



Colorado Science and Engineering Fair

2025 Individual Project Abstract Form

Please print 2 copies of the completed form. Sign both copies, keep 1 for your notebook and submit 1 copy to your Regional Fair Director with your other paperwork.

Title of Project: Toward the Discovery of the Sterile Neutrino: Deep Learning Muon Neutrino Reconstruction at ICARUS

Finalist's Name: Julia Gao

School and City: Fairview High School, Boulder

Sponsor's Name: Michael Mooney

Category: Physics & Astronomy

Division: Senior (grades 9 - 12)

Abstract (250 words or less):

The ICARUS detector at Fermilab is searching for sterile neutrinos, a covert, hypothetical particle that is difficult to detect and a primary candidate for dark matter. Discovery of the sterile neutrino, implicit through a significant muon neutrino disappearance anomaly, would also provide evidence of new physics beyond the Standard Model. ICARUS houses two beams, the preferable one being Neutrinos at the Main Injector (NuMI), which is six degrees off-axis to provide a narrower energy spectrum and reduce uncertainties. It is the consensus that muon selections are ready, especially in NuMI, for sterile neutrino anomaly searches. I created a high-purity, high-efficiency muon neutrino selection at NuMI, looking at various final states. Using novel machine learning techniques, I created an advanced reconstruction and analysis pipeline for energy reconstructions of single sample muon neutrinos. My reconstructed visible energy and muon kinetic energy spectra, combined with the energy-dependent survival probability analysis, provide compelling evidence for sterile neutrino-induced muon neutrino disappearance. Both spectra exhibit a muon neutrino deficit in the 0.5-1.5 GeV range, with an unexpected suppression in event rates, deviating from standard oscillations. Additionally, the neutral-current fraction remains non-negligible at low energies, potentially signaling indirect sterile effects. The survival probability plot further reinforces this, showing oscillatory dips at specific energy values consistent with a $\Delta m^2 \sim 1 \text{ eV}^2$ sterile neutrino hypothesis. The combined findings align with muon to sterile transitions, providing novel, solid evidence for the existence of the sterile neutrino with profound implications for fundamental physics and cosmology.

I hereby certify that the above statements are correct and the information provided in the Abstract is the result of one year's research. I also attest that the above properly reflects my own work.

Finalist's Signature:

Date:

In addition, all students must complete the ISEF Student Checklist (1A), Research Plan, Approval Form (1B), and Checklist for Adult Sponsor (1), and any other ISEF forms required for this type of project. See the International Rules and Guidelines for form requirements. Return COPIES of all of these forms to your Regional Fair Director with you Finalist Verification/Permission Form. **A signed copy of this form must be included in your notebook.**