Form 8

Research Result Report
ICRR Inter-University Research Program 2024

Research Subject: Study of supernova neutrinos in Super-Kamiokande

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Summary of Research Result：

The purpose of this research is detection of the supernova neutrino in SK-Gd. There are two targets, one is neutrinos from nearby supernova explosion, the other is diffuse neutrinos from the past supernovae called 'Supernova Relic Neutrinos (SRN)'. The SK-Gd project is gadolinium (Gd) loading into Super-Kamiokande (SK) to increase inverse beta decay interactions of anti-electron neutrinos.

In 2020 summer, we've doped 13 tons of gadolinium sulfate into Super-Kamiokande, which is equivalent to 0.01% Gd mass concentration, and the SK-Gd experiment officially started. The neutron capture efficiency showed the expected performance, and the detector was operated stably. In 2022 summer, an additional 26 tons of gadolinium sulfate was introduced to the detection. (0.03% Gd mass concentration) The SK-Gd data taking is currently working well.

In FY2024, we reported the first result of supernova relic neutrino in SK-Gd with 0.01% and 0.03% mass concentration gadolinium loaded water in SK-Gd. Though no significant signals were observed, the data showed about 2 sigma level of excess against the expected background events. (left figure) In addition, we applied a fit to the obtained spectra with the prediction of the SRN signal and background event, and found a 2.3 sigma tension from the hypothesis of no SRN signal. (right figure) These results were reported in various conferences and had a strong impact.

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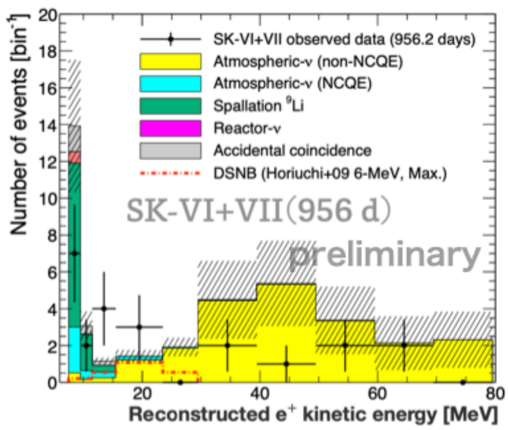
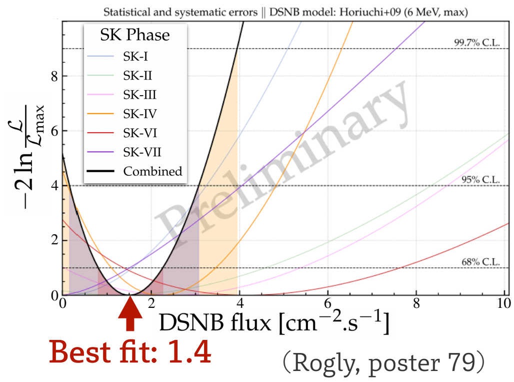


Observed energy distribution and predicted background in SK-Gd.



Significance as a function of SRN flux in all SK phases.

Published paper

[1] Super-Kamiokande collaboration (K.Abe et. al)., Second gadolinium loading to Super-Kamiokande, NIM A 1065, 169480 (2024)

[2] Y. Hino et al., Modification on Thermal Motion in Geant4 for Neutron Capture Simulation in Gadolinium Loaded Water, TPTEP 2025 013C01 (2024)

[3] F.Nakanishi et al., Supernova Burst and Diffuse Supernova Neutrino Background simulator for Water Cherenkov Detectors,The Astrophysical Journal, 965, 91 (2024)

Presentations

(1) M. Harada, Review of Diffuse SN Neutrino Background., Neutrino2024, Milano, Italy, June 16 – 22, 2024.

(2) A. Beauchêne, Diffuse Supernova Neutrino Background: Insights from Super-K & Prospects with Hyper-K, Milano, Italy, June 16 – 22, 2024.

(3) R. Rogly, Overview of the model-dependent approach for the Diffuse Supernova Neutrino Background search with SK-Gd, Milano, Italy, June 16 – 22, 2024.

(4) A.Santos, Y.Kanemura, M.Harada, New limits on the low-energy astrophysical electron antineutrinos at SK-Gd experiment, Milano, Italy, June 16 – 22, 2024.

(5) F. Nakanishi, Search for "mini-burst" supernova neutrinos in Super-Kamiokande, Milano, Italy, June 16 – 22, 2024.

(6) Y. Hino, A comparison of n-O inelastic scattering between the experimental and simulation models towards understanding neutrino reaction, Milano, Italy, June 16 – 22, 2024.

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