# DNN ROI For WireCell Signal Processing

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WireCell Reconstruction Summit

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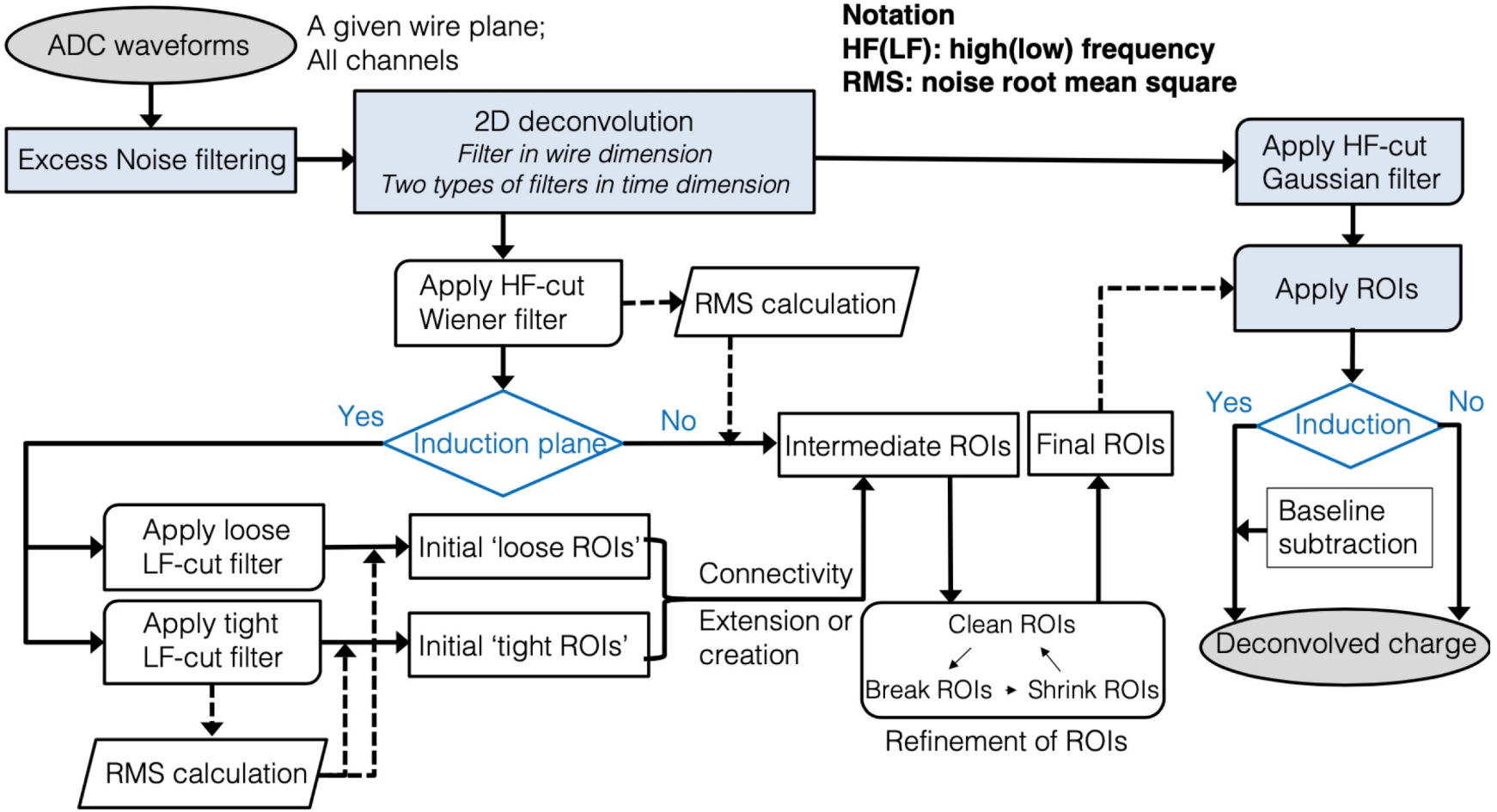
THE UNIVERSITY OF CHICAGO

# WireCell Signal Processing

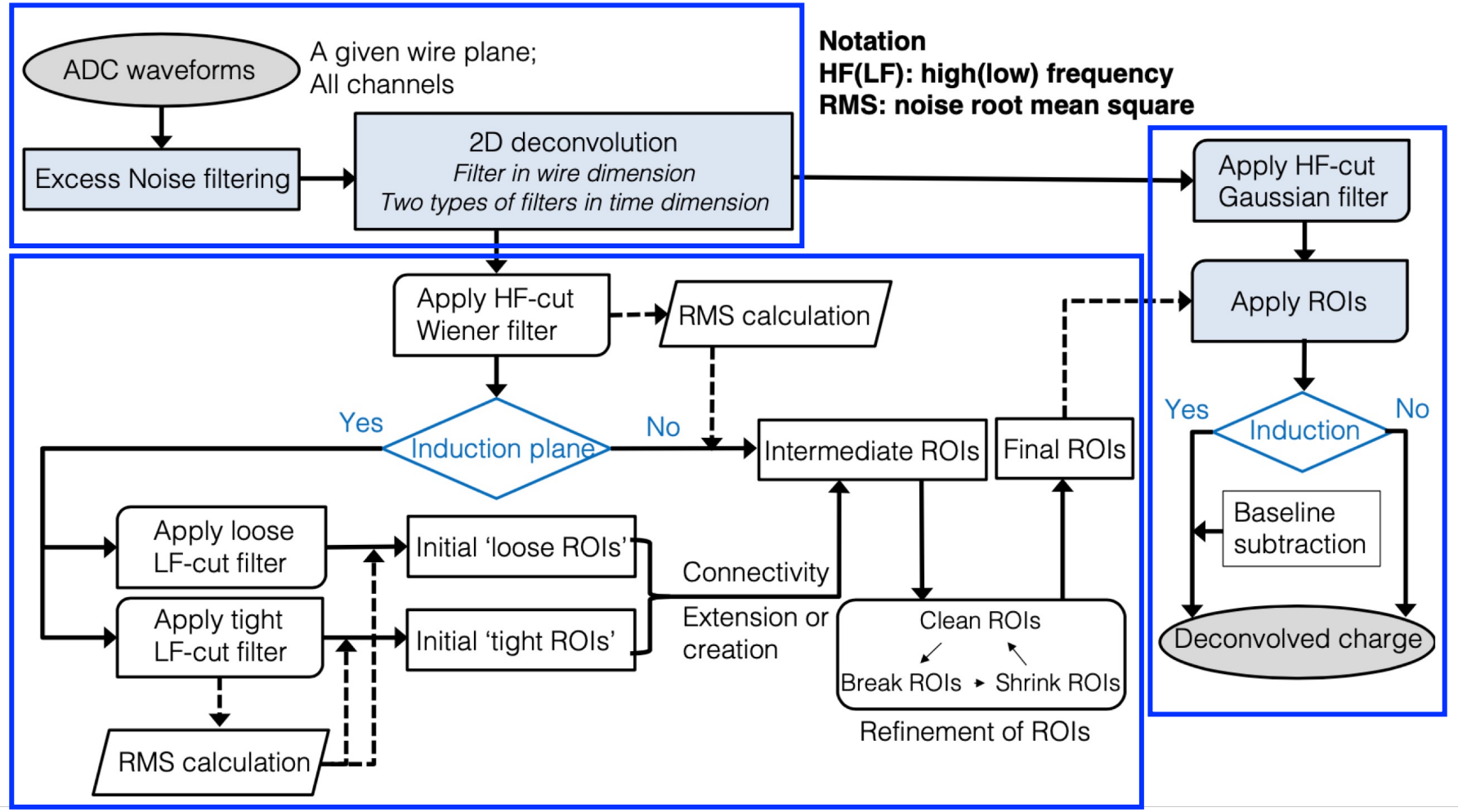


# WireCell Signal Processing

1. 2D Deconvolution

2. ROI Finding

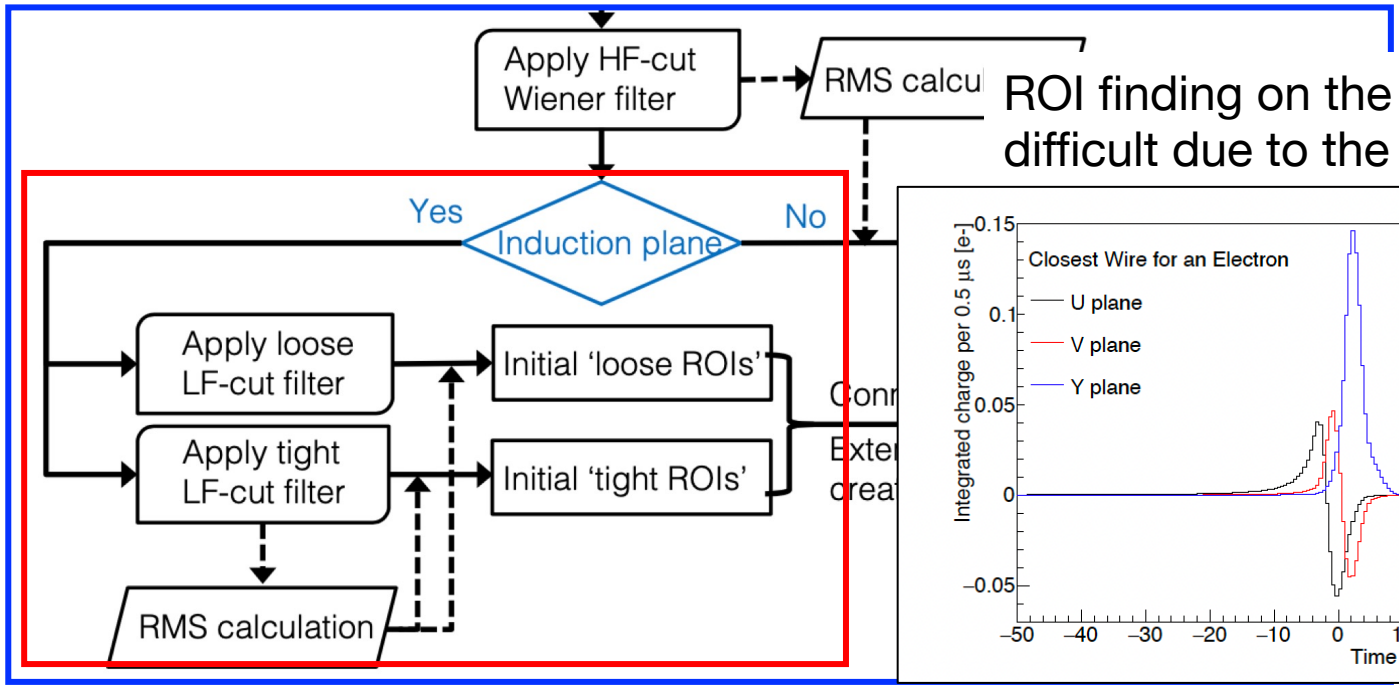
3. Charge Extraction



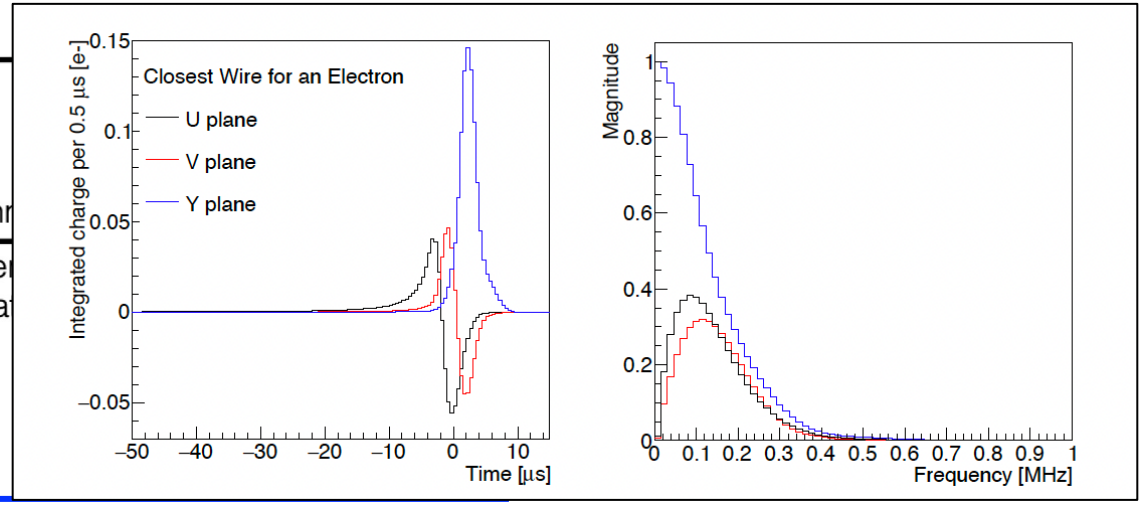
# ROI Finding

- Region of Interest (ROI) finding is the process of identifying the window that contains the signal of interest
  - makes signal processing computationally feasible
  - accurate ROI finding is essential for good charge extraction

2. ROI Finding




ROI finding on the induction planes are difficult due to the bipolar signal response



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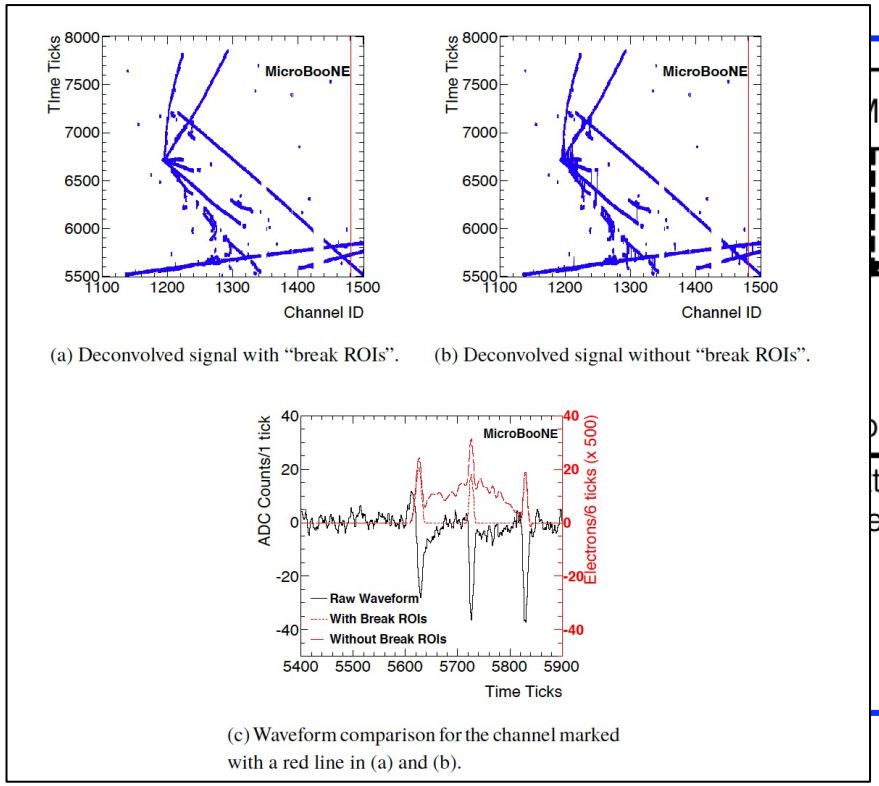
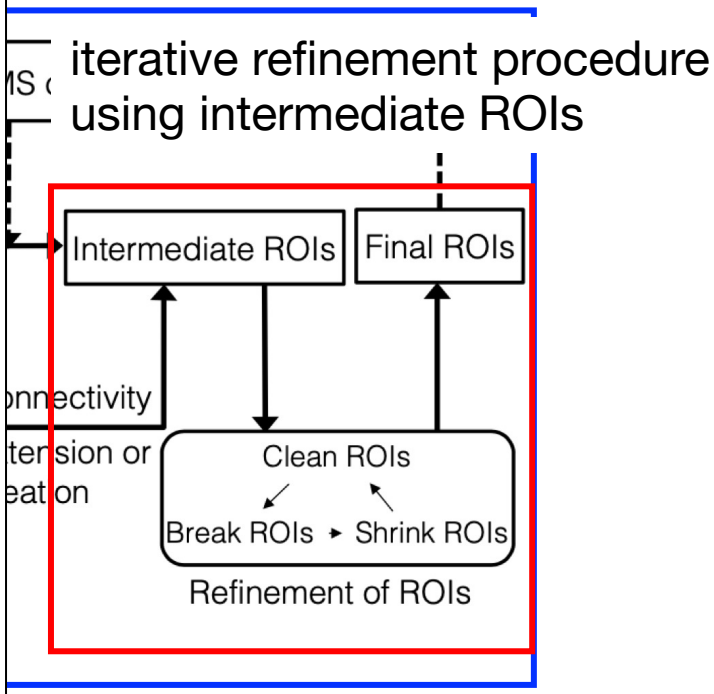
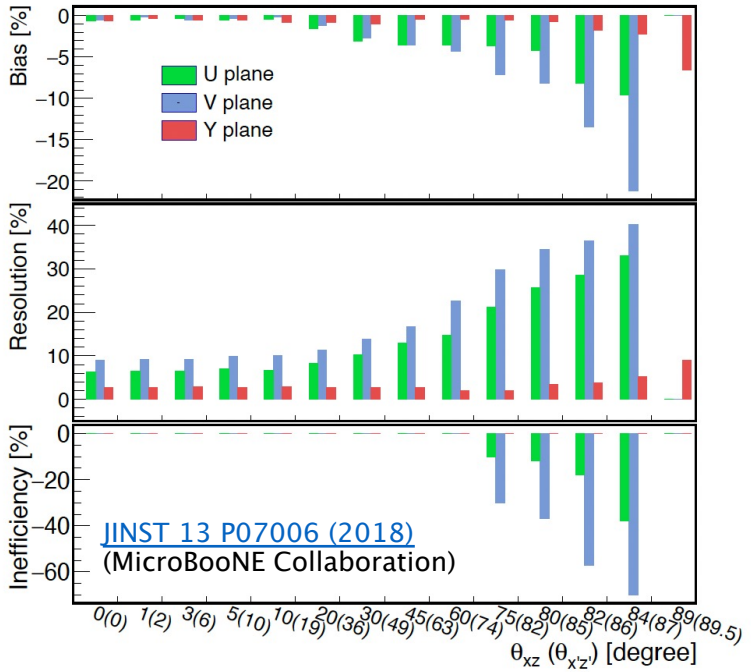
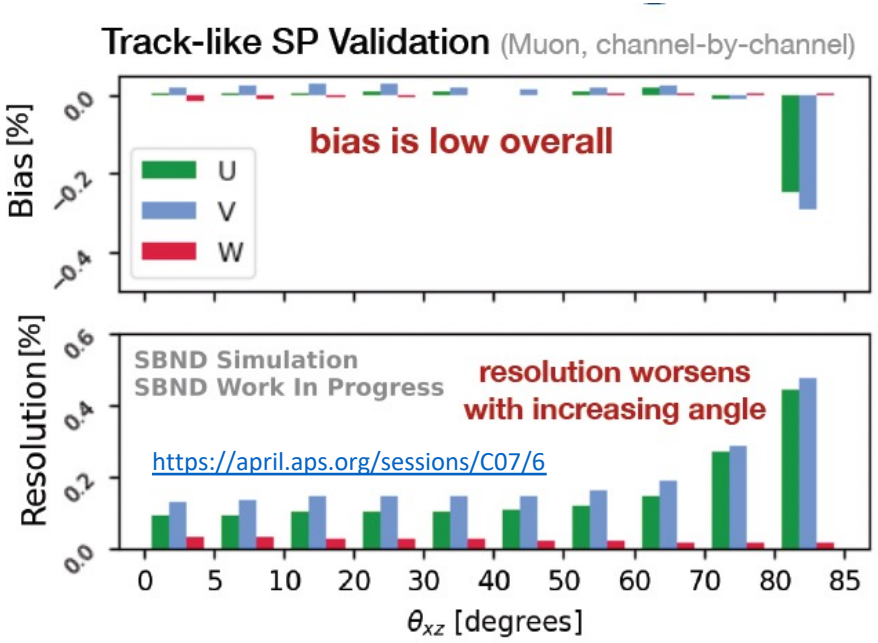


# Limitations of the Traditional Method

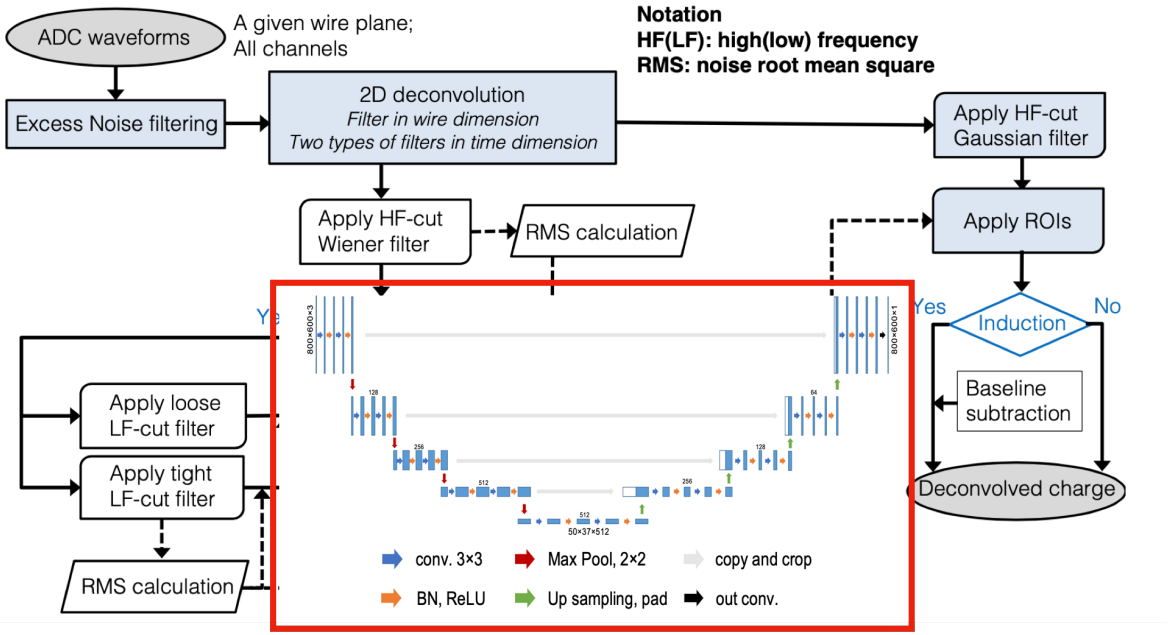
- Procedure for the optimization of the traditional ROI finding algorithm is nontrivial and computationally challenging
  - filters are simultaneously optimized by coordinate descent approach
  - decision of filter values from evaluation on different samples by eye
- Optimized algorithm shows limited performance for prolonged tracks



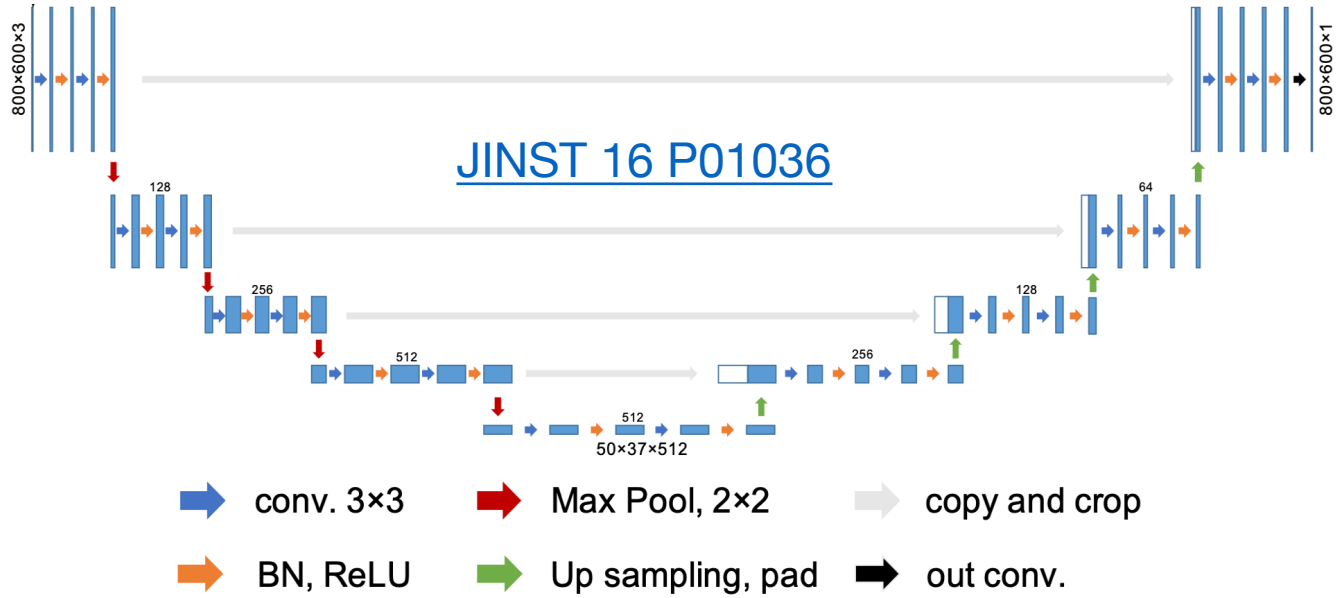
# DNN-based ROI Finding

- DNN-based tool to address the limitations of the traditional method
  - network learns and recognizes features of prolonged tracks from images
  - faster and easier optimization process
- Tool developed by the protoDUNE experiment (JINST 16 P01036)
  - Integration into the data signal processing workflow is work-in-progress at SBND and protoDUNE



# Network Architecture

- ROI finding is a binary classification task of each pixel in an image
- UNet-type network is a suitable architecture for the task
  - widely used for image registration and segmentation
  - output dimension is same as input dimension



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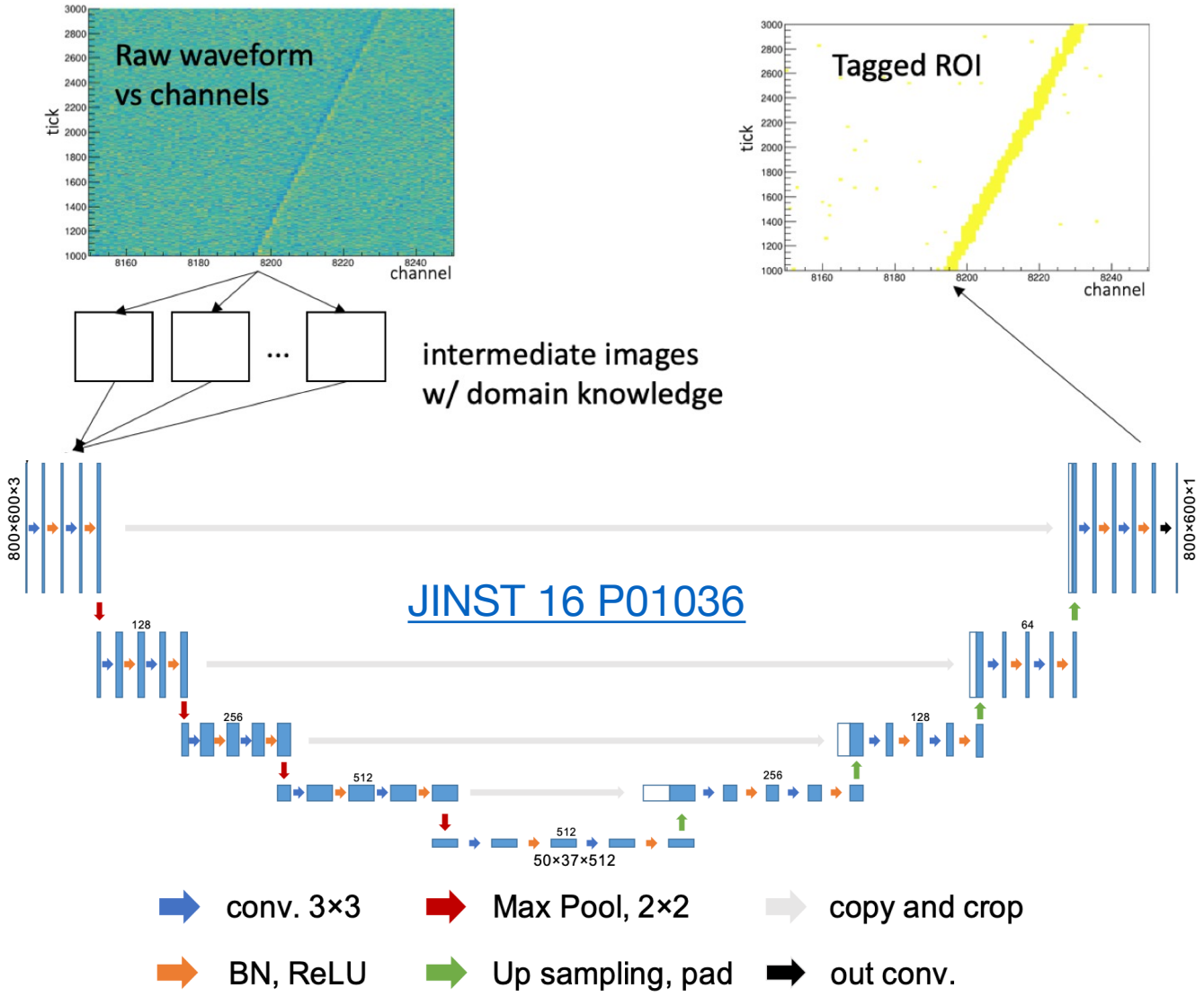
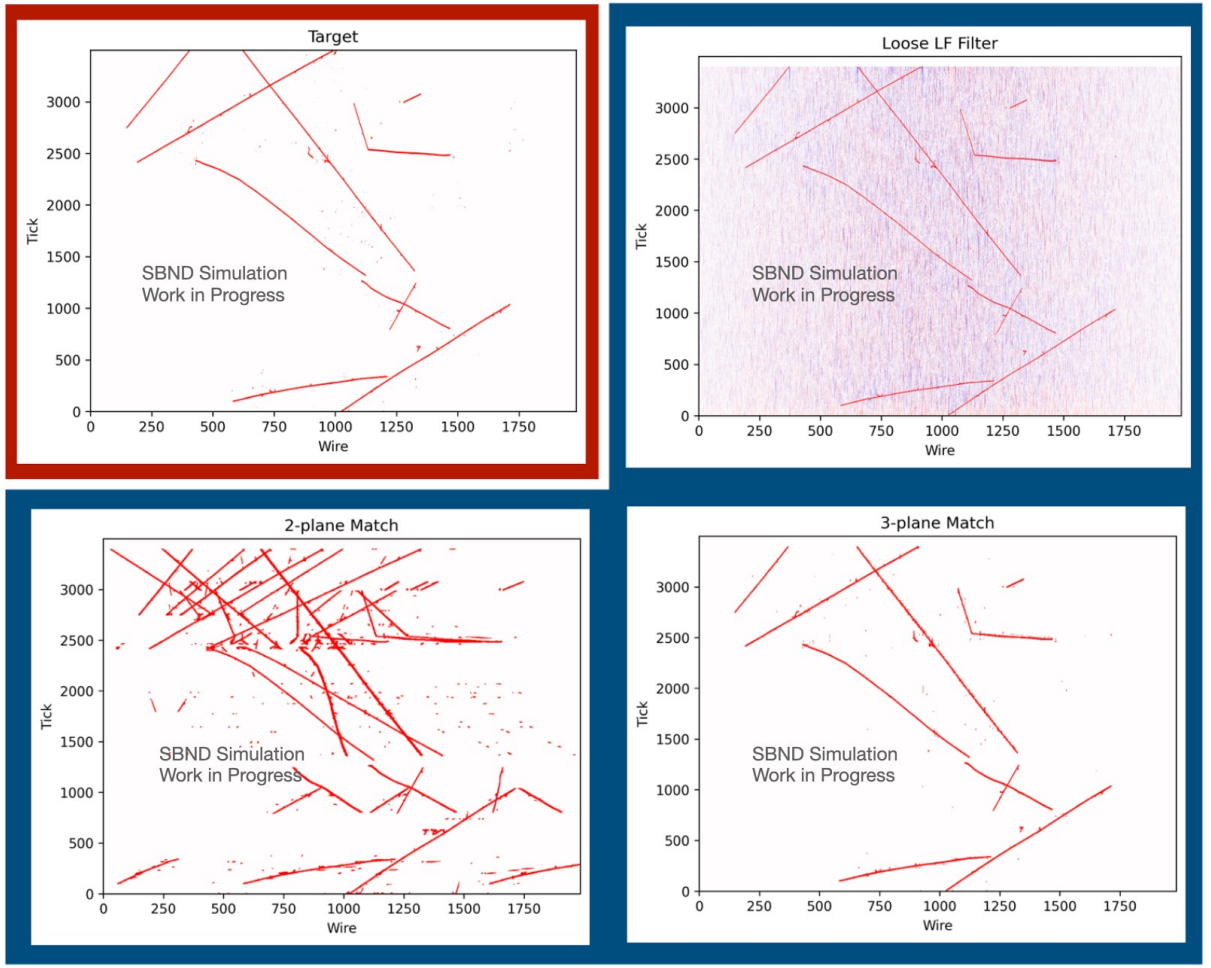


# Training Samples

- Training images made from simulated neutrino events
  - **target images** is made from setting a threshold on simulated charge deposit
  - **input images** are made from intermediate stages of the traditional signal processing chain
    1. Loose LF filter: preserve prolonged track signals that are washed out my tighter filters
    2. 2-plane match
    3. 3-plane match: multiplane match outputs to inform network of geometric constraints from other planes



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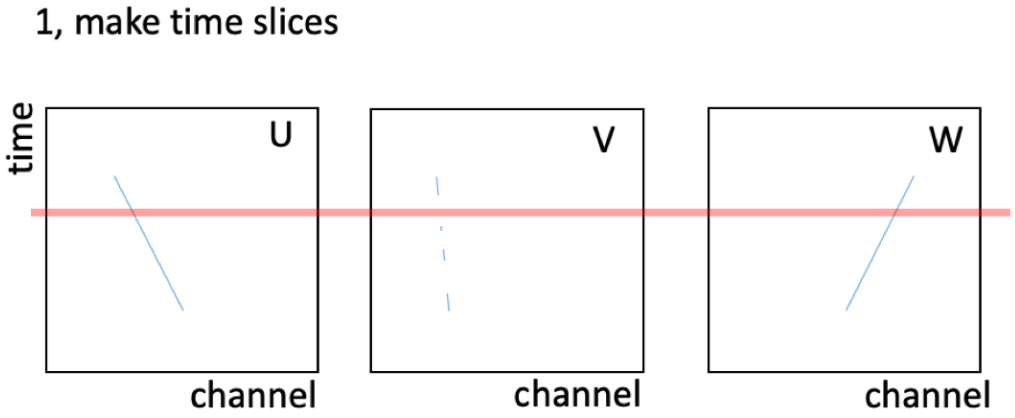
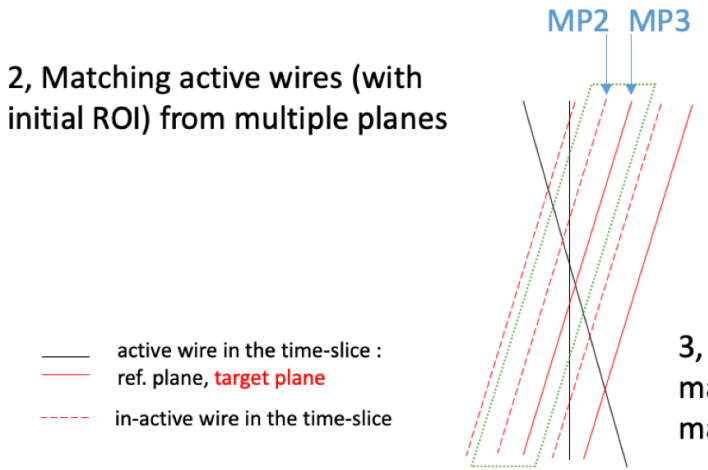


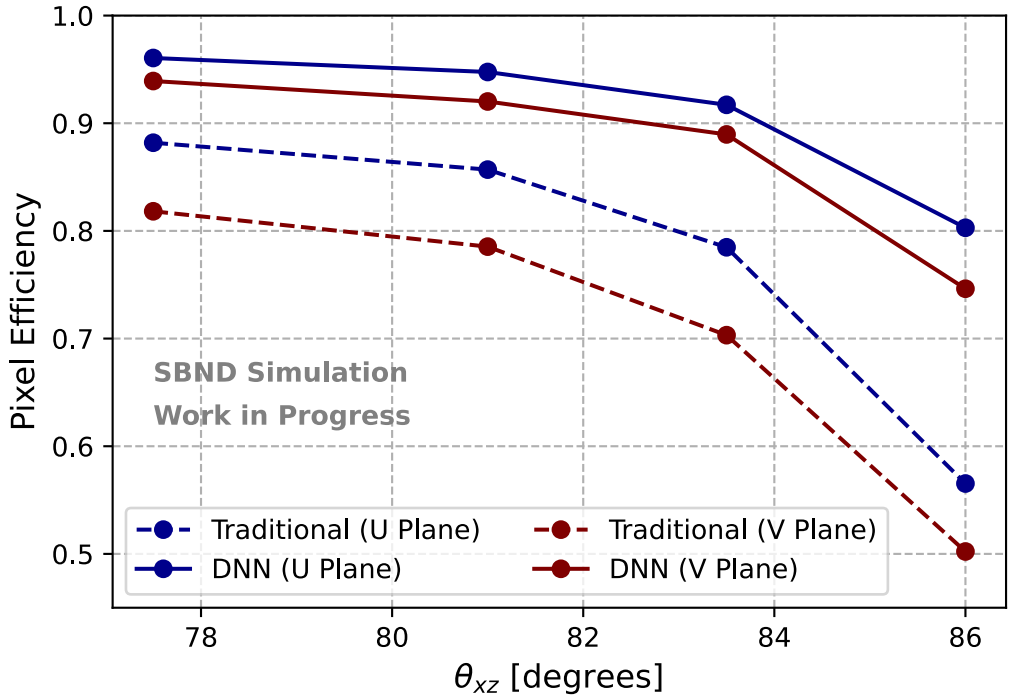




[JINST 16 P01036]

3, On target plane, tag 3-Plane matched ROIs (MP3) or 2-Plane matched ROIs (MP2)

# Pixel Performance Evaluation

- For pixelwise ROI identification performance, DNN-based method shows clear improvement in comparison to the traditional method

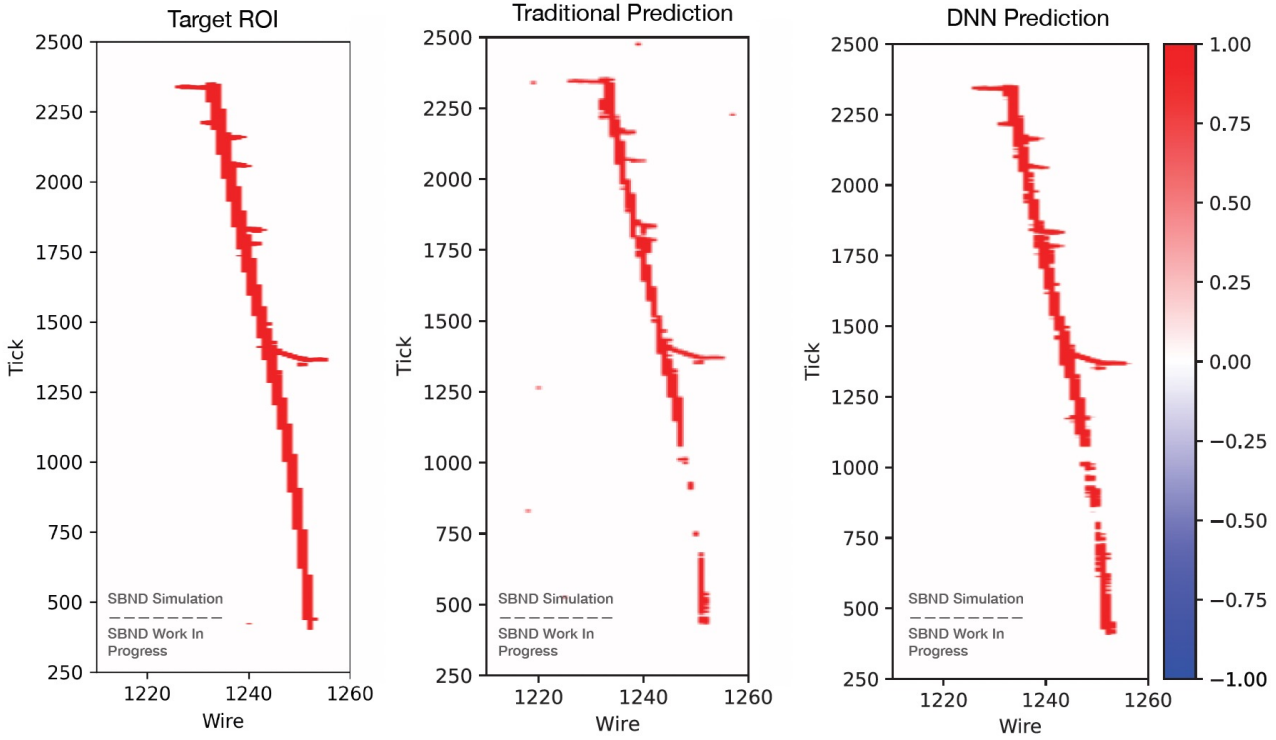



- UNet architecture
  - UResNet and Nested UNet had similar performance but more memory usage
- Performance evaluated on simulated muon tracks
  - positive threshold set to 0.5 for DNN ROI finding inference
  - traditional ROI finding from SBND optimized signal processing algorithm

# Validation on Prolonged Tracks

- Room for improvement
  - approaches from the training side: deeper network, more samples
  - approaches from the inference side: adjust threshold, extra filtering for resulting false positive noises

https://april.aps.org/sessions/C07/6

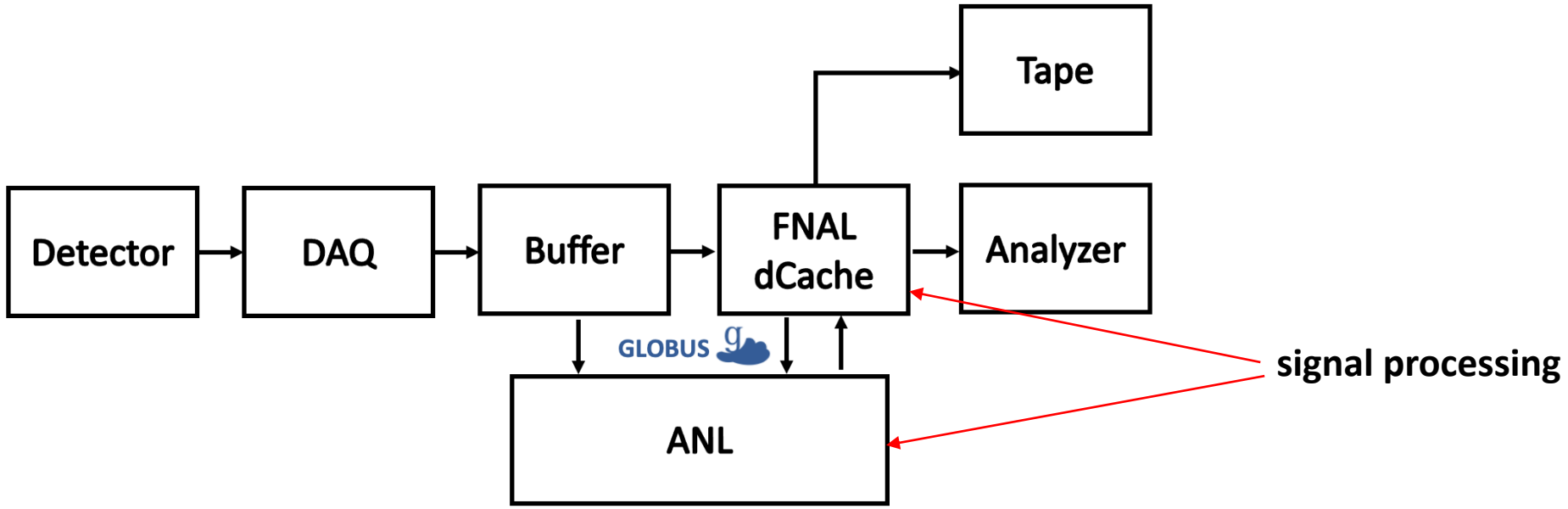


# Computational Resources

- DNN ROI method requires GPUs for feasible integration into actual data processing workflow
- UChicago group has access to vast computational resources at ALCF
  - Polaris (current production machine) has 560 nodes, each with 32 cores/64 threads Intel Xeon processors, 512 GB RAM, 4 Nvidia A100 GPUs (https://docs.alcf.anl.gov/polaris/hardware-overview/machine-overview/)
  - opportunities for using GPU-accelerated tools workflows

# Prompt Signal Processing for SBND

- For SBND, data processing will take place in two locations
  - data will be copied from FNAL dCache to ANL facilities in real-time via GLOBUS
- To take advantage of ANL facilities, signal processing needs to take place after the copying, not after the buffer
- Discussion for data flow has started



# Summary and Future Directions

- The DNN-based ROI finding method for WireCell signal processing shows promising performance
  - speed up optimization process of the algorithm
  - improve signal processing performance on prolonged tracks
- Integration of the tool, along with other GPU-accelerated tools is actively being worked on at UChicago and ANL
  - we have vast computation resources providing opportunities for these studies
  - active work software integration is ongoing
  - discussion on the data flow including prompt signal processing has started
- Studies on implications for charge extractions and robustness against detector variations are being discussed