Form 8

Research Result Report
ICRR Inter-University Research Program 2025

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

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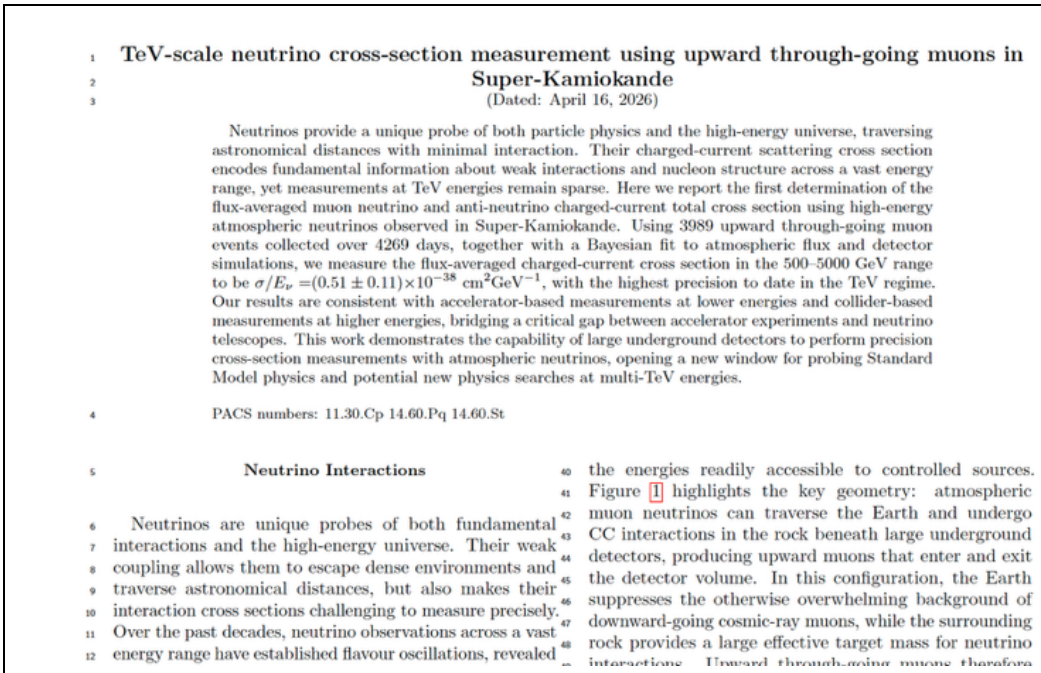
Summary of Research Result : This is a project to measure the first TeV-scale neutrino interaction cross-sections using the Super-Kamiokande (SuperK) up-going through going muon (upmu) samples. SuperK upmu sample contains the highest energy atmospheric neutrino information. This reaches up to several 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 is barely used as the main analyzer (Nahid Bhuiyan) graduated and we had no chance to visit ICRR in Kashiwa. Meantime, the paper draft had been completed and it was reviewed by the Super-Kamiokande collaborators for the final approval. The paper was finally uploaded on ArXiv on May 12, 2026.

https://arxiv.org/abs/2605.10221

In 2026, we aim to conclude this project by publishing it in a peer-reviewed journal. We will submit to *Nature Physics* and after the acceptance we will arrange press release and media appearance to improve visibility of our result.

Form 8



TeV-scale neutrino cross-section measurement using upward through-going muons in Super-Kamiokande

(Dated: April 16, 2026)

Neutrinos provide a unique probe of both particle physics and the high-energy universe, traversing astronomical distances with minimal interaction. Their charged-current scattering cross section encodes fundamental information about weak interactions and nucleon structure across a vast energy range, yet measurements at TeV energies remain sparse. Here we report the first determination of the flux-averaged muon neutrino and anti-neutrino charged-current total cross section using high-energy atmospheric neutrinos observed in Super-Kamiokande. Using 3989 upward through-going muon events collected over 4269 days, together with a Bayesian fit to atmospheric flux and detector simulations, we measure the flux-averaged charged-current cross section in the 500–5000 GeV range to be $\sigma/E_\nu = (0.51 \pm 0.11) \times 10^{-38}$ cm^{2}GeV^{-1}, with the highest precision to date in the TeV regime. Our results are consistent with accelerator-based measurements at lower energies and collider-based measurements at higher energies, bridging a critical gap between accelerator experiments and neutrino telescopes. This work demonstrates the capability of large underground detectors to perform precision cross-section measurements with atmospheric neutrinos, opening a new window for probing Standard Model physics and potential new physics searches at multi-TeV energies.

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Neutrino Interactions

Neutrinos are unique probes of both fundamental interactions and the high-energy universe. Their weak coupling allows them to escape dense environments and traverse astronomical distances, but also makes their interaction cross sections challenging to measure precisely. Over the past decades, neutrino observations across a vast energy range have established flavour oscillations, revealed the energies readily accessible to controlled sources. Figure 1 highlights the key geometry: atmospheric muon neutrinos can traverse the Earth and undergo CC interactions in the rock beneath large underground detectors, producing upward muons that enter and exit the detector volume. In this configuration, the Earth suppresses the otherwise overwhelming background of downward-going cosmic-ray muons, while the surrounding rock provides a large effective target mass for neutrino interactions. Upward through-going muons therefore

Figure 1: The first page screenshot of the draft paper from this project (omitting the author list). This is being circulated among the collaborators for final approval.

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