PROCEEDINGS OF SCIENCE

Neutrino Elastic-scattering Observation with NaI[Tl](NEON)

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Standard-Model predicts the coherent elastic neutrino-nucleus scattering, which is interesting for the measurement of the neutrino properties and demonstration of the possibility of WIMP-nucleus interaction. The process hasn't been detected for reactor neutrinos yet. For this measurement, a NaI(Tl) array detector with high light yield and a low threshold will be used. The Hanbit reactor site in Korea provides 2.8 GW of thermal power and 7.1×10^{12} cm^{-2}s^{-1} of neutrino flux to the detector located at 24 m away from the reactor core. The current research shows that a light yield of a crystal is around 23 photoelectrons(PE)/keV which would make a sub-keV scintillation signal detectable. The target mass of NEON(Neutrino Elastic-scattering Observation with NaI(Tl)) will be 10 kg, surrounded by a liquid scintillator veto detector, and passive shieldings.

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1. Introduction

The NEON(Neutrino Elastic-scattering Observation with NaI(Tl)) experiment aims to observe the Coherent Elastic Neutrino Nucleus Scattering(CEνNS) of nuclear reactor neutrinos with a NaI(Tl) crystal. CEνNS is the weak interaction through the exchange of neutral Z boson, where all kinds of nuclei can interact with neutrinos. The CEνNS process was first predicted 45 years ago [1]. The process is only observed by the COHERENT experiment with CsI(Na) crystal for accelerator-based neutrinos two years ago [2]. However, the CEνNS process is not observed for reactor neutrinos which have different flavors compared to the one from an accelerator. The CEνNS detection can provide opportunities to study neutrino physics such as a neutrino magnetic moment and non-standard interactions. A NaI(Tl) crystal has been used in the WIMP(Weakly interacting massive particle) detection such as the COSINE-100 experiment. As the WIMP-nucleon interaction process is similar to the CEνNS process, it is also possible to demonstrate the feasibility of using NaI(Tl) crystal in the WIMP search. An additional benefit is to monitor the reactor activity using CEνNS

2. Conceptual design of the NEON experiment

A NaI(Tl) crystal is useful in the rare event searches such as CEνNS experiments and the direct dark matter search experiments because it emits a lot of photons for a given energy deposition and its scintillation emission range matches with the high quantum efficiency wave length region of a photomultiplier tube. Furthermore, the characteristics of NaI(Tl) such as light yield, quenching factor, resolution and trigger efficiency, are well understood from COSINE-100 experiment. The detector will be about 10 kg of NaI(Tl) crystals and it will be surrounded by 900 L liquid scintillator for multiple background events veto. A 10 cm thick lead and 20 cm thick polyethylene shields are employed for the further environmental background shielding.

The detector will be installed in the Hanbit Nuclear Power Plant, Yeonggwang, South Korea. Thermal power of the nuclear reactor is 2.815 GW, and the detector will be located 24 m distance from the reactor core [6]. The expected anti-electron neutrino flux from the reactor's fission fraction is 7.1×10^{12} cm^{-2}s^{-1} at the detector location of the expected NEON site [4]. Figure 1 shows the detector location around the reactor, and the spectrum of anti-electron neutrino flux.

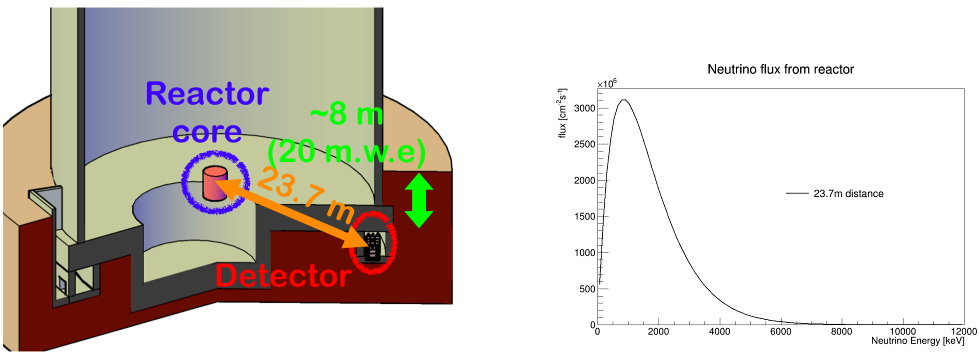

Figure 1: Expected NEON detector site in the Hanbit Nuclear Power Plant(left). Anti-electron neutrino flux at the NEON site(right)

A hight light yield NaI(Tl) crystal is important in order to enable lower energy threshold in the CEνNS detection. The light yield and the energy threshold of the NaI(Tl) crystal of the NaI(Tl) crystal of the COSINE-100 experiment are around 15 PE/keV and 0.4 keV(6 PE) respectively.

We estimated the event rate of the NEON experiment using neutrino flux and the NaI(Tl) crystals characteristics of the COSINE-100 experiment. Around 400 CEνNS events will be detected, assuming on a year of data taking, 4 PE threshold with 10 kg NaI(Tl) crystal detector, and 15 PE/keV light yield. This can be doubled up to 850 CEνNS events when the light yield is improved to 25 PE/keV, as shown in Fig. 2.

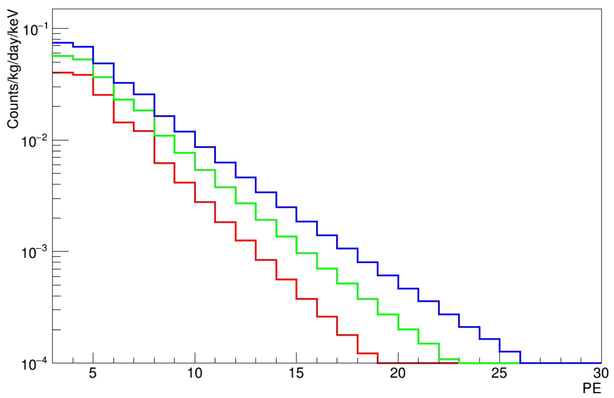

Figure 2: Expected event rate with different the light yield (blue line: 25 PE/keV, green line: 20 PE/keV, red line: 15 PE/keV).

3. NaI(Tl) crystal R&D

The NaI(Tl) crystal should be encapsulated with copper structure, in order to block the contamination of the crystal by humidity. In the COSINE-100 experiment, the size of the crystal base sides is 4.5-inches diameter and the PMT has 3-inches diameter. To match these different sizes, a quartz window having 90% light transmittance at the maximum efficiency region of PMT and optical pads were used for coupling between the COSINE-100 crystals and PMT.

The crystal encapsulation design is improved to increase the light yield of the NEON experiment, as shown in Fig. 3. First, the diameter of the crystal and the PMT were matched by trimming crystal into 3 inches. Second, we minimized coupling materials between the PMT and the crystal. A 3mm thick optical pad for each side is used without a quartz window. The light yield of the NEON crystal is 23 PE/keV which is 1.5 times the COSINE crystals. The NEON crystal resolution measured by gamma-rays from ^{241}Am source is also better than the COSINE crystal resolution. Figures 4 and 5 show the results of PE yield and resolution measurements, respectively.

4. Sensitivity measurements

The developed NaI(Tl) crystal of NEON experiment is tested in Yangyang Underground Laboratory(Y2L), where the cosmic muon rate is low. Also, it enables the internal background measurement by using surrounding the CsI crystals. The background of the NEON crystal is measured

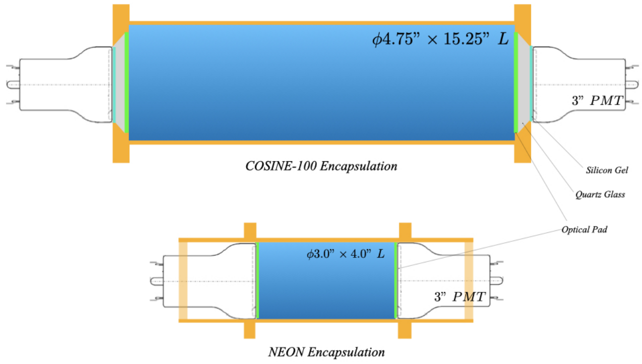

Figure 3: The COSINE-100 detector design(upper) and the new detector design of 3-inch crystal(lower).

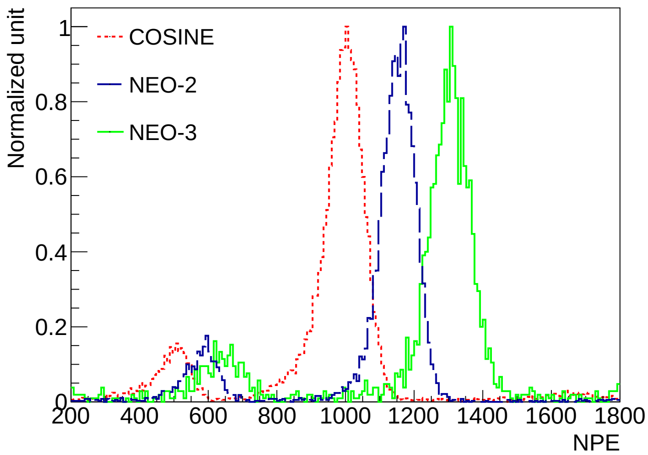

Figure 4: The number of photoelectrons (NPEs) for the ^{241}Am gamma peak. The red-dotted line is from existing COSINE-100 measurements while the blue-dashed line (NEO-2) and the green-solid line (NEO-3) show the NPEs for the newly designed detectors.

to 10 dru (counts/kg/day/keV), which is bigger than that of the COSINE crystals with 3 dru. However, the NEON crystal background can be reduced by removing the external background using a liquid scintillator veto detector. The tagging efficiency of the liquid scintillator detector is more than twice as large as the CsI crystal. The sensitivity is expected about 4.5 σ when assuming 10 kg detector mass, 10 dru background, one year of reactor-on period, 100 days of the reactor-off period, 25 PE/keV light yield, and 4 PE energy threshold. This can give evidence of the CEνNS process of reactor neutrinos.

5. Conclusion

The NEON experiment aims to observe Coherent Elastic Neutrino-Nucleus Scattering(CEνNS) with NaI(Tl) crystals for reactor neutrinos. Improving the light yield of the crystals and lowering

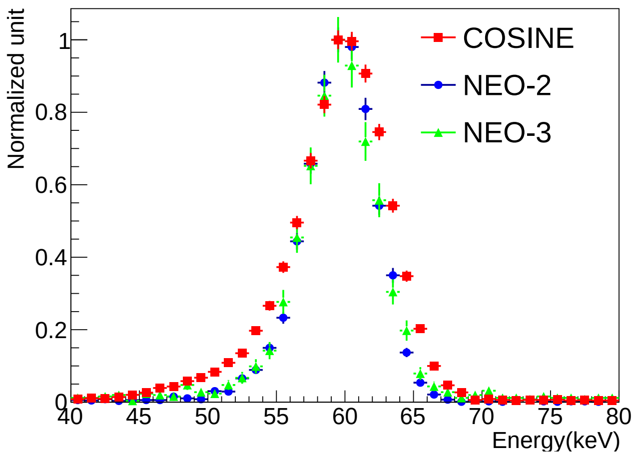

Figure 5: Resolution comparison between the COSINE-100 detector and the NEON detector.

the detection threshold is important to observe CEνNS. NaI(Tl) crystal R&D was done and light yield is increased more than 30% from that of the COSINE-100 detector. We are planning to install the NEON detector in the summer, 2020.

References

[1] D.Z. Freedman, *Observation of coherent elastic neutrino-nucleus scattering*, *Phys. Rev. D* **9** (1974) 1389.

[2] COHERENT collaboration, D. Akimov et al., *Observation of coherent elastic neutrino-nucleus scattering*, *Science* **357** (2017) 1123.

[3] COSINE-100 collaboration, G. Adhikari et al., *An experiment to search for dark-matter interactions using sodium iodide detectors*, *Nature* **564** (2018) 83.

[4] A. Gütlen. *Feasibility Study for a First Observation of Coherent Neutrino Nucleus Scattering Using Low-Temperature Detectors*, Technische Universität München, 2013 Ph.D. Thesis.

[5] COSINE-100 collaboration, G. Adhikari et al., *Initial performance of the COSINE-100 experiment*, *Eur. Phys. J. C.* **78** (2018) 107.

[6] NEOS collaboration, Y.J. Ko et al., *Sterile Neutrino Search at the NEOS Experiment*, *Phys. Rev. Lett* **118** (2017) 121802.