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SPINE Reconstruction Performance in ICARUS for SBN Oscillation Physics

Liquid Argon Time Projection Chambers (LArTPCs) enable precise 3D imaging of neutrino interactions at millimeter-scale resolution, making them a leading technology for accelerator-based neutrino oscillation physics. The SPINE reconstruction chain (Scalable Particle Imaging with Neural Embeddings) leverages Sparse Convolutional Neural Networks for voxel-level feature extraction and Graph Neural Networks for particle-level clustering, forming a unified end-to-end pipeline for neutrino interaction reconstruction. We present the performance of SPINE on the ICARUS detector —a 476-ton LArTPC serving as the Far Detector of the Short Baseline Neutrino (SBN) program at Fermilab—and its critical role in enabling ICARUS' s flagship ν_μ disappearance and ν_e appearance oscillation measurements. Michel electrons from muon decay-at-rest provide a clean, well-understood benchmark for validating reconstruction performance and energy scale calibration, serving as a stepping stone toward the full oscillation analysis.

Primary author: XIA, Junjie (SLAC/Stanford University)

Co-author: Dr DRIELSMA, Francois (SLAC)

Presenter: XIA, Junjie (SLAC/Stanford University)

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