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Pandora 2D -> 3D Matching Efficiency Study

Single Muon Events

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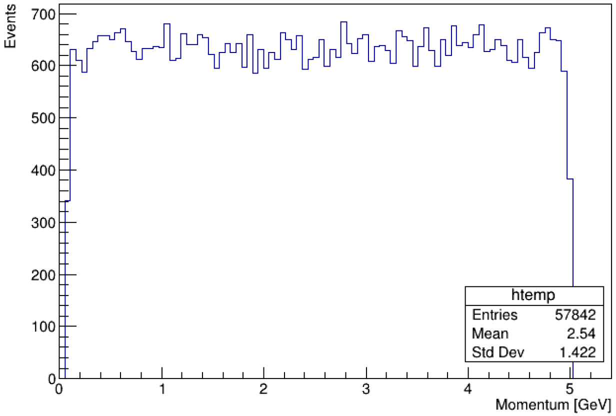
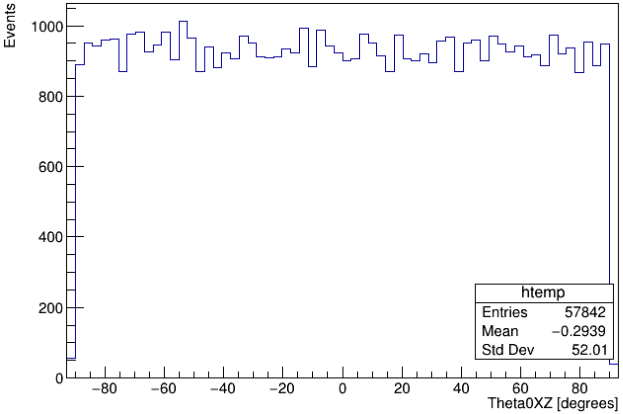
Aim

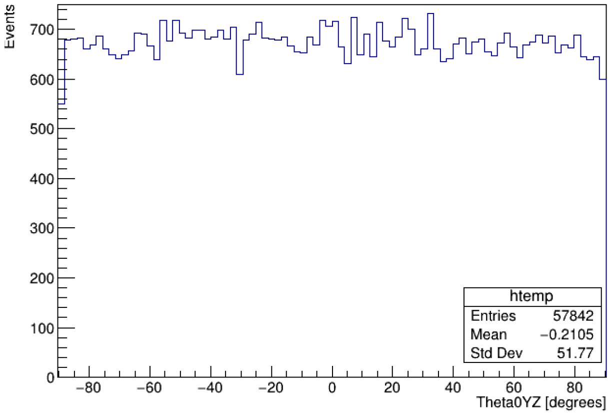
- To investigate the reconstruction of neutrino events, determining where and why Pandora has failed, and to ultimately improve the reconstruction process

Single Muon Events

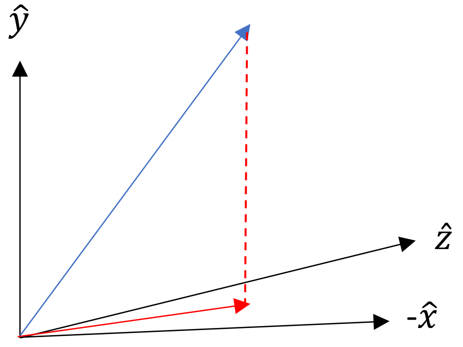
- Begin investigation with single muon events
- Created a sample of ~58 000 events in DUNE FD test volume
- Muons distributed uniformly in momentum (0 -> 5 GeV) and forwards direction

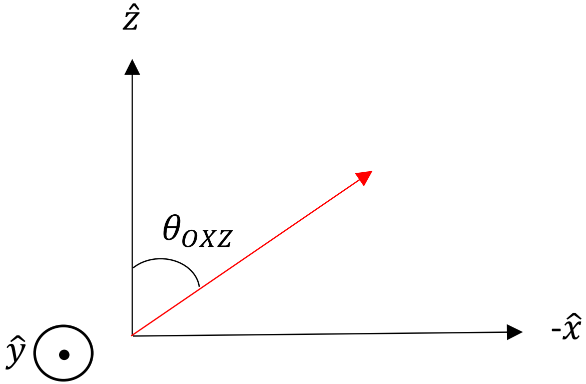


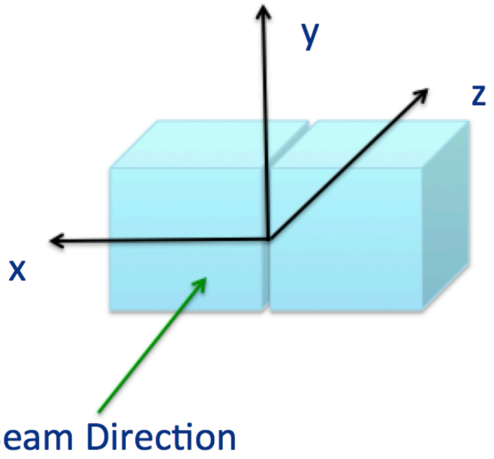




LArSoft Angles: Theta0XZ

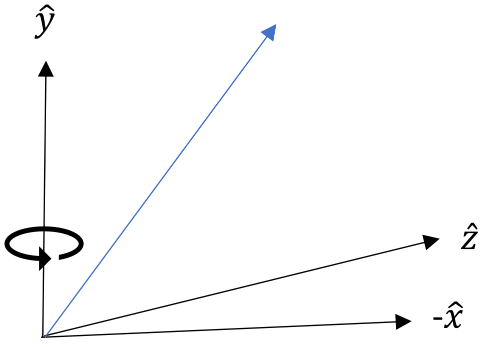


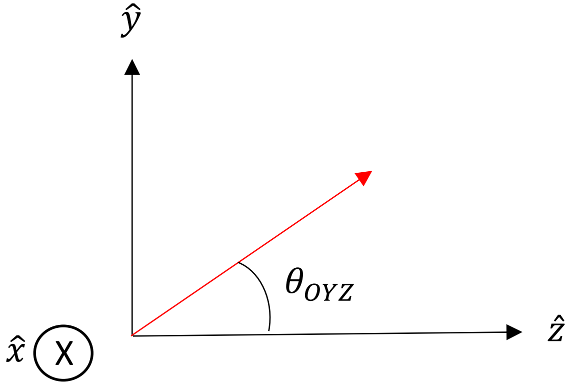


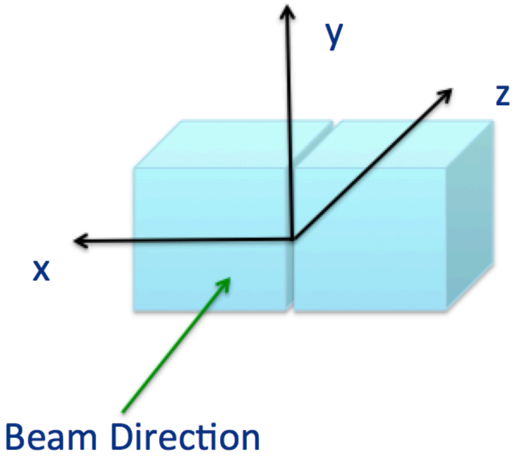


Project vector into XZ plane, θ_{OXZ} is the angle from the Z axis to projected vector

LArSoft Angles: Theta0YZ







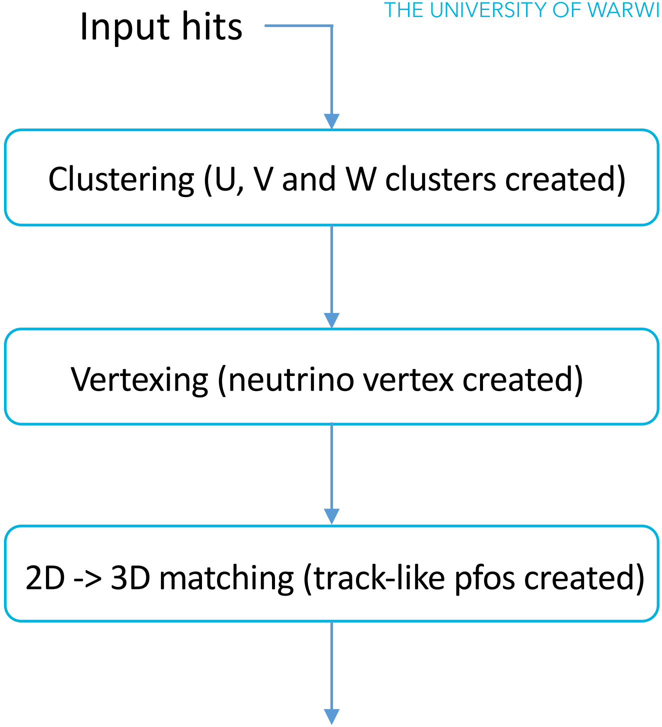
Rotate vector until vector is above plane, θ_{OYZ} is the angle from the Z axis to projected vector, essentially it is the angle from the XZ plane

2D -> 3D Efficiency Study

- Aim to characterise efficiency of 2D -> 3D reconstruction stage
  - Clusters are matched between views to form particle flow objects (pfos)

- Three initial algorithms:
  - Transverse Tracks algorithm
  - Longitudinal Tracks algorithm
  - Track Fragments algorithm

- Each employs a set of tools to merge and split clusters to form pfos



Input hits

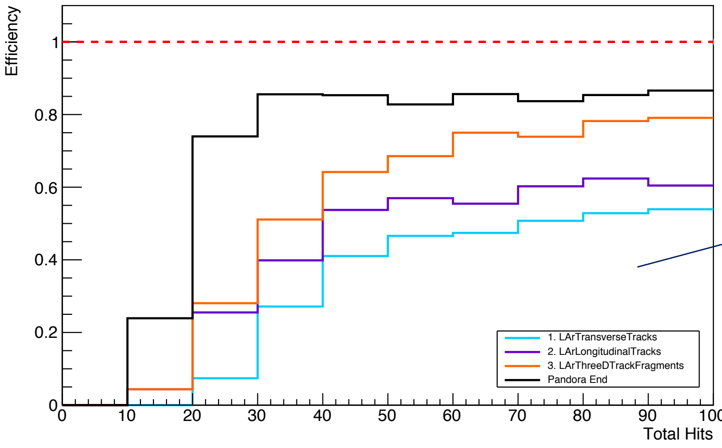
Clustering (U, V and W clusters created)

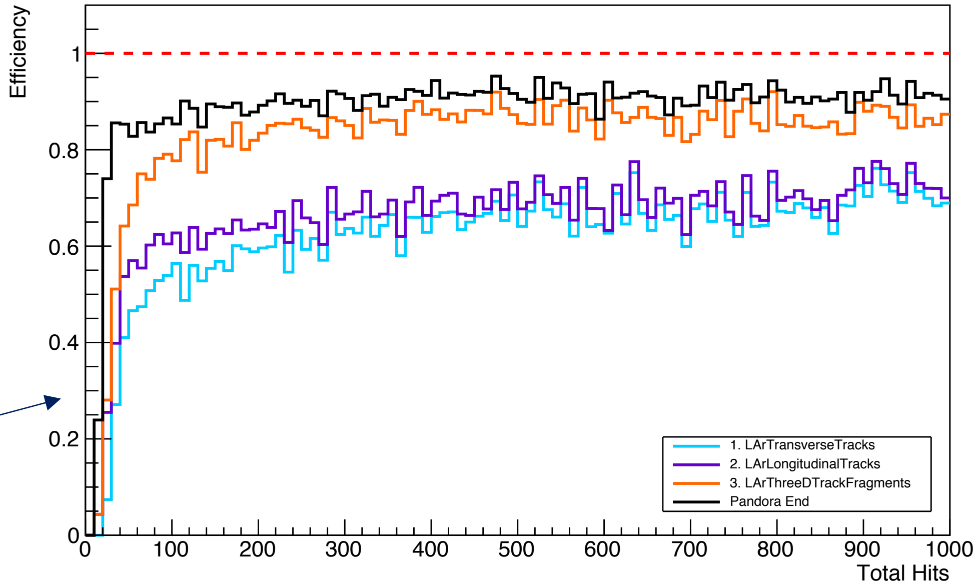
Vertexing (neutrino vertex created)

2D -> 3D matching (track-like pfos created)

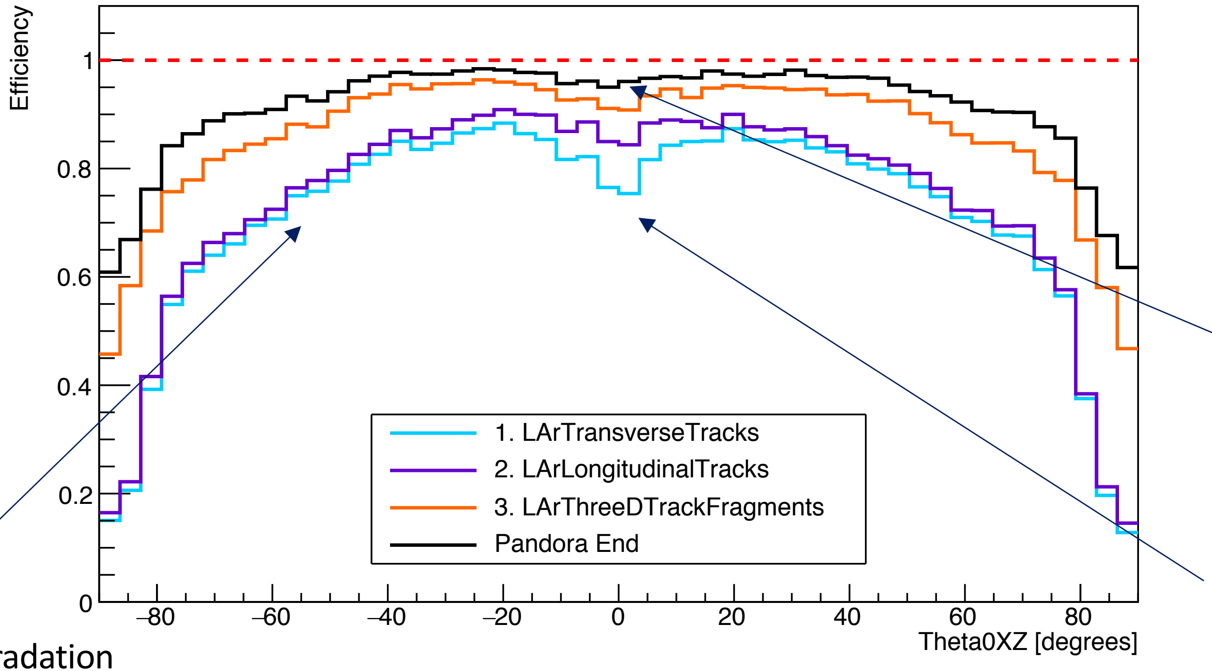
Pandora Efficiency: Total Hits

- To no one’s surprise, tracks with few hits are poorly reconstructed





Pandora Efficiency: Theta0XZ



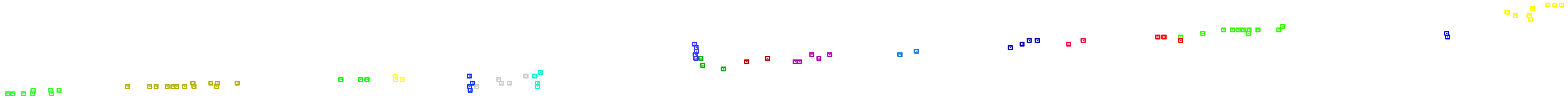
Isochronous failures

Transverse algorithm isn't designed to reconstruct longitudinal events

Surprising degradation as approach extrema, caused by **wispy tracks** as muons spend more time travelling along wires

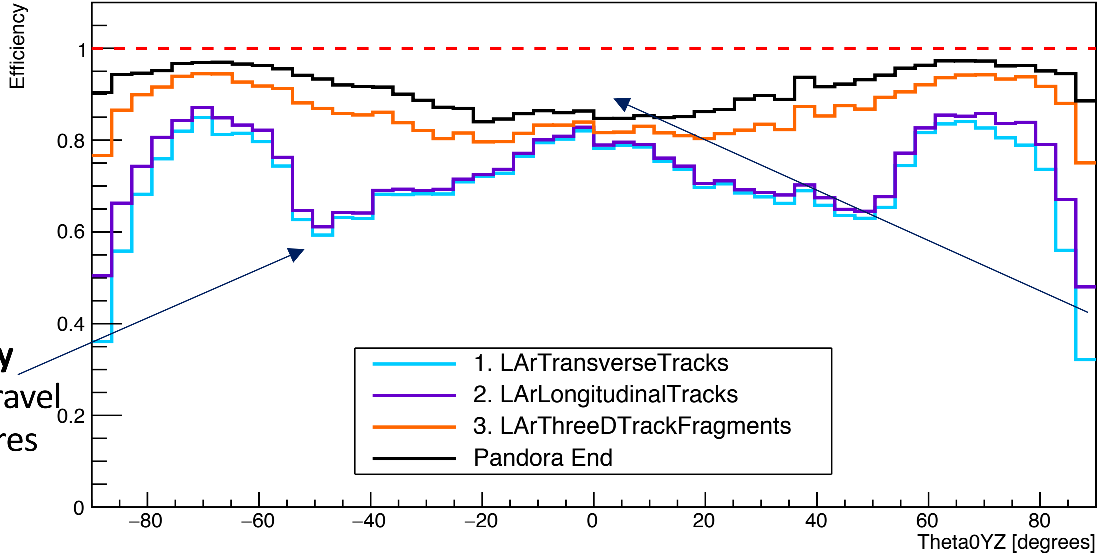
Wispy Tracks

- When a charged particle trajectory follows a wire, there is a long pulse on the wire
- A single Gaussian is fitted to this pulse resulting in a single reconstructed hit
- The hit has a width that represents the length of time the particle spent along the wire
- Pandora does not use this width, all widths set to 0.5



Pandora Efficiency: Theta0YZ

- Would expect to see inefficiencies at Theta0YZ = ±90°, ±54.3°



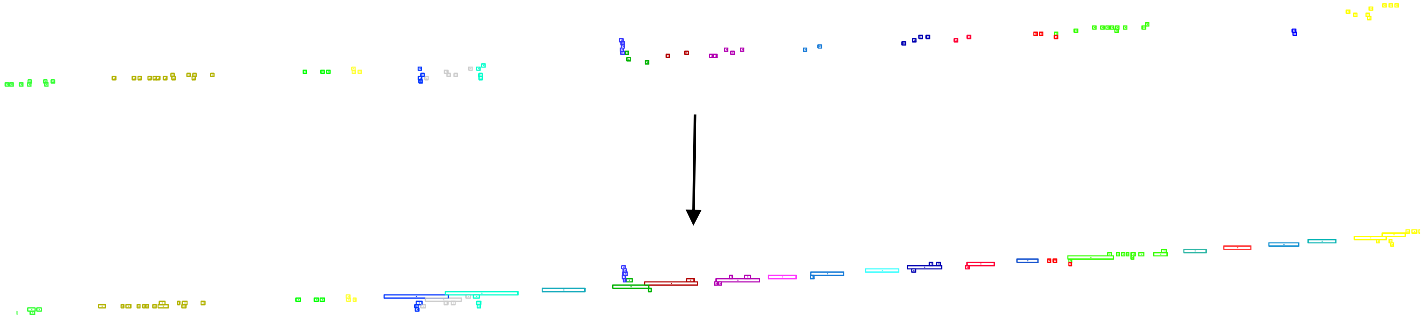
Dips caused by **wispy tracks** as particles travel along on U and V wires

Events that fall within the XZ plane, includes case that is bad for all planes Theta0XZ = 90°

- Demonstrates that the Track Fragments algorithm does recover a lot of these wispy events, but can we do better?

Improving the reconstruction

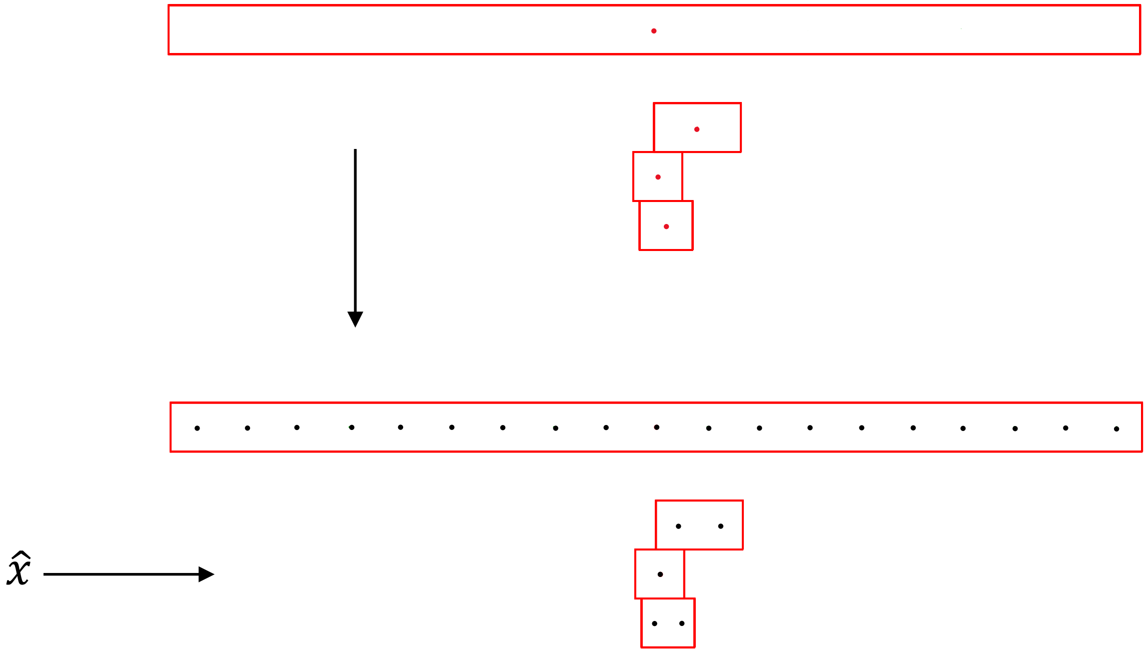
- Option to use the hit widths



- Should be able to use this information to improve the initial clustering and therefore the overall reconstruction

Incorporating Hit Width

- Separate the single hit into constituent hits, each with a width between 0 and 0.5



Dots represent hit center positions

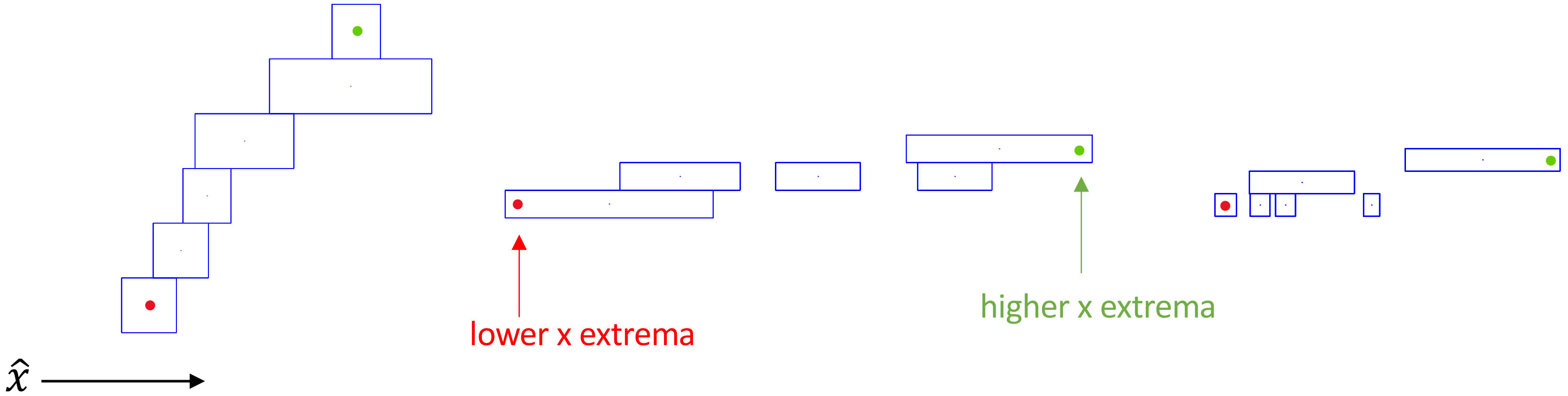
Hit Width Merging Algorithm

- Create a new algorithm to include cluster widths

- There exists a Cluster Associations Base class which takes care of merging associated clusters together
- An inheriting algorithm needs to:
  - Tell the base class how to ‘walk along’ clusters and the directions that correspond to forward and backward associations
  - Provide logic to determine whether clusters are associated

Hit Width Merging Algorithm

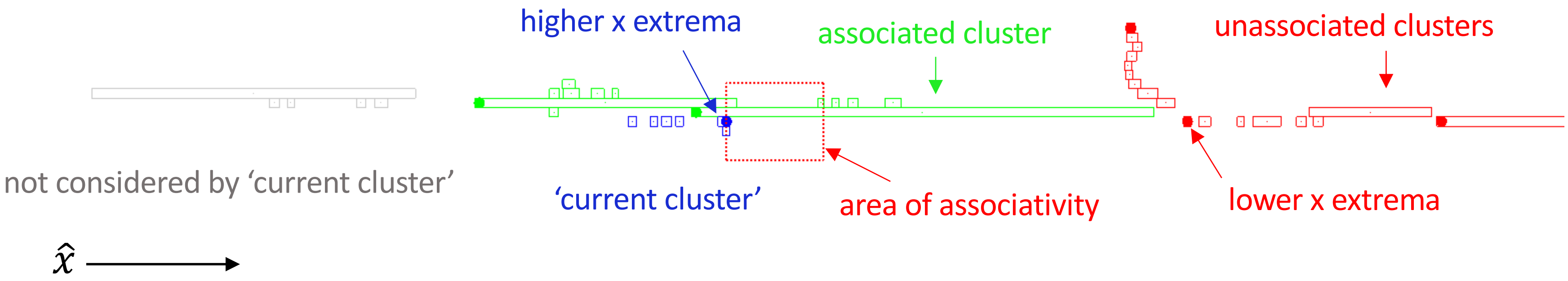
- Give each cluster a lower x extrema, and a higher x extrema



- Order the clusters in increasing higher x extrema, reflects net movement in x
- Walk along clusters, starting from lowest x and for each cluster ask whether those ‘infront’ are associated, if so a forward association and corresponding backwards association are made

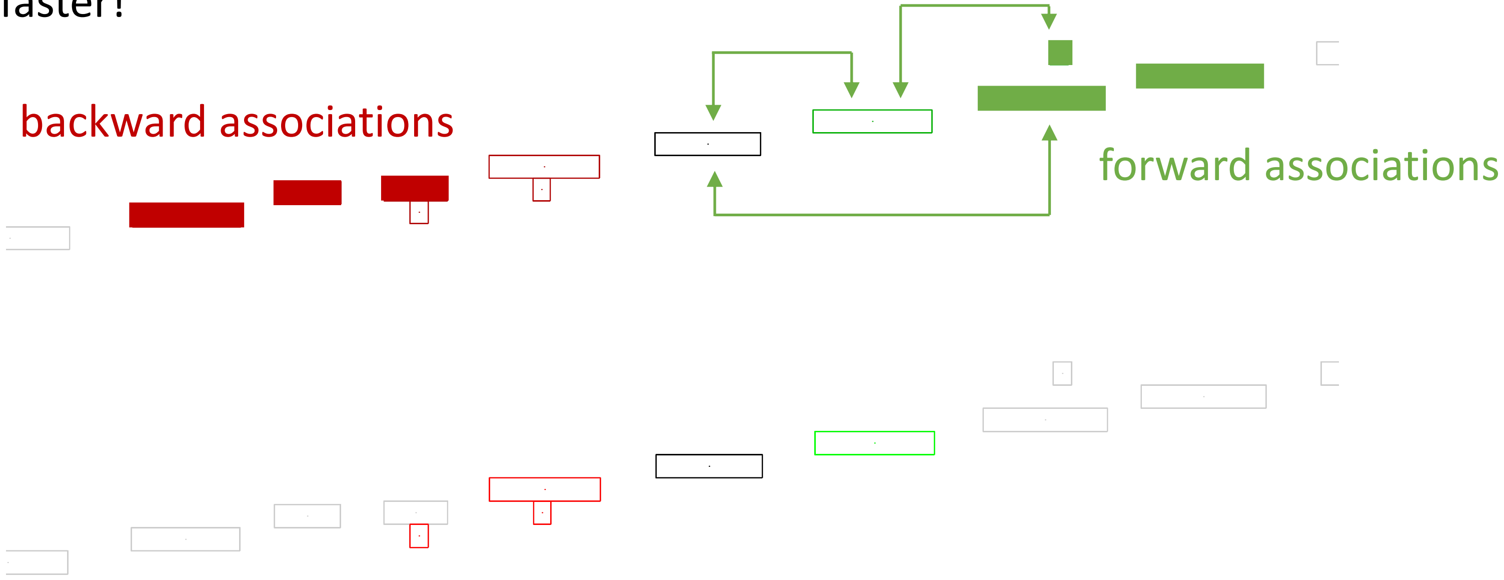
Hit Width Merging Algorithm

- Associated?
  - The cosine of the opening angle between the least squared fitted cluster directions is more than 0.97
  - Lower x ‘in question’ cluster extrema is behind the upper x ‘current cluster’ or less than 5cm away in the forwards x direction
  - Lower x ‘in question’ cluster extrema is less than 2cm away from the upper x ‘current cluster’ extrema in the z direction

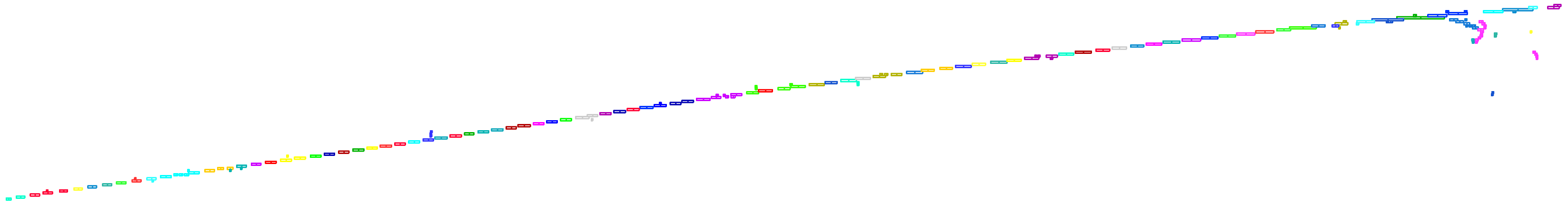


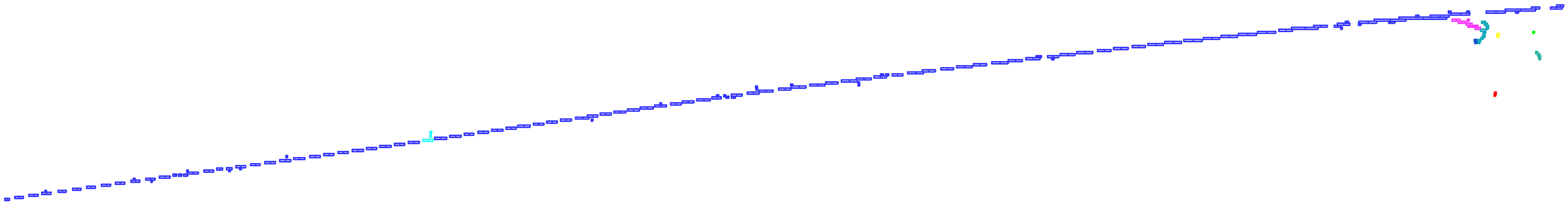
Hit Width Merging Algorithm

- When a cluster has more than one association, each merging pathway is investigated. If this happens often, computational time grows…
- Therefore, removed 'shortcut' associations
- Runs much faster!



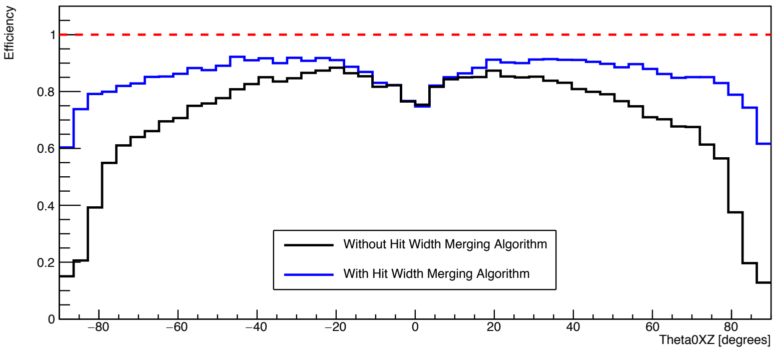
Hit Width Merging Algorithm



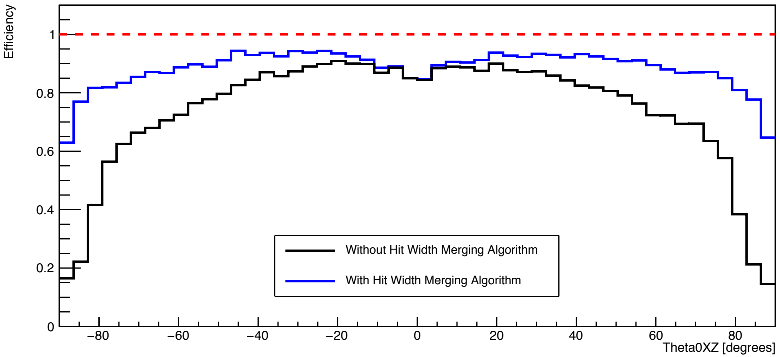


IT WORKS!

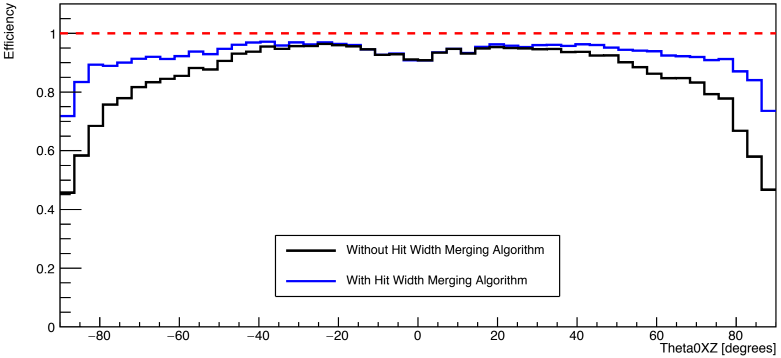
Hit Width Merging Algorithm: Theta0XZ



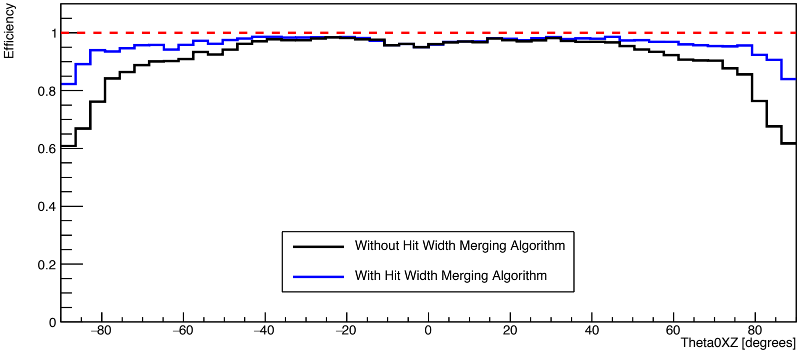
Transverse: 71.2% -> 85.3%



Longitudinal: 73.7% -> 88.2%

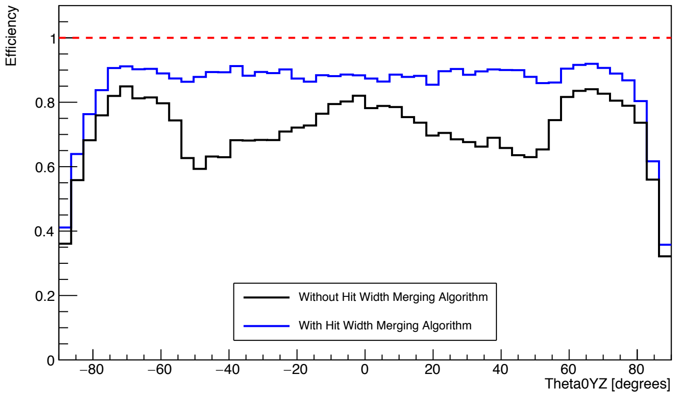


Fragments: 86.3% -> 92.6%



Pandora End: 91.3% -> 96.0%

Hit Width Merging Algorithm: Theta0YZ



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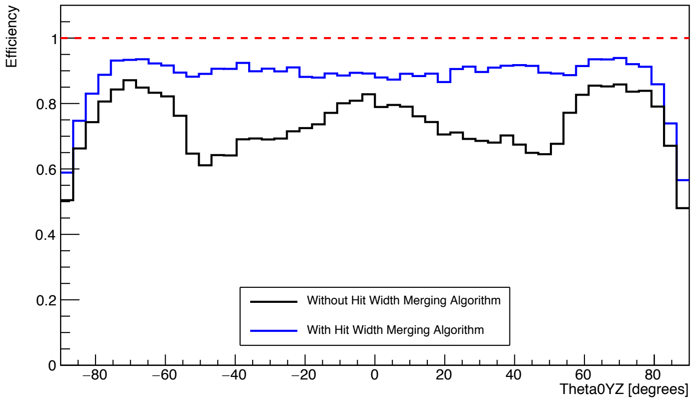

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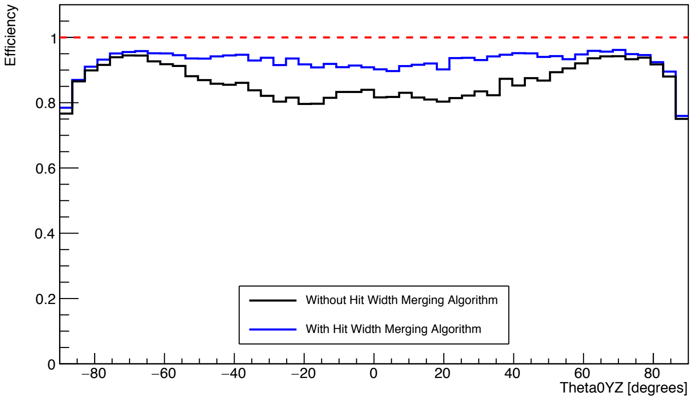

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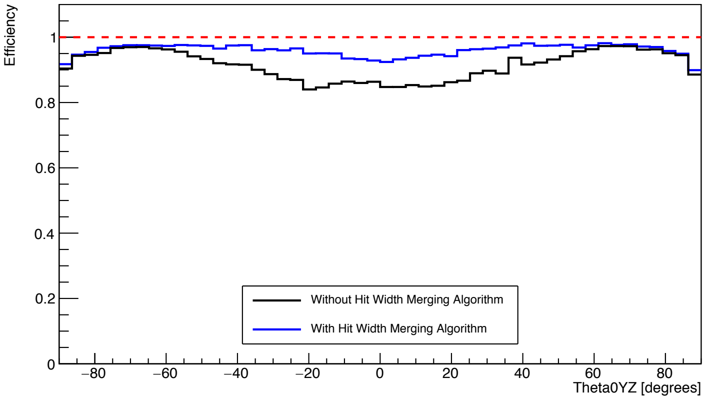

Pandora End: 91.3% -> 96.0%

Hit Width Merging Algorithm: Two Particles

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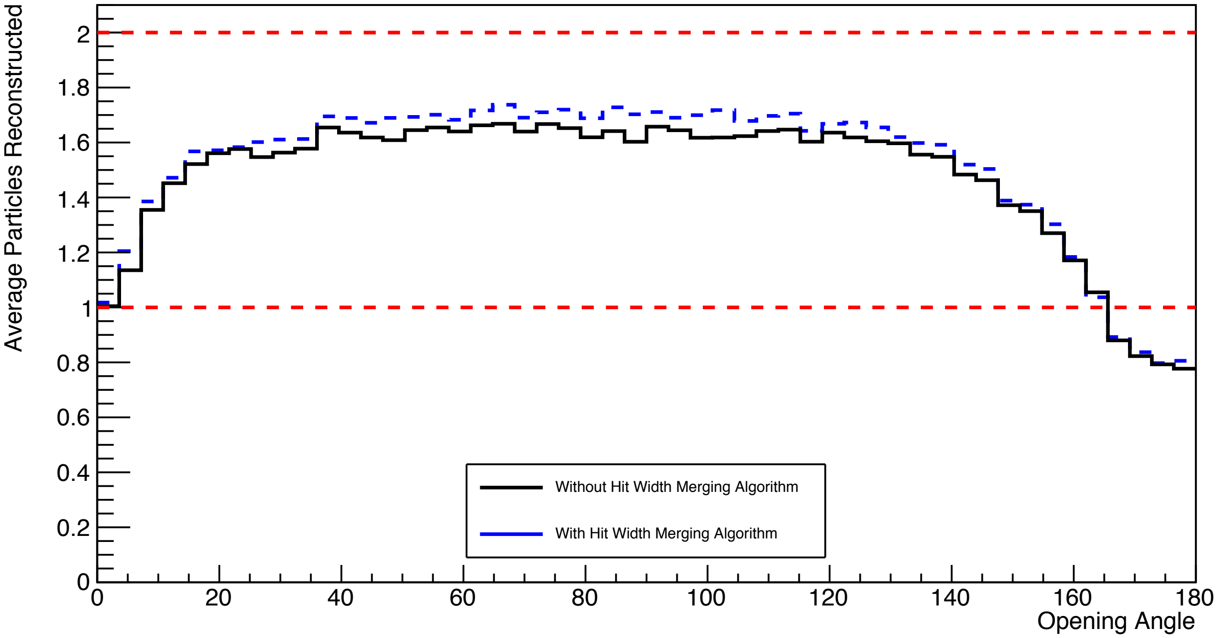


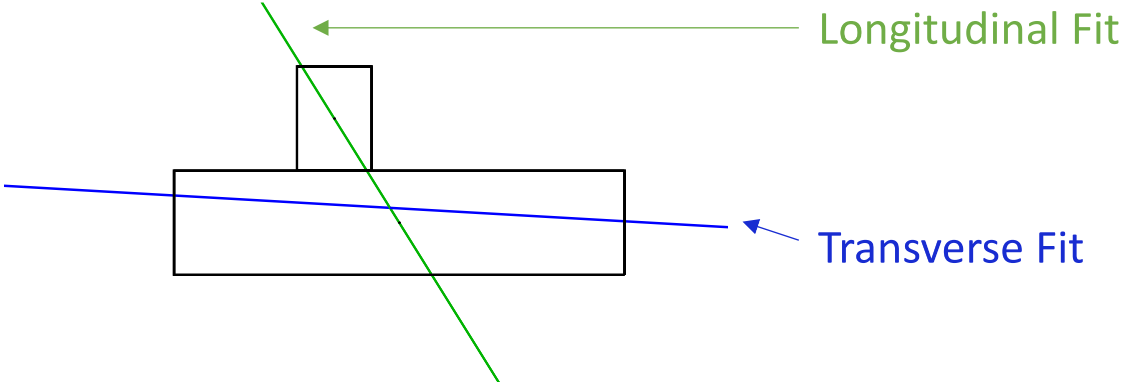
Algorithm doesn't seem to be overgenerous at vertices when merging multiple clusters together…

Next Steps

- Currently looking at high energy cosmic ray muons and constructing an algorithm to improve clustering
- Finalise this algorithm
- Look at multiple particles
- 2D -> 3D algorithm improvement

Hit Width Merging Algorithm

- Cluster direction is determined by making two weighted least squared fits, one that minimises the transverse distance from the fit line and the other the longitudinal distance from the fit line. The one with the lowest chi-squared is chosen



Longitudinal Fit

Transverse Fit

- Two options implemented, one that considers entire cluster and another only section near merging point, both have advantages. Which one is better overall?