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Pandora – Improvements to the Muon Reconstruction

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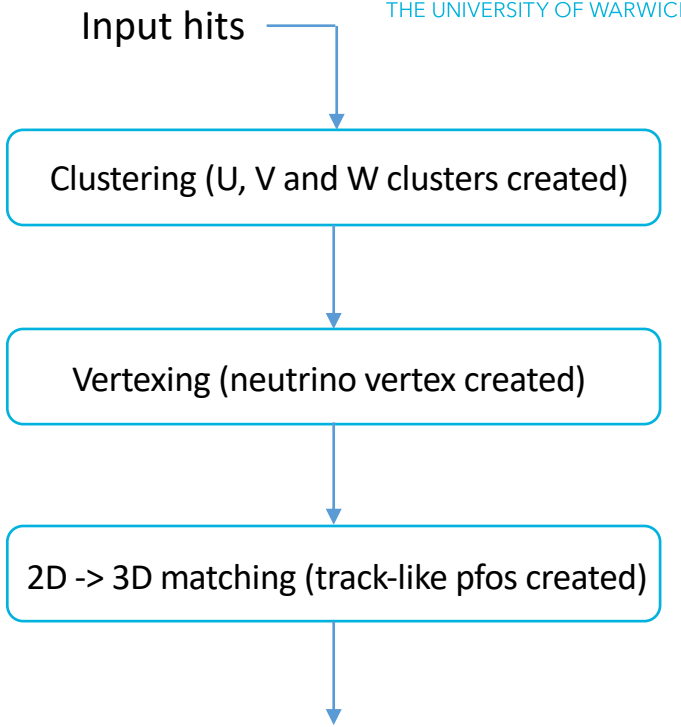
Overview

- Aim to re-examine the muon reconstruction, seeking out and fixing the difficult cases that remain
- Will outline three main contributions to the Pandora reconstruction process:
  - HitWidthClusterMerging algorithm
  - TrackInEMShower algorithm
  - CR stitching algorithm upgrade
- For each, will discuss their motivation, mechanics, performance and status

Part 1: Hit Width Algorithm - Motivation

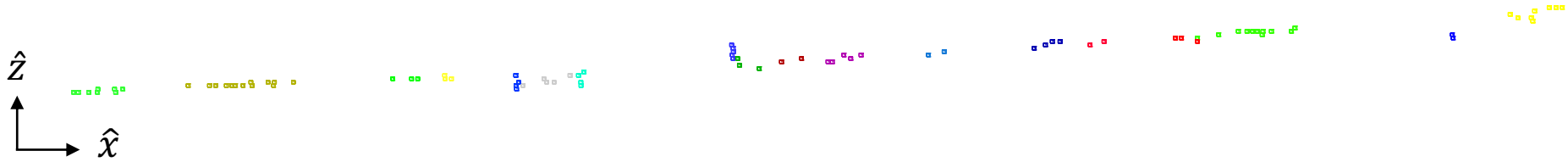
- More information:
  - https://indico.fnal.gov/event/23529/
  - https://indico.fnal.gov/event/43136/ (update)

- Part of the 2D reconstruction step

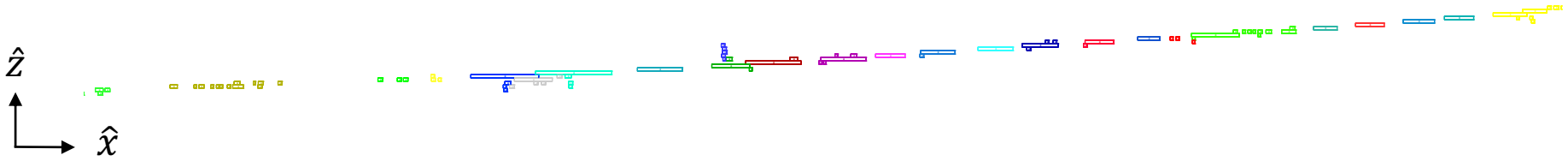


Part 1: Hit Width Algorithm - Mechanism

- HW algorithm focuses on the reconstruction of incredibly sparse tracks which belong to particles that travel along the induction/collection wires



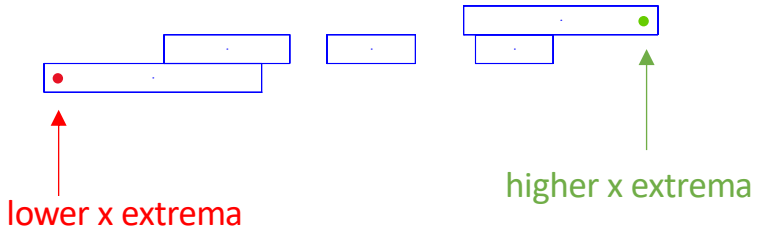
- Turn hit widths on (UseHitWidth = true in pandoramodules_dune.fcl – will soon be default)



Part 1: Hit Width Algorithm - Mechanism

Hit Width algorithm process:

1) Pick out the sparse clusters in an event – only these will be considered
2) Break up the sparse clusters into constituent hits
3) Parameterise each cluster by its extremal points
4) Walk along the clusters determining associated clusters using a criteria that examines:
   - The relative positions of cluster extrema points
   - The relative cluster directions
   - The change in cluster direction if a merge was to occur
5) Remove ‘shortcut’ associations
6) Fall back to the ClusterAssociations base class to merge associated clusters



Part 1: Hit Width Algorithm - Performance

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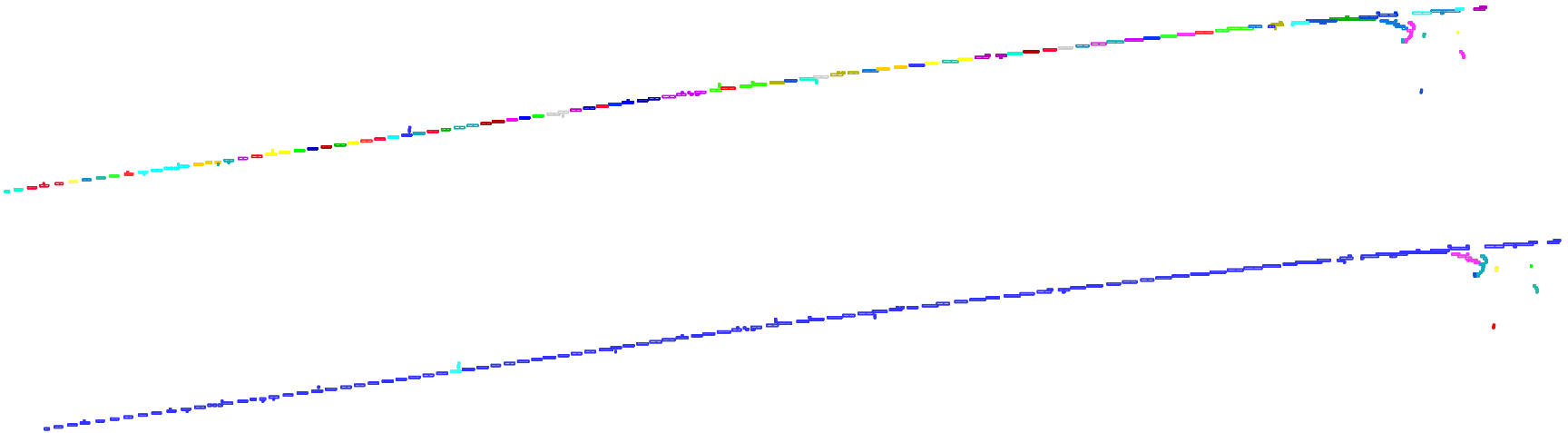
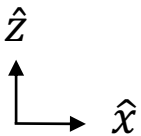
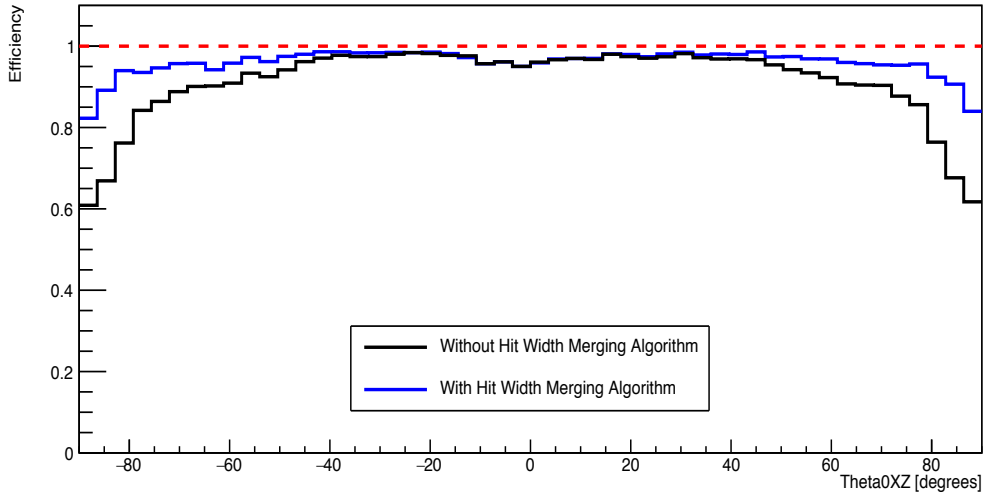
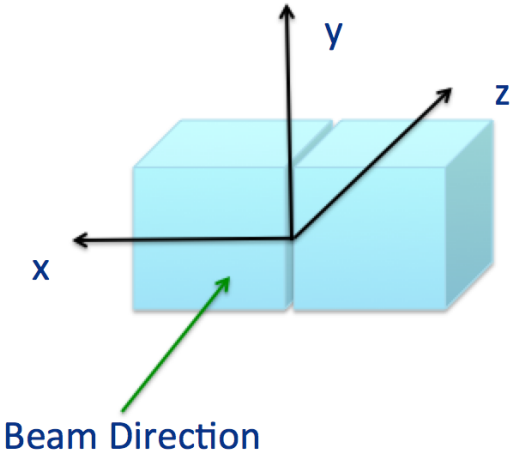




Part 1: Hit Width Algorithm - Performance

- Investigated the application of the algorithm to single muon events in the DUNE FD test volume (58 000 events)
- Improvements in the ‘sparse’ area of the Theta0XZ phase space

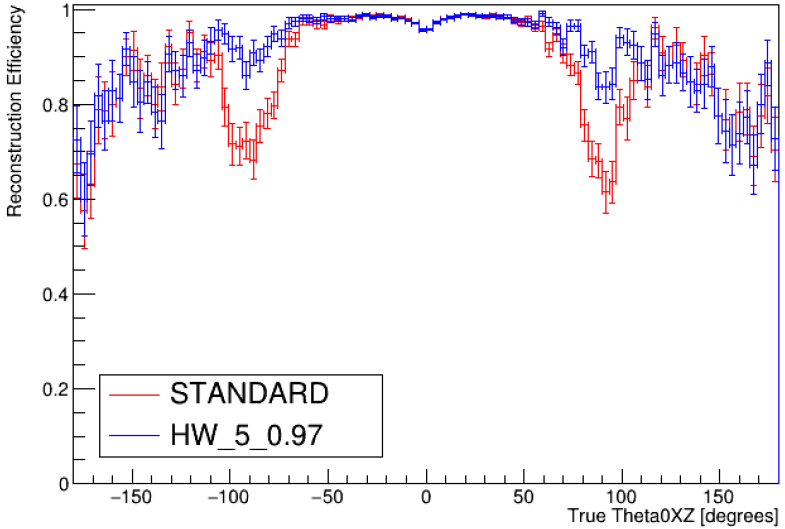




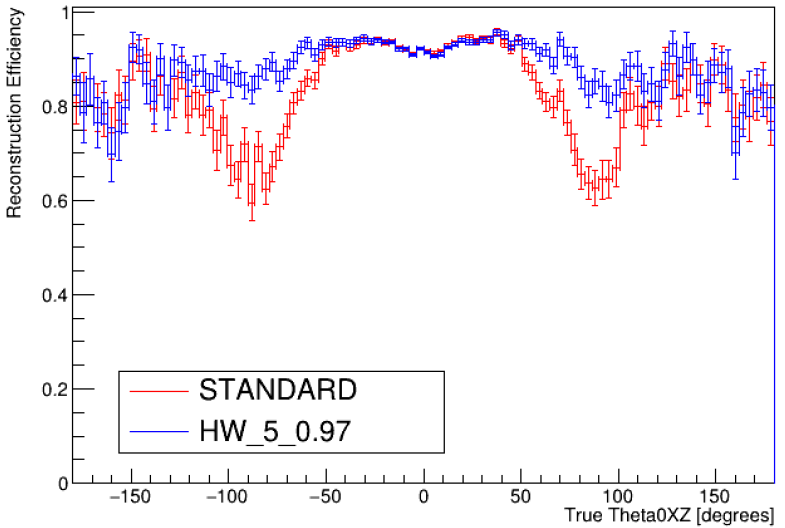
Part 1: Hit Width Algorithm - Performance

- Investigated the application of the algorithm to neutrino events in the DUNE FD test volume (279 000 events)
- Improvements in the ‘sparse’ area of the Theta0XZ phase space

Muon

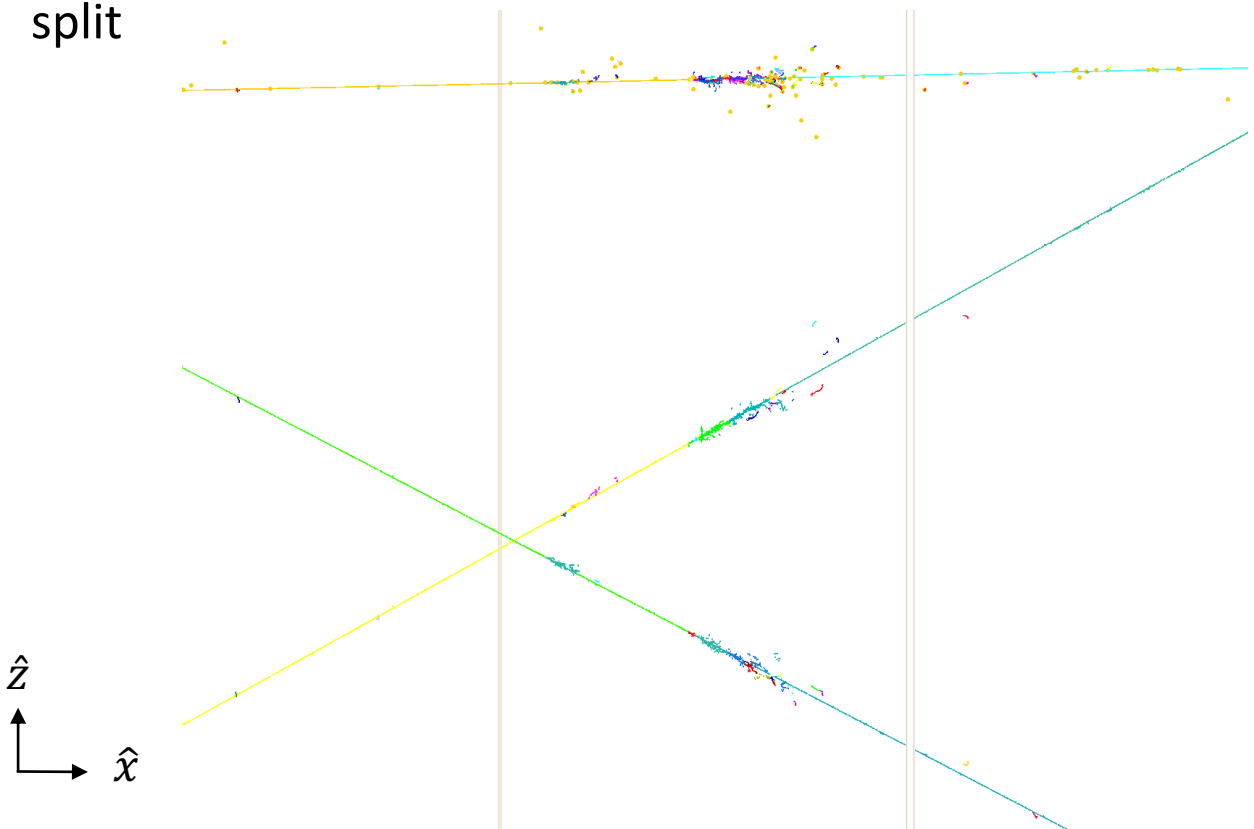


Electron



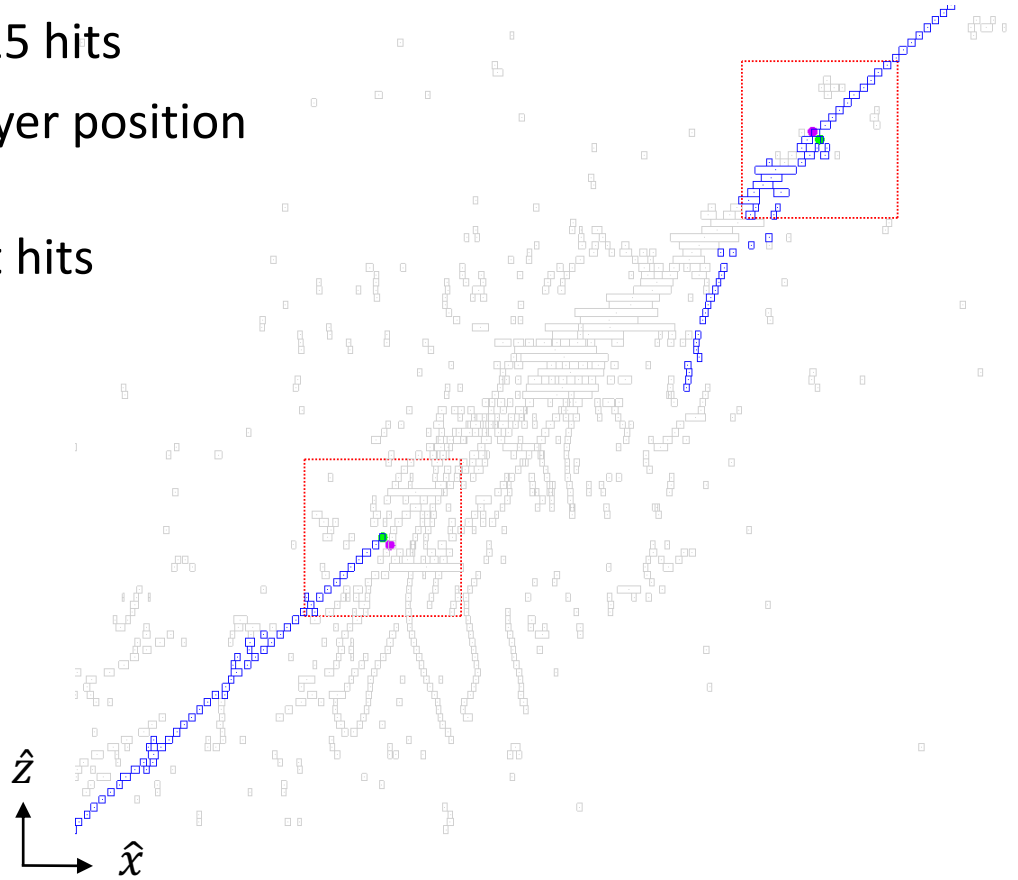
Part 2: TrackInEMShower Algorithm - Motivation

- Lots of electromagnetic activity along track, can cause track to be split



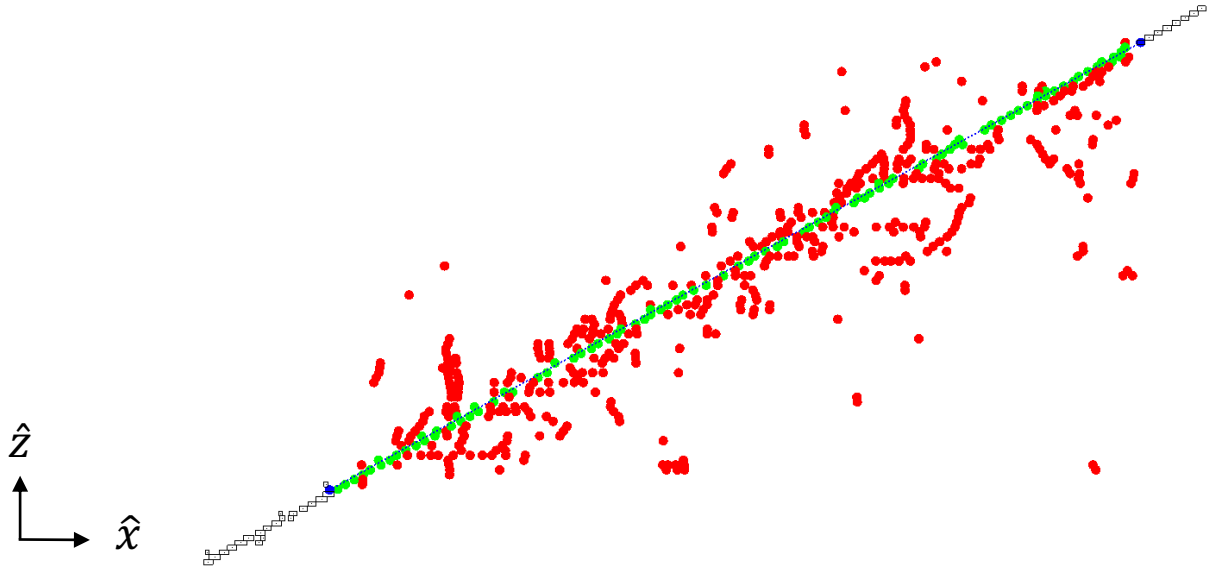
Part 2: TrackInEMShower Algorithm - Mechanism

- Require clusters to have above 25 hits
- Order clusters by their lowest layer position
- For a current cluster, find the associated cluster with the most hits
- Associated:
  - Merging points separated > 30 cm
  - Extrapolated merging points close together in X and Z
  - Cosine opening angle of cluster directions > 0.99



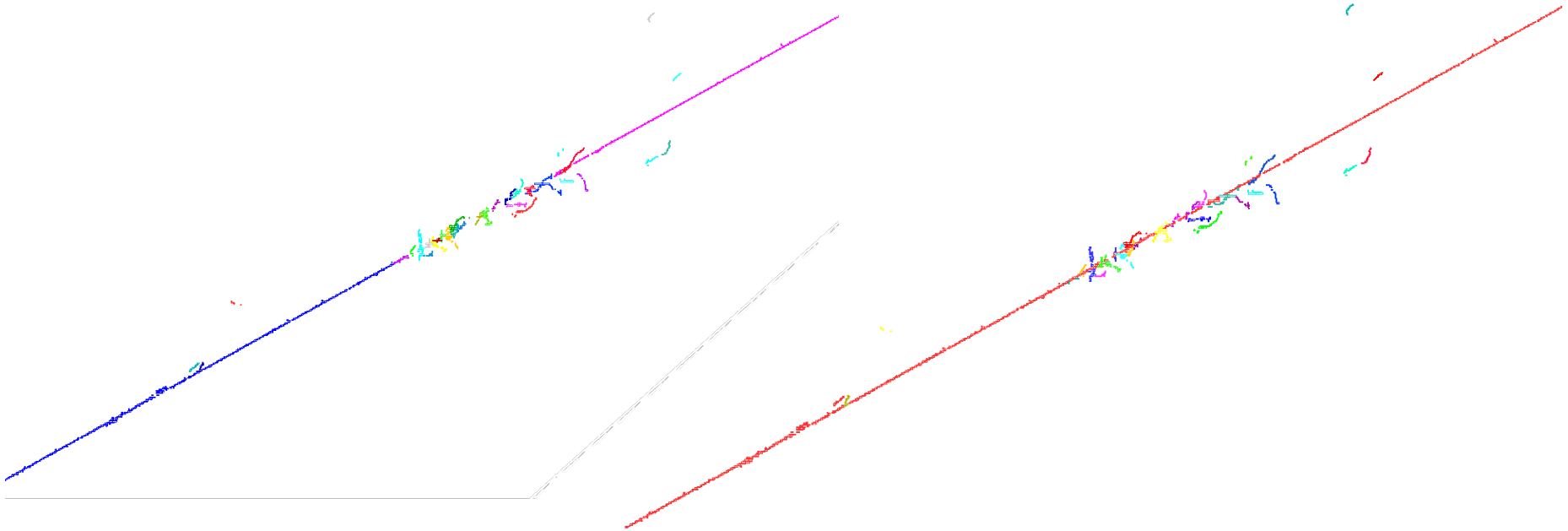
Part 2: TrackInEMShower Algorithm - Mechanism

- Connect ‘merging points’ with a line, find hits that lie within the box defined by the merging points and that are less than 0.35 cm away from line
- Check that this line is continuous, if not abort merging process



Part 2: TrackInEMShower Algorithm - Mechanism

- If preceding checks pass, merge clusters together
- Update fits and ‘relevant’ cluster lists
- Repeat until no merges are made

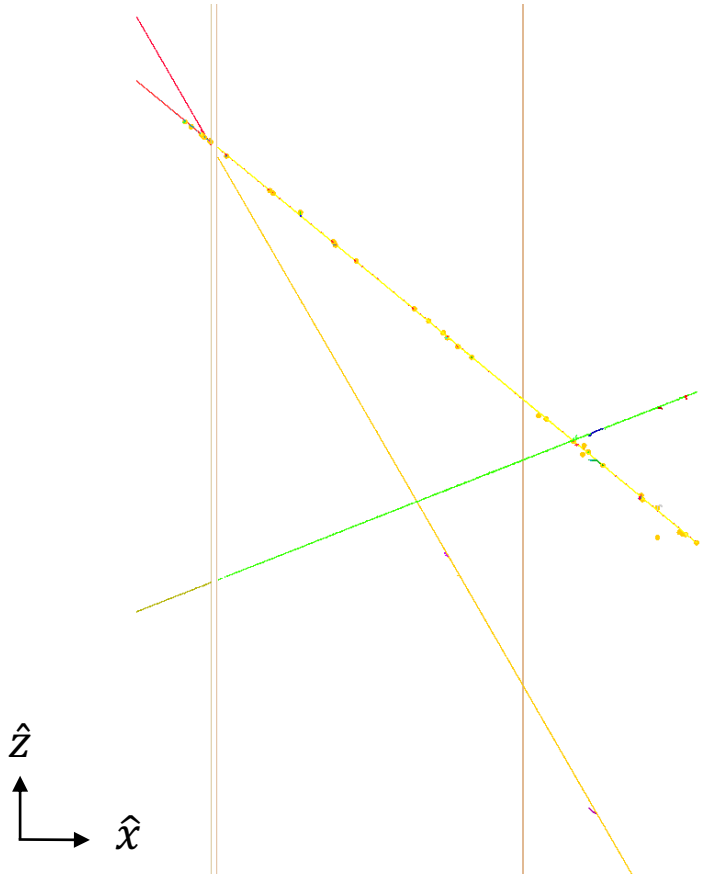


Part 2: TrackInEMShower Algorithm - Performance

- 7930 cosmic ray muons in the DUNE FD (full geometry) reconstructed with the CR reconstruction chain

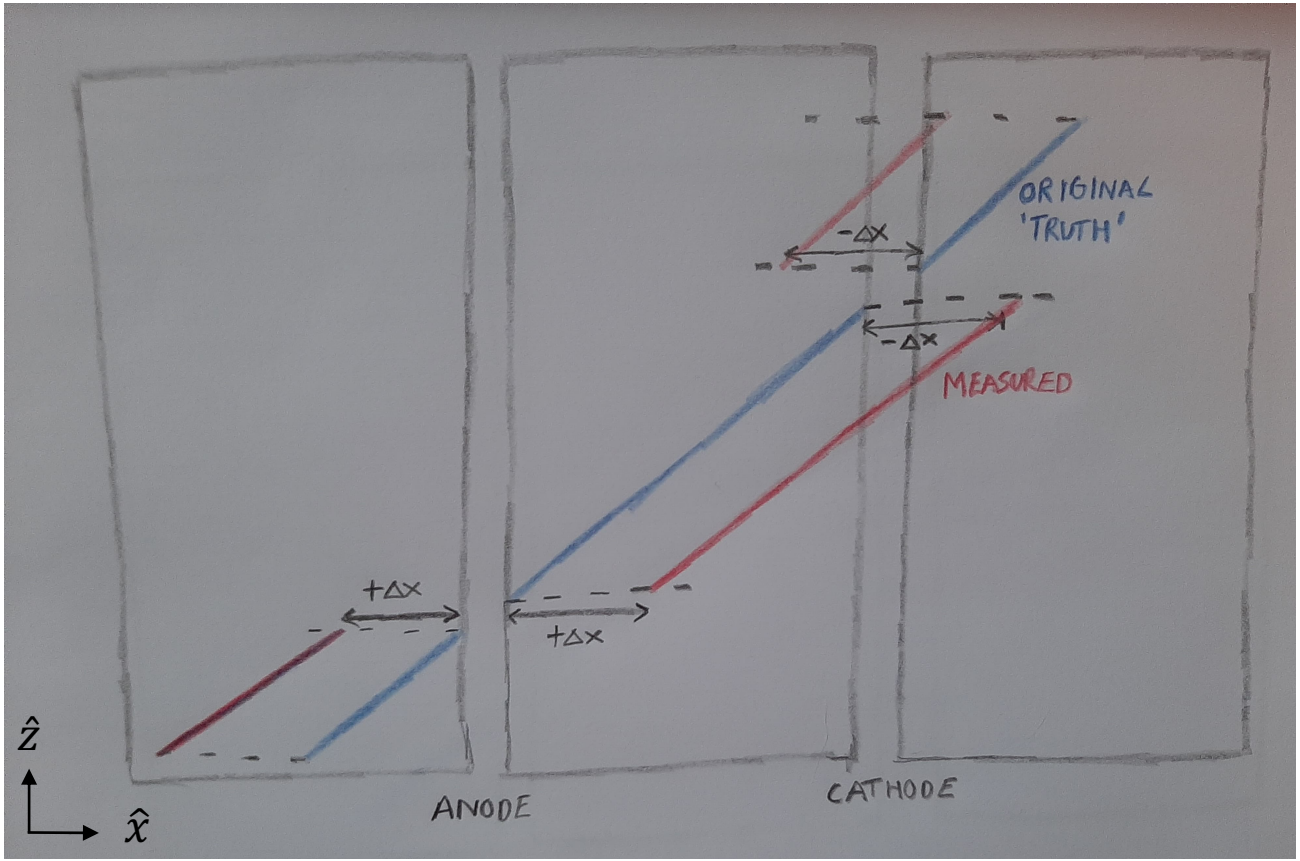
- Without any changes: 83.7%
- With TrackInEMShower algorithm: 86.4%

Part 3: Stitching Upgrade - Motivation



- In the CR reconstruction, each TPC is reconstructed in isolation and the ouput pfos are stitched together
- Currently, Pandora only stitches pfos across a single LArTPC boundary
- If multiple boundaries are crossed, the match with the highest number of hits will be merged and the other pfo is left

Part 3: Stitching Upgrade - Mechanism



- A CR muon arrives after the beam spill, the anode thinks it has been travelling for longer than it has…

Part 3: Stitching Upgrade - Performance

- 7930 cosmic ray muons in the DUNE FD (full geometry) reconstructed with the CR reconstruction chain

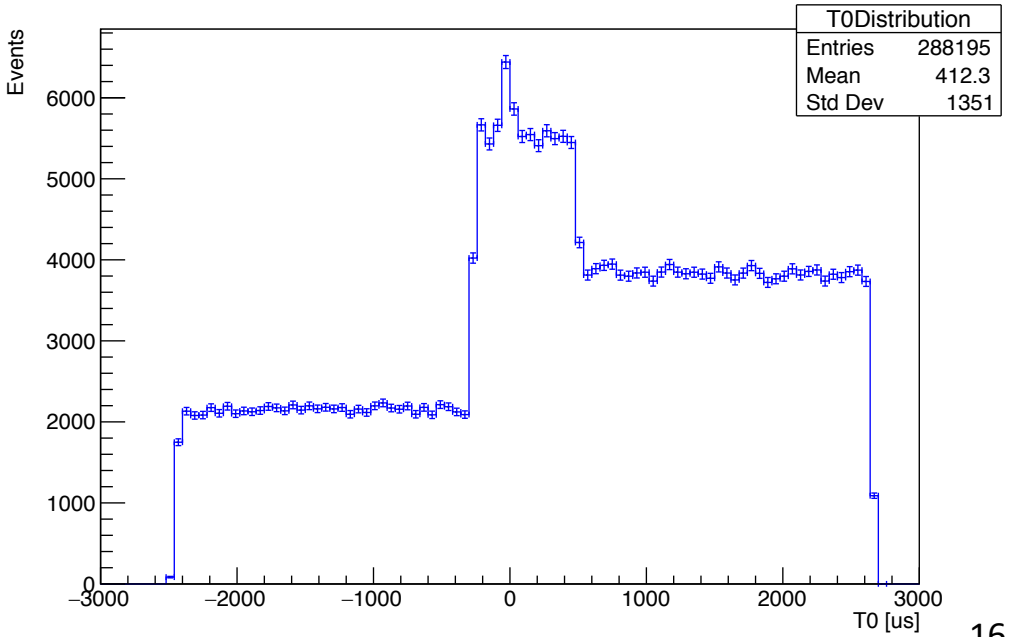
- Without any changes: 83.7%
- With TrackInEMShower algorithm: 86.4%
- With TrackInEMShower algorithm and stitching improvements: 92.2%

Part 3: Stitching Upgrade - Performance

- Obtained T0 distribution of 288000 shifted CRs in ProtoDUNE-SP

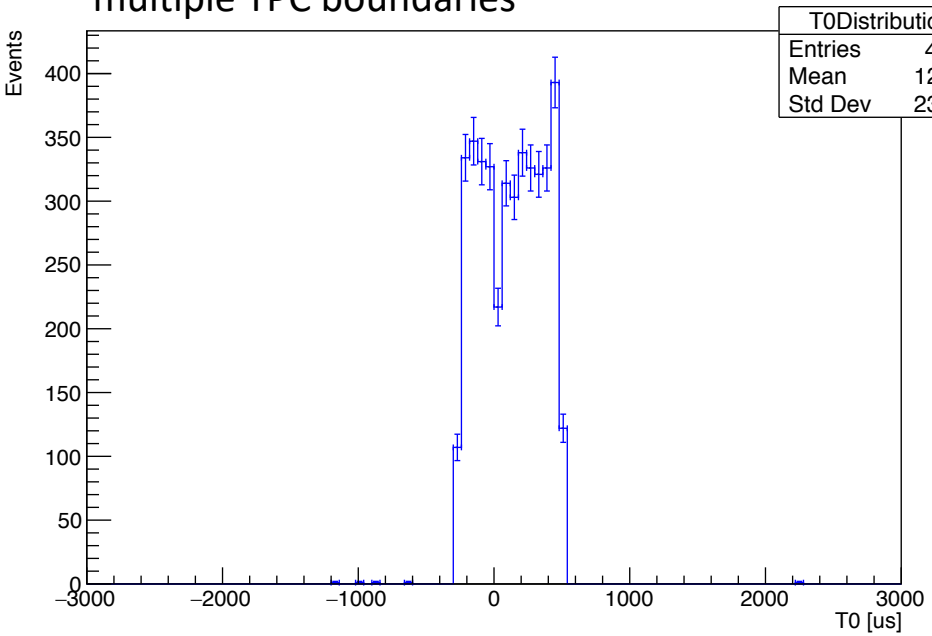
- CPA stitches [-2500, 500] us
- APA stitches [-250, 2750] us
- APA/CPA/APA stitches [-250, 500] us

Standard – All matches (No Space Charge)

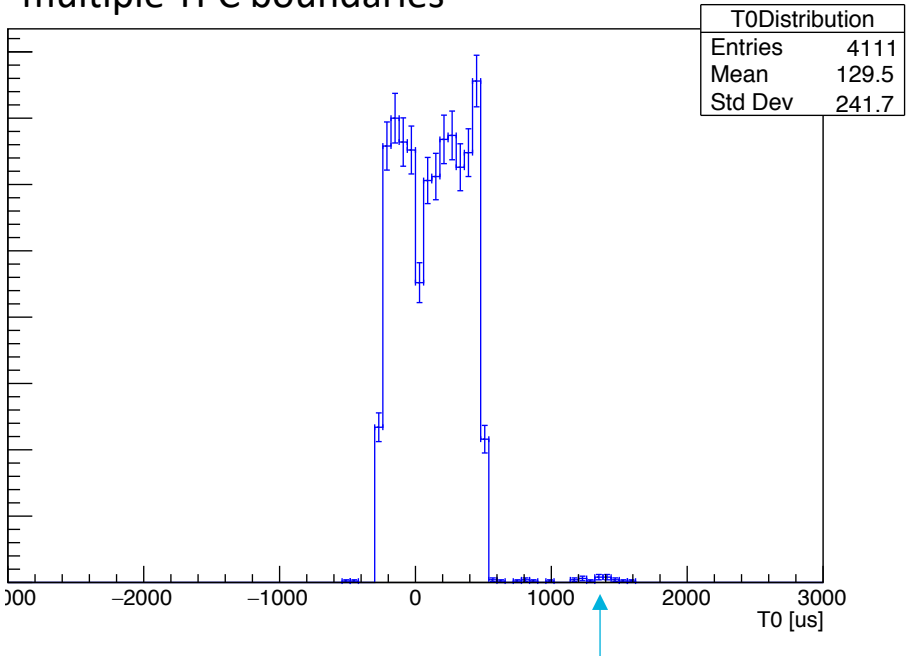


Part 3: Stitching Upgrade - Performance

Standard – Matches across multiple TPC boundaries



Upgrade – Matches across multiple TPC boundaries



APA/CPA/APA stitches [-250, 500] us

Outliers caused by incorrect matches, these will be removed

No Space Charge

What's Next?

- In the very near future, will be looking to release this work:
  - HW alg: Neutrino & CR reconstruction chains
  - TrackInEMShower & Stitching Improvements: CR reconstruction chain

- Further improvements to the high energy muon reconstruction
  - Investigate improvements to the sliding fits of sparse clusters
  - Fix stitching errors
  - Resolve remaining issues with CR reconstruction

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BACKUP

Backup: Pandora Correct Event Fraction Definition

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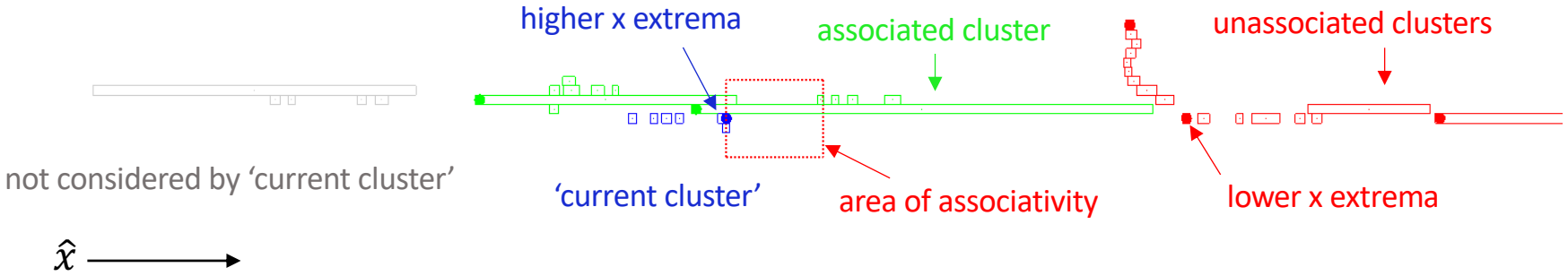
- Determine the reconstructable particles in the event
- Find the shared hits between the reconstructable MCParticles and the pfos
- Identify matches that you will consider in the metrics
  - Shared hits > 5
  - Purity > 50% (so pfo will be more associated to this MCParticle than to any other)
  - Completeness > 10% (remove low quality matches)
- Identify matches in order of number of shared hits, once match is made MCParticle marked as unavailable
- Assign remaining pfos to MCParticles
- An event is deemed correct if there is one reconstructed particle for each target MCParticle at the end of this procedure

Backup: Hit Width Algorithm - Associations



Backup: Hit Width Algorithm – Shortcut Associations

- When a cluster has more than one association, each merging pathway is investigated. If this happens often, computational time grows…