Jet Energy Resolution and Single Pion Energy Reconstruction without BIB

Brief Overview

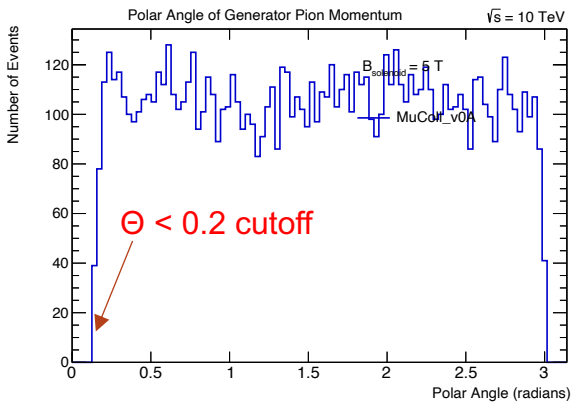
Analysis Objectives and Goals

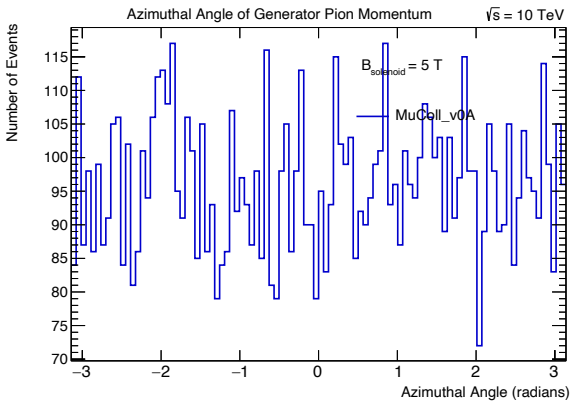
- **Objectives**
  - Simulate the calorimeter response to an incident single pi+ gun with a pT between 1 GeV to 1 TeV
  - Study jet and pion reconstruction methods and efficacy
- **Goals**
  - Match reconstructed jets to initial pions
  - Quantify the energy resolution of matched jets
  - Quantify the pion reconstruction efficiency from the matched jets

Initial Pion Simulation

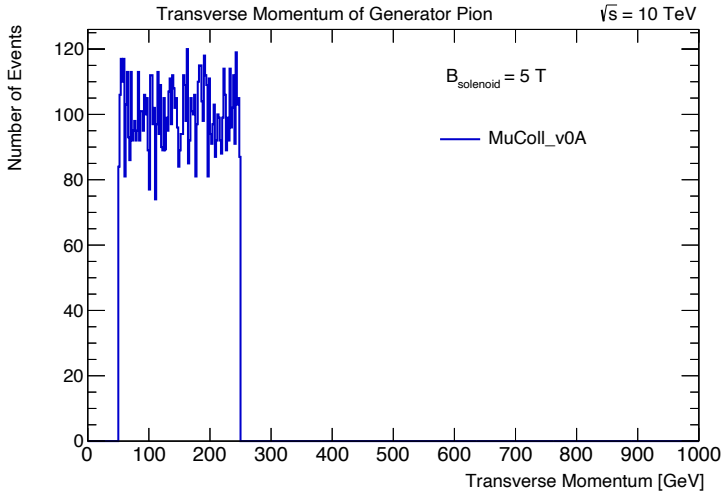
- **Simulation Parameters**
  - Pion samples simulated in 3 pT batches of 1000 incident pions each
    - 0 – 50 GeV, 50-250 GeV, 250-1000 GeV
      - Fourth 1000-5000 GeV batch not used here
  - Initial pion momenta is mostly transverse with some z component
    - Uniform distribution in polar angle (θ) and azimuthal angle (ϕ)

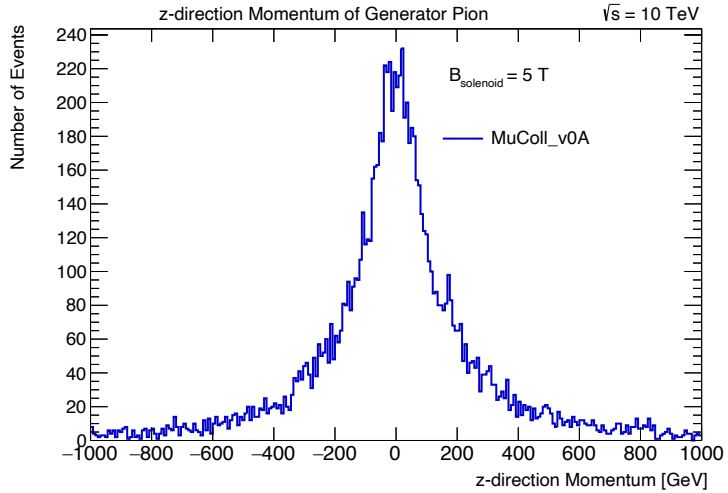
250-1000 GeV pT Batch





50-250 GeV pT Batch



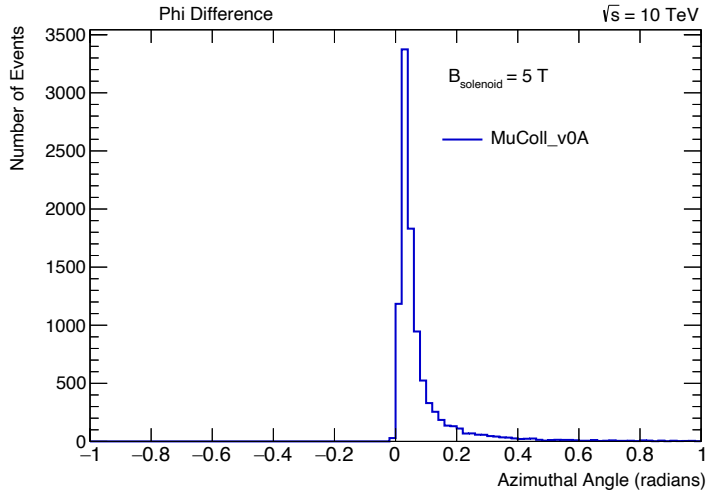


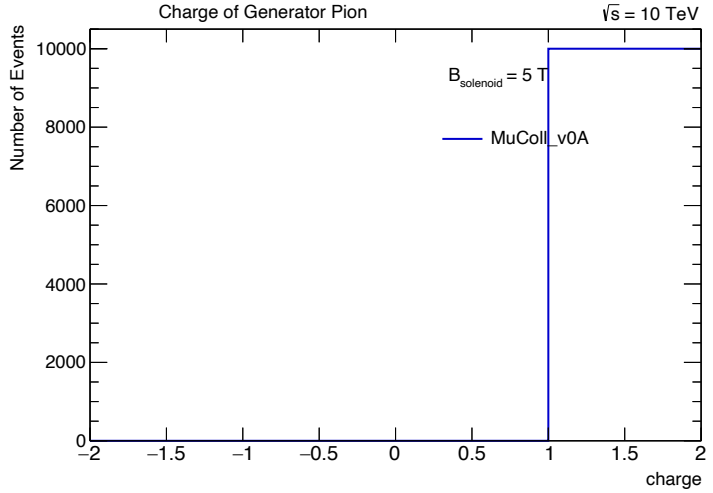
Plots for all batches in backup

Generator Pion Information

0-50 GeV pT Batch

- **Pion Generation**
  - Only pi+ are being generated
    - Should we also run tests with other pion guns?
- **Azimuthal Angular Separation**
  - Azimuthal angular separation defined as:
    - $\Delta\phi = \phi_{pion,decay} - \phi_{pion,generation}$
  - The generation of only pi+ along with the B field cause a tail in the $\Delta\phi$ distribution





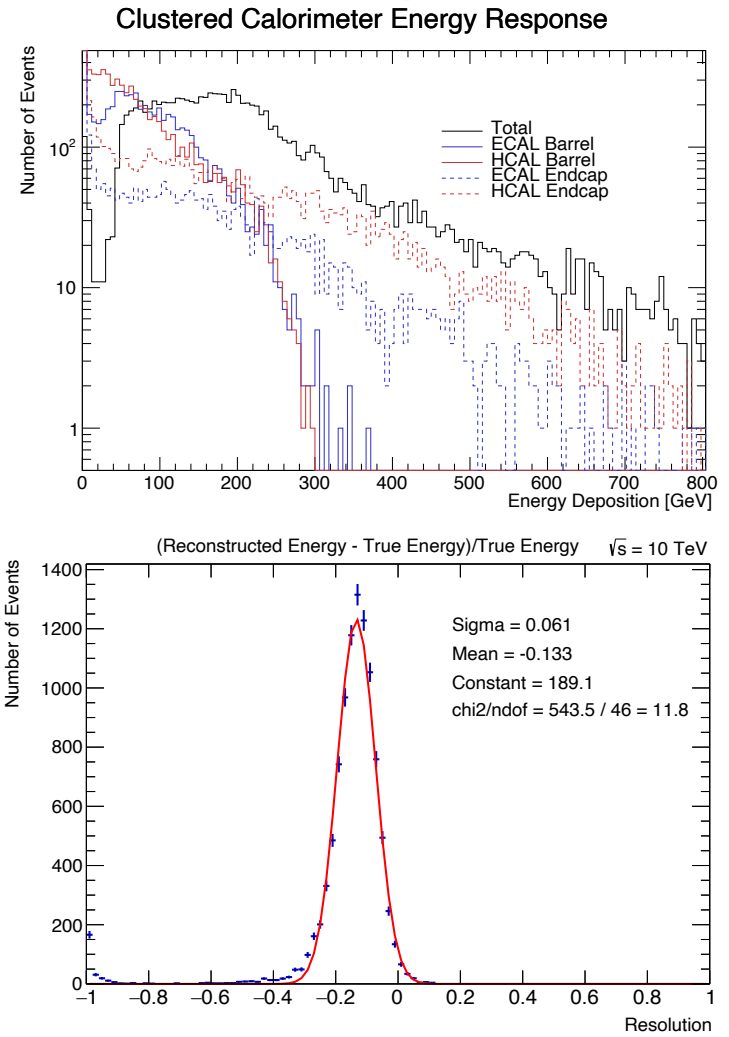
Previous Results

- **Energy Reconstruction**
  - Previously, Junjia completed energy reconstruction analysis by clustering calorimeter hits in a cone

$$E_{rec} = \sum_{\substack{|\theta_p - \theta_{\text{end}}| < 0.1 \\ |\phi_p - \phi_{\text{end}}| < 0.1}} E^{hit}_{\{r_p, \theta_p, \phi_p\}}$$

  - This resulted in roughly 15% energy loss and an energy resolution of roughly 0.075
    - This resolution is comparable to the anti-kt jets analyzed later but the anti-kt jets have lower energy loss
    - Resolution = $\sigma(\Delta_E)/E_{true}$

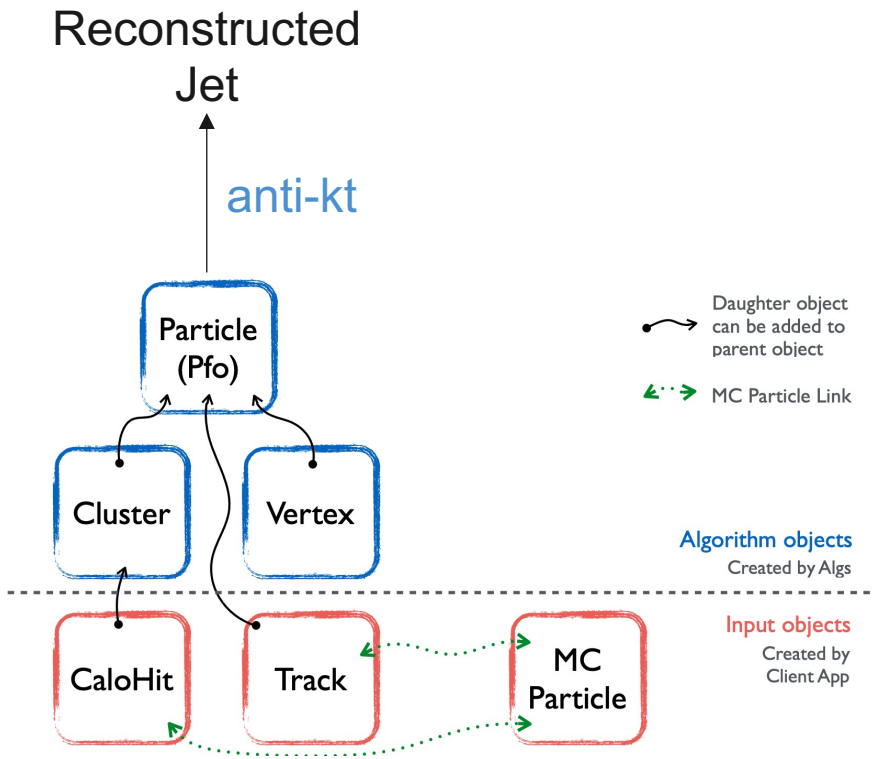
50-250 GeV pT Batch



New Jet Analysis

Anti-kt Jets

- **Reconstruction Method**
  - Jets were constructed by Federico Meloni using the anti-kt jet clustering algorithm
  - This takes reconstructed Pandora Particle Flow Objects (PFOs) and clusters them with R = 0.4
- **Jets**
  - The constituent particles of these jets includes: electrons, muons, photons, pions, and neutrons

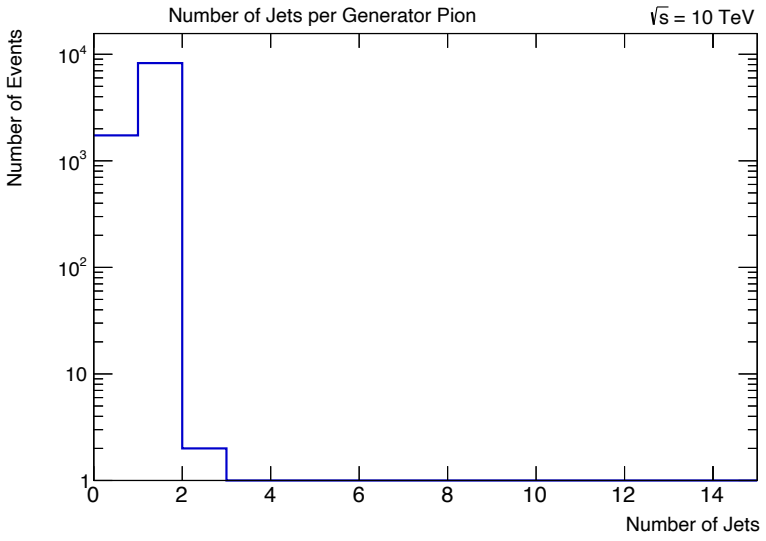


anti-kt distance measure

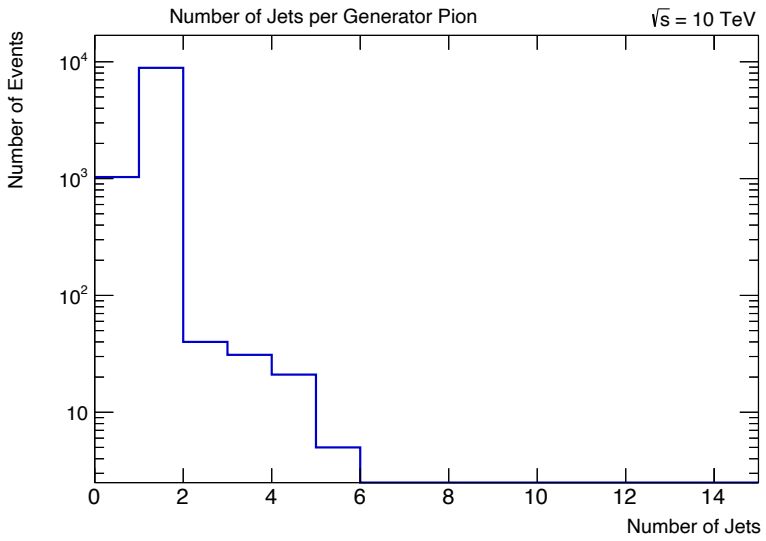
$$d_{ij} = \min\left(\frac{1}{k_{ti}^2}, \frac{1}{k_{tj}^2}\right)\frac{\Delta y^2 + \Delta \phi^2}{R^2}$$

Jet Multiplicity

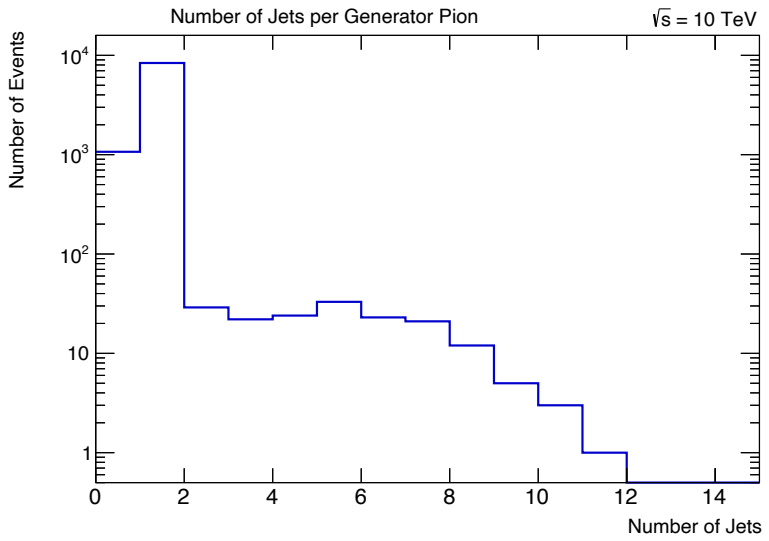
0-50 GeV pT Batch



50-250 GeV pT Batch



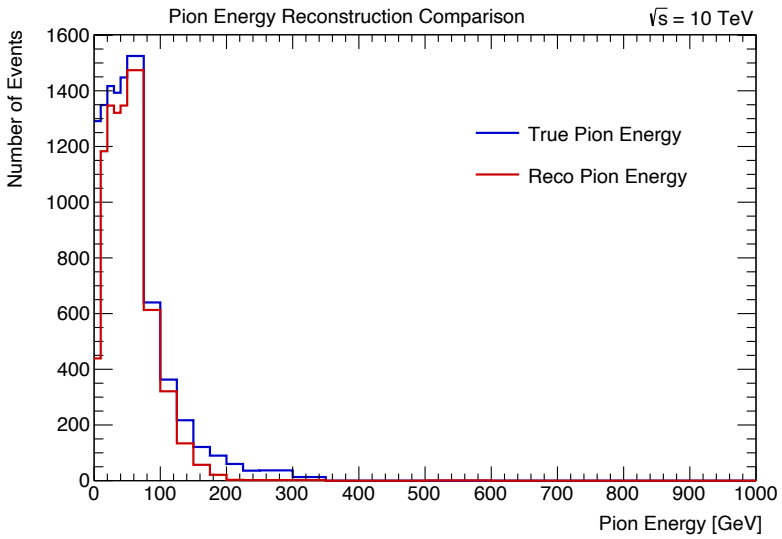
250-1000 GeV pT Batch



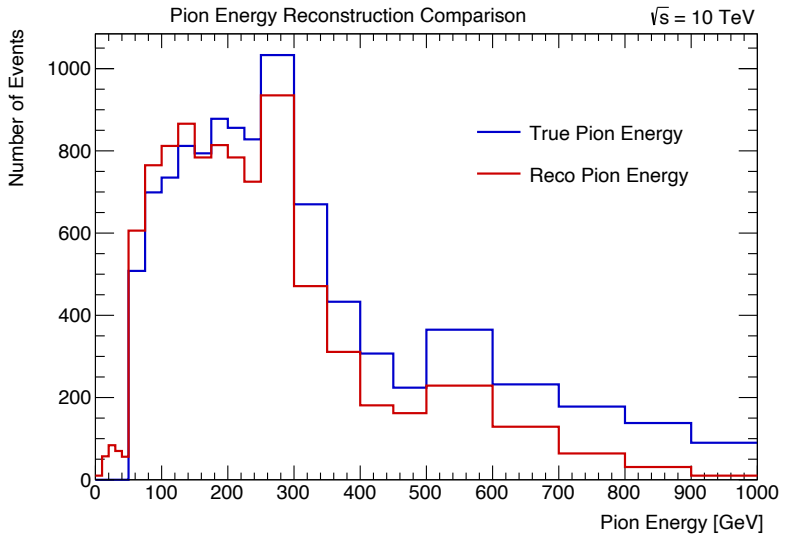
- More jets are reconstructed for higher pion pT
  - Multiplicity dependence on initial pT is in backups slides
- Due to this jet multiplicity, the best fitting jet must be matched to the initial pion
  - In the following analysis, this is done by using the jet closest in angular distance to the initial pion
  - $\Delta R = \sqrt{(\Delta\phi)^2+(\Delta\theta)^2}$

Pion Reconstruction Energy Comparison

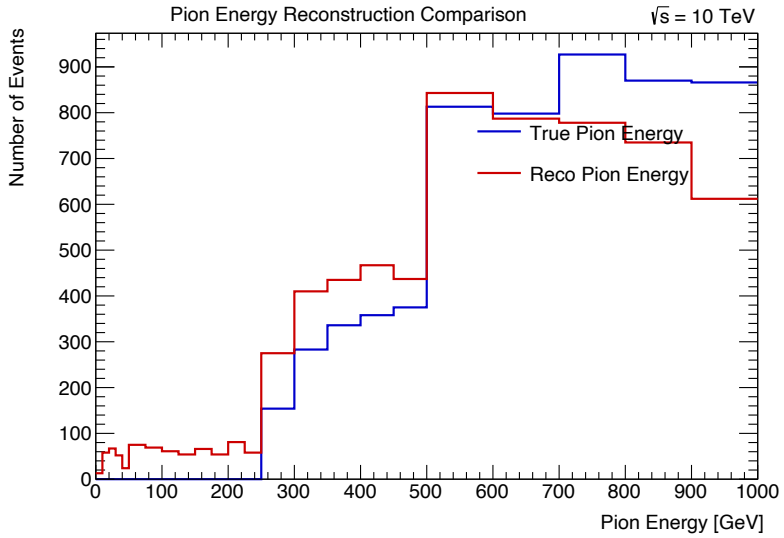
0-50 GeV pT Batch



50-250 GeV pT Batch



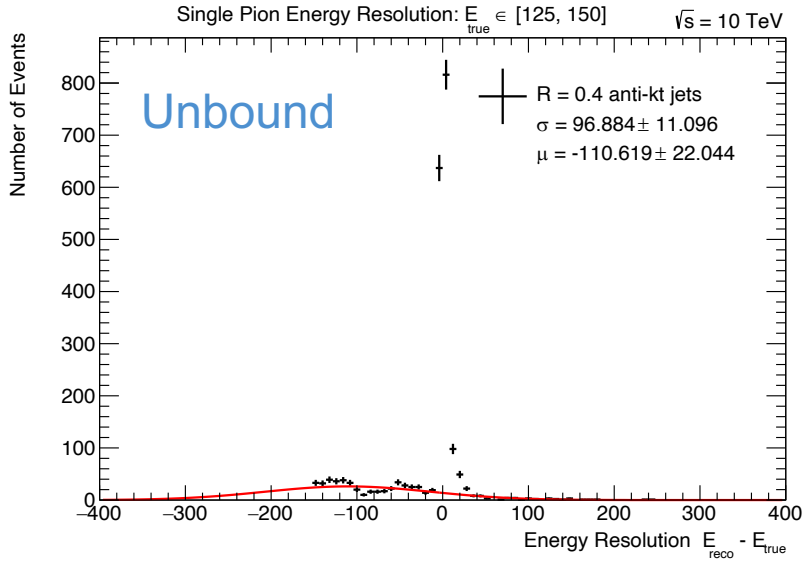
250-1000 GeV pT Batch

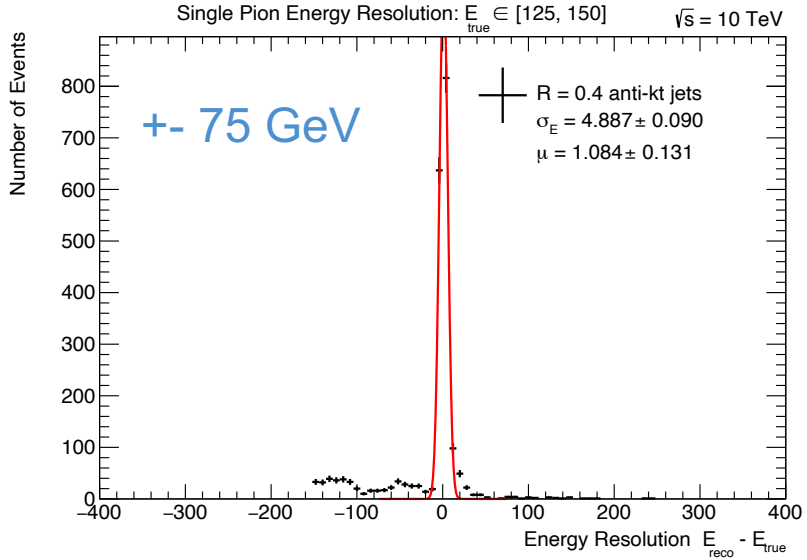


- These results suggest that pions are being reconstructed with lower energies than is accurate
  - (This same plot for the sum of all pT batches is in the backup slides)
- I am planning to develop these results more thoroughly next week to create reconstruction efficiency plots
  - As well as look at angular dependence

Jet Resolution Fitting

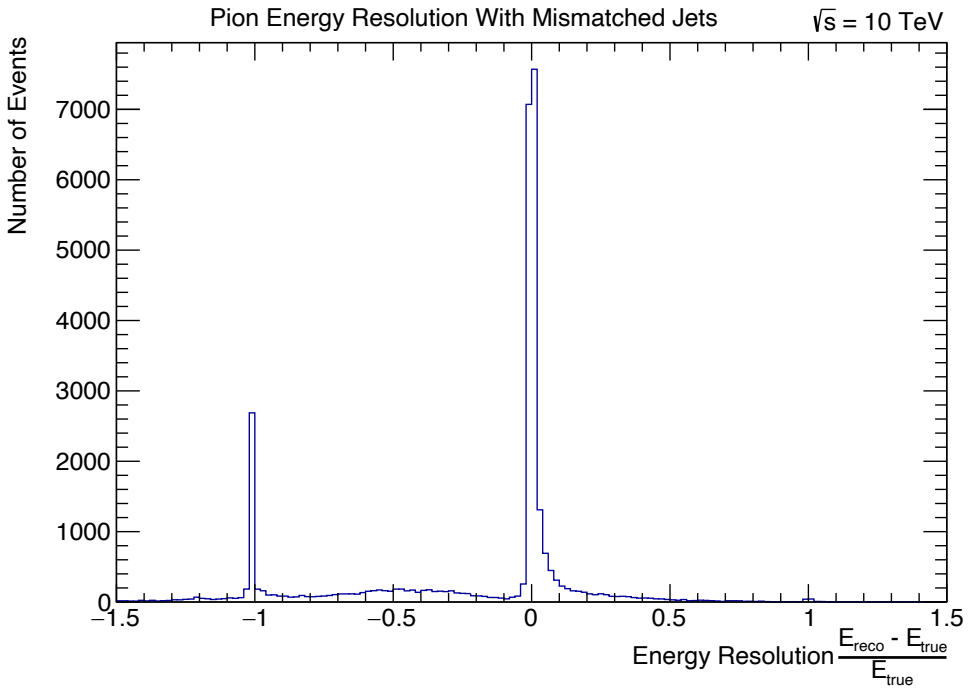
- **Fitting Method**
  - Following analysis from Federico Meloni:
    - Cumulated the results from all 3 pion batches
    - Fit the single pion energy resolution in each energy bin of roughly 25 GeV
- **Fitting issues**
  - The input deltaE needed to be restricted in order to generate sensible results
    - I choose a range of +-75 GeV to generate the following results





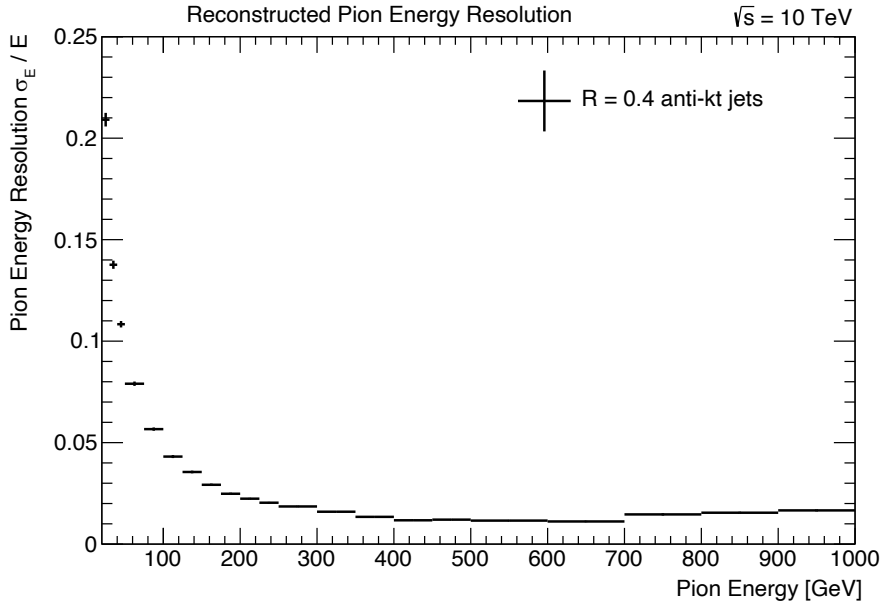
More Fitting Issues!

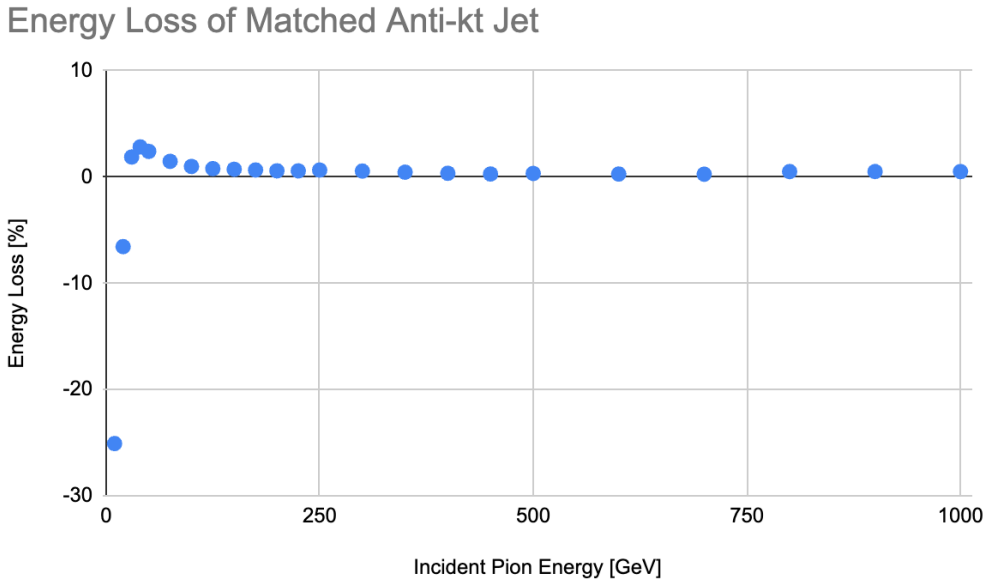
- **Mismatched Jets**
  - Roughly 10% of initial pions do not result in a matched jet being being found
  - I'm next planning to look at these pions which do not generate a jet to see if the pions decay in the detector
    - As well as making future plots with cuts on jet matching criteria



Jet Resolution

- **Resolution Results**
  - The reconstructed energy resolution is < 0.05 for most incident pion energies
    - Previous clustering resolution: 0.075
  - The energy loss using anti-kt jets is significantly improved with roughly 1% loss for most pion energies
    - However, low pion energies result in much larger energy loss
    - Previous clustering energy loss: 13-18%

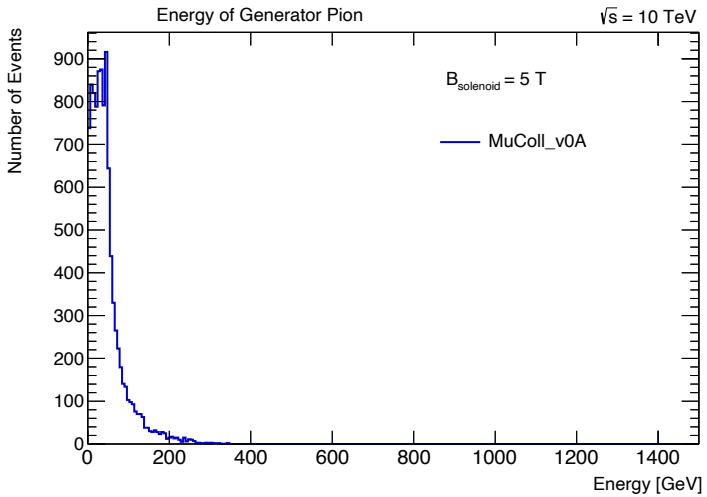


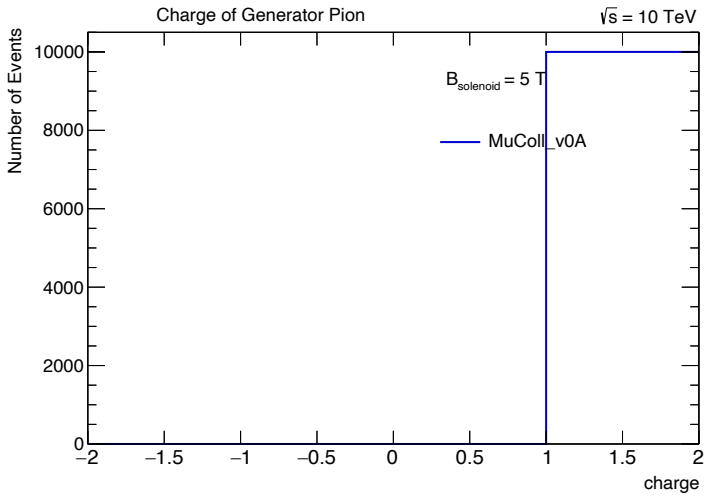


Backup Slides

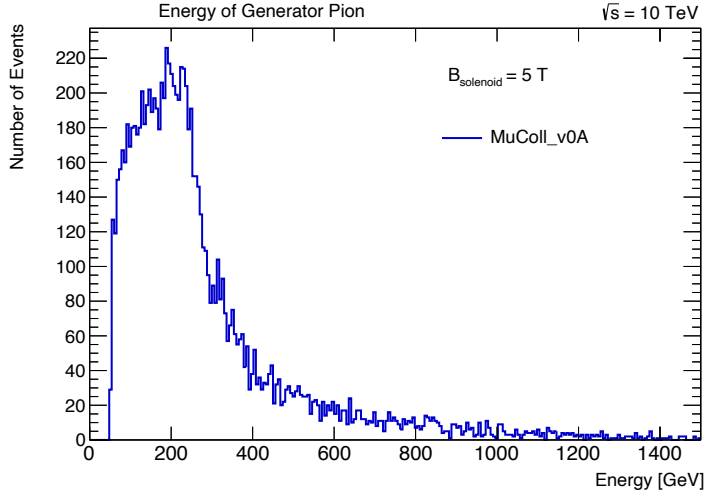
Pion Energy and Charge

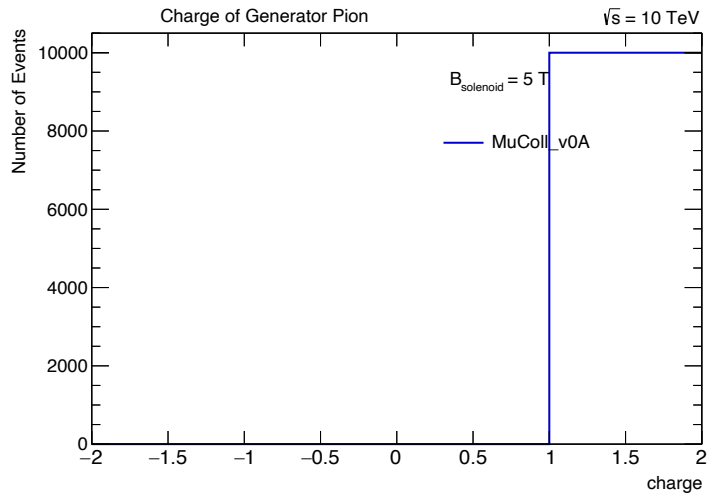
0-50 GeV



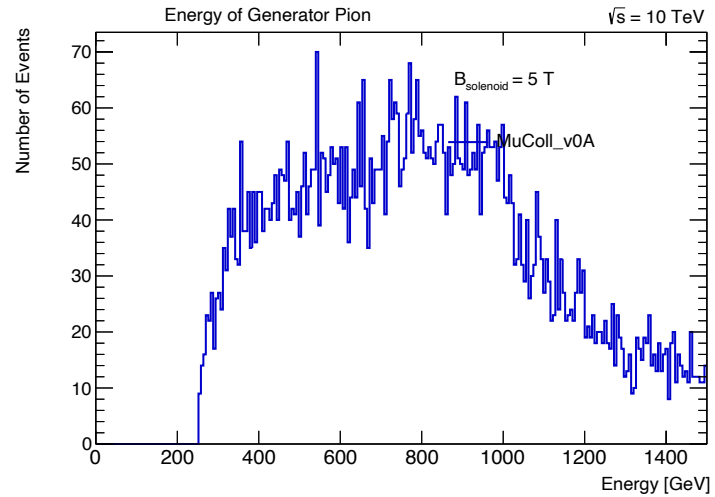


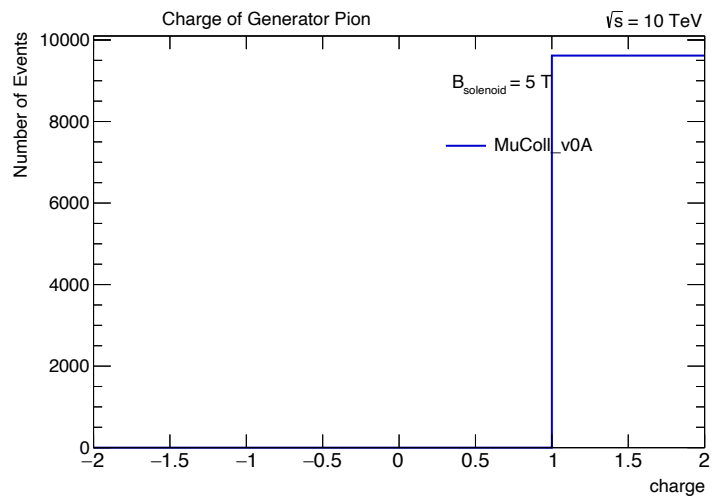
50-250 GeV





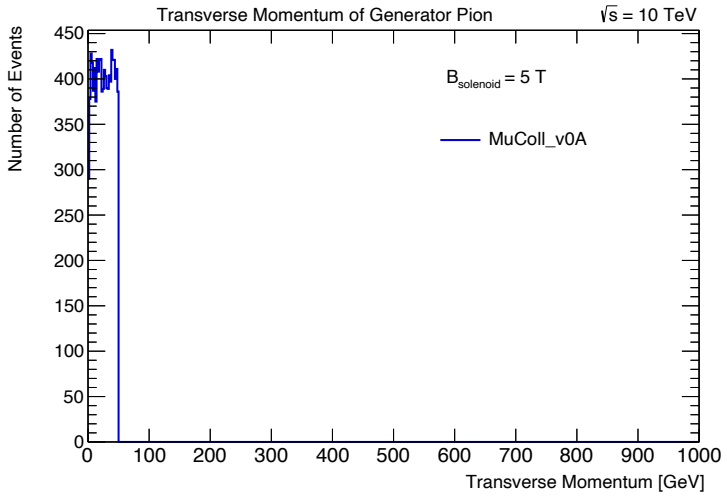
250-1000 GeV

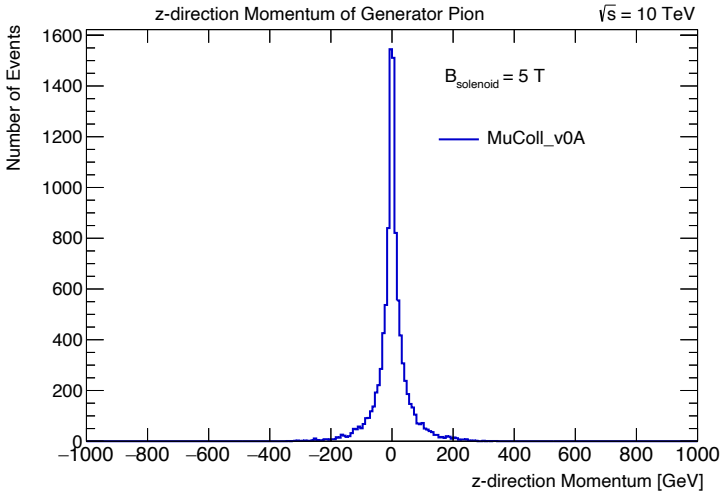




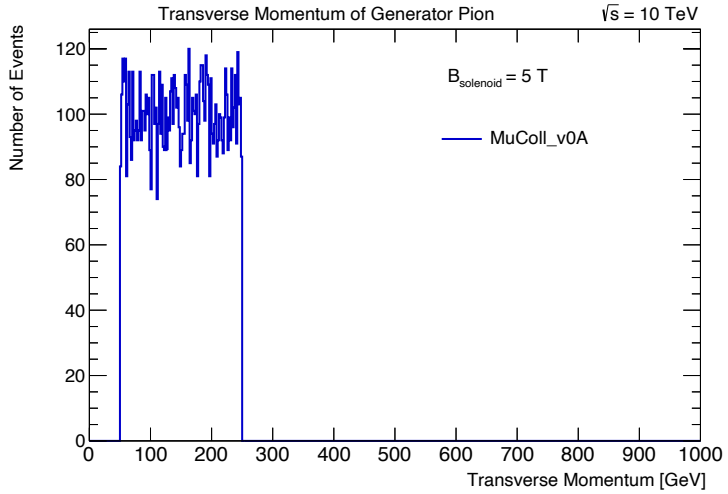
Initial Pion Momenta

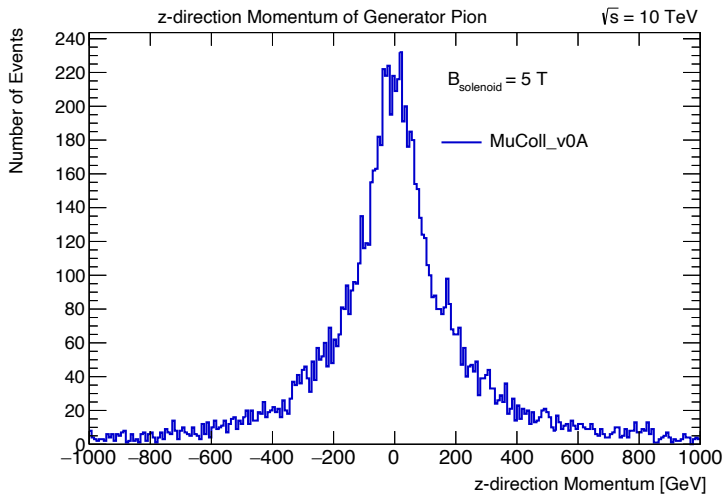
0-50 GeV



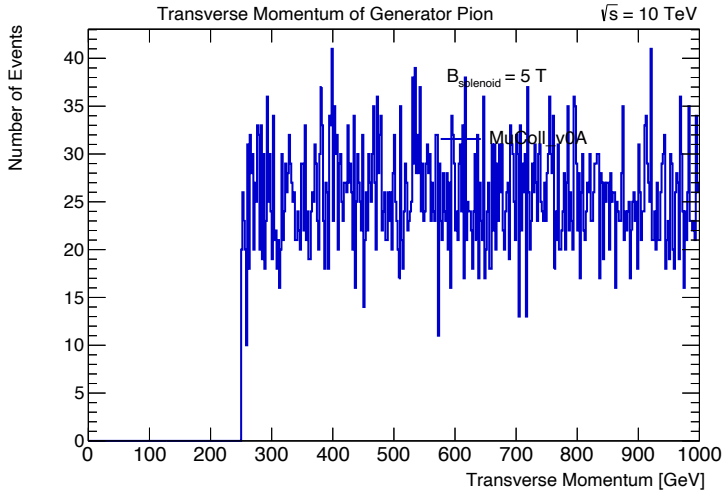


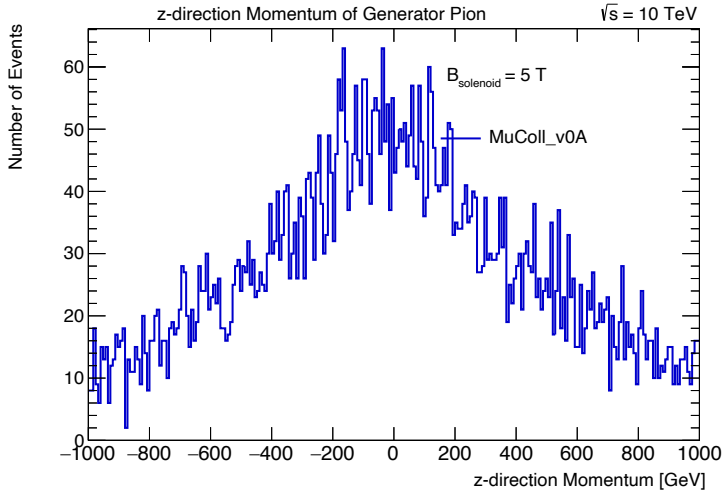
50-250 GeV





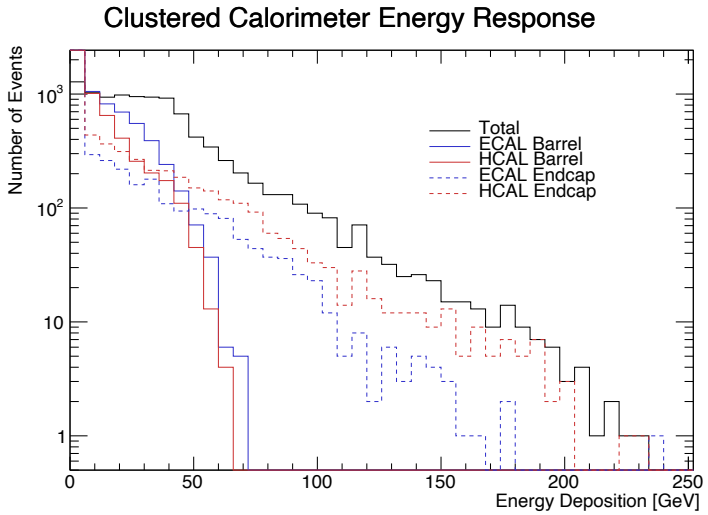
250-1000 GeV

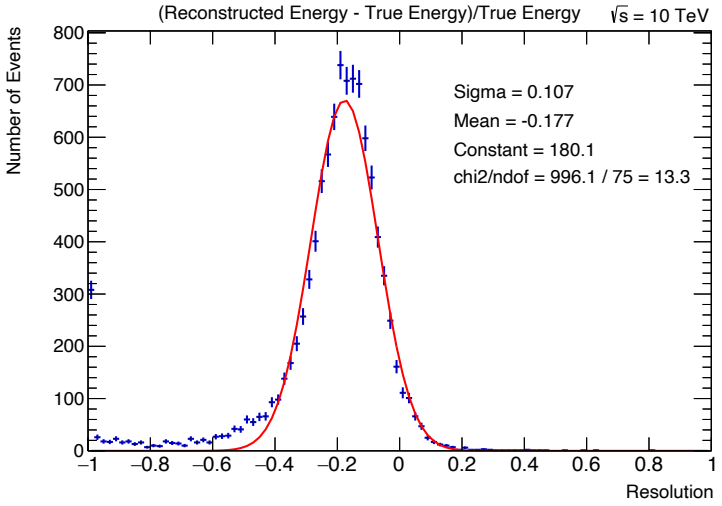




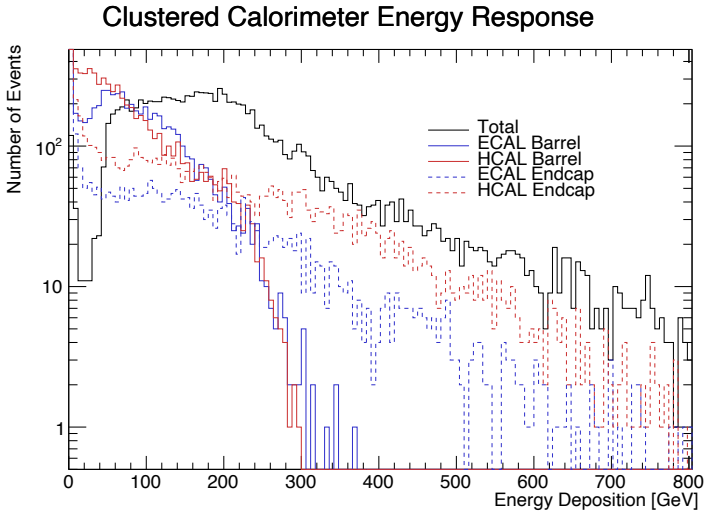
Cone Calorimeter Energy Response and Resolution

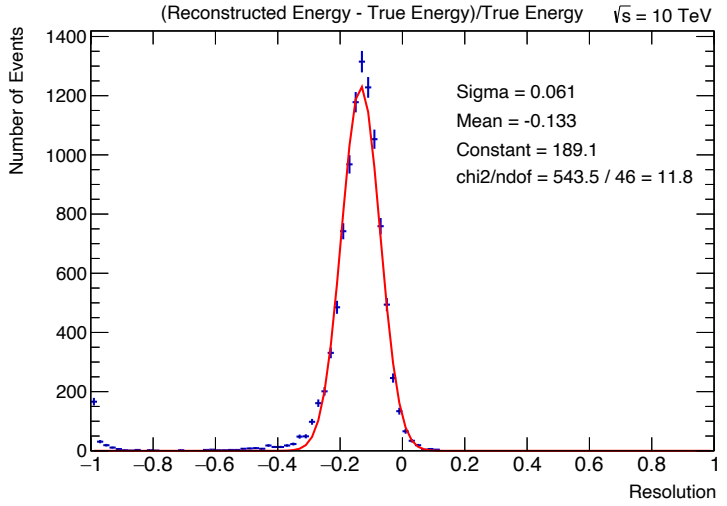
0-50 GeV



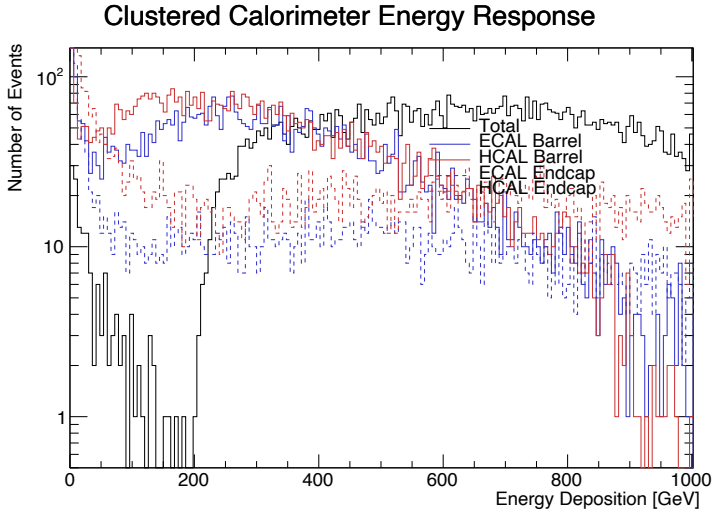


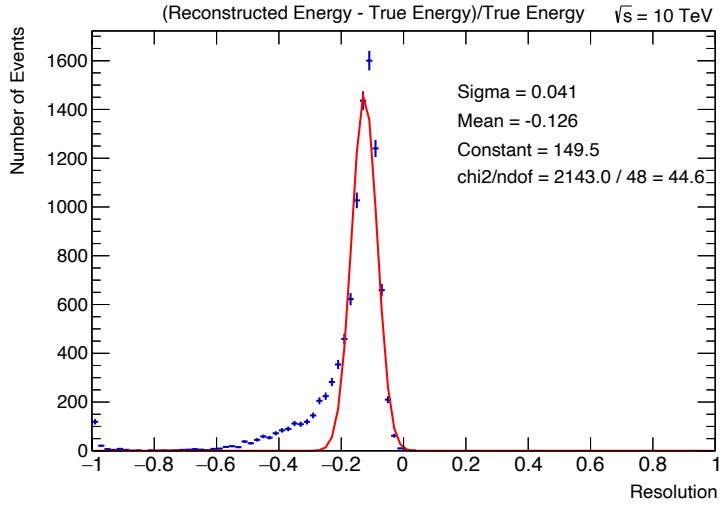
50-250 GeV





250-1000 GeV



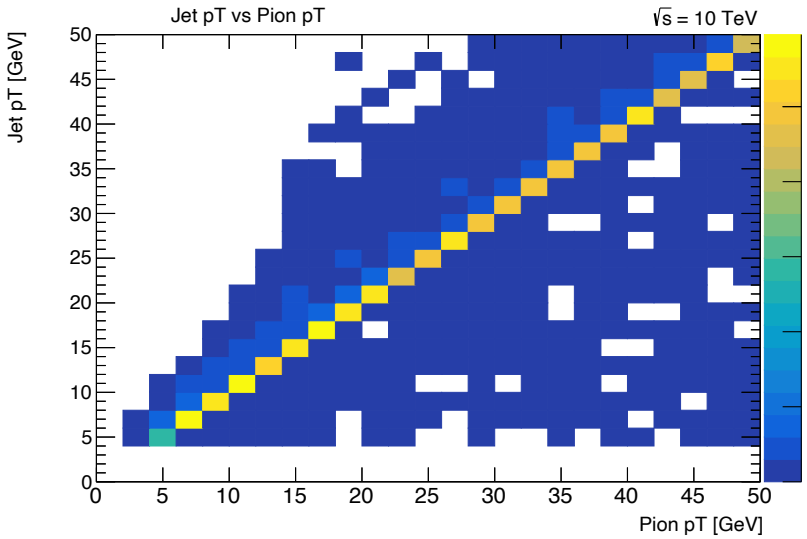


Polar Angle

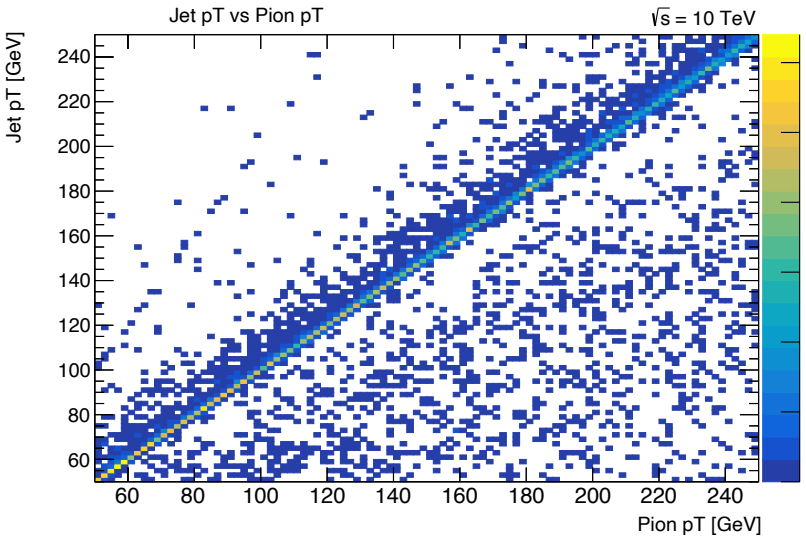
Azimuthal Angle

Correlation between jet pT and true pion pT

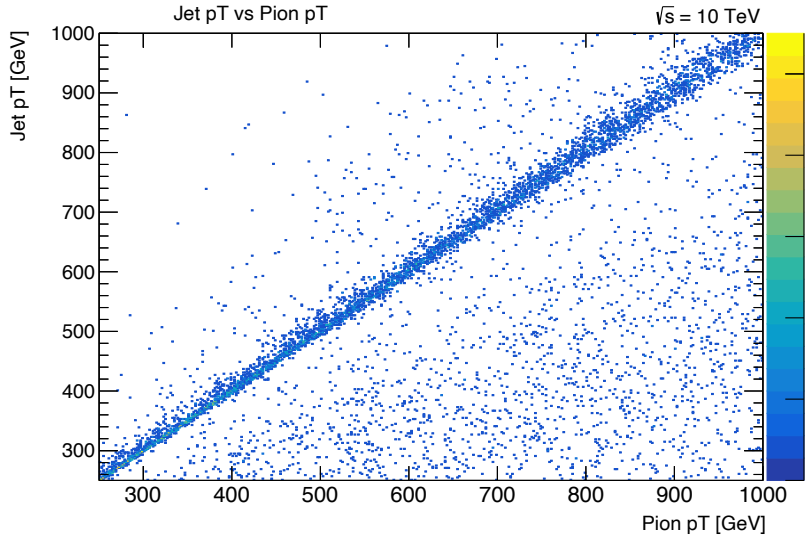
0-50 GeV pT Batch



50-250 GeV pT Batch



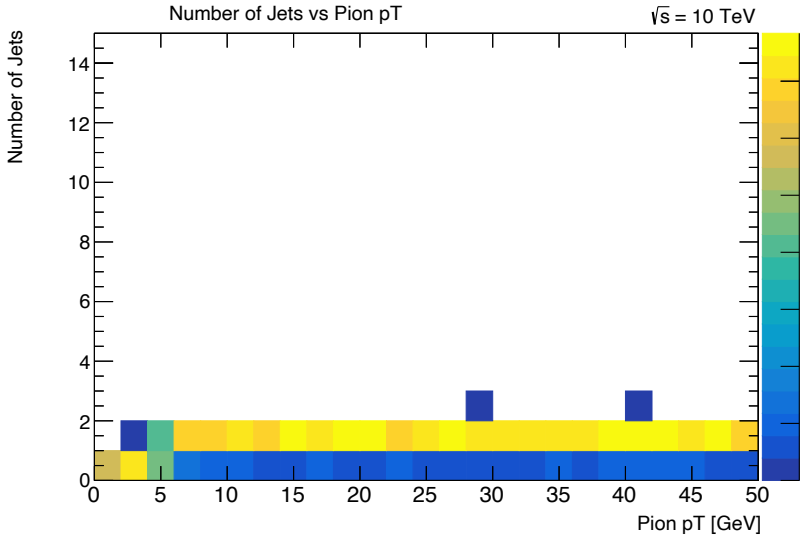
250-1000 GeV pT Batch



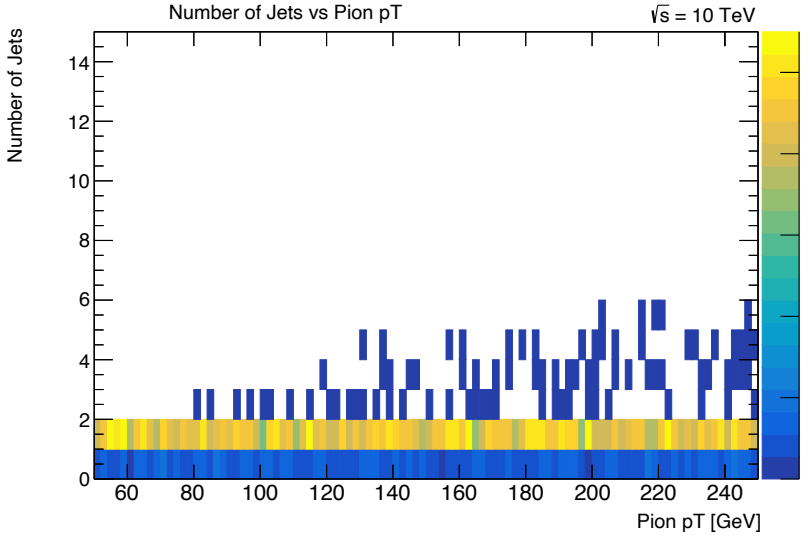
- These plots are made without jet matching
- Anti-kt jet pT seems to correlate quite nicely with the initial pion pT with some extreme outliers both high and low
- However, these plots do not account for the fact that multiple jets are reconstructed for each individual incident pion

Jet Number Dependence on Pion Energy

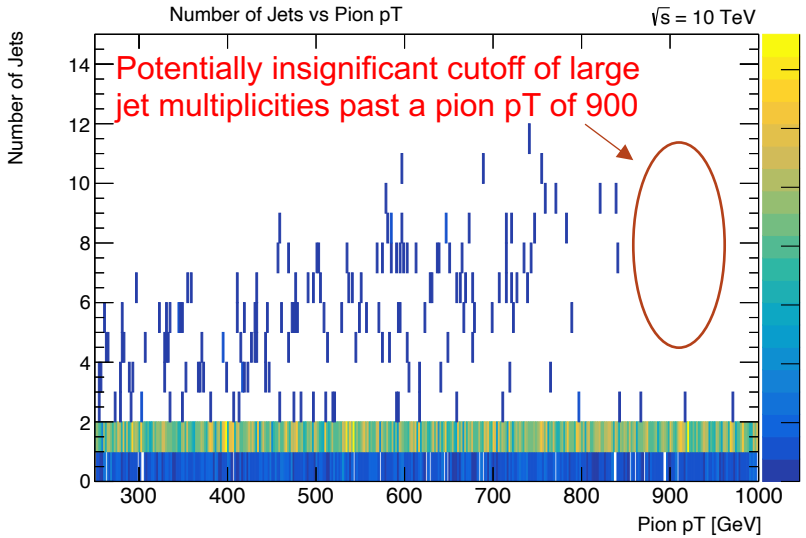
0-50 GeV



50-250 GeV



250-1000 GeV



- For almost all pion pT, most events seem to generate only 1 event
- However, for high pT pions, larger jet multiplicities are more likely

Total Pion Reconstruction Energy Comparison

Sum of All pT Batches