Deep Neural Net for LArTPC Region of Interest (ROI) Identification

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Fermilab AI Jamboree

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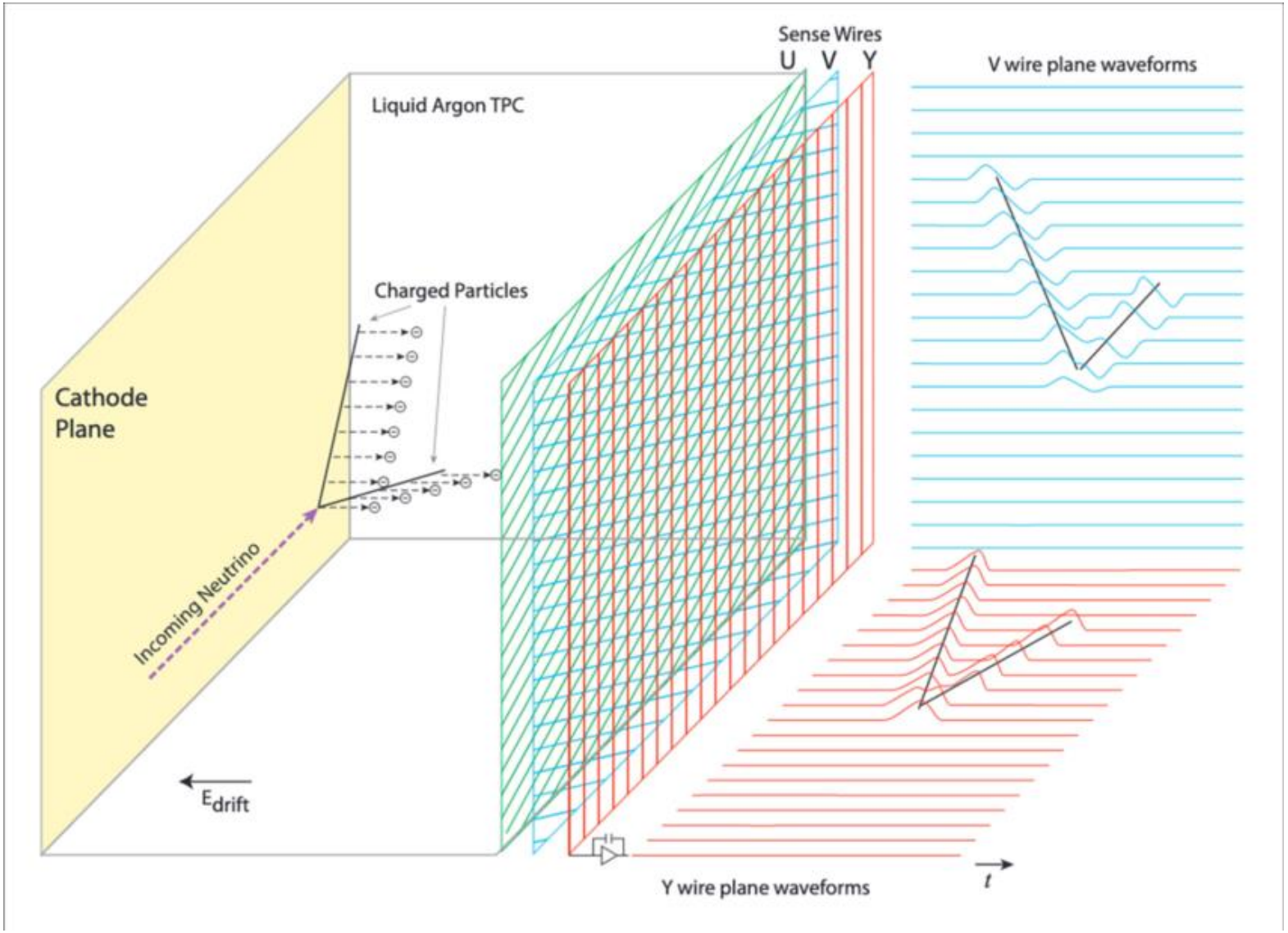
Introduction

- I’ve been working towards integrating a Deep Neural Net based Region of Identification (DNN ROI) for the Short-Baseline Neutrino Program
  - This has been a joint effort with many people across the Short Baseline Near Detector (SBND) and far detector (ICARUS)

- This network identifies where the charge is in the low-level signal processing of the LArTPC waveforms

- I’ll go through the scope of the network and our resent work on it

Liquid Argon Time Projection Chamber (LArTPCs)



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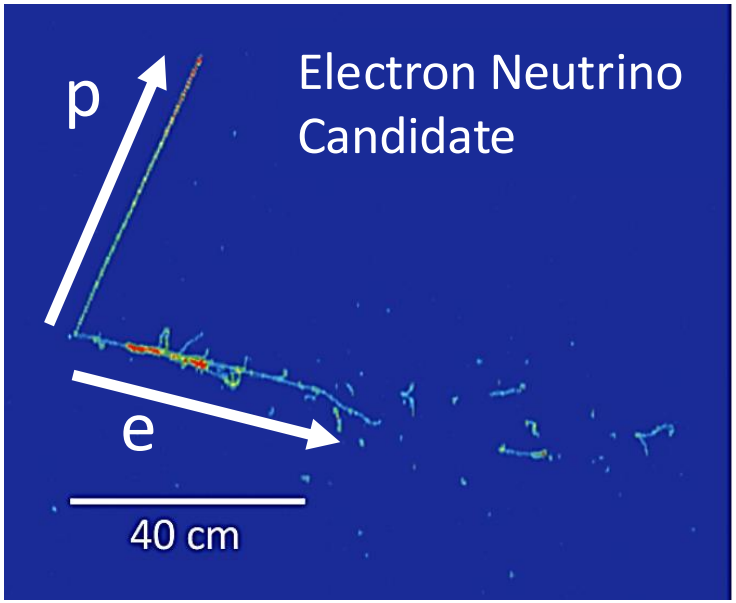
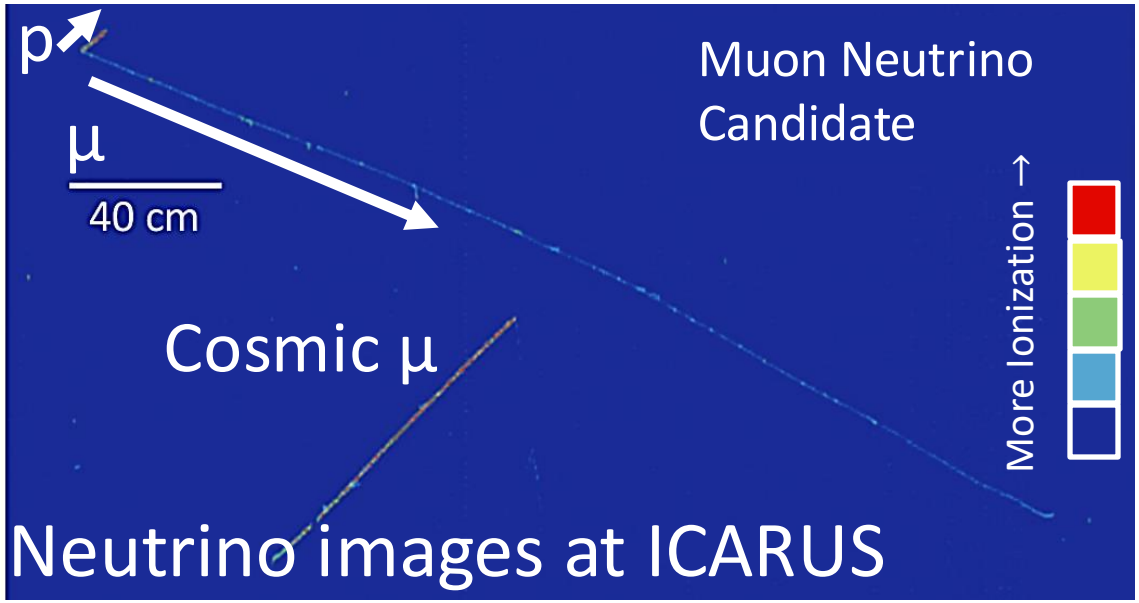
Neutrino Images in the ICARUS LArTPC





https://news.fnal.gov/2021/05/icarus-gets-ready-to-fly

NuMI Data

BNB Data

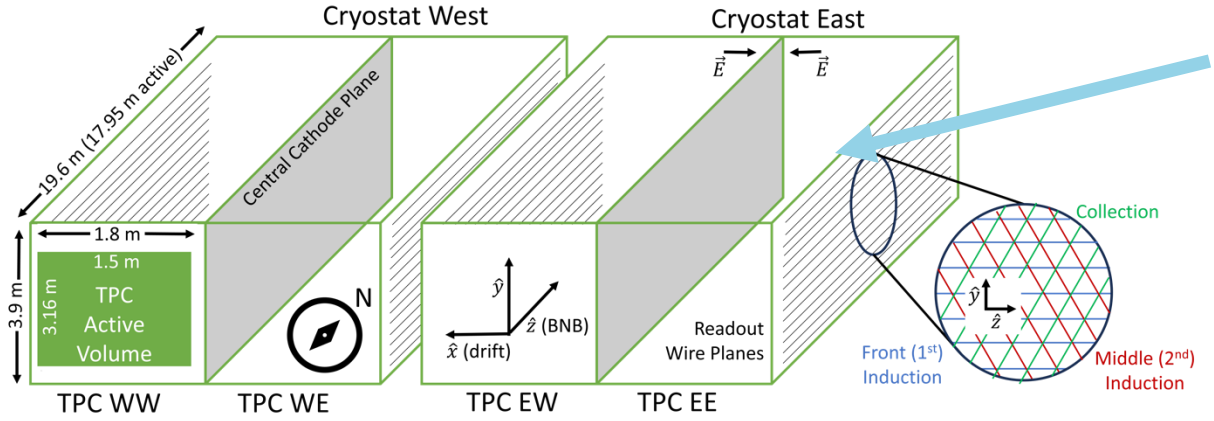


Image from one TPC inside each cryostat

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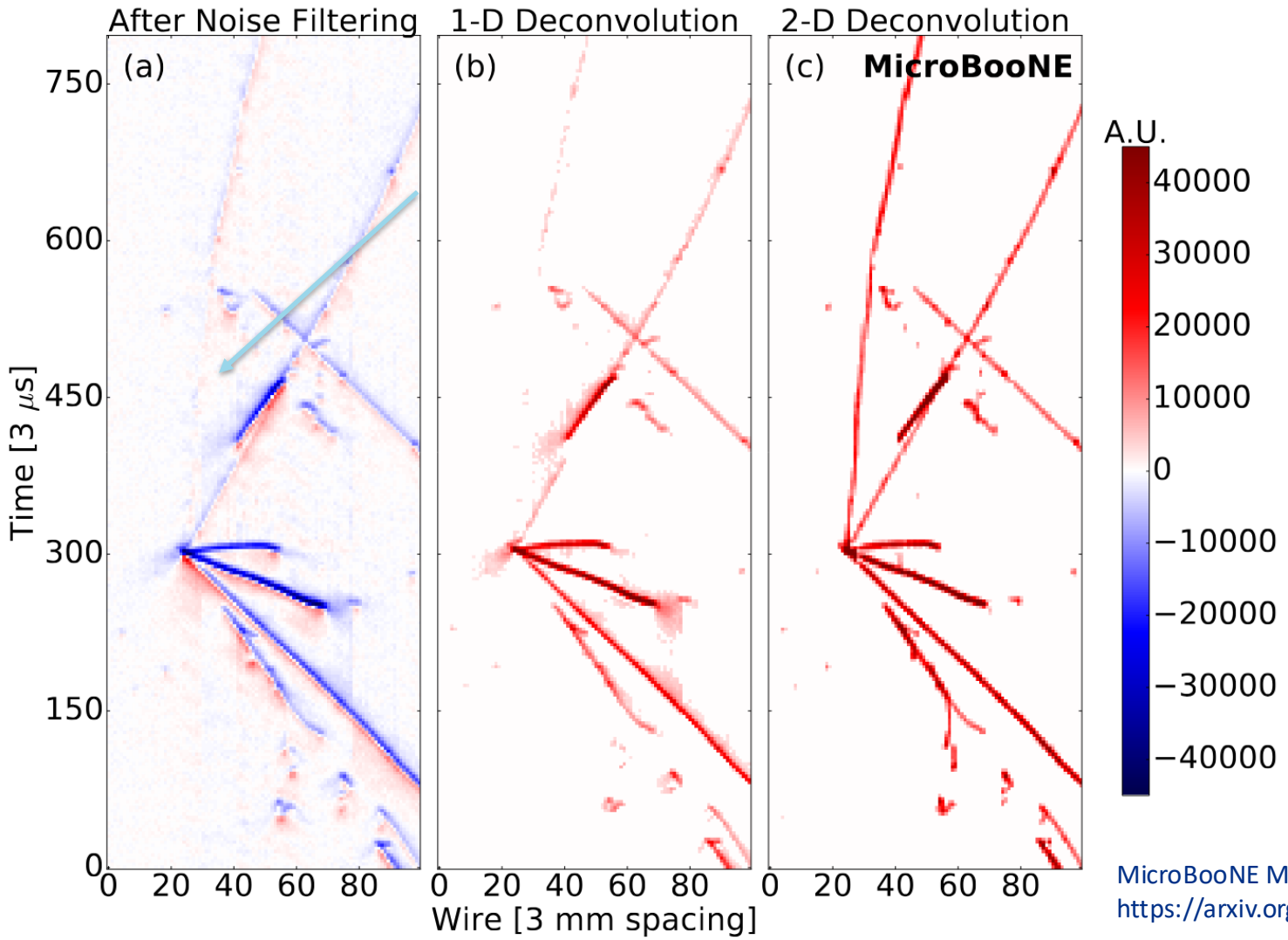
Raw Signals are “De-Convolved” to Reduce Noise and Produce Gaussian Signal Shapes



MicroBooNE MC
https://arxiv.org/abs/1802.08709

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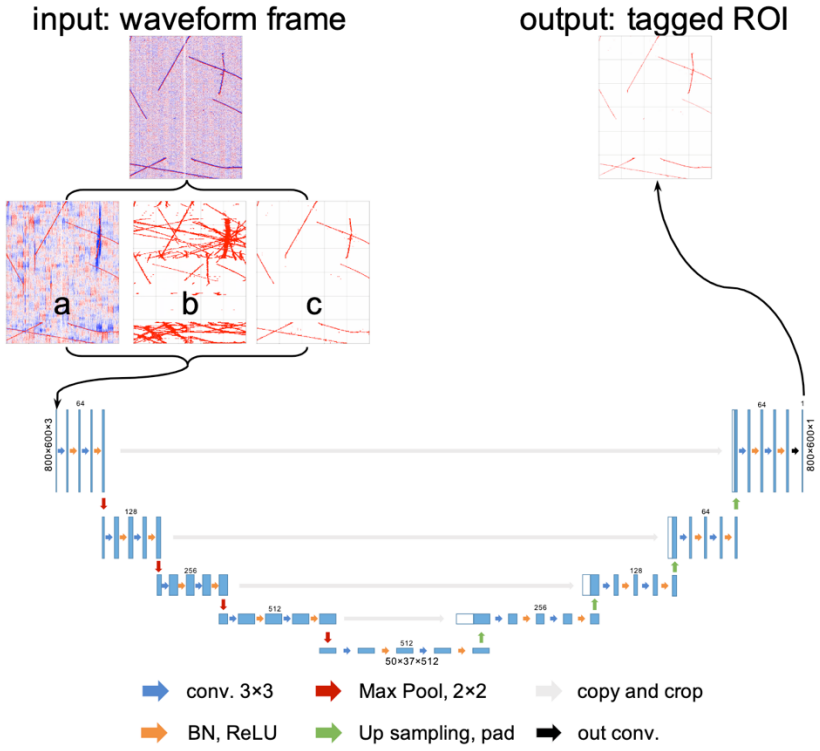
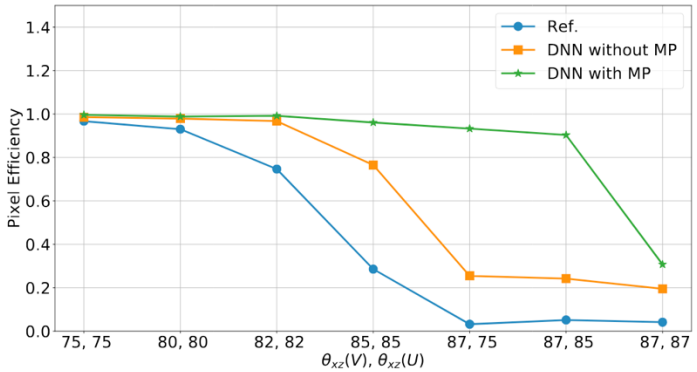
DNN ROI Architecture

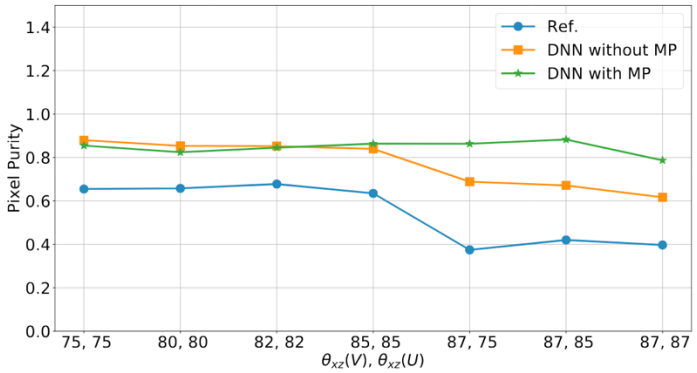
Architecture: deconvolved signal + “conventional ROI” as inputs



Details: https://arxiv.org/abs/2007.12743

Performance (ProtoDUNE-SP): improved purity, better efficiency at large track angle





DNN ROI = “Deep Neural Net Region of Interest” identification

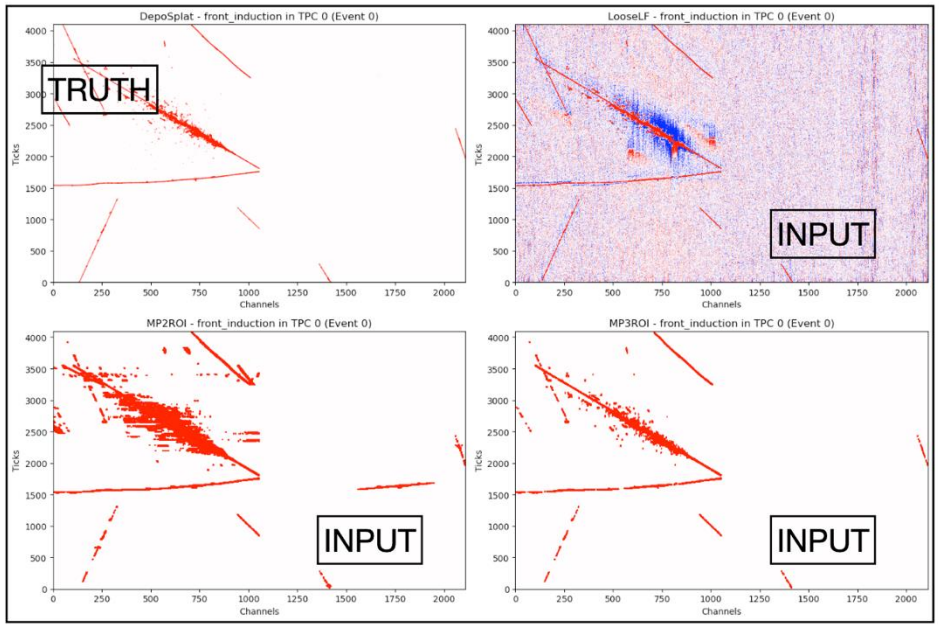
Who's Working on This?

- SBND:
  - Haiwang Yu (BNL), Brett Viren (BNL), Moon Jung (UChicago), Lynn Tung (UChicago), Avinay Bhat (UChicago), as well as other Wire-Cell collaborators

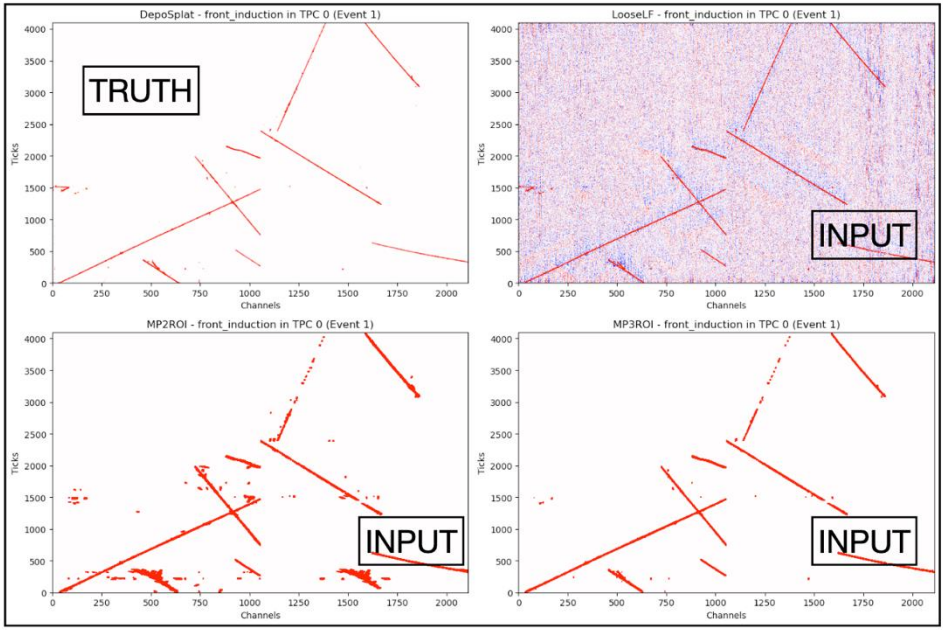
- ICARUS:
  - Avinay Bhat (UChicago), Gray Putnam (Fermilab)

Example Inputs in ICARUS

Avinay Bhat



U Plane



V Plane

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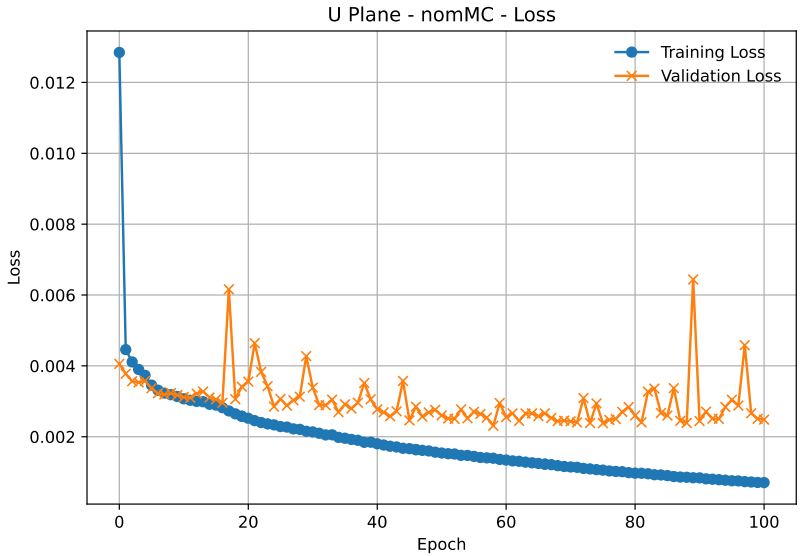
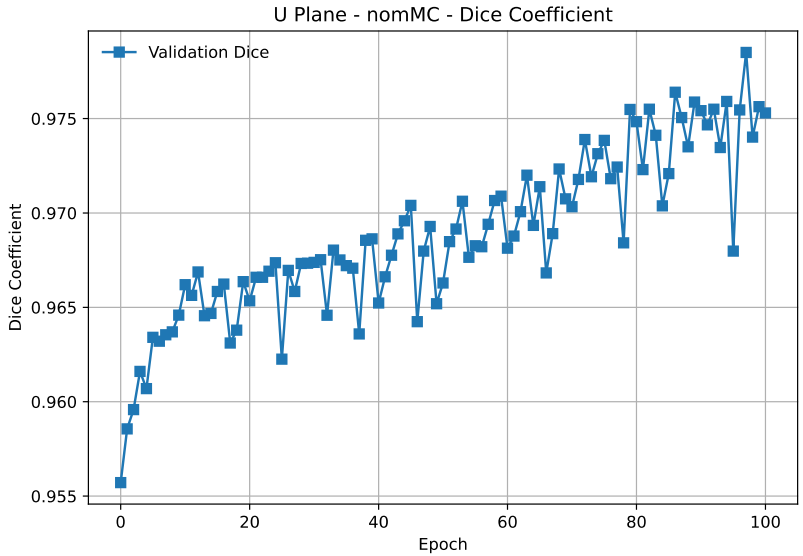
Example Training in ICARUS

Avinay Bhat

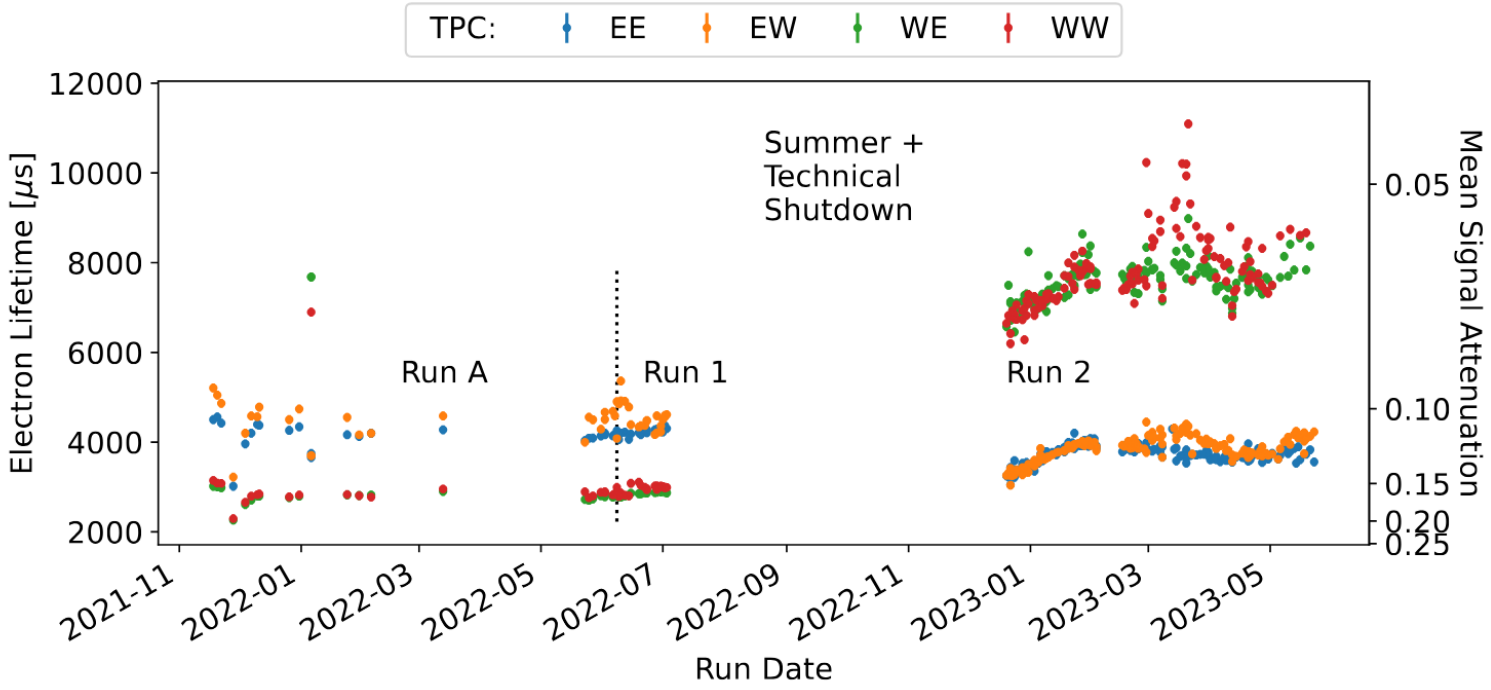




- Example training on front induction
- Validation loss converges after a few epochs

What I've Been Working on Recently: Detector Variations

- The performance of the ICARUS detector varies across its dataset in various ways



Argon Purity / Electron Lifetime

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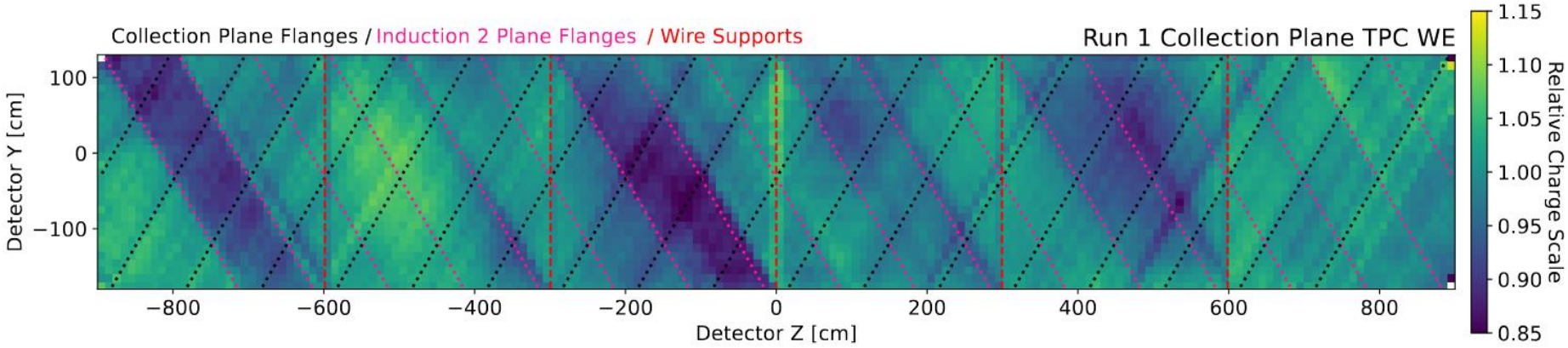
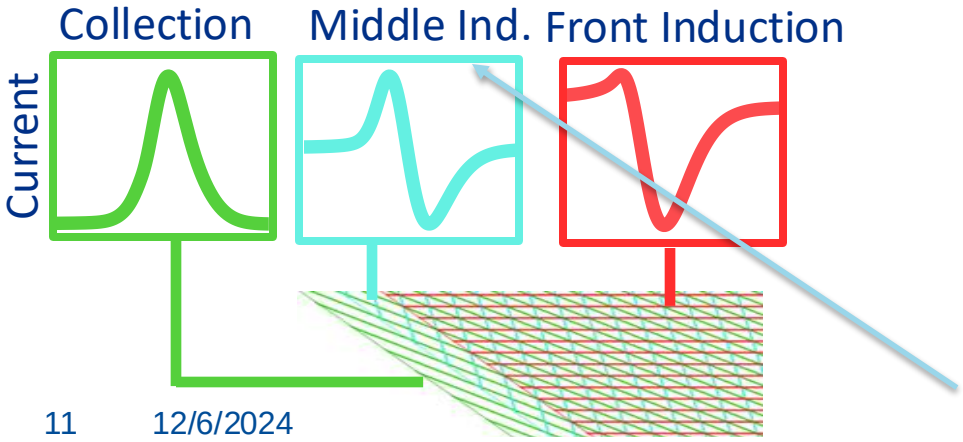


Wire Plane Transparency / Charge Scale Across Plane



Anomalous collection on middle induction

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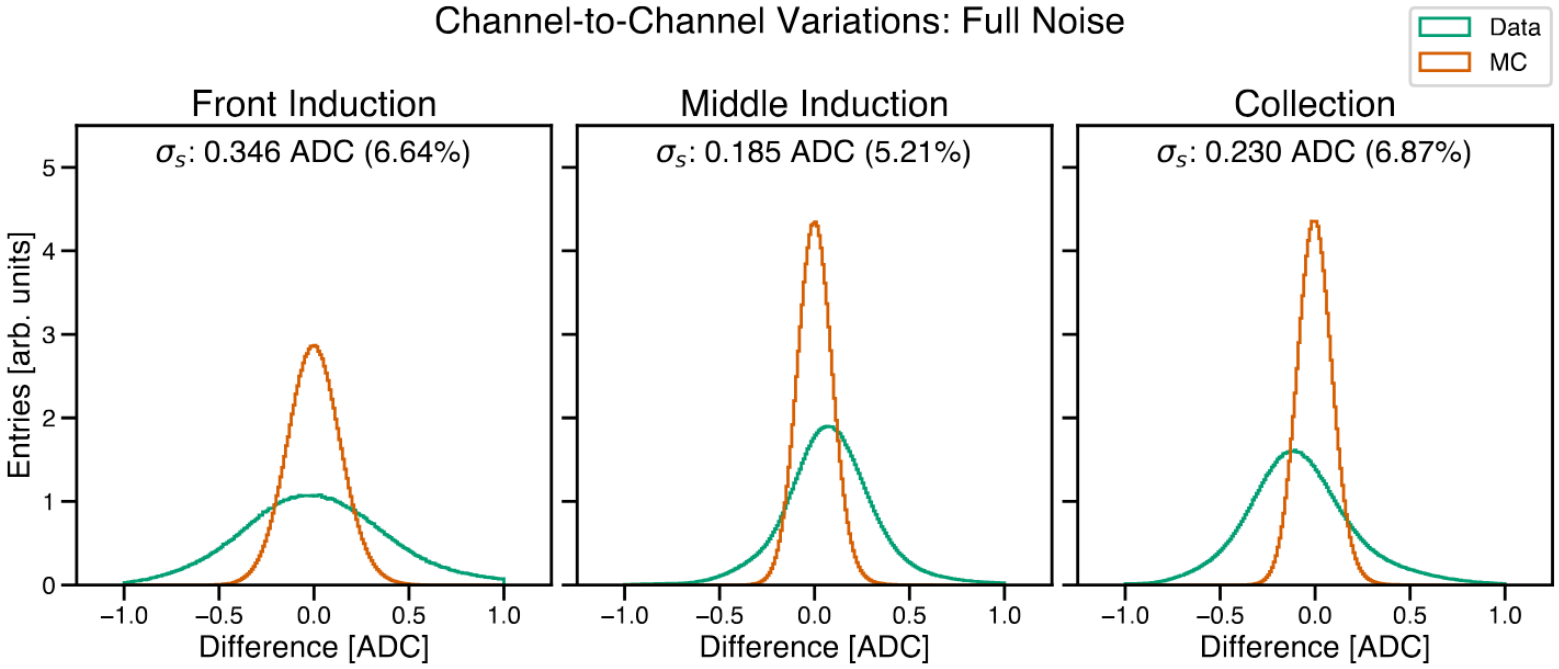

Channel-to-Channel Noise Variations

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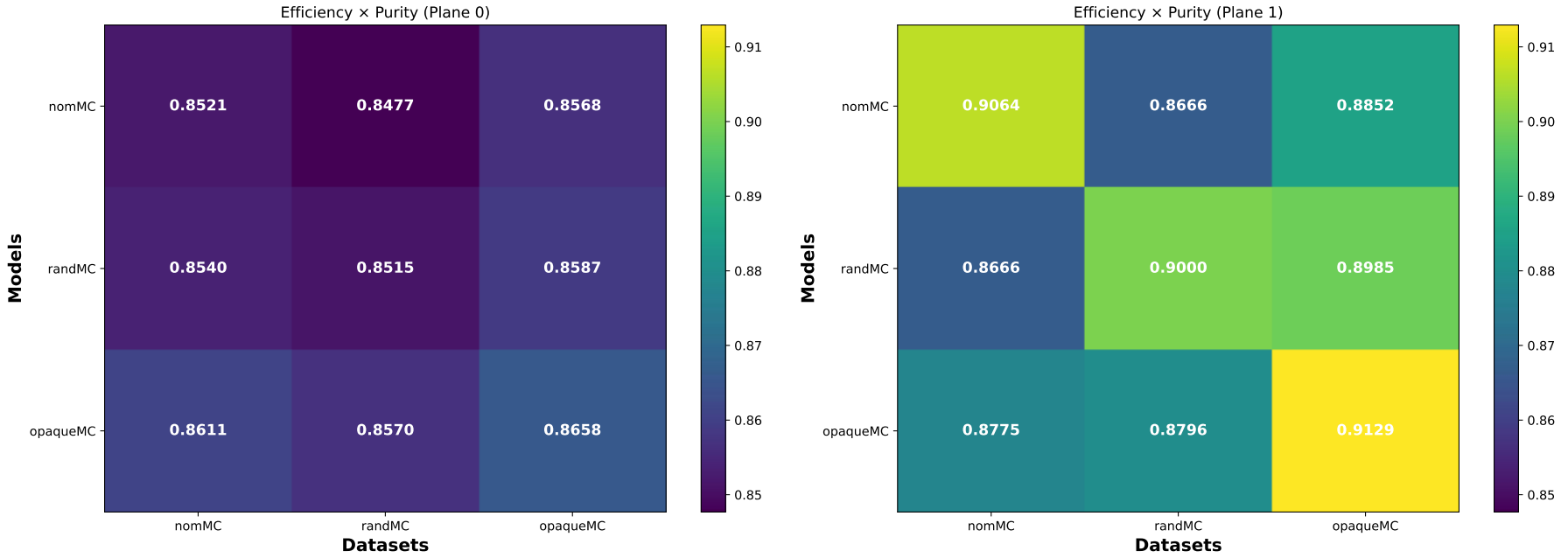
Omnidetector Detector Simulation

Github Link

- Omnidetector: generate a sample varying detector simulation values over their plausible range (*not necessarily 1σ*)
- Baseline variations:
  - Electron lifetime, uniform from 2-15 ms
  - Channel gain, gaussian 10% variation
  - Noise, gaussian 5% variation
  - Electronics response width, gaussian 5% variation
  - Middle induction signal shape, uniform from least to most transparent

Performance Comparison



- Table of model training sample (rows) v. validation sample (columns)
  - Nom: nominal detector simulation
  - Rand: omnidetector random variations
  - Opaque: maximum intransparency (challenging detector sim.)

Conclusion

- Deep Neural Network Region of Interest (DNN ROI) identification improves the low-level signal processing in LArTPCs

- I'm working with a group of people to integrate these for the SBND and ICARUS detectors in the Short-Baseline Neutrino Program

- Omnidetector simulation integrates a variety of detector simulations into model training and validation samples
  - The DNN ROI networks looks robust against these variations