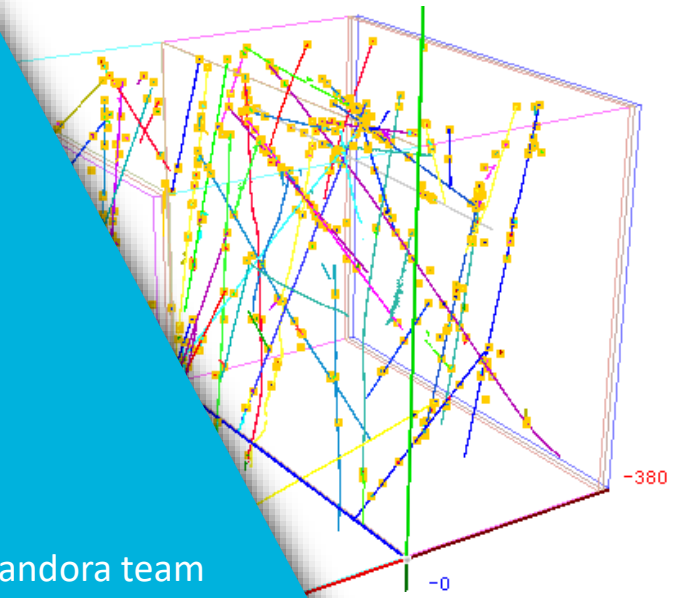
Debugging reconstruction

(Exercise)



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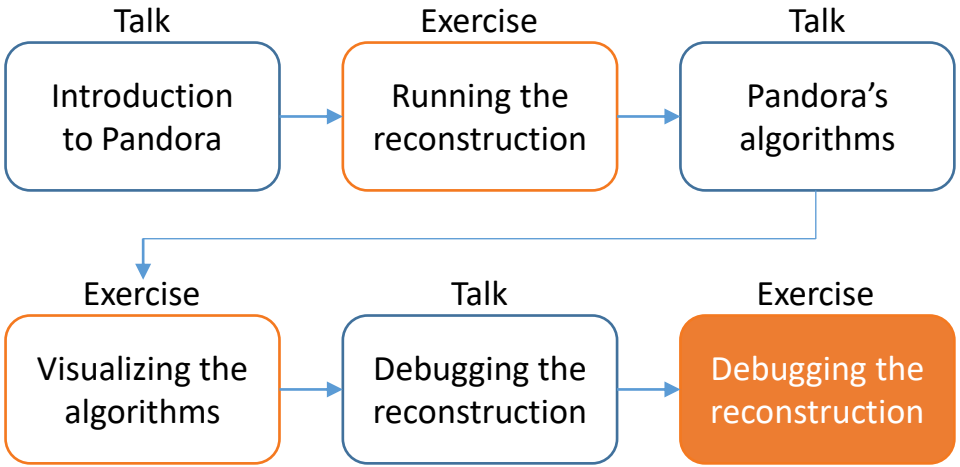
8th UK LArTPC Software and Analysis Workshop

Reconstruction session



Credit: These slides are based on previous LArSoft workshop slides by Andrew Smith

Key references: Pandora ProtoDUNE paper
Pandora MicroBooNE paper

Goals

- This session scheduled for 50 minutes
- Main goal – Identify the source of reconstruction failures
  - Add visualisations at key points of the reconstruction chain to spot when things go wrong
  - Investigate the behaviour of relevant algorithms to understand how they work
- Secondary goal – Fix the event
  - Attempt to tune key parameters (ideally in XML) to address the problem
  - If you're feeling ambitious, come up with an idea to modify the algorithm code
- Please don't worry if you don't fix the event
  - Even if you fix the error in one place, your efforts might be undone later in the reconstruction chain
  - Reconstruction is hard

Investigate the reconstruction output

A new event

- We'll be using a custom event for this task (you can copy it locally or directly run using this path):

```
/home/share/october2023/reconstruction/prodres_sbnd_Gen_G4_DetSim.root
```

- This is a particle gun event mimicking resonant pion production that we know gets mis-reconstructed
- Make sure to be in the directory you've been working in so far for the reconstruction tutorials:

```
$ cd $MRB_TOP/reco/config
```

- Copy the neutrino XML configuration file from LARPANDORA_DIR again to start with a clean XML

```
$ cp $LARPANDORA_DIR/scripts/PandoraSettings_Neutrino_Standard.xml MyPandoraSettings_Neutrino_Standard.xml
```

- For this step we need to run the reconstruction, not just the event display, so let's set up a new fhicl file…

Writing a FHiCL file to run custom reconstruction

- Let's make a new FHiCL file that just runs the reconstruction using our custom XML configuration and produces an output file without the default timestamp tag

```
$ vim reco_driver.fcl
```

- Add the lines below to reco_driver.fcl, save and close:

```
#include "standard_reco1reco2_sbnd.fcl"

outputs.out1.filename: "%ifb_%p.root"

# Use our custom settings file
physics.producers.pandora.ConfigFile: "MyPandoraSettings_Master_Standard.xml"
```

Use our modified settings for reco

Add process name to input filename for output

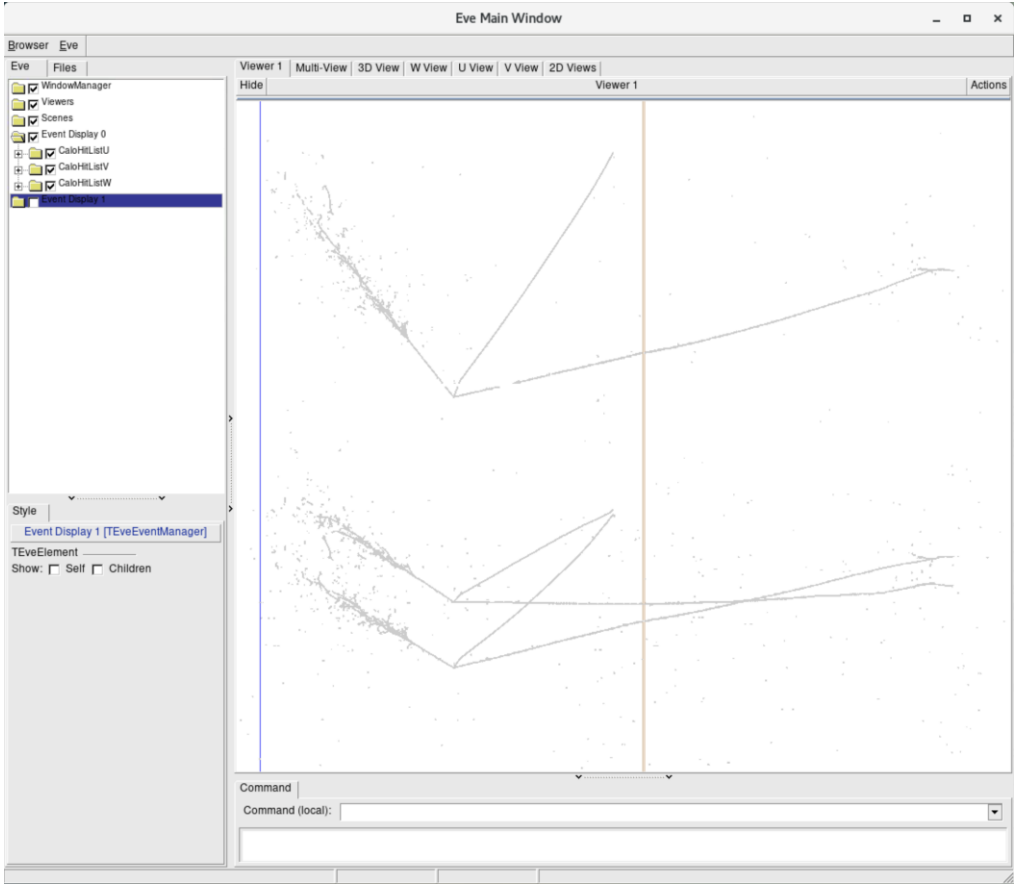
Point to our new XML settings file

- Run Pandora over the event and look at the reconstruction output

```
$ lar –c reco_driver.fcl –s /home/share/october2023/prodres_sbnd_Gen_G4_DetSim.root –n 1
```

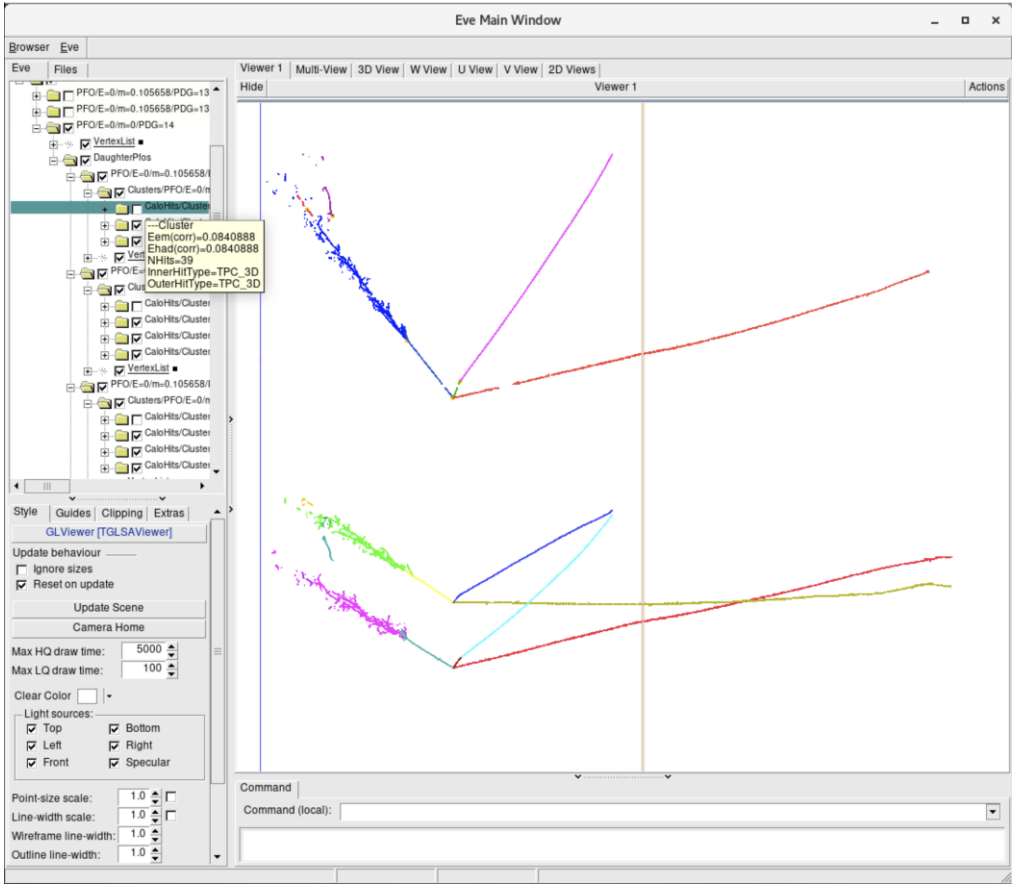
Reconstructing the event

- The primary particles in the event are an electron, a proton and a pion
- The particles are well separated and densely populated with hits
- So, what could go wrong?
- Press Return ↵ to move onto the event display with the reconstructed PFOs



The final reconstruction output

- We want to focus on the 2D hits to understand what's going on here
- Expand the tree and turn off the 3D clusters for each PFO
- The track reconstruction looks reasonable
  - Some of the downstream pion interaction gets merged into the primary pion, but that's not our main interest here
- The key failure is that the MIP-like stub of the electron is reconstructed as a separate track to the downstream shower cascade
- We want to fix this*



* Pandora has dedicated algorithms to address this, but today we're going to try parameter tuning

Tracing the source of the error

- We're going to take the techniques introduced in the last tutorial to try to understand where things go wrong
- We're going to focus on the 2D clustering algorithms
- After the LArClusteringParent algorithm for the U view, add the following instance of the LArVisualMonitoring algorithm
  - Note we're using a slightly different version here, showing "current" clusters, because current lists are set to the U view for the entire block

```
<algorithm type = "LArClusteringParent">
    <algorithm type = "LArTrackClusterCreation" description = "ClusterFormation"/>
    <InputCaloHitListName>CaloHitListU</InputCaloHitListName>
    <ClusterListName>ClustersU</ClusterListName>
    <ReplaceCurrentCaloHitList>true</ReplaceCurrentCaloHitList>
    <ReplaceCurrentClusterList>true</ReplaceCurrentClusterList>
</algorithm>
<algorithm type = "LArVisualMonitoring">
    <ShowCurrentClusters>true</ShowCurrentClusters>
</algorithm>
```

Tracing the source of the error (2)

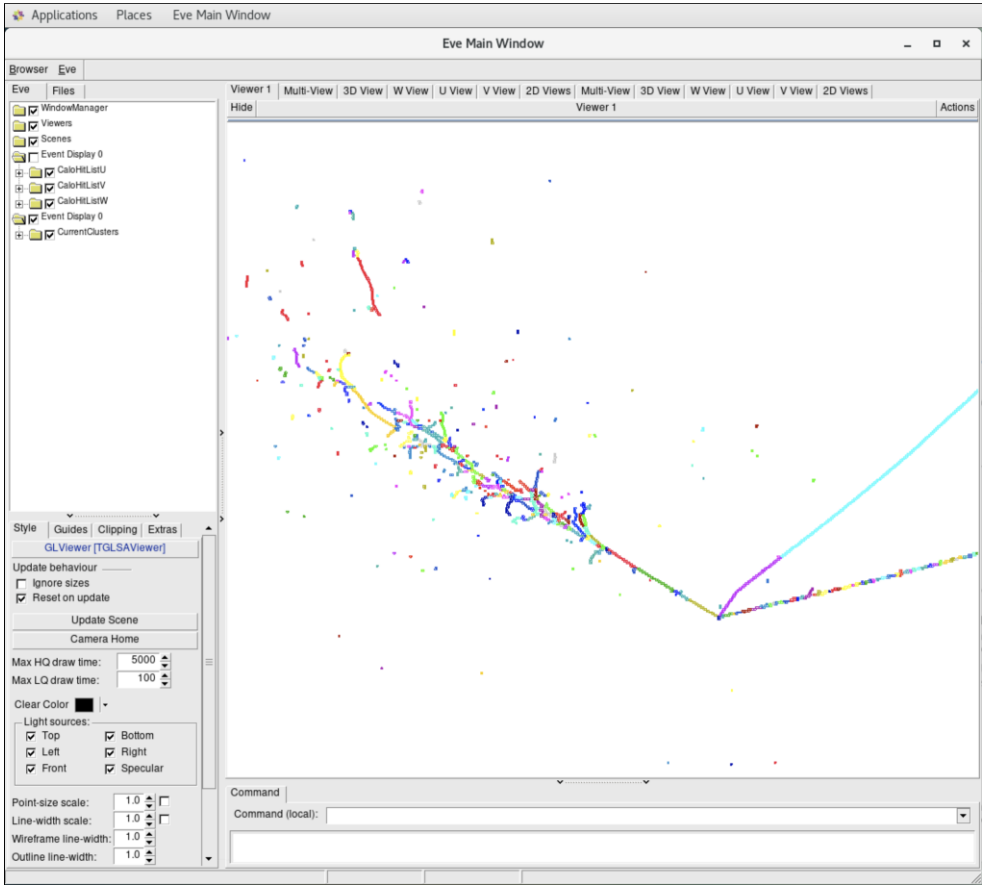
- Add the same monitoring algorithm after LArLongitudinalAssociation, LArTransverseExtension and LArTrackConsolidation

```
<algorithm type = "LArLongitudinalAssociation"/>
<algorithm type = "LArVisualMonitoring">
    <ShowCurrentClusters>true</ShowCurrentClusters>
</algorithm>

...

<algorithm type = "LArTransverseExtension"/>
<algorithm type = "LArVisualMonitoring">
    <ShowCurrentClusters>true</ShowCurrentClusters>
</algorithm>

...

<algorithm type = "LArTrackConsolidation">
    <algorithm type = "LArSimpleClusterCreation" description = "ClusterRebuilding"/>
</algorithm>
<algorithm type = "LArVisualMonitoring">
    <ShowCurrentClusters>true</ShowCurrentClusters>
</algorithm>
```

- Repeat this process for the V and W view blocks
- You may also want to set ShouldDisplayAlgorithmInfo to true at the beginning of both the master and neutrino XML, in order to keep track of where you are as you step through the event displays

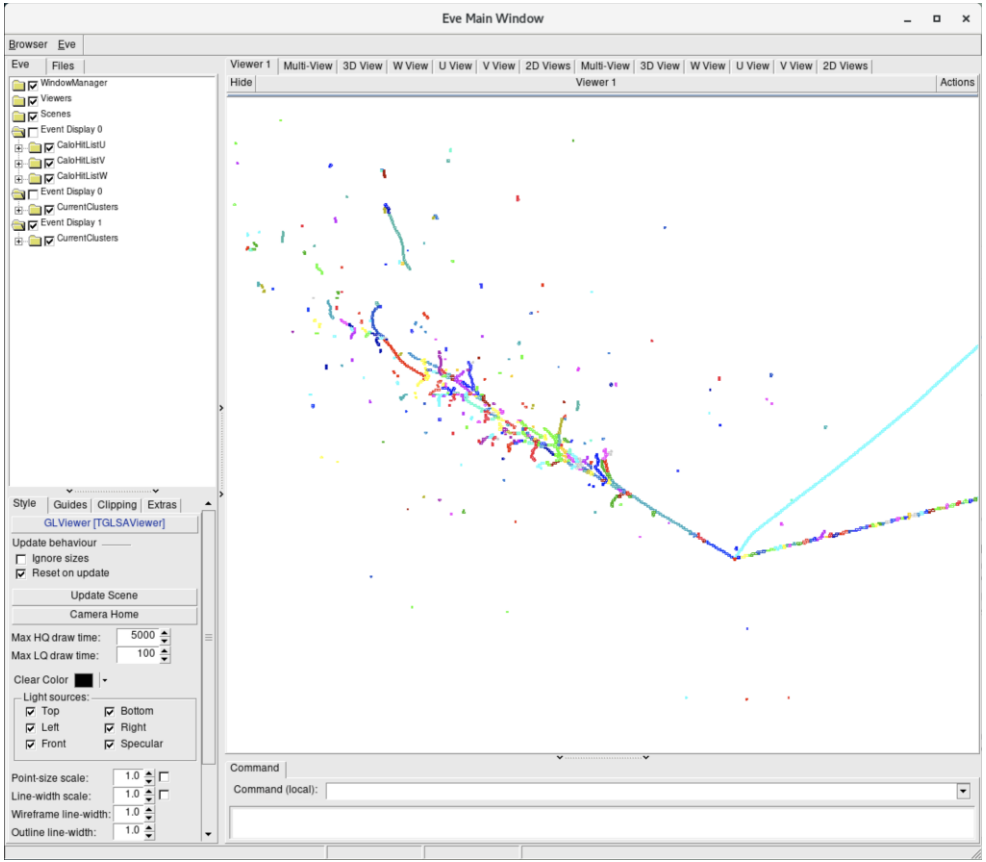
Tracing the source of the error (3)

- Run Pandora again and start to observe how the clustering proceeds
- Note how small many of the clusters are
- Provisional clustering is very strict
  - Any ambiguity prevents further growing of a cluster
  - The transverse pion results in a stepped pattern of hits, which represent large changes in local direction
  - The electron shower is similarly highly fragmented
- Press Return ↵ to see the result of the LArLongitudinalAssociation algorithm



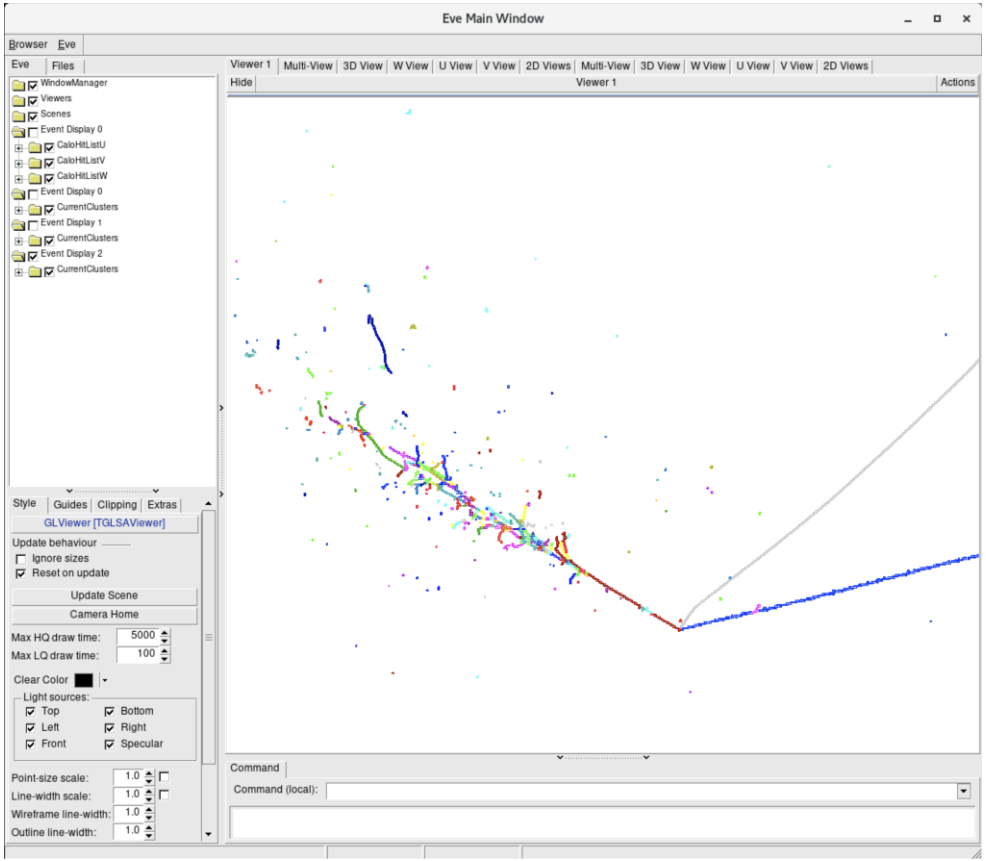
Tracing the source of the error (4)

- The LArLongitudinalAssociation algorithm does little for the transverse pion due to the very short nature of the tracks
- However, within the shower stub and the proton track are long clusters with sufficient pointing information to conclude that merging is appropriate
- Press Return ↵ to move onto the LArTransverseExtension algorithm



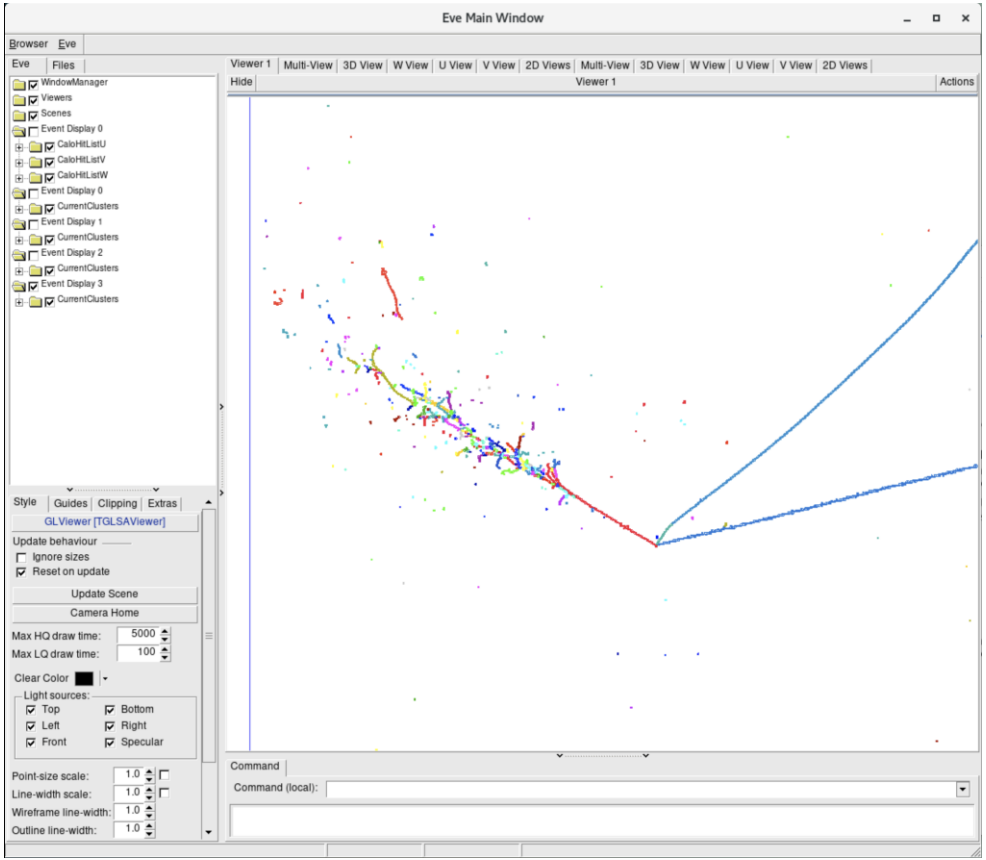
Tracing the source of the error

- The LArTransverseExtension algorithm largely clusters the pion by being able to accommodate the overlapping steps pattern
- The shower stub also sees additional merging
- Press Return ↲ to move to the end of 2D clustering in the U view



Tracing the source of the error

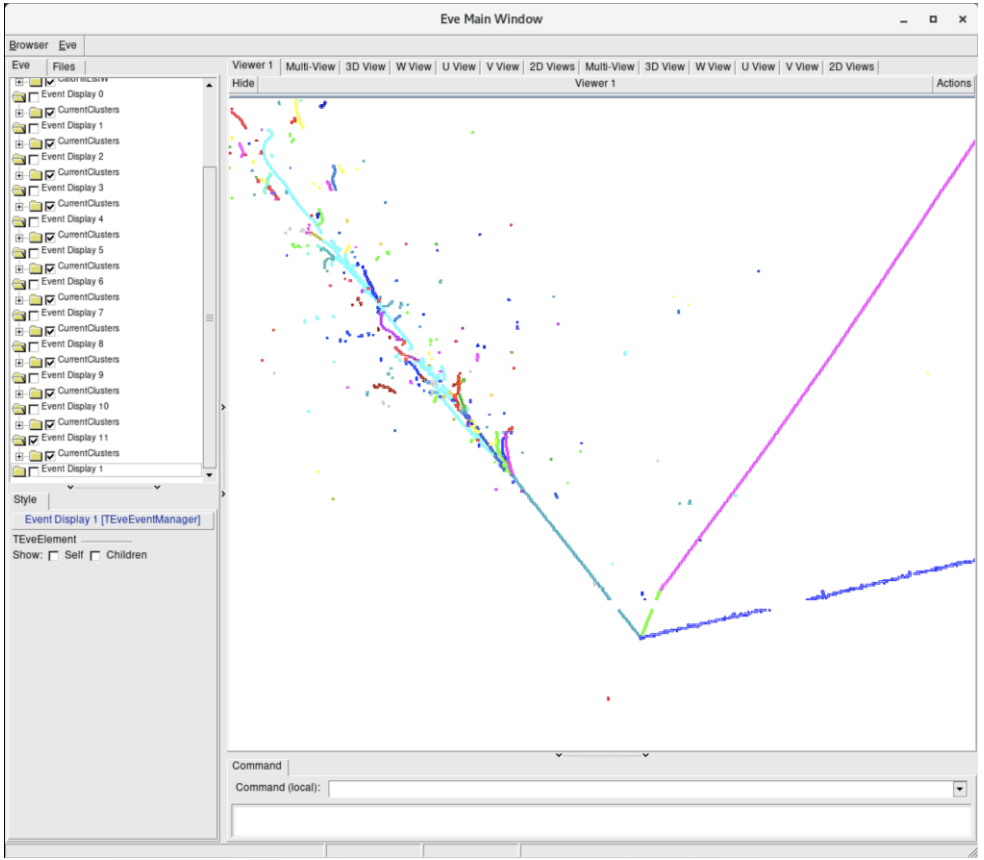
- By the end of the 2D clustering in U you can see that the shower cascade remains highly fragmented
- This is normal, with early clustering being very track oriented
- However, note that the MIP-like stub of the electron doesn't penetrate much into the shower cascade
- Now press Return ↵ to walk through the remaining event displays to see the same process for the V and W views



Fixing the reconstruction output

The nature of the problem

- You'll have seen the V and W views exhibit similar behaviour, albeit with different algorithms doing the bulk of the work due to variations in how forward going particles appear in each view
- In each case the MIP-like stub of the electron doesn't penetrate much (or at all) into the shower cascade, so the cascade and the MIP-like stub remain separate
- If we can get the track to penetrate into the shower cascade in each view, later shower growing algorithms may be able to connect them



Fixing the error

- Where might we intervene?
- Much of the work is performed by the LArLongitudinalAssociation and LArTransverseExtension algorithms, so these seem like fruitful places to try to tune the behaviour
- We can find these algorithms in the Pandora repository https://github.com/PandoraPFA/LArContent
  LongitudinalAssociationAlgorithm.cc
  TransverseExtensionAlgorithm.cc
- In particular, you can look at the ReadSettings function to see which parameters can be tuned via the settings XML
- Parameters you might want to focus on in LongitudinalAssociation are
  - MaxTransverseDisplacement
  - MinCosRelativeAngle
- And in TransverseExtension
  - MaxTransverseDisplacement
- These parameters set limits on deviations between clusters when considering merges

Fixing the error

- Note that in the XML, each of these algorithms is specified in the form <Name/>

```
<algorithm type = "LArLongitudinalAssociation"/>
<algorithm type = "LArTransverseExtension"/>
```

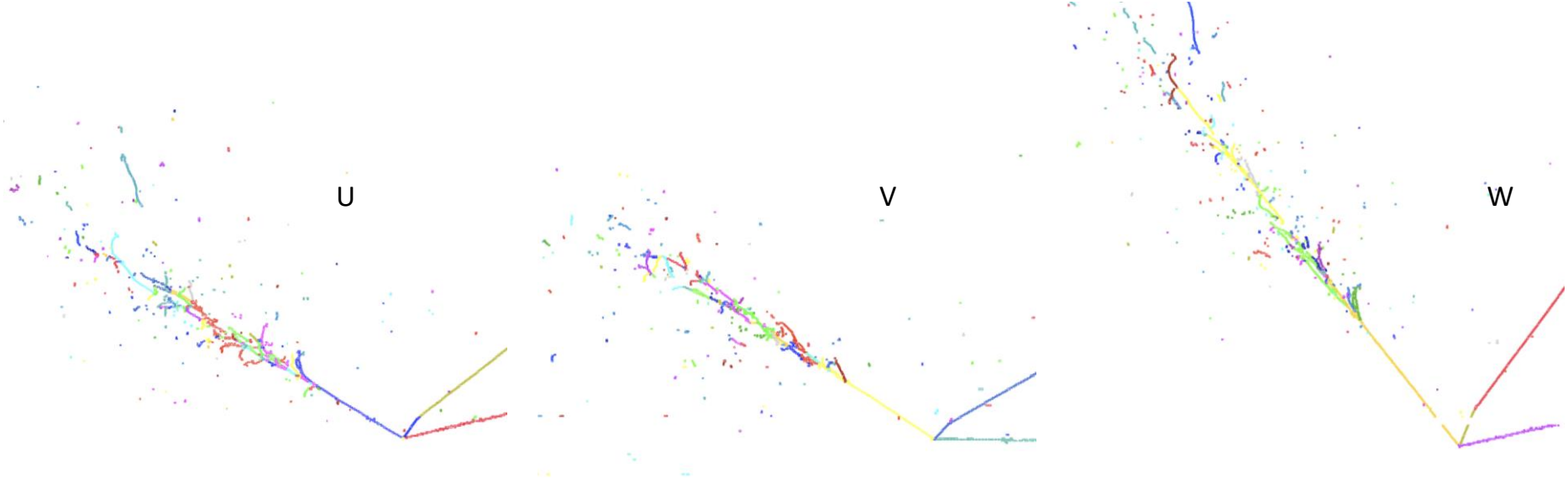
- You'll need to expand the XML tag to include parameter tunings, for example

```
<algorithm type = "LArLongitudinalAssociation">
    <MaxTransverseDisplacement>3.0</MaxTransverseDisplacement>
</algorithm>
```

- You should also keep in mind that you shouldn't necessarily expect to see large changes at the 2D clustering stage
- Pandora's multi-algorithm approach means that small alterations in early algorithms can propagate to produce more notable changes in later algorithms
- In this case, we're recommending try to force the track-like part of the shower further into the cascade such that later shower growing algorithms can pull in the surrounding cascade
- As a result, you should be sure not only to see the immediate effect of changes you make to a given algorithm, but also then see what happens by the end of the reconstruction chain

Fixing the error

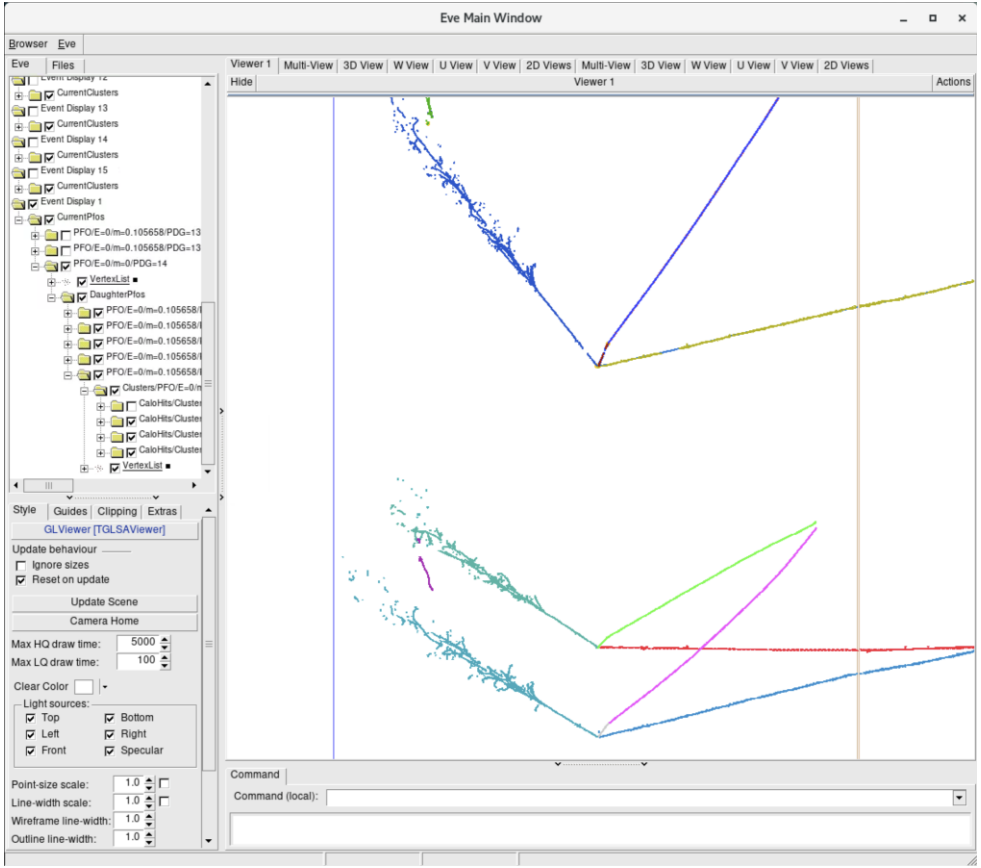
- As an example, here is how things look in each view after applying some tuning that is sufficient to recover the shower



- The U view is little changed, but the yellow MIP-like stubs in V and W now intersect the start of the shower cascade

Fixing the error

- The final reconstruction resulting from these tunings can be seen here



A few closing thoughts

- How useful is this tuning?
- We've focused here on a specific single example, so the tunings you've adopted might not work in other cases, and may even break previously well reconstructed events
- However, you may find common cases in your experimental context that warrant global tuning of some parameters
- In addition, our goal here is to show you how to investigate reconstruction
- Tuning may not always be possible, but if you know where and how things are going wrong, this can tell you where new reconstruction algorithms may be warranted