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DNN + MLEM synergy for imaging of neutrino interactions in LAr

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DUNE is a next-generation long-baseline neutrino experiment aiming to determine the neutrino mass ordering, study CP violation in the leptonic sector, observe supernova neutrinos, and search for physics beyond the Standard Model. It will feature a Near Detector 547 m from the source and a Far Detector ~1300 km away. Within the Near Detector, the System for on Axis Neutrino Detection includes GRAIN (GRanular Argon for Interactions of Neutrinos), a novel liquid argon detector designed to image neutrino interactions via scintillation light, providing vertexing and tracking.

GRAIN features an innovative cryogenic light readout system consisting of a matrix of SiPMs with optics based on coded aperture masks (grids of alternating opaque material and holes). The reconstruction algorithm, based on Maximum Likelihood Expectation-Maximization (MLEM), combines the views of ~60 cameras providing a three-dimensional map of the energy deposited by charged particles. This iterative approach presents a significant computational challenge, requiring optimized use of multiple GPUs.

The aim of this work is to provide a prior of the expected three-dimensional energy deposition to serve as a seed for the MLEM algorithm, rather than a uniform distribution. This improves convergence and reduces GPU load. A deep neural network (DNN) was trained on simulated charged-current muon neutrino interactions, using timing information from the cameras. Efficient hyperparameter optimization was carried out using the OPTUNA framework. The resulting model produces a better seed for the MLEM algorithm.

The synergy between machine learning and classical algorithms leverages the speed of DNN predictions together with the precision of MLEM.

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