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Research Result Report
ICRR Inter-University Research Program 2024

Research Subject: High-energy neutrino measurement at Super-Kamiokande

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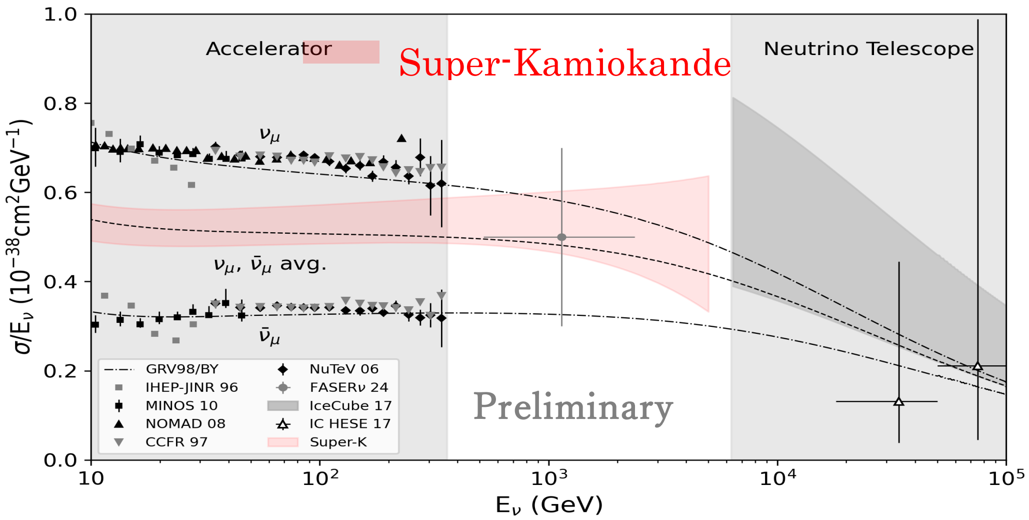
Summary of Research Result : This is a project to measure the first TeV-scale neutrino interaction cross-sections using the Super-Kamiokande (SuperK) up-going through going muon (upmu) samples. SuperK upmu sample contains the highest energy atmospheric neutrino information. This reaches up to several TeVs, surpassing all man-made high-energy neutrinos. These neutrinos can investigate various new neutrino sources, including galactic plane neutrinos, prompt charm decay atmospheric neutrinos, solar atmospheric neutrinos, and high-energy supernova neutrinos. On top of these, it is possible to measure the neutrino interaction cross-sections in the TeV region like the FASERnu experiment at CERN, Switzerland. We use the latest upmu data sample, with state-of-the-art atmospheric neutrino flux and interaction cross-section systematics. The funding was used to support the main analyzer |(Nahid Bhuiyan) to visit ICRR in Kashiwa. By utilizing Markov chain Monte Carlo (MCMC) method, we forward-fold the muon-neutrino and muon-antineutrino atmospheric-neutrino-flux-averaged charged current total neutrino interaction cross-sections with the function of neutrino energy (Figure). The result is significant for several reasons;

1. This result fill the missing data between the Fermilab accelerator-based neutrino interaction cross-section measurements (NuTeV, CCFR, etc) and neutrino telescope-based cross-section measurements (IceCube).
2. This is the only result to extend to ~5 TeV, extending the result by the collider neutrinos thanks to the continuous spectrum of atmospheric neutrinos.
3. This opened a new field (atmospheric neutrino-based TeV science), a new field with high discovery potential for the Hyper-Kamiokande (HyperK) which can extend even higher energy.

The preliminary results have been presented at several conferences already, including Moriond 2025 Electroweak in Moriond, Italy, WIN2025 conference in Brighton, UK, then will be presented at ICRC2025 in Geneva, Switzerland, and National Astronomy Meeting 2025 in Durham, UK.

The paper draft is being written and the results are being finalized. In the coming year, we focus on publishing this result in prestigious peer-reviewed journals including Physical Review X and Nature Physics.



Furthermore, we are planning to set up a high-energy neutrino program in the HyperK as an extended goal of this project with an upcoming 2025-2026 ICRR international collaboration grant. Through this grant, we apply the analysis we developed to the HyperK, including the simulation production and systematic error propagation method. Under this study, we can repeat a similar, or more advanced analysis using the upmu sample to look for TeV-scale neutrinos in the HyperK making this topic to be one of the new scientific topics in the HyperK.

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