DNNROI for ProtoDUNE-HD

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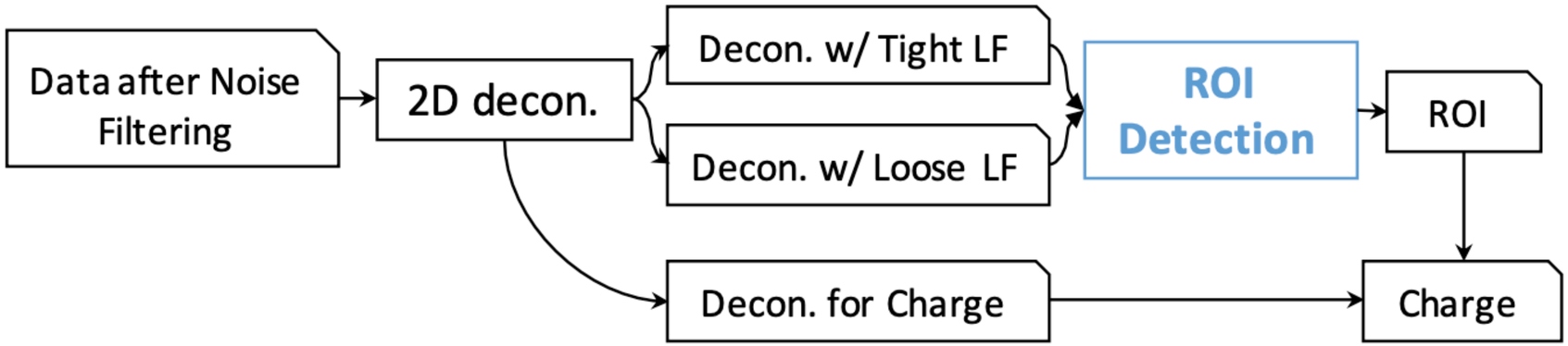
Introduction

- We have working Wire-Cell signal processing (SP) for ProtoDUNE-HD, inherited from ProtoDUNE-SP

- Want to improve ROI finder by integrating DNNROI described in *Yu, Haiwang W., et al. "Augmented signal processing in Liquid Argon Time Projection Chambers with a deep neural network." Journal of Instrumentation 16.01 (2021): P01036.*

- Today:
  - Briefly describe signal processing and DNNROI model
  - Initial training of DNNROI model
  - First look at performance and future work

LArTPC signal processing



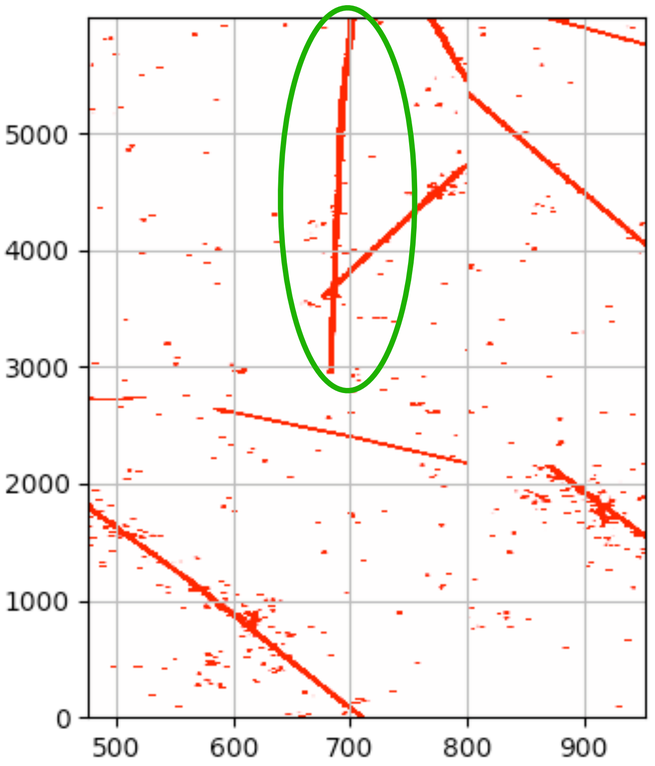
- Wire-Cell signal processing contains “ROI finding” algorithm
  - the low frequency noise is amplified in the deconvolution process
  - limit the deconvolution to a small time window that contains signal waveform
    - limit the low frequency noise in induction planes
    - reduce the data size and speed up the decon. procedure

ROI finding in Wire-Cell signal processing

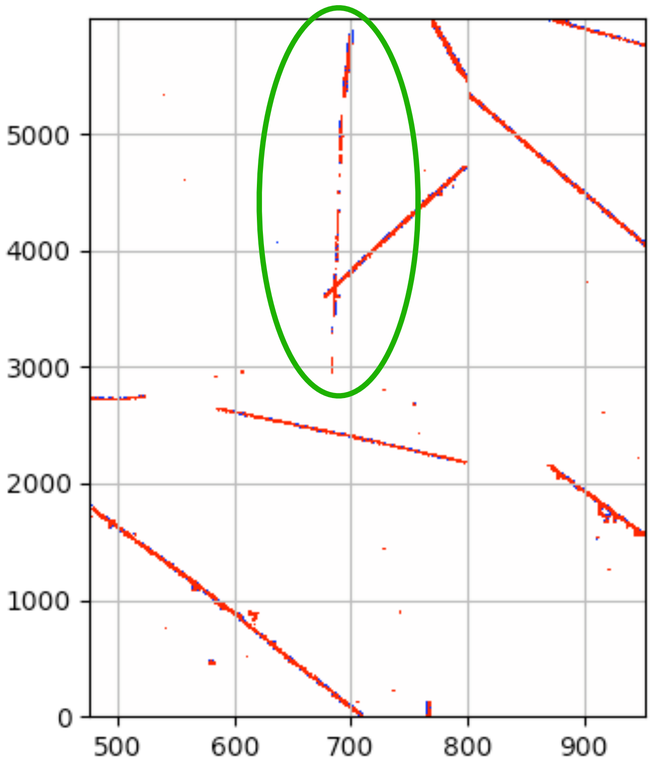
- Traditional ROI finding has its limitation
  - distorted waveform
  - weak signal/broken track for “prolonged track” events
  - noisy dots

Can solve with DNN ROI?

True MIP
PDHD sim.

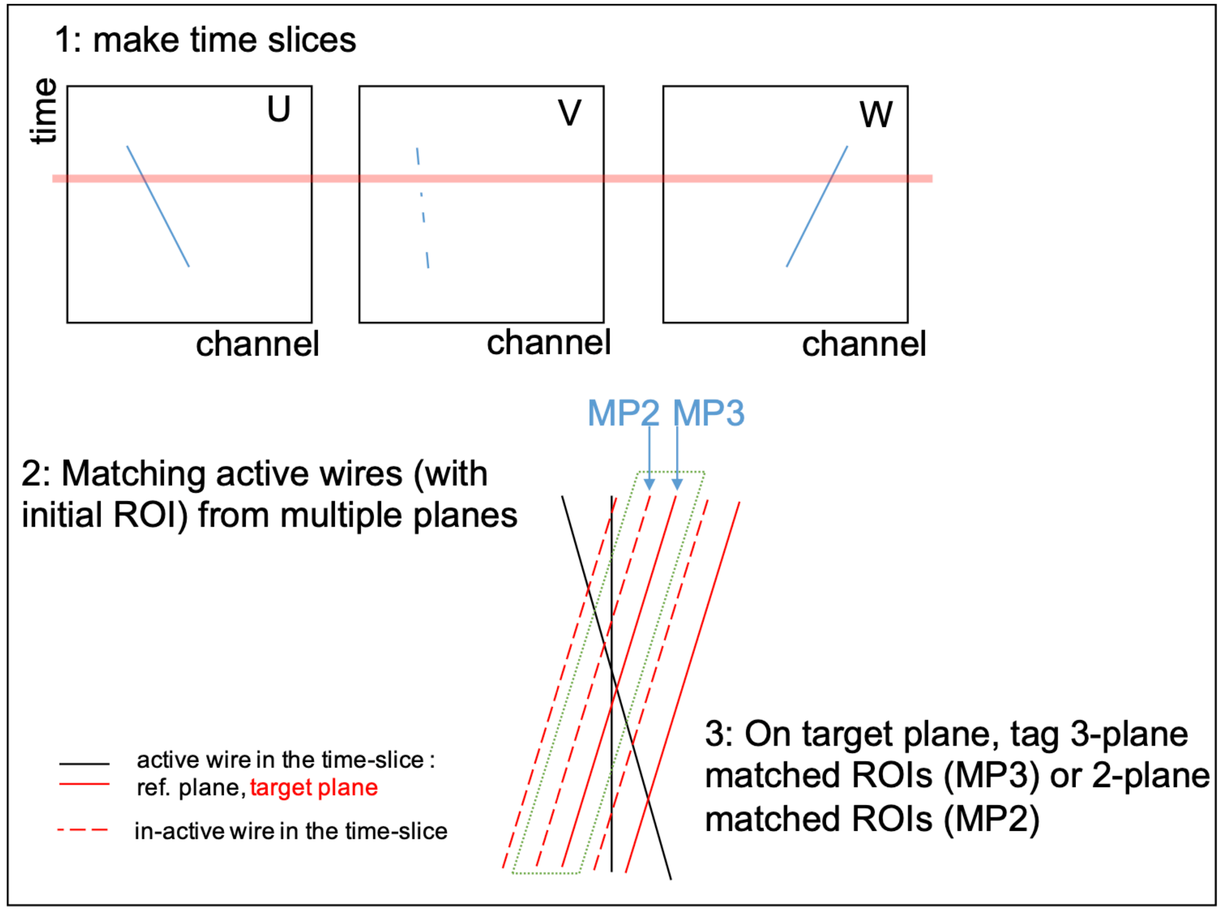


After SP



DNN ROI input

- the current DNN ROI for PD-HD has 3 training inputs:
  - loose low frequency filter (loose_lf)
  - 2-planes matched (MP2)
  - 3-planes matched (MP3)

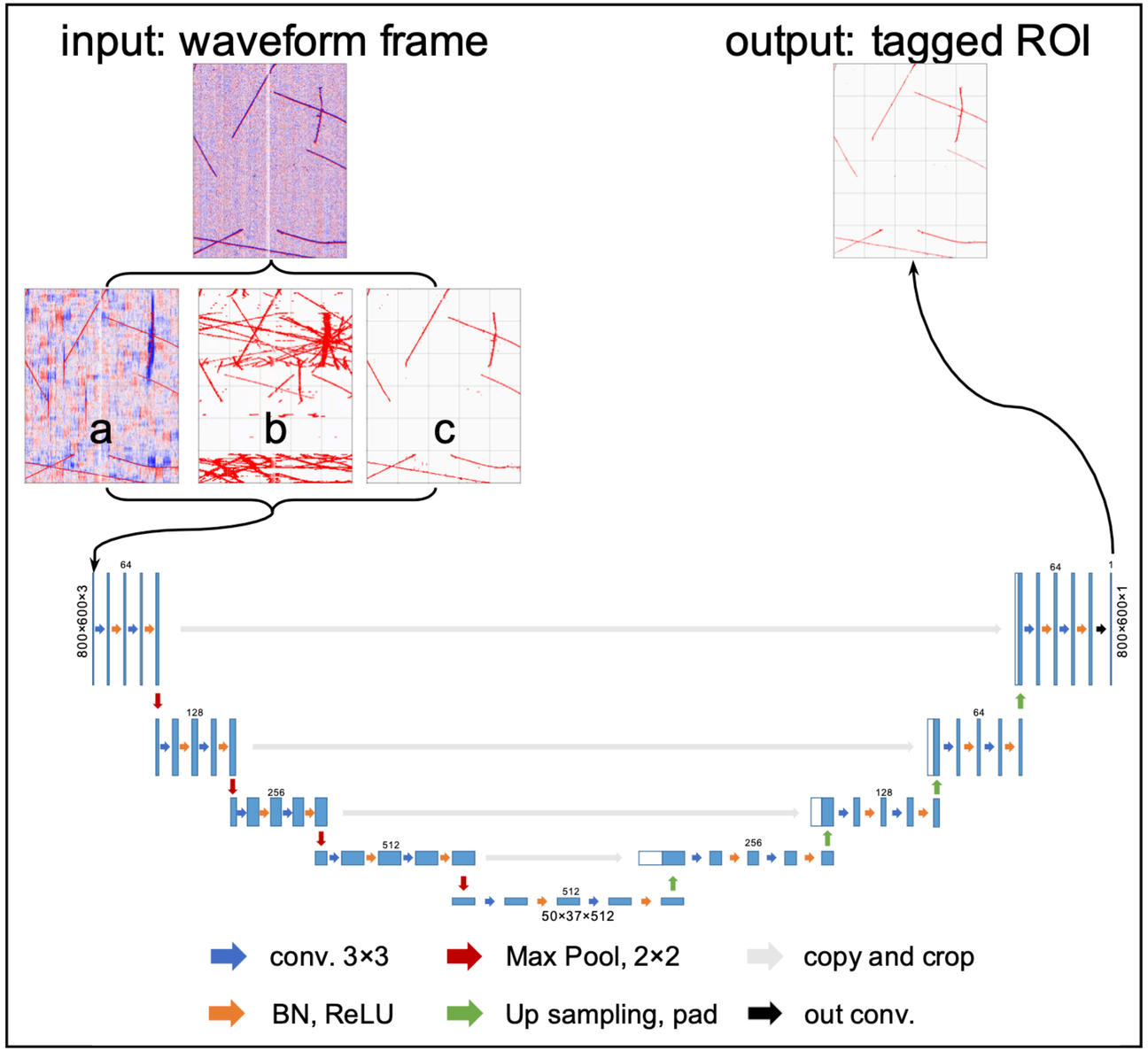


DNN ROI network

Uses Deep Neural Network – UNet
- arXiv:1505.04597

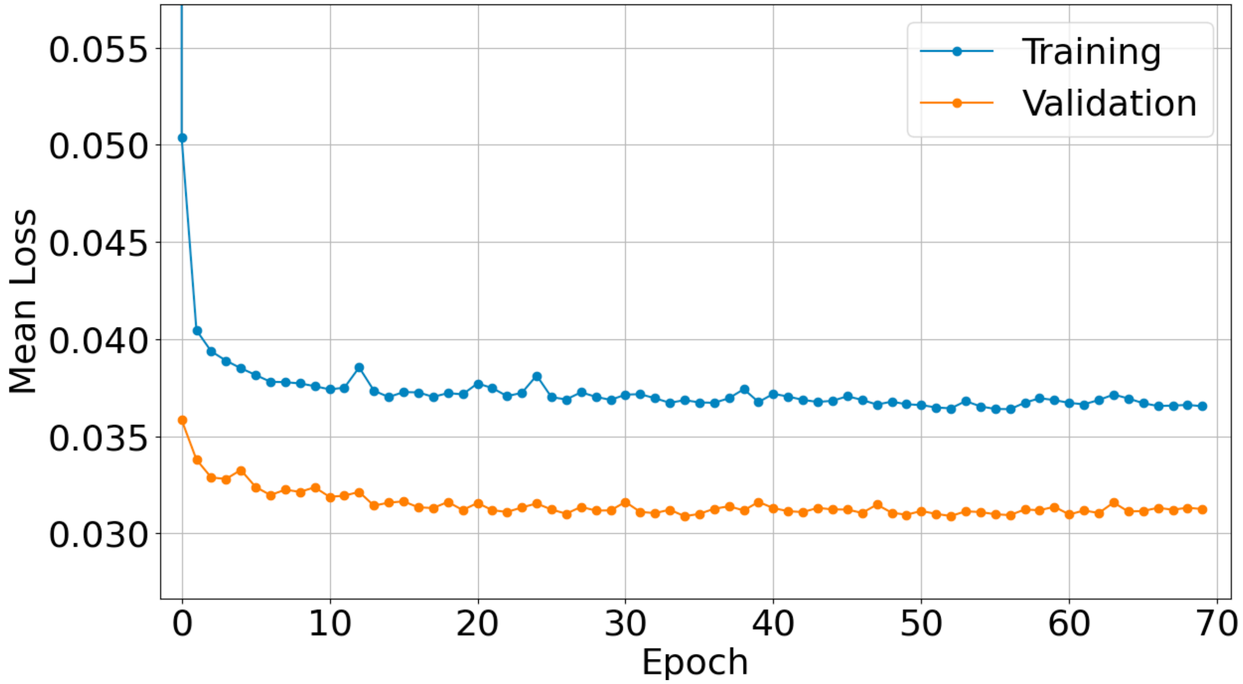
UNet: auto encoder-decoder + skip connections
- Output is sparsely connected components
- Input and output are similar at leading order

ROI finding as image segmentation
- Utilizing domain knowledge



DNN ROI Training

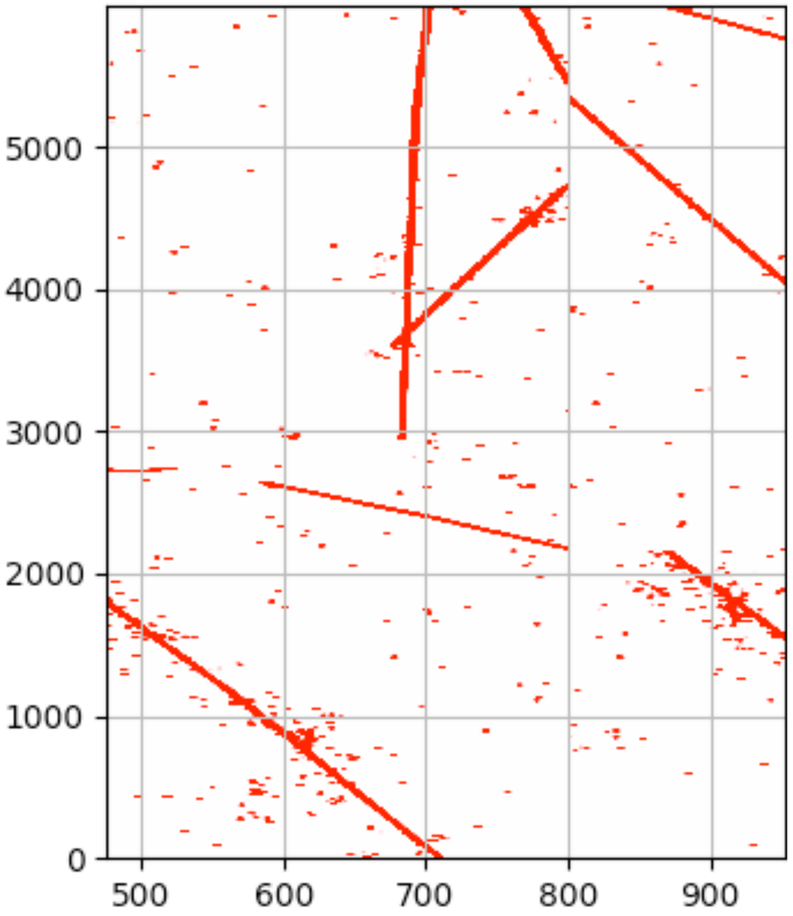
- 400 cosmic events in PDHD (80/20 %training/validation split)
- Loss: cross entropy
- Optimizer: Stochastic Gradient Descent with momentum
- Platform: I9-9900K, 32 GB memory, Nvidia GTX 2080 Ti 11GB, Samsung 970 500GB NVMe SSD [~5h]



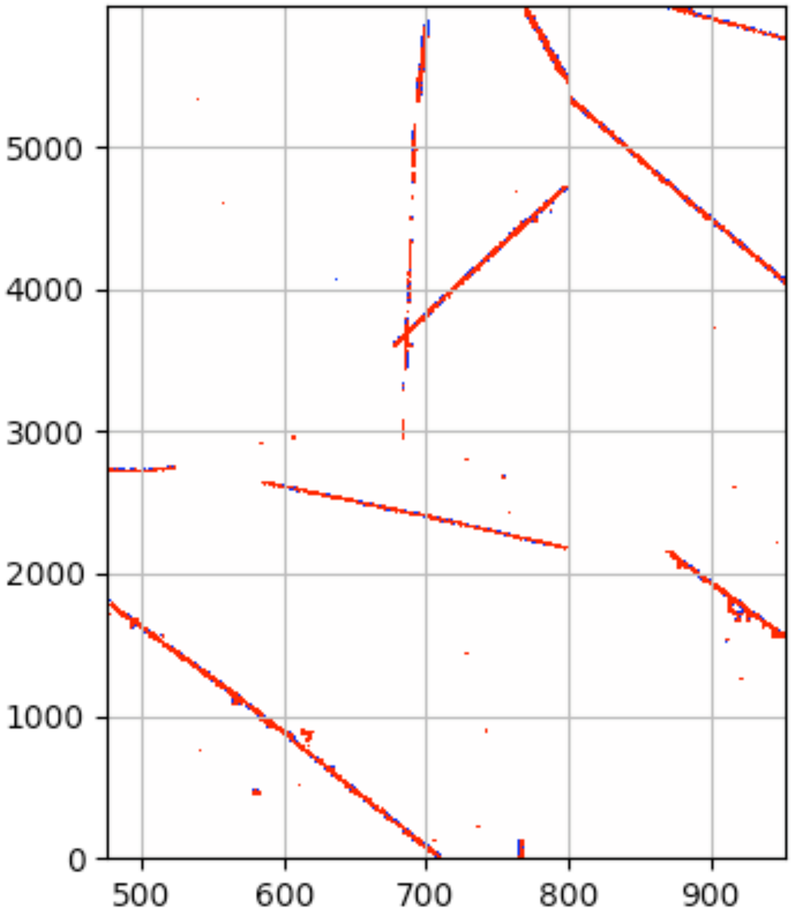
Cosmic event

Clear improvement
for prolonged cosmic track

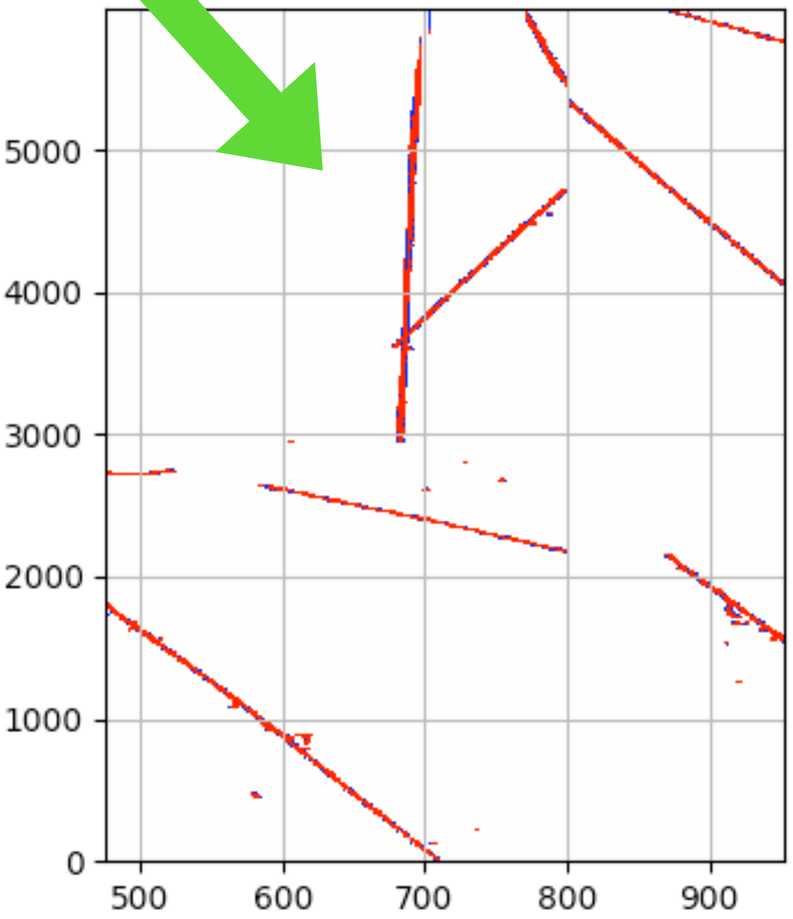
True Info



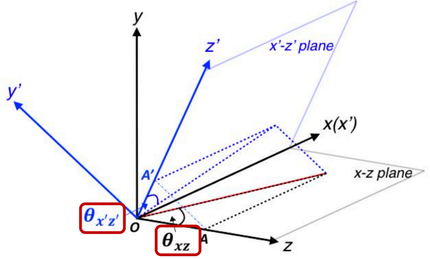
Standard ROI



DNN ROI



Pixel Efficiency/Purity



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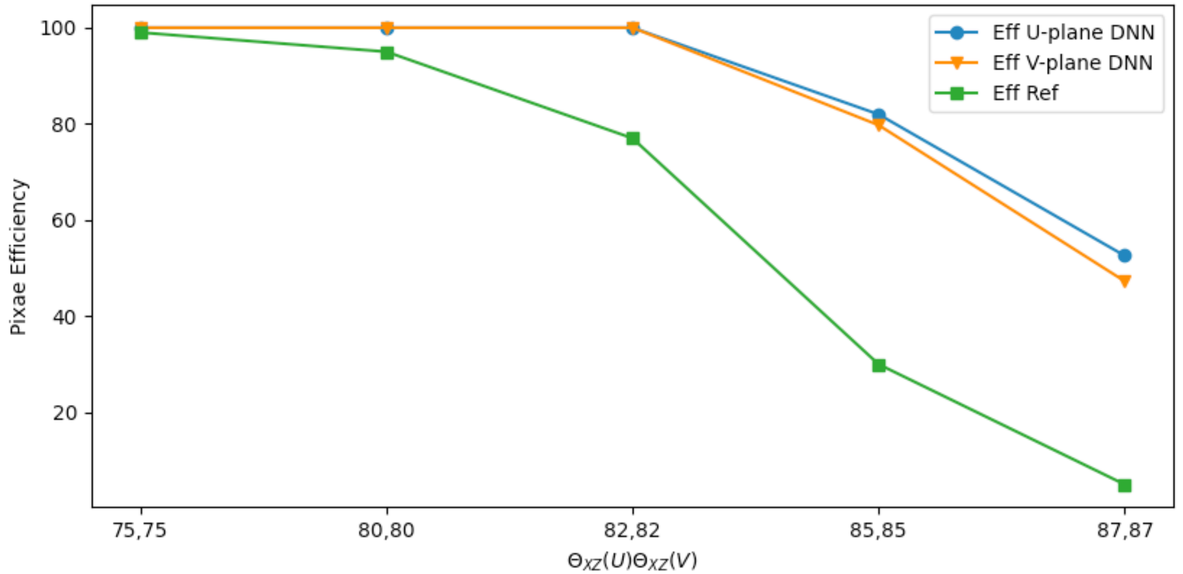
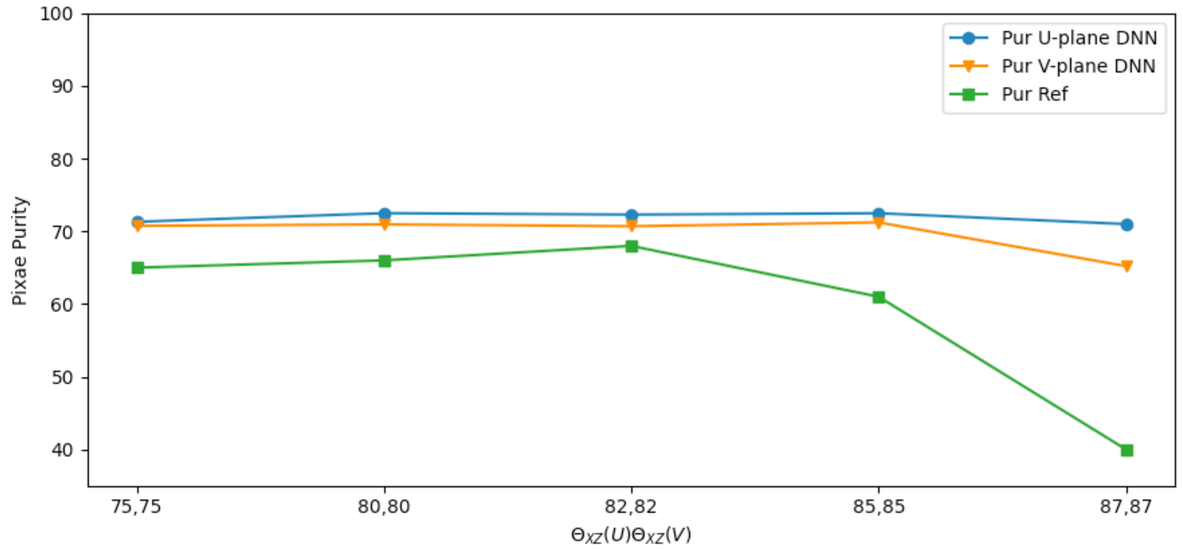
- Test for ideal tracks (1 per event)
- Evaluate network performance using :

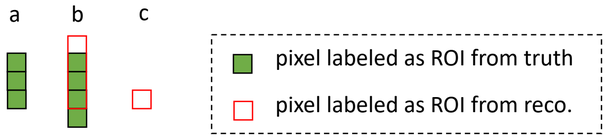
- $PixelEff. = \frac{\#\ of\ correctly\ abeled\ pixels}{\#\ of\ pixels\ from\ Truth}$
- $PixelEff. = \frac{\#\ of\ correctly\ labeled\ pixels}{\#\ of\ pixels\ from\ Reco}$



- Similar performance for lower angled tracks between DNN and reference approach
- DNN performs better for higher angled tracks



pixel based evaluation:
eff = (0 + 3 + 0)/(0+3+4) = 3/7
purity = (0 + 3 + 0)/(0+4+1) = 3/5

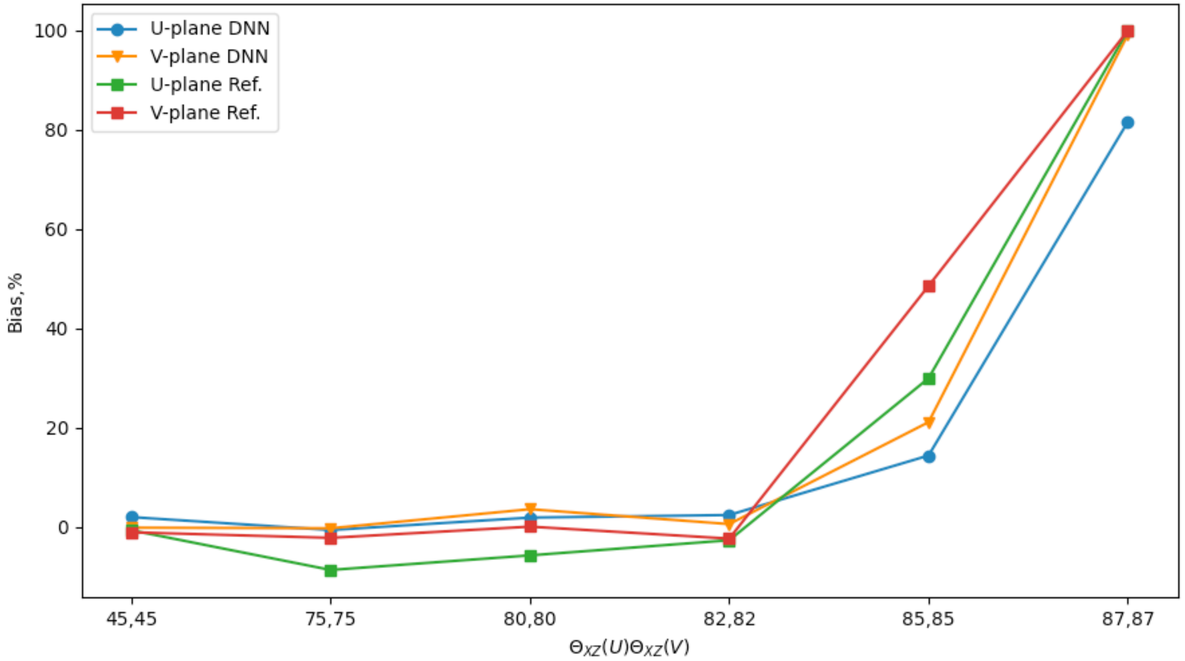


Charge bias

- Bias is 50% quantile of distribution :
  $100 * (\frac{q_{true} - q_{reco}}{q_{true}})$ per channel

- Thresholding in ROI finding is major source of charge bias: signal loss can occur due to its exclusion from the final ROI window

- Larger bias in large angle tracks (as expected)

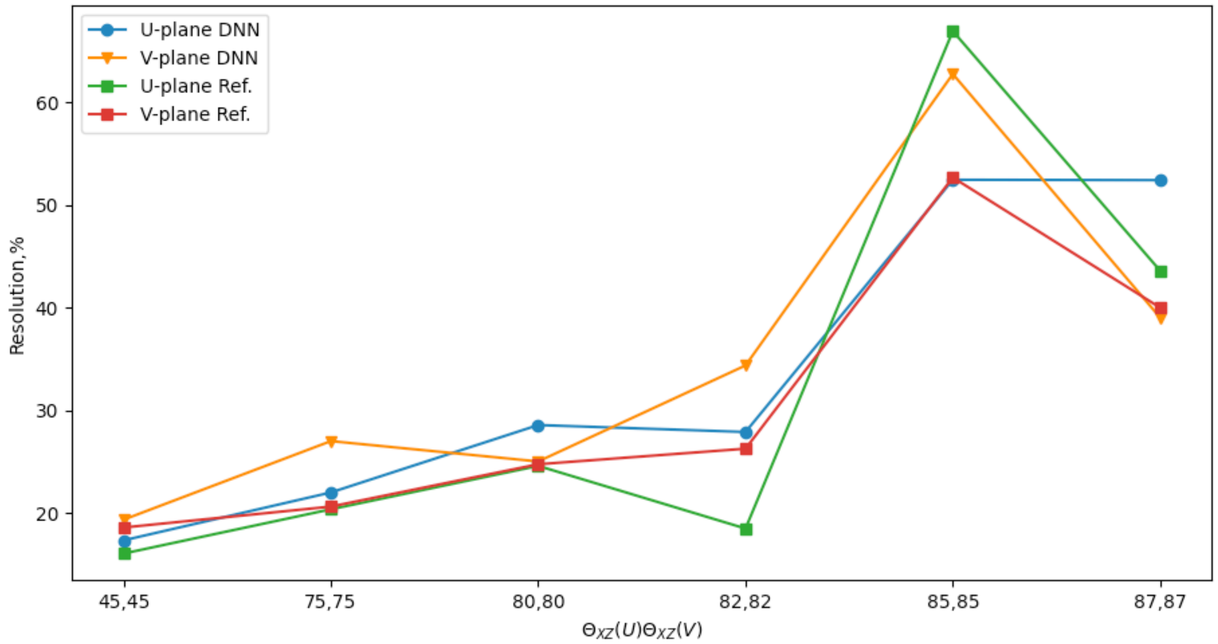


Charge Resolution

- Resolution also drawn from distribution $100 * (\frac{q_{true} - q_{reco}}{q_{true}})$ per channel based on difference between 50% 16%, and 84% quantiles

- electronics noise is the main contributor to the charge resolution

- worse resolution in large angle tracks (as expected)



Summary

- DNNROI is implemented as part of SP for ProtoDUNE-HD
- Trained with small sample of simulated cosmic events
- Shows improvement over reference WC ROI-finding algorithm for high-angle tracks

- Future Work:
  - Current tests only show small phase-space of track angles
  - Need test on EM-showers (probably with separate training)
  - Work on possible use of DNNROI in production chain (memory/speed evaluation)