RECONSTRUCTING 3D POSITIONS OF CHARGE IN MICROBOONE

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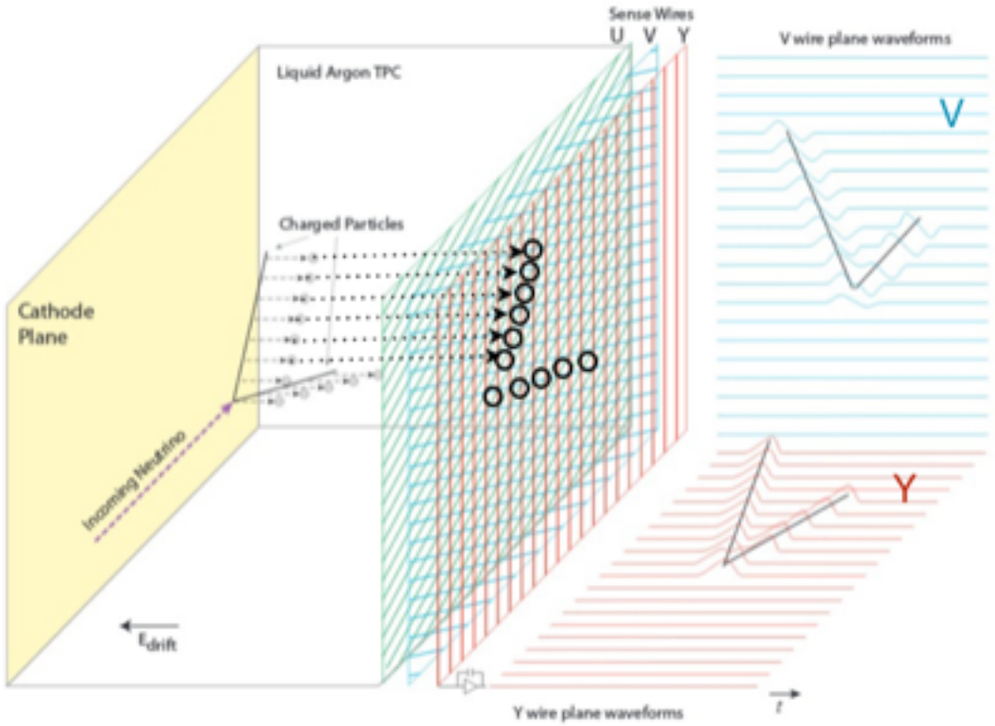
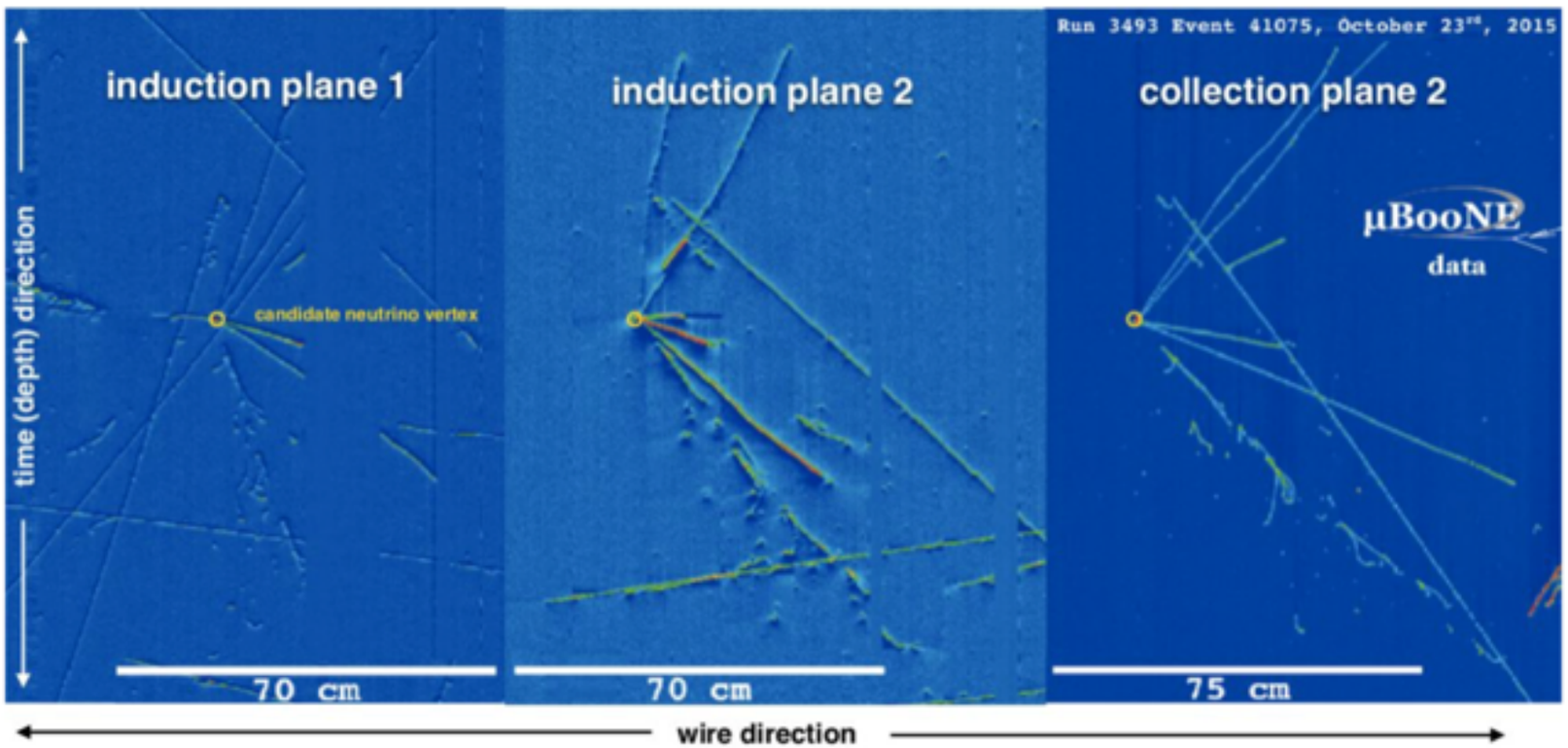
Wire Readout LArTPC



- Charged particles ionize Ar
- Ionization e^- drift in E field towards anode
- Induce charge on wires while passing by **induction** planes
- Collected on **collection** plane



Data recorded as 2D images of charge on **wires** vs **time:** projections of 3D trajectory

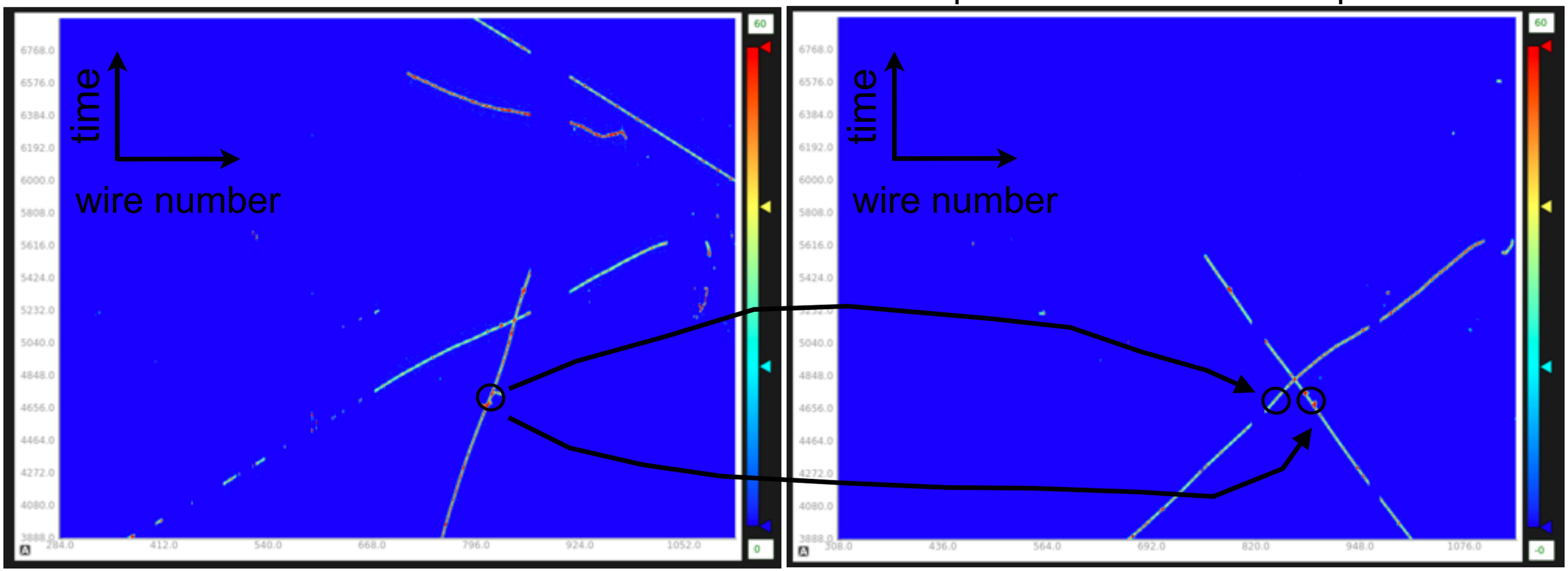
3 images for the three wire planes

3D Space-point Reconstruction In LArTPCs

- 3D reconstruction in LArTPCs: requires association b/n same-time charge deposits in 2D wire-plane images
- Degeneracies when having multiple trajectories at the same time
  - problem in shallow LArTPC experiments where CRs abundant

Charge depositions on Induction plane 1

Same time window charge depositions on Collection plane

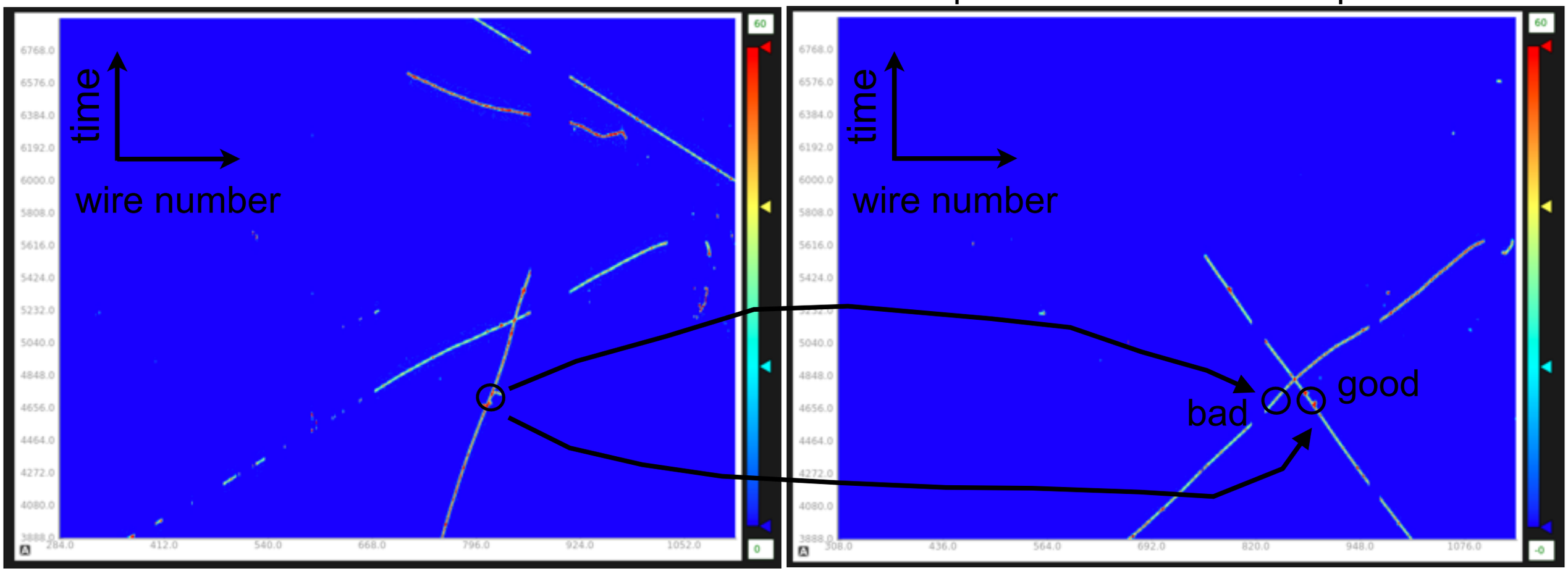


3D Space-point Reconstruction With LArMatch

- LArMatch algorithm
  - generate possible wire-plane charge matches
  - classifier scores matches between 0 (bad) and 1 (good)
  - 3D space-point reco'ed from wire match

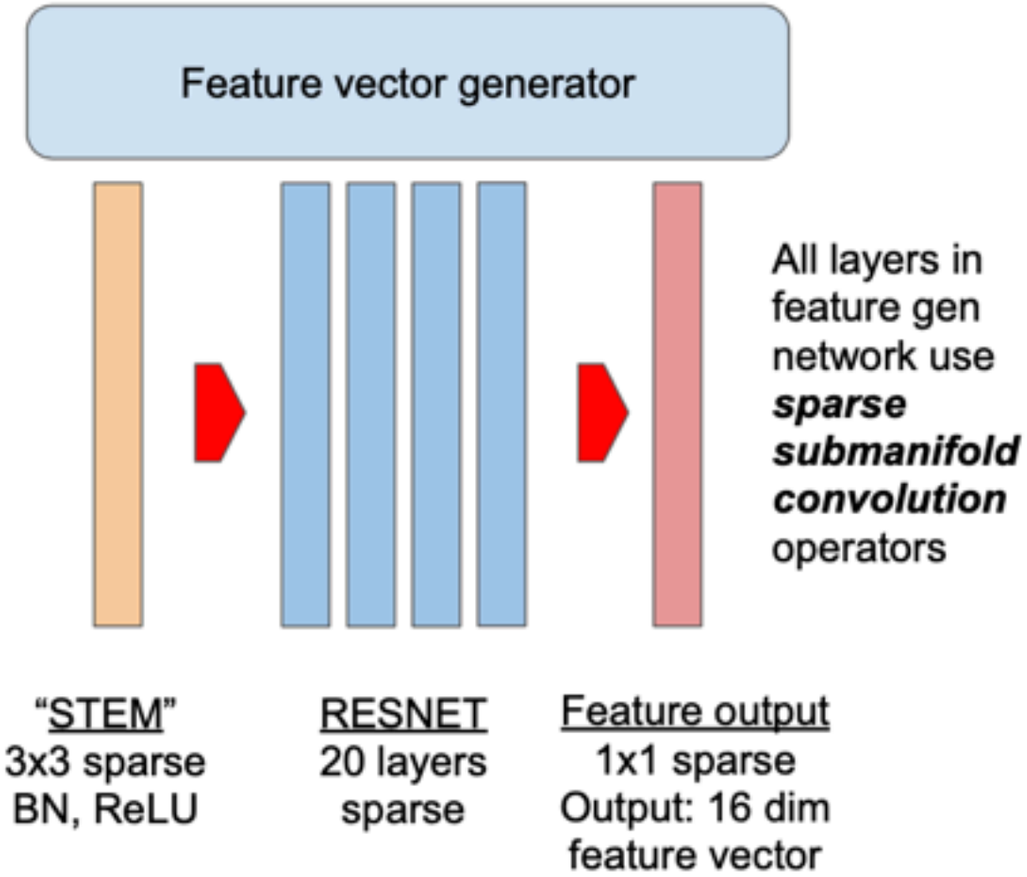
Charge depositions on Induction plane 1

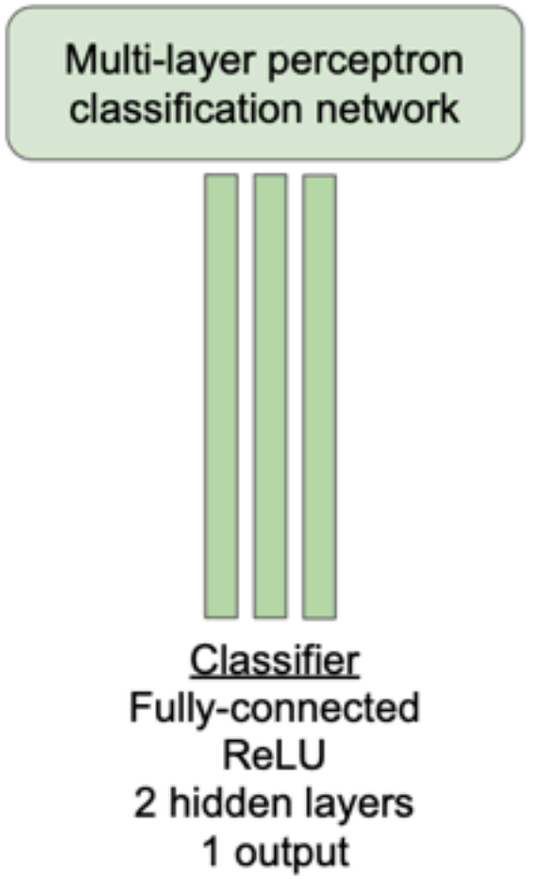
Same time window charge depositions on Collection plane



LArMatch Network

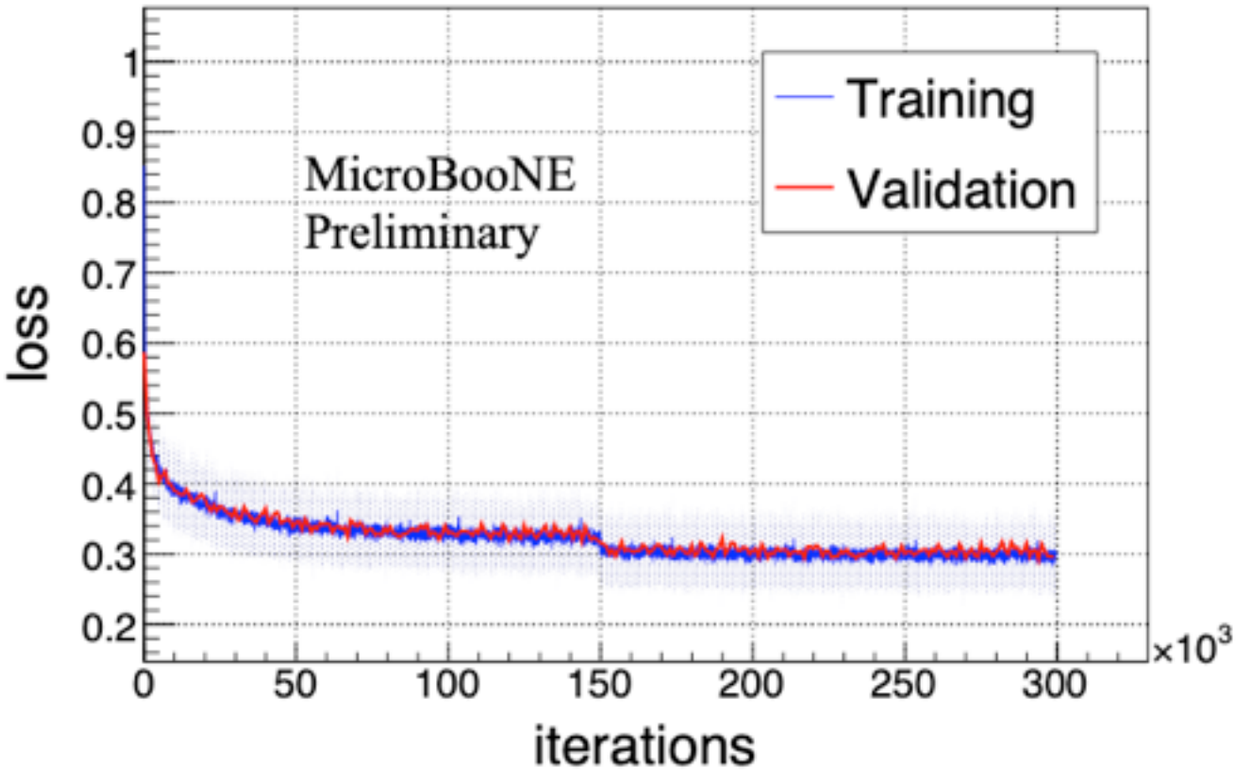
- Sparse CNN feature generator + MLP classifier
- Feed charge deposited on all 3 planes: helps reconstruct vertical tracks
- Generates a probability score for all geometrically possible combinations of charge on the 3 planes (“wire triplets”)
- 3D space-points generated from wire triplets using detector geometry

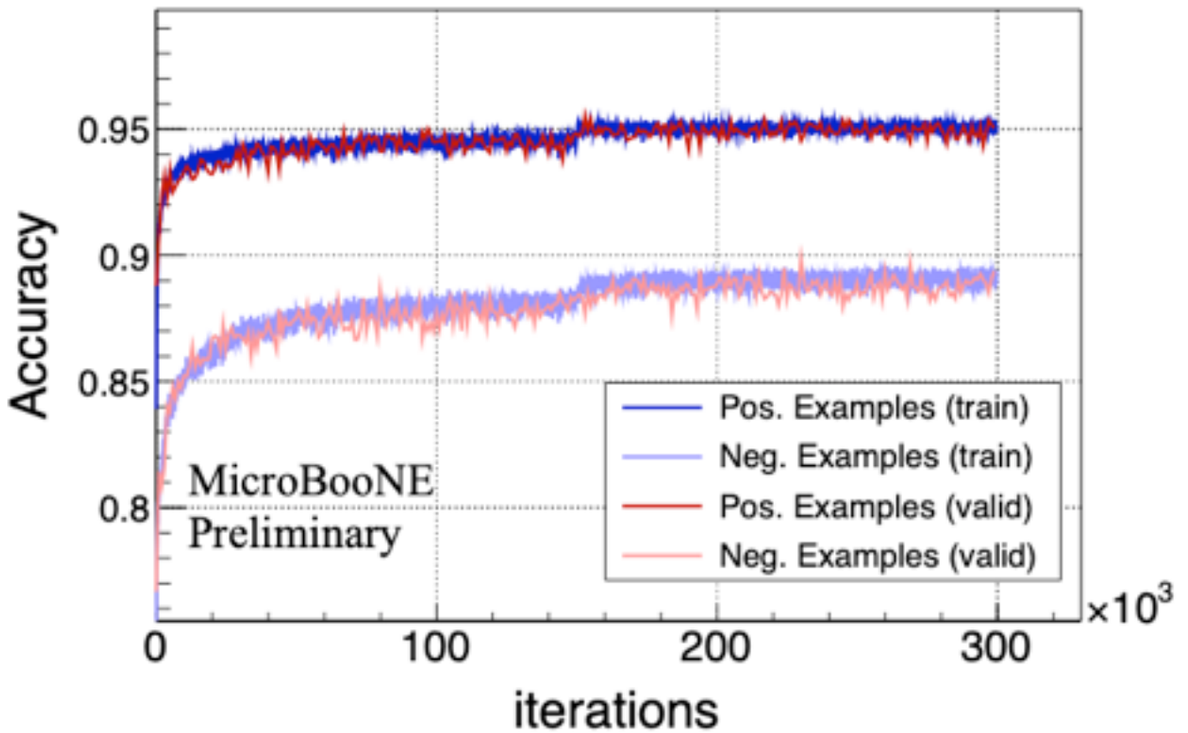




Network Training

- Trained on 40,000 BNB + CR simulated events
- Learning rate updated at 150,000 iterations
  - 50,000 triplet examples per iteration
- Stopped training after 3.75 epochs
  - loss & accuracy plateaued
  - no overtraining observed

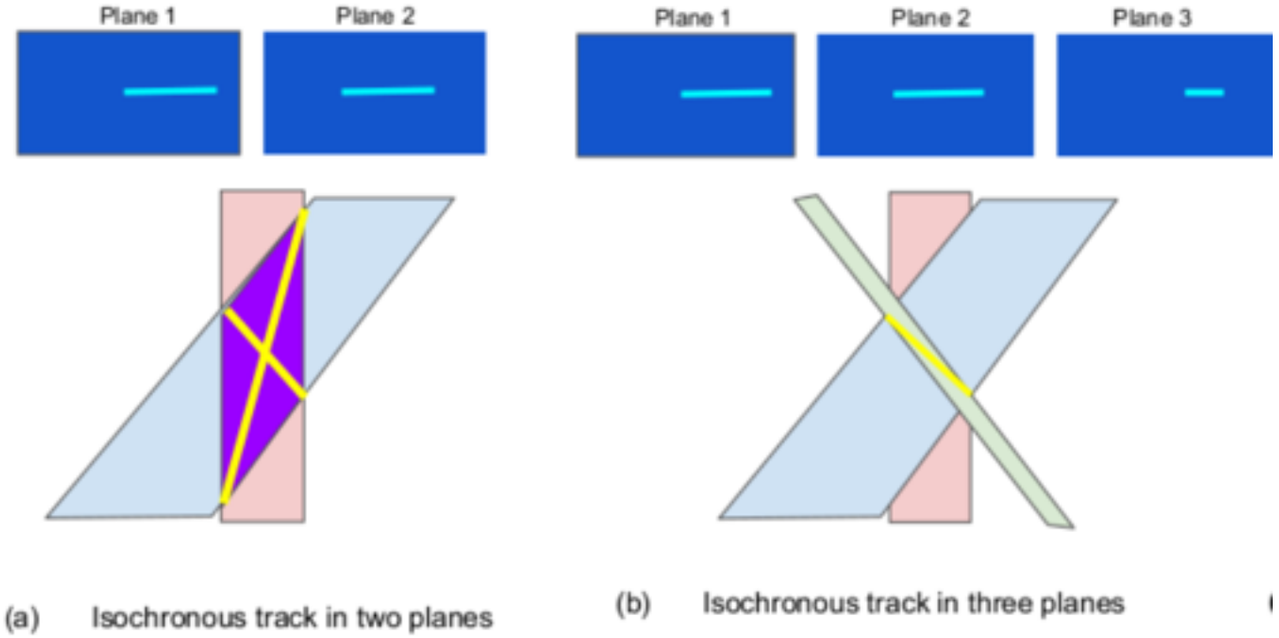




Resolving Vertical Track Degeneracies

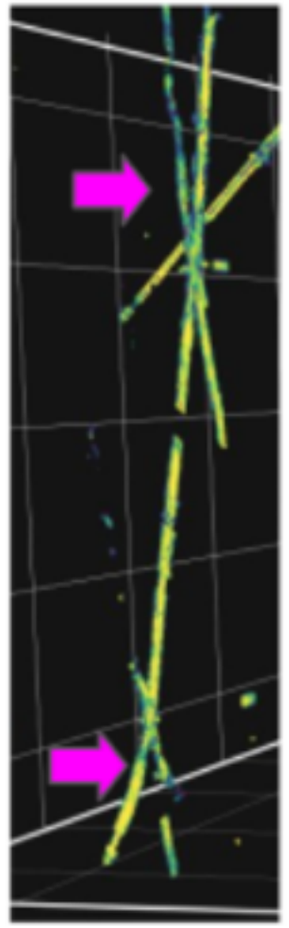
- Vertical tracks: difficult to reconstruct since full trajectory in same time-slice
- Using 3 planes helps break degeneracies

Comparing 2-plane LArMatch output to 3-plane version

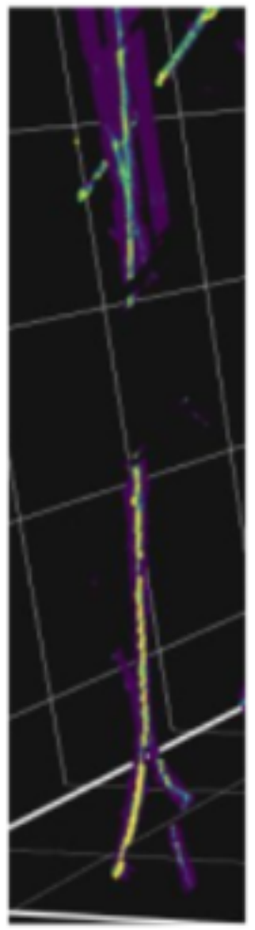


(a) Isochronous track in two planes

(b) Isochronous track in three planes



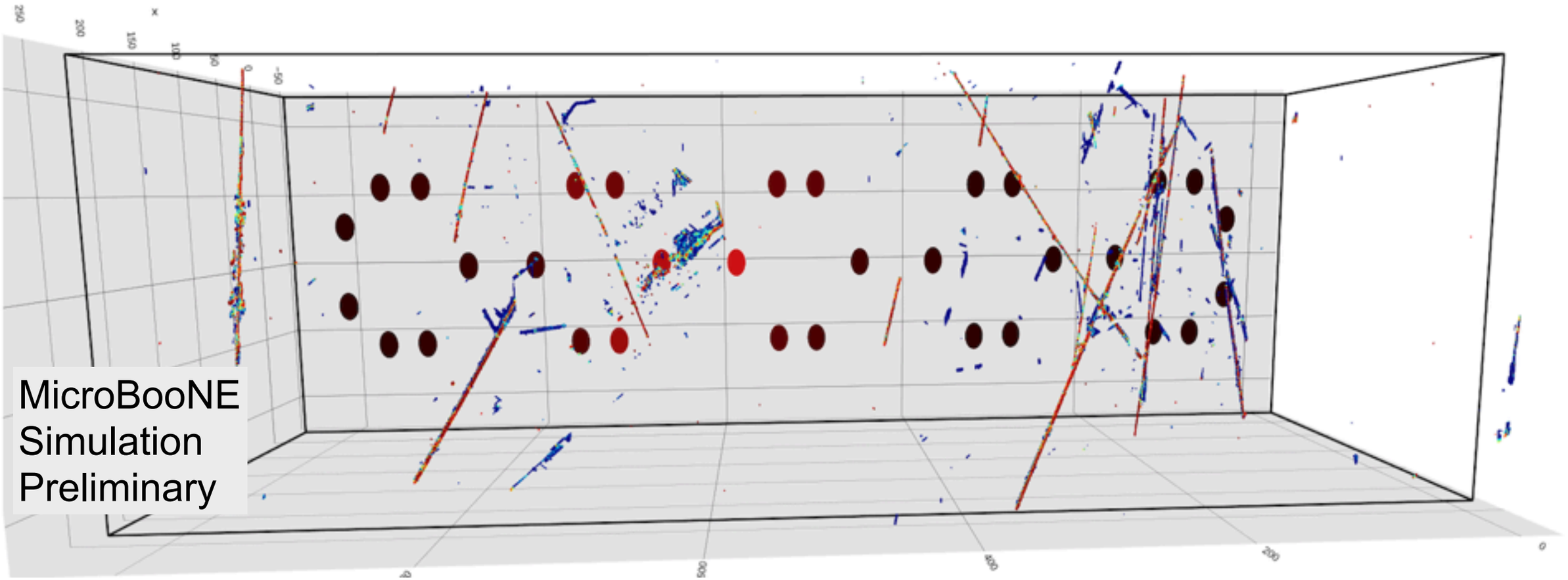
c) Degeneracies using 2 planes



(d) Reduced degeneracies using 3 planes

LArMatch Example On Simulation

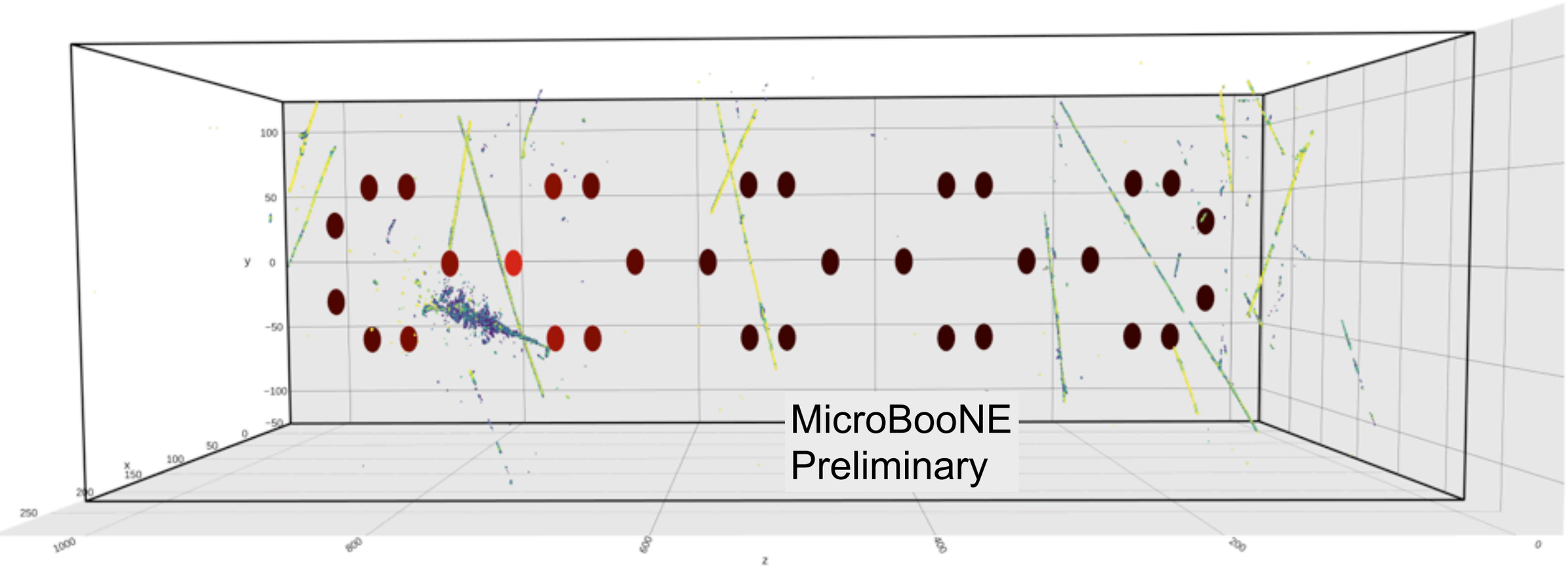
3D space points generated with LArMatch. BNB+CR simulation.



Color represents network score. Plotting all generated 3D points. Ghost points and unresponsive regions feature lower scores, trajectory ‘cores’ have high scores

LArMatch Example On Data

3D space points generated with LArMatch. BNB On-beam data. Neutrino candidate selected by DL LEE analysis (neutrino BDT score in [0.5,0.7] range)

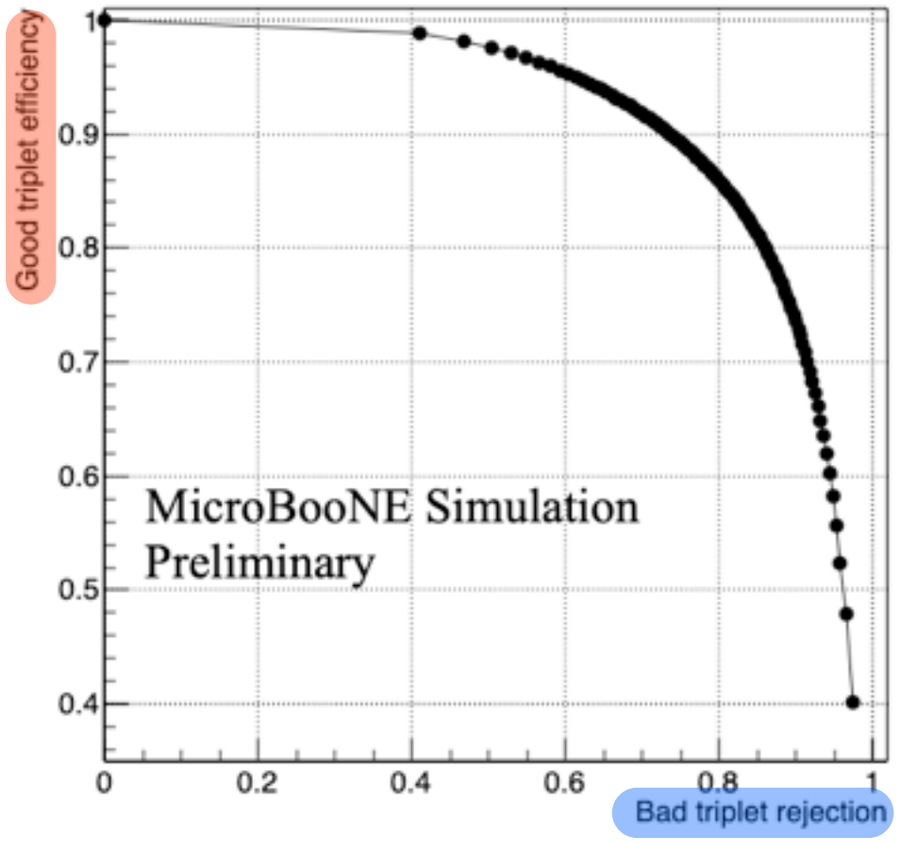


Color represents network score. Only showing points with score >0.7
CCQE candidate successfully reconstructed

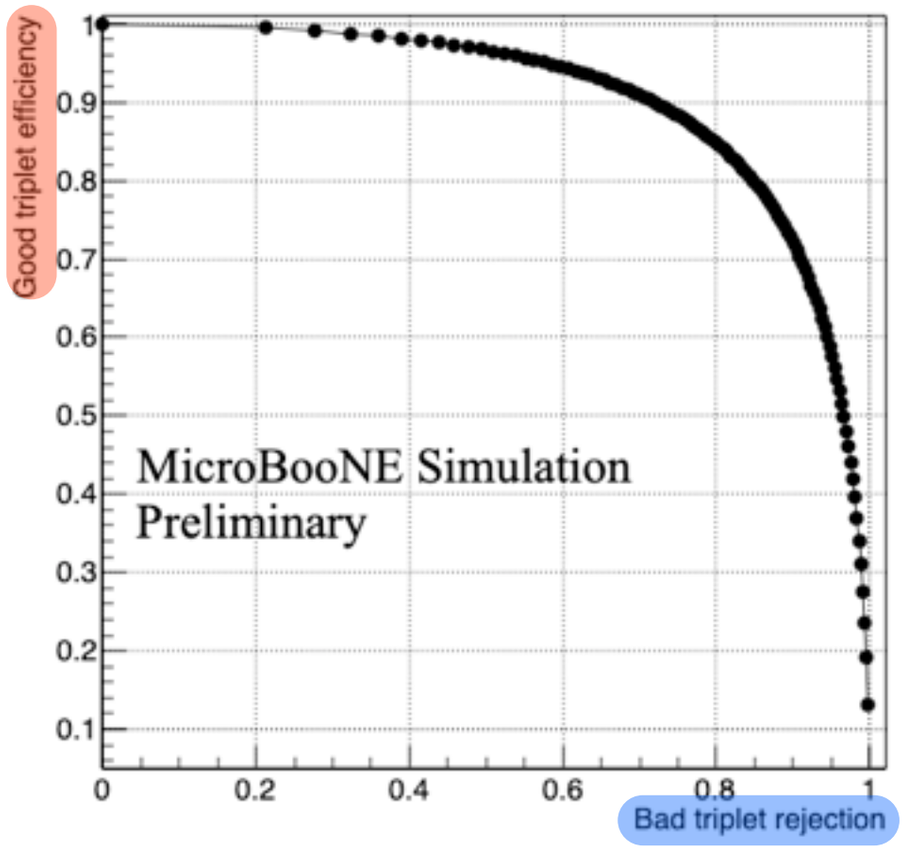
LArMatch Network Performance

Estimating performance on CR + BNB neutrino simulation

Track



Shower



Plotting good point* efficiency vs bad point** rejection as a function of network score.

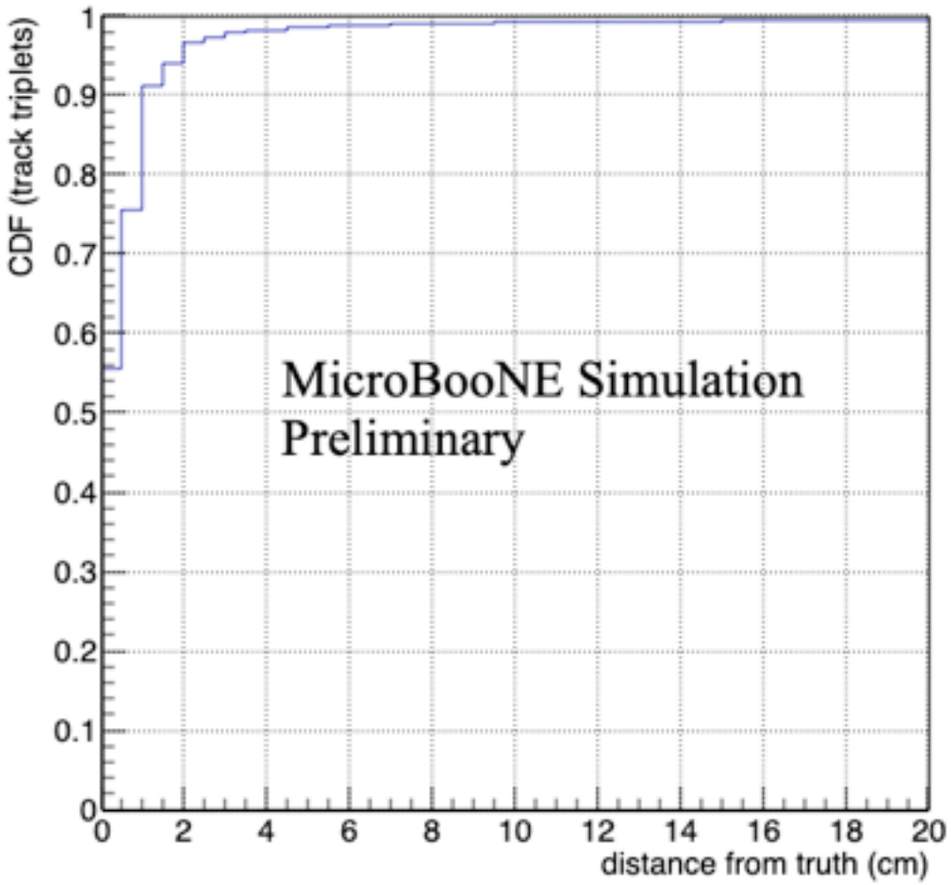
Network score reflects actual goodness of reconstructed points

*good point: within 1 cm from true 3D point
**bad point: >1 cm from true 3D point

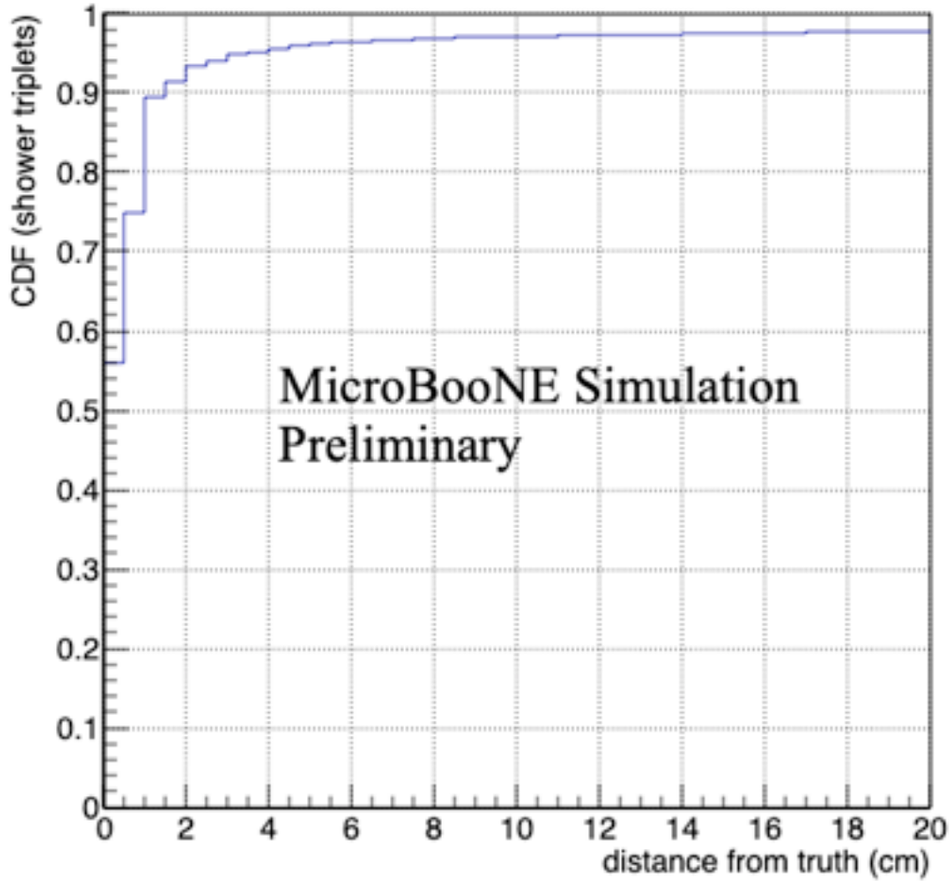
LArMatch Network Performance

Estimating performance on CR + BNB neutrino simulation

Track



Shower



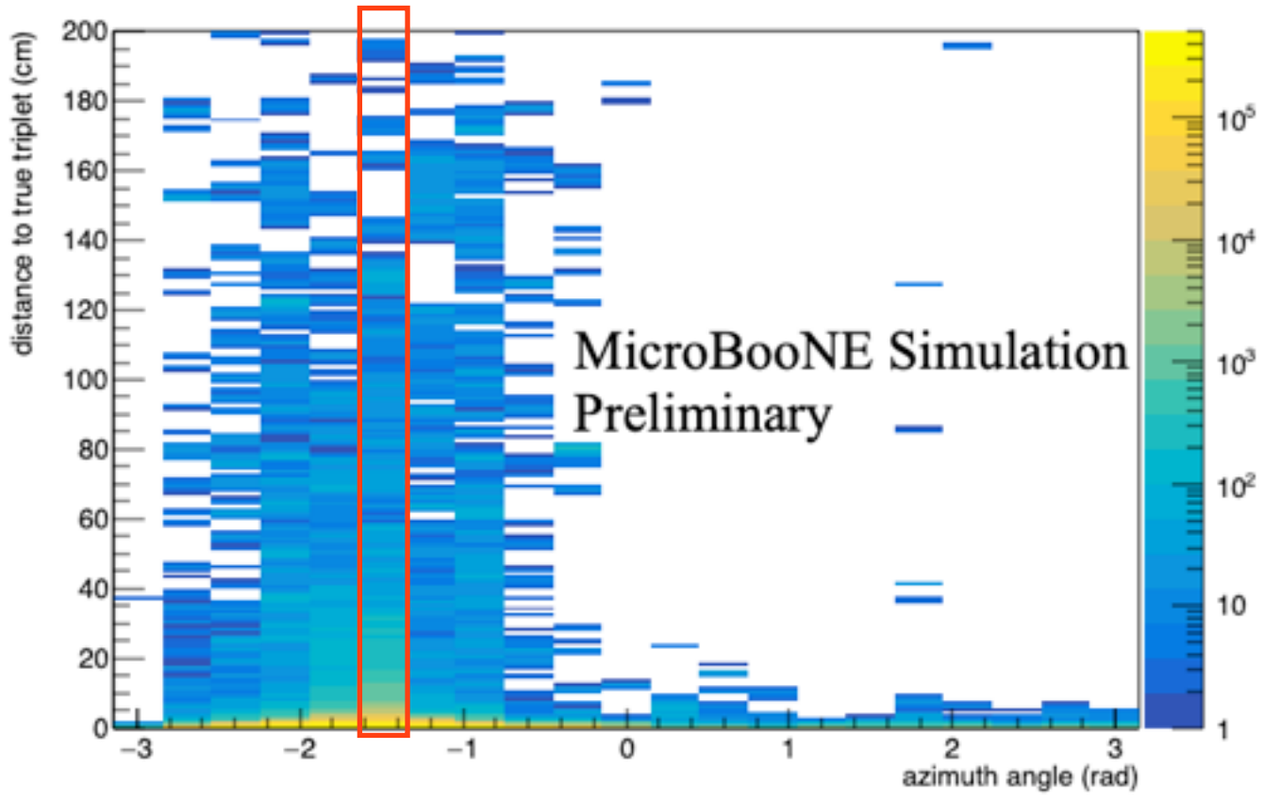
Plotting distance from true 3D point for best-match* reconstructed points.
O(90%) of reconstructed points are good (within 1 cm of truth)

* Network outputs multiple predictions for each 3D point; keep only highest score

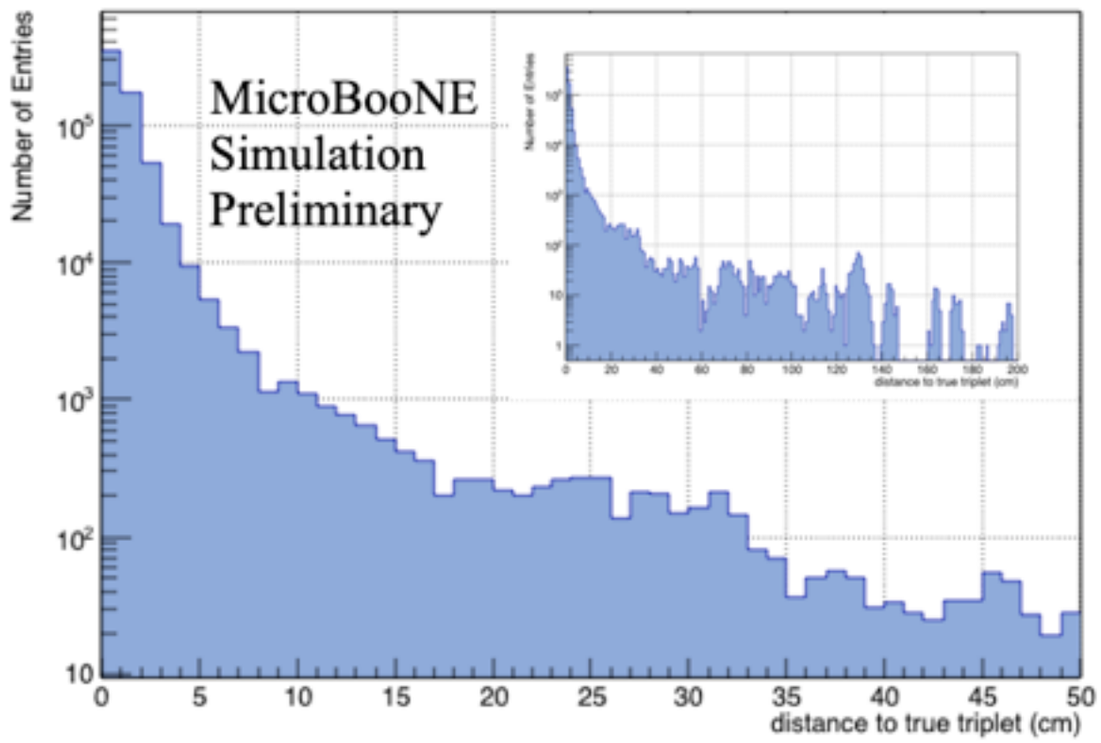
LArMatch Network Performance: Vertical Tracks

Estimating performance on CR + BNB neutrino simulation

Track



Track phi = [-1.64, -1.35]



Left: distance from true 3D point for best-match reconstructed points vs. azimuth angle. Sample dominated by down-going CR tracks.

Right: Projection for vertical tracks. Majority or 3D points are within 5cm from truth

Summary And Outlook

- 3D reconstruction in wire-readout LArTPCs can be a challenge
  - multiple trajectories crossing at the same time: degeneracies
  - vertical tracks (same time slice for all trajectory points)
- LArMatch: exploits correlated features between wire plane images
- Future work
  - Estimate network performance on data using Cosmic Ray Tagger data
  - Estimate systematic uncertainty using simulations with varied detector response & signal processing