

RENO: Reactor Experiment for Neutrino Oscillation at Yonggwang

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Abstract. The RENO experiment is under construction to measure the value of the smallest and unknown neutrino mixing angle θ_{13} . The experiment will compare the measured fluxes of electron antineutrinos at two detectors located at 290 m and 1.4 km distances from the center of the Yonggwang nuclear reactors in Korea. It is planned to start data-taking in early 2010. An estimated systematic uncertainty associated with the measurement is less than 0.6%. With three years of data, the experiment will search for the mixing angle values of $\sin^2 2\theta_{13}$ down to 0.02.

1. Introduction

There have been great progresses in understanding the neutrino sector of elementary particle physics in the last decade. The discovery of neutrino oscillations is a direct indication of physics beyond the Standard Model and it provides a unique new window to explore physics at the Grand Unification energy scale. The neutrino oscillations are in general described by the PMNS mixing matrix consisting of three mixing angles and a CP violating phase.

The current best limit on the last unknown mixing angle θ_{13} is given by the Chooz reactor neutrino experiment [1]. A high precision measurement of reactor neutrino oscillation can be achieved by multiple detectors because experimental sensitivity would be nearly unaffected by the uncertainties related to antineutrino flux and detection [2]. The RENO experiment will try to measure θ_{13} or at least improve the current constraint using reactor neutrinos.

It is now widely recognized that the possibility exists for a rich program of measuring CP violation and matter effects in future accelerator based neutrino experiments. However, in these long baseline experiments there are degeneracies and parameter correlations among θ_{13} , CP violation phase, neutrino mass hierarchy, and θ_{23} , whereas reactor neutrino experiments provide a clean information on $\sin^2 2\theta_{13}$. The possibility of measuring CP violation can be fulfilled only if the value of θ_{13} is such that $\sin^2 2\theta_{13}$ should be greater than the order of 0.01. A measurement of or stringent limit on θ_{13} would be crucial as a part of a long-term program to measure CP violation parameters at accelerators. The sufficient value θ_{13} measured in this reactor experiment would strongly motivate the investment required for a new round of accelerator neutrino experiments.

2. The RENO Experiment

Consideration of the RENO experiment began in early 2004 based on “White Paper for a New Nuclear Reactor Neutrino Experiment” [3], and it was approved by the Ministry of Science and Technology in

Korea in May 2005. Since the major funding of the experiment is secured, it is expected to start civil engineering and detector construction in 2008 in order to start data-taking in early 2010.

2.1. Yonggwang Nuclear Reactors

The Yonggwang nuclear power plant is located in the west coast of southern part of Korea, about 400 km from Seoul. The power plant has six reactors producing total thermal power of 16.4 GW, the second largest in the world. The six reactors are lined up in roughly equal distances and span ~1.3 km.

2.2. Near and Far Detectors

The experimental setup consists of two identical detectors with one at a near site, roughly 290 m away from the reactor array center, and the other at a far site, roughly 1.4 km away from the reactor array center. Identical arrangement of the near and far detectors will significantly reduce the total systematic uncertainty to less than 0.6%. Each detector will contain 15 tons of liquid scintillator target doped with 0.1% of gadolinium by weight. The near detector is to be under a 70 m ridge with an overburden of ~130 mwe whereas the far detector is to be located under a 200 m mountain with an overburden ~460 mwe.

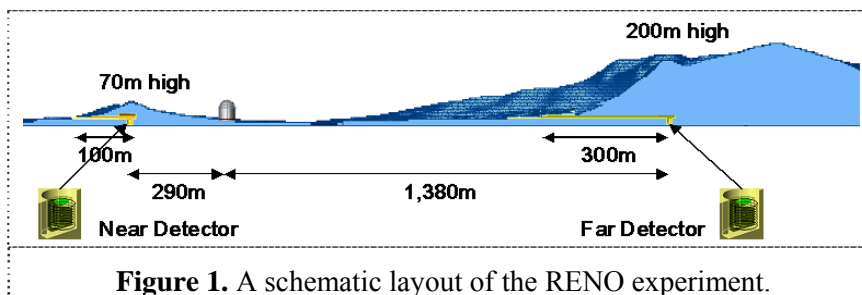


Figure 1. A schematic layout of the RENO experiment.

2.3. Time Scale

An overall schedule of the RENO experiment is given in Fig. 2. The KHNP, the company operating the Yonggwang nuclear power plant, has allowed us to carry out the experiment in the restricted area. The local government and residents have also expressed their best cooperation for RENO. Geological survey and tunnel design are completed in 2007. Civil construction for underground facility, including excavation of two tunnels, is expected to start in early 2008 and will be completed by early 2009. Construction of both near and far detectors will be completed by the end of 2009. Data-taking is expected to start in early 2010. RENO has gone through rapid development stages, to date, of project planning, fund approval, administrative negotiation, detector design, and tunnel design.

Activities	2006				2007				2008				2009			
	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12
Detector Design & Specification	[Yellow bar]															
Geological Survey & Tunnel Design					[Green bar]											
Detector Construction									[Purple bar]							
Excavation & Underground Facility Construction									[Cyan bar]							
Detector Commissioning																

Figure 2. An overall schedule of the RENO experiment. Data-taking is planned to start in early 2010.

3. The RENO Detector

The RENO detector, having a cylindrical shape of 7.8 m in height and 7.4 m in diameter, consists of a neutrino target, a gamma catcher, a buffer and a veto.

3.1. Neutrino Target

The neutrino target consists of 0.1% Gd loaded liquid scintillator in a cylindrical acrylic container of 140 cm in radius, 320 cm in height, and 8 mm in thickness. It has a total volume of 19.7 m³ and a target mass of 15.4 tons.

3.2. Gamma Catcher

Gamma catcher surrounds the neutrino target with 60 cm thick unloaded liquid scintillator of 35.2 m³ in volume and 27.5 tons in mass. The gamma catcher is contained in a cylindrical acrylic vessel of 200 cm in radius, 440 cm in height, and 12 mm in thickness.

3.3. Buffer

A 70 cm thick non-scintillating liquid surrounds the gamma catcher to reduce the accidental backgrounds coming from outside, mainly from radioactivity in the photomultiplier tubes, by almost two orders of magnitude. A total 59.2 tons of mineral oil is contained in a stainless steel vessel of 270 cm in radius, 580 cm in height, and 4 mm in thickness. This buffer is necessary for keeping the single rate below 10 Hz in the neutrino target and gamma catcher regions.

3.4. Acrylic Vessels

The acrylic vessels should contain aromatic liquids without leak and changing properties for a long-term period, roughly more than 10 years. They should not develop any chemical reaction with the scintillating liquids of neutrino target and gamma catcher, and with non-scintillating mineral oil of buffer for a long time period.

3.5. Photomultiplier Tube

A total 342 of 10-inch PMTs in a uniform array are mounted from the inner surface of the buffer vessel, providing 12.6% photo-sensitive surface coverage. The cylindrical steel vessel optically isolates the inner detector part from the outer veto system.

3.6. Veto

A 1 m thick water layer of 201.8 tons surrounds the whole inner detector with a volume of 102.1 tons. A total 51 of 8-inch PMTs are mounted in front of Tyvek reflector on a cylindrical steel tank.

3.7. Liquid Scintillator

The neutrino target will be filled with 1g/ℓ Gd loaded liquid scintillator. For Gd loading, two scintillator formulations are investigated, one based on carboxylic acids (CBX) and the other on beta-diketonates (BDK) to guarantee long-term stability. Linear Alkyl Benzene (LAB) will be used as scintillator solvent to replace dodecane and pseudocumene admixture. LAB has a high flash-point of 130 °C and a good optical property, and is commercially available in Korea.

4. Sensitivity

RENO is expected to improve the sensitivity on $\sin^2 2\theta_{13}$ by an order magnitude relative to the current best limit. This will be achieved by reducing both statistical and systematic errors, less than 0.6%.

The reactor antineutrinos are detected via the capture on a free proton, emitting a positron and a neutron, with an energy threshold of 1.8 MeV. The signature of a neutrino event is a prompt signal of positron followed by the neutron capture on Gd creating gammas with about 8 MeV.

An expected number of observed antineutrino is roughly 5,000 per day and roughly 100 per day in the near detector and far detector, respectively. An estimated systematic uncertainty associated with the measurement is less than 0.6%.

Based on three years of data, it would be sensitive to measure the neutrino mixing angle in the range of $\sin^2 2\theta_{13} > 0.02$. This sensitivity is five times better than the current limit obtained by Chooz.

5. Summary

The RENO experiment will try to measure θ_{13} or at least improve the current best limit by an order magnitude using two identical detectors. Geological survey and tunnel design are completed. Data-taking is planned to start in early 2010. Based on three years of data, it would be sensitive to measure the neutrino mixing angle in the range of $\sin^2 2\theta_{13} > 0.02$.

References

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