

Vertex Performance Study Update

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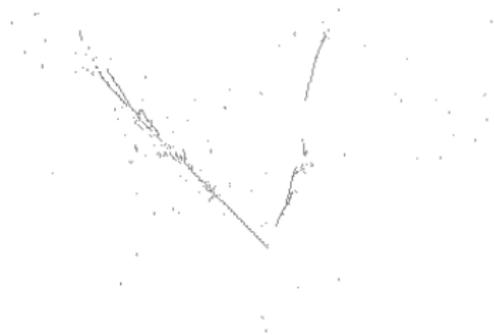
Introduction

- Have begun a study into the vertexing performance in SBND, motivated in particular by the issues we were seeing in the $CC\nu_e$ selection.
- Presented a couple of updates at SBN meetings and Andy asked if I could do the same here.
- I've explored the performance of vertexing using a simple distance between the true and reconstructed vertices.
- Was initially hampered by an issue in the x -coordinate having not accounted for the simulation of the beam spill but this has now been corrected for.
- Have identified some common failure modes and begun using cheated reconstruction to locate areas to target.

Vertex Reconstruction

Reconstruction Chain

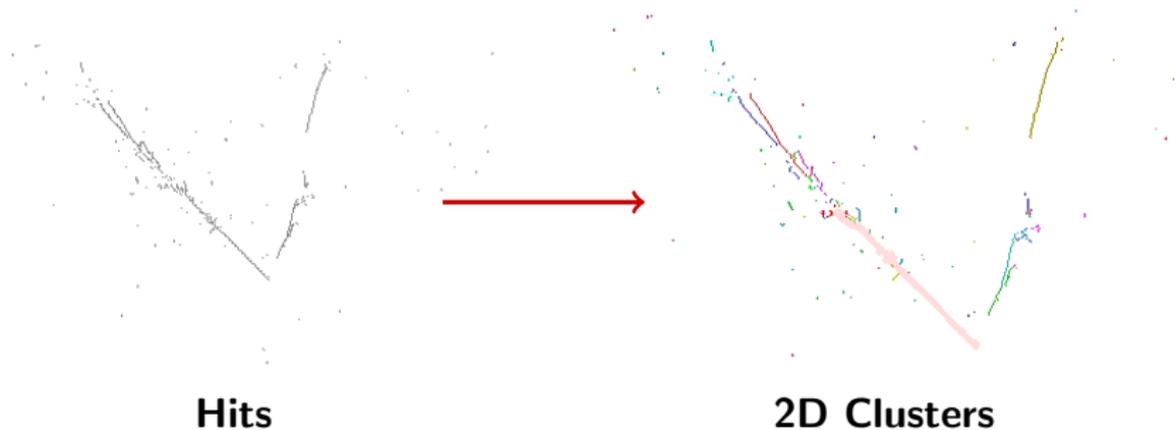
Worth understanding where vertexing takes place within the pandora reconstruction chain...



Hits

Reconstruction Chain

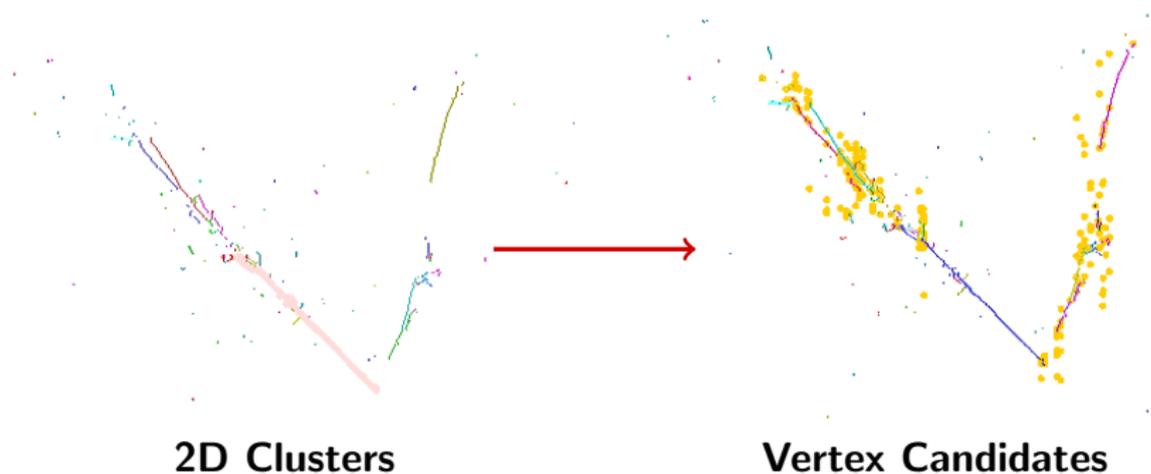
Worth understanding where vertexing takes place within the pandora reconstruction chain...



hits are clustered in each 2D view

Reconstruction Chain

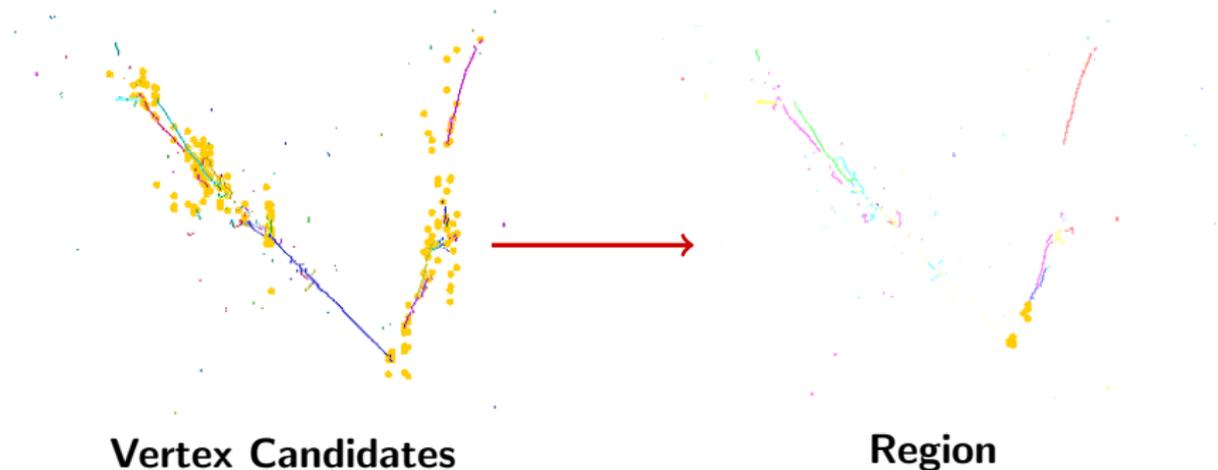
Worth understanding where vertexing takes place within the pandora reconstruction chain...



vertex candidates produced using cluster end points

Reconstruction Chain

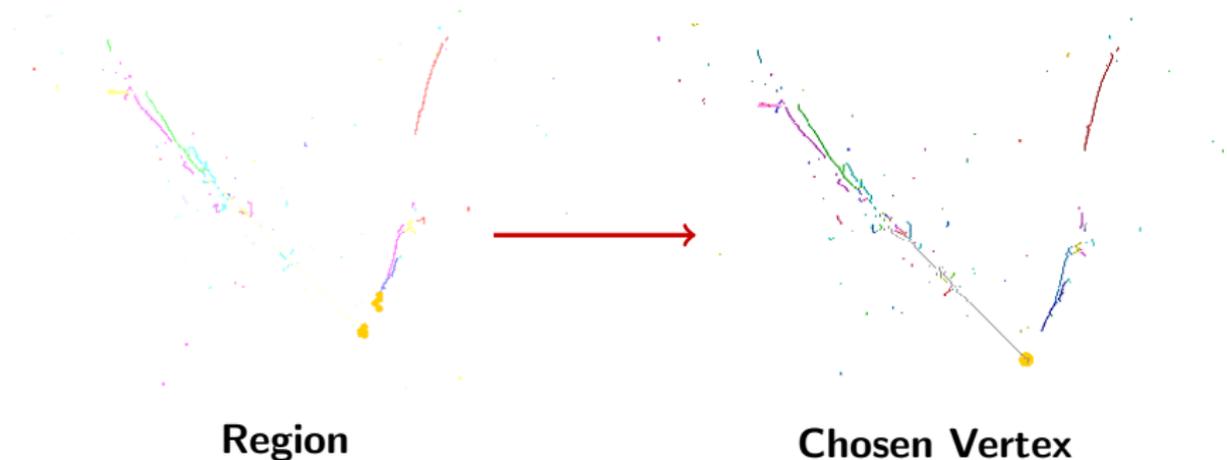
Worth understanding where vertexing takes place within the pandora reconstruction chain...



BDT locates the best region for the vertex to be chosen in

Reconstruction Chain

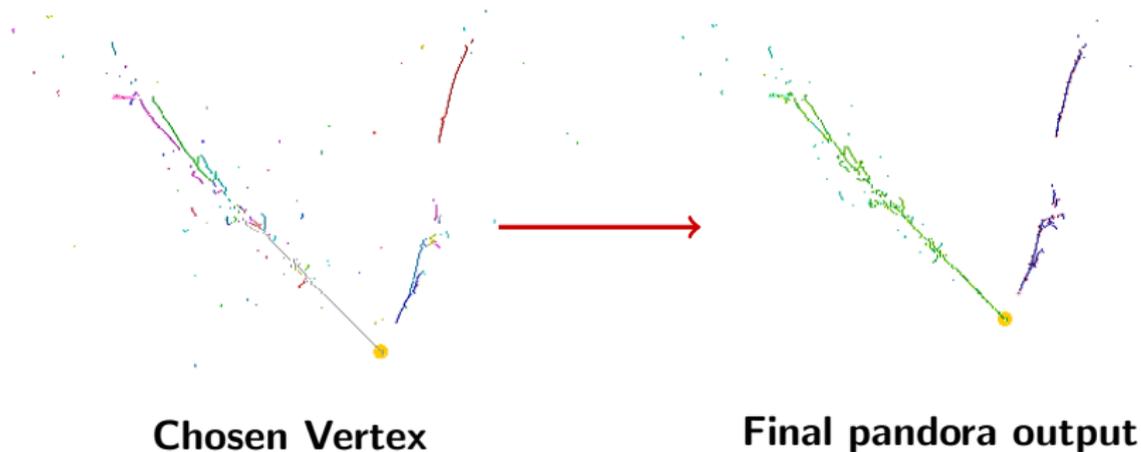
Worth understanding where vertexing takes place within the pandora reconstruction chain...



Another BDT then choses the best vertex in the region

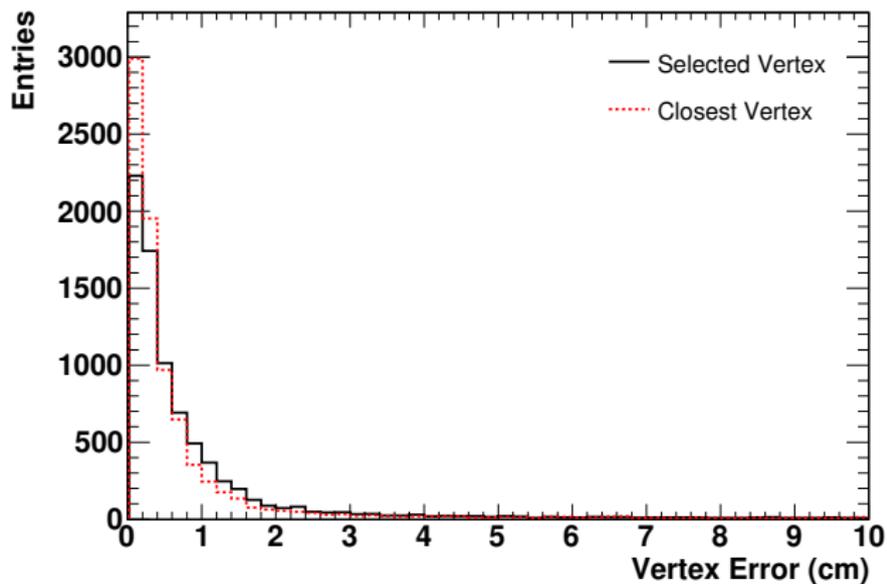
Reconstruction Chain

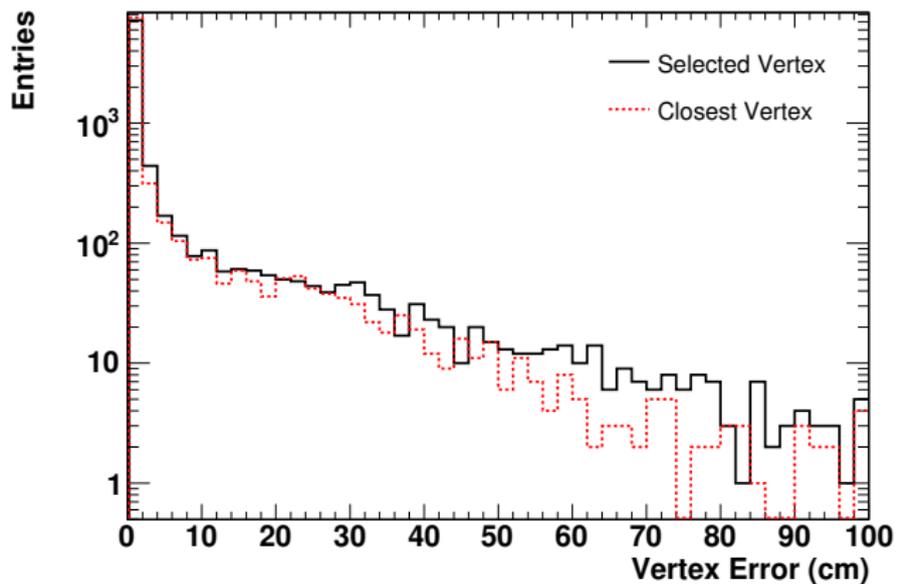
Worth understanding where vertexing takes place within the pandora reconstruction chain...

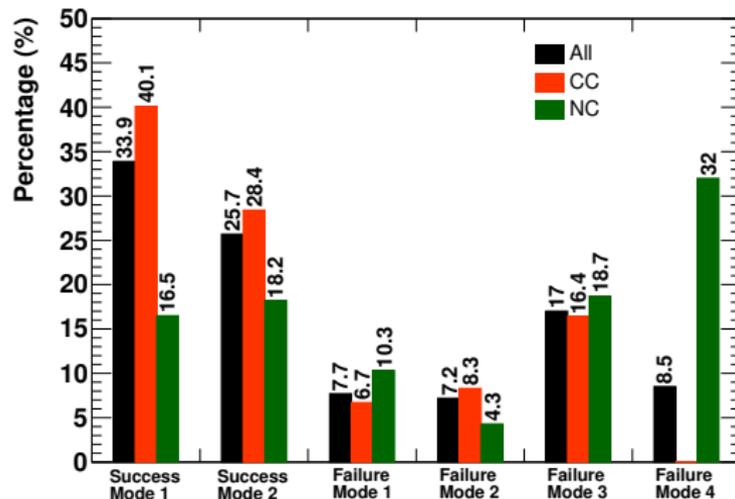


Rest of 2D and 3D reconstruction procedure

General Performance with Corrections







Success Mode 1: Selected vertex is within 1cm of the true vertex and is the closest

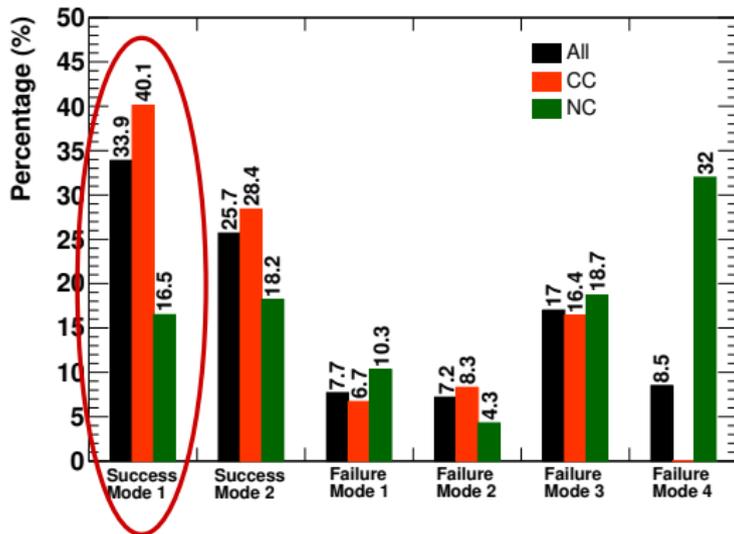
Success Mode 2: Selected vertex is within 1cm of the true vertex but is not the closest

Failure Mode 1: Selected vertex is the closest but is not within 1cm of the true vertex

Failure Mode 2: Selected vertex is not the closest and is beyond 1cm of the true vertex but there is a potential candidate within 1cm

Failure Mode 3: Selected vertex is not the closest and there is no candidate within 1cm

Failure Mode 4: There are no reconstructed vertices



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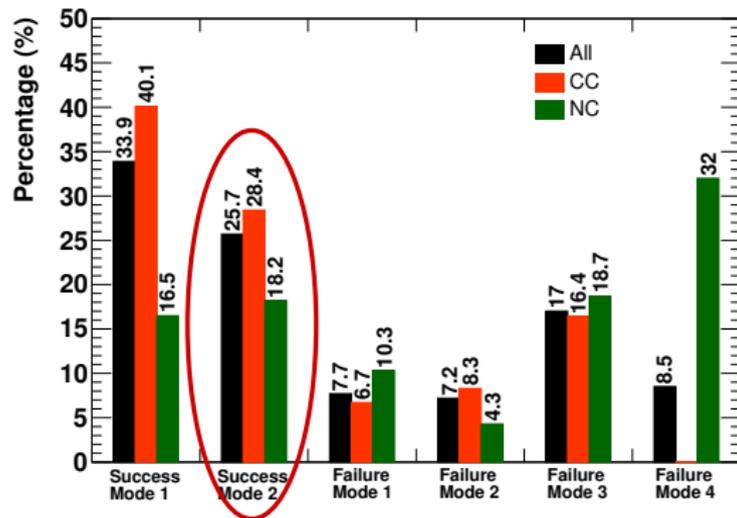
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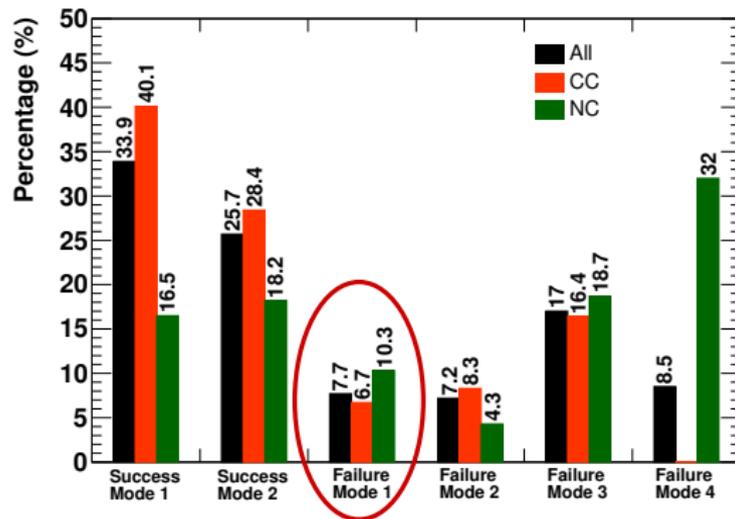
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Categorised Vertex Performance

ν_e Sample



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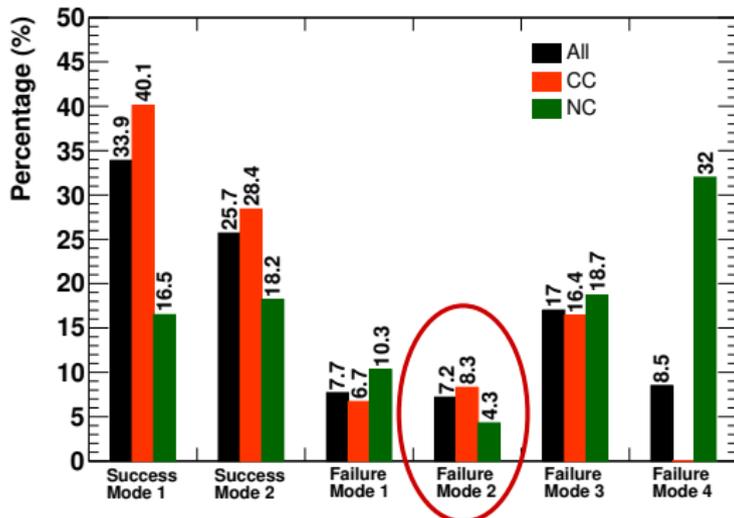
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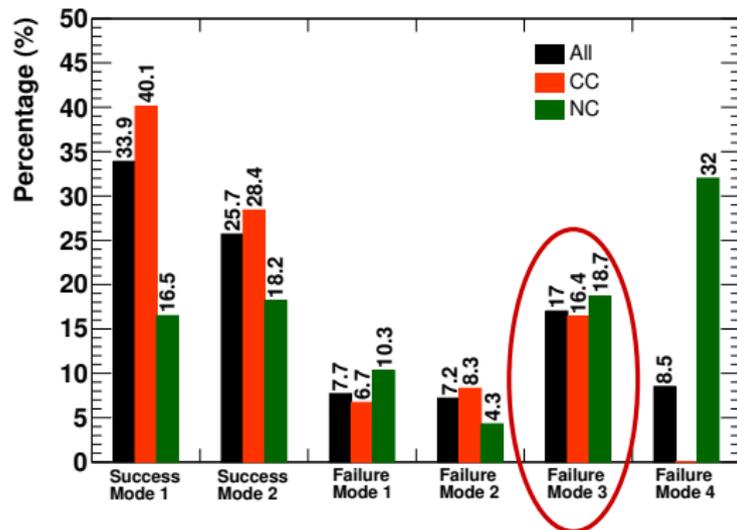
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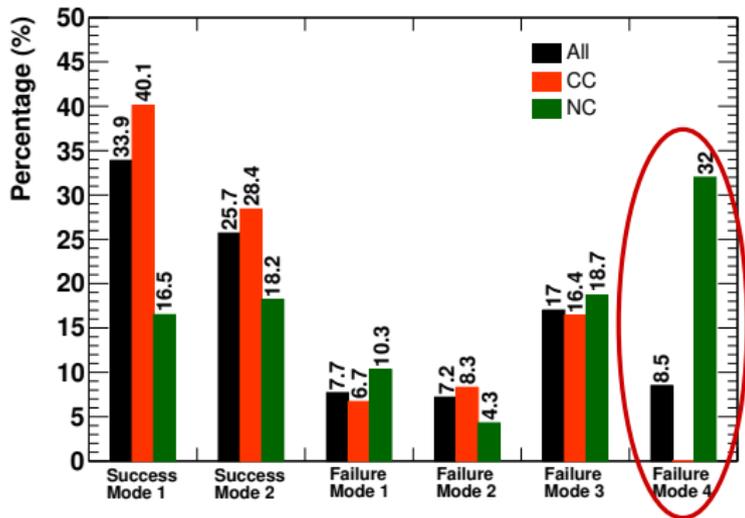
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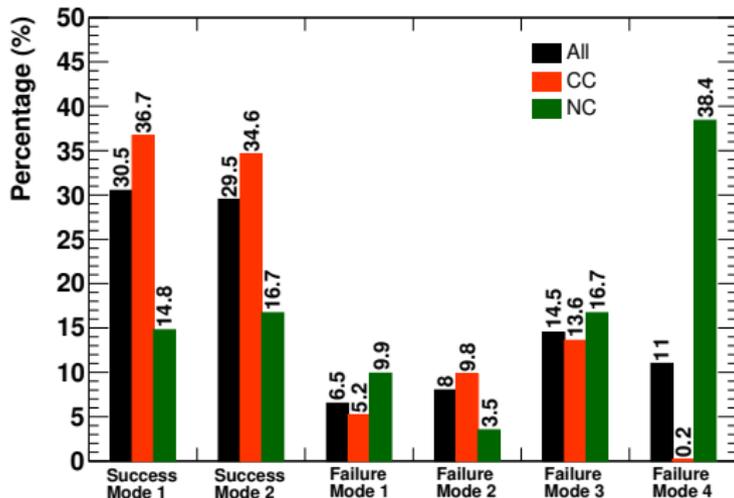
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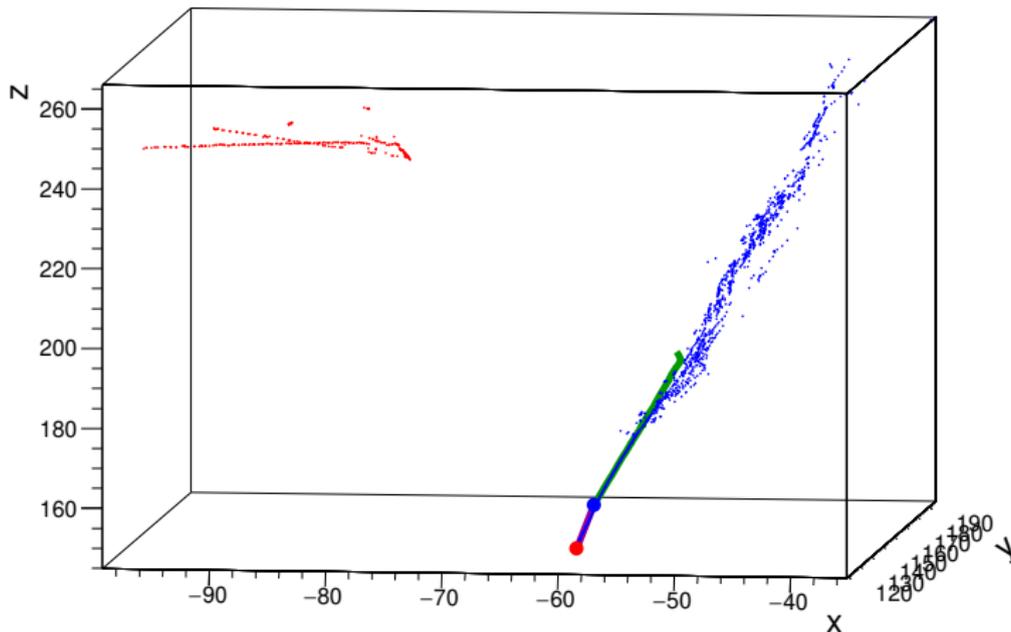
Common Failure Modes

Event Displays

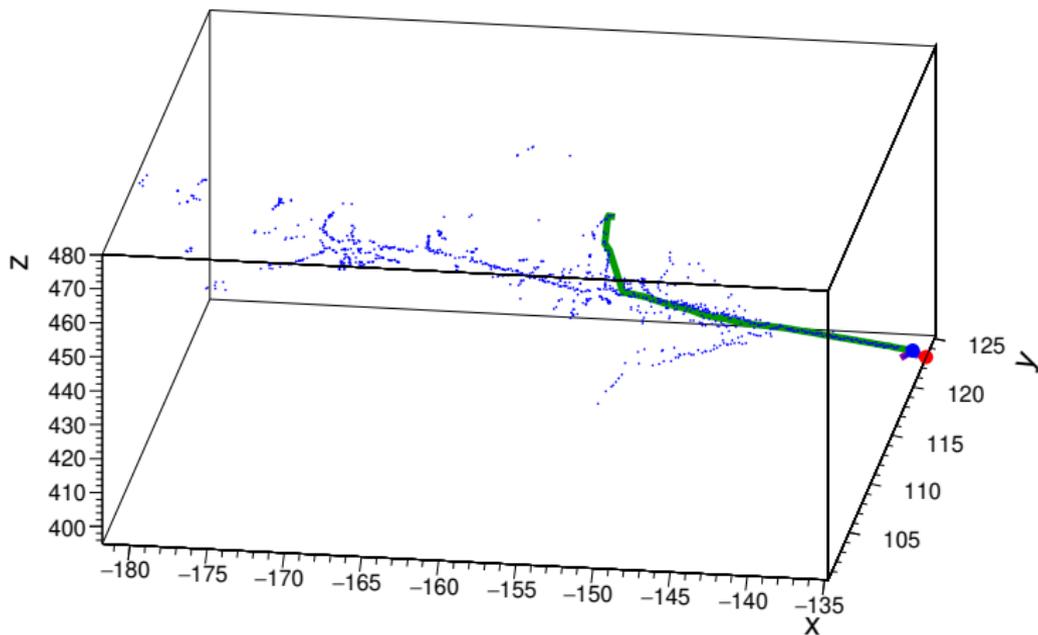
I looked through about 100 events of each type to try and determine some common failure modes. I've plotted some 'event displays' to easily view in 3D what is going on. They use the following style:

- Thick lines are true particle trajectories (green - electron, magenta - proton, orange - muon)
- Small dots are space points from final reconstructed pfos (blue - showers, red - tracks)
- Large blue marker is the true vertex
- Large red marker is the reconstructed vertex

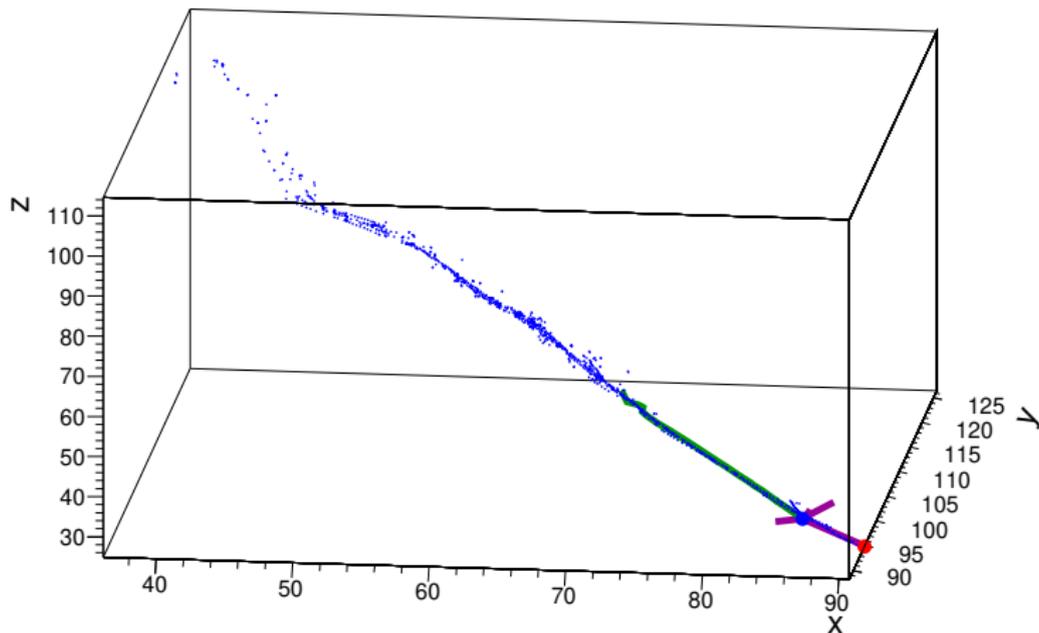
Run: 1 SubRunID: 72 EventID: 18 Error: 10.624227 cm



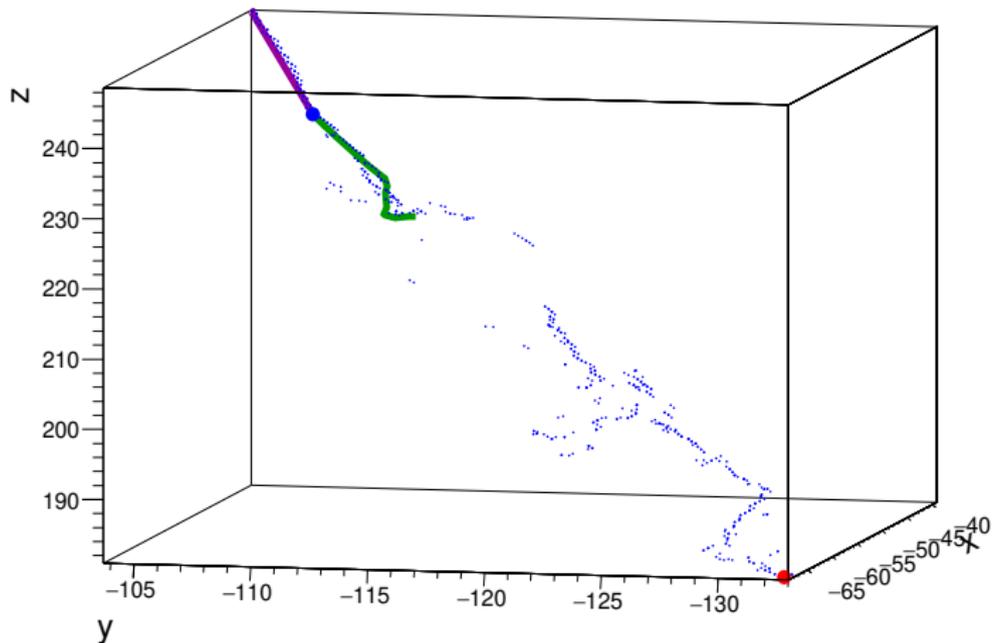
Run: 1 SubRunID: 378 EventID: 67 Error: 1.394922 cm



Run: 1 SubRunID: 302 EventID: 87 Error: 7.692391 cm



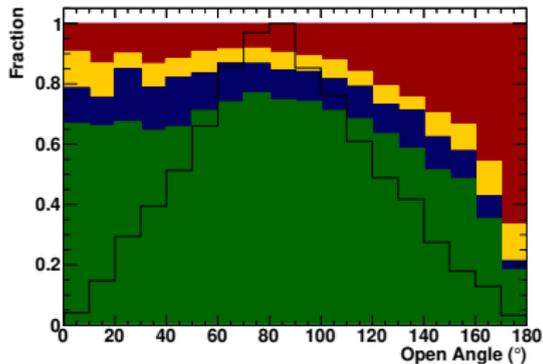
Run: 1 SubRunID: 72 EventID: 51 Error: 65.514389 cm



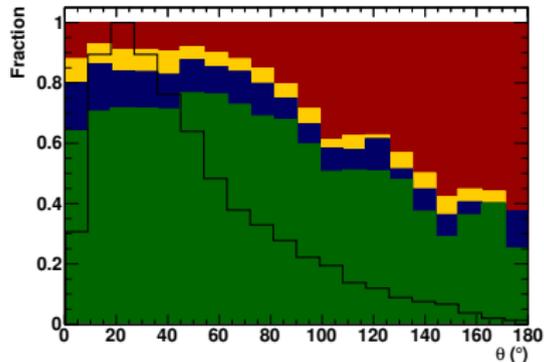
There were some common themes looking through the ν_e failure modes:

- Vertex ended up at proton stopping/scattering point
- Electron back scattered
- Very large angle between lepton and leading hadron

Worth (roughly) establishing that these themes are consistent across the whole sample.



Angle between the electron and the leading charged hadron



Angle between the electron and z-axis



Vertex Error < 1cm



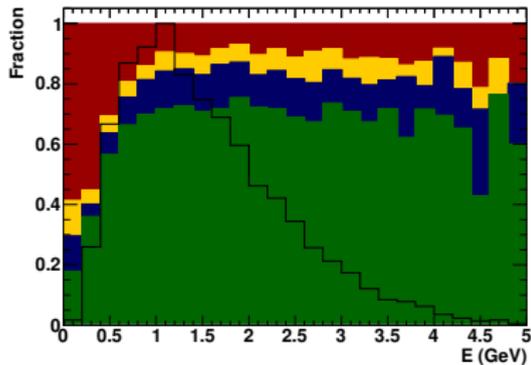
1cm < Vertex Error < 2cm



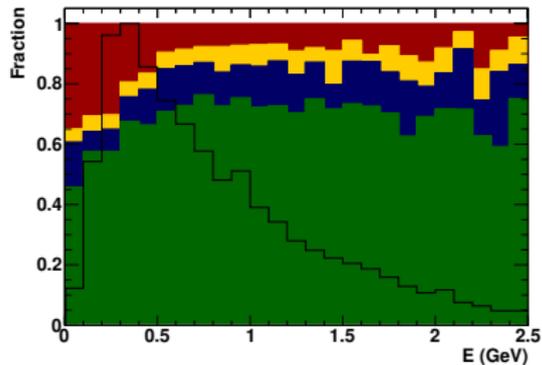
2cm < Vertex Error < 5cm



5cm < Vertex Error



Neutrino energy



Electron energy



Vertex Error < 1cm



1cm < Vertex Error < 2cm

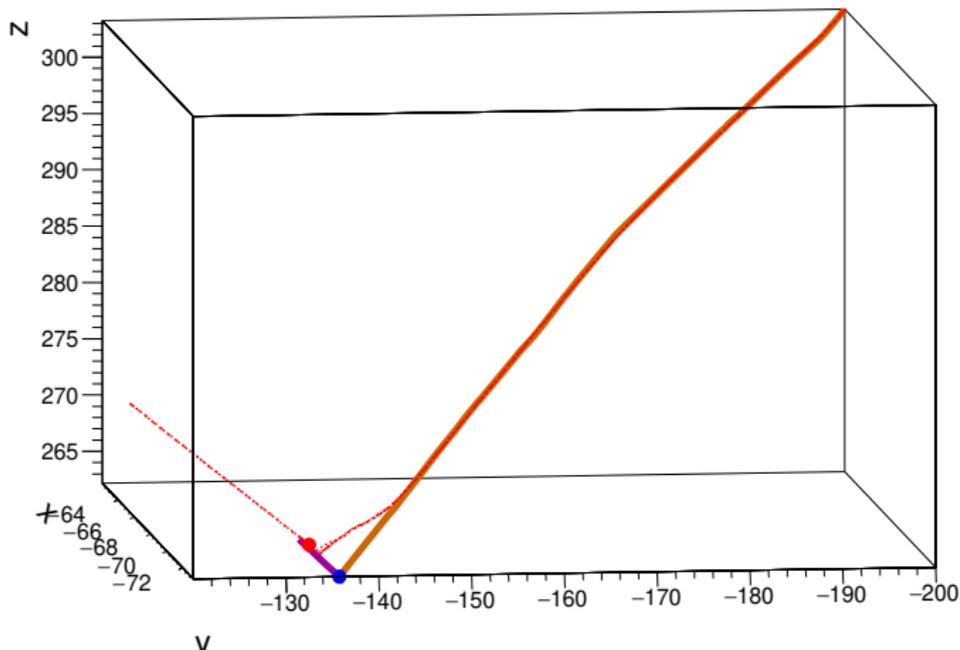


2cm < Vertex Error < 5cm

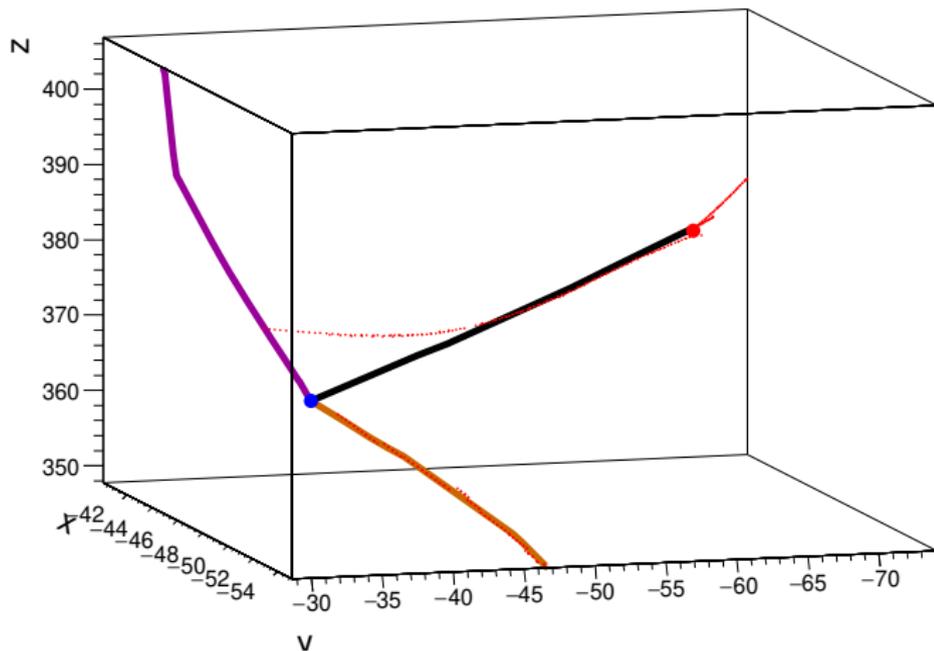


5cm < Vertex Error

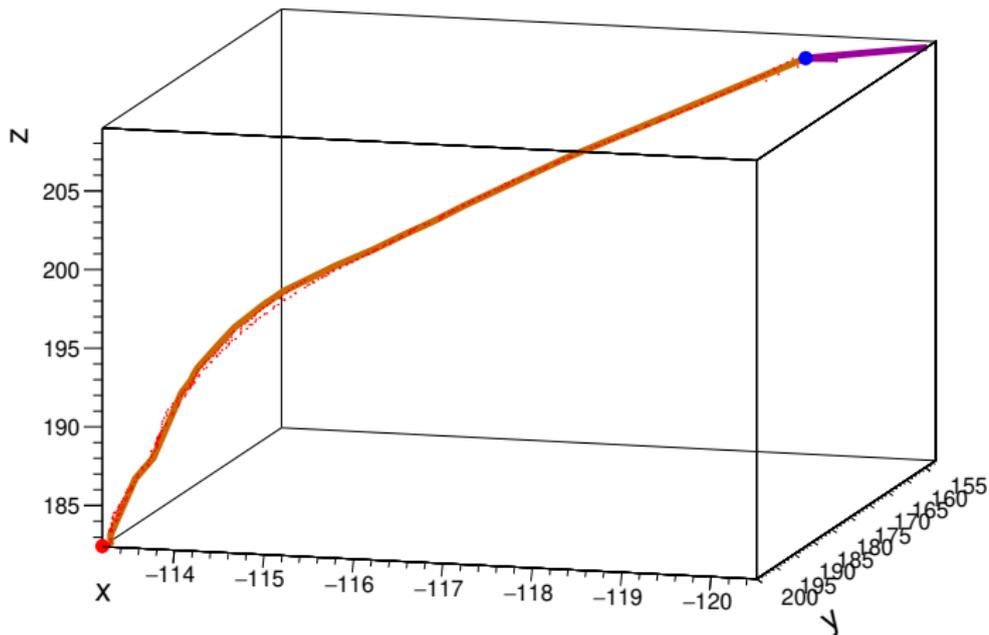
Run: 19 SubRunID: 46 EventID: 14 Error: 4.253484 cm



Run: 19 SubRunID: 46 EventID: 67 Error: 34.016994 cm



Run: 19 SubRunID: 46 EventID: 71 Error: 54.368179 cm



Cheating

Cheated Vertex Selection

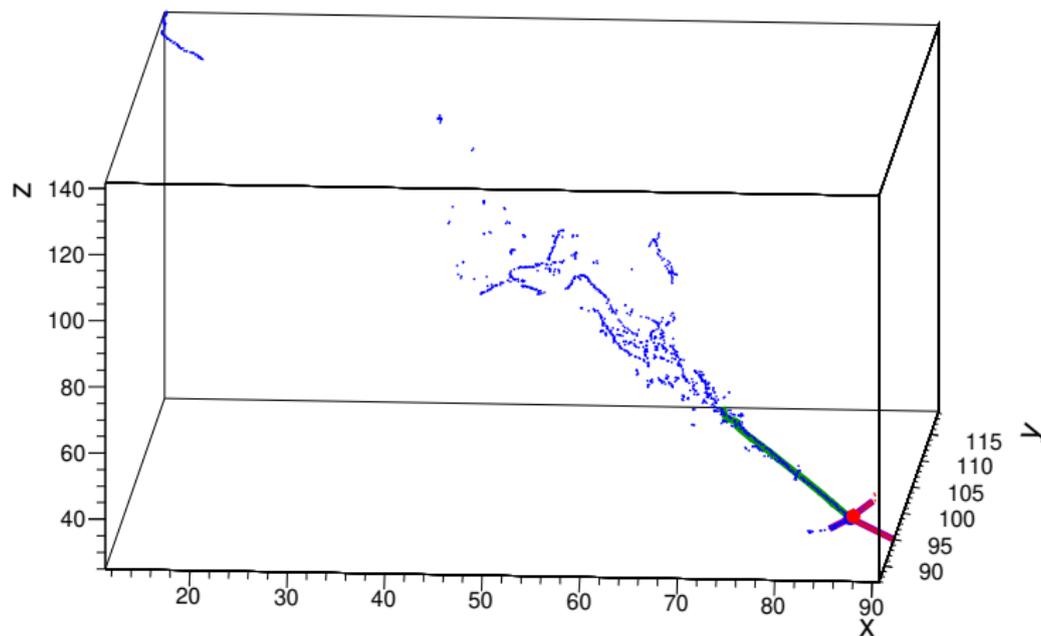
Allow pandora to create the vertex candidates in its usual manner. The two BDT stages (finding region and then finding vertex) are then replaced with a 'cheating' algorithm which selects the closest candidate vertex to the true location.

```
<algorithm type = "LARbdVertexSelection">
  <InputCaloHitListNames>CaloHitListU CaloHitListV CaloHitListW</InputCaloHitListNames>
  <InputClusterListNames>ClustersU ClustersV ClustersW</InputClusterListNames>
  <OutputVertexListName>NeutrinoVertices3D</OutputVertexListName>
  <ReplaceCurrentVertexList>true</ReplaceCurrentVertexList>
  <MvaFileName>PandoraMVAS/PandoraBdt_v08_33_00_SBND.xml</MvaFileName>
  <RegionMvaName>VertexBDTRegion</RegionMvaName>
  <VertexMvaName>VertexBDTVertex</VertexMvaName>
  <FeatureTools>
    <tool type = "LAREnergyKickFeature"/>
    <tool type = "LARLocalAsymmetryFeature"/>
    <tool type = "LARGlobalAsymmetryFeature"/>
    <tool type = "LARShowerAsymmetryFeature"/>
    <tool type = "LARPhiFeature"/>
  </FeatureTools>
</algorithm>
```

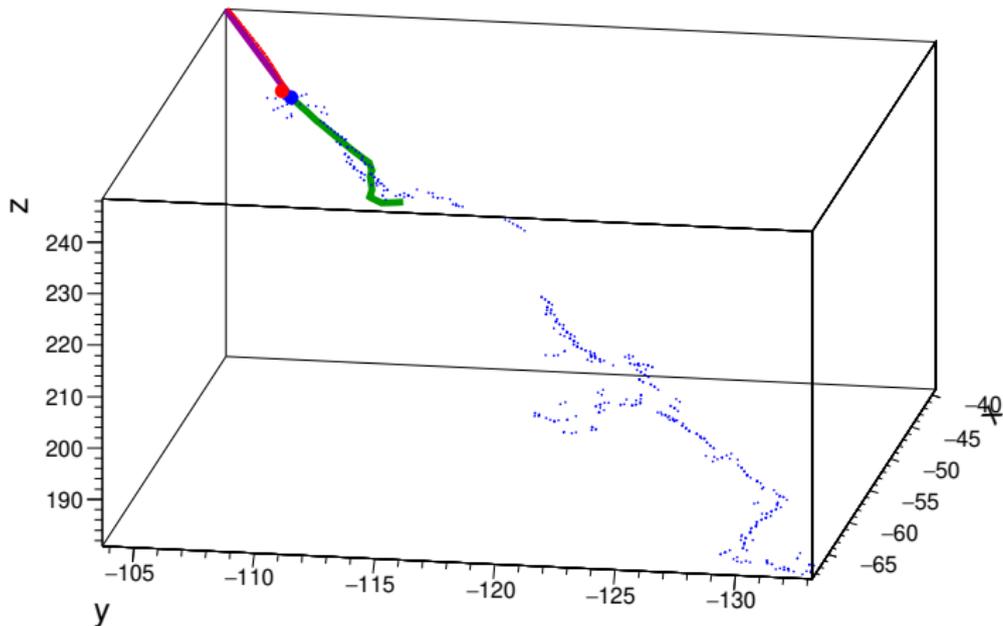


```
<algorithm type = "LARCheatingVertexSelection">
  <MCParticleListName>Input</MCParticleListName>
  <InputCaloHitListNames>CaloHitListU CaloHitListV CaloHitListW</InputCaloHitListNames>
  <InputClusterListNames>ClustersU ClustersV ClustersW</InputClusterListNames>
  <OutputVertexListName>NeutrinoVertices3D</OutputVertexListName>
  <ReplaceCurrentVertexList>true</ReplaceCurrentVertexList>
</algorithm>
```

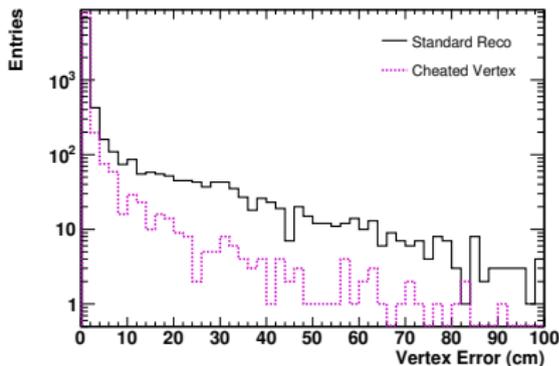
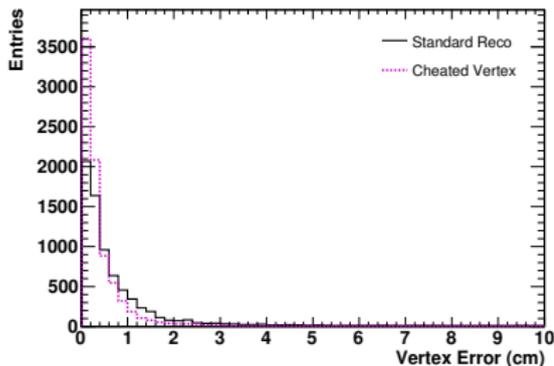
Run: 1 SubRunID: 302 EventID: 87 Error: 0.472521 cm



Run: 1 SubRunID: 72 EventID: 51 Error: 1.184112 cm

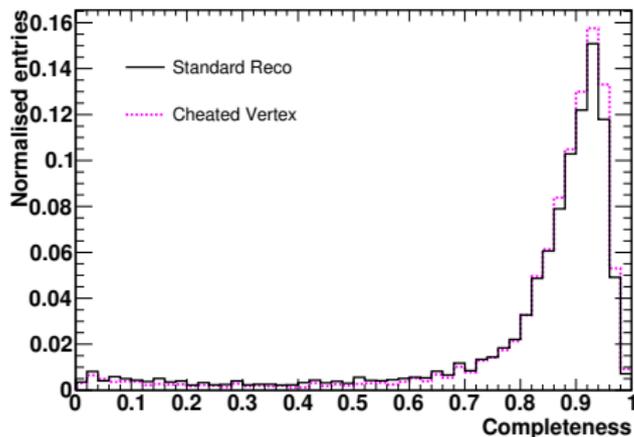


This allows us to evaluate what the largest possible gains could be from improving the selection without touching the candidate creation.



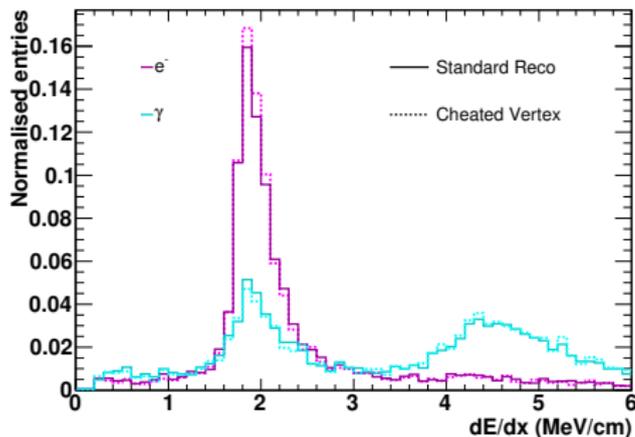
There are clearly a significant number of events in which there are *possible* improvements to be made to the selection of the vertex.

Its worth viewing how much impact this can have on downstream reconstruction.



The completeness for the ν_e CC electron showers improves. The total number of these electrons that are reconstructed also increases.

Its worth viewing how much impact this can have on downstream reconstruction.

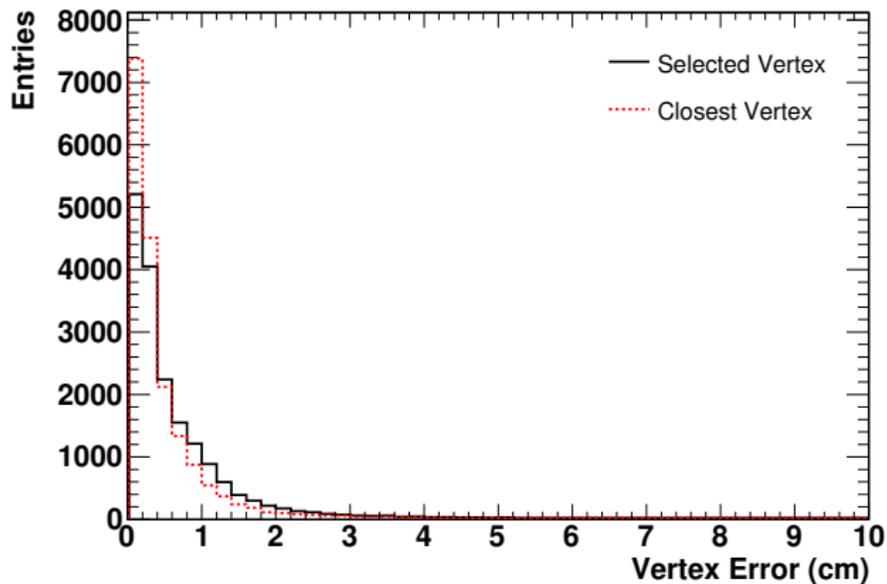


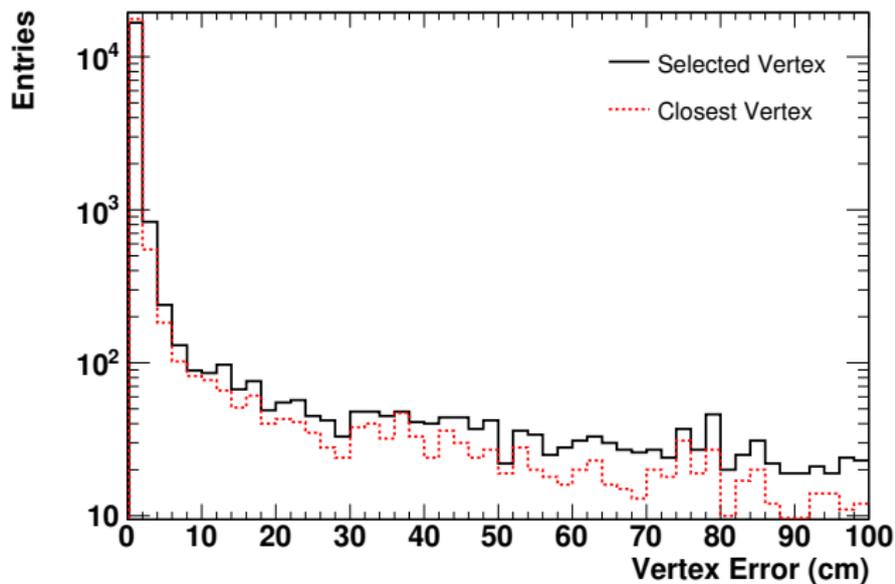
Unfortunately improvements in a rough e/γ separation plot aren't as immediately noticeable. The electron shape improvements are not insignificant, however.

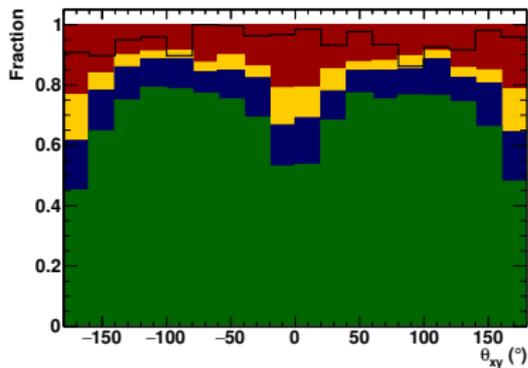
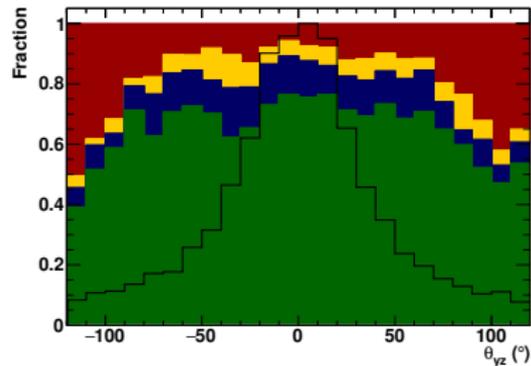
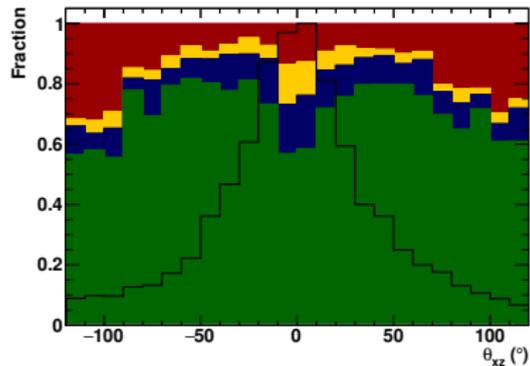
Conclusions and Directions

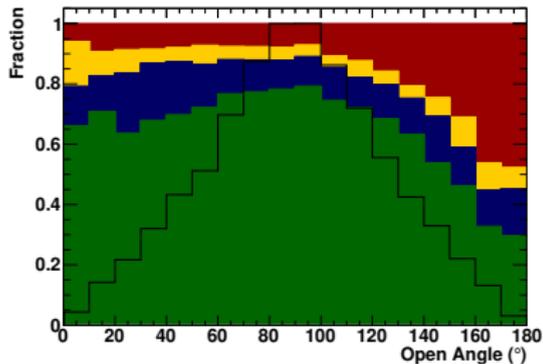
- The vertexing performance for $CC\nu_e$ events is nominally around 68.5% of “good” events.
- Identified some common failure modes in both the ν_e and ν_μ events
- Cheating the vertex selection shows that there are definitely gains possible from improving the selection.
- Ed has provided me with the scripting he used to train the current vertex selection BDT for SBND, I've run this on his old training data and been able to begin tinkering with parameters. Intend to begin looking at whether by adding/removing/updating the variables we can begin to claw back any of these failure modes.

BACKUP

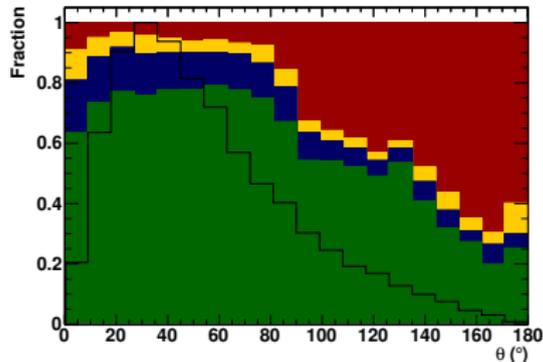








Angle between the muon and the leading charged hadron



Angle between the muon and z-axis



Vertex Error < 1cm



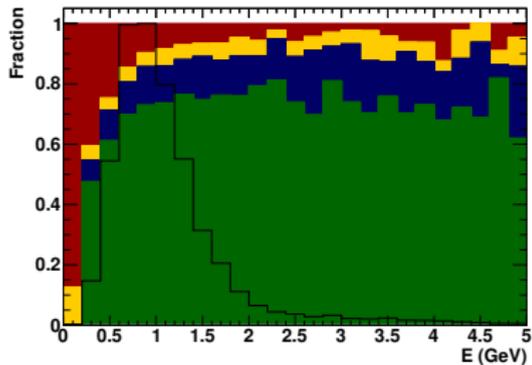
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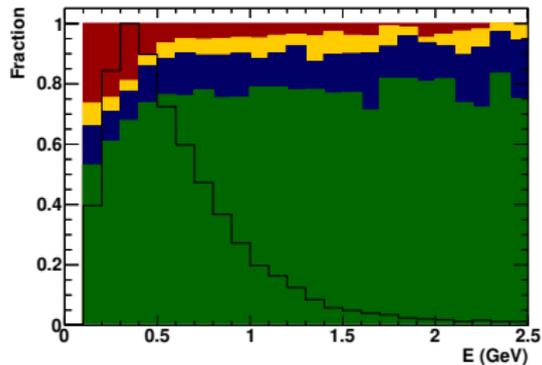
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Neutrino energy



Muon energy



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1cm < Vertex Error < 2cm



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