PFA0: Electromagnetic Calorimeter Detectors Performance

(Merge Clusters based on E/p for Single Particle Analysis)

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PFA0

1. For track cluster matching I used the example by Derek (MatchTrackClusterProjections), instead of using the outputs from campaign. Added Cluster-merging and its purity algorithms for this analysis.
2. We start with seed Cluster that matched with the track (in eta-phi space)
3. Particle energy deposition in calorimeter can often be split into two or more clusters that need to be merged; The clusters with max Eop are **seed clusters**, and **split clusters** are **Fragmented clusters**.
4. We calculate parameters like E/p, purity as a function of ΔR (defined in next slide) to quantify merging the fragmented clusters.

Merging Window

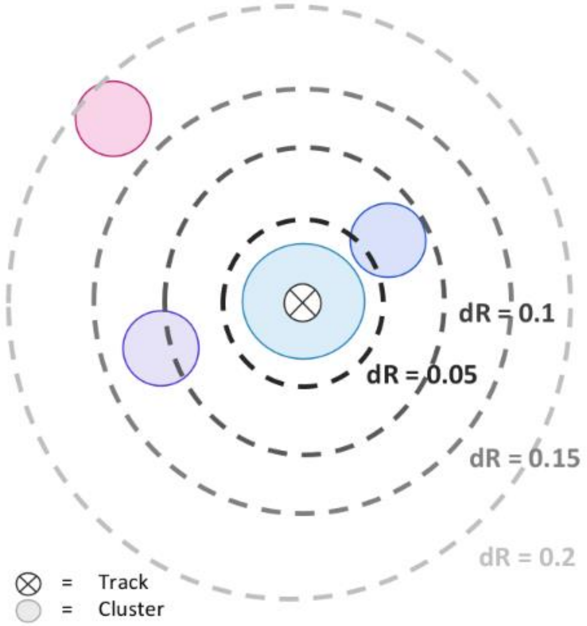
1. Find a seed cluster in each event associated with the track. The one with best ΔR match. Lets call it **EClust**.
2. Look for other clusters around the **seed** cluster.
3. If the distance between other cluster and track pointing to it is less than ΔR, then add it to EClust, call it eSum.
4. Varied ΔR in steps between 0.1 to 0.5
5. Plotted Eop distributions for ΔR = 0.1, 0.2, 0.3, 0.4, 0.5
6. This also gives us the first hint of upper cut on ΔR for track cluster matching

Terminolgies used: $$Eop = \frac{E^{\text{Clust}}}{p^{\text{Trk}}}$$

$$\Delta\eta = \eta^{\text{Clust}} - \eta^{\text{Trk}} \qquad \Delta\phi = \phi^{Clust} - \phi^{Trk}$$

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

Attached visualisation made by Derek →



Purity

1. Purity is a measure of what fraction of the *true* deposited energy is captured in a given cluster.
2. We use RawHitLinks to get the SimHit of each RawHit. This is to compute the truth level eDep
3. As ΔR is increased, we merge the cluster energies and check purity varying with ΔR . If all split clusters are merged, ideally the purity should be 1, for single particle events.

$$\boxed{\text{Purity} = \frac{E^{\text{clust}}}{E^{\text{Total}}}}$$

SIMULATION

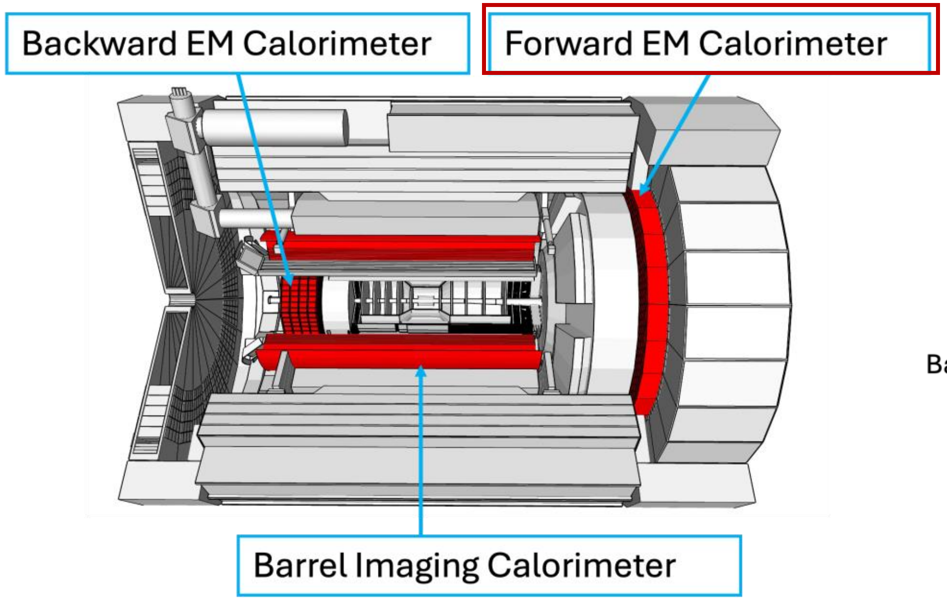
The RootFiles in campaigns doesn't store RawHitLinks.

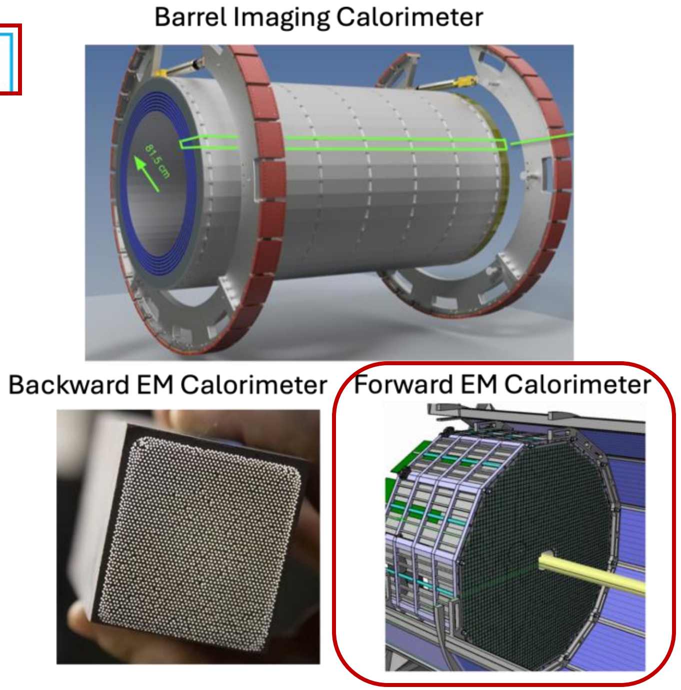
So, I generated the following simulations and ran EICRecon on them (Tutorial: Full Chain Analysis)with the following settings

1. Particle gun used for single particles.
2. Compact file used = epic.xml
3. Number of events = 10k
4. For 3to50deg ROOT Files :
   - Gun Particle = e-, pi-
   - ThetaMin = 30 and ThetaMax= 50
   - Energy of particle = 1,2,5,10 GeV
   - Gun position = (0,0,0)
5. For 45to135deg ROOT Files :
   - Gun Particle = e-, pi-
   - ThetaMin = 45 and ThetaMax= 135
   - Energy of particle = 1,2,5,10 GeV
   - Gun position = (0,0,0)
6. For 130to177deg ROOT Files :
   - Gun Particle = e-, pi
   - ThetaMin = 130 and ThetaMax= 177
   - Energy of particle = 1,2,5,10 GeV
   - Gun position = (0,0,0)

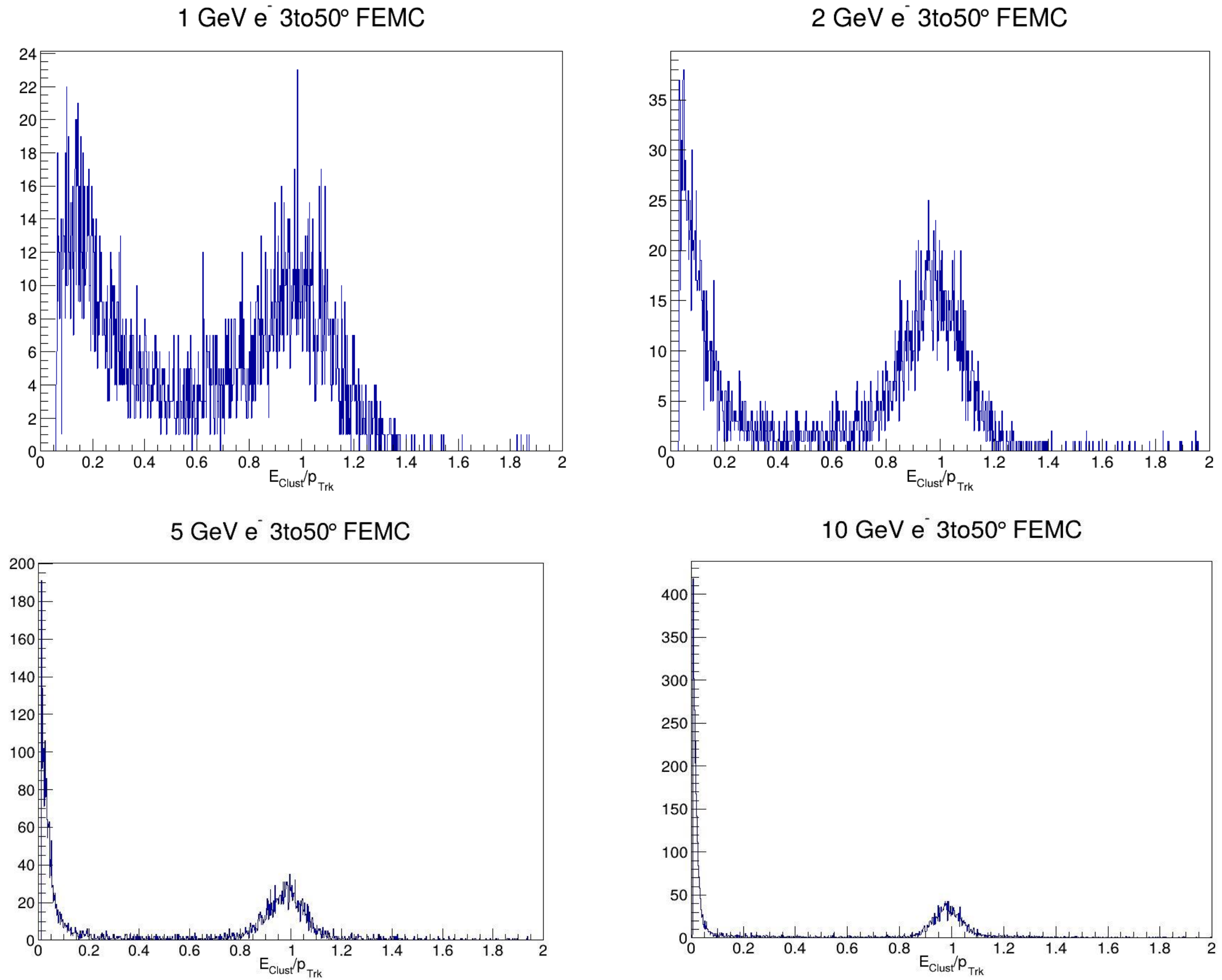
FORWARD ELECTROMAGNETIC CALORIMETER

eta: (1.4,3.9)



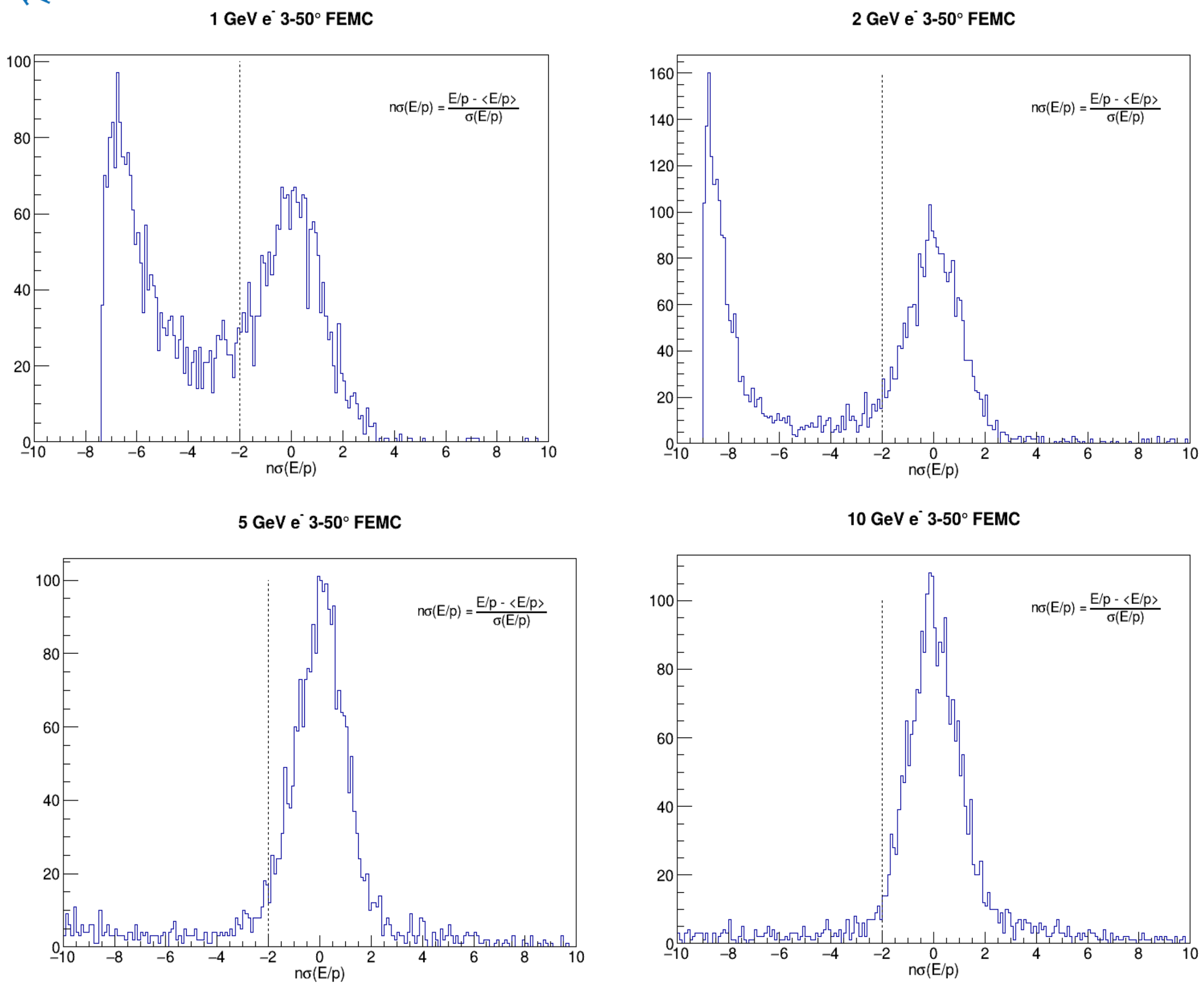


E/p distribution of seed clusters for different e- incident energies in FEMC



Electrons deposit most of their energy in EMCals. If all of that energy is contained in a single cluster, the E/p distribution would be a Gaussian around 1. But due to split clusters, we see a forward peak for smaller E/p values -> indication of split clusters

Significance distribution of all seed clusters in FEMC

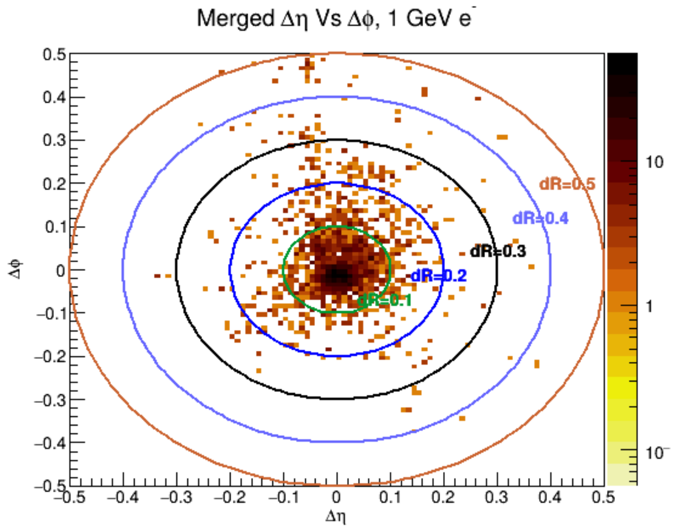


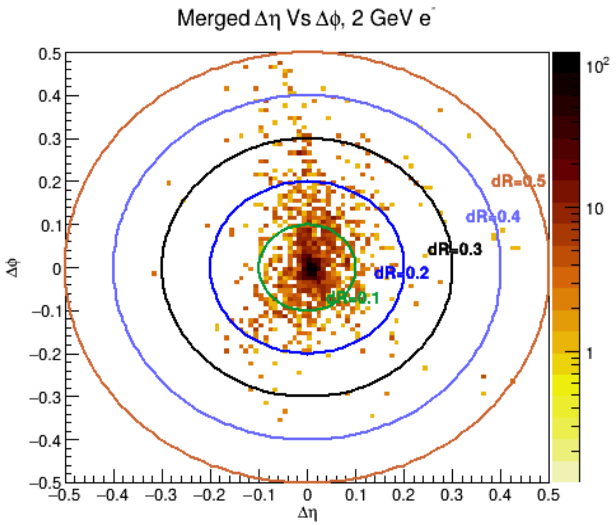
$$Eop = \frac{E^{\mathrm{Clust}}}{p^{\mathrm{Trk}}}$$

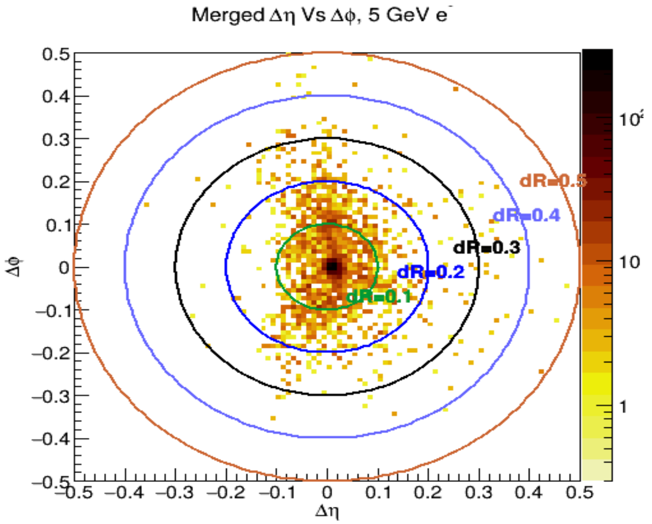
$$n\sigma = \frac{Eop - \langle Eop \rangle}{\sigma\left(Eop\right)}$$

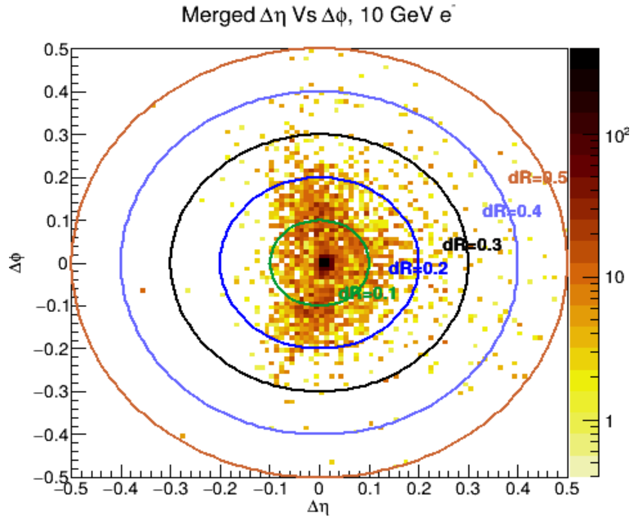
- Shows the sigma boundary between the two populations.
- Sigma < -2 could be due to the split clusters. The same for all incident e- energies.

Distribution of clusters around the seed cluster in FEMC



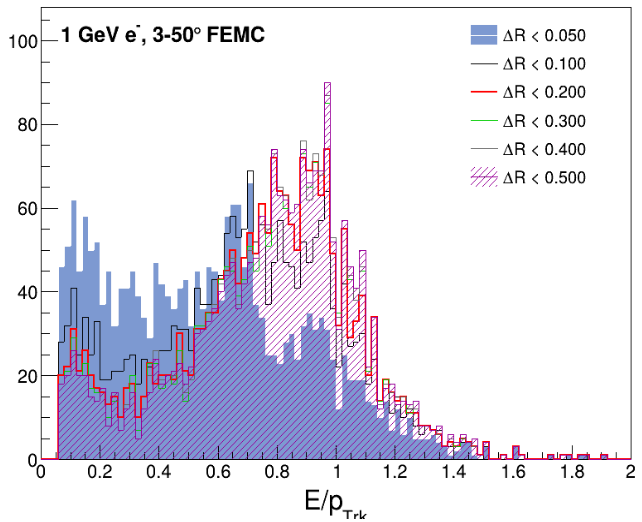


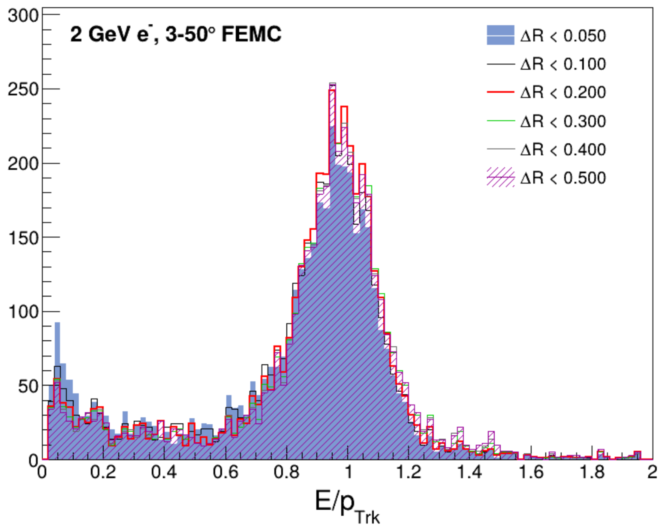


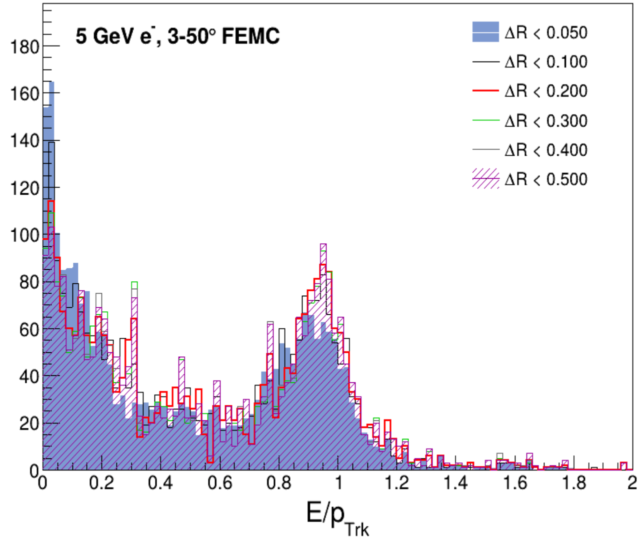


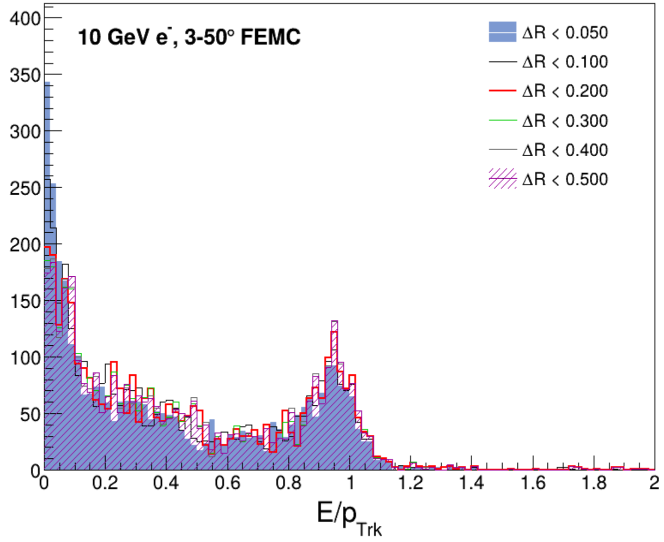
Most clusters are in a radius between 0.2 to 0.3.

E/p distribution against dR (after merging). For fragmented clusters.



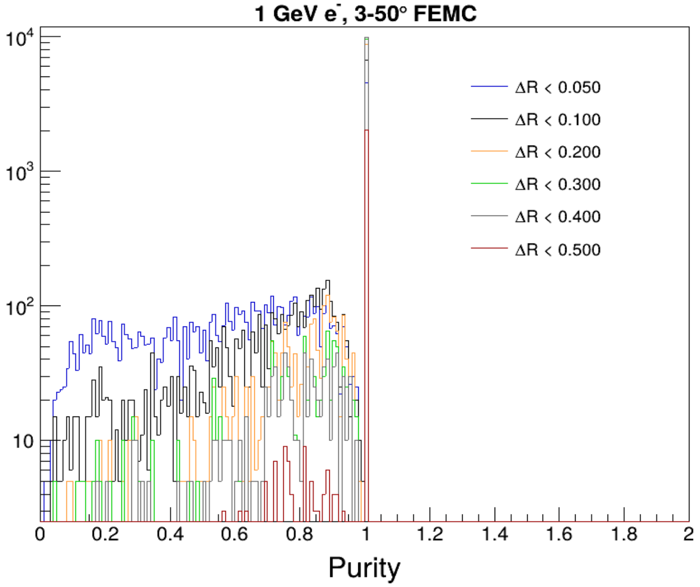


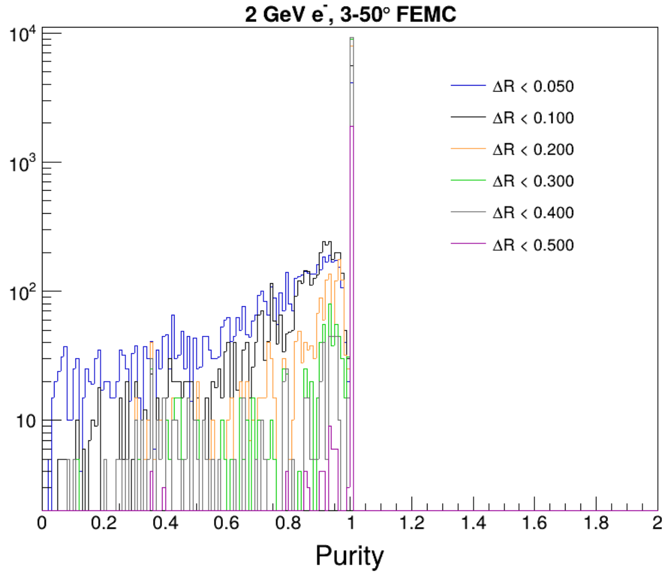


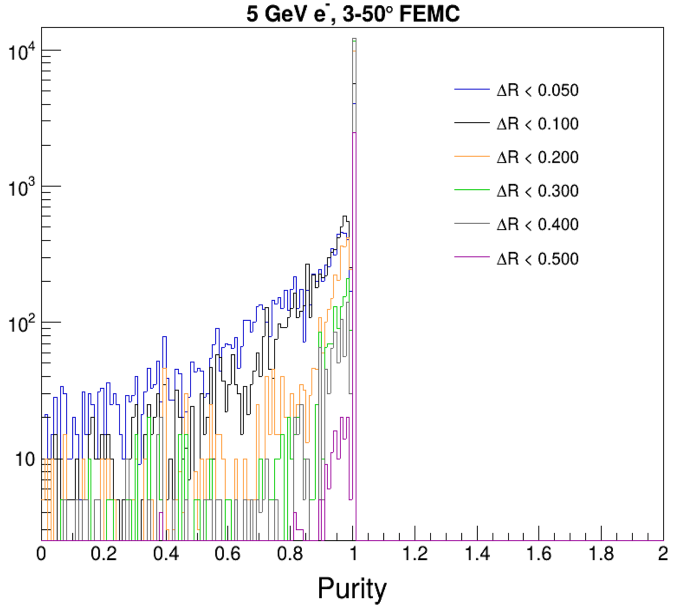


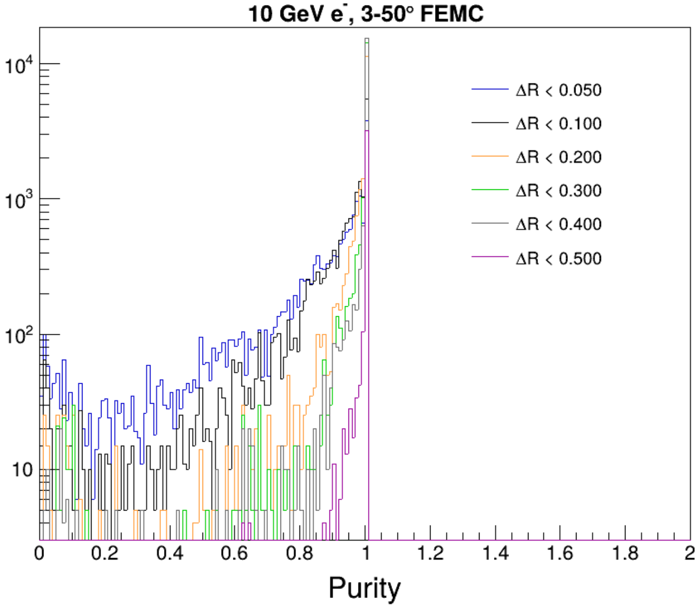
Observed distribution changes as we increase ΔR

Purity distribution against dR in FEMC

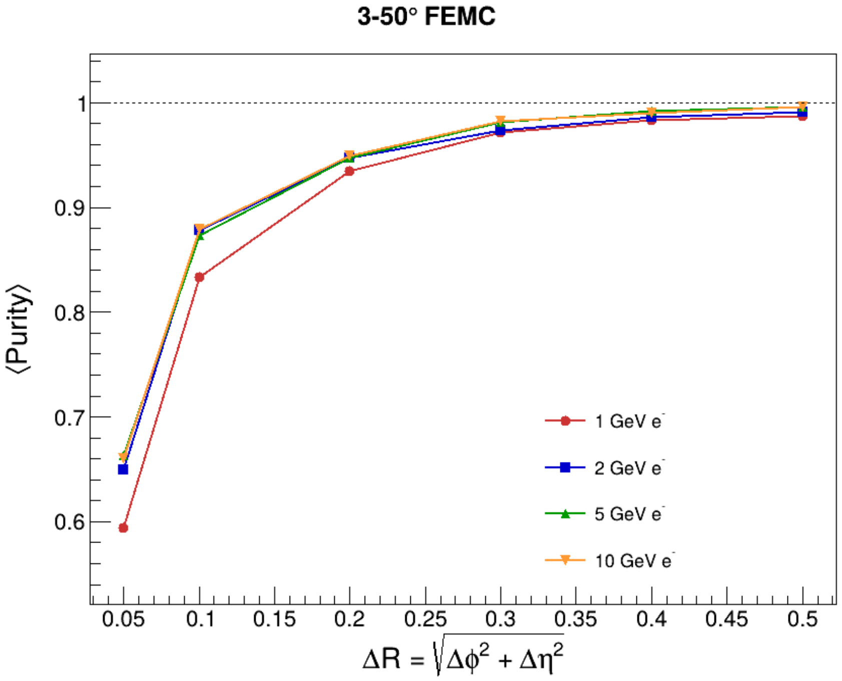








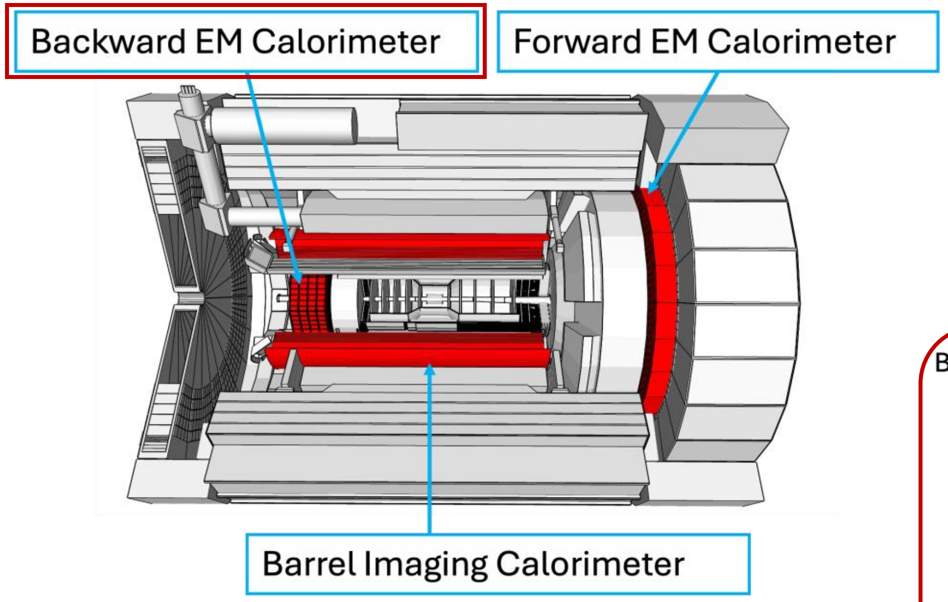
Avg purity for different energies

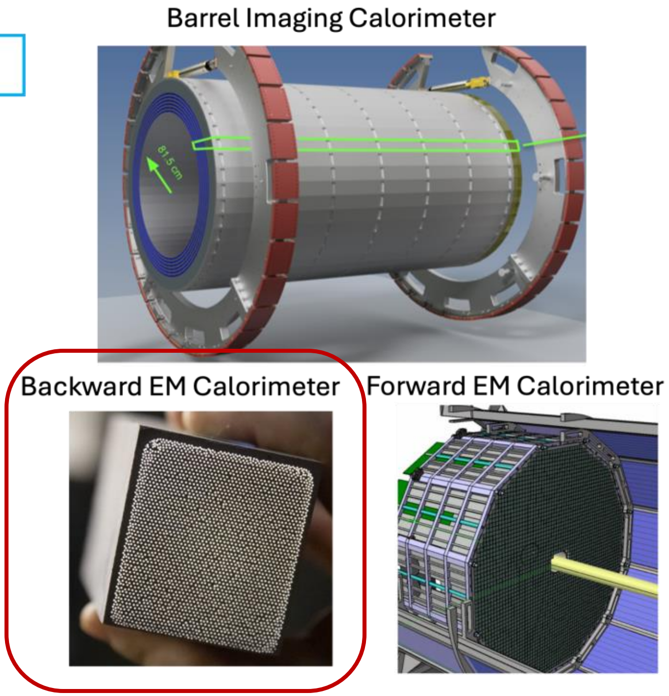


Merging window of
$\Delta R = 0.2$ suffices

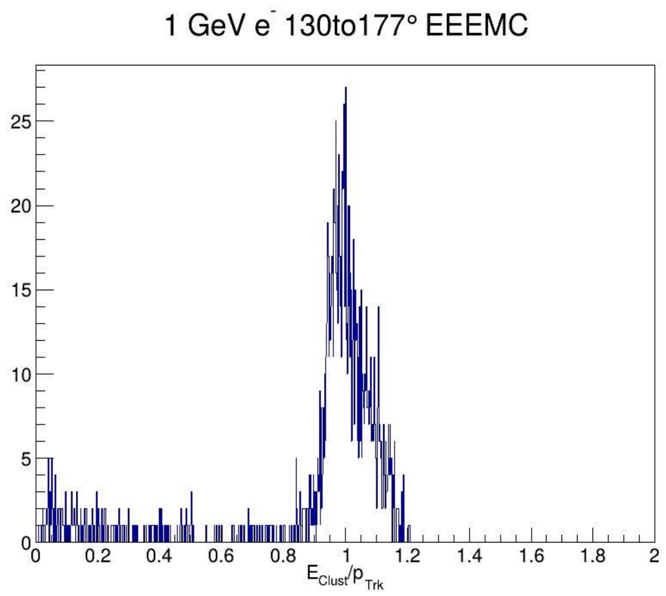
ELECTRON END ELECTROMAGNETIC CALORIMETER (EEEMC)

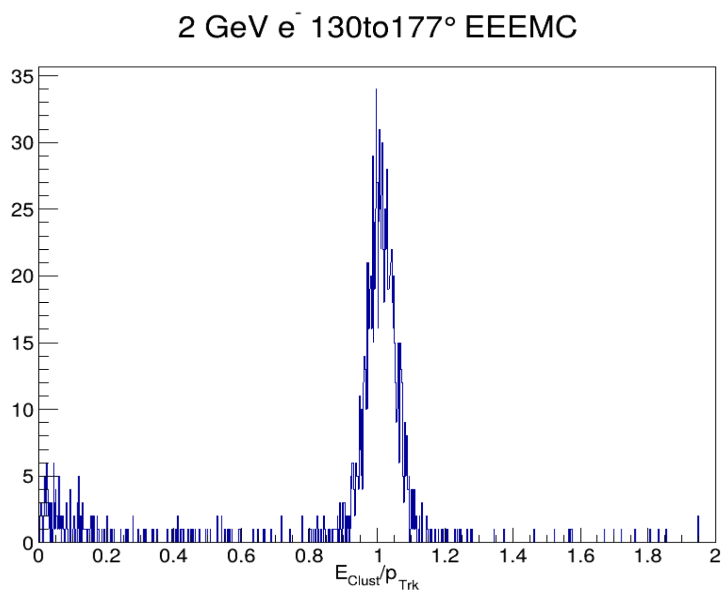
eta: (-3.5, -1.8)

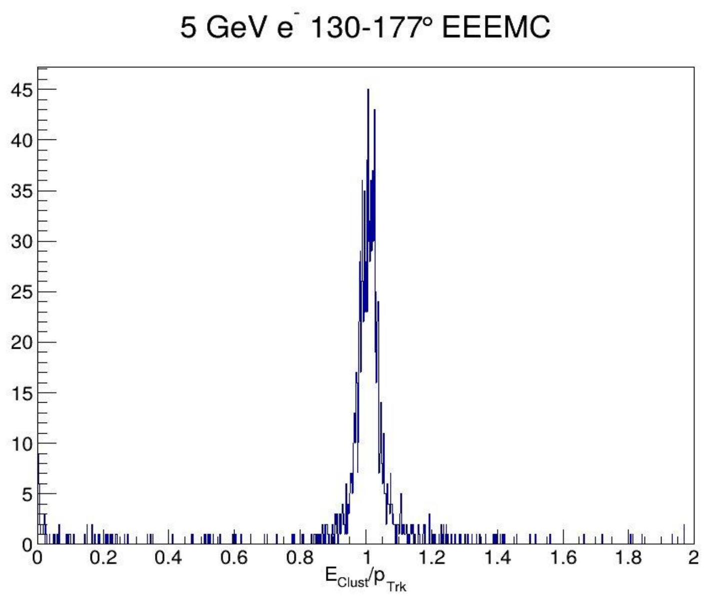


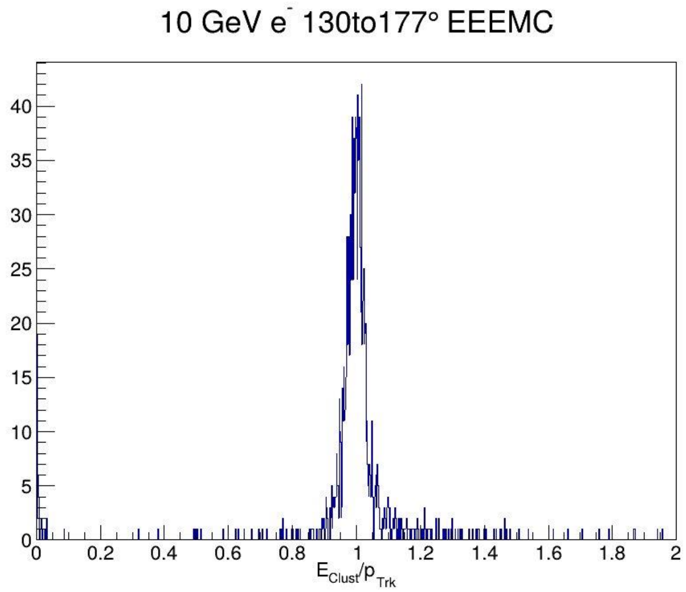


E/p distribution of seed clusters for different e- incident energies in EEEMC



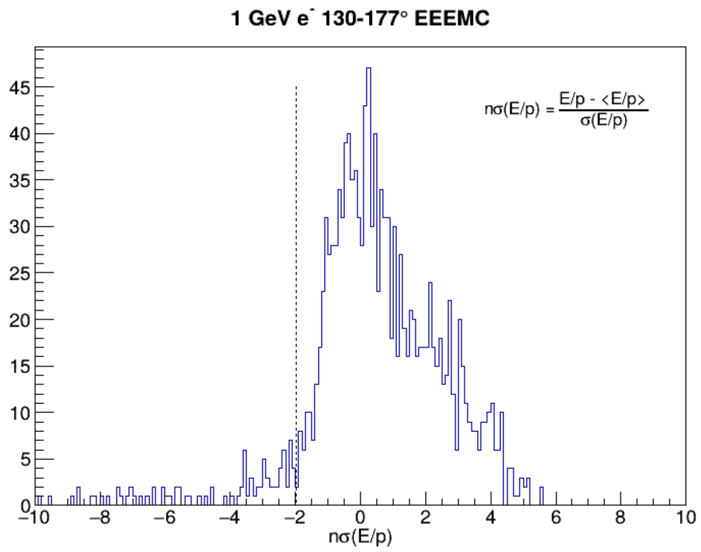


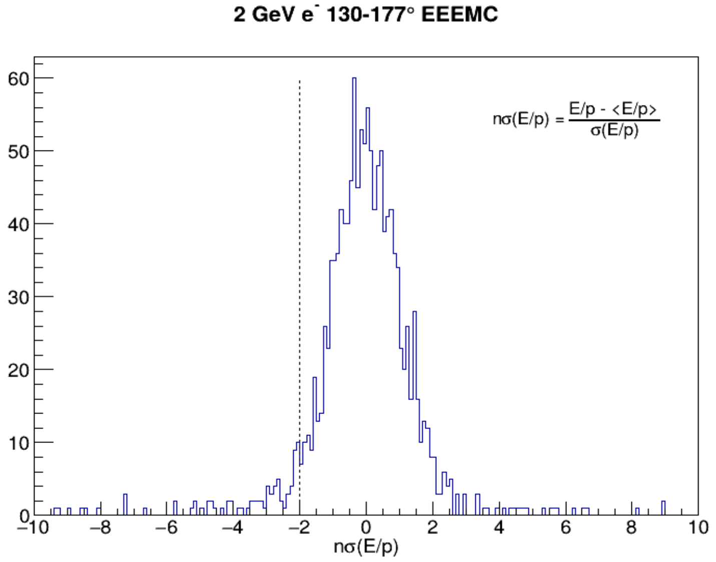


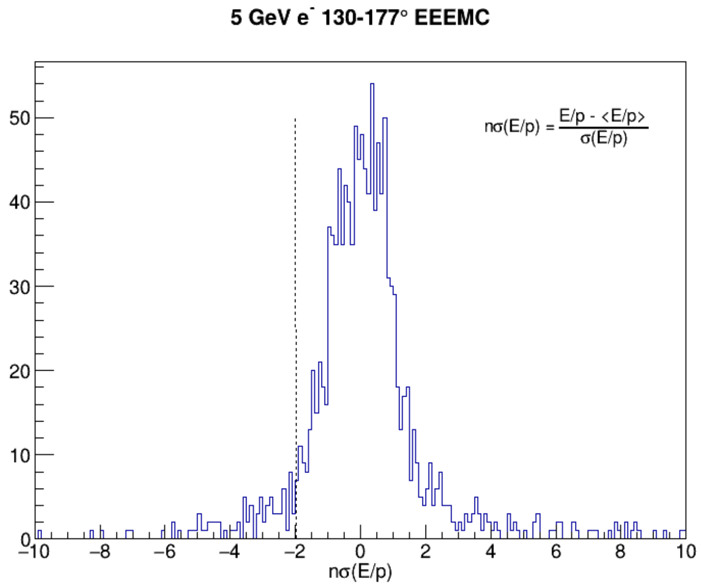


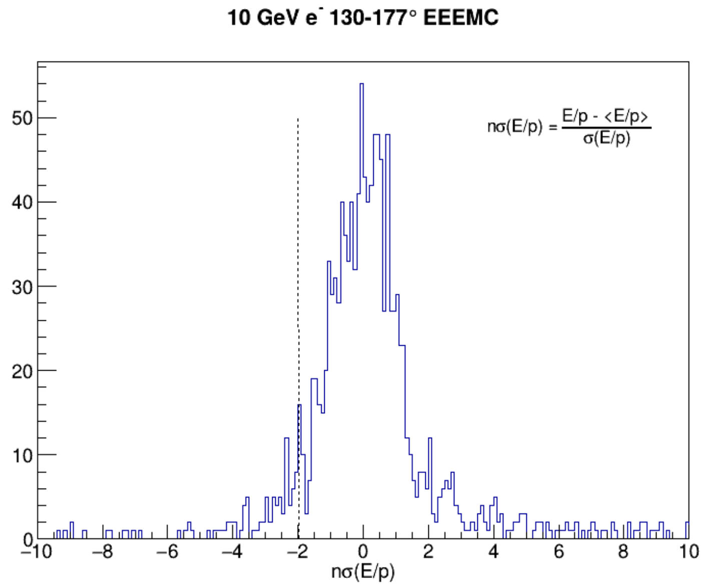
The splitting is less in EEEMC.

Significance distribution of all seed clusters in EEMC



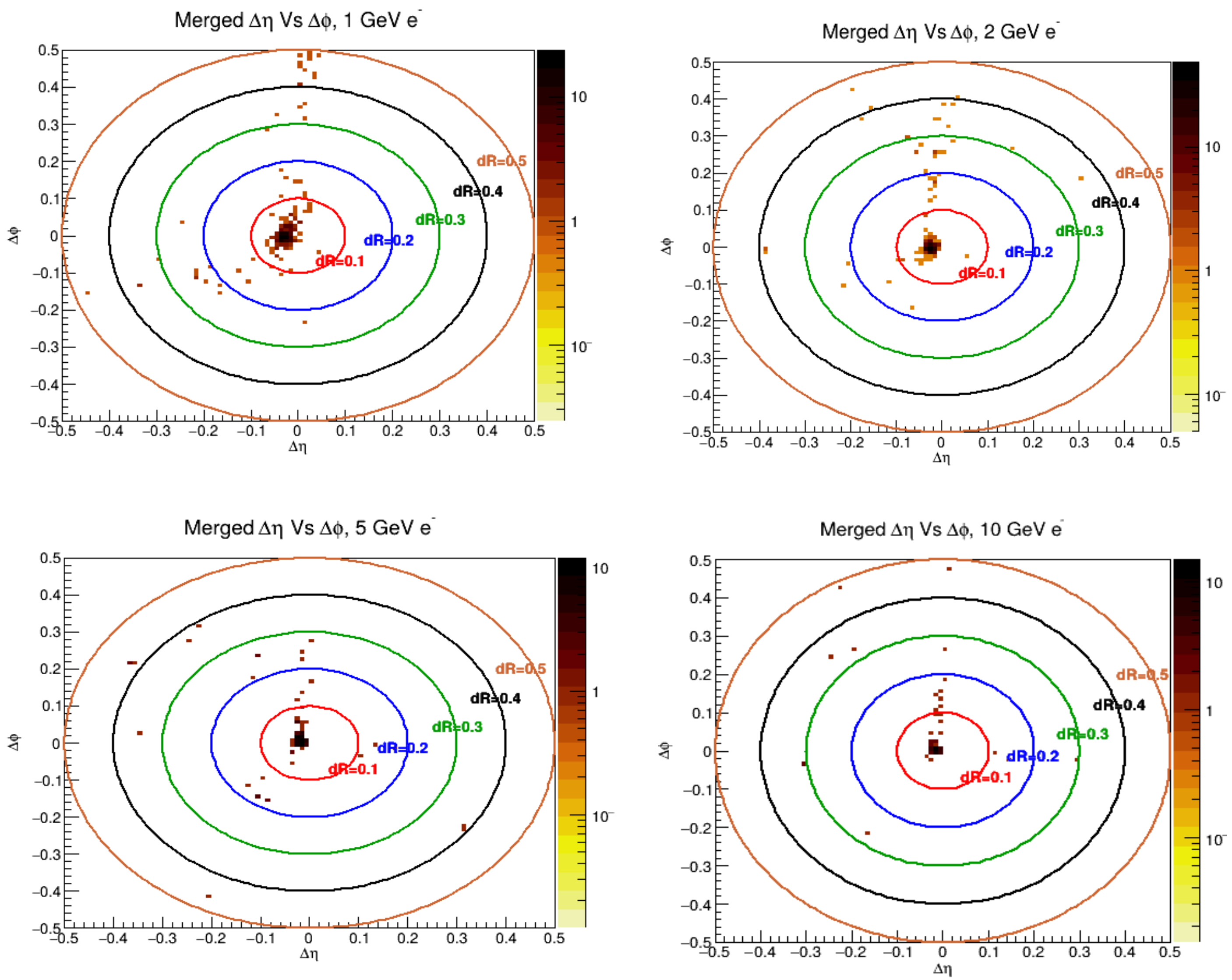






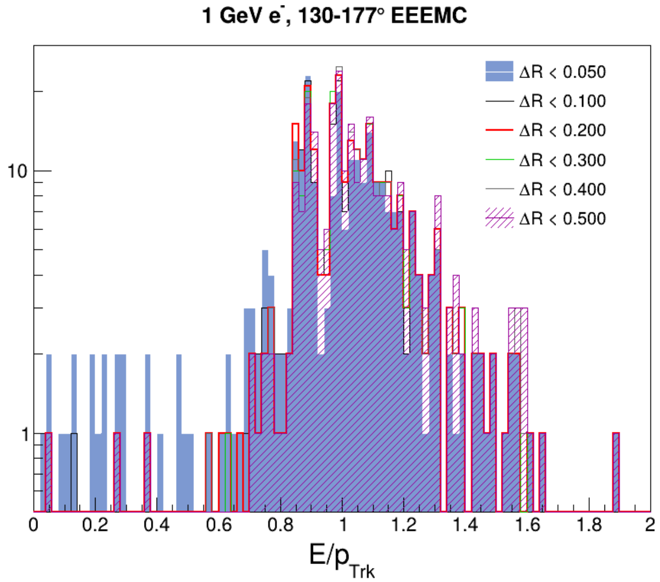
- Shows the sigma boundary between the two populations.
- Sigma < -2 could be due to the split clusters. The same for all incident e- energies.

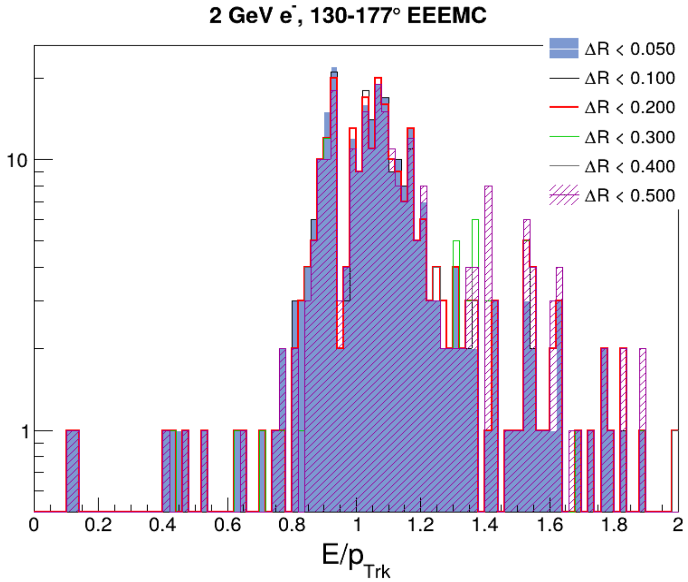
Distribution of clusters around the seed cluster in EEEMC

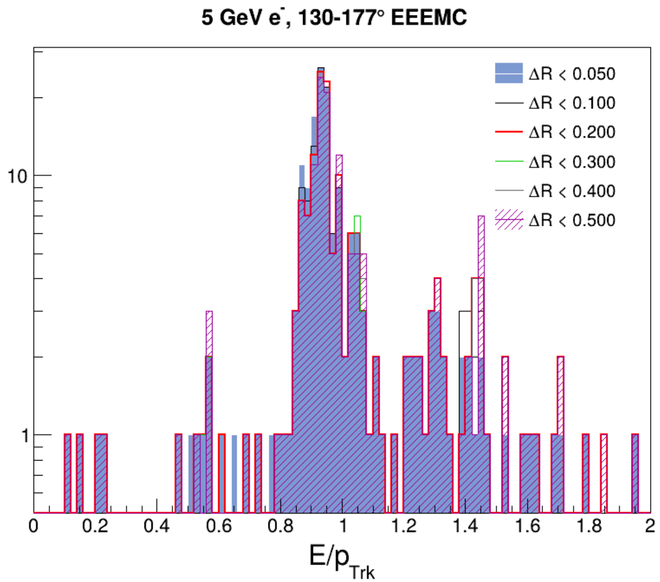


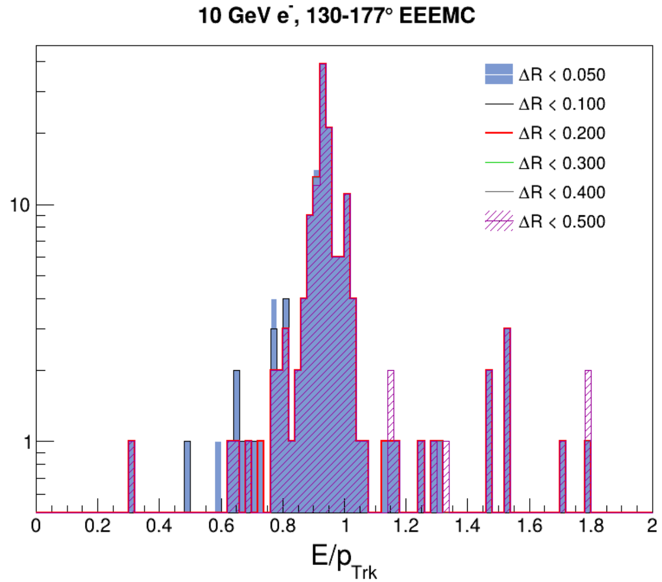
Since there is less splitting, there is fewer clusters around a seed cluster.

E/p distribution against dR (after merging). For fragmented clusters.



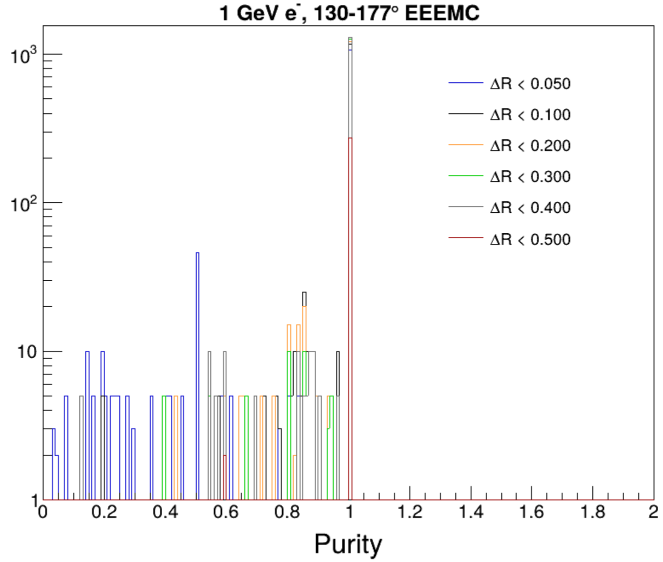


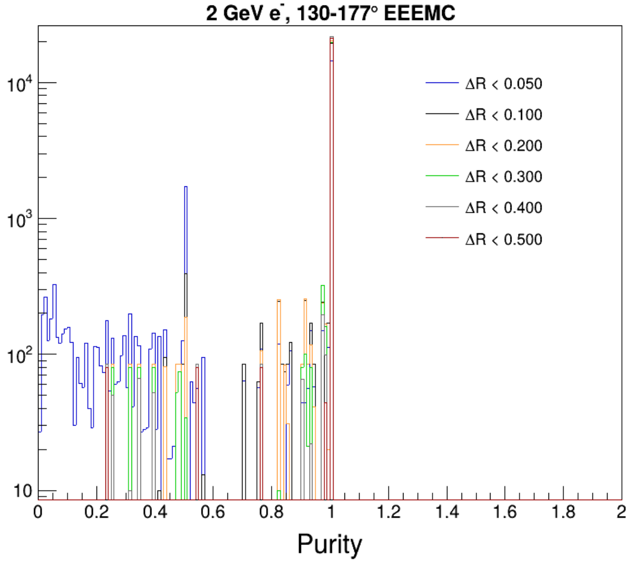


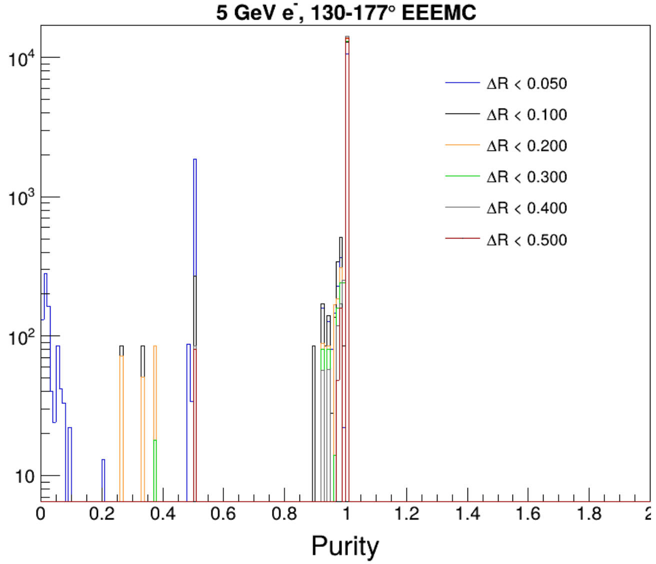


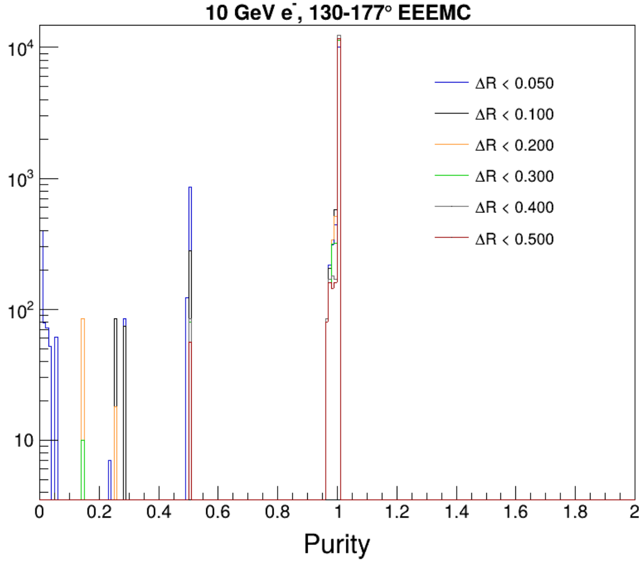
Observed distribution changes as we increase ΔR

Purity distribution against dR in EEEMC

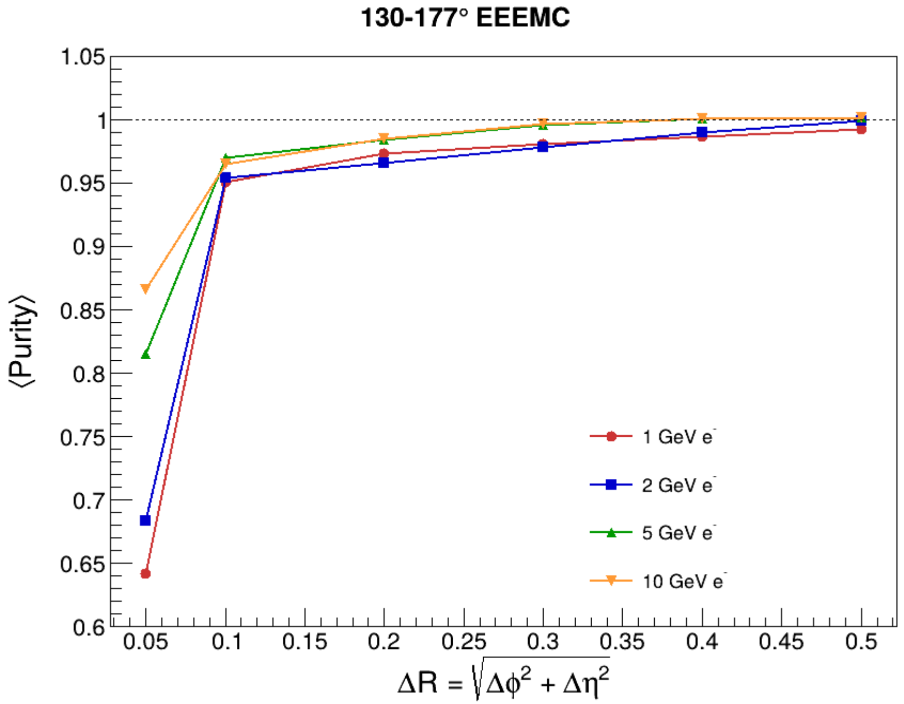








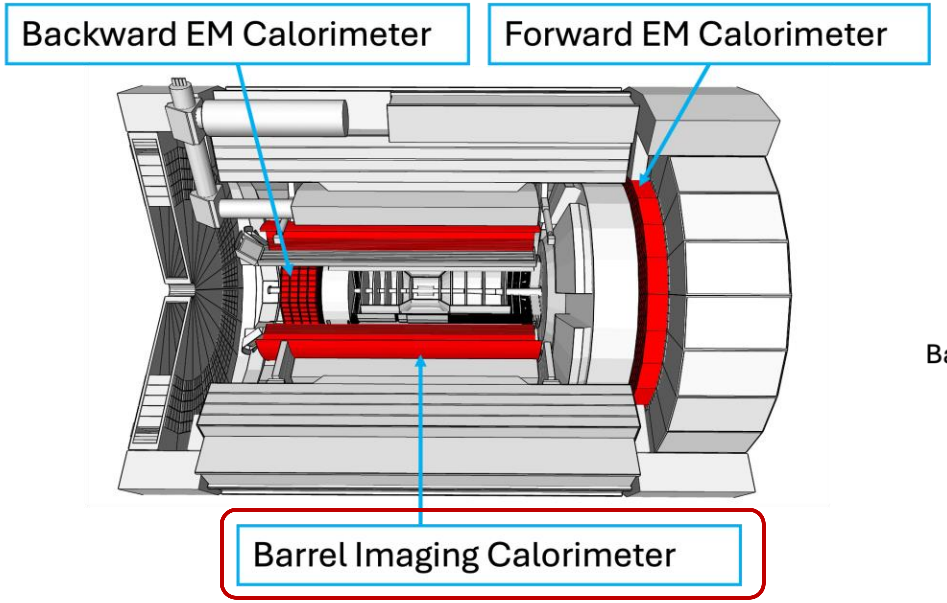
Avg purity for different energies

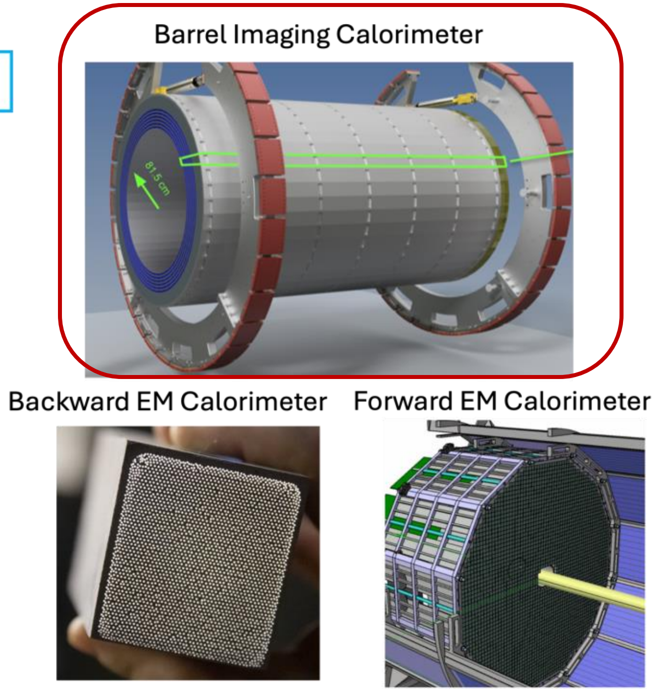


Merging window of $\Delta R = 0.2$ suffices

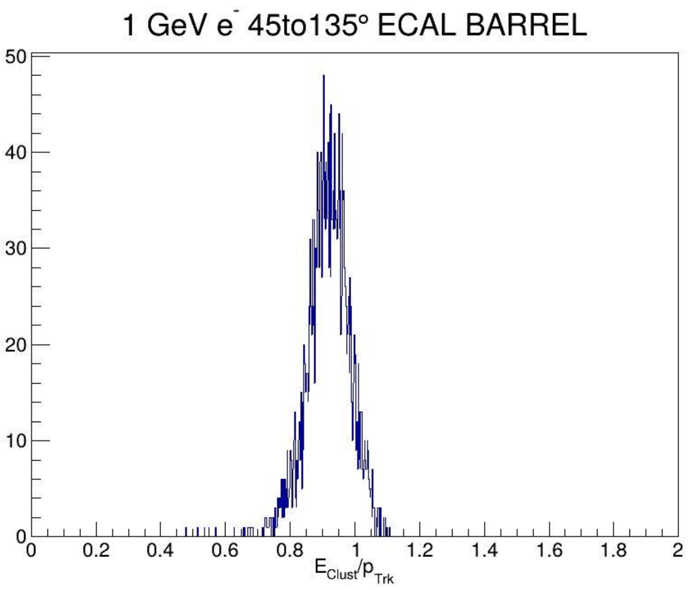
BARREL ELECTROMAGNETIC CALORIMETER (BEMC)

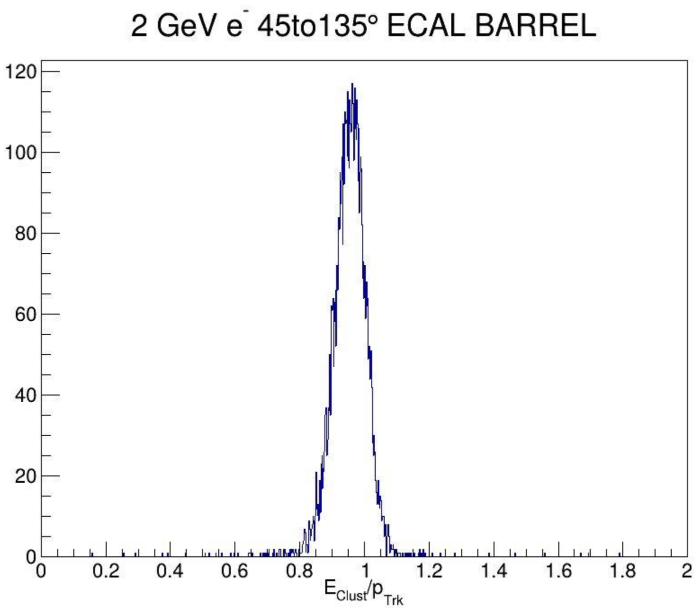
eta: (-1.7, 1.3)

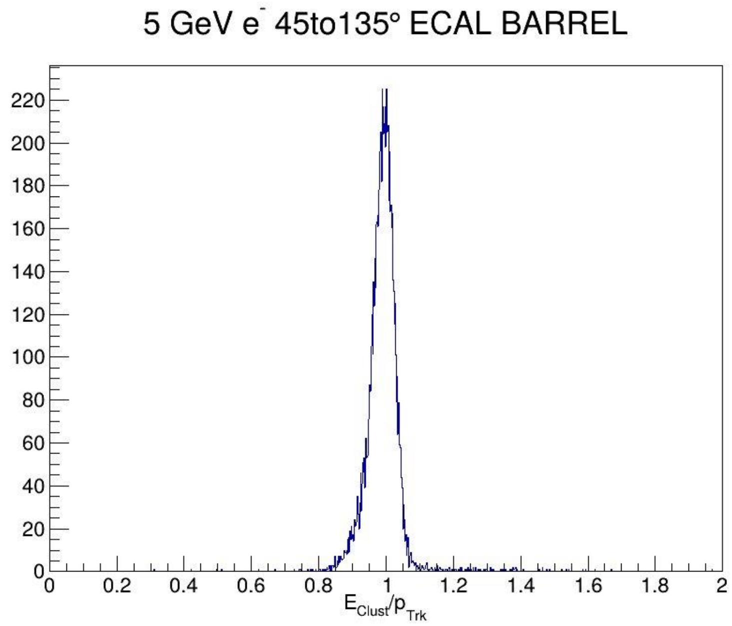




E/p distribution of seed clusters for different e- incident energies in BEMC

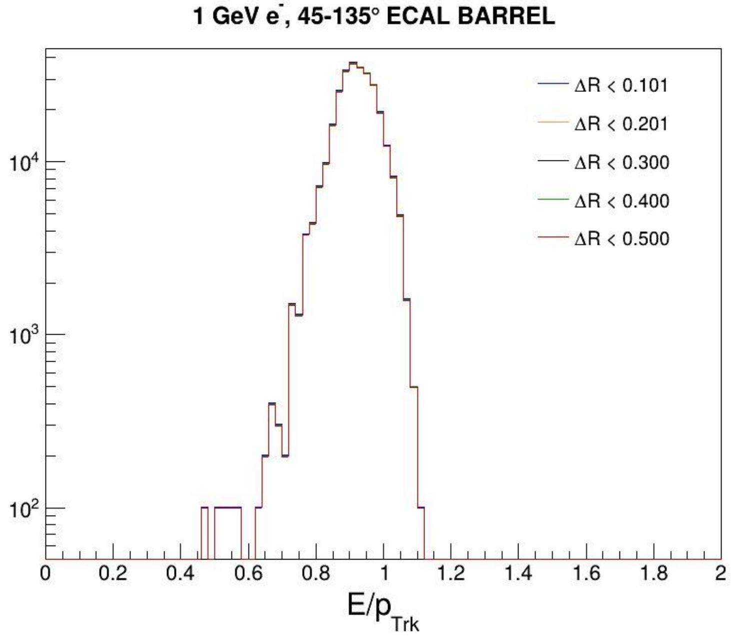


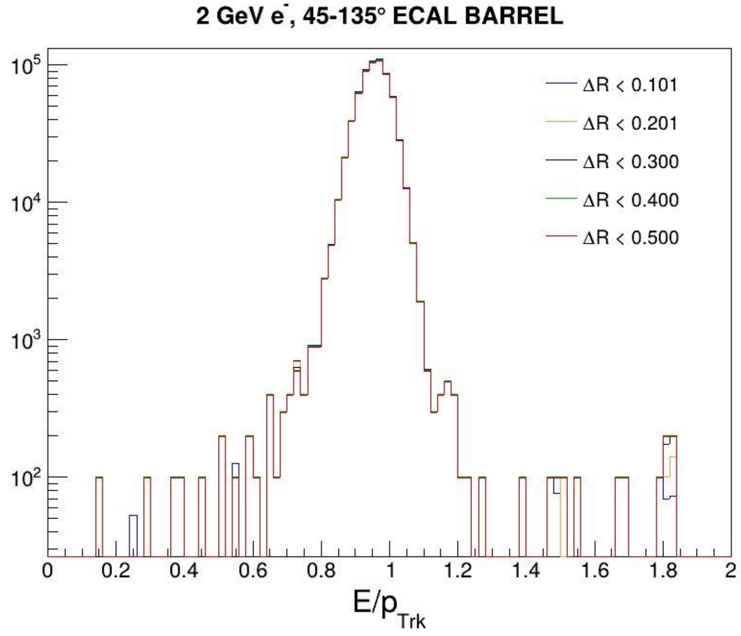


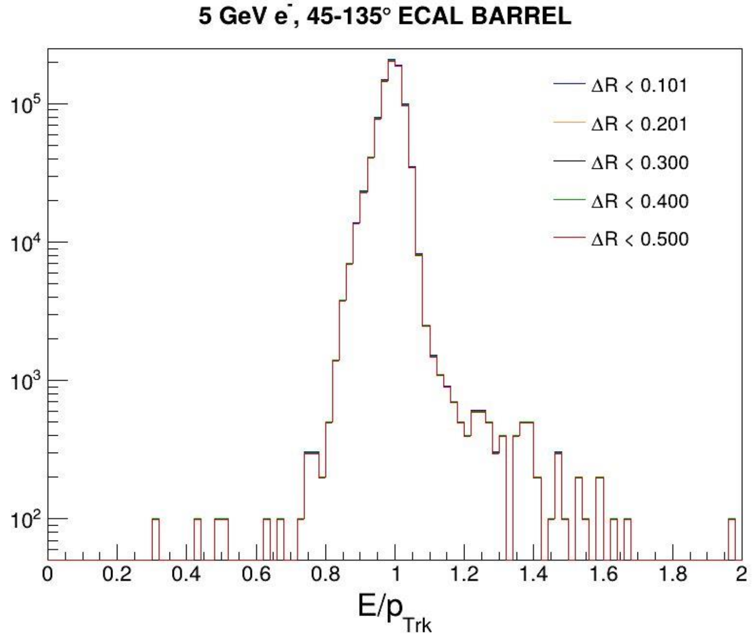


Shows that there's no splitting in BEMC

E/p distribution against dR (after merging). For all seed clusters.







E/p shows no improvement after merging, as there is no splitting

Discussion and Results

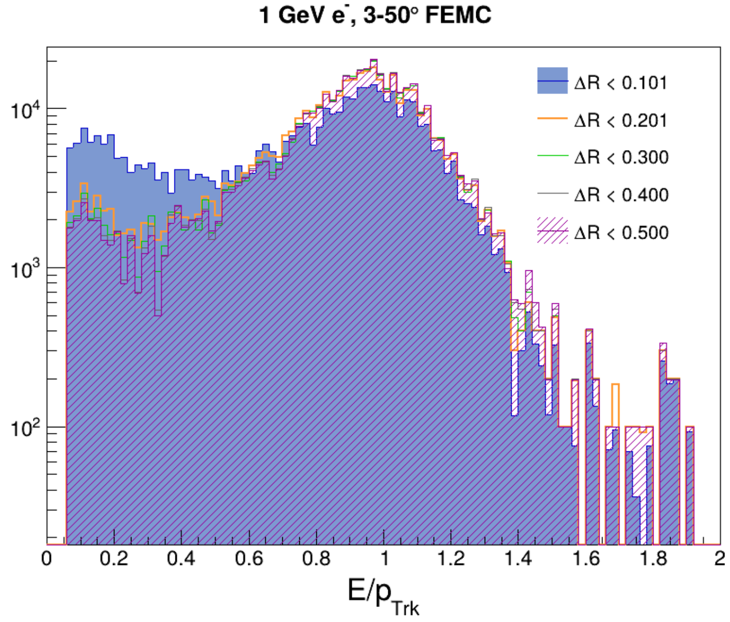
1. For EMCal, merging window, dR ~ 0.2-0.3
2. These values also serve as tuning for Track-cluster matching.
3. Sigma Threshold for EMCals can be set to –2 for merging split-clusters

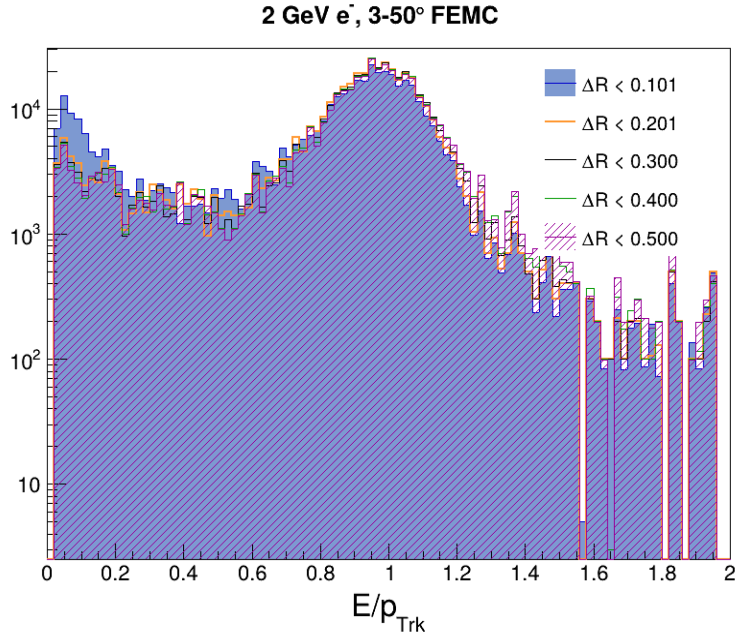
Future Plan

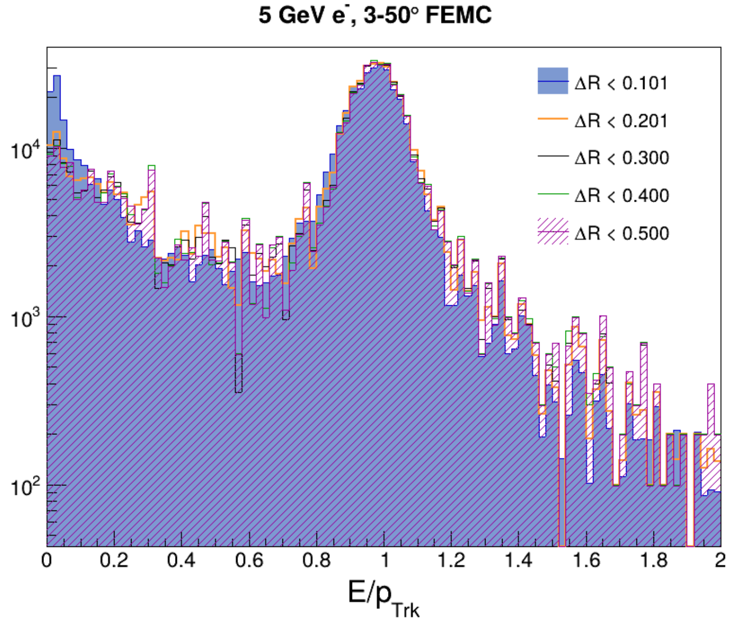
1. Same analysis for Hadronic Calorimeters
2. Do the same analysis for DIS samples. Event generation using Pythia-8.3 . With phase space settings Q2(10to100) => ep_10x100_q2_10to100.root
3. Planning to work on Full jet reconstruction using Particle Flow algorithms.

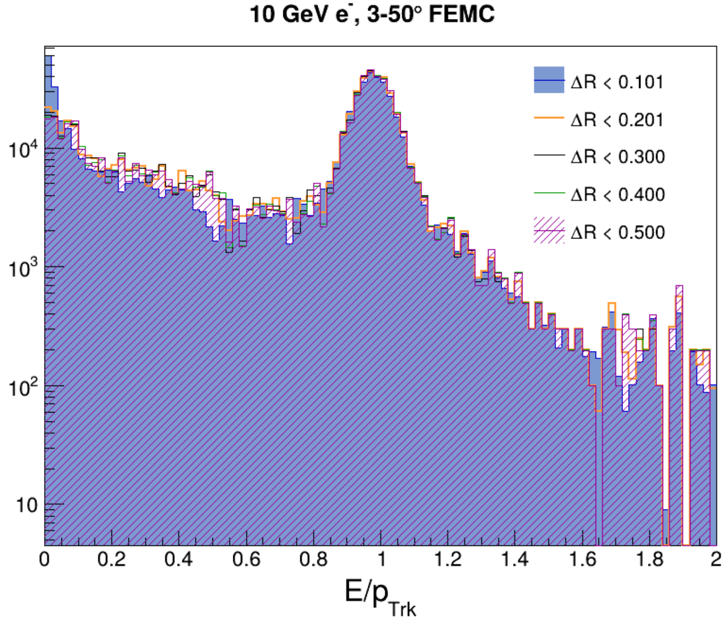
Backup

E/p distribution against dR (after merging). For all seed clusters.

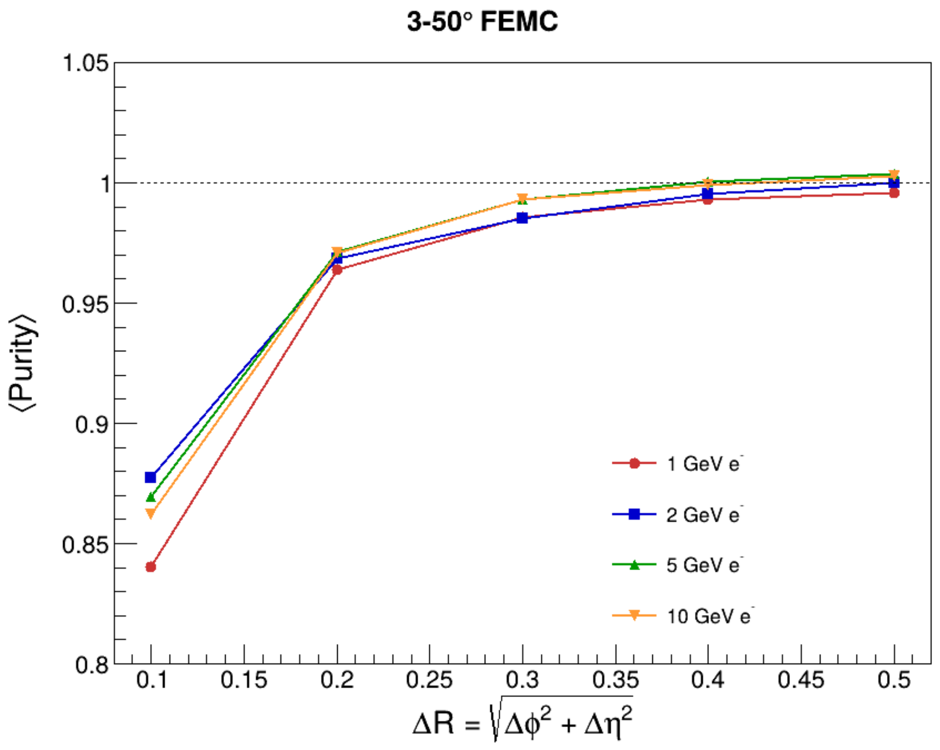




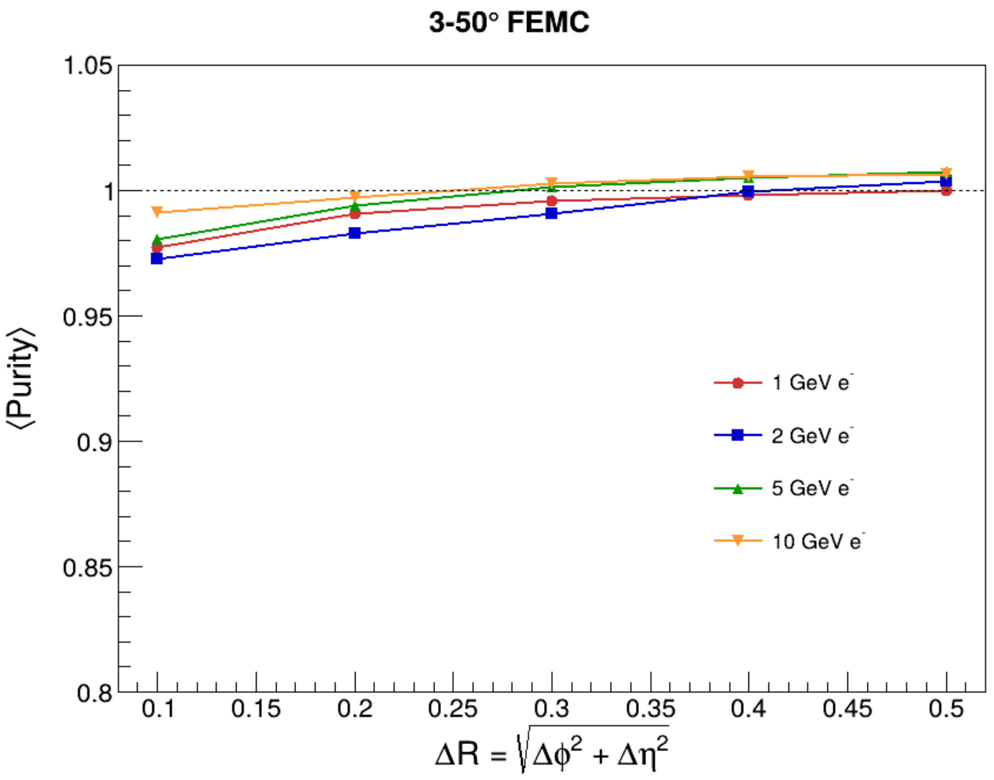




Purity distribution against dR in FEMC

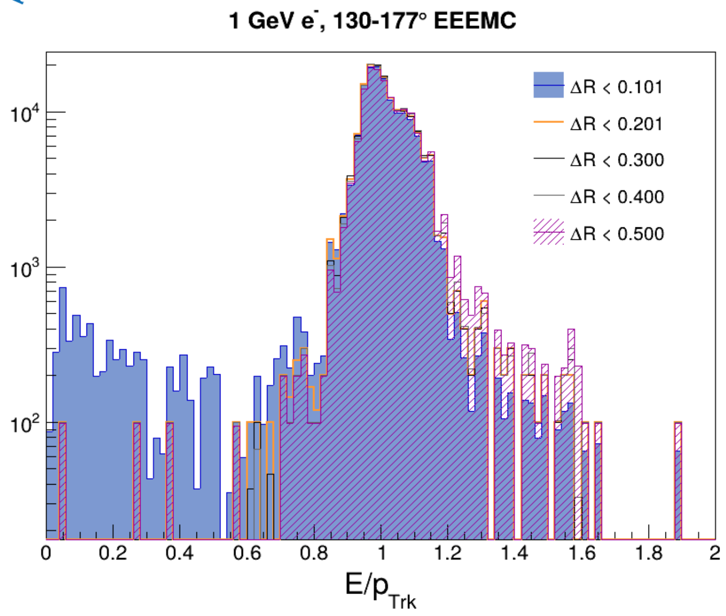


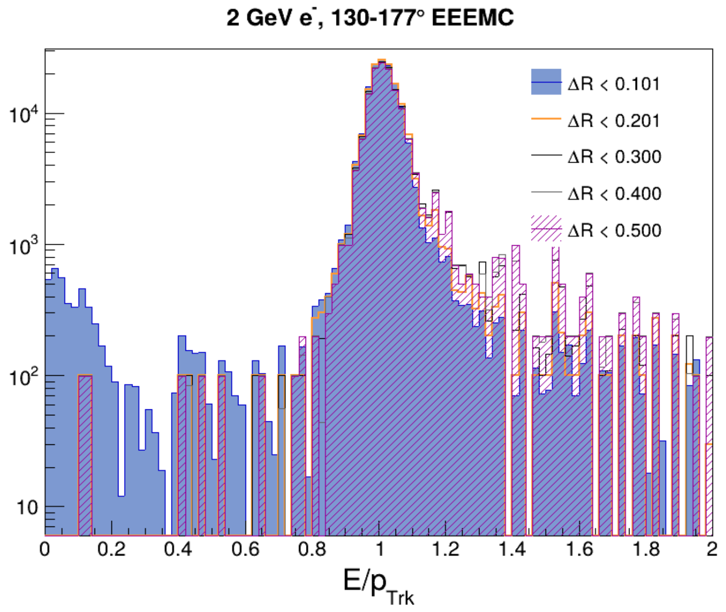
All seed clusters

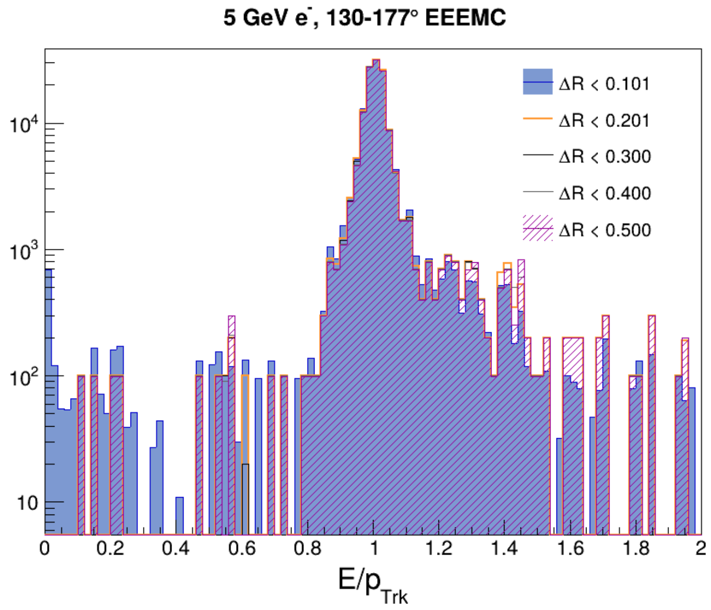


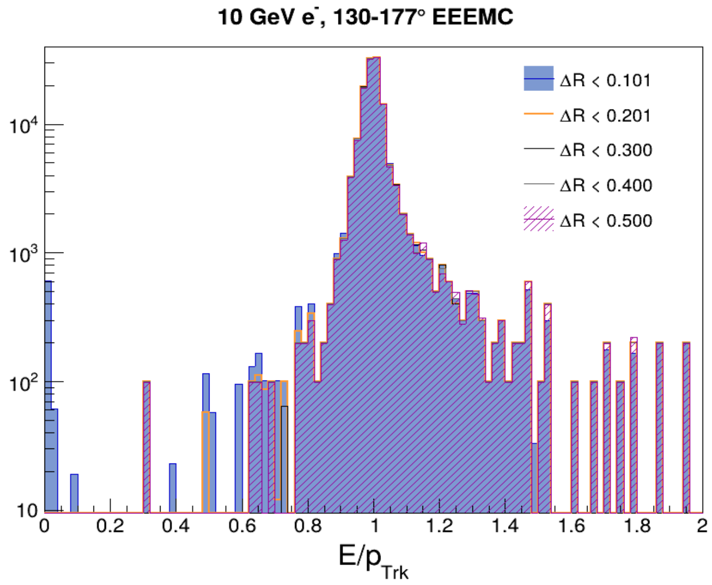
Major clusters

E/p distribution against dR (after merging). For all seed clusters.



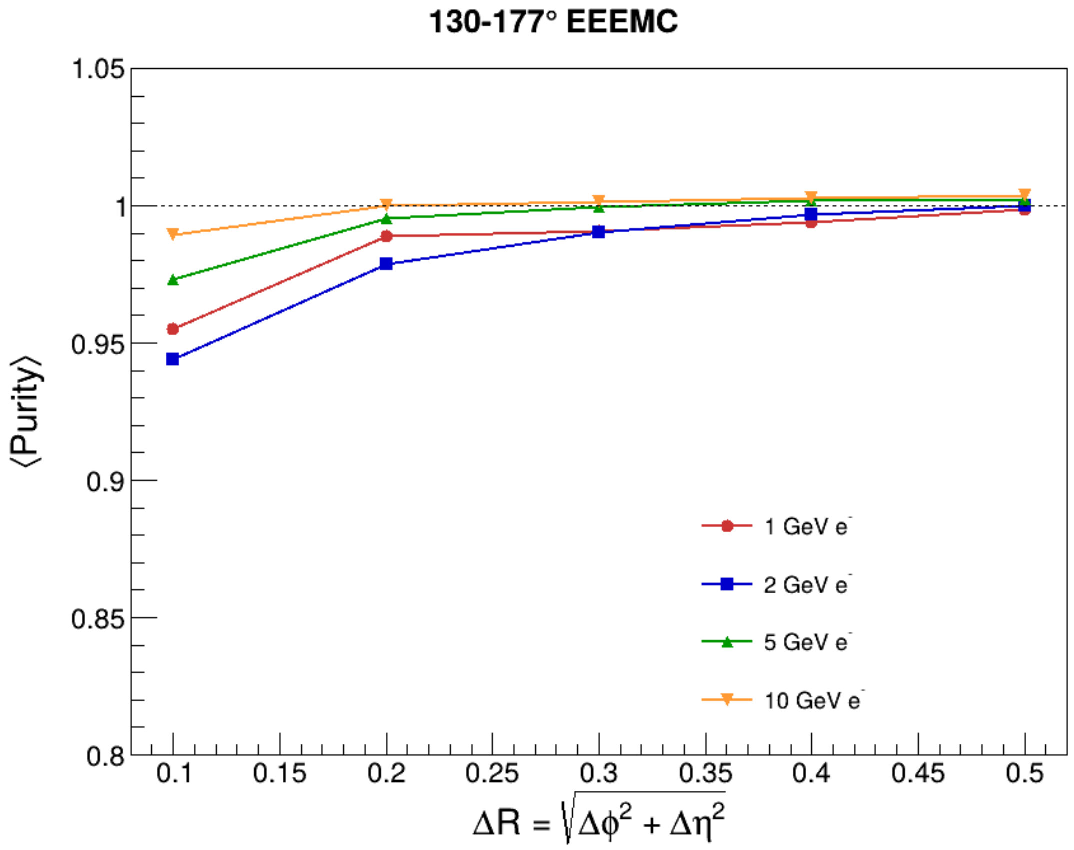




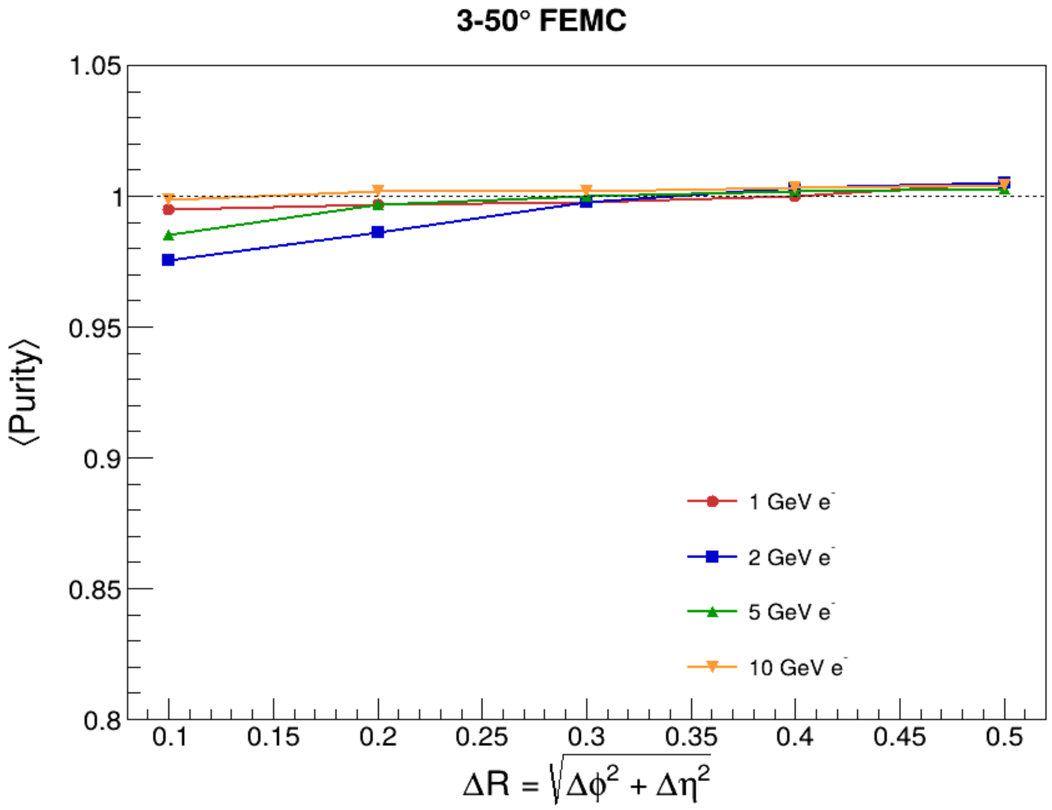


The E/p distribution, shows the suppression of peak near zero as the split clusters are merged.

Purity distribution against dR in EEEMC



All seed clusters



Major clusters