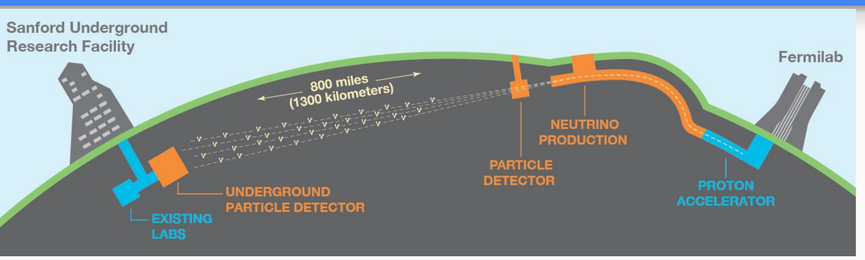
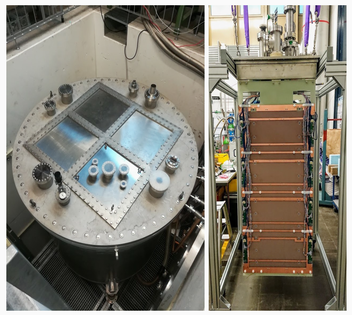
FERMILAB-POSTER-24-0146-LBNF

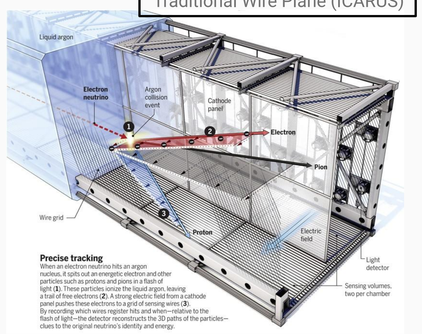
ML-based Reconstruction in a Pixelated LArTPC

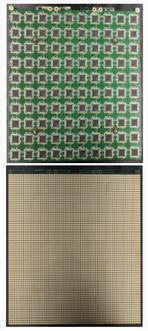


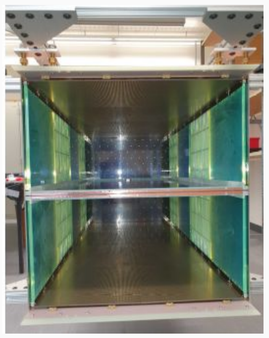
The Deep Underground Neutrino Experiment (DUNE) is a leading-edge, international experiment for neutrino science. Discoveries over the past half-century have put neutrinos, the most abundant matter particles in the universe, in the spotlight for further research into several fundamental questions. DUNE will consist of two sets of neutrino detectors placed in the world's most intense neutrino beam. This can help us answer questions about the origin of matter, unification of forces, and black hole formation.



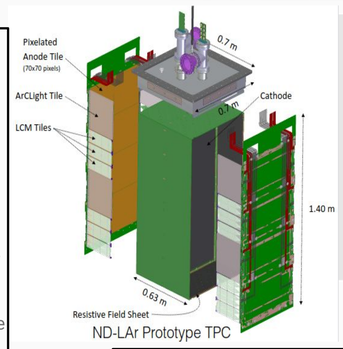
Traditional Wire Plane (ICARUS)



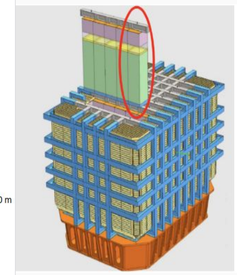




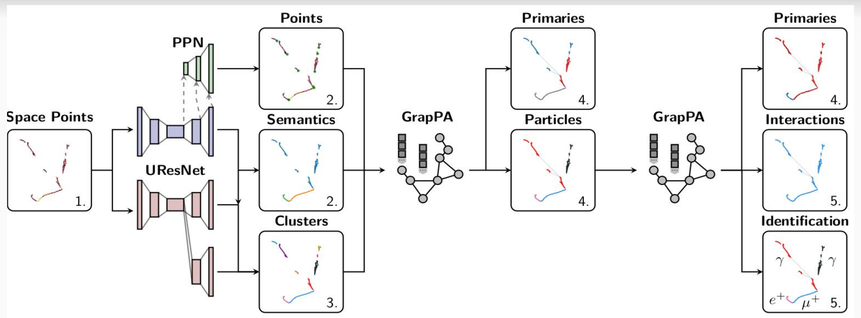
Traditionally LArTPC detectors have been made with a wire plane design. This can create ambiguity in reconstruction due to ghost points in some circumstances. The near detector for DUNE is a modularized design with a pixelated detector. It will be 5 x 7 modules that are 1m x 1m x 3m in volume. The 2x2 demonstrator contains four modules in a 2x2 array, each sized at 0.67m x 0.67m x 1.8m. The pictures to the right show a module in the 2x2.

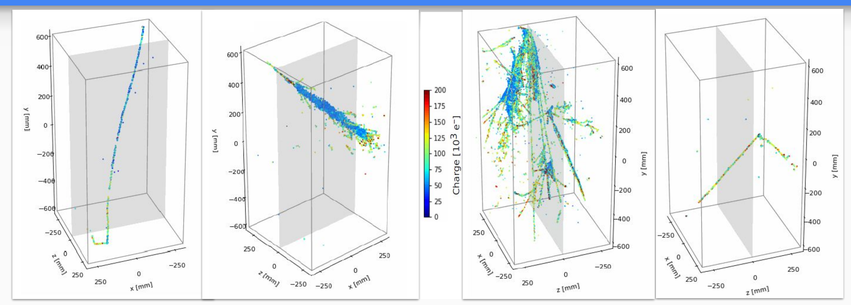


ND-LAr Prototype TPC



Novel Pixelated Detector (2x2)





(a) Stopping Muon + Michel e⁻ (b) EM Shower (c) Multi-Prong Shower (d) "Neutrino-like"

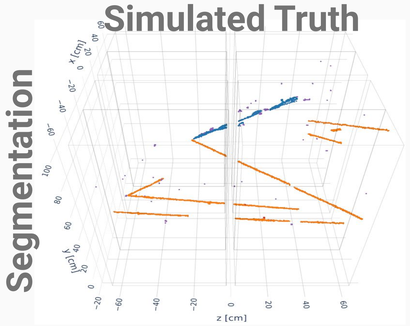
The picture to the top right shows the types of events we are trying to recreated in the 2x2 detector. No single machine learning model takes the raw hits and converts them into a complete reconstruction. That's why the SPINE package is a series of models that synergize with each other to complete the reconstruction.

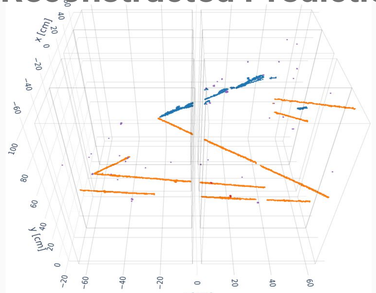
Event Displays

Simulated Truth

Reconstructed Prediction

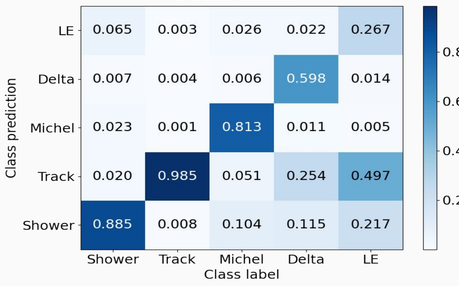
Semantic Segmentation



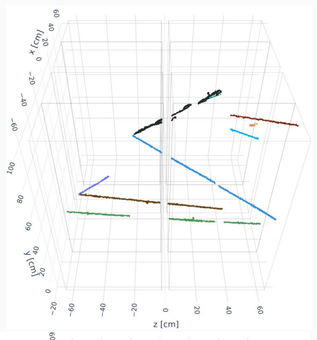


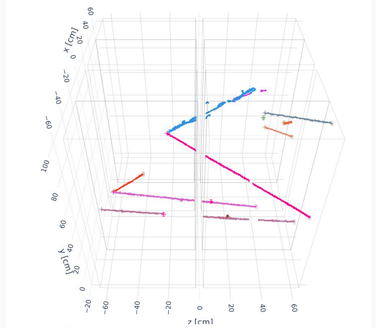
The first part of the pipeline is semantic segmentation and point proposal network. Semantic segmentation is done with a combination of unet and resnet models to form the uresnet convolutional network. It classifies each raw hit into the topographically distinct classes of electromagnetic showers, tracks, Michel electrons, delta rays, and low energy depositions. The point proposal network (PPN) identifies the start and end point of tracks and the start points of showers.

Results

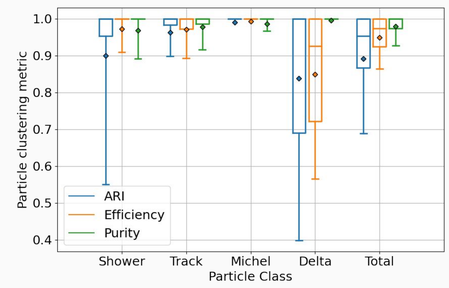


Particle Clustering

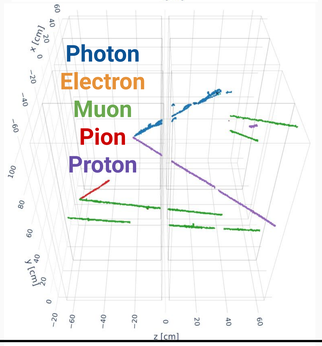


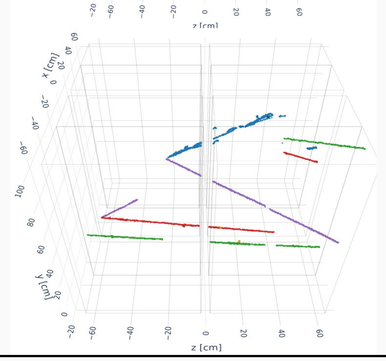


The individual hits are taken and then clustered into track and shower fragments using graph neural networks. It tries to determine which track and shower fragments belong together.

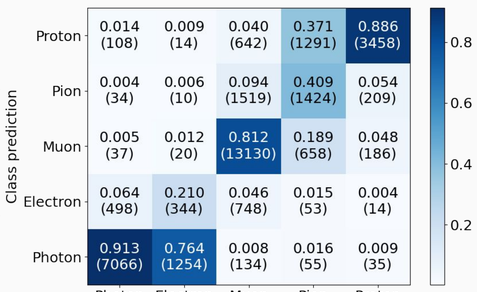


Particle ID





The last step is to identify the particles in the individual interactions as well as determine which vertices are primaries and which are secondaries. This is also done using a graph neural net.



Resources:
https://pos.sissa.it/441/221
https://www.dunescience.org/
https://arxiv.org/abs/2007.01335
https://journals.aps.org/prd/pdf/10.1103/PhysRevD.104.032004
https://journals.aps.org/prd/pdf/10.1103/PhysRevD.102.012005
https://github.com/DeepLearnPhysics/lartpc_mlreco3d/raw/develop/images/full_chain.png
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