

Shower energy correction and π^0 reconstruction in ProtoDUNE

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Weekly Hadron Analysis Meeting

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Outline

To examine reconstruction performance and study the shower energy correction

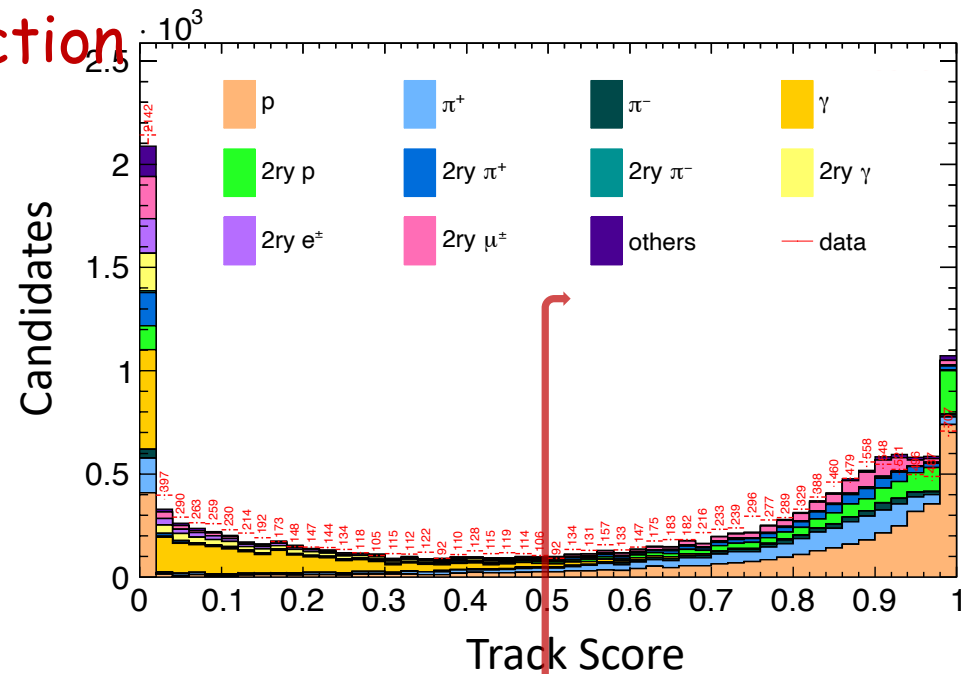
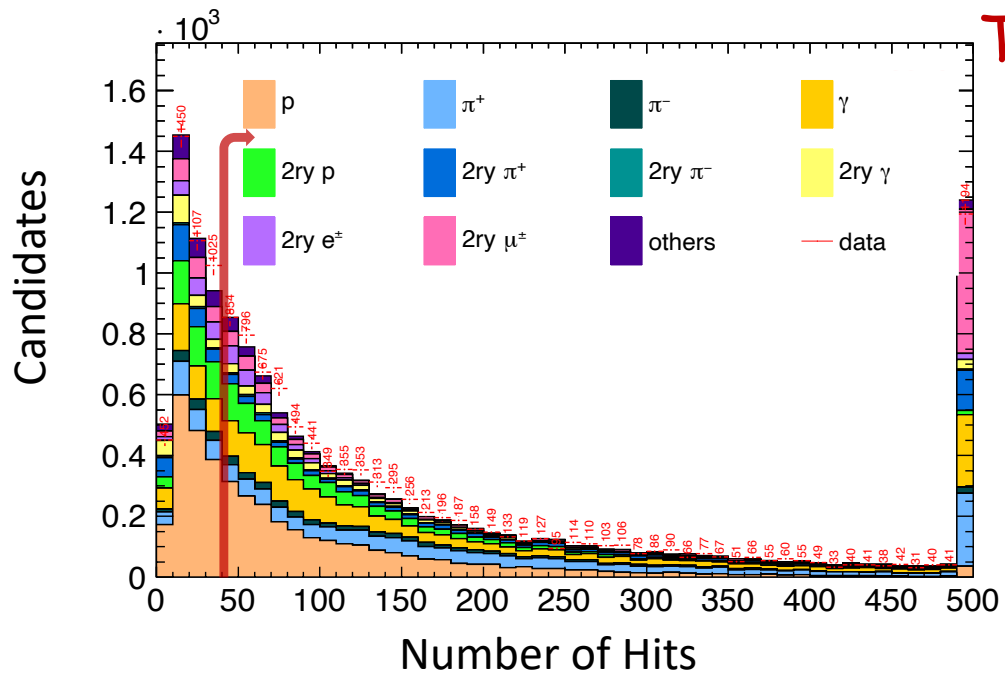
1. Recap of Particle Selection and Reconstruction
2. Introduce the Impact Parameter (IP) for Shower Candidates **(NEW!)**
3. Improved Shower Selection and Energy Correction **(NEW!)**
4. π^0 Mass and Momentum Reconstruction

NEW Production 4 MC Sample:

Data: pionana_Prod4_5387_1GeV_1_14_21.root

MC: pionana_Prod4_mc_1GeV_1_14_21.root

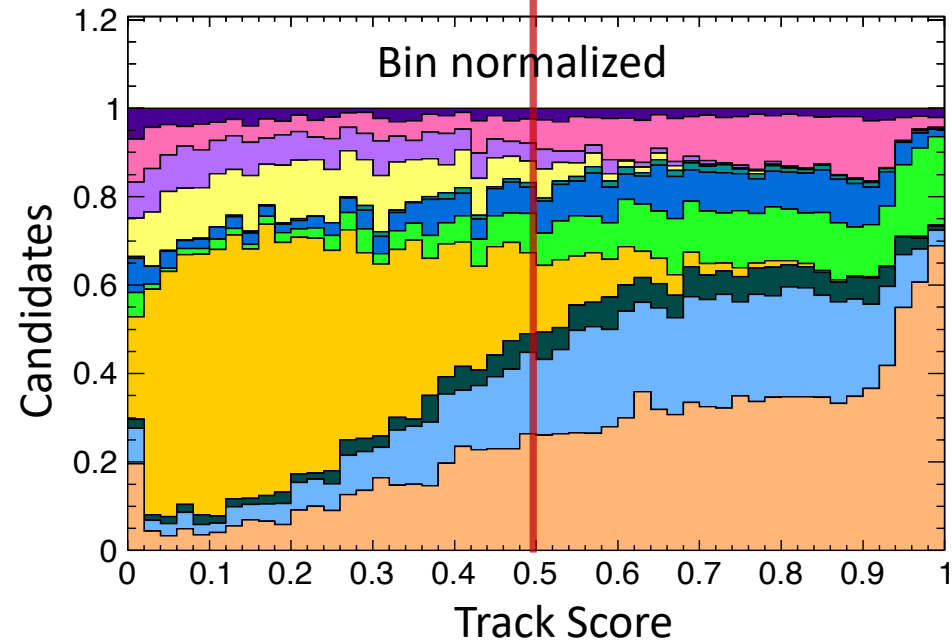
Track Selection



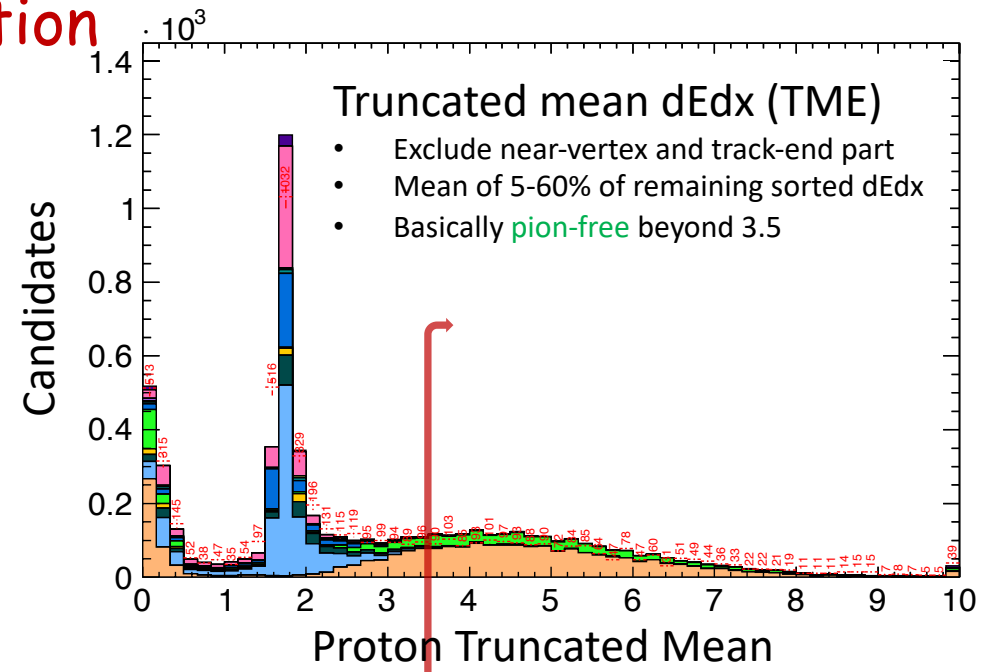
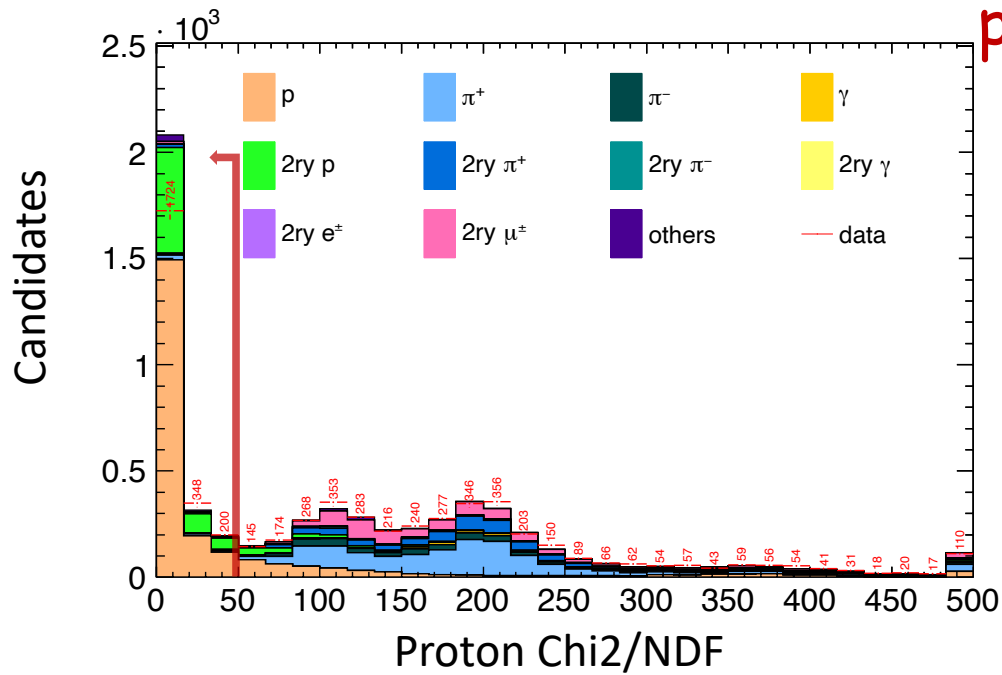
Counted as a **track** if :

1. reco_daughter_allTrack_ID != -1
2. TrackScore > 0.5
3. nHits > 40

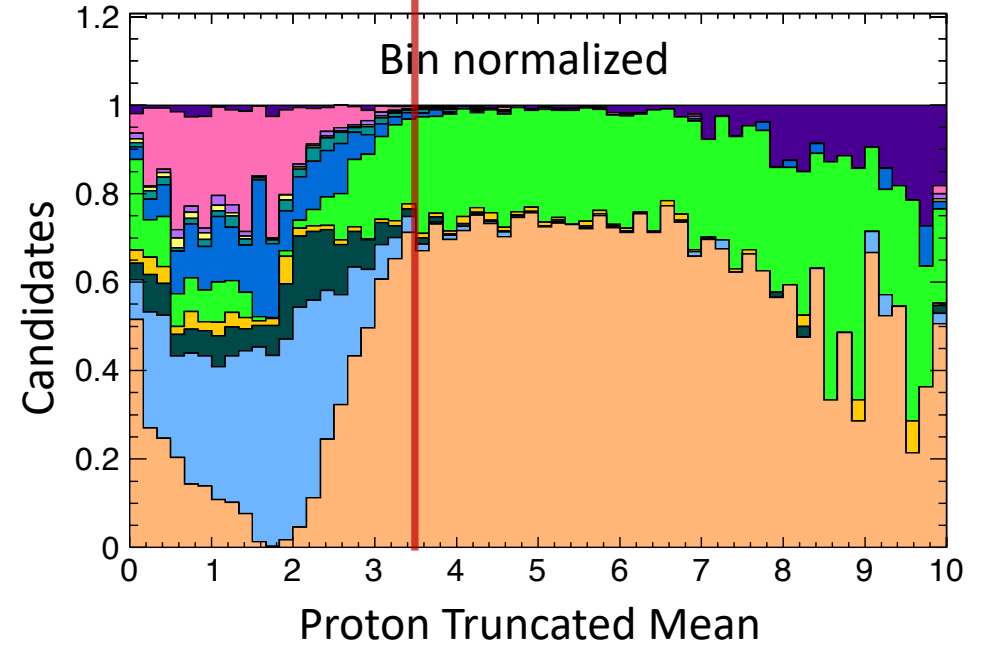
reco_daughter_allTrack_ID
 reco_daughter_PFP_trackScore_collection
 reco_daughter_PFP_nHits



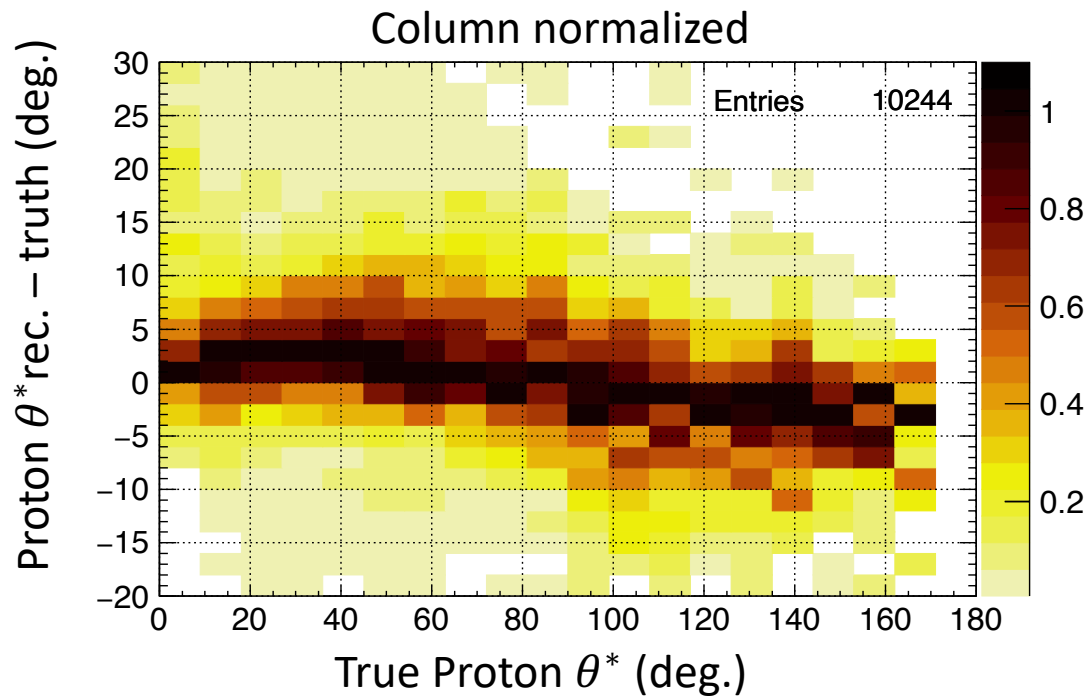
p/ π^+ Selection



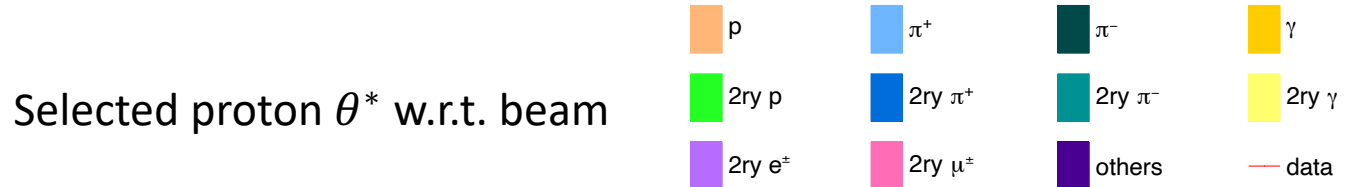
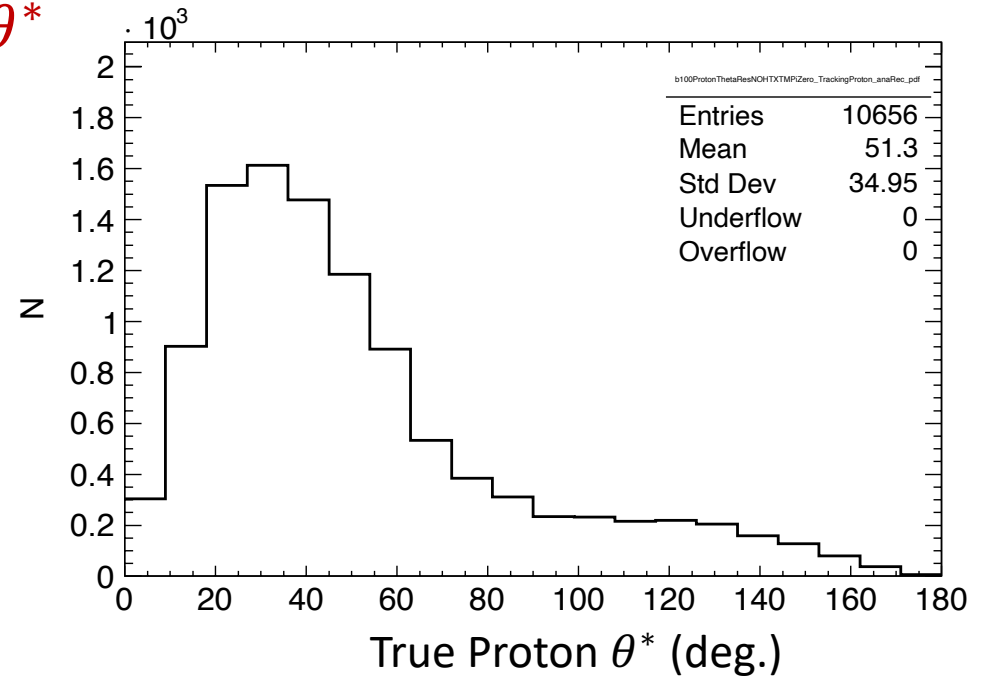
- Counted as a **proton** if :
 1. Counted as a track
 2. $\text{Chi2/NDF} < 50$ or $\text{TME} > 3.5$
- Counted as a **π^+** if :
 1. Counted as a track
 2. Not counted as a proton



```
reco_daughter_allTrack_Chi2_proton
reco_daughter_allTrack_Chi2_ndof
TME = GetTruncatedMean(lastEarray, 2, ndEdx-8, 0.05, 0.6)
```



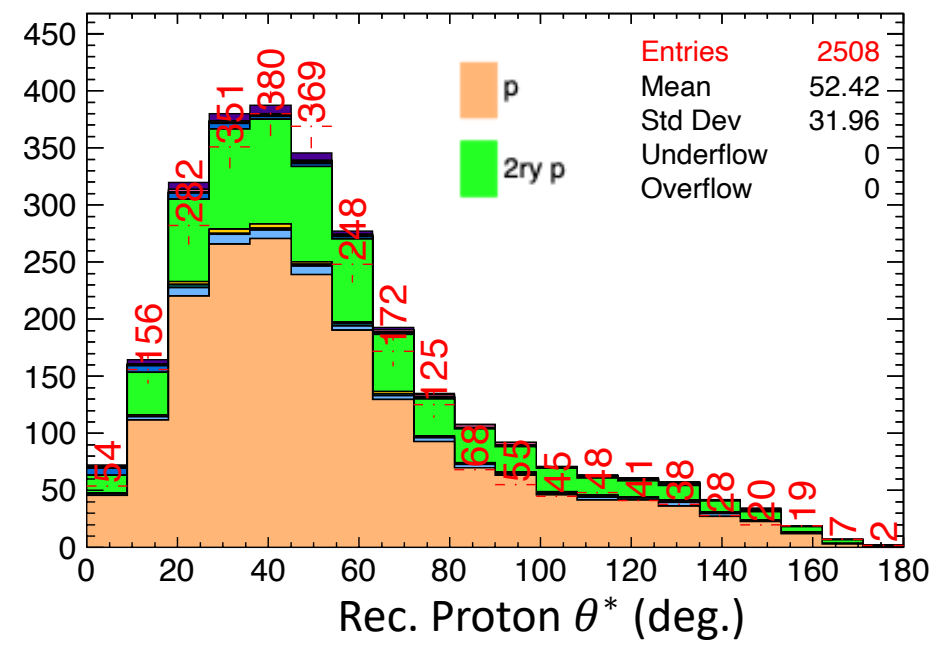
Proton θ^*

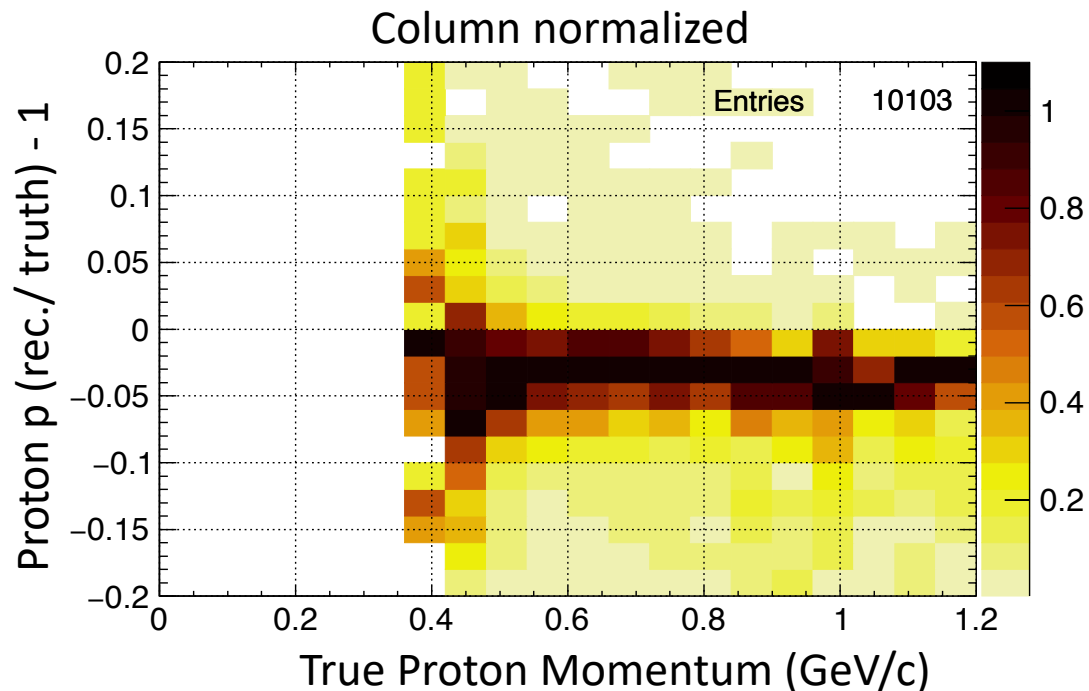


- Reconstruction: -3 to +4 deg. bias, resolution with a long tail.
- Data-MC are consistent.

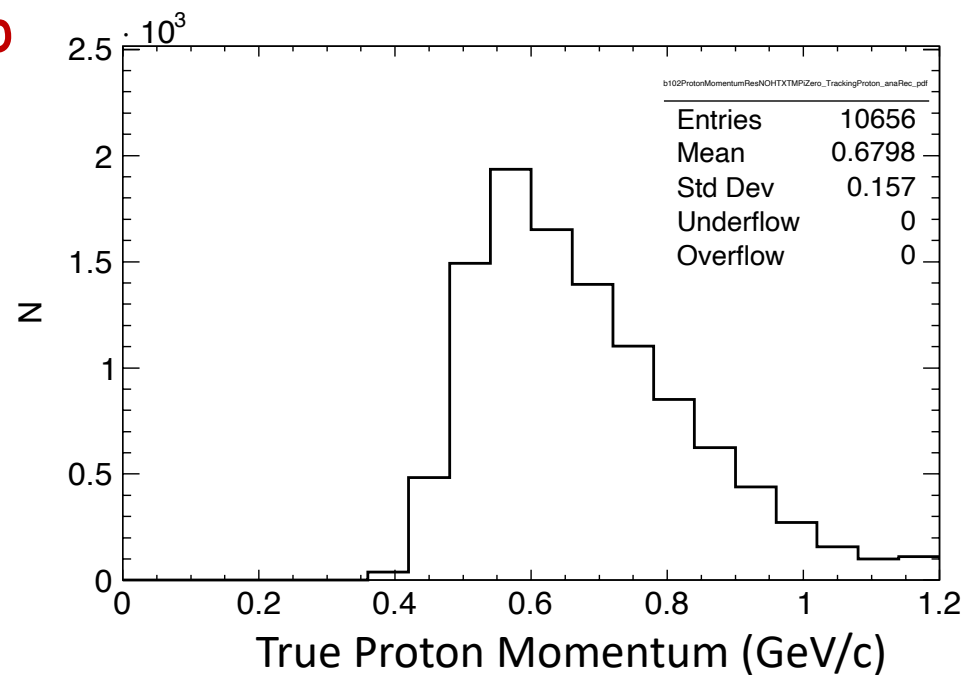
Contamination from 2ry protons

true_beam_daughter_startPx/y/z
 reco_daughter_allTrack_Theta/Phi/momByRange_proton
 *w.r.t. beam reco *





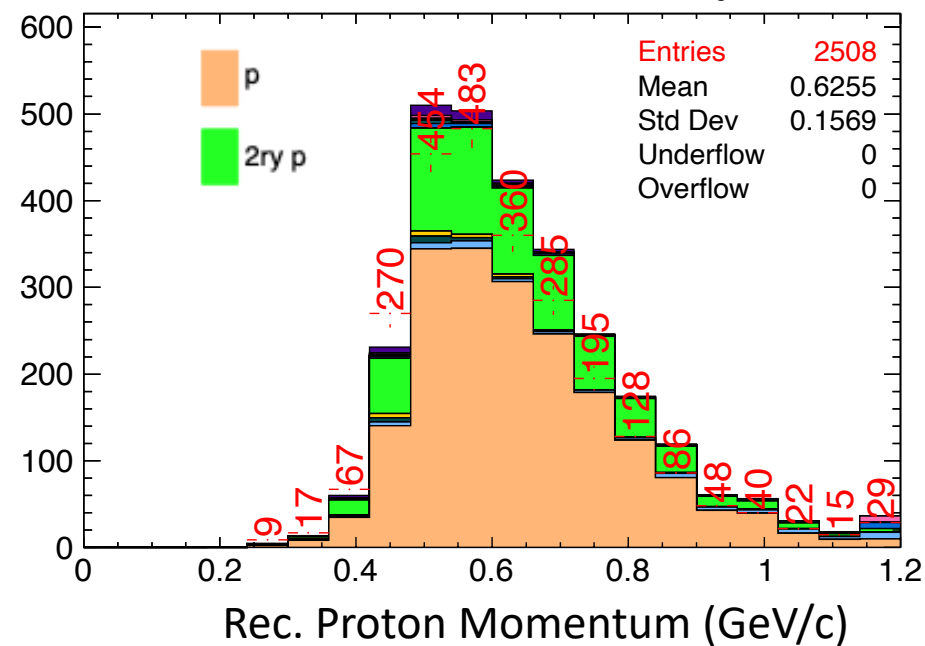
Proton p

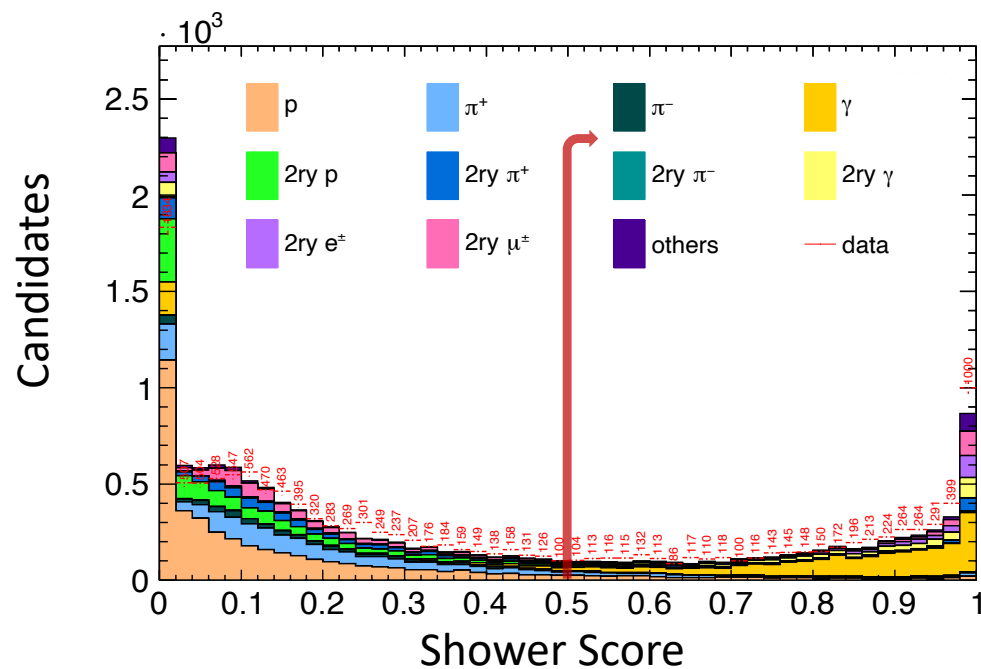


Selected proton momentum.

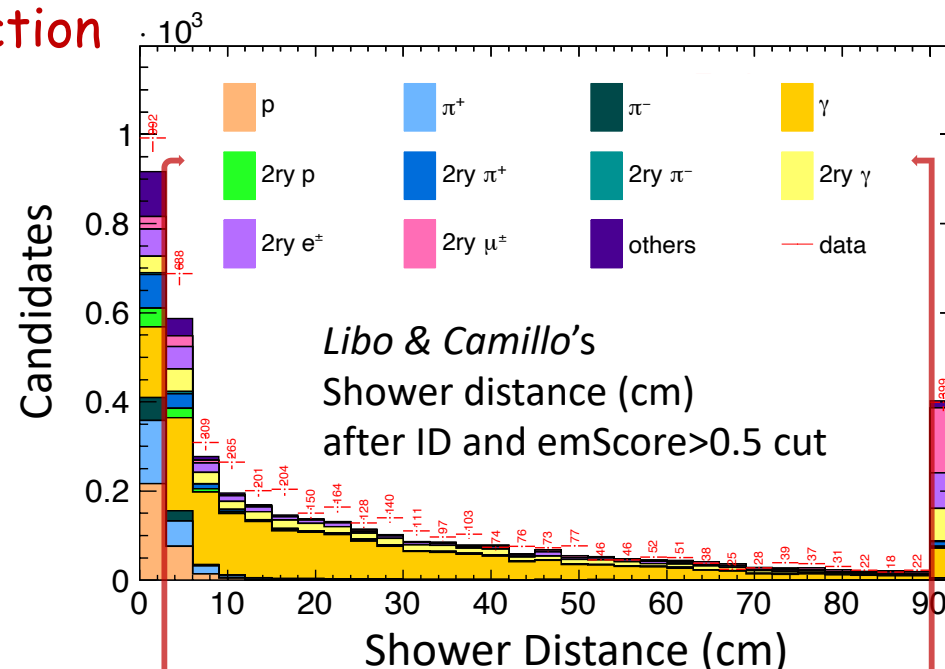
- Reconstruction: ~ -3% bias
- Data-MC are consistent.

Contamination from 2ry protons



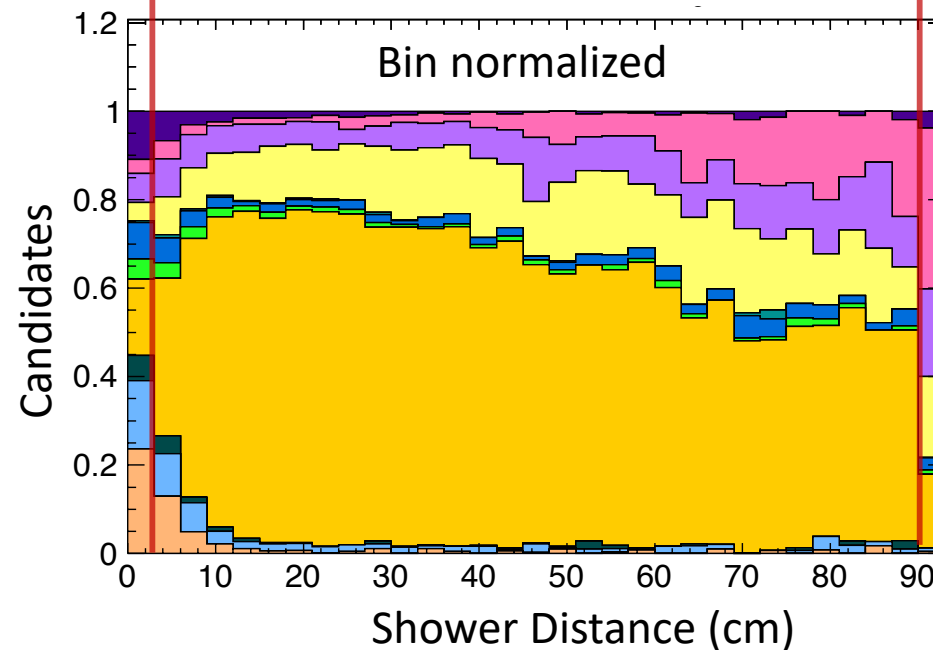


Shower Selection



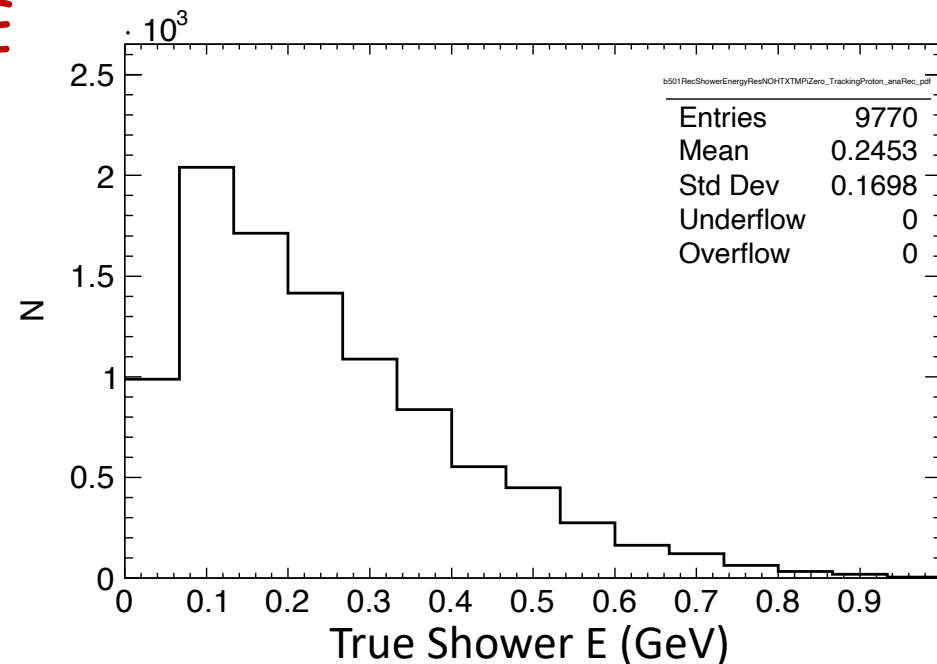
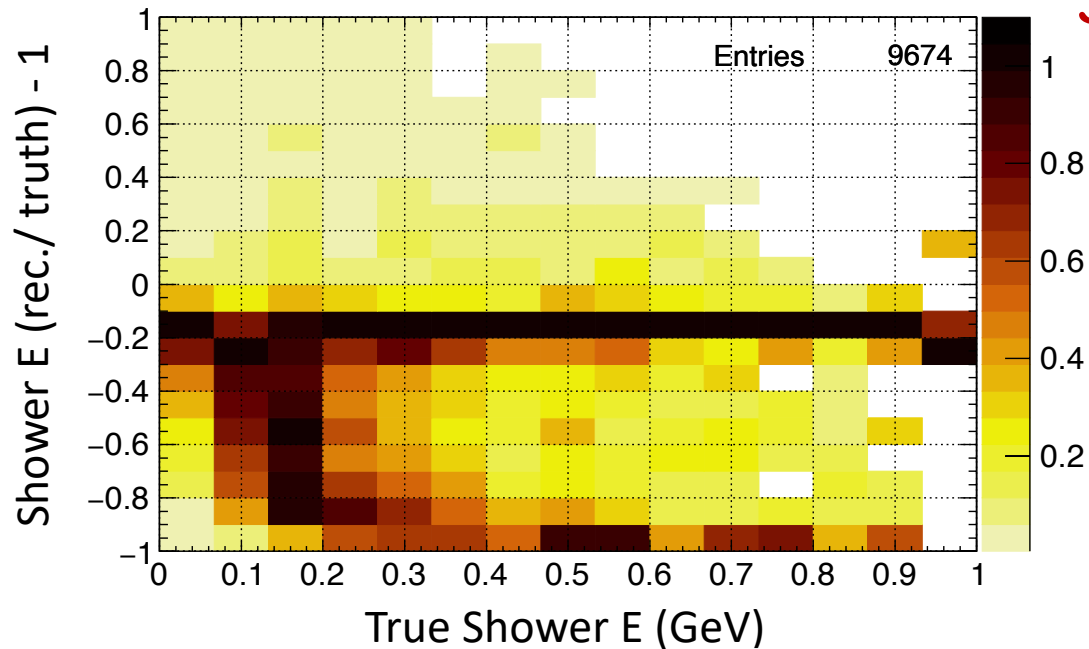
• Counted as an **EM track** if :

1. reco_daughter_allShower_ID != -1
2. ShowerScore > 0.5
3. shower distance is between 3-90 cm

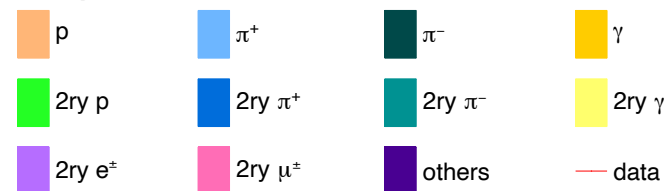


reco_daughter_allShower_ID
reco_daughter_PFP_emScore_collection

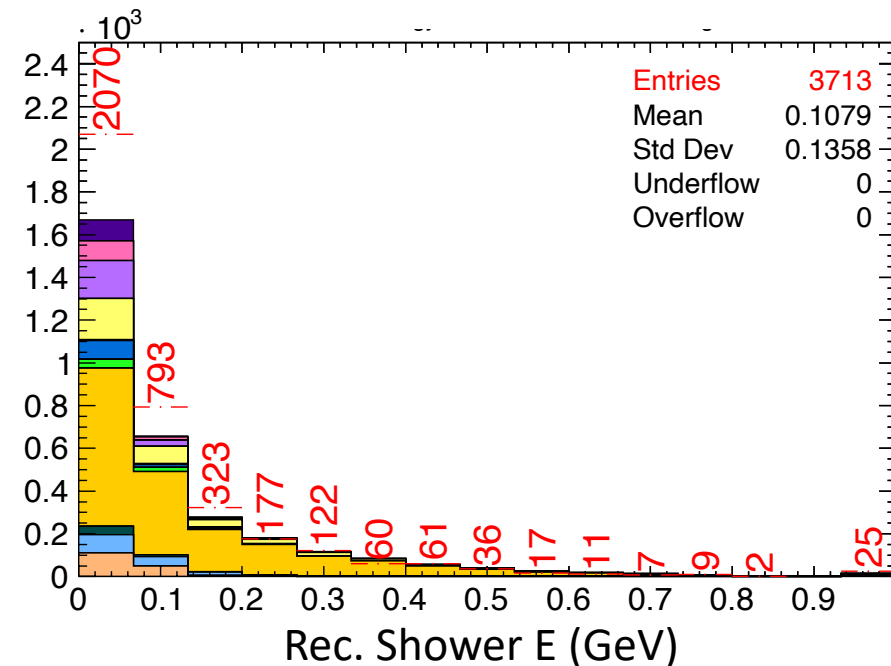
Shower E



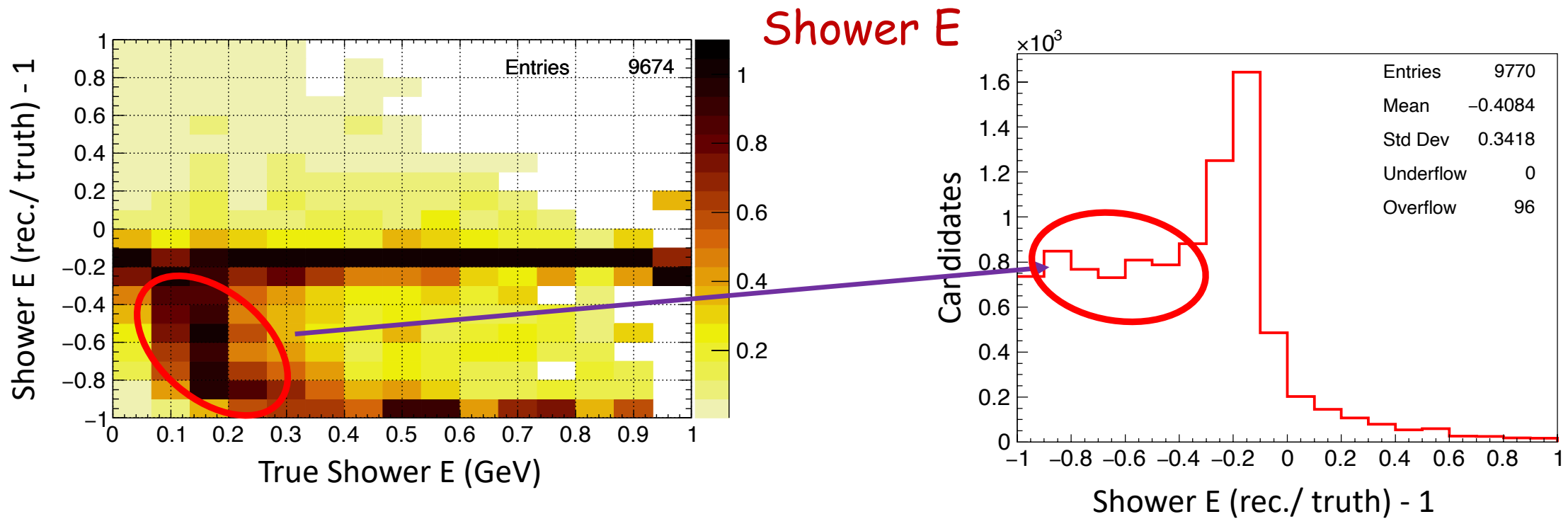
Selected shower Energy



- Rec. shower energy is always **less than** the true shower energy
- **Reconstruction: ~ - 20% bias, poor resolution around truth peak**
- **Data-MC discrepancy is found in first bin**



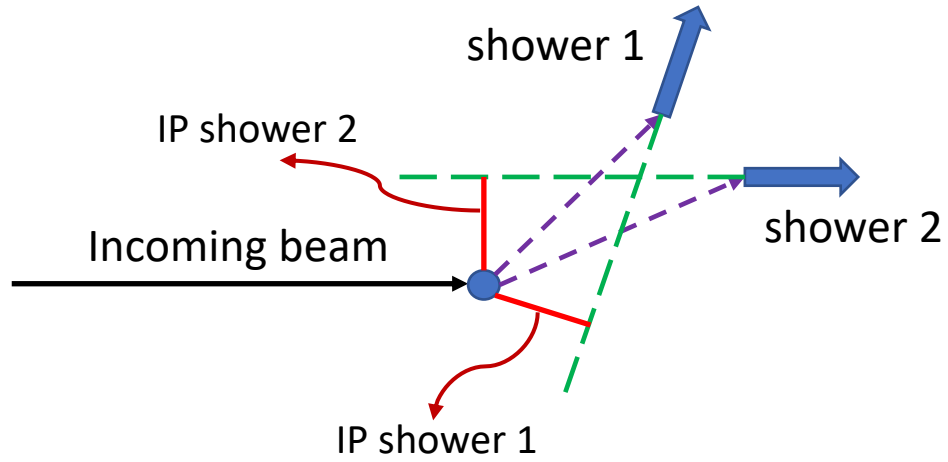
reco_daughter_allShower_dirX/Y/Z
 reco_daughter_allShower_energy – Shower candidates.
 reco_daughter_PFP_true_byHits_startPx/y/z



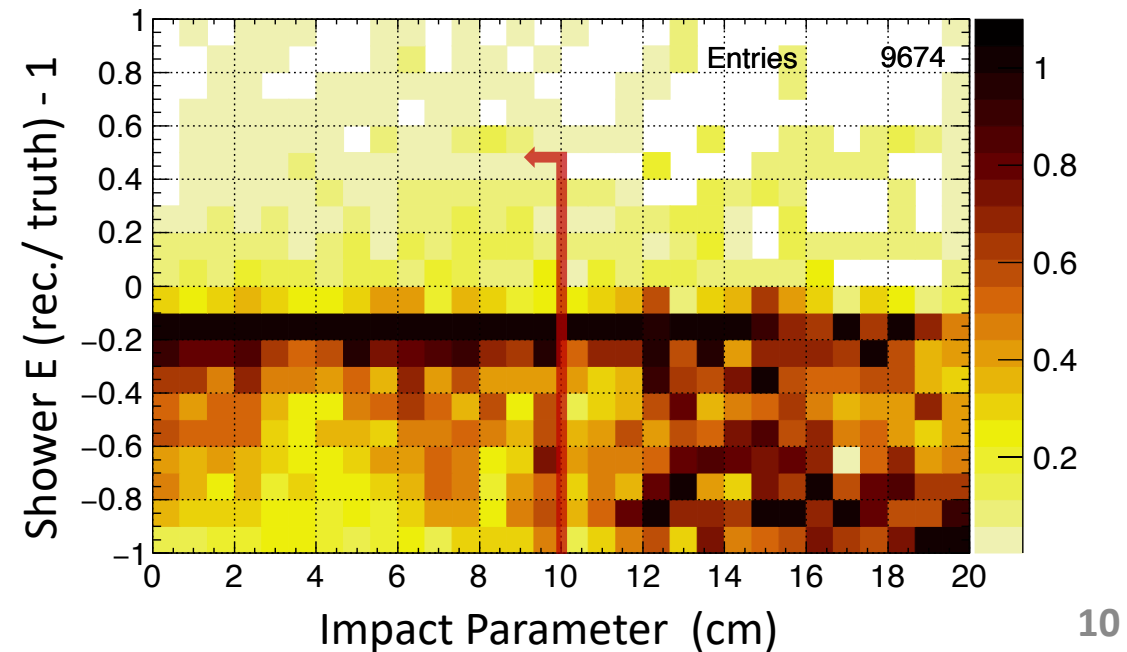
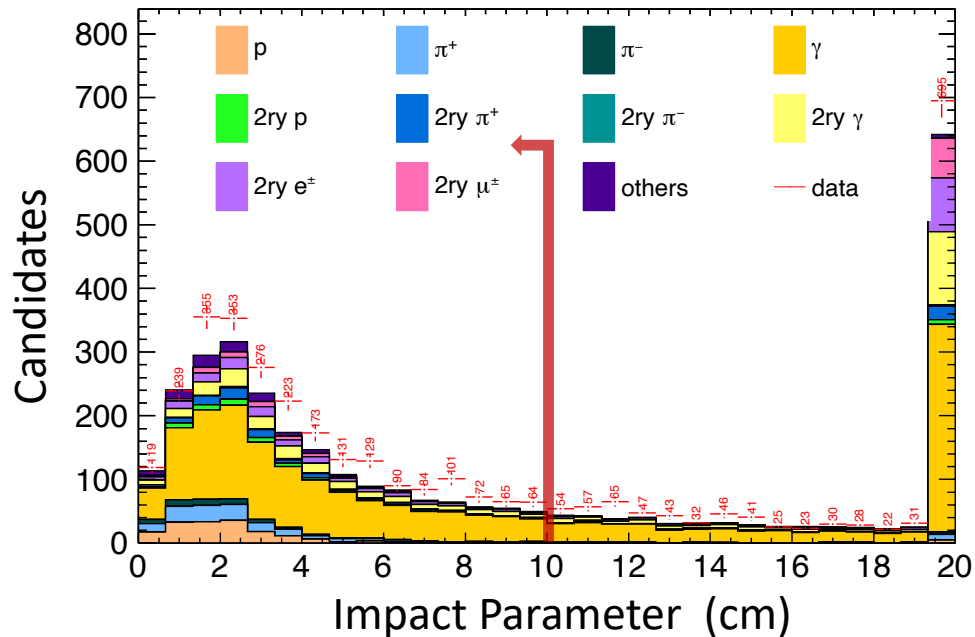
- The plot on the right is the 1D histogram for the shower E resolution.
- There are many shower candidates with very bad resolution as indicated by the red circle.
- Need to find a way to reduce this region using reconstructed objects.
- The easiest way is to use the hits purity and completeness, however these variables are not available in data.

Impact Parameter Cuts

Definition of IP:

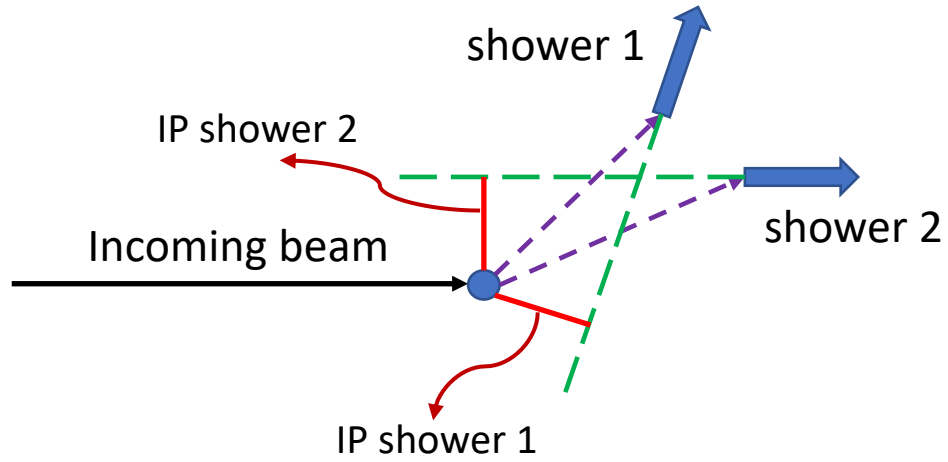


- A smaller impact parameter means the shower direction is more aligned with the pi0 direction.
- These showers usually have more energies due to Lorentz boost and easier to reconstruct.

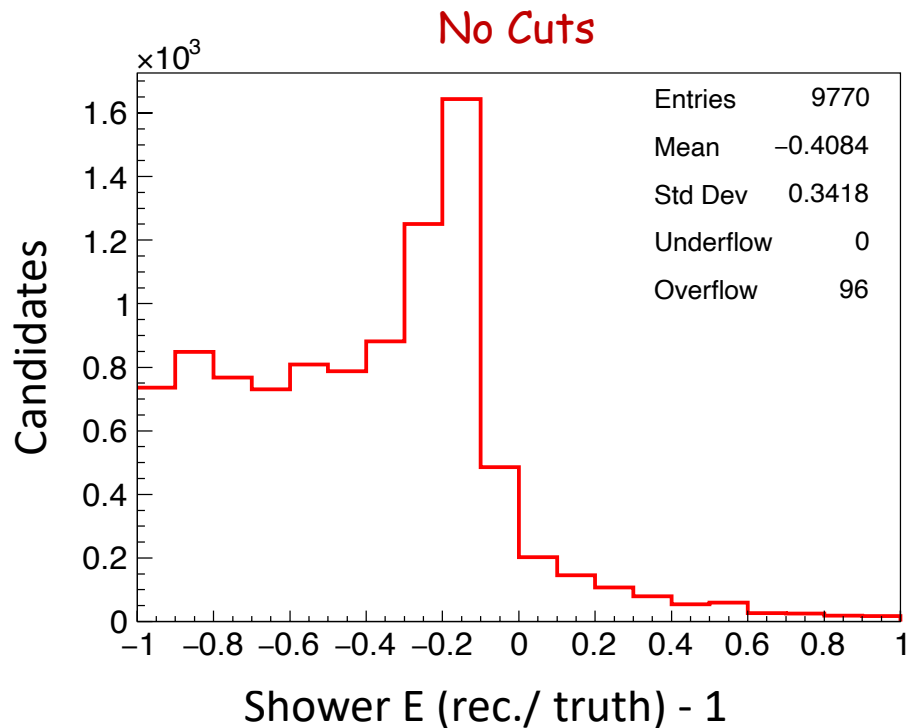


Impact Parameter Cuts

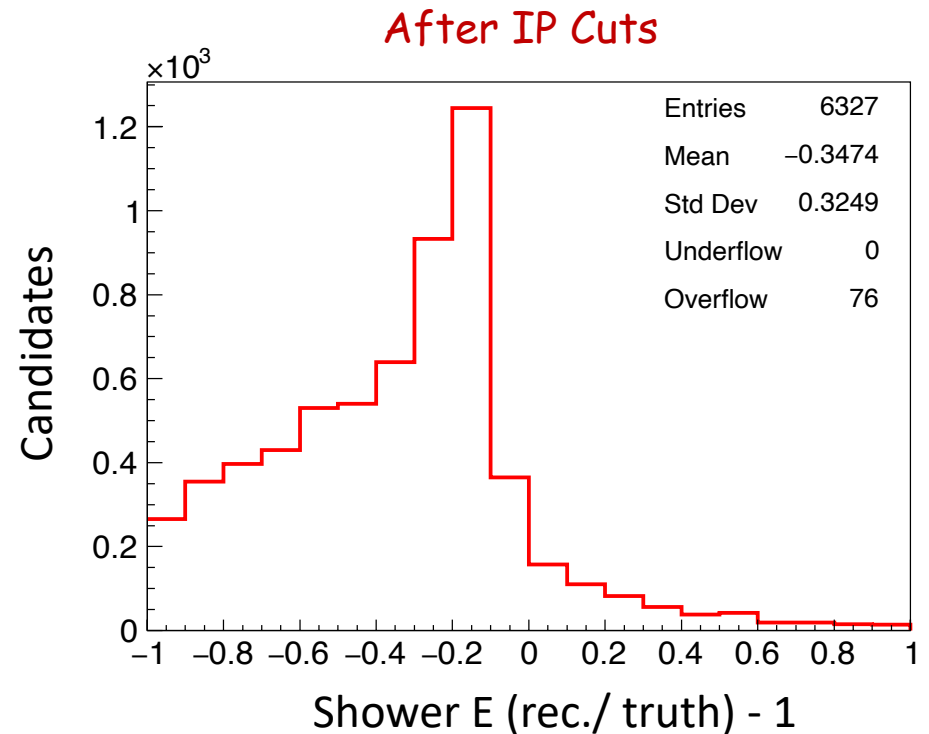
Definition of IP:



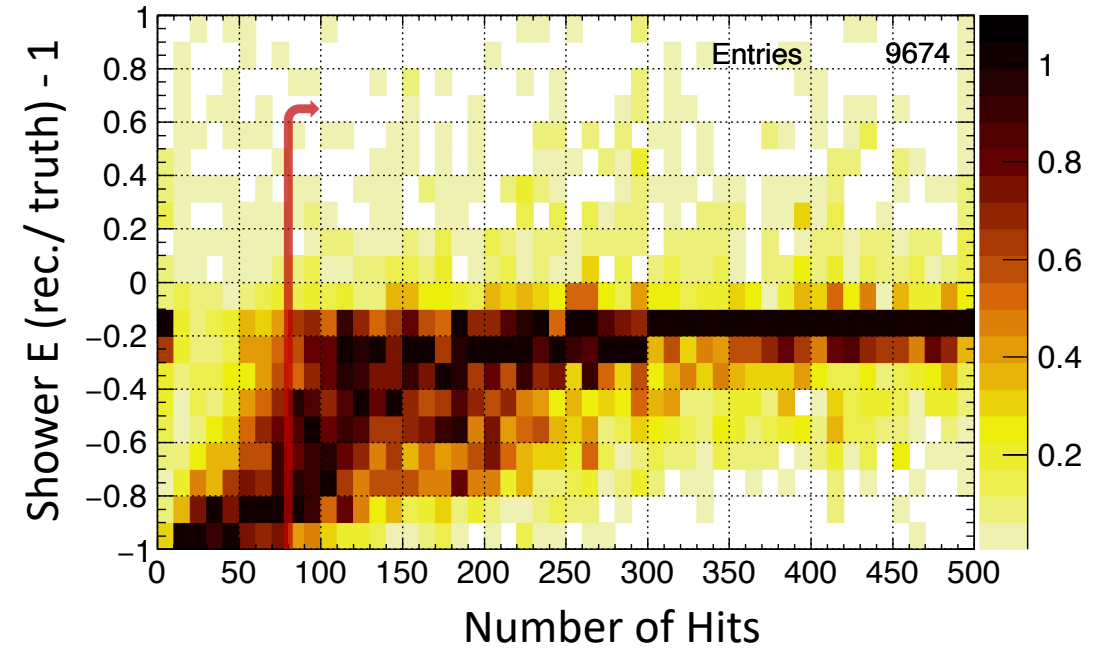
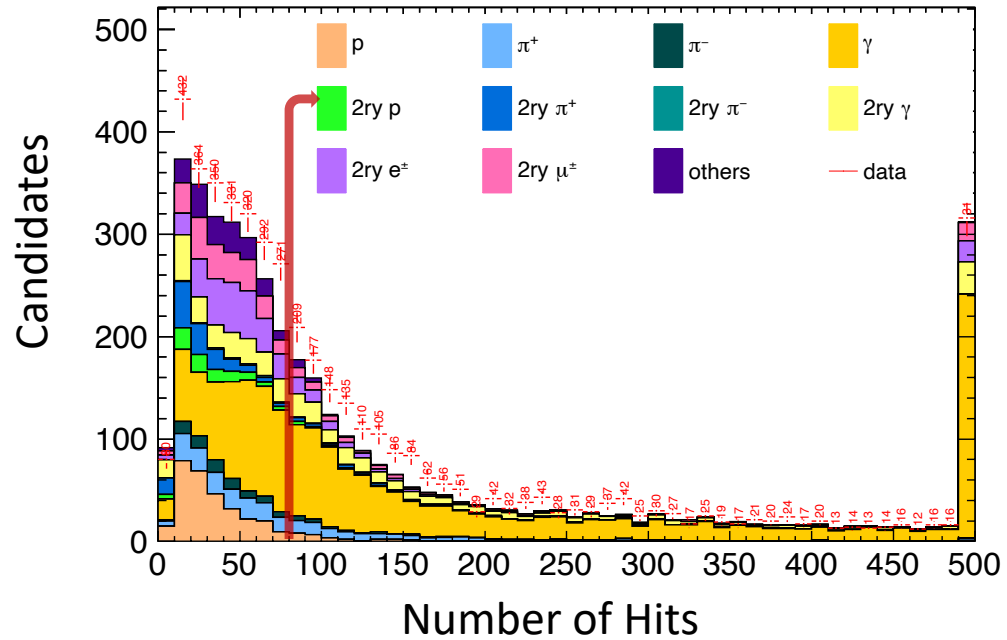
- A smaller impact parameter means the shower direction is more aligned with the pi0 direction.
- These showers usually have more energies due to Lorentz boost and easier to reconstruct.



IP < 10 cm

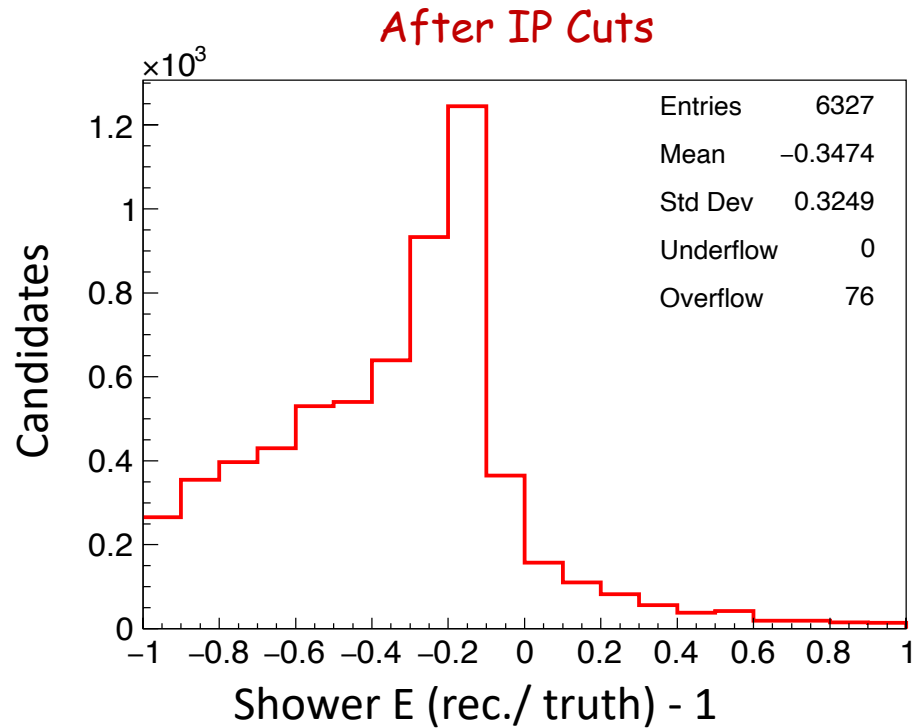


Number of Hits Cuts

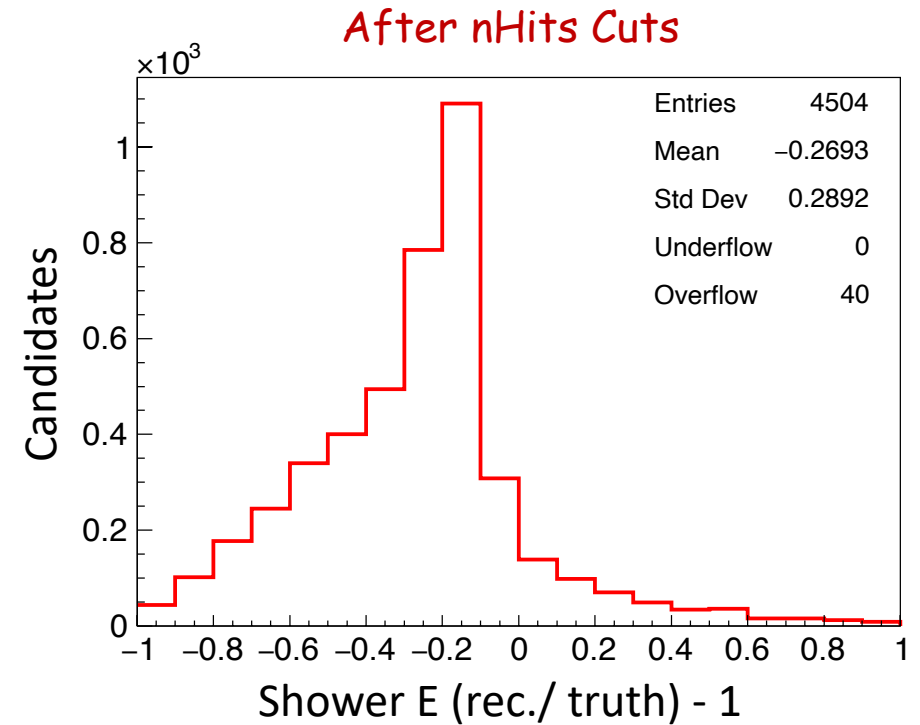


- The 2D plots on the right show the shower E resolution against the number of hits.
- Small number of hits usually corresponds to low completeness .
- Showers have number of hits **less than 80** are rejected to improve the resolution.

Number of Hits Cuts



nHits > 80



- Shower candidates with very bad resolution have been reduced a lot after the IP and hHits cuts.
- Now we have a negative bias about -20% in shower energy bias.
- These cuts also reduced our MC sample by 50%.

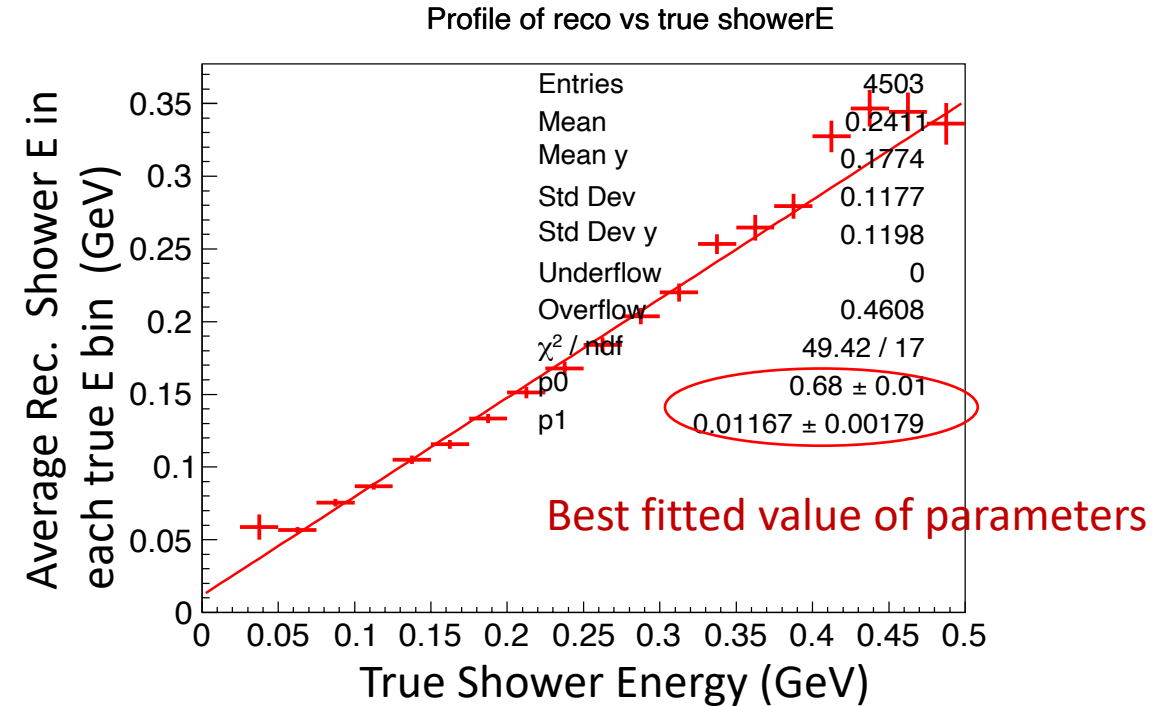
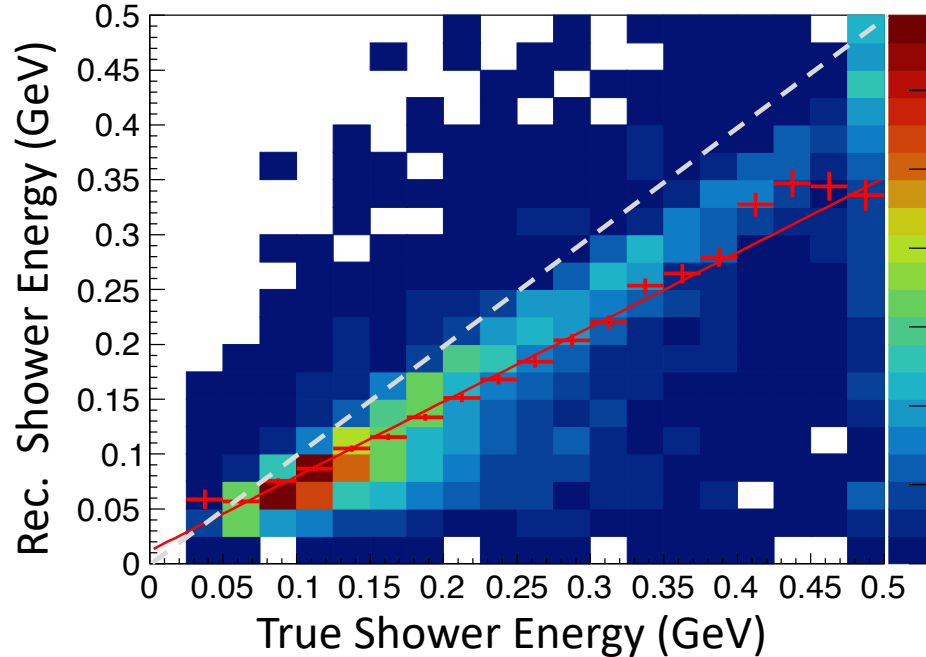
Shower Cuts Summary

- 1) Each shower candidate has an IP less than 10 cm.
- 2) Each shower candidates has at least 80 hits.
- 3) Leading shower energy E_{uncorr} larger than 50 MeV.
- 4) Two showers have an opening angle $> 20^\circ$ and $< 80^\circ$.

Now, I need to consider the energy loss due to the inefficiencies of the clustering methods.

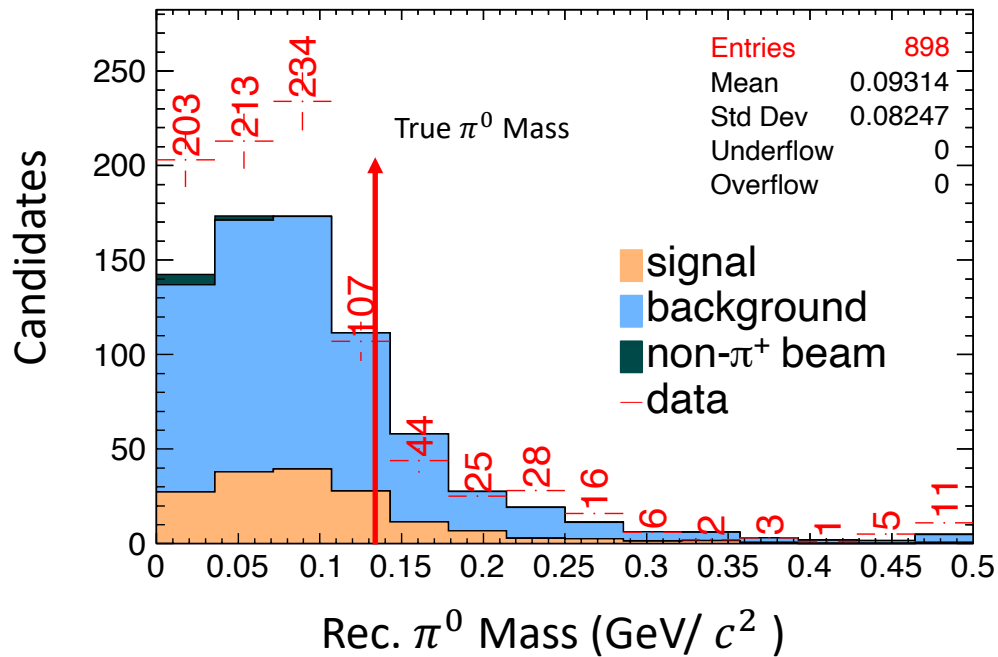
See my [previous talk](#) for last two cuts

Shower Energy Correction

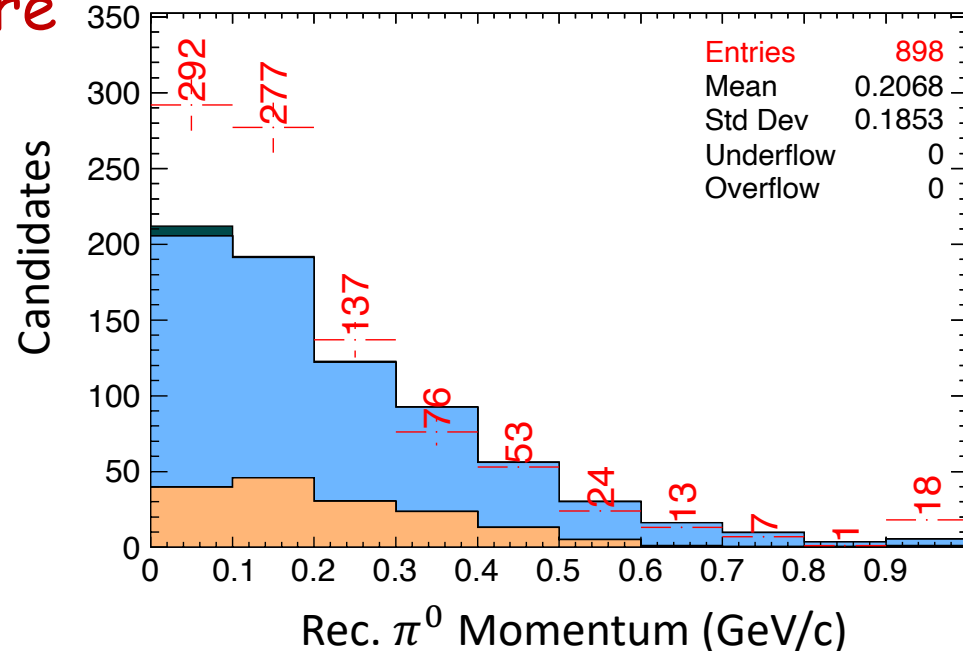


- The red line on top the 2D histogram is the profile histogram. This profile histogram plots the mean reconstructed shower energy in that bin of true shower energy with the uncertainty.
- The plot on the right is the best fit of the profile histogram using the assumption $E_{uncorr} = p_0 E_{corr} + p_1$

➔
$$E_{corr} = (E_{uncorr} - 0.01167) / 0.68$$

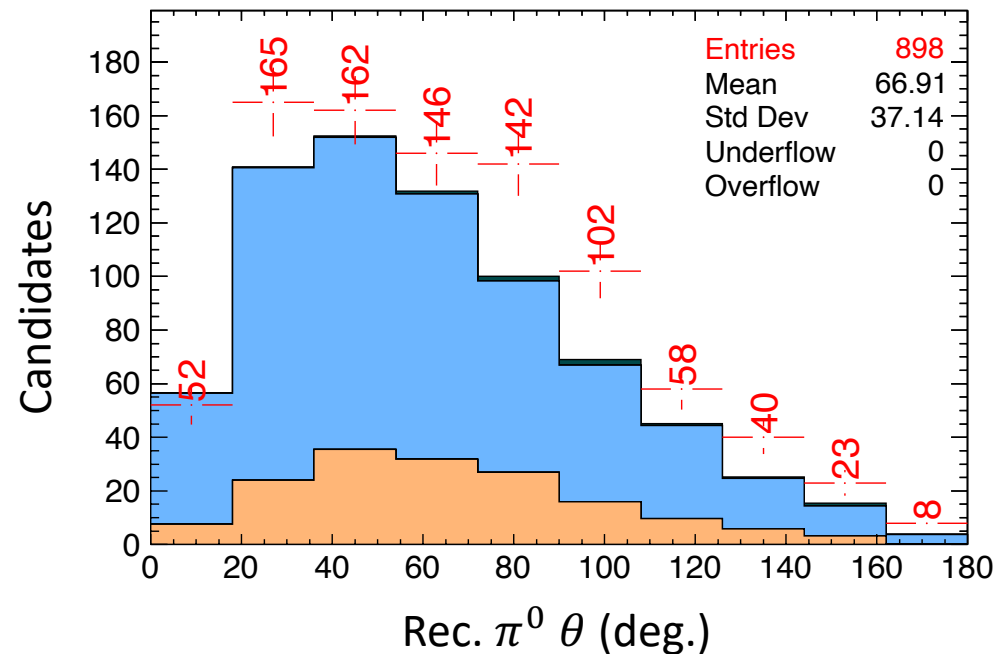


π^0 Before

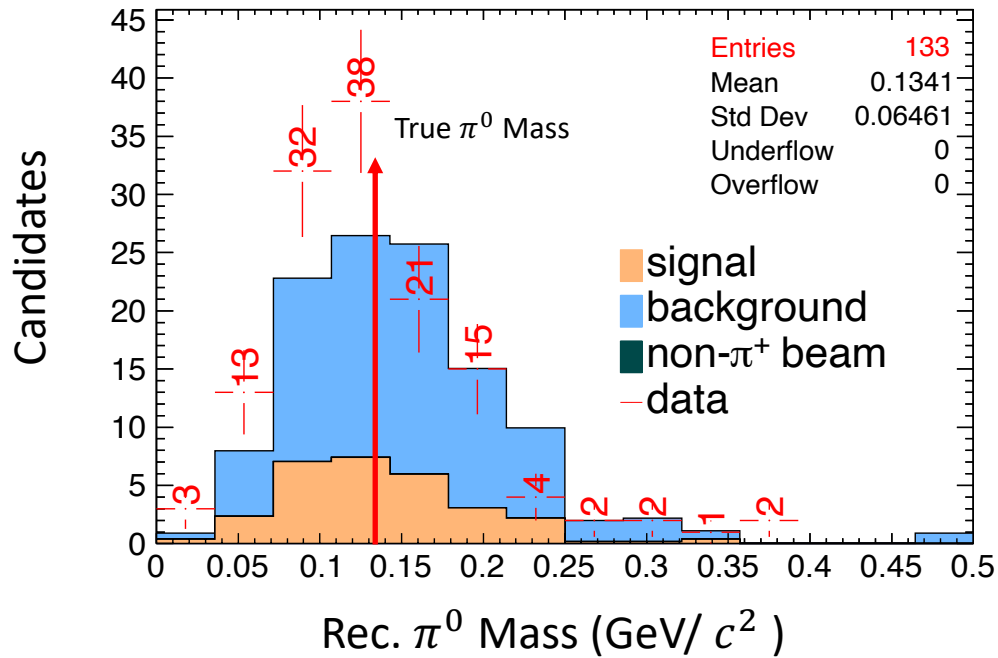


Reconstructed π^0 mass, momentum and theta

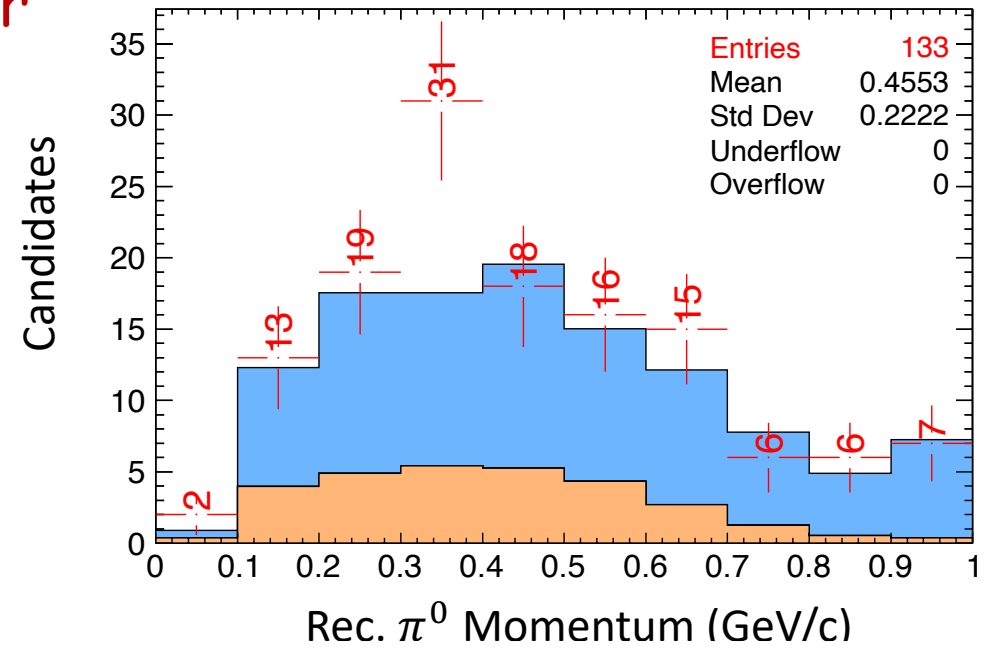
- π^0 mass is peaked in the wrong position
- There is a data-MC discrepancy for first few bins.



reco_daughter_allShower_dirX/Y/Z
 reco_daughter_allShower_energy

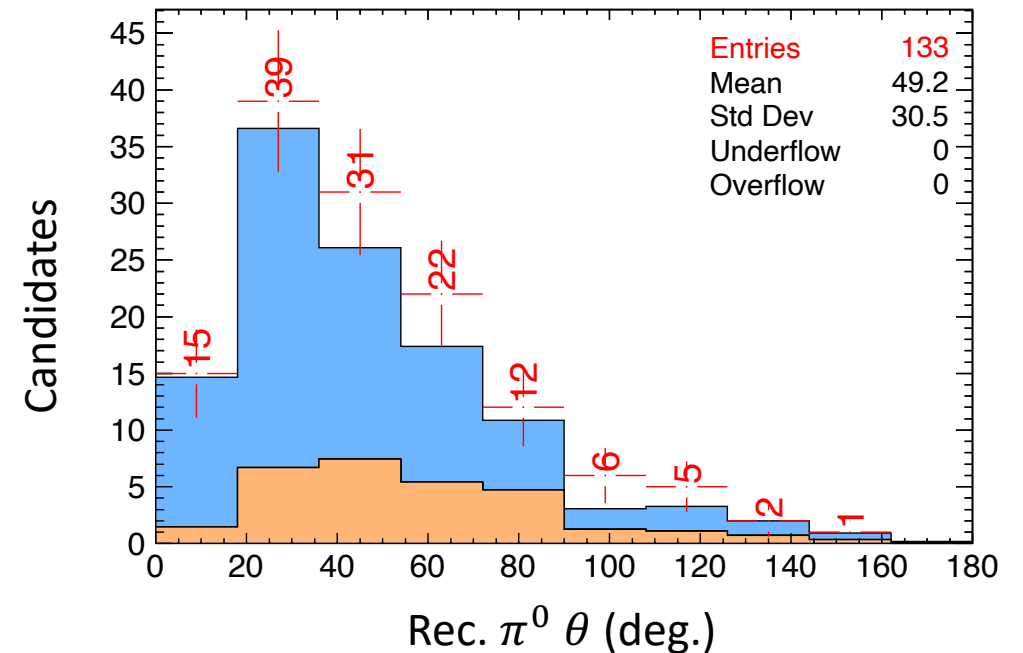


π^0 After



Reconstructed π^0 mass, momentum and theta

- π^0 mass is peaked around 0.134 with $\sigma = 0.065$
- However, there is a data-MC discrepancy around the mass peak.
- In general, the π^0 momentum and direction are good.



Summary and Discussions

Studied proton, shower and π^0 reconstruction:

1. Proton

- Proton angle (w.r.t. beam) and momentum reconstructions are okay.
- Has contaminations from the secondary protons but reduced after event selection.

2. Shower

- By applying 4 cuts on shower candidates, the reconstruction energy has been improved.
- From the truth-matching information, a correction $E_{corr} = (E_{uncorr} - 0.01167)/0.68$ is found from the inverse of the linear fit to the profile histogram.

3. Pion π^0

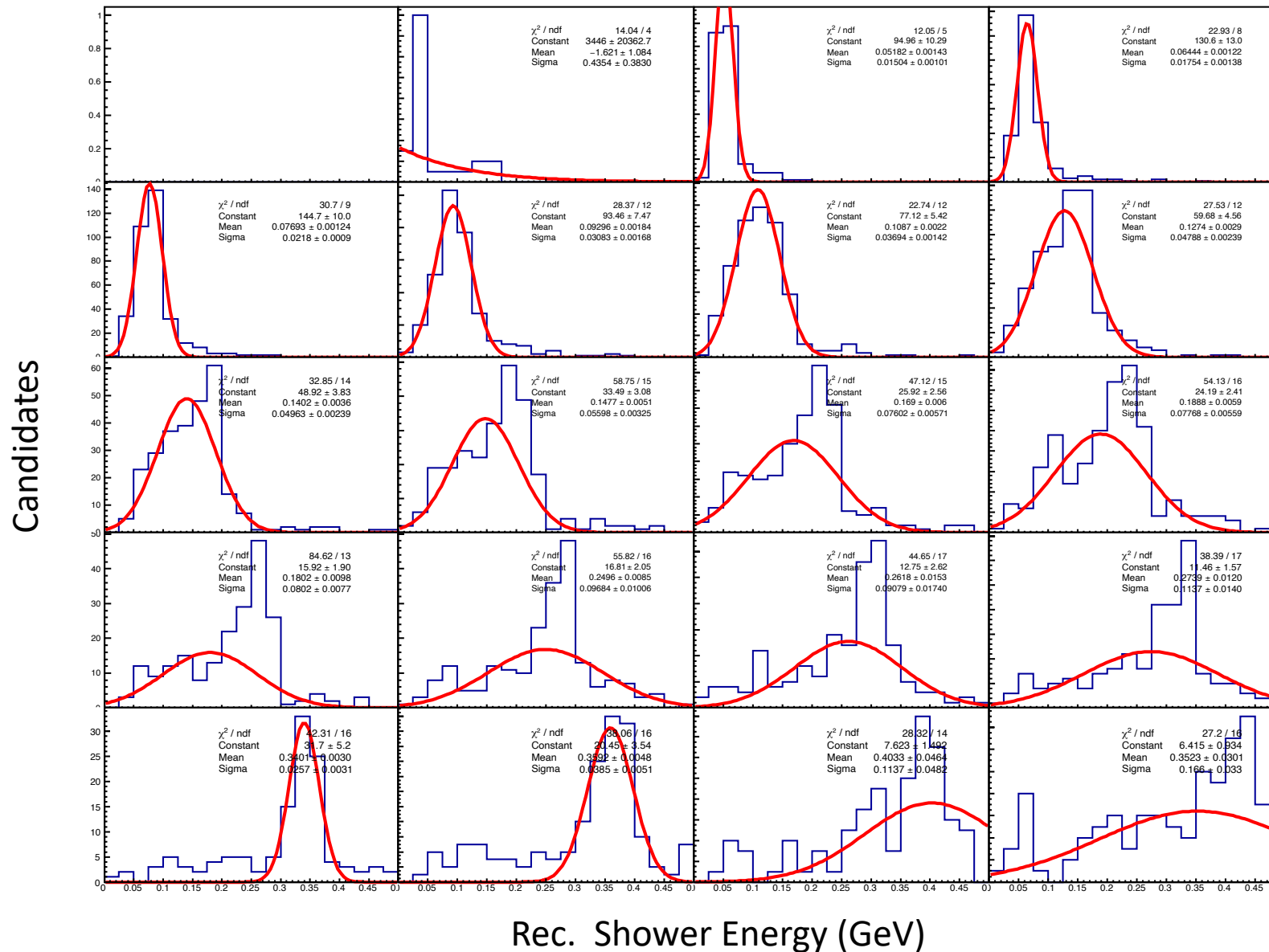
- Reconstructed π^0 mass has been improved with a mean value 0.134 with $\sigma = 0.065$
- There is a data-MC discrepancy around the mass peak.
- π^0 momentum and direction are good.

ToDOs:

- Instead of using the mean value of reco. Shower E, It's better to fit the reco. distribution for each true bin.
- Find out why there is a large data exceed in some π^0 reconstruction bins.
- Read the tech notes from Aaron Higuera (<https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=18355>) about the ProtoDUNE-SP Electron Analysis.

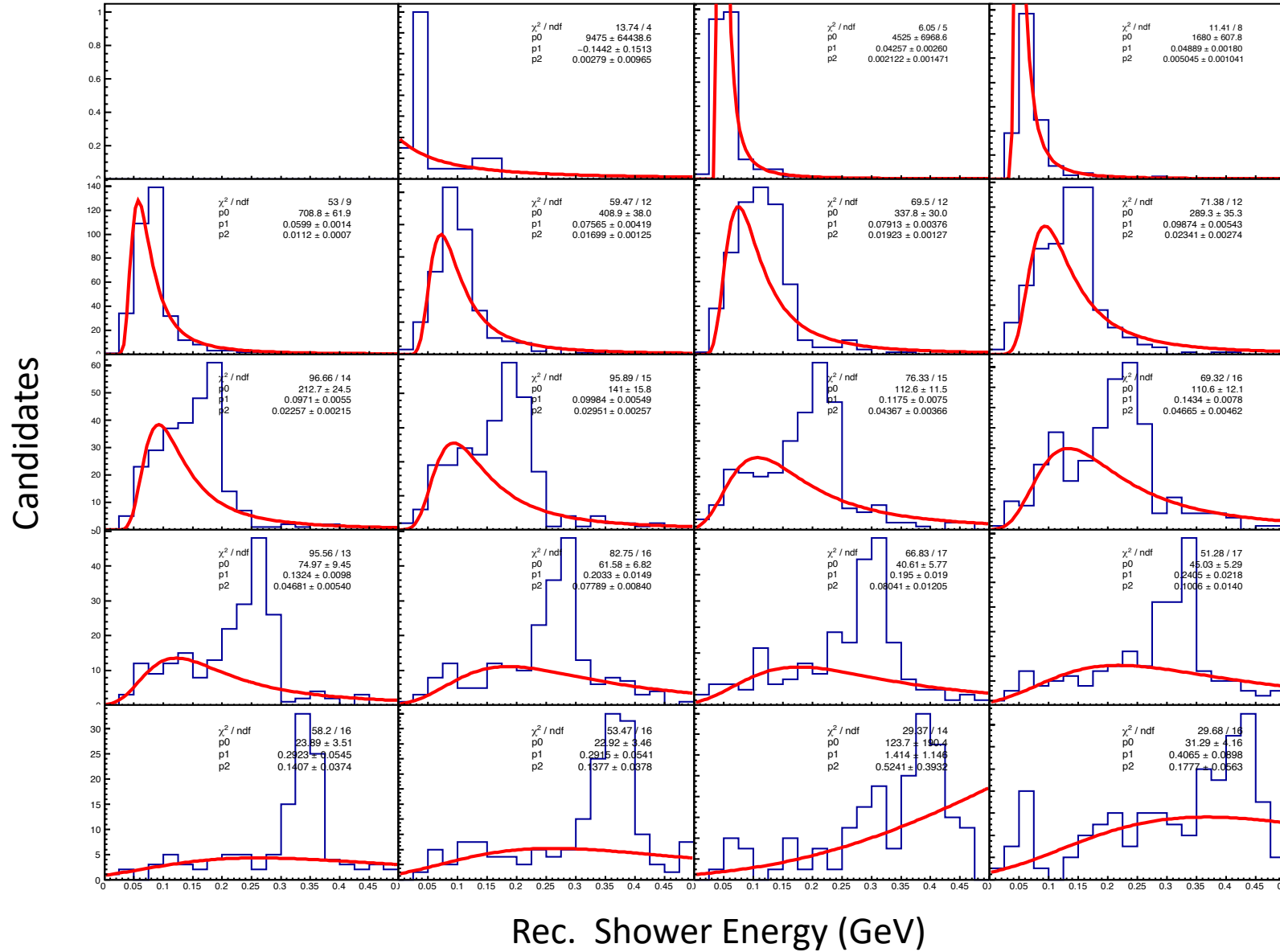
BACK UP

Gaussian Fit



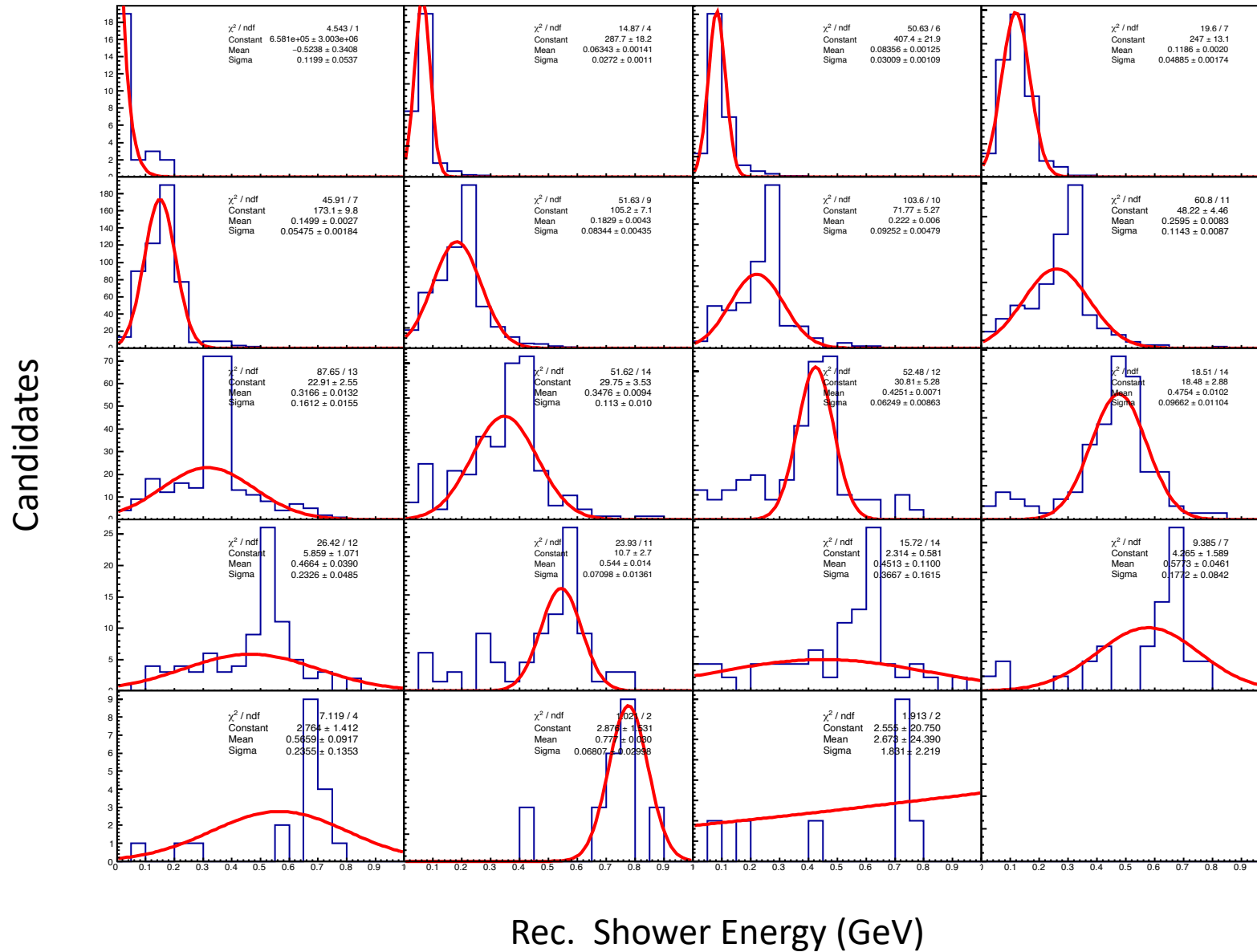
Each panel represent one bin in truth shower energy

Landau Fit



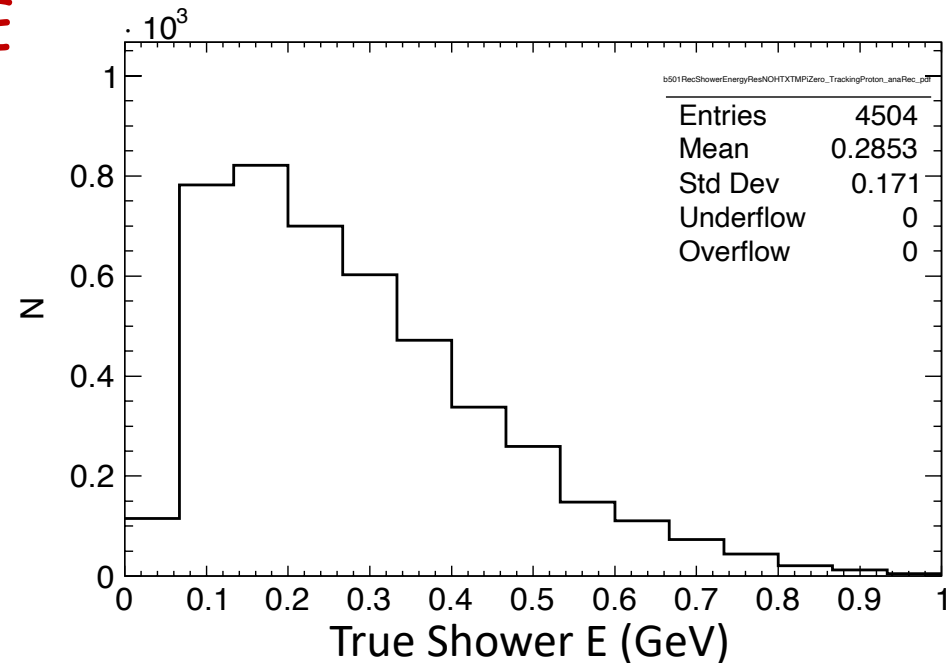
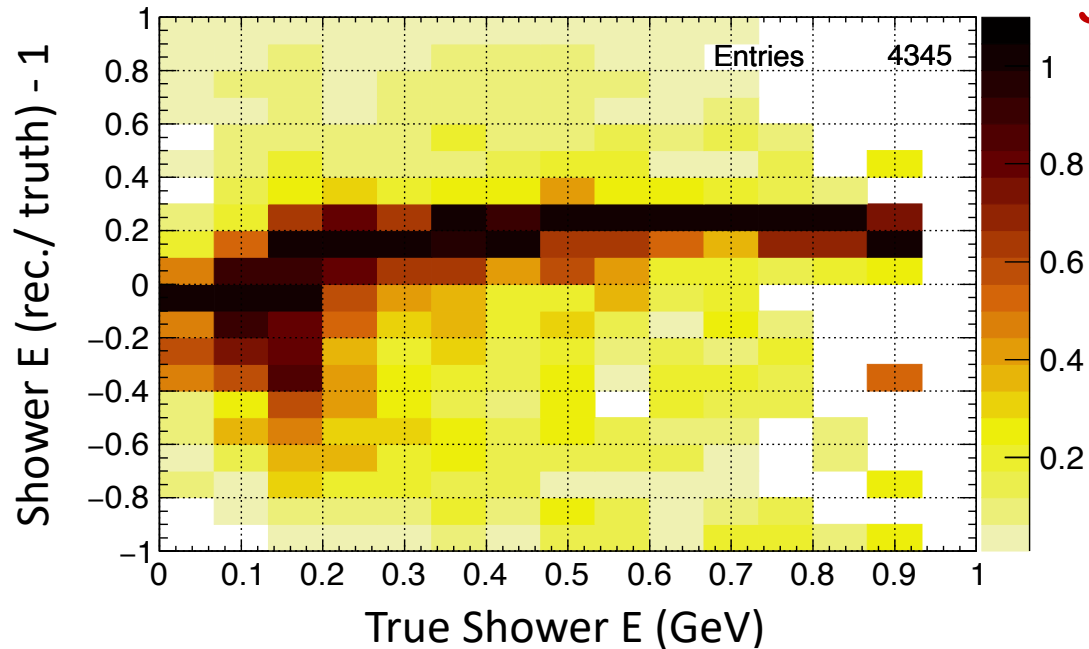
Each panel represent one bin in truth shower energy

Gaussian Fit (with extended x range)

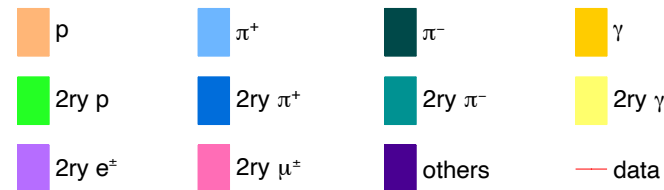


Each panel represent one bin in truth shower energy

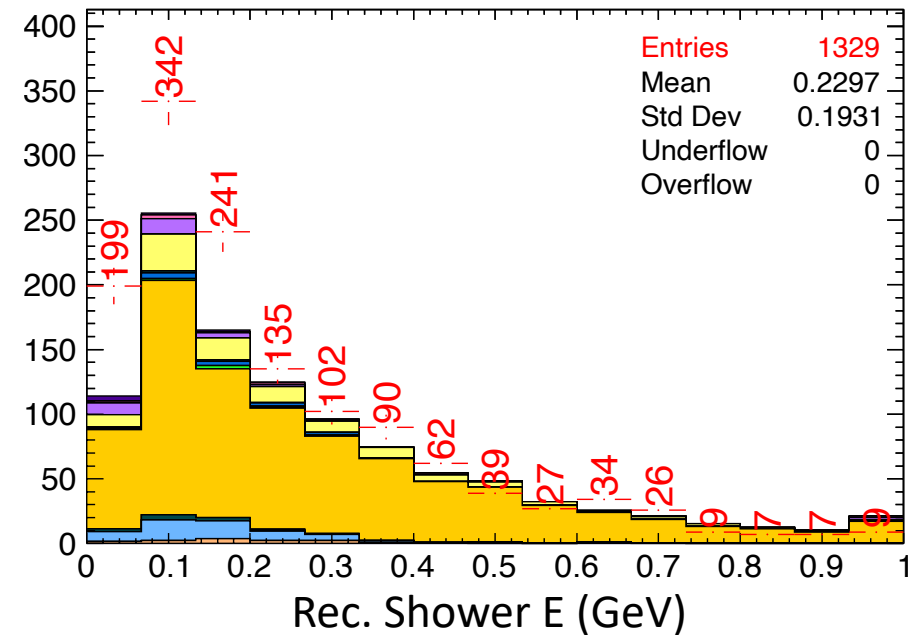
Shower E



Shower Energy after correction



- Reconstruction: $\sim +20\%$ bias for $E > 0.2$ GeV
- Data-MC discrepancy for energy less than 0.2 GeV



reco_daughter_allShower_dirX/Y/Z
 reco_daughter_allShower_energy
 reco_daughter_PFP_true_byHits_startPx/y/z

– Shower candidates.

