Leveraging 3D hits in Pandora

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FD Sim/Reco Meeting

DEEP UNDERGROUND NEUTRINO EXPERIMENT

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Pandora reconstruction

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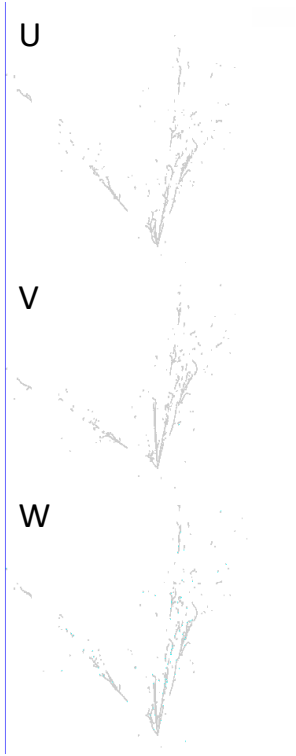
- Pandora's primary goal is to reconstruct a hierarchy of track-like and shower-like particle flow objects
- The starting point for the pattern-recognition in any DUNE far detector is the collection of 2D hits from each available view
- Provisional clustering proceeds independently in each view
- Attempt to match clusters between views, attempting to resolve ambiguities and fix errors by using projections of two view topological solutions into the third view or calorimetric matching if only two views are available
- A major challenge in this approach comes from overlapping trajectories due to the 3D->2D projection
- Misclustering in such an environment is easy, fixing such errors can be extremely difficult



Inter-view hit relationships

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- Working in 3D from the outset would be very helpful in mitigating problems with overlapping trajectories
- However, Pandora's inputs are 2D, and the suite of 100+ algorithms are built on this basis, so it makes no sense to simply throw that infrastructure away
- But maybe we can augment selected algorithms with 3D information to aid decision making
- Step 1: Can we relate Pandora's 2D inputs at the hit-level before any clustering is performed?

Identifying hit relationships

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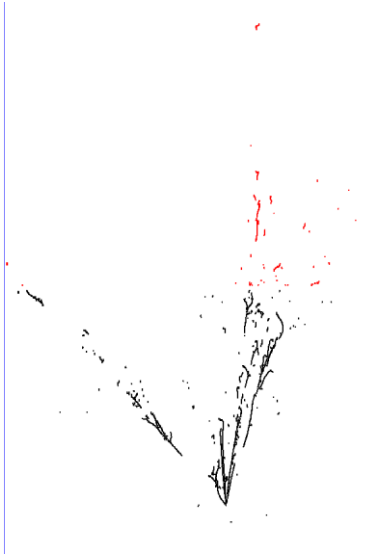
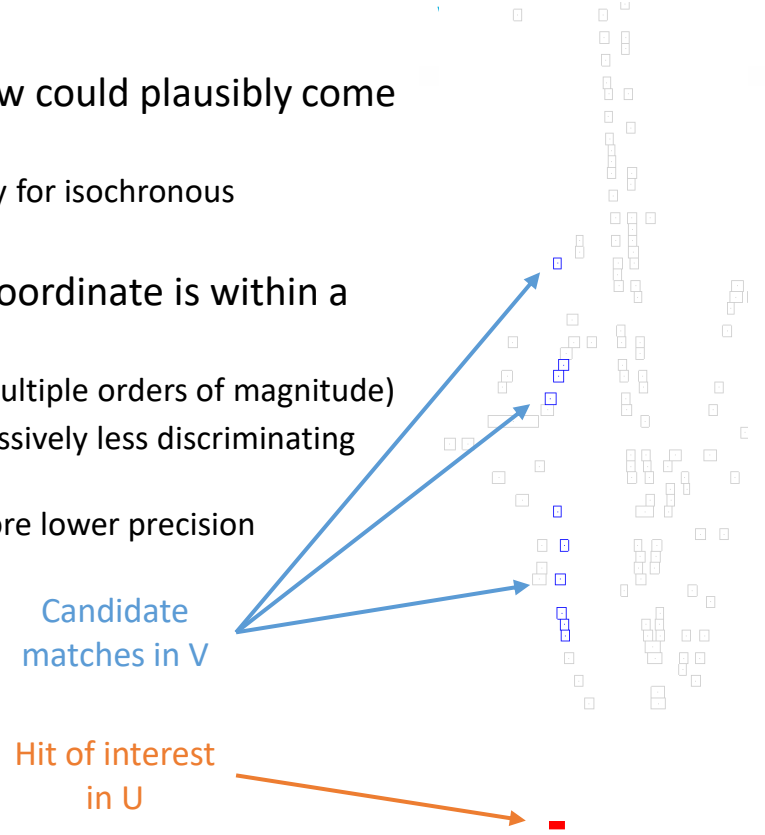
- Split the event into TPC child volumes
  - Potentially reduces combinatorics for high hit multiplicity events
  - Also eliminates potential rotational transform degeneracy in W view due to stacked APAs (problem first identified at Icarus by Bruce Howard)



Different colours represent different child volumes within a TPC

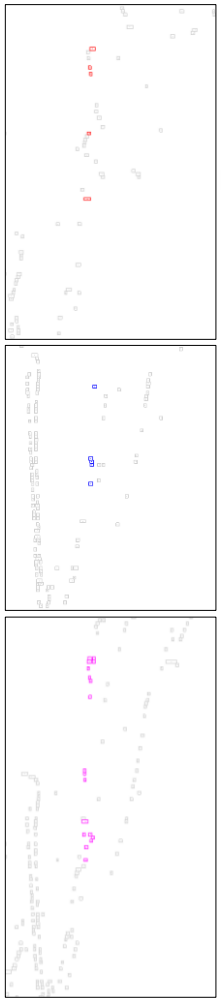
Identifying hit relationships

- In each volume determine which hits in each view could plausibly come from the same 3D hit based on drift coordinate
  - This can become a combinatorial nightmare, especially for isochronous trajectories
- A hit is potentially related to another if its drift coordinate is within a region proportional to the partner hit's hit width
  - This process is iterative to reduce combinatorics (by multiple orders of magnitude)
  - The multiplicative factor for hit width becomes progressively less discriminating with each pass
  - Matched hits can be removed from consideration before lower precision passes



Expanding hit relationships

- Hits that fulfil the “plausible match” criterion between two views might not meet that criterion for the third view
  - i.e. (U_7, V_{12}), (U_7, V_{13}), (U_7, W_{10}), (V_{12}, W_9), (V_{13}, W_{10})
  - No pair-wise match (U_7, W_9)
- We still want to consider them collectively to try to get the best global match, so expand the relationships to allow secondary (and tertiary) relationships
  - Don’t really want to go beyond this, the matches ought to become implausible and the combinatorics become problematic again



Expanded set of potential relationships in U, V and W

Identifying good triplets

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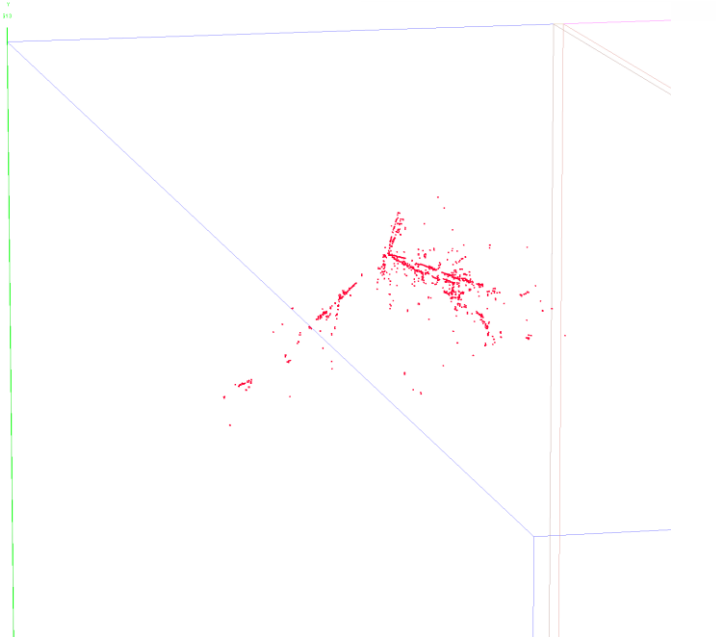
- For each grouping of potential triplets use our knowledge of the detector geometry to compute an analytic χ^2 and assess the quality of the match
  - Require a sufficiently low χ^2 value and if threshold met pick the best within the group
  - Remove the triplet from further consideration, repeat
- At the end of this process we have a collection of matched triplets and a collection of leftover hits that can be considered in the next pass with a more inclusive overlap region
- Note: nothing has been reconstructed here, it's just a single cluster of all 3D hits that could be produced



Current status

- Provisionally things look encouraging
- In a handful of events investigated so far, about 75-80% of 2D hits can be allocated to a 3D hit
- Main failure case seems to come from transverse trajectories and wide hits resulting in χ^2 values above a simple threshold
  - Need to add some flexibility to this decision
- After some optimisation appears computationally tractable
  - Typical hit matching takes O(1 second)
  - Very high multiplicity event on the right takes O(1 minute) – hit Ctrl-C on the first version after 3 hours

Hit widths

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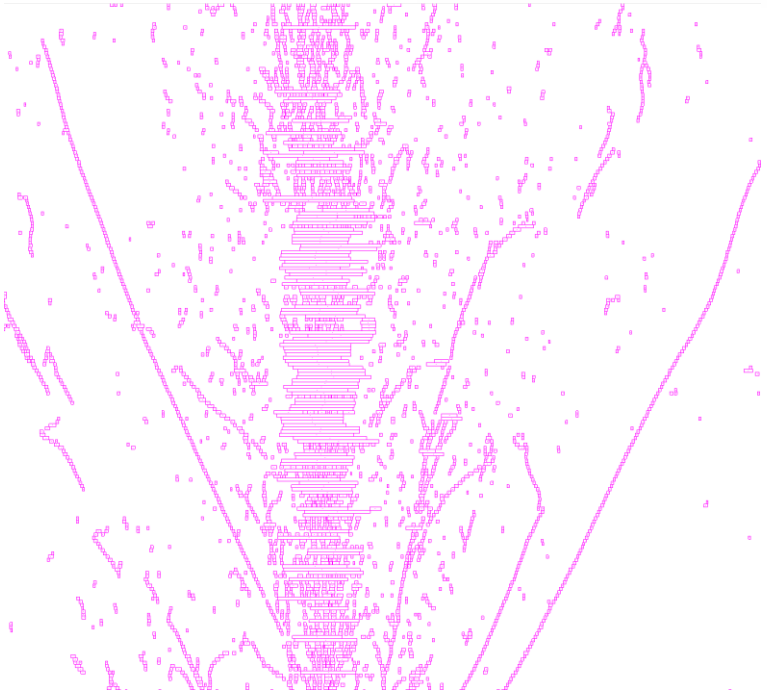
- Zooming in on the dense region of the aforementioned event makes the problem clear
- This might look somewhat different in newer productions (this is MCC11)
- Otherwise need to decide on how to match such hits between views



Next Steps

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- Which algorithms to target first?
- Potential options
  - 3D hit creation – this method essentially looks to construct 3D hits anyway, so this idea could be applied directly to the 3D hit creation stage for PFPs after current reconstruction, and unmatched hits might act as red flags for mis-reconstructed particles
  - Longitudinal clustering – augment the 2D algorithm with associated 3D hits for better separation (we'd still have 3 sets of 2D clusters at the end, but guided by 3D info)
  - Slicing – interaction separation ought to work better in 3D and unmatched hits can be allocated to a slice based on intra-view proximity to projected 3D hits
  - Cosmic ray reco – as per slicing, identifying muon tracks in 3D ought to aid separation
  - Other thoughts welcome