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Reconstruction of Tau Neutrinos in LArTPC Detectors

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Our understanding of three-flavor neutrino oscillations has undergone significant improvement. However, most progress has come from studying ν_e and ν_μ while the ν_τ remains the least explored particle in the Standard Model. The Deep Underground Neutrino Experiment (DUNE), a next-generation long-baseline neutrino experiment under construction, is designed to address this gap.

DUNE will deploy two high-resolution detectors exposed to the world's most intense neutrino beam: the Near Detector (ND) at Fermilab and the Far Detector (FD), 1,300 km away at the Sanford Underground Research Facility in South Dakota. With liquid argon time projection chamber (LArTPC) technology, DUNE's LArTPC detector will provide high statistics and excellent resolution capabilities, allowing us to make precision studies of oscillation parameters, search for CP violation in the lepton sector, test interaction models, and study phenomena that have, until now, seemed too complex to measure, like ν_τ detection and therefore, provide the completion of the 3-flavor neutrino paradigm. ν_τ data can impact a broad spectrum of open questions; among these include searching for non-standard neutrino interactions, constraining the unitarity of the PMNS matrix, and the unmeasured F_4 and F_5 structure functions for neutrino interactions.

The DUNE FD, is also ideally suited to collect atmospheric ν_τ . These events predominantly occur near the first atmospheric oscillation maximum and at a rate of ˜1 CC-ν_τ per kton-year. This atmospheric sample will provide a valuable complement to the beam data, enhancing sensitivity to three-flavor parameters and beyond the Standard Model scenarios.

To address all these questions, a key factor is to get a reliable event reconstruction, which is challenging. For this, we apply machine learning techniques. In the context of the DUNE FD, I will present NuGraph, a graph neural network (GNN) that models detector hits as nodes linked by spatial and temporal edges for classification and event reconstruction for LArTPC detectors. I will also present a review of the significance of ν_τ physics.

Author: YAEGGY ALVAREZ, Barbara

Co-author: DALLAWAY, William Gregory (University of Toronto (CA))

Presenter: DALLAWAY, William Gregory (University of Toronto (CA))

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