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題目(和文)	Measurement of electron antineutrino flux in Super-Kamiokande with gadoliniumloaded water
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論 文 要 旨

THESIS SUMMARY

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要旨（英文800語程度）
Tbhesis Summary（approx.800 English Words ）

I measured electron antineutrino flux in the energy region from a few MeV to ten MeV with a large water Cherenkov detector, Super-Kamiokande (SK). The measurement covers the period from 2020 to 2022 when SK was operated with 0.01% gadolinium (Gd) concentration. This Gd-loaded water is a large upgrade from the long operation of SK since 1996 to enhance the performance distinguishing neutrino and antineutrino. Utilizing the Gd-loaded water phase, we developed a new method to identify electron antineutrinos of a few MeV with SK and conducted this measurement. This resulted in the observation of distant reactor antineutrinos. This observation in large-scale water Cherenkov detectors is the first time. In addition, we demonstrated the sensitivities to the astrophysical electron antineutrino flux, which are comparable sensitivities with the world-leading experiments using liquid scintillator detectors.

Super-Kamiokande is a large water Cherenkov detector located in Kamioka, Japan. Its total volume is 50 kt, and 22.5 kt of the 50 kt was available volume for this physics analysis. To avoid cosmic ray muons, SK is installed inside a mountain with a 1 km overburden. The detector is cylindrical in shape with two layers: an inner detector for the main volume and an outer detector for the active muon veto. 11000 PMTs with 50 cm diameter are equipped on the inner wall of the inner detector to observe Cherenkov radiations. We can identify neutrino events from the pattern of the Cherenkov radiation.

Diffuse Supernova Neutrino Background (DSNB) is a diffused neutrino flux emitted by past supernova explosions and a unique probe to reveal a mechanism of supernova explosion and history of star formation, which are strongly related to the history of nucleosynthesis. Because of its small flux, DSNB has not been observed yet, even though the large-scale neutrino detectors searched for DSNB. Whereas the typical energy region of DSNB is several MeV and DSNB consists of all neutrino flavors, the dominant detectable channel is an inverse beta decay of electron antineutrino. In addition to DSNB, several models expect astrophysical electron antineutrino flux in similar energy regions, for example, solar and diffused dark matter.

Electron antineutrino flux in the same energy region with DSNB is dominated by reactor antineutrino, which played significant roles in understanding the nature of neutrino in terms of particle physics. However, the measurements of reactor neutrinos are conducted by scintillator detectors due to the energy scale of reactor neutrinos of a few MeV, and no water Cherenkov detector observed neutrinos of distant reactors at present except for evidence of the SNO+ experiment in 2023. The difference in neutrino oscillation probability between electron neutrino and electron antineutrino can be a good test of CPT invariance, and the different measurement techniques are important. Furthermore, monitoring distant reactor activities over several tens of km is expected for the safeguard of atomic energy.

The IBD interaction is an interaction in which an electron antineutrino interacts with a proton and generates one positron and one neutron. This neutron is visible in the Cherenkov detector by neutron capture with some delays. The delayed coincidence is a unique feature to identify IBD from background events, which are induced by environmental radioactivities and other types of neutrino. Gadolinium is one of the good isotopes to capture neutrons. To extend lower energy region than previous SK analysis, we developed the analysis method utilizing a low energy trigger and an efficient reduction method for large background events. Even though the low energy trigger was not originally introduced for the delayed neutron events and did not work for the pure-water phase of SK, the neutron capture signal by Gd can be triggered by this. The developed method works for the IBD events in the Gd-loaded phase.

We searched for IBD events in the dataset of SK with 0.01% gadolinium concentration from the 2020 summer to the 2022 spring. The observed yield of IBD candidates was consistent with the expectation of reactor antineutrinos and had no excess of astrophysical electron antineutrinos other than the expectation of reactor antineutrinos and background contamination. From the aspect of reactor neutrinos, we observed the reactor neutrinos and confirmed the time trend along the varying reactor activities. For the astrophysical flux, we set an upper limit on their flux in the newly extended energy region from a few MeV to ten MeV. From the observed and expected background contamination, we estimated future sensitivities of SK with a higher gadolinium concentration, 0.03%, and a next-generation water Cherenkov detector.