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Development of A Prototype Short Baseline Detector for Antineutrinos from the HANARO Research Reactor

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1. Introduction

Antineutrino is a by-product of the fission process in a nuclear reactor. When a fissile isotope absorbs a neutron, it breaks into energetic daughter nuclei emitting many neutrons and gamma-rays. The neutrons then cause more fissions, and the daughter nuclei decay emitting an antineutrino with each decay. Because neutrino can penetrate every thick matters composed of heavy concrete, lead and metals and so on, it is considered to be a promising monitoring probe for civil nuclear facilities and nuclear inventories. In fission process of the reactor core, uranium-235 produces antineutrinos in greater abundance than plutonium-239 over a certain energy range. As burnup proceeds, the neutrino energy spectrum deviates from an initial one. And the rate of antineutrino production is correlated to the amounts of specific fissile elements in the reactor core. By monitoring the antineutrinos during the fission process in the reactor core, scientists can estimate the variation of fissile material. Recent report [1] published by the Department of Safeguards of IAEA also said that a short baseline (SBL) neutrino detector has an intrinsic characteristics for monitoring status, operation power, nuclear fuel composition ratio in real time outside the containment building of the nuclear reactor with no-interference mode.

And many reactor neutrino experiments have searched for neutrino flavor oscillation by measuring the electron antineutrinos produced at nuclear reactor. Since KamLAND experiments in 2002 [2] gave a precise observation, neutrino flavor oscillation model has been accepted to be an actual phenomenon. One of interesting issues on the reactor neutrino is an anomaly that number of measured neutrinos shows a deficit of 6% comparing with the expectation [3,4], which means that there should be an undetected sterile neutrino in addition to the known three flavors. It should be created in the flavor oscillations and does not participate in a weak interaction [5]. The recent high precision and high statistics data from Double Chooz [6], Daya Bay [7] and RENO experiments [8] may imply it.

This research develops a short baseline neutrino detector and the technology for reactor monitoring by measuring precisely the neutrino energy spectrum with a detector located close to the HANARO research reactor. Also it will develop a liquid scintillator containing metals which has large neutron capture cross section, and pulse shape discrimination methods, then we will have a more flexible technology which can detect reactor neutrinos at overground.

2. Prototype detector for SBL neutrino detection

A SBL neutrino detector is designed to be installed inside of the HANARO research reactor, which is an open-pool type reactor being operated with a power of 30 MW(th) and uses low enriched uranium (19.75%) for fuel. The reactor core size is about 20 cm x 40 cm x 60 cm. The detector will be installed on the heavy shielding block before the PNS drum on a ST1 beam line, where a thermal neutron - prompt gamma activation analysis facility (SNU-KAERI PGAA) is now operated but will be decomposed and moved during neutrino experiment. Figure 1 shows the location for the detector to be installed at the baseline of 6 m from the core center.

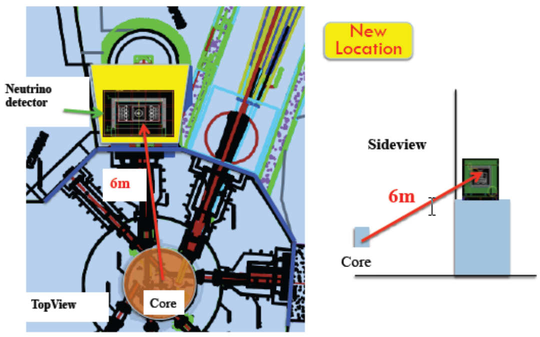

Fig. 1. The location of a neutrino detector at 6 m from the reactor core.

The purpose of the prototype detector is to study the background events which resemble the inverse beta decay and are not separable from the real neutrino event. Because the SBL experiment is carried out near the reactor, there should be little overburden. In addition to the background induced by muons, various neutron and gamma-ray sources in the reactor hall results in the high background in the neutrino detector. We intend to study the background neutrino-like events by comparing of the data from the prototype detector with the detail Monte-Carlo simulation studies by GEANT4[9].

The prototype detector has an identical shielding structure of the main detector, which consists of a target volume of 500 liters. Figure 2 shows the schematic drawing of the prototype detector. The outmost layer is 20 cm thick liquid scintillator, which acts as a muon veto counter and provides shielding from cosmic rays and radioactivity from surrounding radiation sources. Inside the outmost layer is a 10 cm thick lead shield and a stainless steel rectangular vessel, which contains an acrylic cylinder of 50 liter in the center with six 8 inches photomultiplier tubes mounted at the both end cap of the cylinder and mineral oil is filled between the acrylic and cylinder stainless vessel. The inner barrel surface of acrylic cylinder has 3 mm thick PTFE plate to reflect the scintillation lights directing toward the photomultiplier tubes. There is a chimney at the acrylic cylinder to insert the calibration sources.

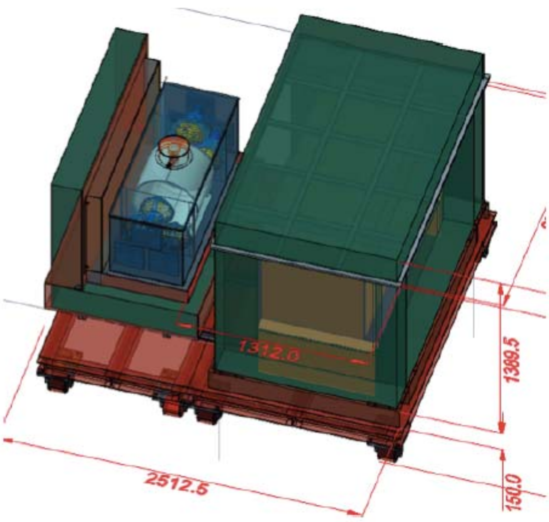

Fig. 2. A schematic drawing of 50L proto-type detector. The outmost layer is 20cm thick liquid scintillator which works for muon veto.

3. Conclusion

Reactor antineutrino experiment is under preparation for the development of reactor monitoring. For this, the short baseline neutrino detector with a 500 liter liquid scintillator at the baseline of 6 m near the HANARO research reactor is now being designed and the prototype detector with a 50 liter target volume will be tested to measure and evaluate the backgrounds for the detector. The data from the prototype detector will be compared with a Monte-Carlo simulation and utilized to reduce the backgrounds before locating the detector at reactor site.

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