Error Mitigation Methods in Track Reconstruction of ICARUS

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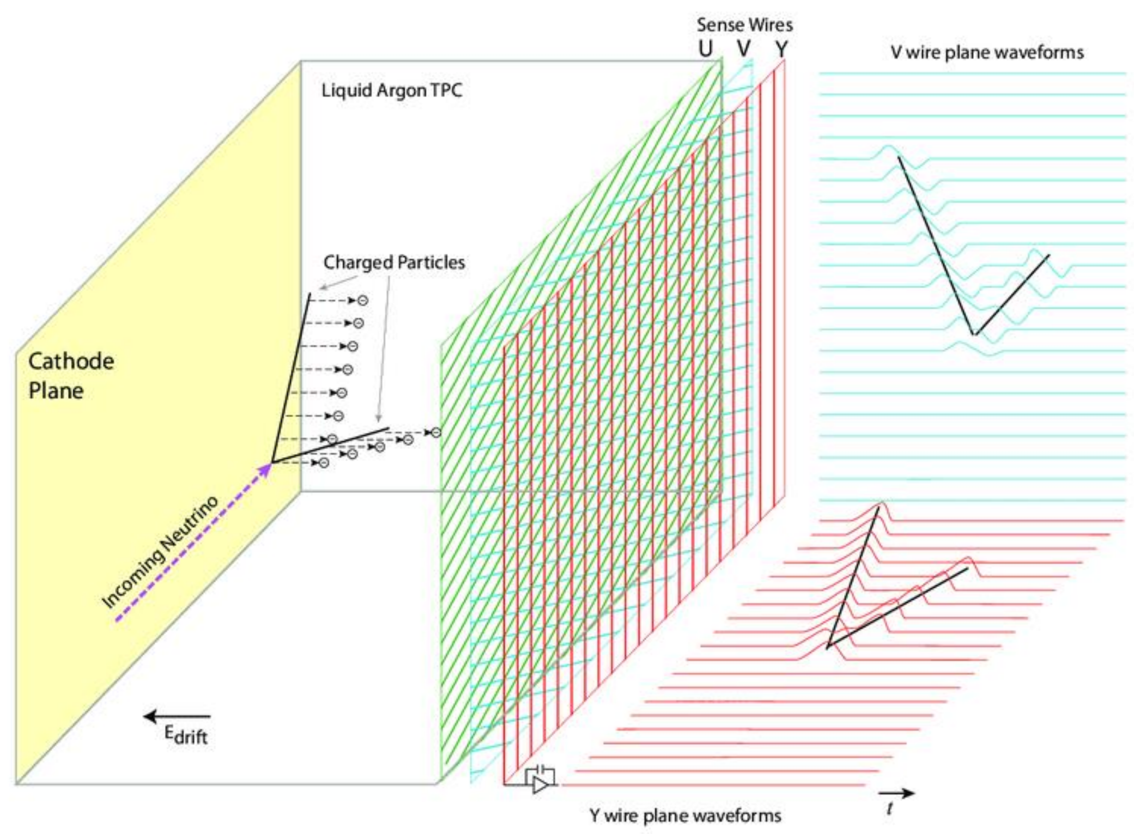
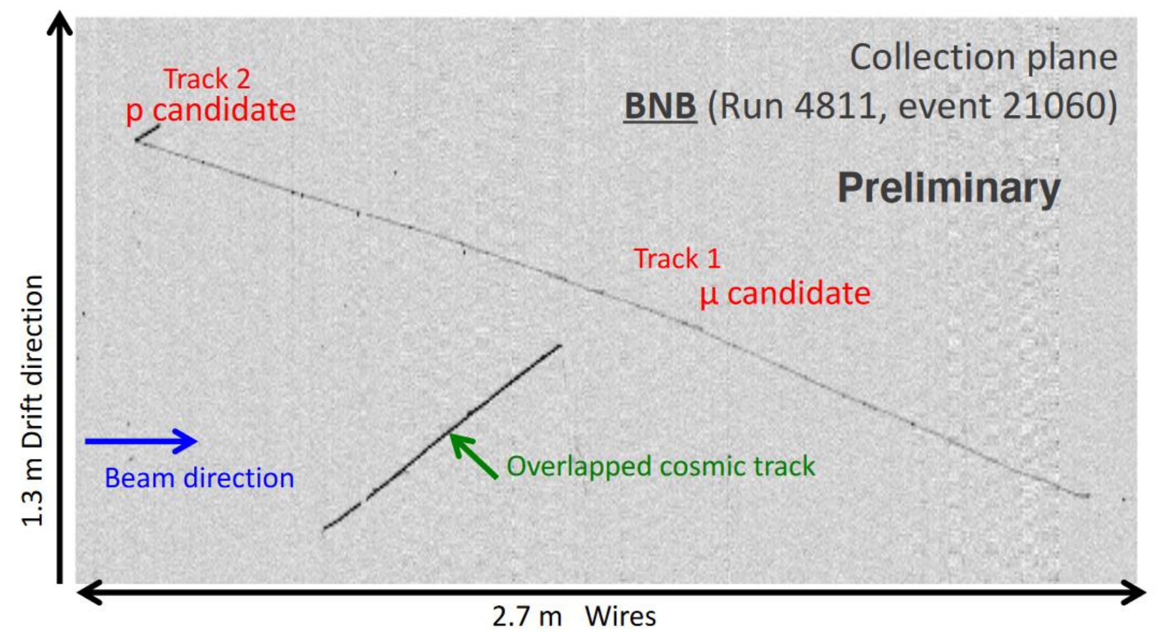
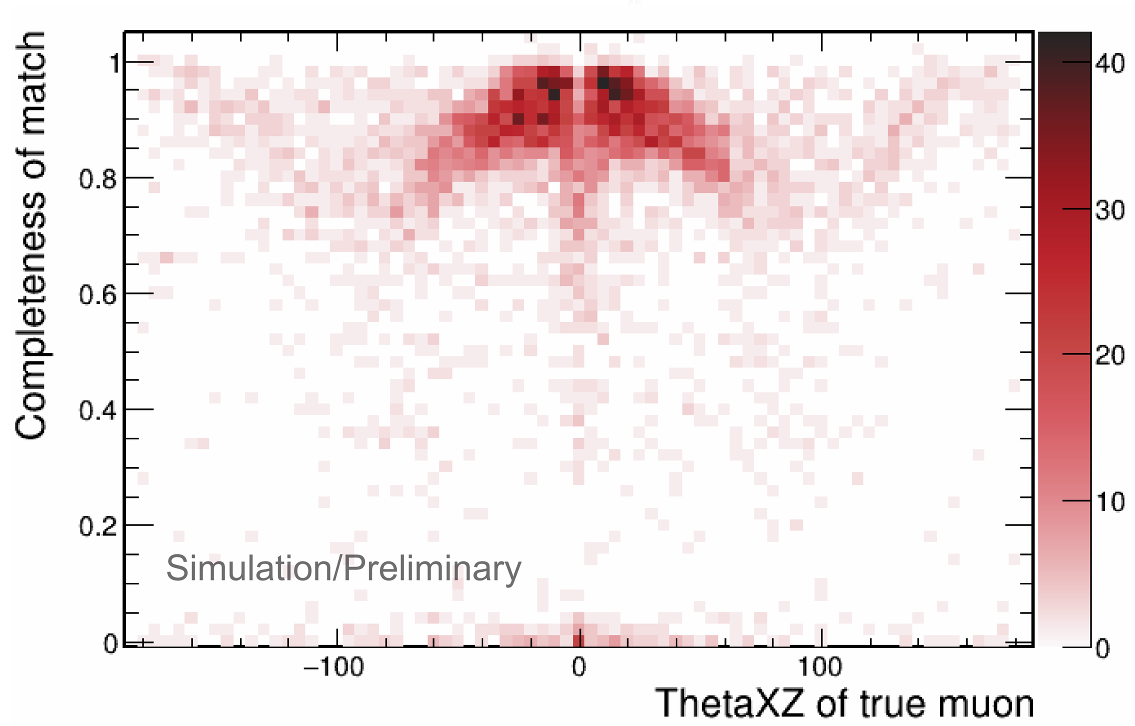
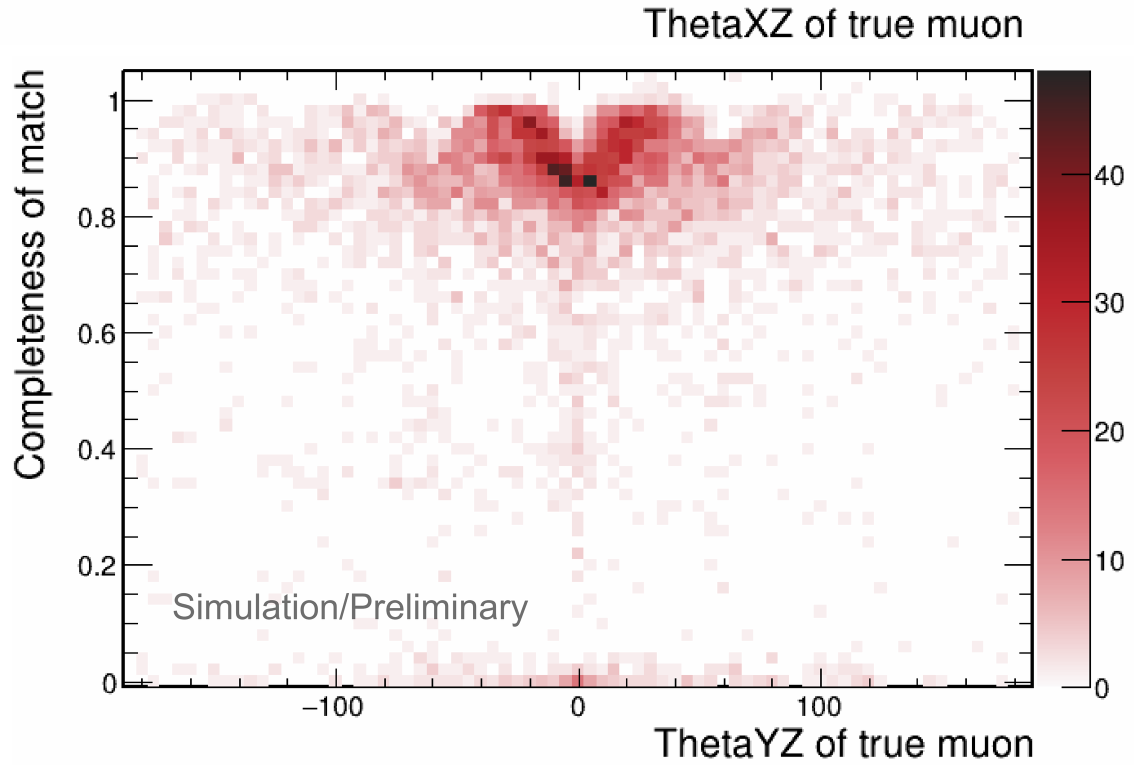
Introduction

Liquid Argon Time Projection Chambers (LAr-TPCs) are a common and powerful detector for neutrino interactions. Charged particle interactions ionize the liquid Argon, whereafter the electrons, under influence of an electric field, drift toward the three wire planes. Reconstruction takes the resultant signal, and after checking for agreement between all three planes, creates a 3D space point. These points are then passed to Pandora[1], a pattern recognition software for reconstruction used in several LArTPCs, and then reconstructed particles are fit under a track or shower hypothesis. Track losses can be created when computational noise reduction methods in the pre-Pandora stage incorrectly remove valid hits, which effects the whole line of reconstruction. With this study we hope to identify and address some threads of improvement for error mitigation pre-Pandora as well as post-Pandora.









(Top left) Diagram of a LAr-TPC and the signal received by its wires.

(Top right) A muon neutrino candidate interaction illustrating the signal received by the collection plane of the LAr-TPC.

(Left) Graph of Completeness Vs angle the muon makes in the XZ plane (top) or YZ plane(bottom), where 0° is along the Z-axis. Subtraction of coherent noise (a phenomenon where noise in the LAr appears on multiple wires simultaneously) may cause forward-going (XZ° ≈ 0, XY° ≈ 0) isochronous tracks to have lower completeness- an idea to be looked at via generation of a coherent noise-less dataset.

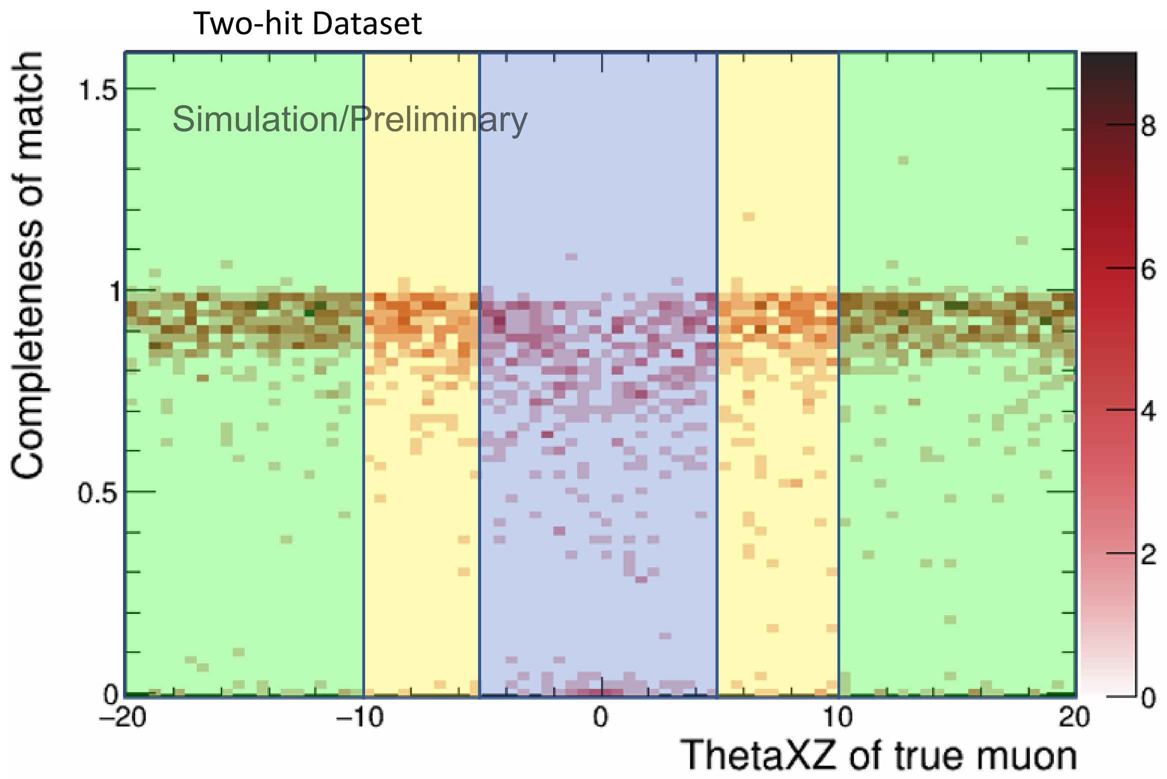
Methods

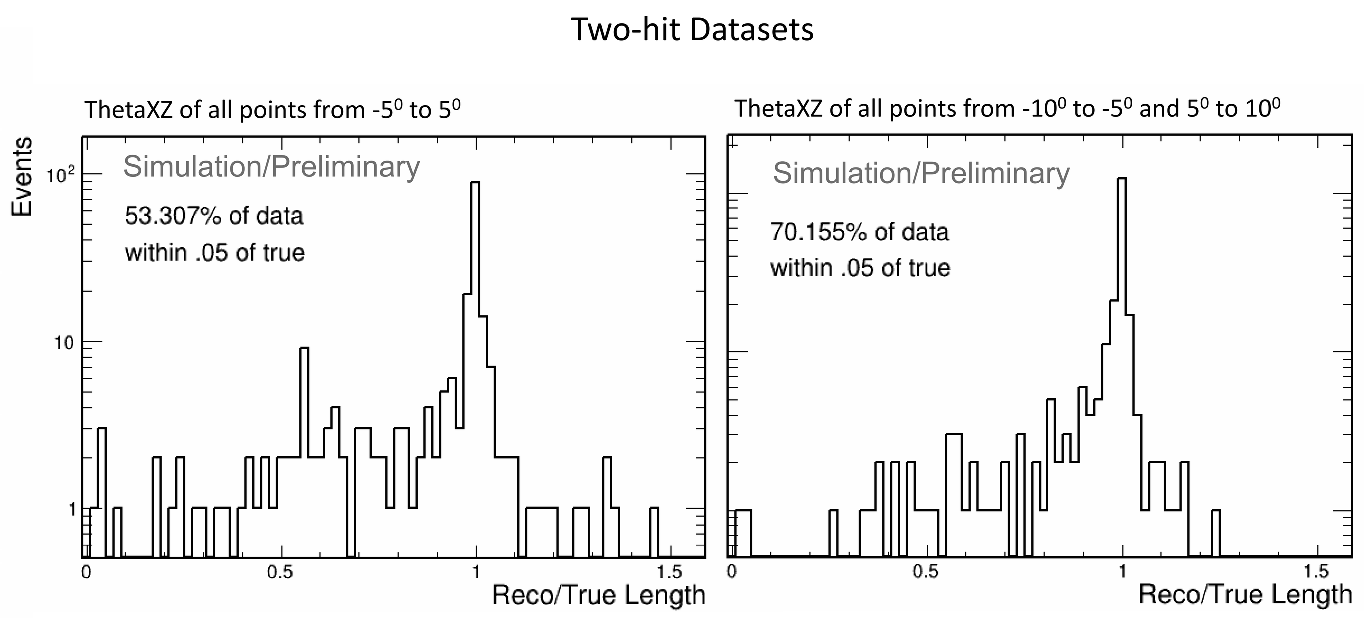
Three datasets (excluding "default" for control), made using different true events and reconstructed through Pandora, were analyzed using CAFAna, a data analysis framework in use in NOvA, DUNE, and SBN–

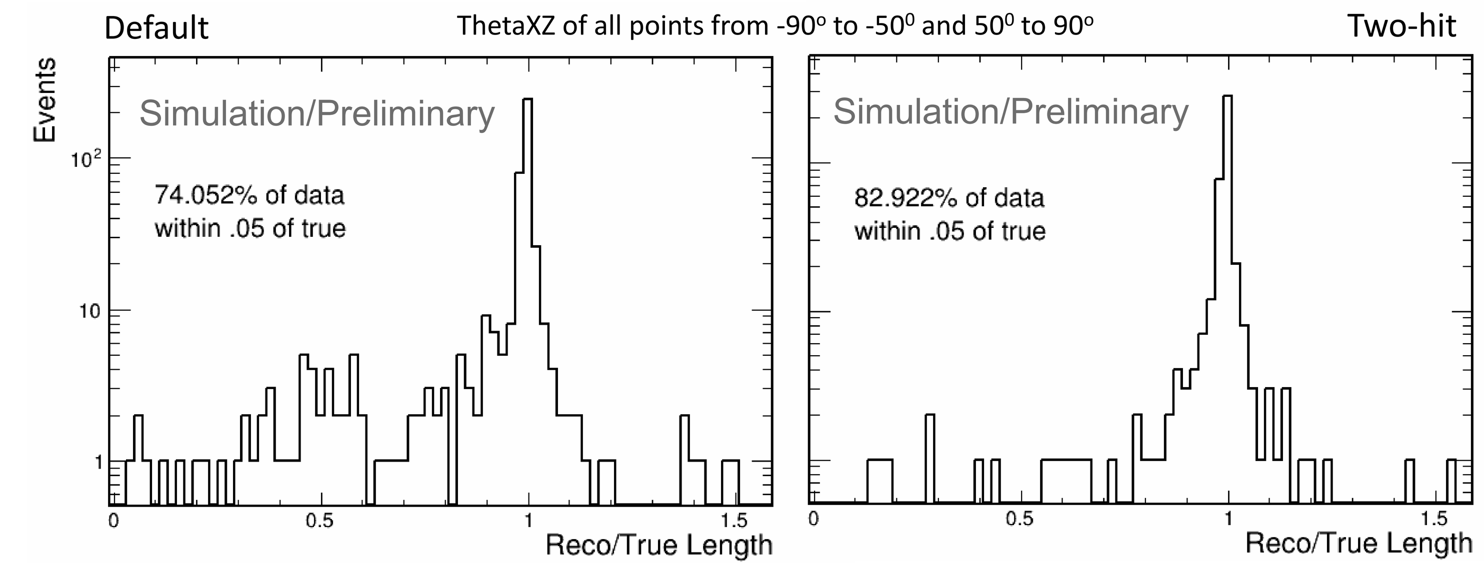
- "Two-Hit Space Points", to keep noise in check, creation of a 3D Space Point requires a hit on all three planes, this method gauges recovery when only two planes are required for a 3D Space Point (Two-hit)
- "Hit Recovery", utilizes information from signal and hits/clusters from pre-Pandora to try to gain back hits otherwise rejected by Cluster3D (Hit-recovery)
- "All gaussians", all hits from the hit-finding stage were kept.

The mitigation methods were analyzed for improvement in two metrics on events with a neutrino interaction resulting in a true muon of length greater than 50cm: Completeness of the Reconstruction tracks by Energy, (matched energy in hits divided by the deposited energy for contained muons); and Reconstructed track/True track Length (RTL).

The Two-hit dataset was separately analyzed using LArSoft to count hits in the clusters versus those in the tracks.







XZ Plane Dependent Recovery

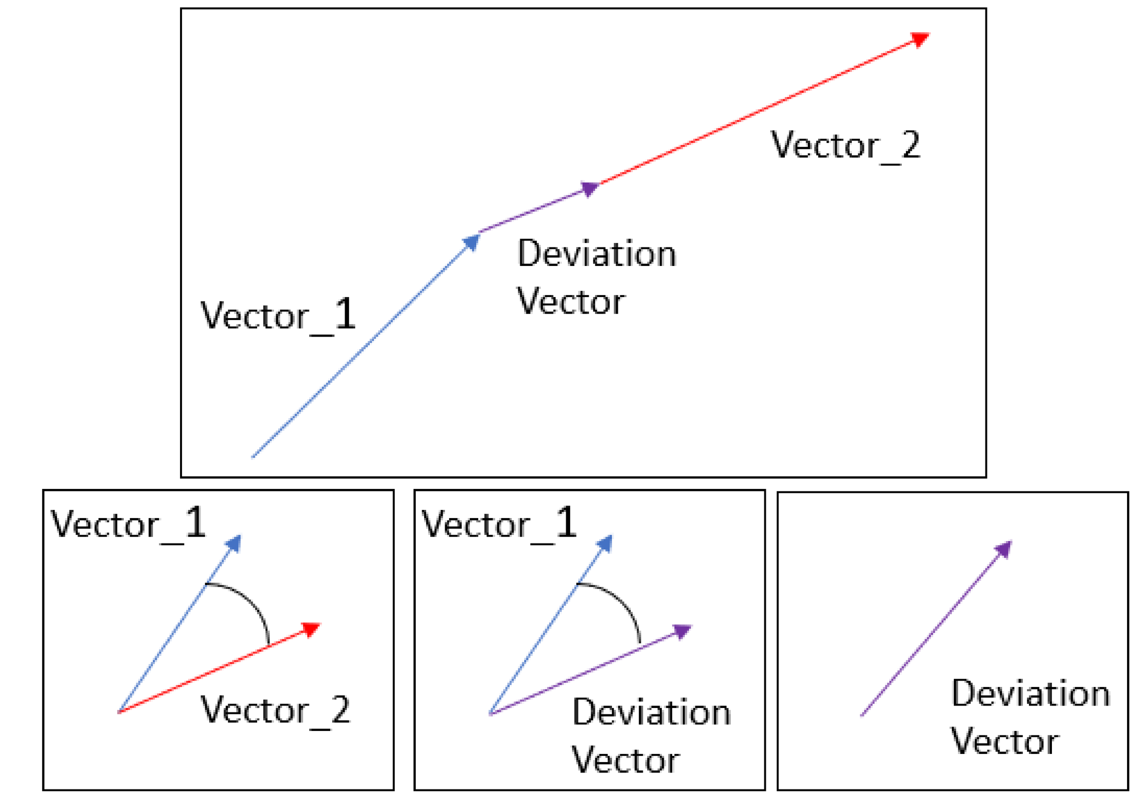
The Two-hit and Hit-recovery datasets had a +1% and +2% improvement over the default dataset in terms of the RTL, respectively. Upon further investigation into the angle dependency of these improvements however, it was found that the three bins from 0±20 showed a consistent small decrease in accuracy of RTL. The improvement in fact came from off axis tracks in the [-90,-50)U(50,90] bin, where RTL was improved by ~9%.

Results & Conclusion

In the Two-hit and Hit-recovery datasets there was noted a slight improvement in the RTL of reconstructed muons, attributable to an improvement in the ±50 to ±90 bin of ThetaXZ. It remains to be seen why these muons receive a boon from the mitigation methods implemented. Additionally, after analysis in LArSoft, it was found that ~5% of events result in zero cluster hits, and that another ~5% of events misidentify track hits as showers- a potential source for improved metrics. A population of split tracks was also found, with a recommendation that these could bare improving from "Track Gluing."

Next Steps- Track Gluing

A potential way to recover tracks is to use what's already there. Tracks that have lost hits due to noise or improper noise reduction can be separated into two (or three, four, etc.) distinct tracks incorrectly. Similar work[2] was previously done by Michael Vayninger for muons crossing cryostats, and we can continue his work for muons within the same cryostat. We can correctly regroup and "glue" these muon tracks together by cutting for several variables on the characteristics of these split tracks. To the right there are a few variables which have already been explored and show promising results for gluing together split muon tracks.



Change in Direction | Angle of Deviation | Magnitude of Deviation Vector

Acknowledgements

Many thanks to my supervisor, Dr. Bruce Howard. Without his guidance, none of the work seen above would be possible. I find myself a more competent and lively physicist because of his time, patience, and wisdom.

[1] Https://github.com/PandoraPFA
[2] Vayninger, Michael. Reconstructing Crossing Muons in ICARUS Detector. United States: N. p., 2021. Web. doi:10.2172/1825307

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