Current GArSoft Efficiency and Resolution Capabilities

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UNIVERSITY OF MINNESOTA

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Purpose

- Provide a comprehensive study of the current efficiency and resolution capabilities of GArSoft for final state protons
- Perform one of the first analysis studies using GArAna
- Working towards stronger efficiency and resolution for low energy protons
- Tuning GArSoft proton momentum reconstruction, and hopefully using this reconstruction on data to tune FSI models in GENIE.

GArAna

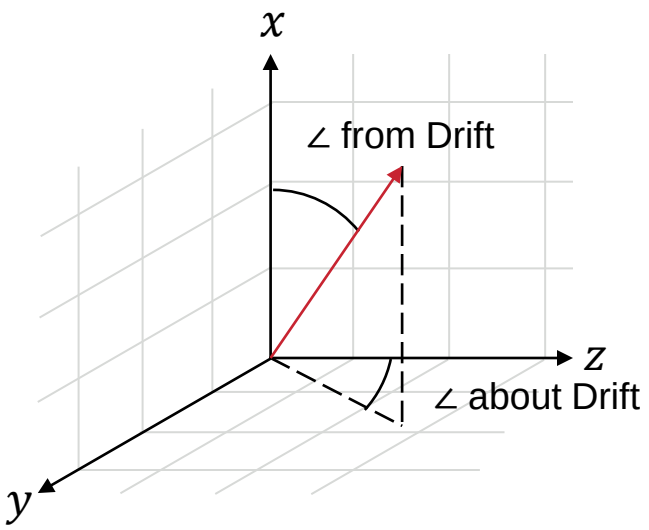
- GArAna is a light-weight, portable, general purpose analysis framework that is both usable by young C++ coders and useful to experts.
- C. Hilgenberg built three GArAna trees along with a GArAna specific Backtracker
  - GenTree—GENIE level information
  - G4Tree—Geant-4 level information
  - RecoTree—Reconstruction level information
- Functions in the Backtracker allow for truth matching between GENIE particles, G4 particles, and reconstructed tracks.
- More sophisticated capabilities have been released since the June 4th training such as a function that takes a track ID and returns a sorted list of the particles used to reconstruct the track and the energy they deposited

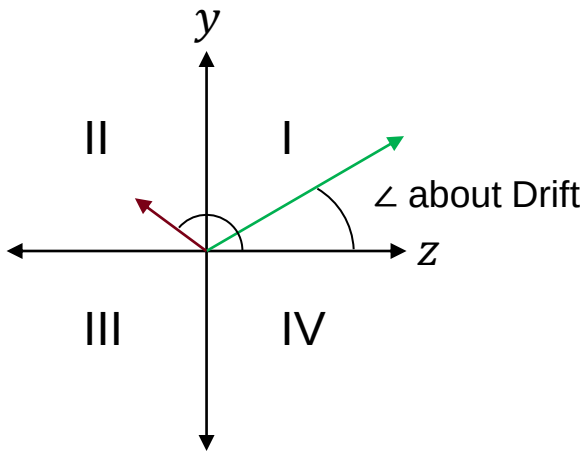
File Specifics

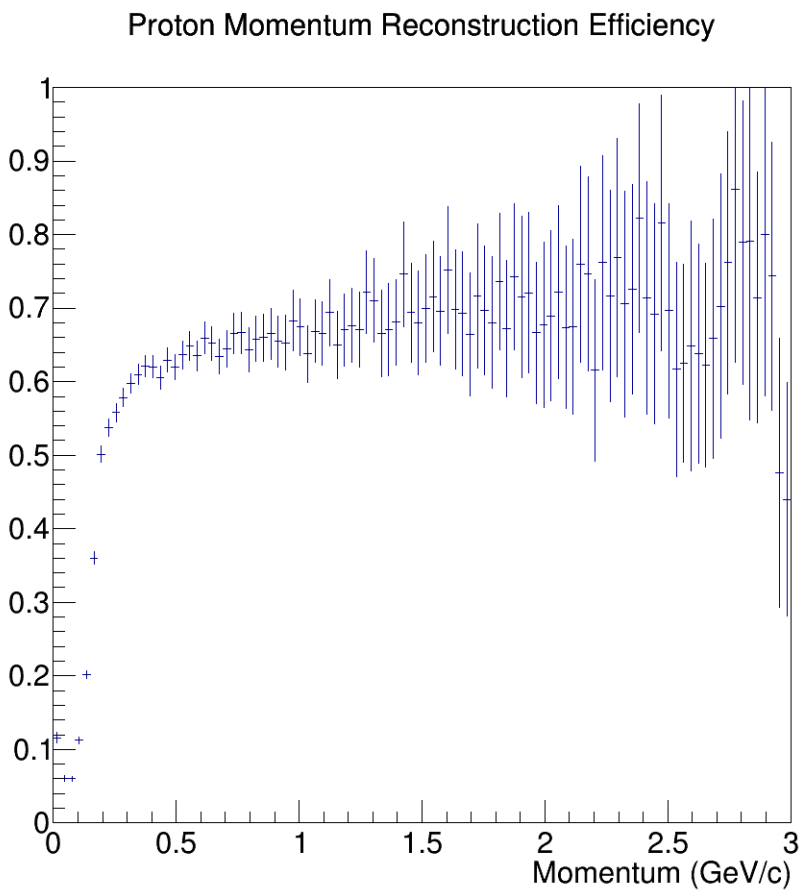
- File used to generate all following plots was created by Eldwan Brianne and is located at:
  - /pnfs/dune/persistent/users/ebrianne/ProductionSamples/ND-GAr/nd_hall_mpd_only_ECal12sides_42l_SPY_v3_wMuID/Reconstruction/neutrino/
- These plots were created using an 87000 event subset of the above 500k event file. All vertices are inside the TPC.
- File contains 127737 true protons

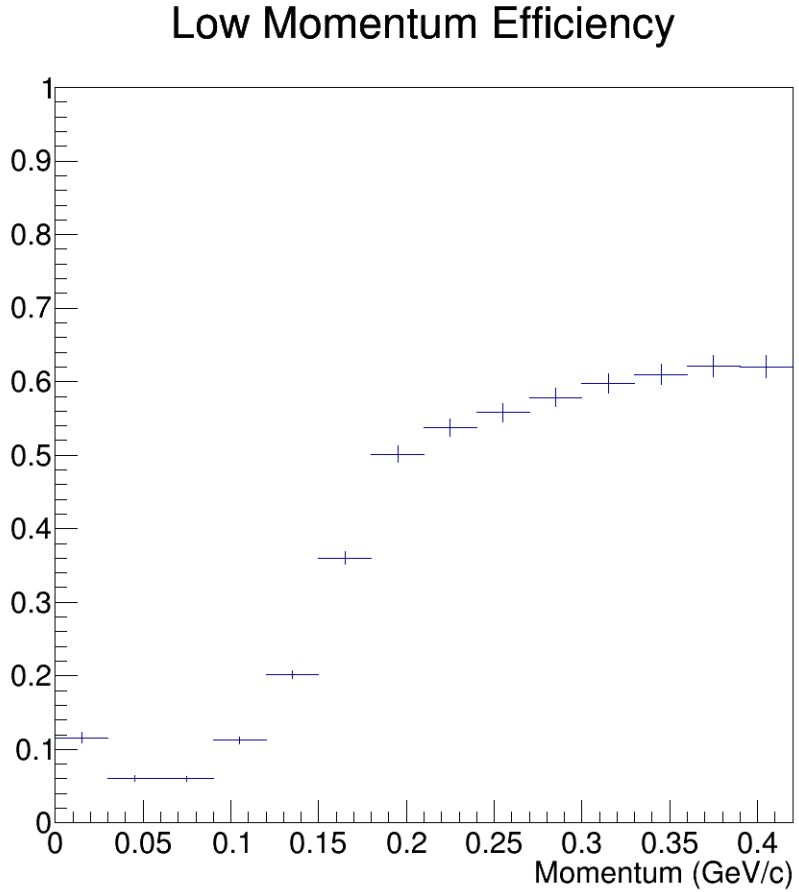
Efficiency

- Studied two different efficiencies using three different variables:
  - Momentum Efficiency
  - Drift Angle Efficiency
    - Angle from Drift Direction
    - Angle about Drift Direction
- The true proton was only associated with the one track that it donated the largest amount of energy to.

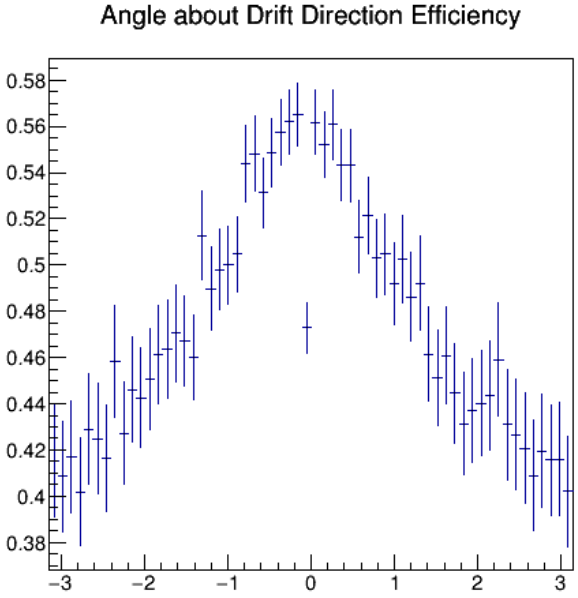


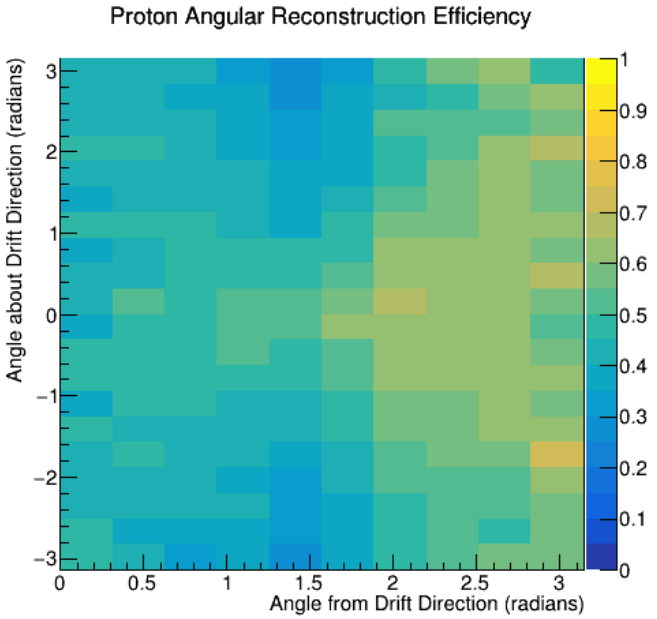






- Efficiency plots were used to implement a 300 MeV/c momentum threshold to cut out low momentum protons





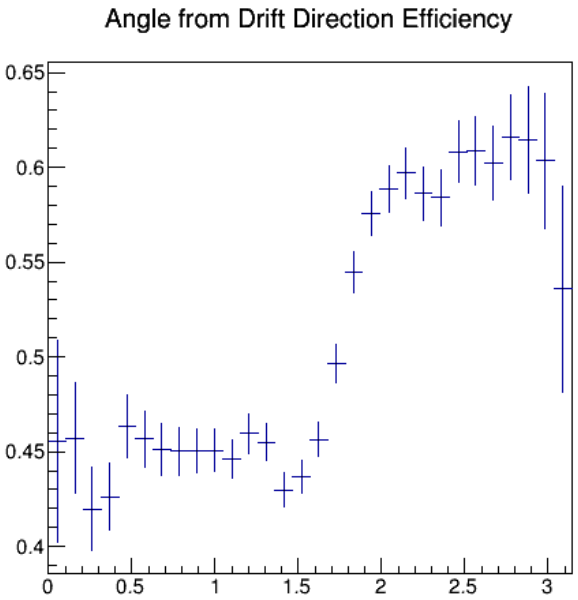
- These two angles were chosen to characterize the efficiency due to the detector's cylindrical symmetry.
- Angle from drift direction:

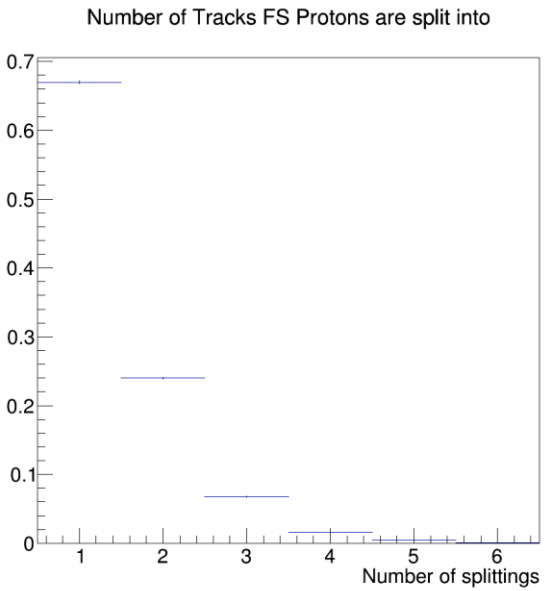
$$\cos^{-1}\left(\frac{p_x}{|\vec{p}|}\right)$$

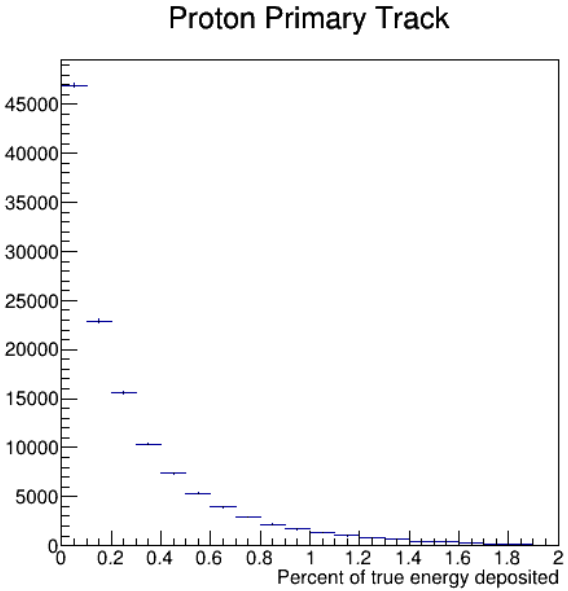
- Angle about drift direction (chosen due to the cylindrical symmetry):

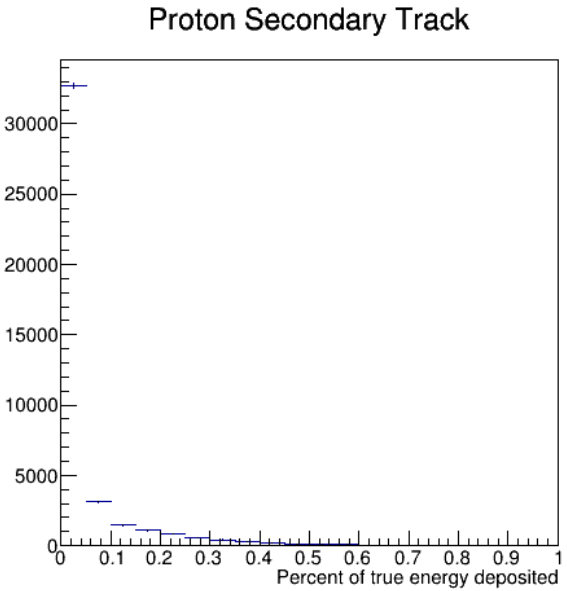
$$\tan^{-1}\left(\frac{p_y}{p_z}\right)$$

- Physically, scattering at 0 degrees from the Drift direction is scattering to the left and 180 degrees from the Drift direction is to the right.

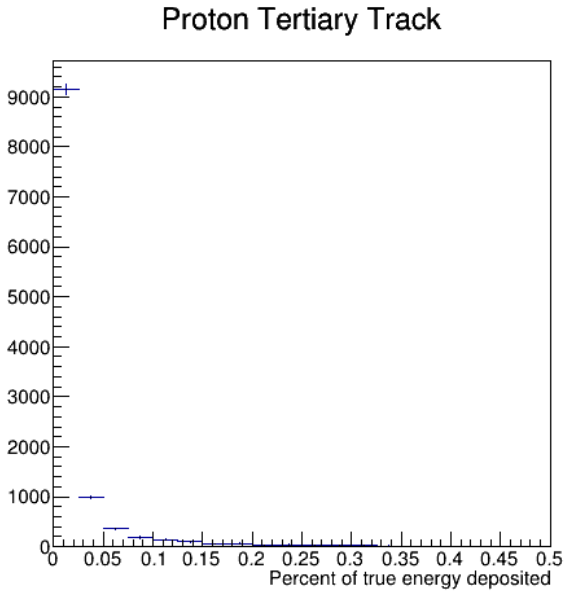


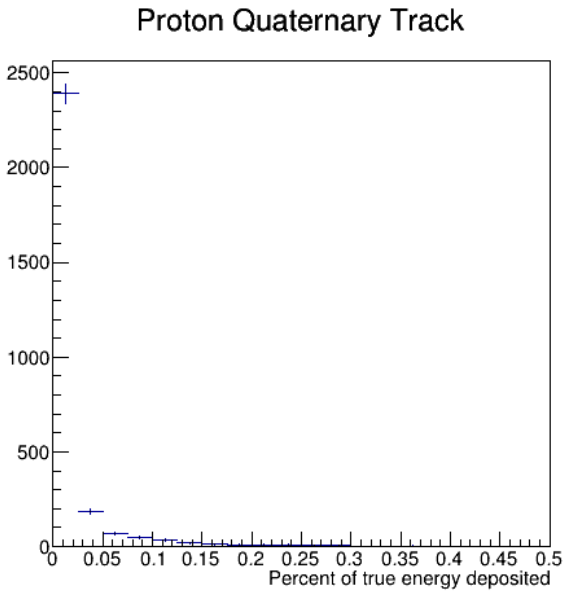


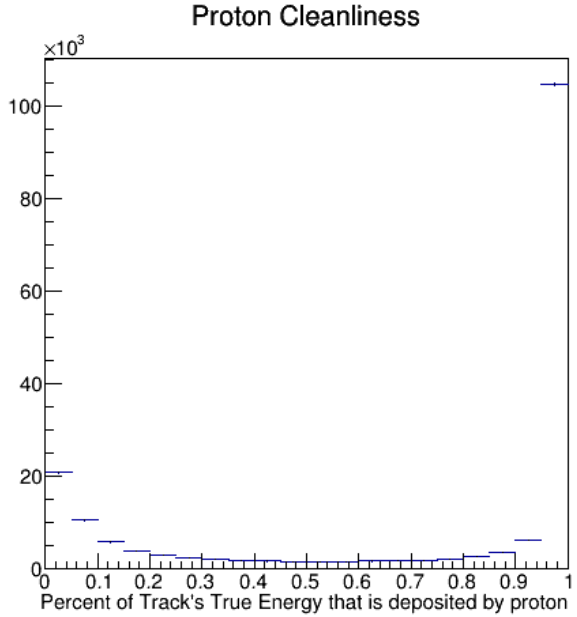


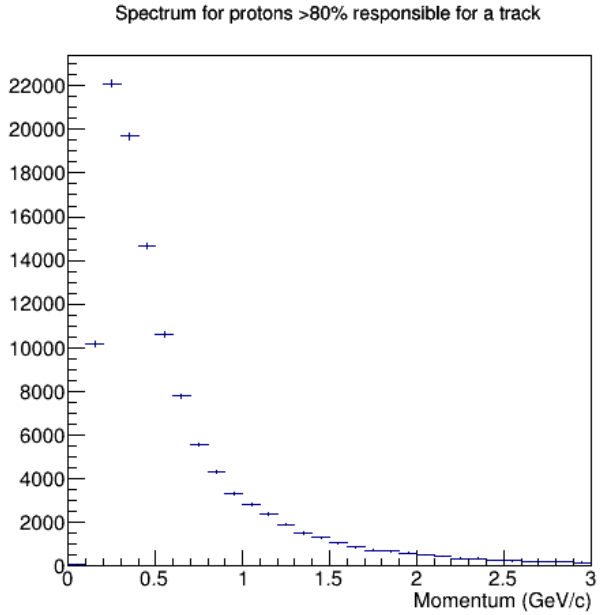


- The above plot is area-normalized
- Found bug: True energy of that particle donates to a track is sometimes larger than the true energy of the particle
- Similar shape is expected once bug is corrected

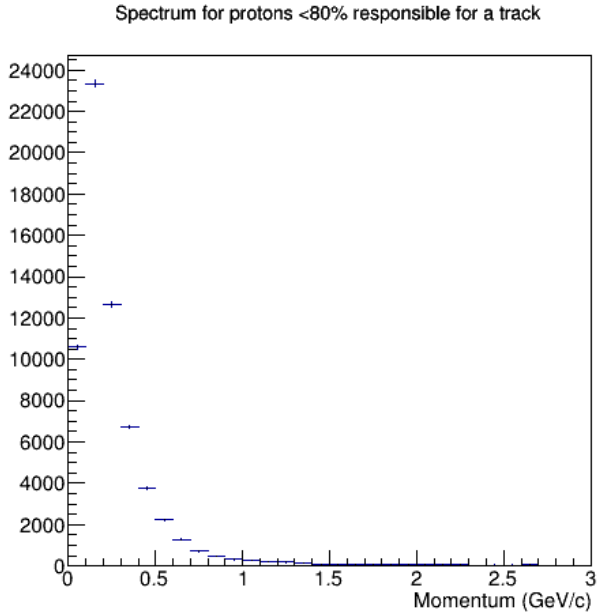






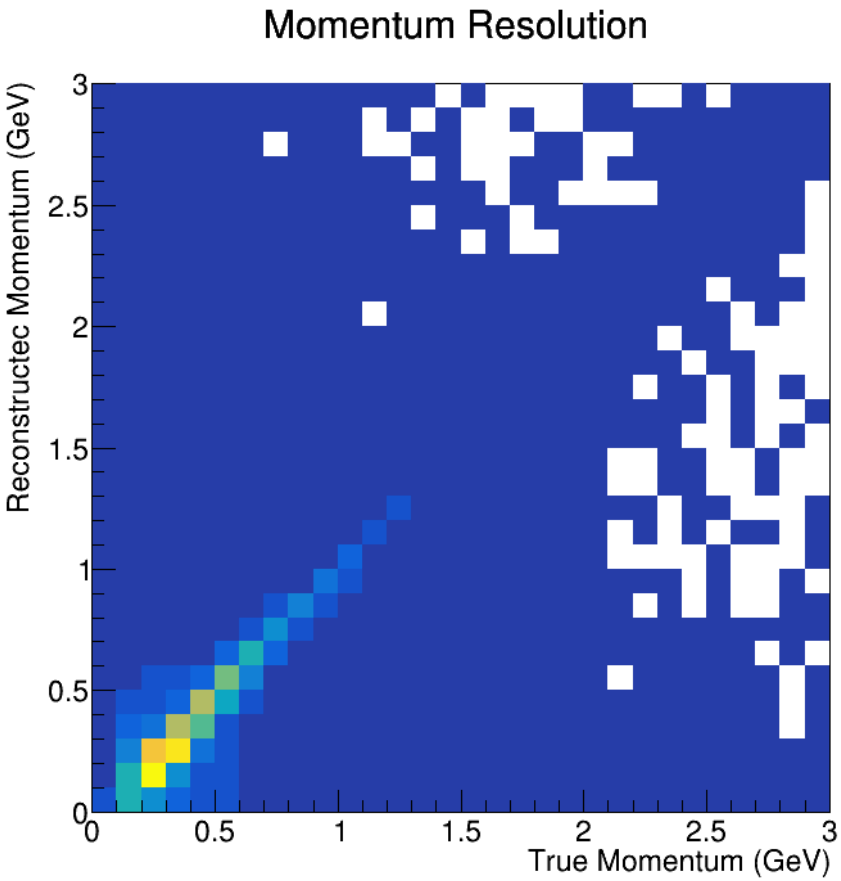


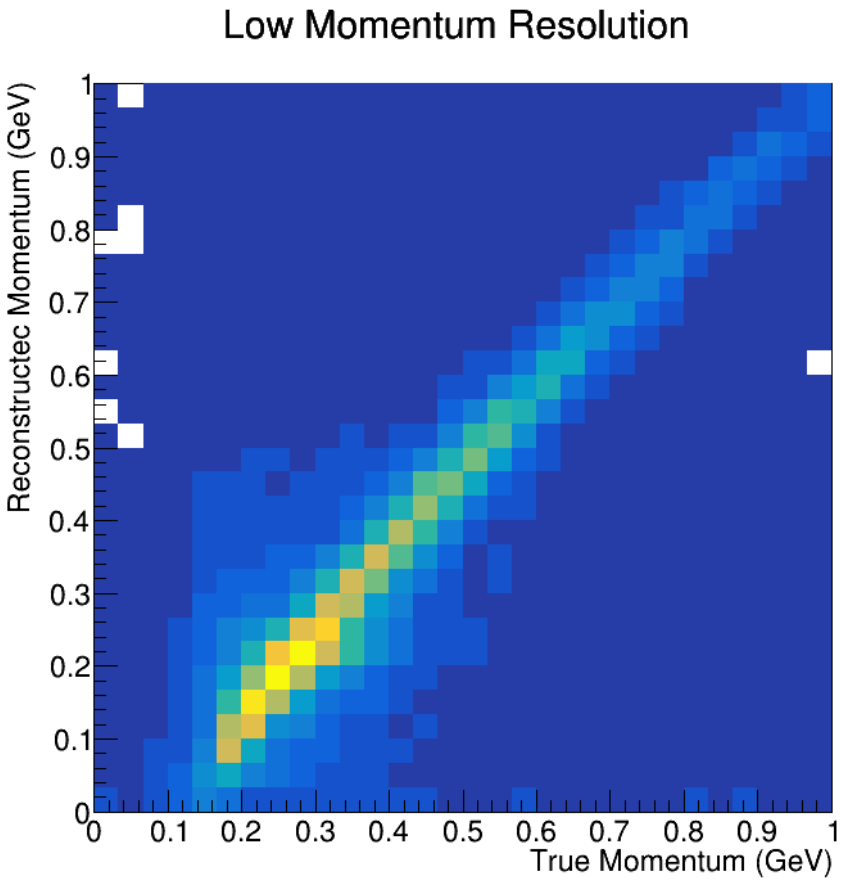
- Cleanliness is defined as the percent of the track's energy that was deposited by the proton
- Despite the issues with the previous slide, it not uncommon for protons to give less than half their energy to a track. However, this energy almost always is the primary energy source for the track.
- Odd structure around 0 cleanliness



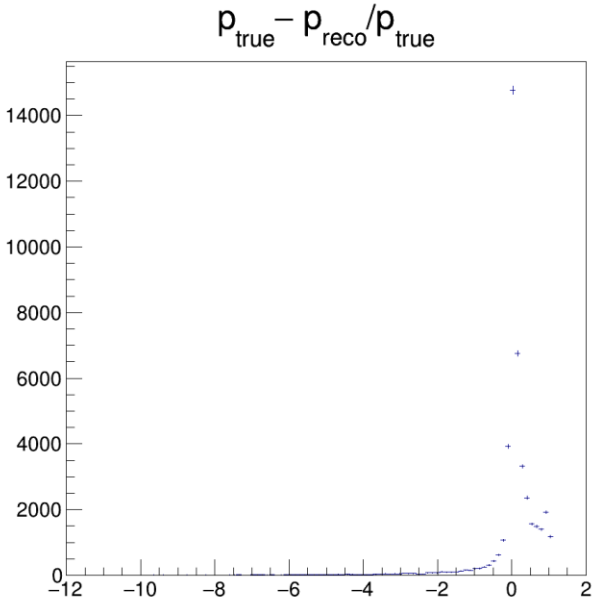
Resolution

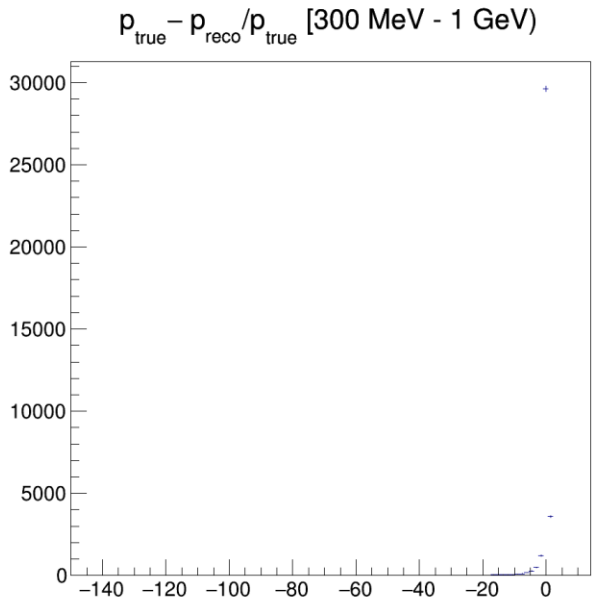
- Associated track that took the largest fraction of a proton's energy with the true proton.
- Studied different resolutions
  - True p vs Reconstructed p
  - Fractional Difference in p ($^{p_{true}-p_{reco}}/_{p_{true}}$)
  - Absolute Difference in p ($p_{true} - p_{reco}$)
  - 1 and 2-D Drift Angle Resolutions
- Findings show sub-par resolution for low momentum protons.

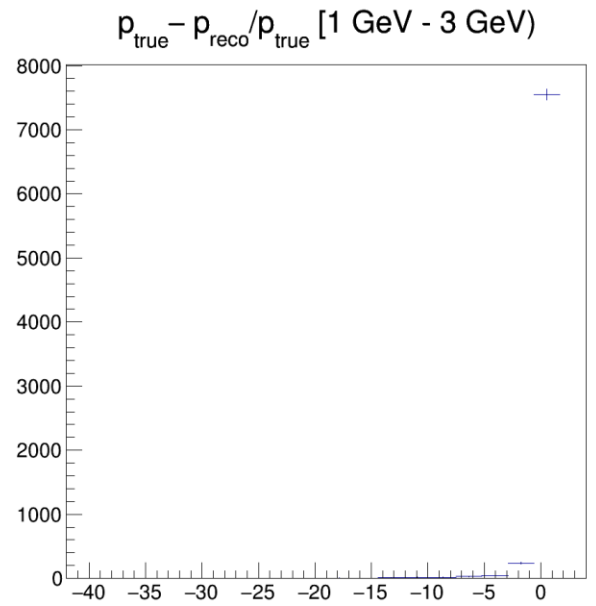

Momentum Resolution
Reconstructec Momentum (GeV)
True Momentum (GeV)
0
0.5
1
1.5
2
2.5
3

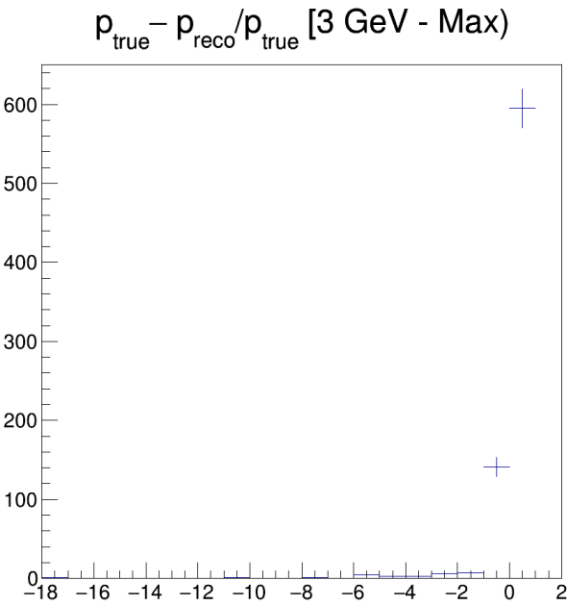

Low Momentum Resolution
Reconstructec Momentum (GeV)
True Momentum (GeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

- The fractional difference plots show many instances of reconstructed momentum being many factors larger than the true momentum.
- Poorest resolution is from low momentum protons - perhaps too short to use curvature reliably?

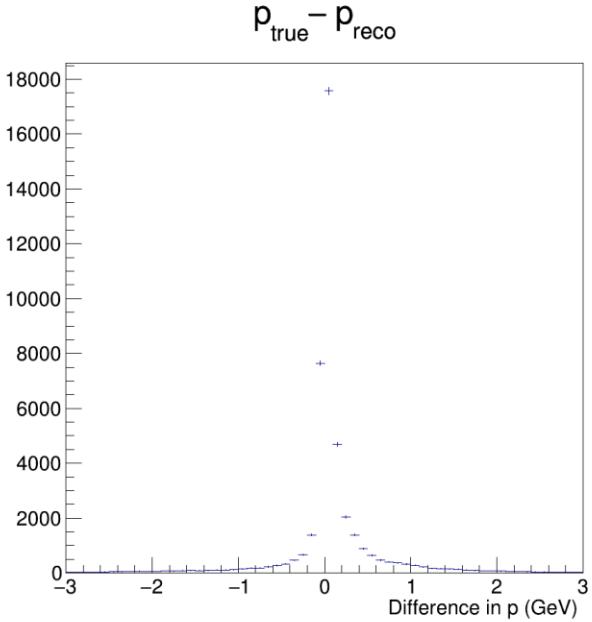


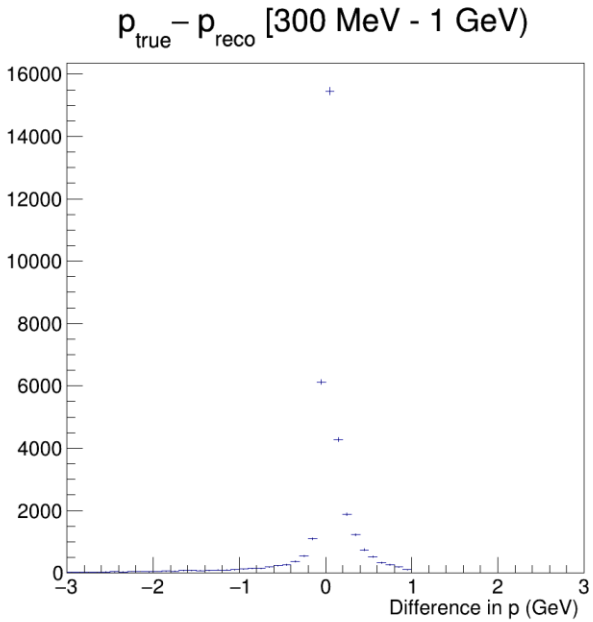


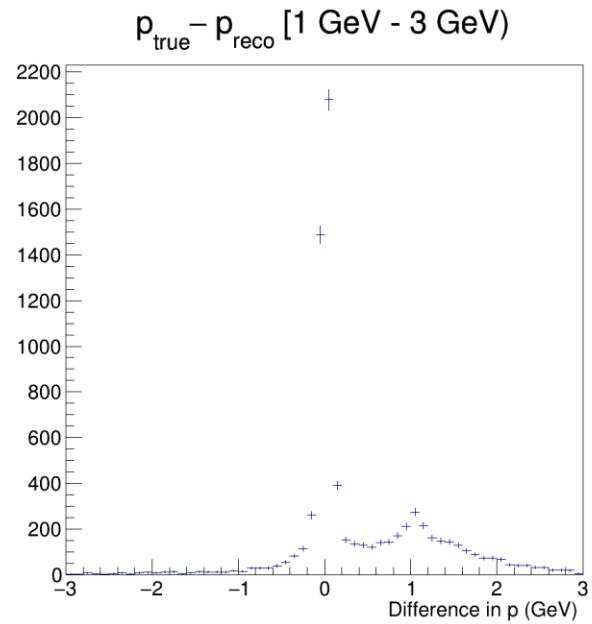


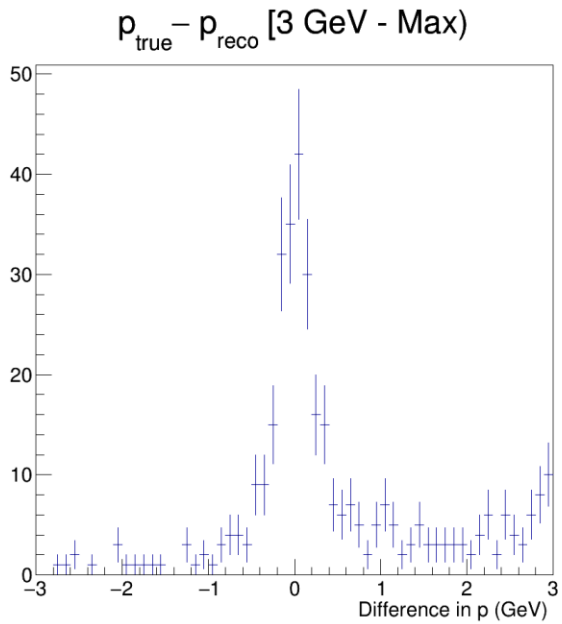


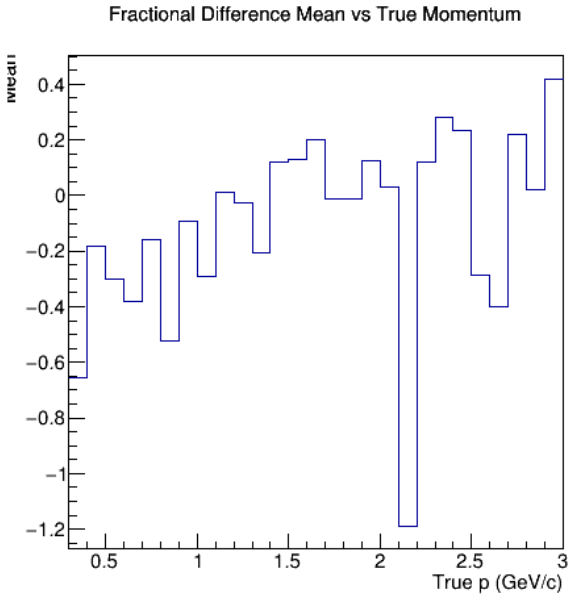
- The difference in momentum resolution plots show a nice grouping around 0. This suggests small differences between the true momentum and the reconstructed momentum.
- Additionally, differences of 50 MeV between reco and true momentum are less important here than in fractional resolution.
- Interesting double peak in the [1 GeV – 3 GeV) range

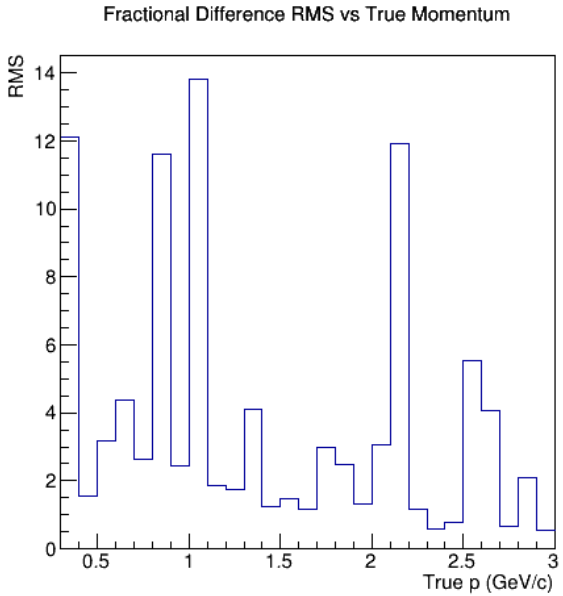


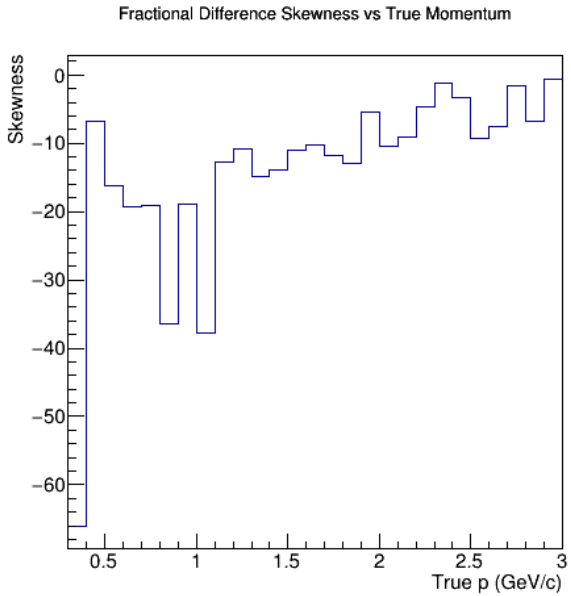


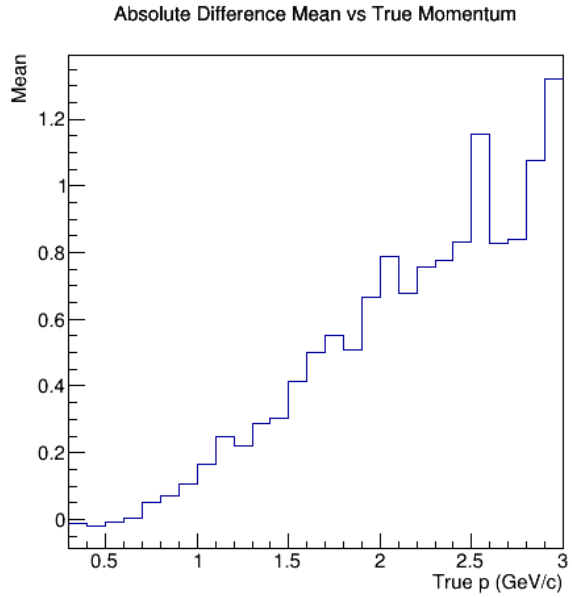


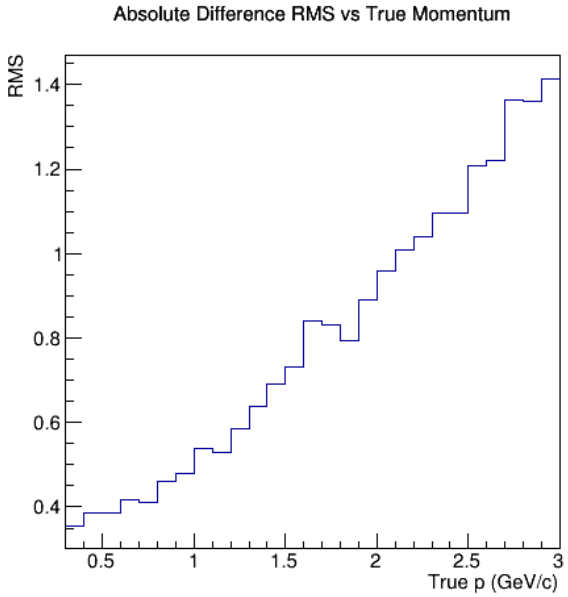


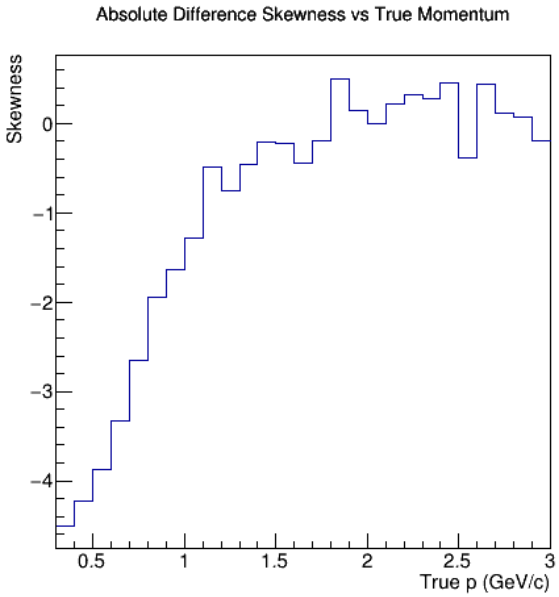

Fractional Difference Mean vs True Momentum
Mean
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
0.5
1
1.5
2
2.5
3
True p (GeV/c)


Fractional Difference RMS vs True Momentum
RMS
14
12
10
8
6
4
2
0
0.5
1
1.5
2
2.5
3
True p (GeV/c)

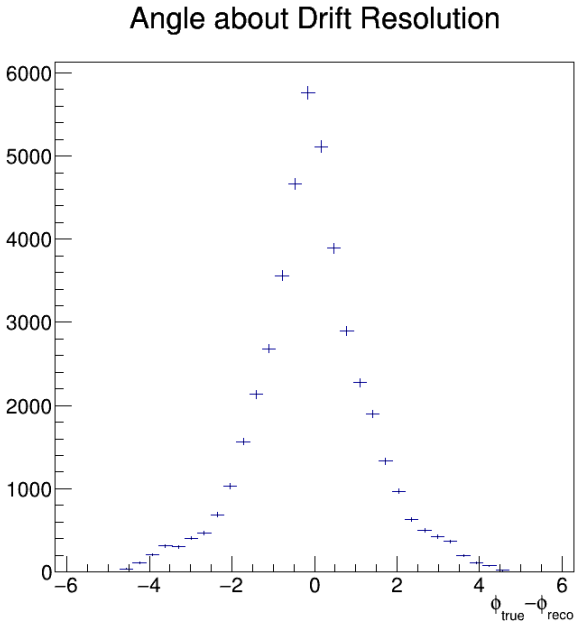

Fractional Difference Skewness vs True Momentum
Skewness
0
−10
−20
−30
−40
−50
−60
0.5
1
1.5
2
2.5
3
True p (GeV/c)

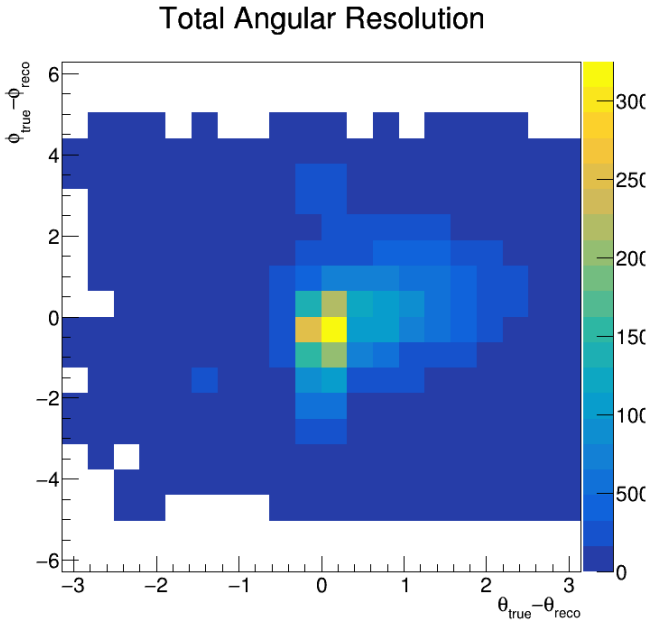

Absolute Difference Mean vs True Momentum
Mean
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
True p (GeV/c)

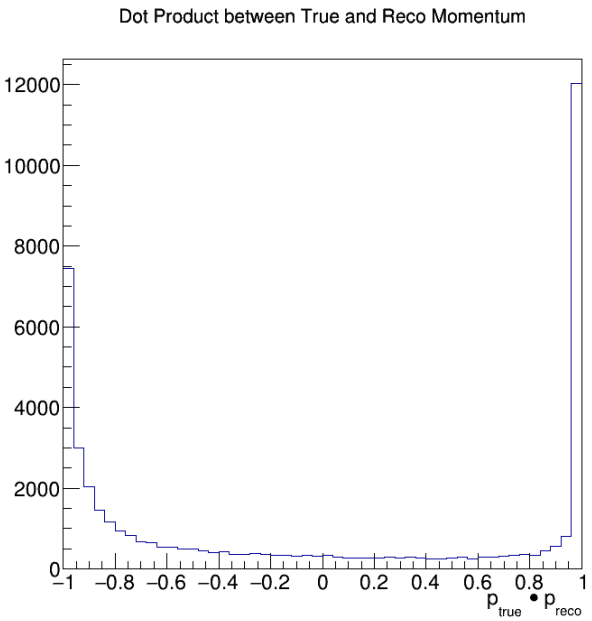

Absolute Difference RMS vs True Momentum
RMS
1.4
1.2
1
0.8
0.6
0.4
0.5
1
1.5
2
2.5
3
True p (GeV/c)

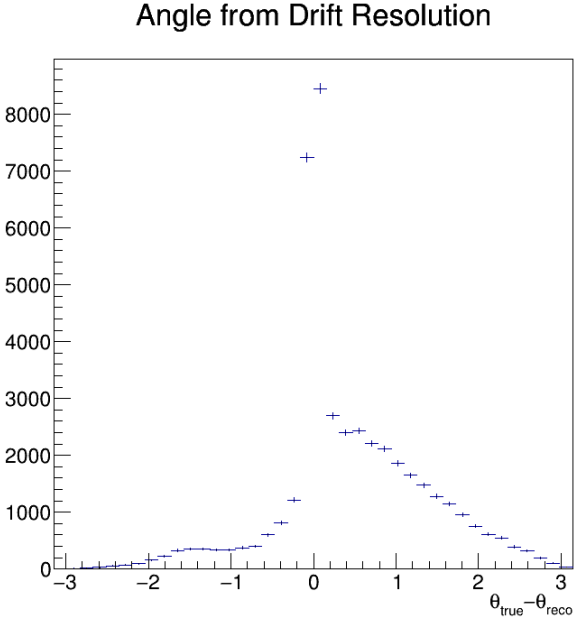

Absolute Difference Skewness vs True Momentum
Skewness
0
−1
−2
−3
−4
0.5
1
1.5
2
2.5
3
True p (GeV/c)

- The asymmetry in the Angle from Drift efficiency could have had an affect on the same resolution.
- Reassuring that the dot product between the true and reconstructed momentum unit vectors peaks near 1.
- The second peak in the dot product plot is likely due to low momentum protons being reconstructed as travelling in the opposite direction.









Next Steps

- Produce same study for muons, charged pions, and charged kaons
- See how much energy is distributed between each track a proton donates to
- Identify why there is an imbalance in the drift angle efficiency and resolution
- Continue to advance GArAna performance
- Increase the overall momentum efficiency once it plateaus
- Work towards optimizing when to reconstruct low-momentum protons using curvature and when to use distance travelled

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