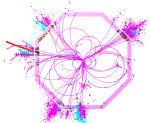


Vertex Reconstruction Improvements in Pandora

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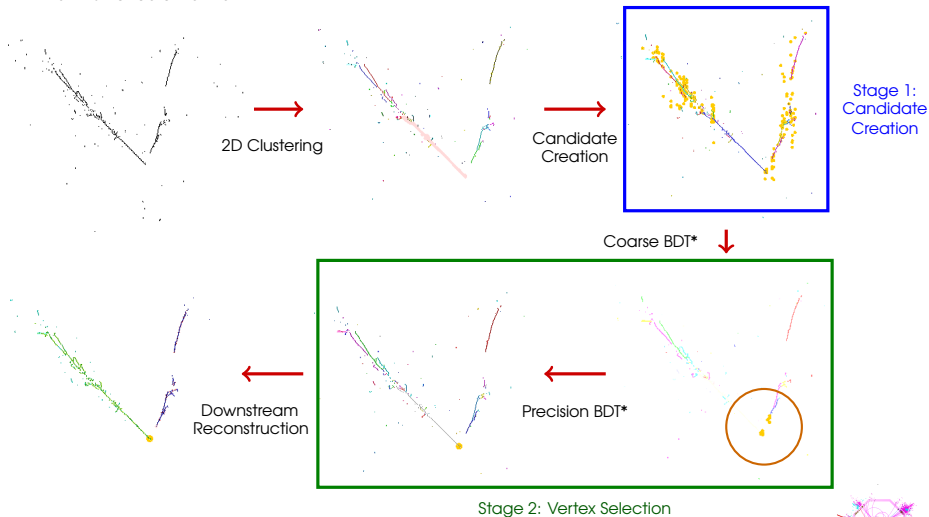
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Introduction

- Vertex reconstruction is a particular challenge in neutrino physics, where the point of interaction is not known in advance.
- Pandora uses the reconstructed vertex location in downstream reconstruction decisions (e.g. merging & splitting).
- Have been working on improvements to the vertex reconstruction in the context of SBND but the updates have all been merged into `larpandoracontent` and so can be used within DUNE as well.

Pandora's Vertex Reconstruction

Vertex reconstruction is a particular challenge in neutrino physics and forms a core component of the Pandora workflow.

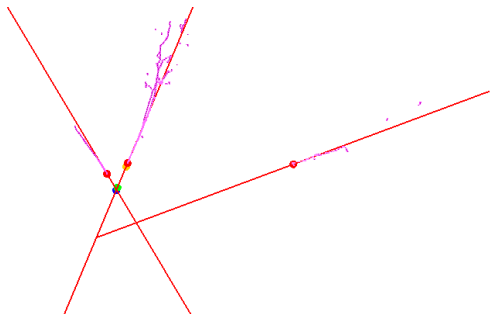


*Boosted Decision Tree

Refinement Algorithm

Developed a new algorithm to refine the candidates' positions before the selection stage.

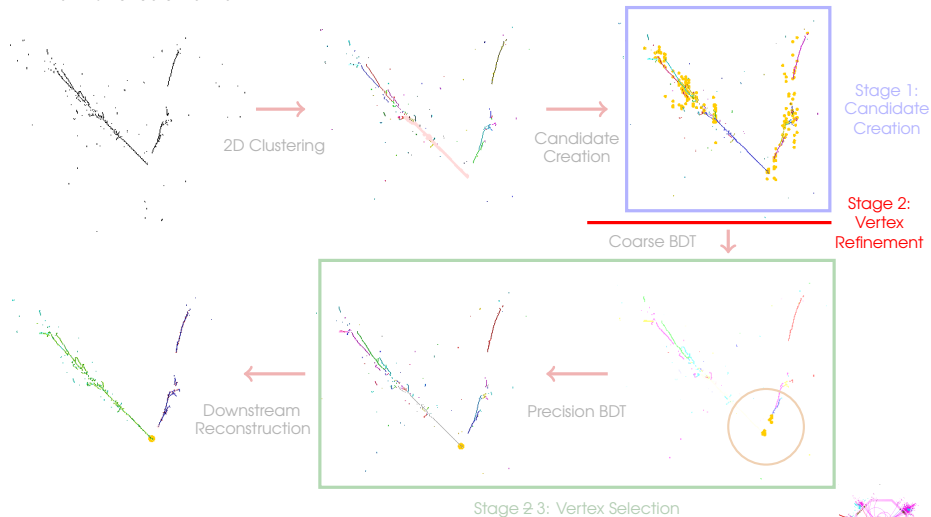
The direction of nearby clusters are used to make precision adjustments to each candidates' position.



- The algorithm takes the initial vertex position (yellow dot) and collects any clusters that pass within 10cm of it (pink hits)
- A principal component analysis is done on all of the clusters to produce a line equation (red lines & dots) representing its direction
- The lines are weighted by their distance to the initial vertex and then solved as a matrix equation to find the least squares best fit point (blue dot) to use as the new vertex position
- ...which moves it nearer to the true vertex (green dot)

Where does this fit in?

Vertex reconstruction is a particular challenge in neutrino physics and forms a core component of the Pandora workflow.



Selection BDT Changes

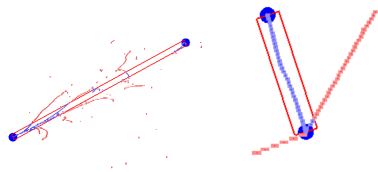
Also made some changes to the vertex selection algorithm.

- Two boosted decision trees (BDTs) are used to make the selection from the list of candidates.
- First BDT selects the best 10cm region, second BDT selects the best candidate within that region.
- Both operate by making comparing two candidates and selecting the best candidate, the algorithm iterates through all candidates to find the selected vertex.
- New variables added describing the relationship between the two candidates (Separation and AxisHits).
- Other new variables added describing the energy deposition around the vertex candidate (dEdxAsymmetry and VertexEnergy).
- Results show a significant improvement in selection of correct vertex candidates (77.3% \rightarrow 82.6%).

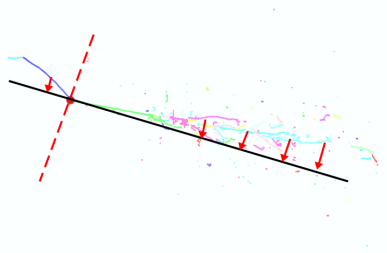
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shared variables construction

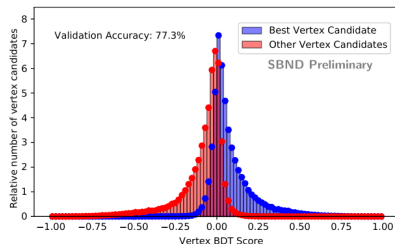


dE/dx asymmetry construction

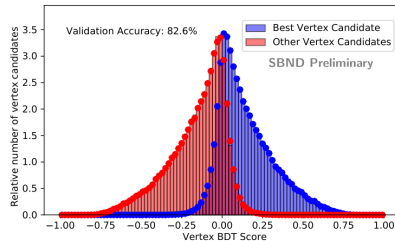
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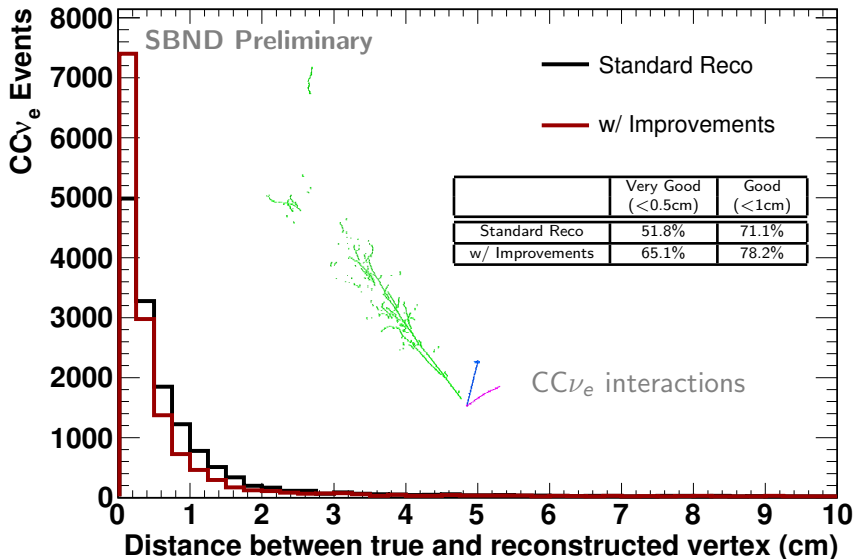


Before Changes

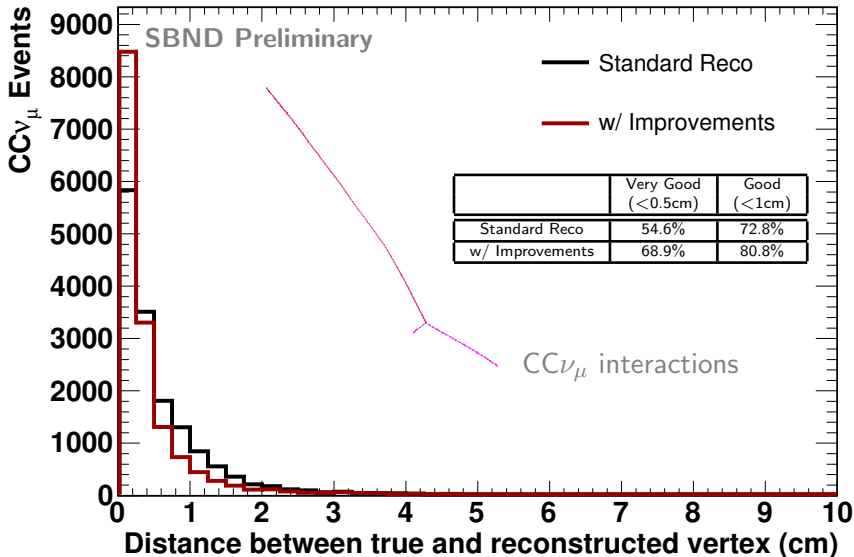


After Changes

Results of Vertex Improvements



Results of Vertex Improvements



Conclusions

- Accurate vertex reconstruction is a significant challenge in neutrino physics and is core to the Pandora reconstruction workflow.
- Improvements were made to the configuration of the vertex selection BDT algorithm, and an entirely new algorithm was produced for refining the vertex position.
- Large performance gains are seen in the context of SBND for both ν_μ and ν_e interaction events as a result of this work.
- These improvements will be available for use across any experiments that utilise the Pandora framework, and work is already ongoing within the DUNE team to retrain their vertex BDT with these updates included.

