per Fission	< 0.1
Reactor/Detector Distances	0.06
H/C Ratio	0.1
Target Mass	0.1
Gd Concentration	0.3
Positron Energy	0.05
Positron Geode Distance	-
Neutron Energy	0.1
Neutron Geode Distance	-
Neutron Capture Time	< 0.1
Positron-Neutron Distance	-
Dead Time	< 0.1
Neutron Multiplicity	< 0.1
Combined	< 0.6

Sensitivity

The average total thermal output of the Yong-gwang power plant is 16.4GW. Each detector has 1.2 x 10^{30} free protons in the target vessel. We expect 4.7 x 10^5 and 4.2 x 10^4 inverse beta decay interactions per year within the target volumes of the near and far detectors, respectively. We assume 40% and 70% event acceptance and selection efficiencies for the near and far detectors, respectively, accounting for the dead time incurred by cosmic muon veto. Therefore, we expect 5.6 x 10^5 and 8.7 x 10^4 events for three years at the near and far detectors, respectively [7].

FIGURE 3 shows the 90% CL limits for three years of data taking. The limits with the power uncertainty of 0.8% and 3.2% (1/2 and 2 times of the nominal uncertainty of 1.6%) are also shown.

Schedule

Construction of experimental halls and access tunnels for both near and far detector sites was completed in early 2009. The detectors are near completion, and the installation of electronics and liquid handling system are underway. The data-taking with two detectors is planned to start in early 2011.

SUMMARY

The RENO detectors are near completion, and data-taking is planned to start in early 2011. An expected number of observed antineutrino events is roughly 510 and 80 per day in the near detector and far detector, respectively. An estimated systematic uncertainty associated with the measurement is less than 0.6%. With three years of data, an expected statistical error is about 0.3% and the experiment would be sensitive to measure the neutrino mixing angle values of $\sin^2(2\theta_{13})$ down to 0.02 in 90% CL limits.

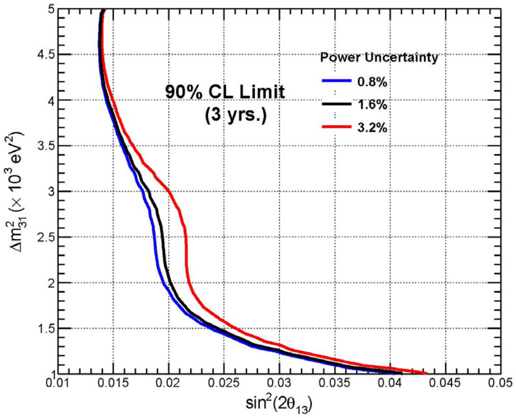

FIGURE 3. Expected 90% CL limits for three years of data taking with the systematic uncertainties given in TABLE 1.

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