Neutral energy reconstruction via charged hadron correction in nHCal

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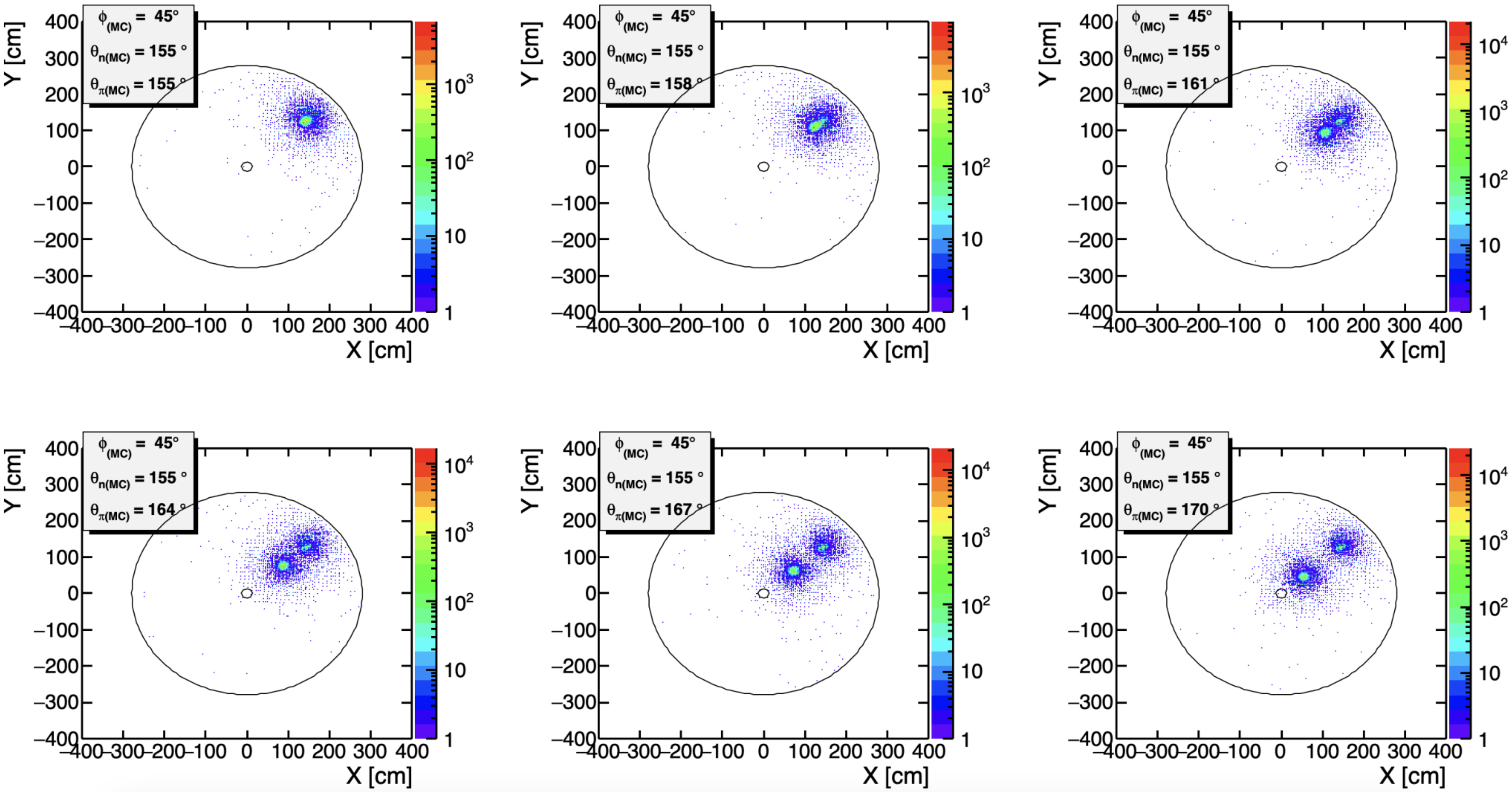
Setup

Objective ***:*** *Use clusters to distinguish between neutron/pion shower reconstruction.*

- ❑ (1 n + 1 π^-) / event. ---- *Standalone ddsim*
- ❑ φ = 45°
  - θ_n = 155° (η = -1.51) ------ *fixed*
  - θ_π = 155° (η = -1.51), 158° (η = -1.64), 161° (η = -1.79), 164° (η = -1.96), 167° (η = -2.17), 170° (η = -2.44)

- Only Backward HCal was taken into account [not the whole ePIC geometry – scattering effects neglected]
- $-4.14 < \eta < -1.18$
- Alternating Steel and Scintilator slices
- 10 cm. x 10 cm. Polystyrene tiles

Cluster Positions (xy coordinates)



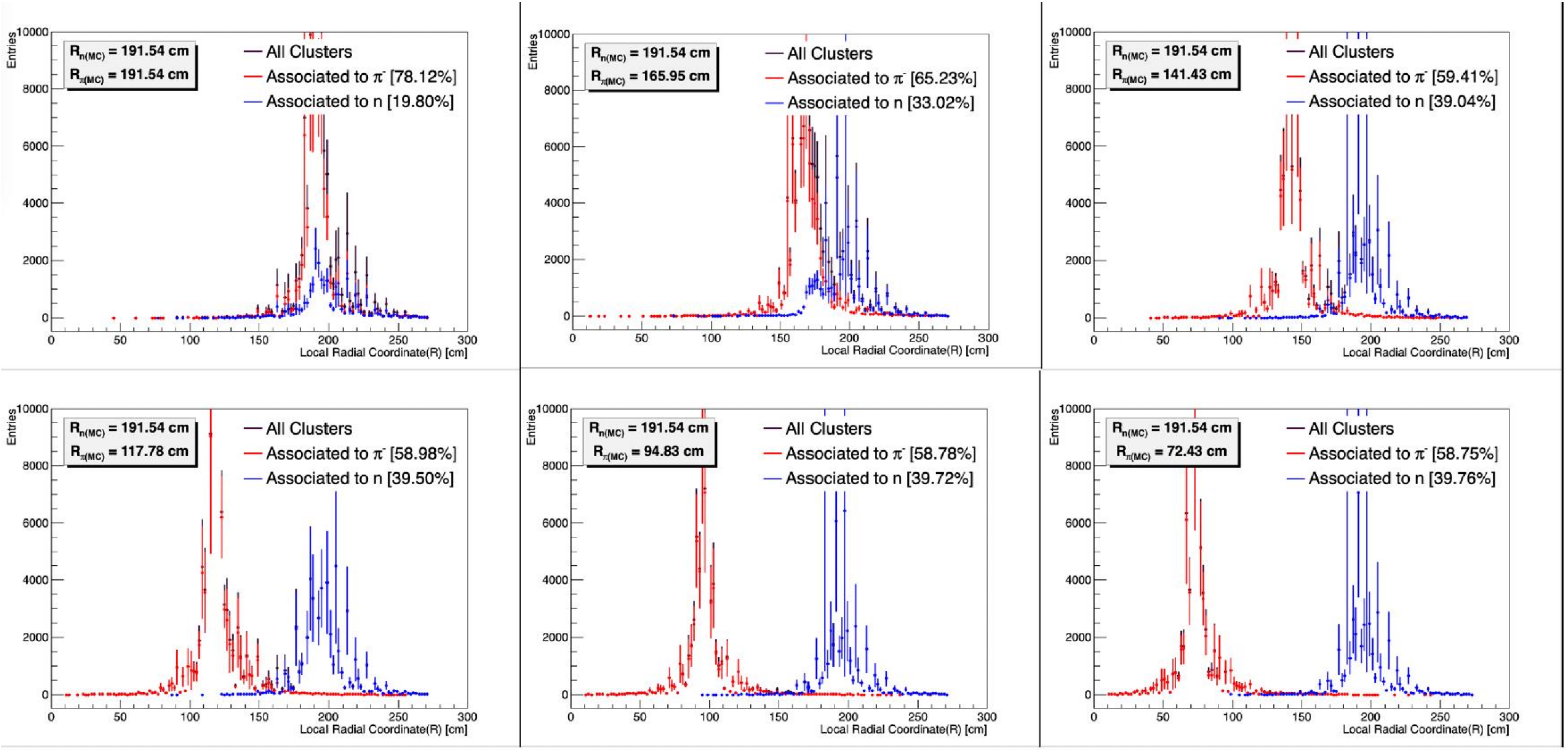
Cluster (x,y) are shown along with simulated angular coordinates

p = 1 GeV/c

[neutron showers in outer region; pion showers in inner region]

Distributions are becoming more distinguishable as (θ_{π} - θ_{n}) increases…

Cluster Radial Coordinates



p = 1 GeV/c

Percentages (fraction of clusters identified as π-/n clusters) are based on ClusterMCParticle associations

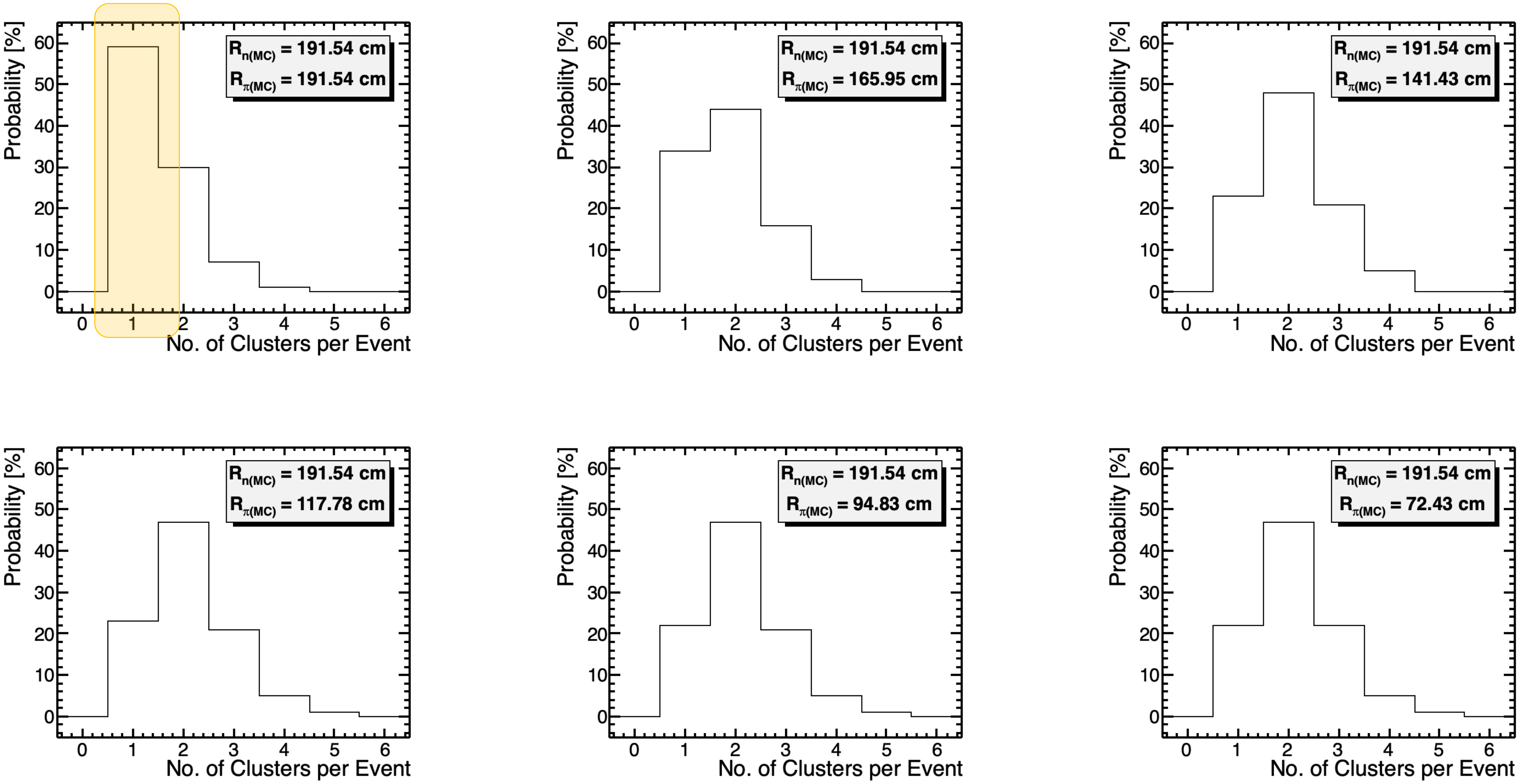
[better performance as the π-n distance increases]

Neutron clusters are “confused” to be pion clusters as the showers start to overlap.

π^- : n ≈ 60:40 when $\Delta R_{clusters} \geq 50.11$ cm

≈ 80:20 when $\Delta R_{clusters} = 0$ cm

Cluster Reconstruction



As the showers start to overlap, neutron hits are "hijacked" into pion clusters.

Clustering Correction (Neutral hadron detection)

- Tests of a particle flow algorithm with CALICE test beam data, 2011
  CALICE Collaboration (https://doi.org/10.1088/1748-0221/6/07/P07005)
- Particle flow calorimetry and the PandoraPFA algorithm, 2009
  M.A. Thomson (https://doi.org/10.1016/j.nima.2009.09.009)

The previous four stages of the PandoraPFA algorithm are found to perform well for jets with energy less than about 50 GeV. At higher energies the jet energy resolution degrades due to the increasing overlap between the hadronic showers from different particles. It is possible to detect such reconstruction failures by comparing the charged cluster energy, E_C, with the momentum of the associated track, p. A possible reconstruction failure is identified if $|(E_C - p)/\sigma_{E_C}| > \texttt{ChiToAttemptReclustering}$ [3.0]. In this case the PandoraPFA algorithm attempts to find a more self-consistent clustering of the calorimeter hits. If, for example, a 10 GeV track is associated with a 20 GeV calorimeter cluster, shown schematically in Fig. 5(a), a potential reconstruction failure is identified. One possible approach would be to simply remove hits from the cluster until the cluster energy matched the track momentum. However, this does not use the full information in the event. Instead, the clustering algorithm is modified iteratively

Not done in this study

https://www.hep.phy.cam.ac.uk/~thomson/pandoraPFA/

Charged Particle Correction

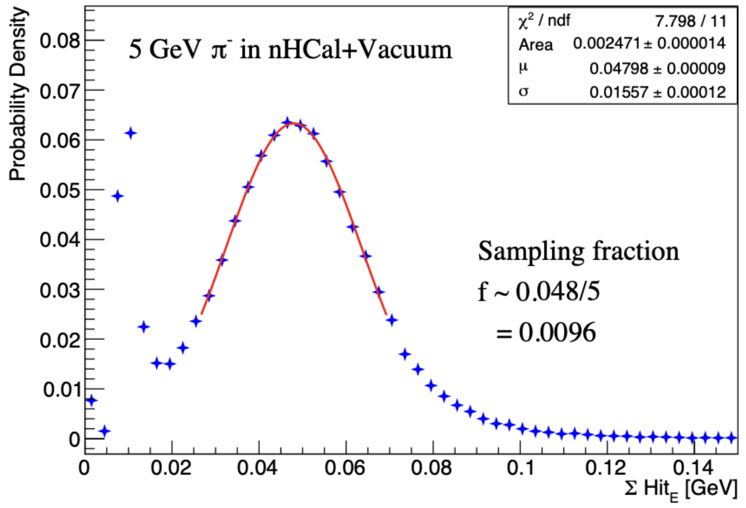
$$|(E_C - p)/\sigma_{E_C}| > \texttt{ChiToAttemptReclustering}\ [3.0].$$

Condition to determine possible reconstruction failure and make charged particle correction

E_c = Energy of the cluster that is matched to a track

p = Momentum obtained from tracking

σ_{E_c} = uncertainty on the cluster energy due to hadronic nature of energy deposition



Charged Particle Correction

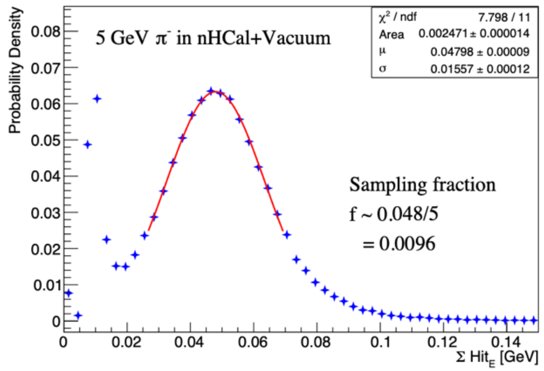
$$|(E_C - p)/\sigma_{E_C}| > \texttt{ChiToAttemptReclustering}\ [3.0].$$

E_c = Energy of the cluster that is matched to a track → Energy of Pion Cluster based on ClusterMCParticleAssociation

p = Momentum obtained from tracking → Momentum of generated Pion

σ_{E_c} = uncertainty on the cluster energy due to hadronic nature of energy deposition →

$$\sigma_{E_c} = \frac{\sigma f_p}{f_{EICrecon}} E_c$$



Uncertainty in sampling fraction (f) depending on the momentum (p) of the track

Charged Particle Correction

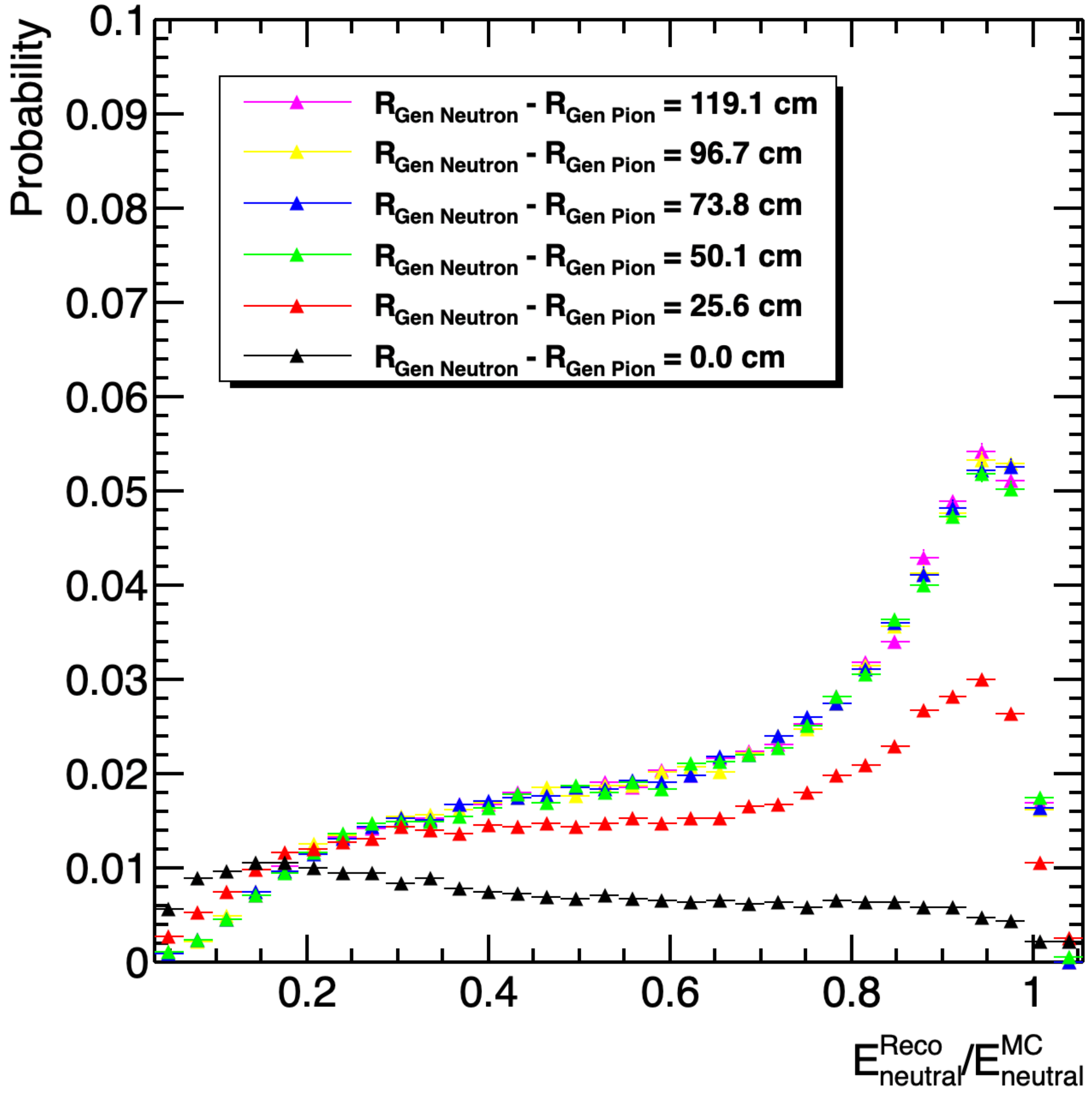
If $|(E_C - p)/\sigma_{E_C}| >$ `ChiToAttemptReclustering` [3.0].

$$E^{Reco}_{neutral} = E^{Reco}_{total} - p$$

Energy hijacking (aka “confusion”) was involved

Else, $E^{Reco}_{neutral} = E^{Reco}_{total} - E^{Reco}_{charged}$

Charged Particle Correction



When, $|(E^{Reco}_{charged} - p)/\sigma_{E^{Reco}_{charged}}| > 3.0$

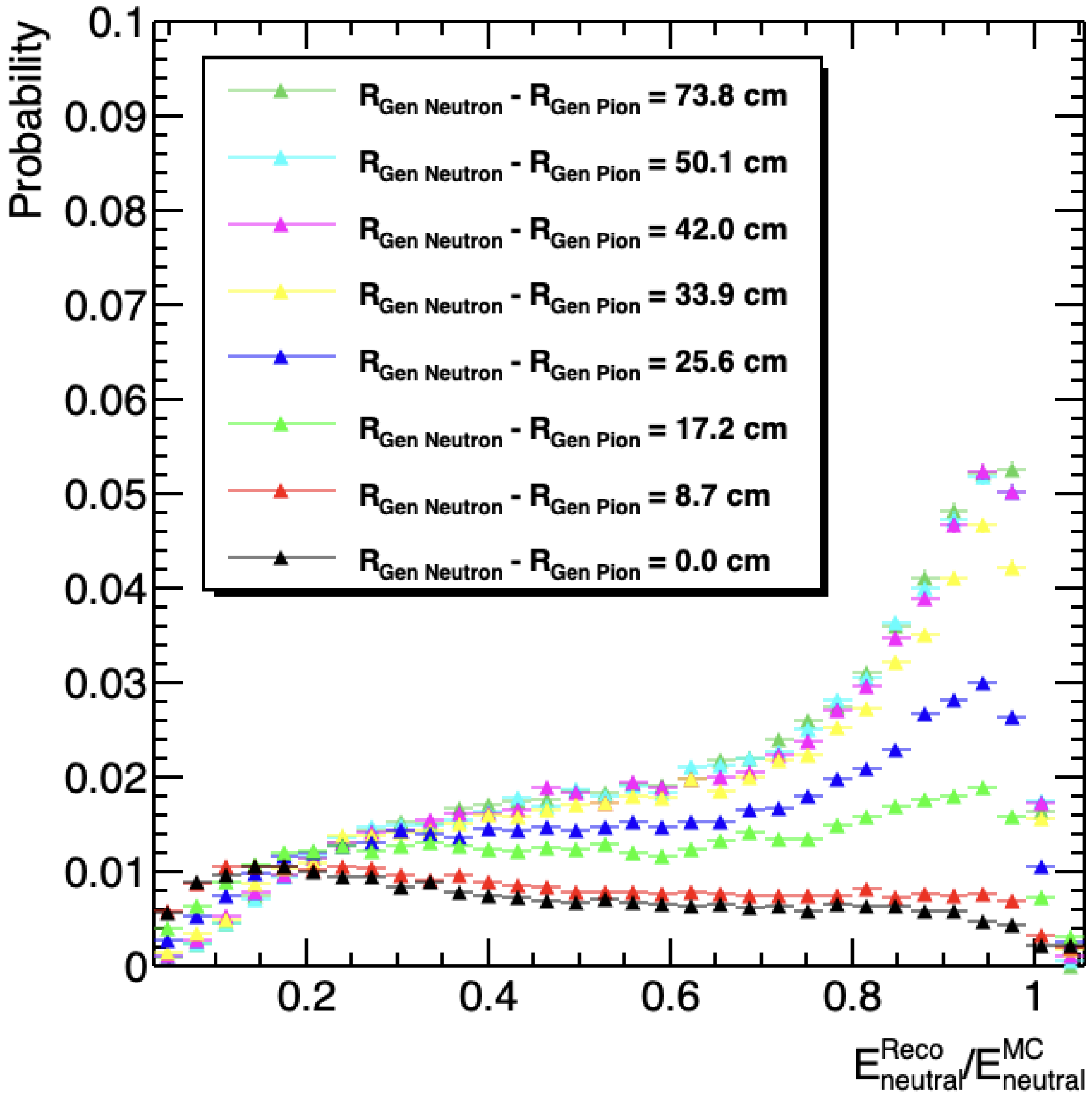
$$E^{Reco}_{neutral} = E^{Reco}_{total} - p$$

Otherwise,

$$E^{Reco}_{neutral} = E^{Reco}_{total} - E^{Reco}_{charged}$$

$E^{MC}_{neutral}$ = MC energy deposition by neutron

Charged Particle Correction



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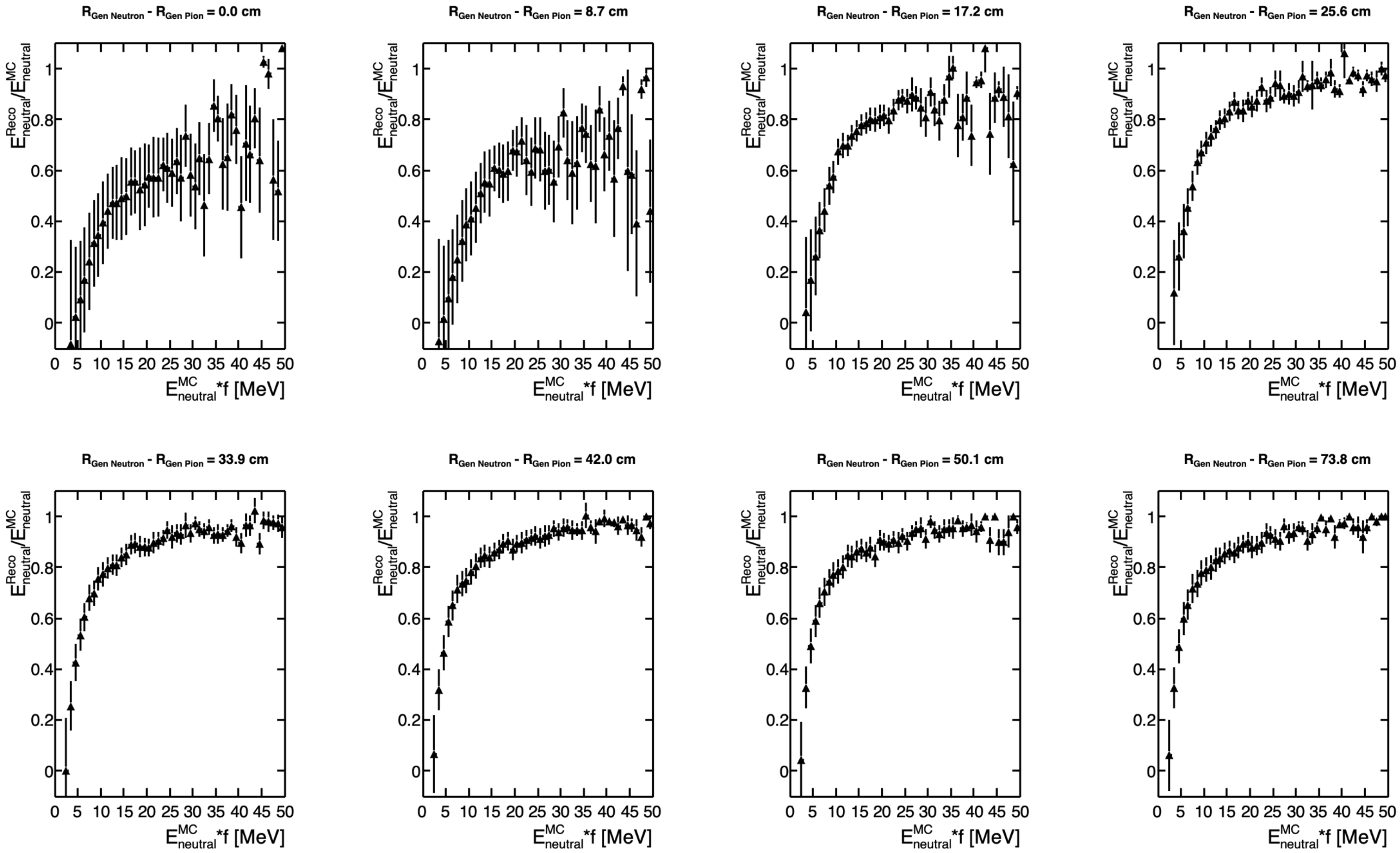
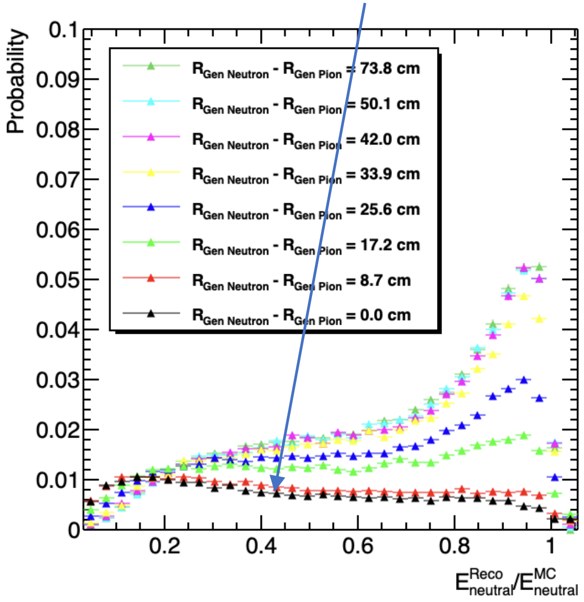
Charged Particle Correction



$E^{MC}_{neutral}$*f = the actual (not corrected to sampling fraction) energy deposition on the Sci-tiles

Performance improves with increasing $E^{MC}_{neutral}$*f

Plots with more uncertainty corresponds to flat distributions below



Charged Particle Correction : Sampling Fraction (f)

When, $|(E^{Reco}_{charged} - p)/\sigma_{E^{Reco}_{charged}}| > 3.0$

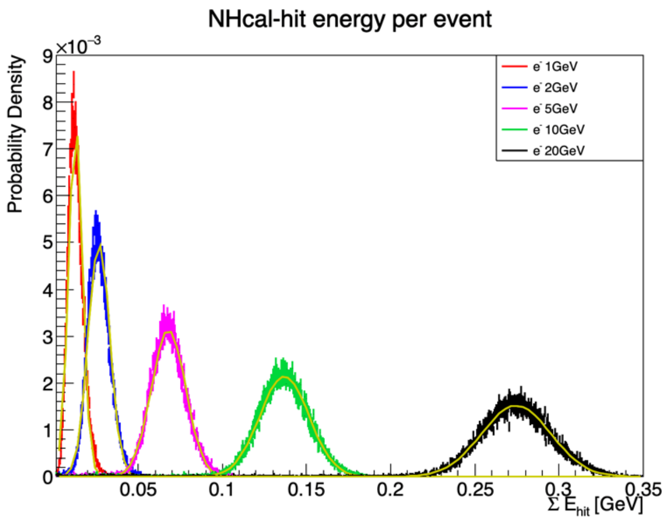
$$E^{Reco}_{neutral} = E^{Reco}_{total} - p$$

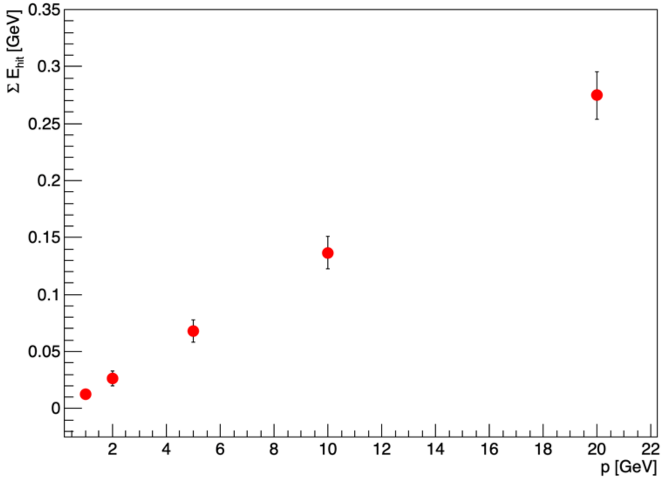
σ_{E_c} = uncertainty on the cluster energy due to hadronic nature of energy deposition

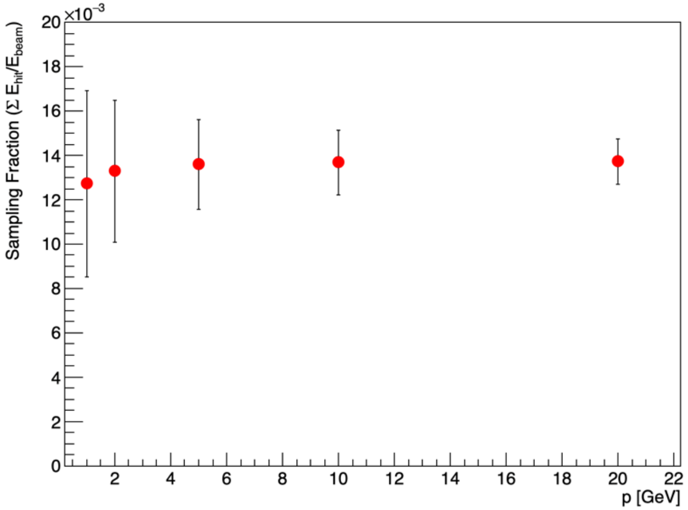
$$\sigma_{E_c} = \frac{\sigma f_p}{f_{EICrecon}} E_c$$

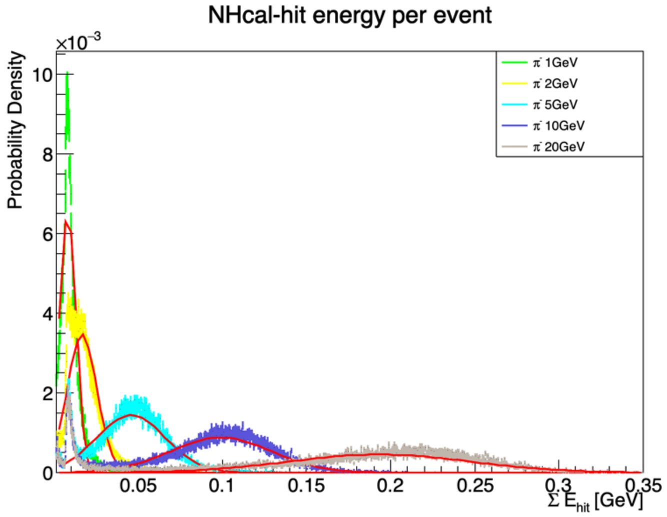
What sampling fraction (depends on particle species and momentum) value should we use?

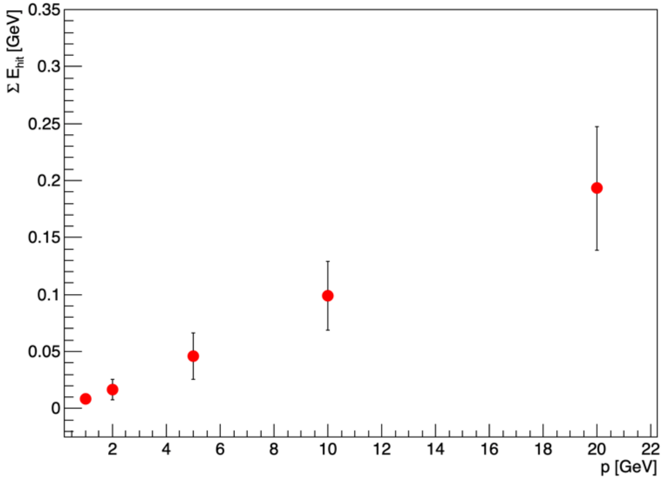
Charged Particle Correction : Sampling Fraction

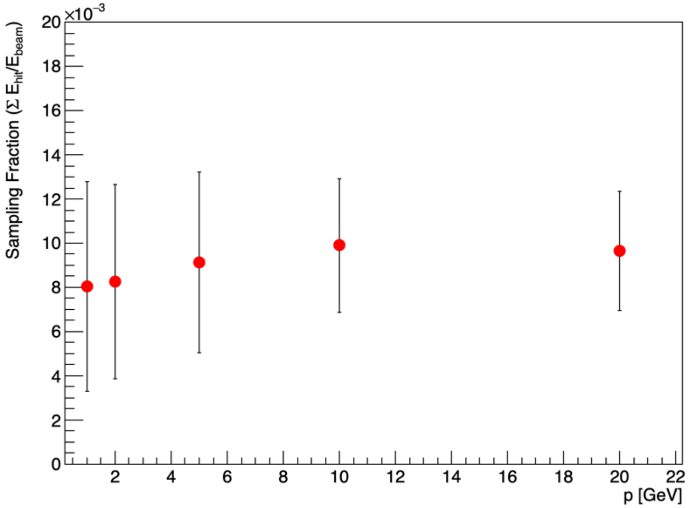




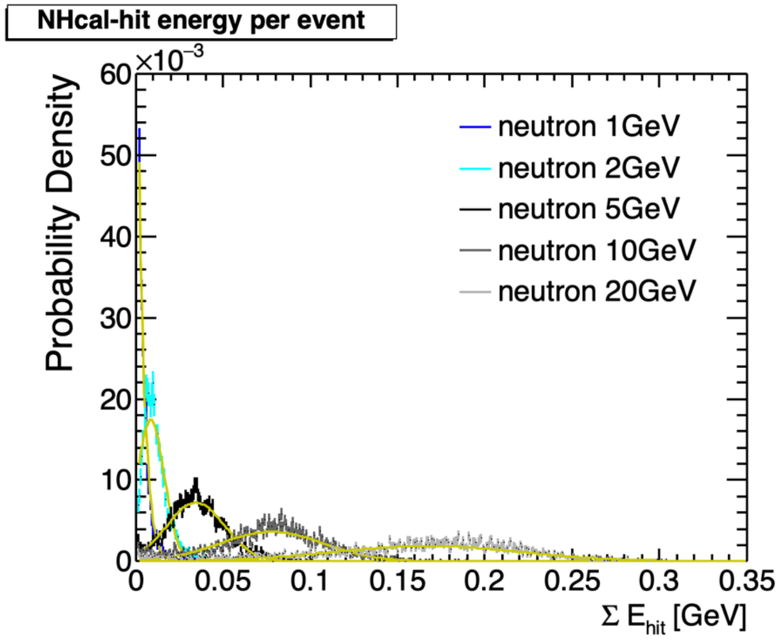


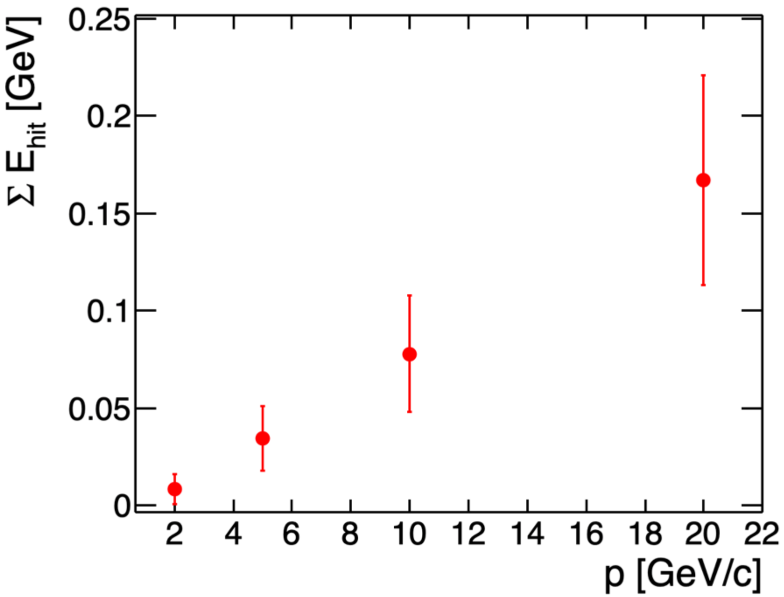


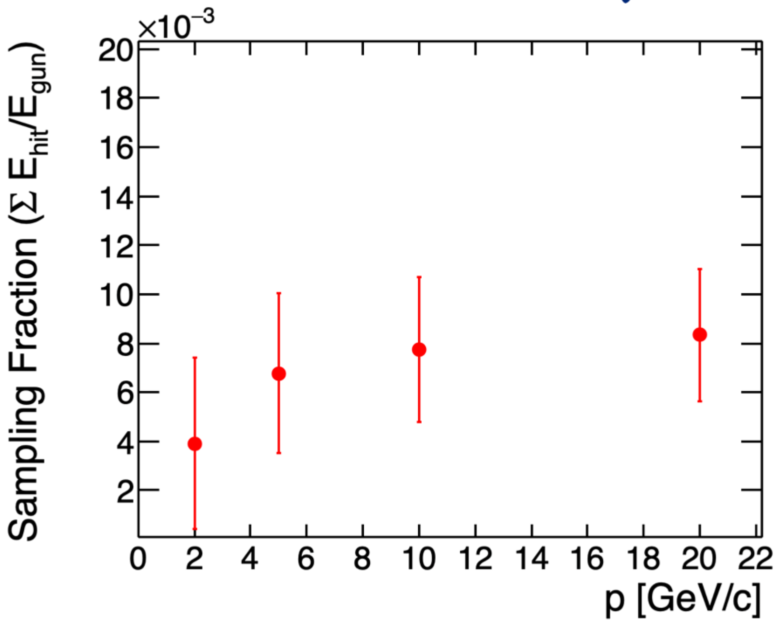




Charged Particle Correction







Particle	Momentum (GeV/c)	Sampling Fraction (%)	Uncertainty (%)
Electron	1.0	1.28	± 0.42
Electron	2.0	1.33	± 0.31
Electron	5.0	1.36	± 0.21
Electron	10.0	1.37	± 0.15
Electron	20.0	1.37	± 0.10
Pion	1.0	0.79	± 0.46
Pion	2.0	0.83	± 0.44
Pion	5.0	0.91	± 0.40
Pion	10.0	0.98	± 0.31
Pion	20.0	0.96	± 0.27
Neutron	1.0	N/A	N/A
Neutron	2.0	0.40	± 0.32
Neutron	5.0	0.67	± 0.30
Neutron	10.0	0.79	± 0.30
Neutron	20.0	0.84	± 0.39

Table 1: Sampling Fraction of nHCal for Different Particle Species

Charged Particle Correction

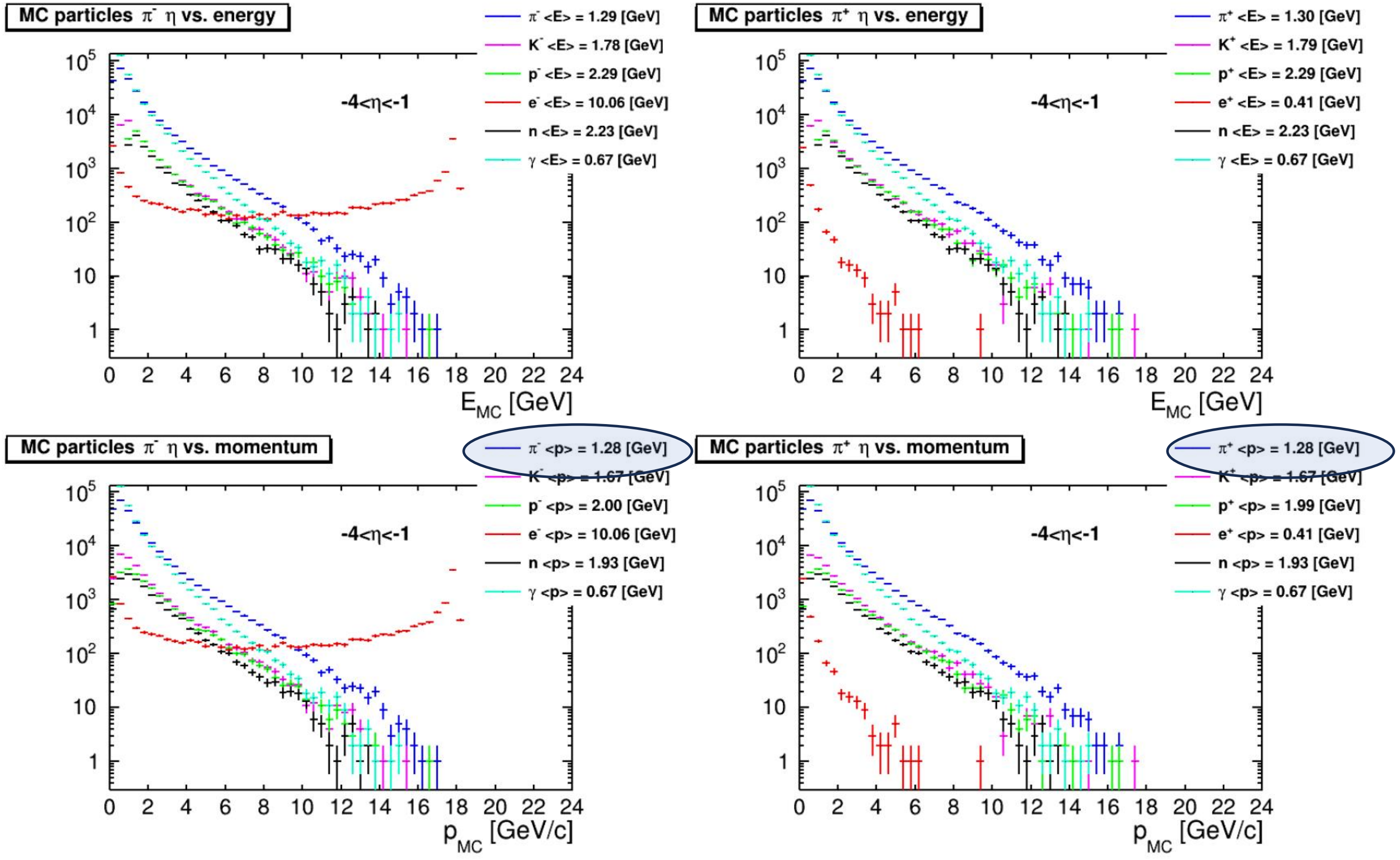


Figure 8.105: Top: Primary, generated particle E distributions in nHCal acceptance $-4.0 < \eta < -1.0$. Bottom: Primary, generated particle p distributions in nHCal acceptance $-4.0 < \eta < -1.0$.

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Neutron	1.0	N/A	N/A
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Neutron	10.0	0.79	± 0.30
Neutron	20.0	0.84	± 0.39

Table 1: Sampling Fraction of nHCal for Different Particle Species

Summary

- The neutral energy component is obtained by subtracting the expected energy of charged particles, determined from the momentum measurement.
- Reconstruction performance depends on how much energy was deposited by neutron.
- Neutron and pion clusters can be distinguished when separated by ≈ 30 cm.

Limitations:

1. Did not take into account unusual split clusters (> 1 clusters for one-particle gun).
2. Track-Cluster Matching not used. Relying on ClusterMCParticle association.

Thank You

Backup

Charged Particle Correction

E_c = Energy of the charged cluster obtained from EICrecon

$f_{EICrecon}$ = Sampling fraction incorporated in EICRecon

$f_{EICrecon}\, E_c$ = Uncorrected energy of cluster corresponding to actual energy deposition without the sampling fraction correction.

Lets call it $E_c^{uncorrected}$

Objective : To find out the error in E_c due to uncertainty in sampling fraction.

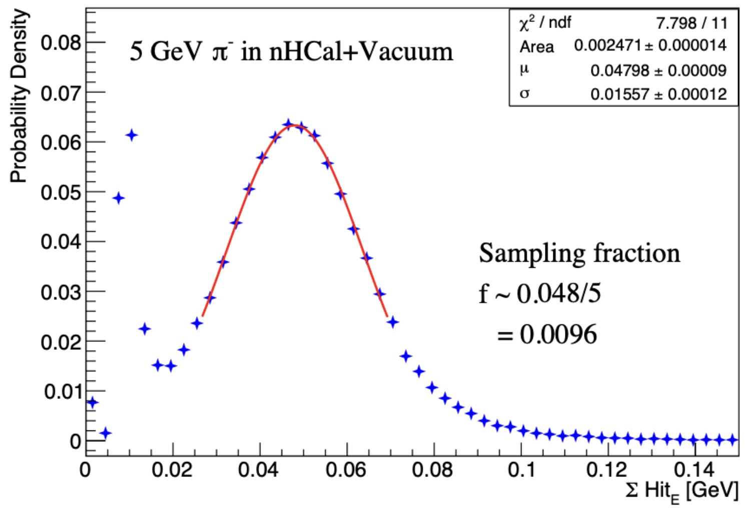
$$E_c^p = E_c^{uncorrected} / f_p$$

p = momentum of the track matched to the cluster

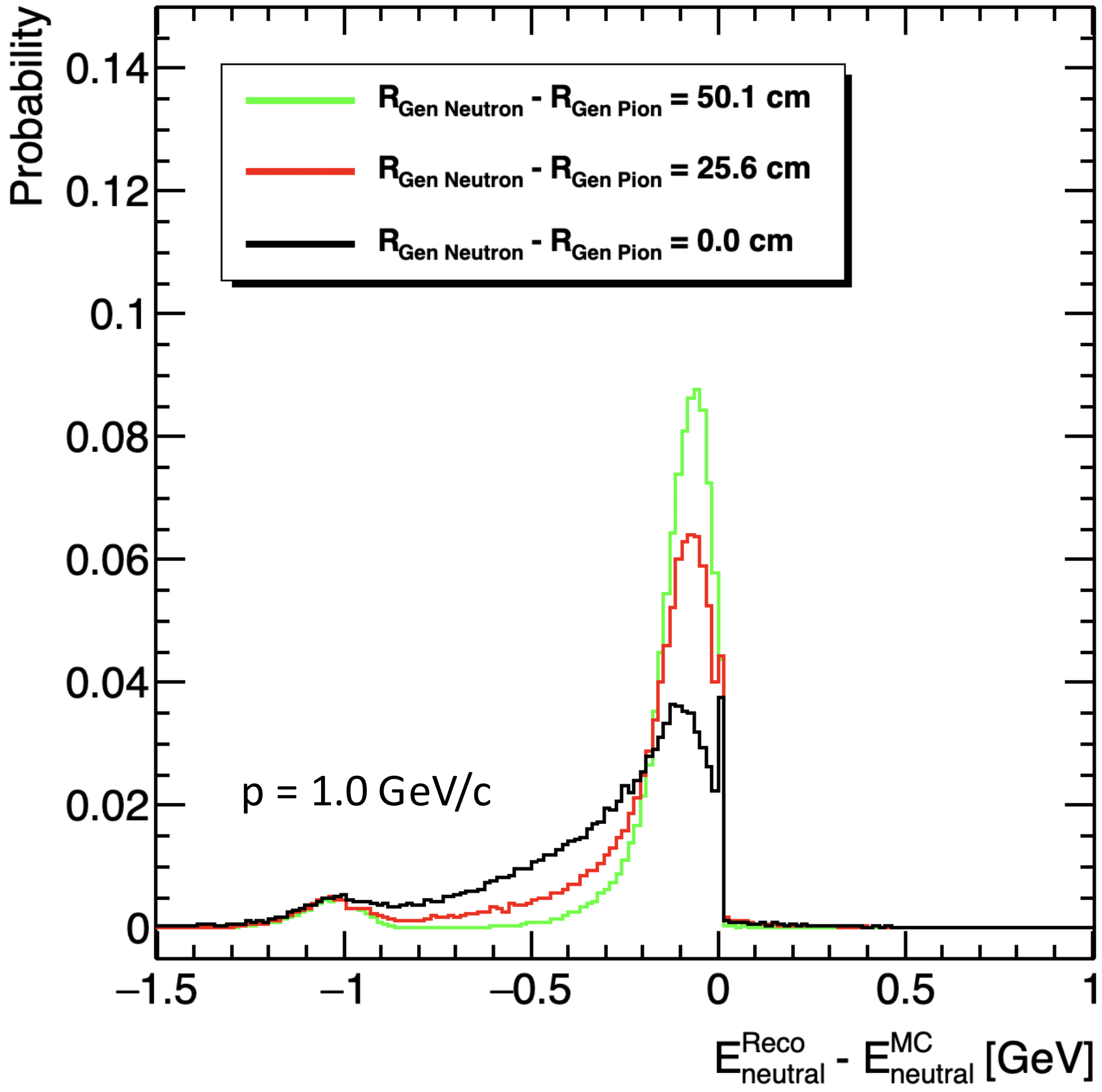
$$\frac{\sigma E_c^p}{E_c^p} = \frac{\sigma f_p}{f_p} \Rightarrow \sigma E_c^p = \frac{\sigma f_p}{f_p} E_c^p$$

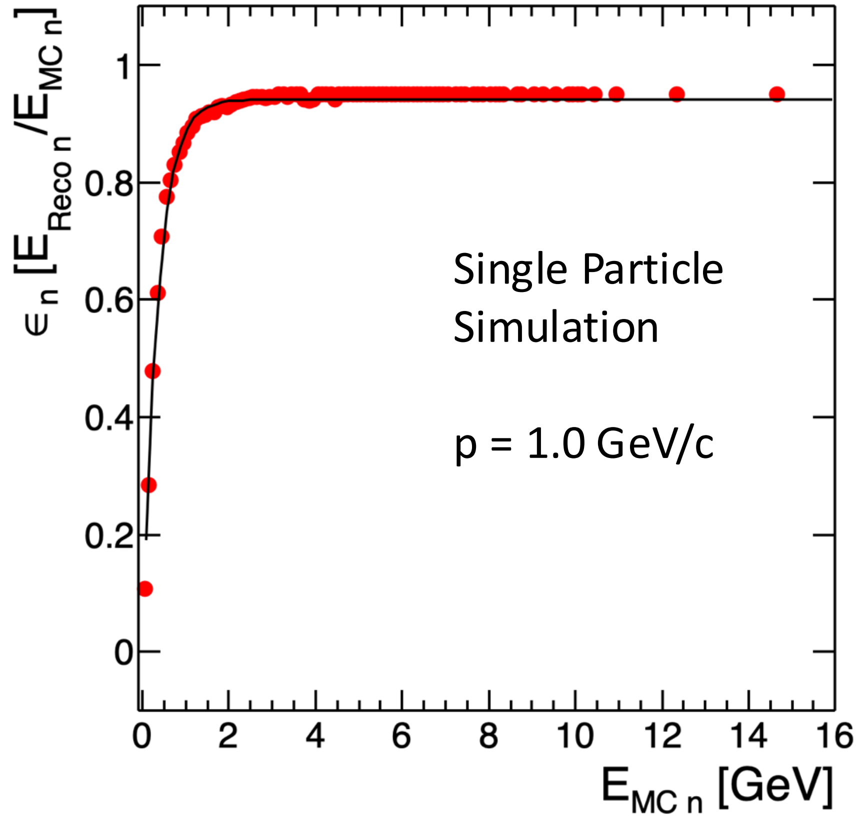
$$\sigma E_c^p = \frac{\sigma f_p}{f_p^2} E_c f_{EICrecon} \approx \frac{\sigma f_p}{f_{EICrecon}} E_c$$

f does not change much with p



Charged Particle Correction

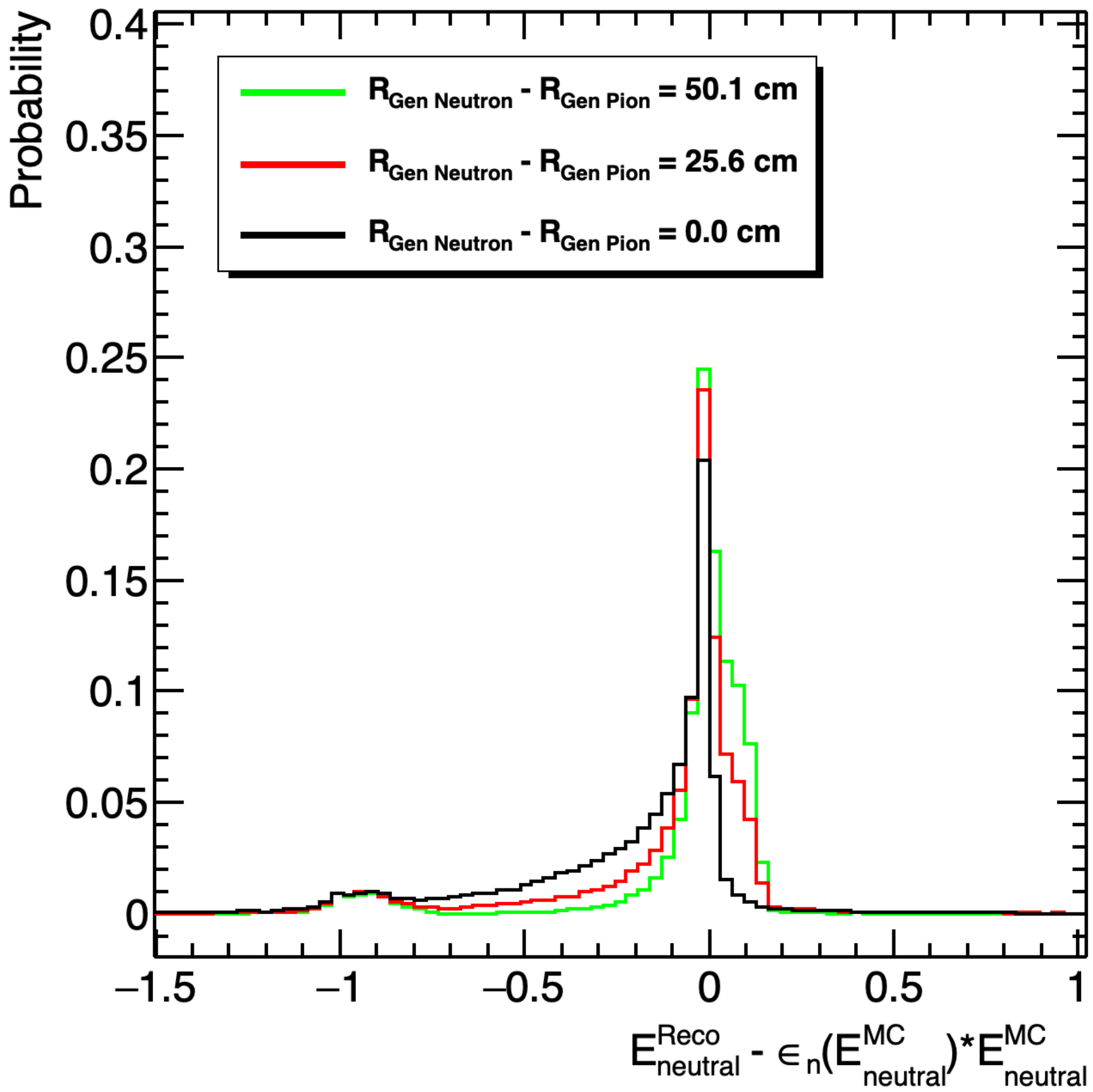




When, $|(E^{Reco}_{charged} - p)/\sigma_{E^{Reco}_{charged}}| > 3.0$

$$E^{Reco}_{neutral} = E^{Reco}_{total} - p$$

Charged Particle Correction

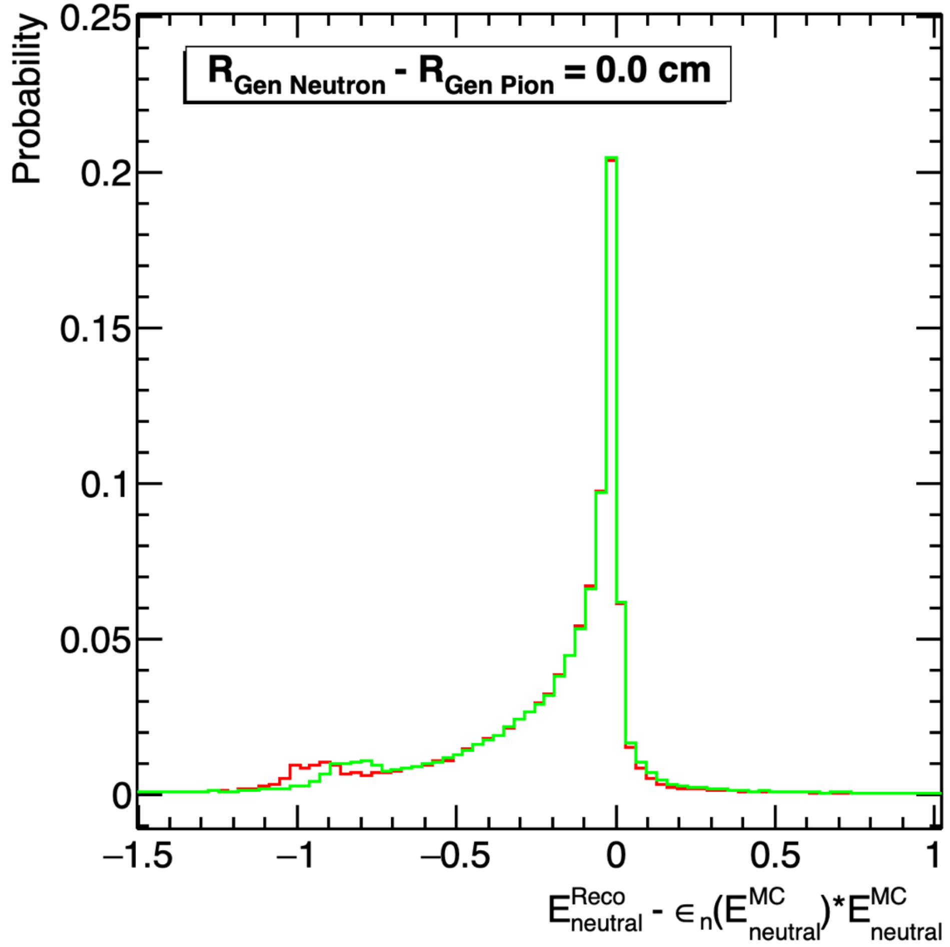


Limitations:

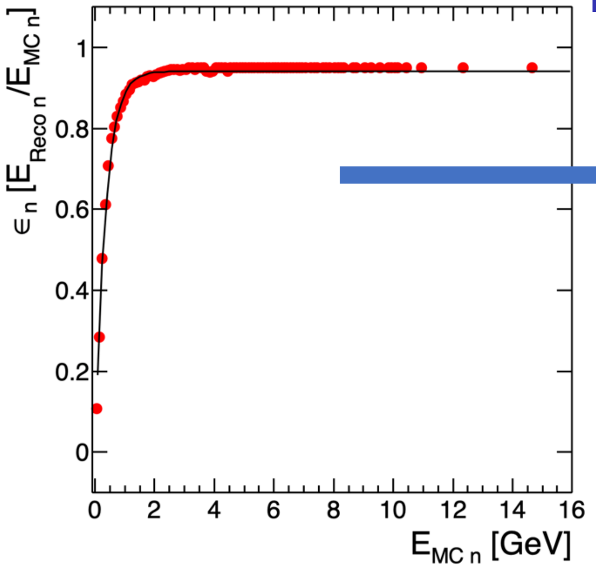
1. Did not take into account unusual split clusters (> 1 clusters for a pion gun).
2. Track-Cluster Matching not used. Relying on ClusterMCParticle matching.

Can add more histograms corresponding to in-between distances (if needed)

Charged Particle Correction



p = 1.0 GeV/c



Considering it would not be species dependent

When, $|(E^{Reco}_{charged} - p)/\sigma_{E^{Reco}_{charged}}| > 3.0$

$$E^{Reco}_{neutral} = E^{Reco}_{total} - p$$

$$E^{Reco}_{neutral} = E^{Reco}_{total} - \epsilon(p) * p$$

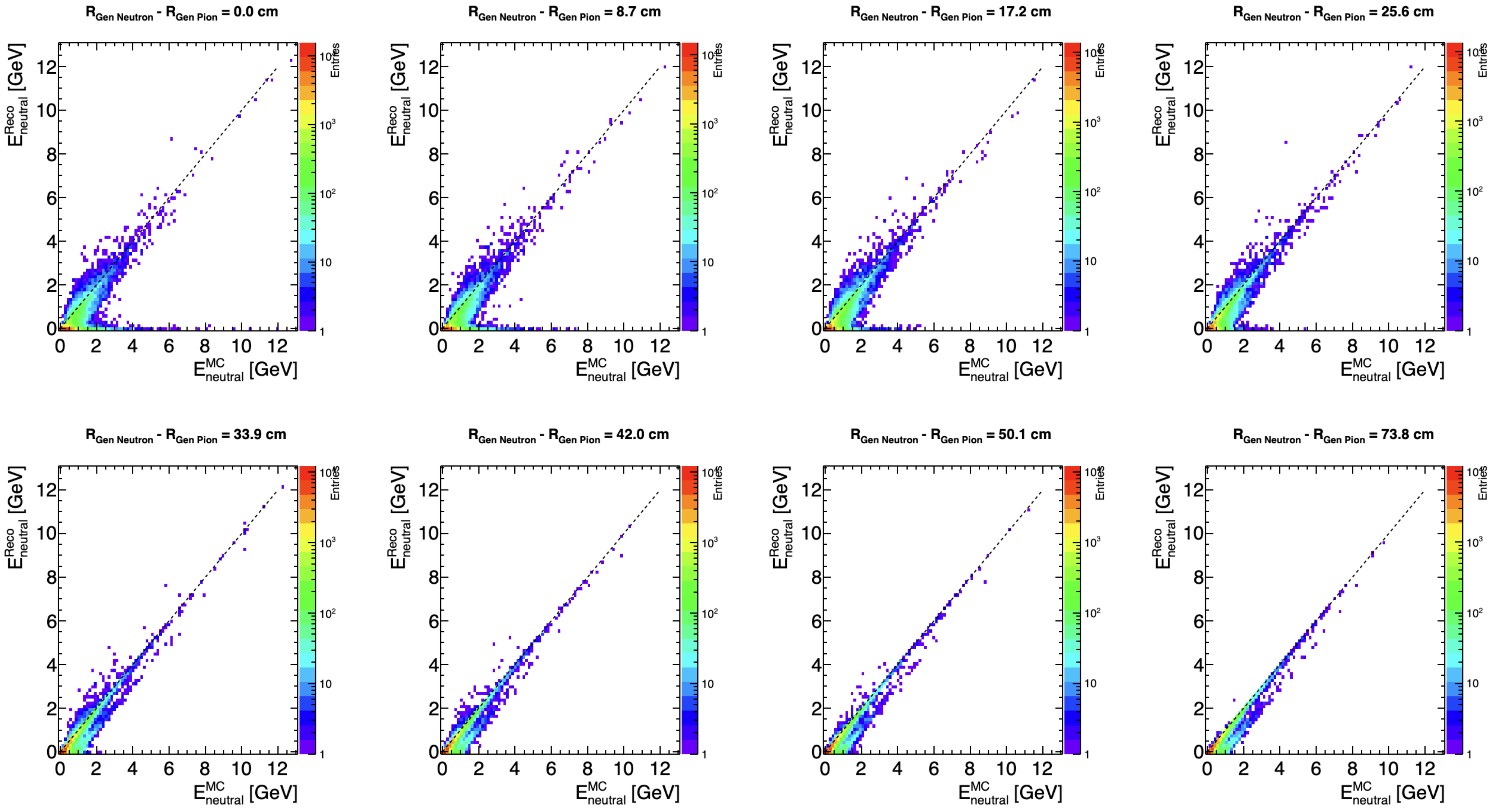
Old

New

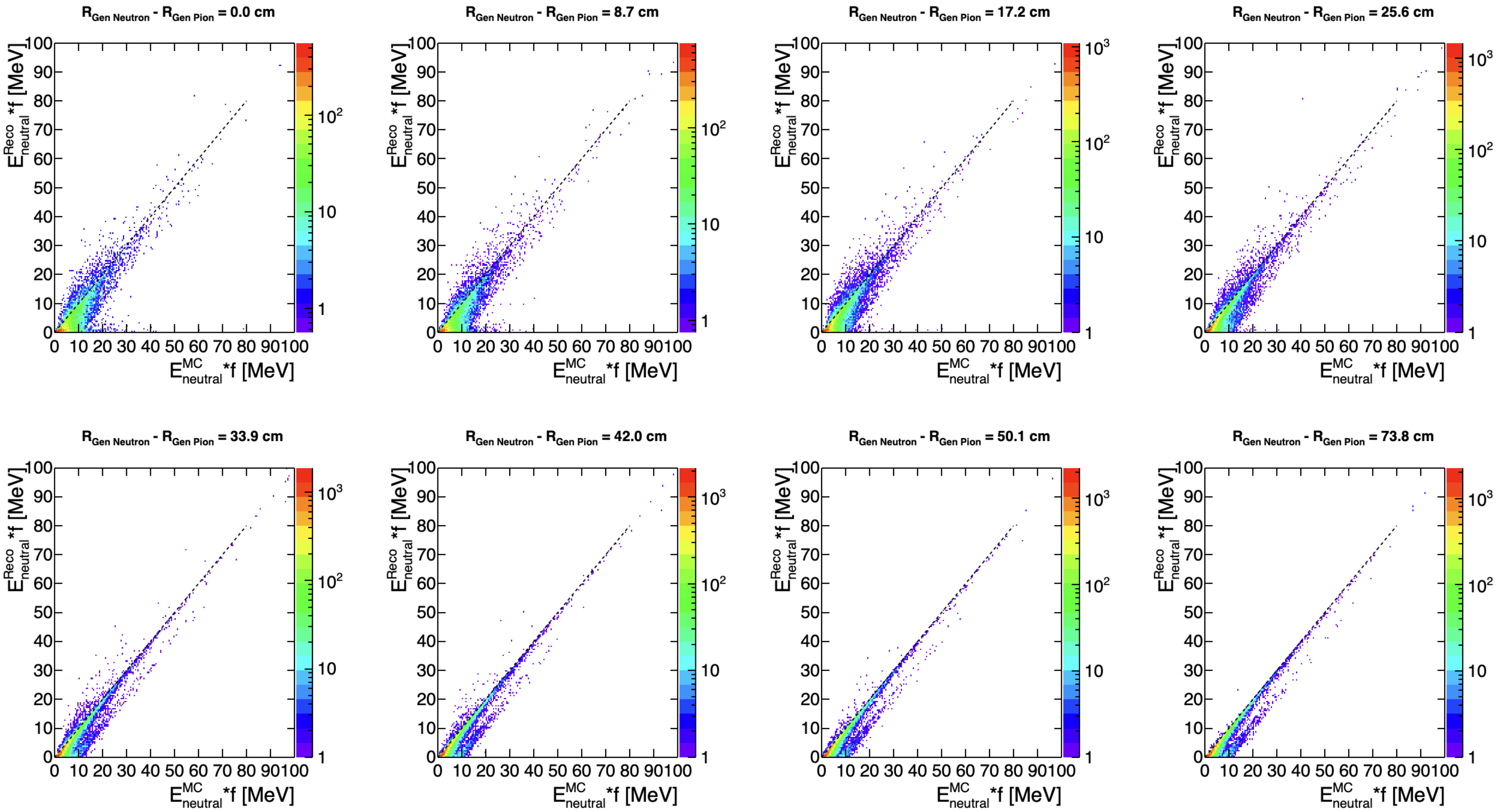
Otherwise,

$$E^{Reco}_{neutral} = E^{Reco}_{total} - E^{Reco}_{charged}$$

Charged Particle Correction



Charged Particle Correction



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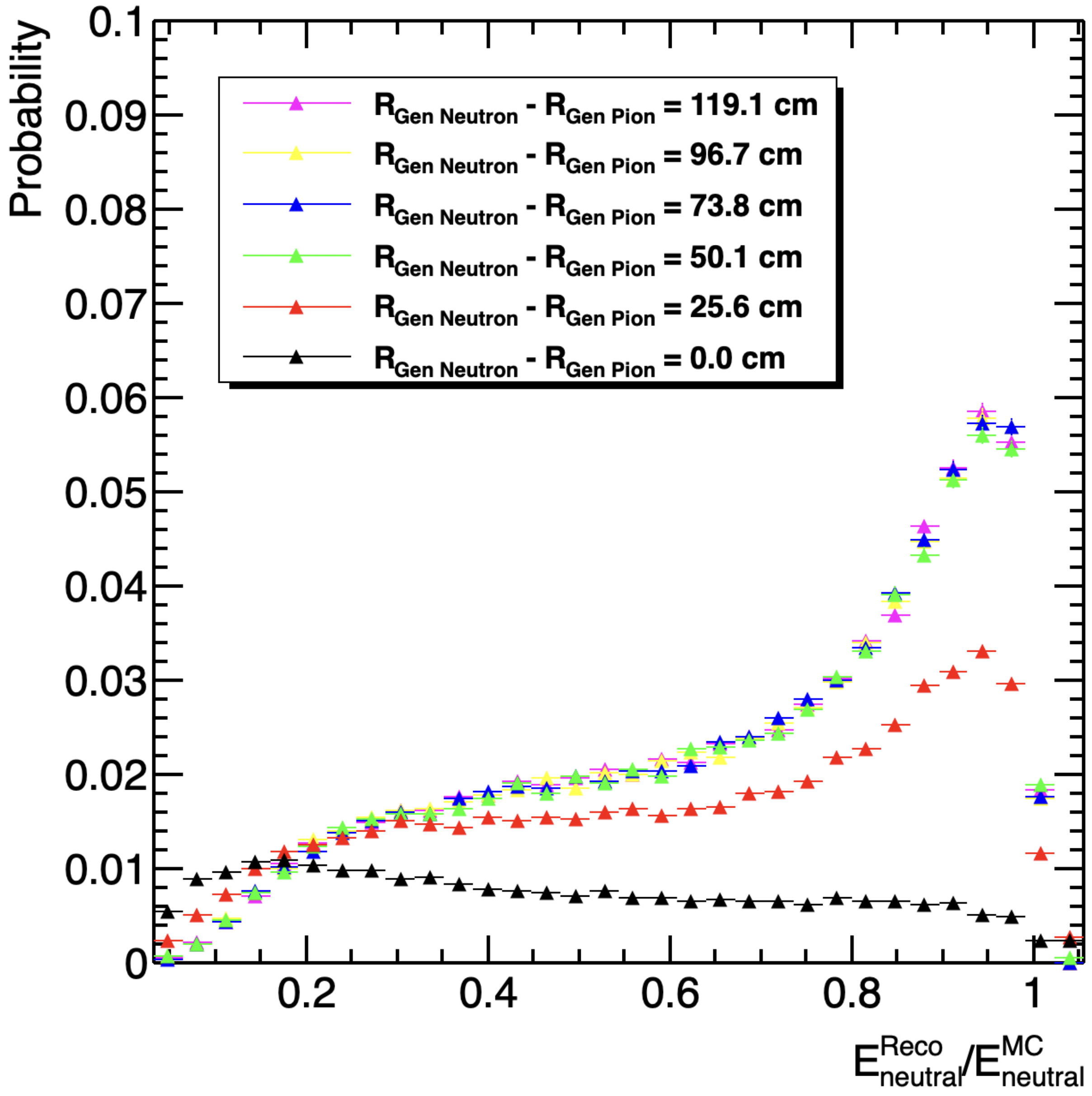
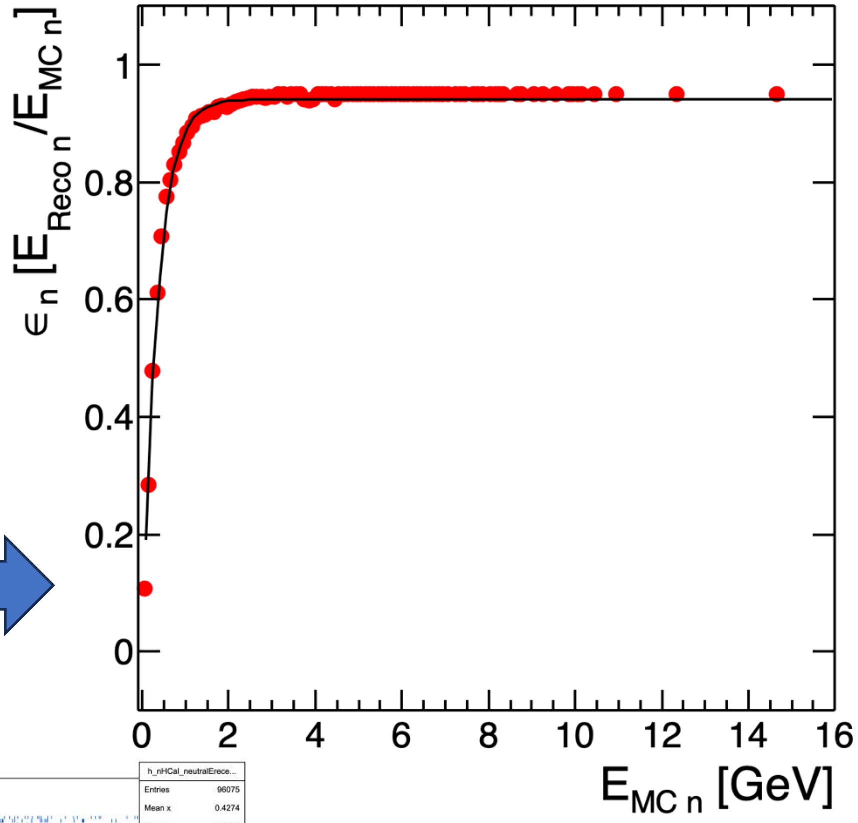
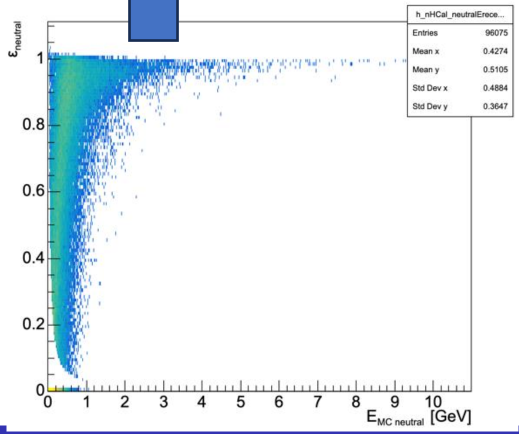
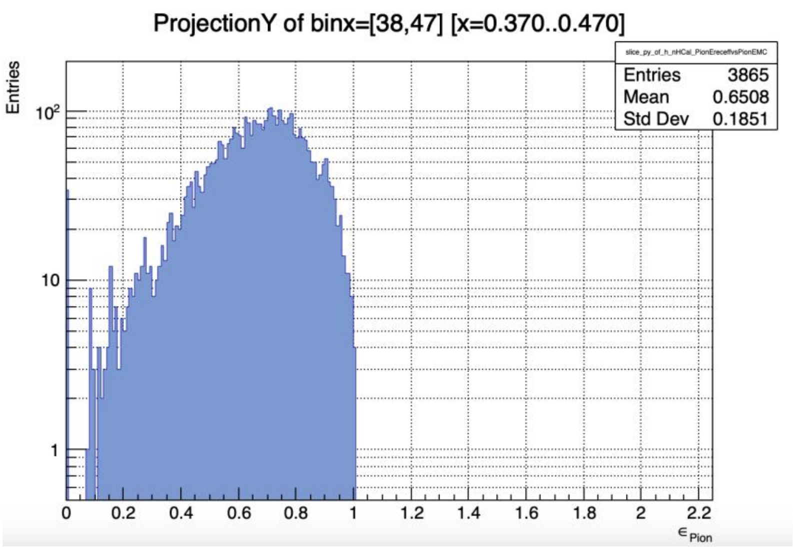
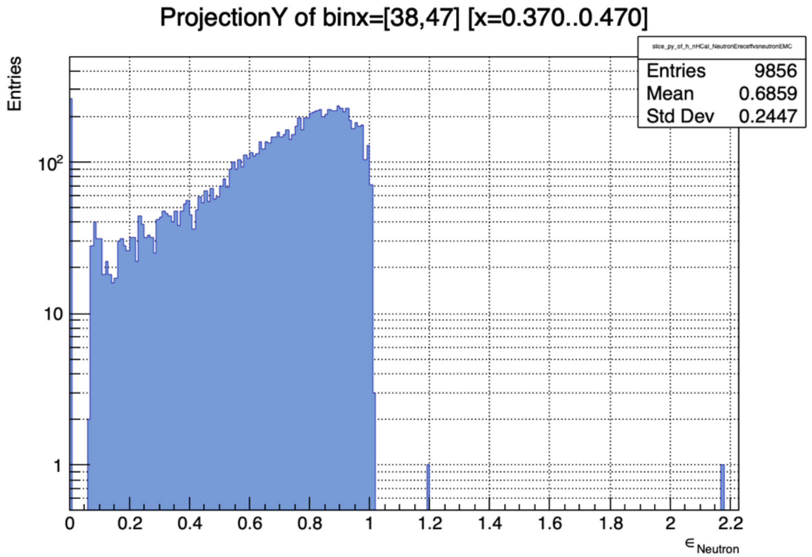


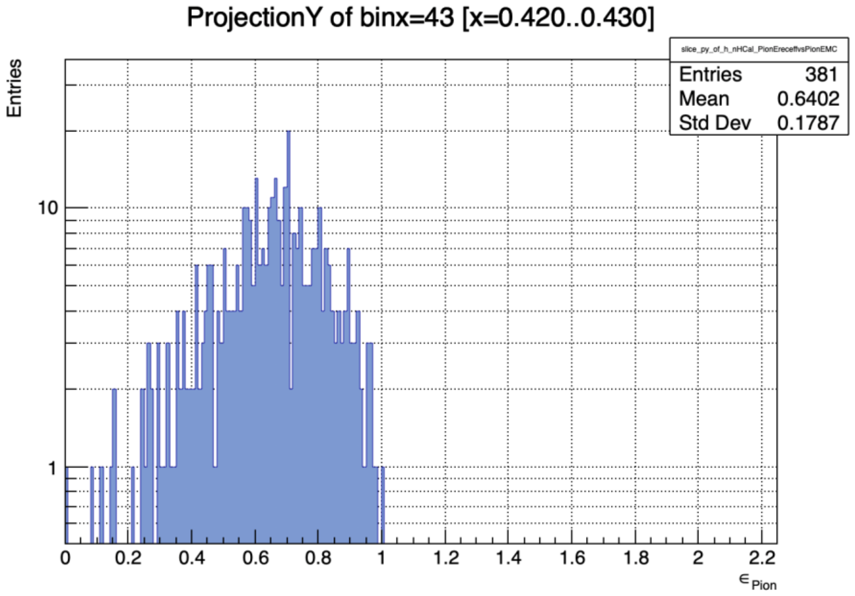


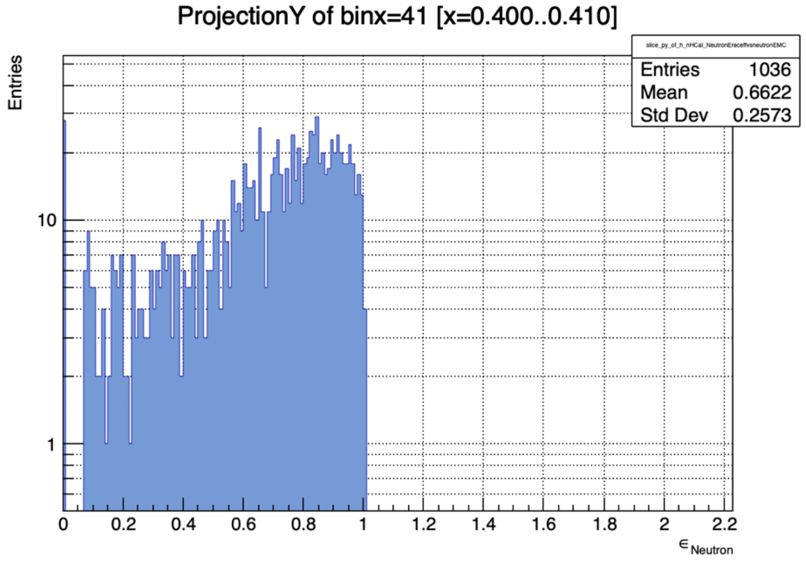


$R_{gen\ Neutron} - R_{gen\ Pion}$ = 119.11 cm

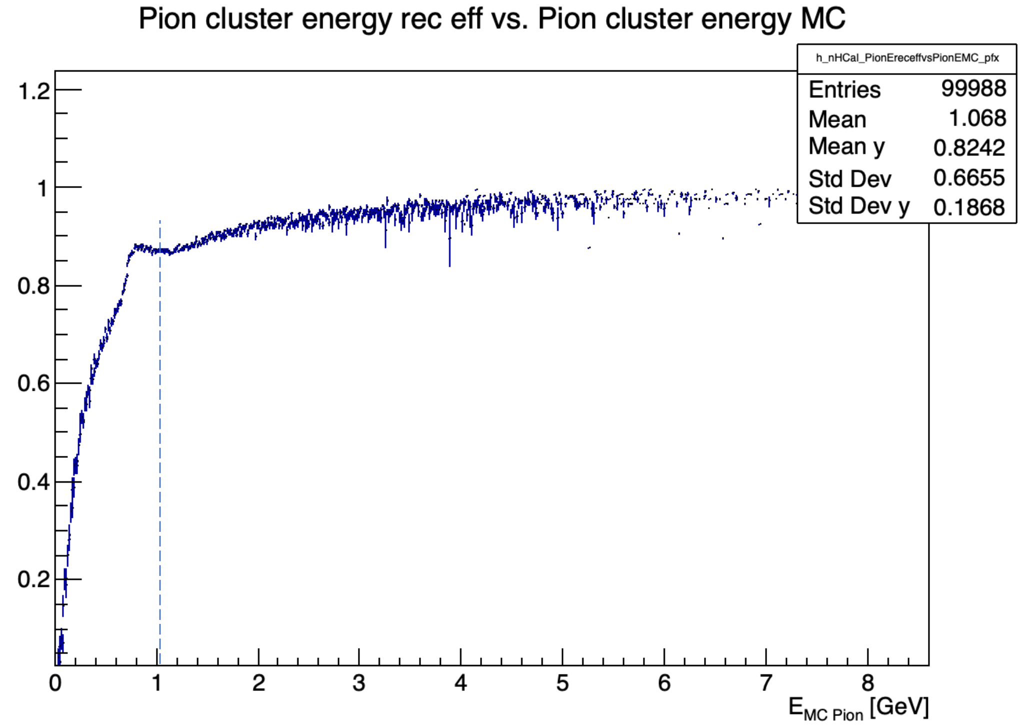


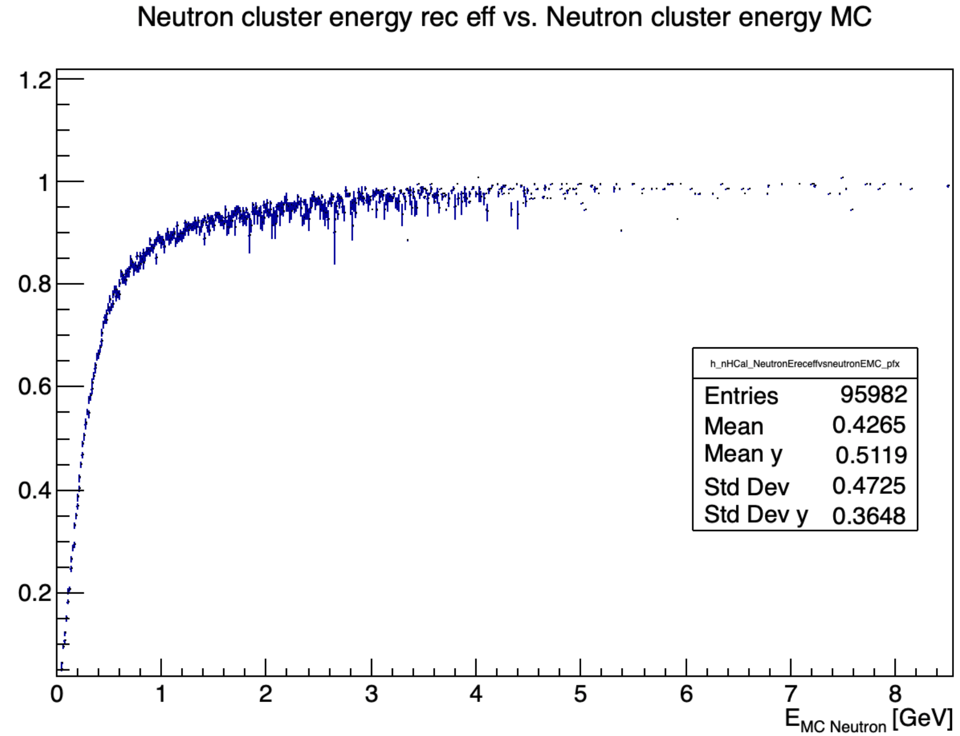






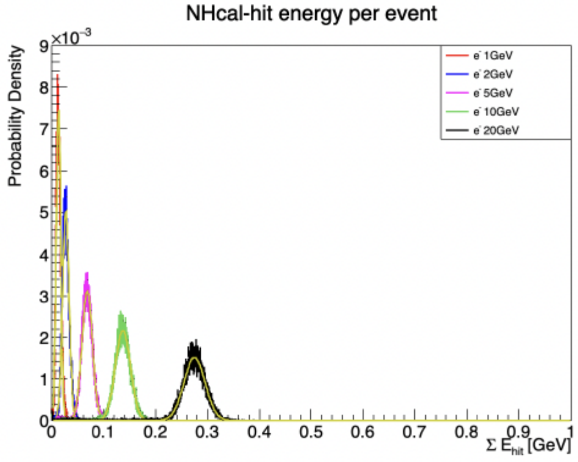
$R_{gen\ Neutron} - R_{gen\ Pion} = 119.11$ cm

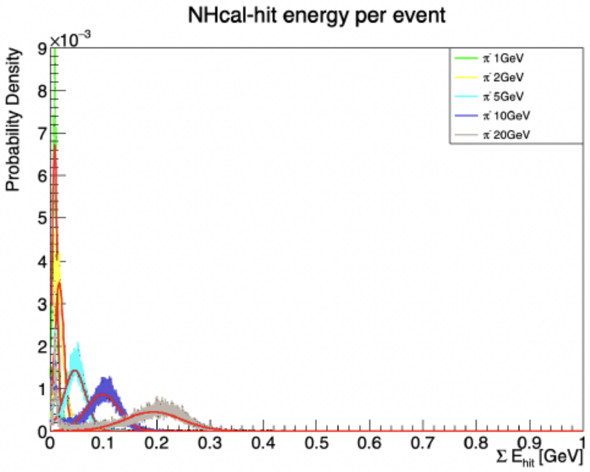


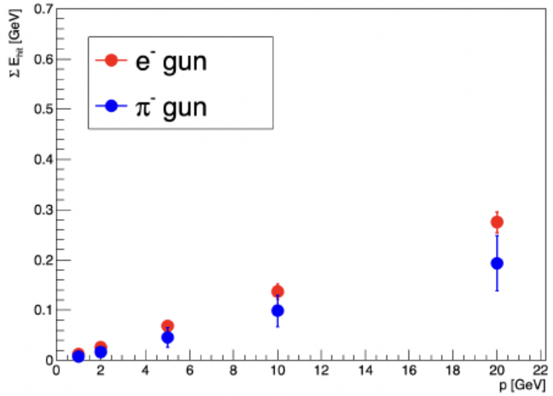


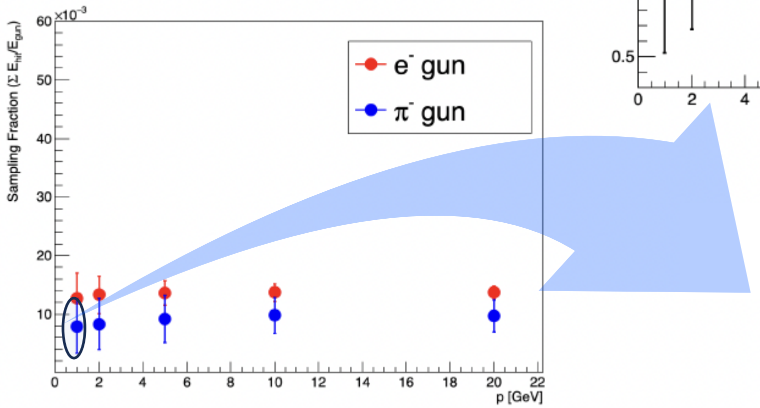
Recap – e/h study

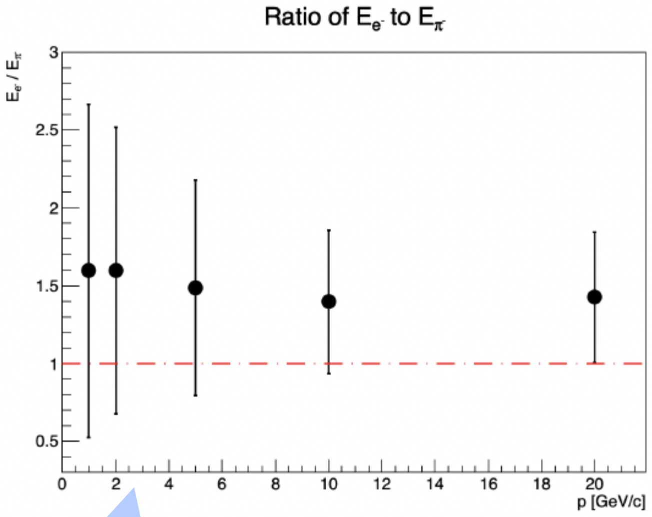
Steel/Scint = 10:1; 10 layers [40 mm Steel + 4 mm Scint]











f = 0.0080 ± 0.0046

2