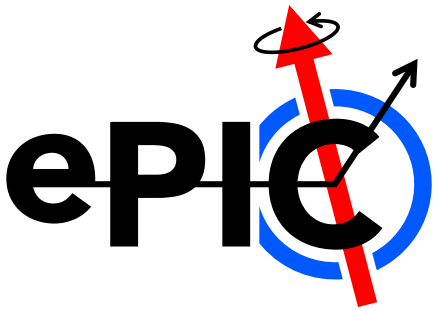
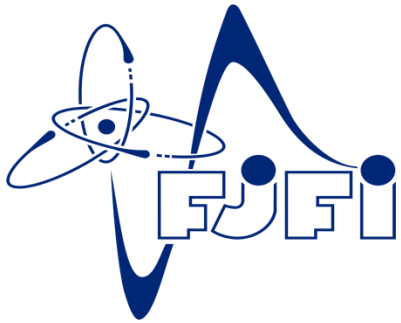
Two-Particle Position Resolution Study from Backward HCal

Leszek Kosarzewski, Alexandr Prozorov, **Subhadip Pal**





ePIC nHCal-DSC meeting – September 6, 2024

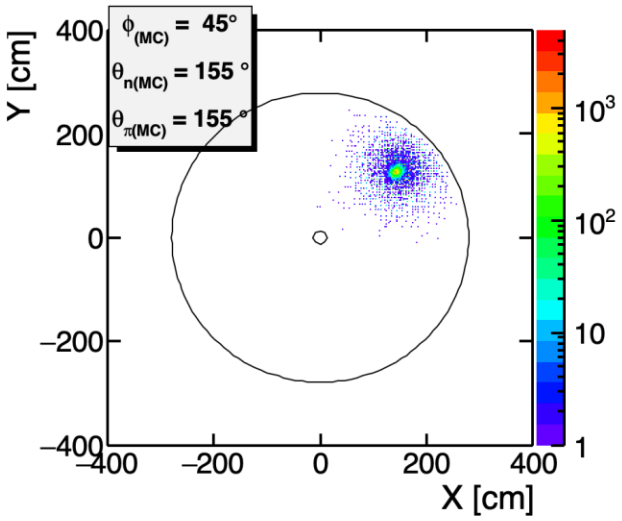
Setup

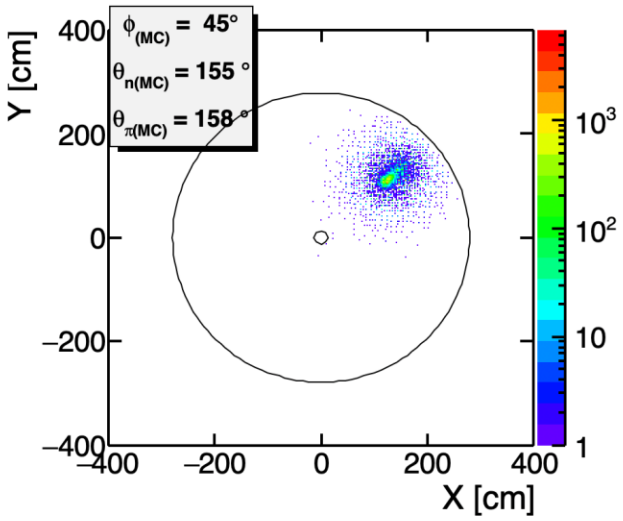
Objective ***:*** *Use clusters to distinguish between neutron/pion shower reconstruction.*

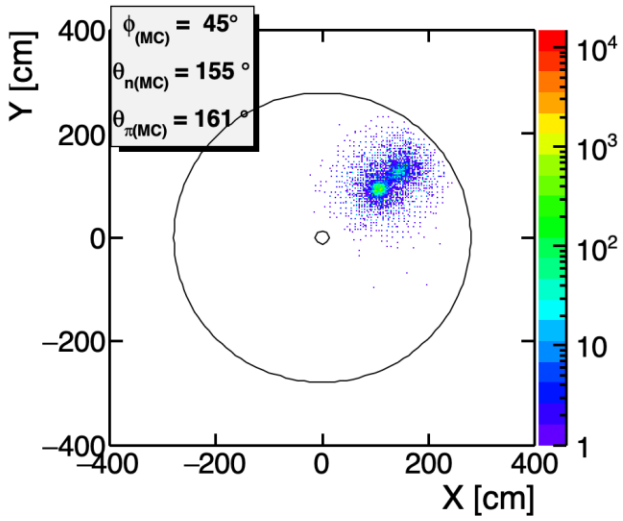
- (1 n + 1 π^-) / event. ---- *Standalone ddsim*
- φ = 45°
  - θ_n = 155° (η = -1.51) ------ *fixed*
  - θ_π = 155° (η = -1.51), 158° (η = -1.64), 161° (η = -1.79), 164° (η = -1.96), 167° (η = -2.17), 170° (η = -2.44)

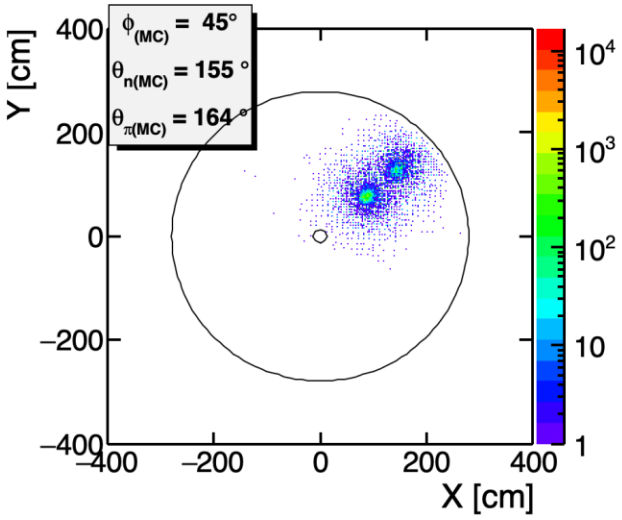
- Only Backward HCal was taken into account [not the whole ePIC geometry – scattering effects neglected]
- −4.14 < η < −1.18
- Alternating Steel and Scintilator slices
- 10 cm. x 10 cm. Polystyrene tiles

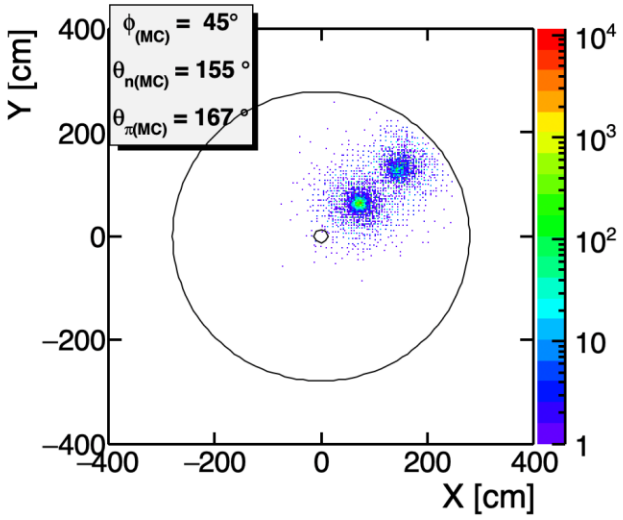
Cluster Positions (xy coordinates)

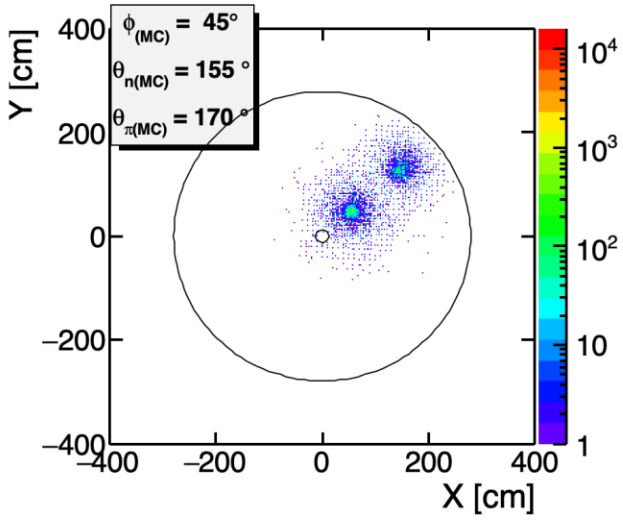












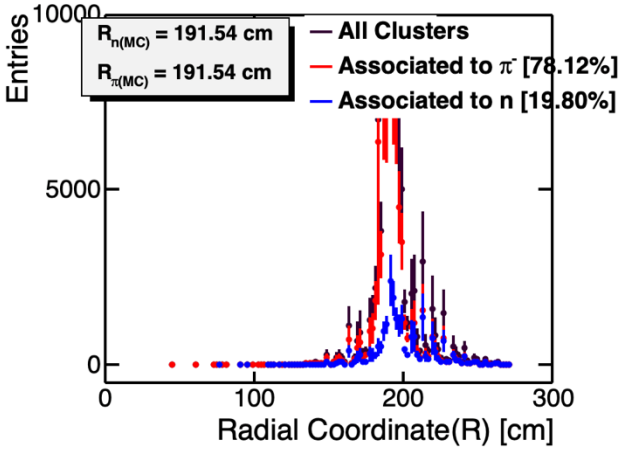
Cluster (x,y) are shown along with simulated angular coordinates

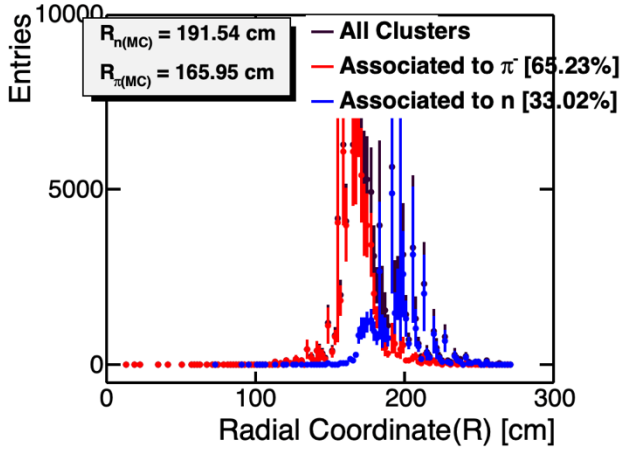
p = 1 GeV/c

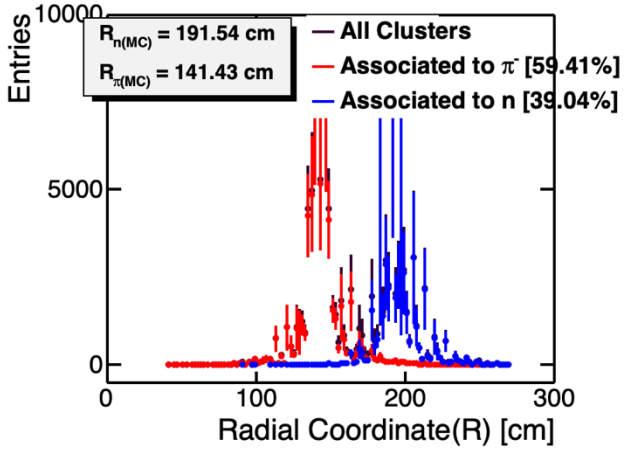
[neutron showers in outer region; pion showers in inner region]

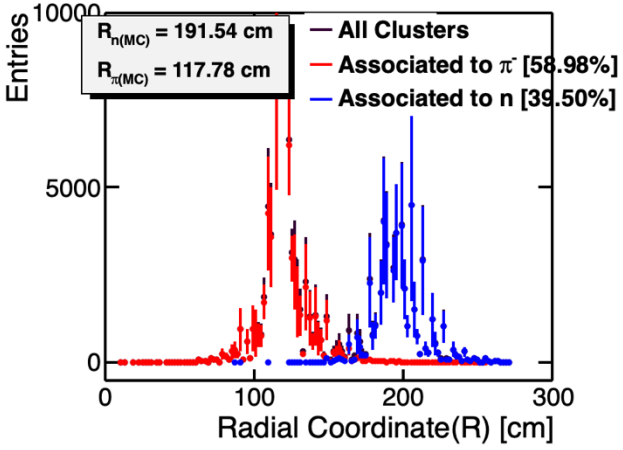
Distributions are becoming ~~more smeared~~ more distinguishable as (θ_π - θ_n) increases…

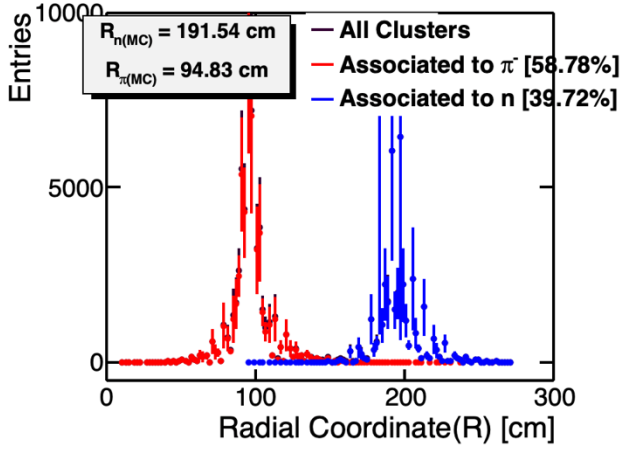
Cluster Radial Coordinates

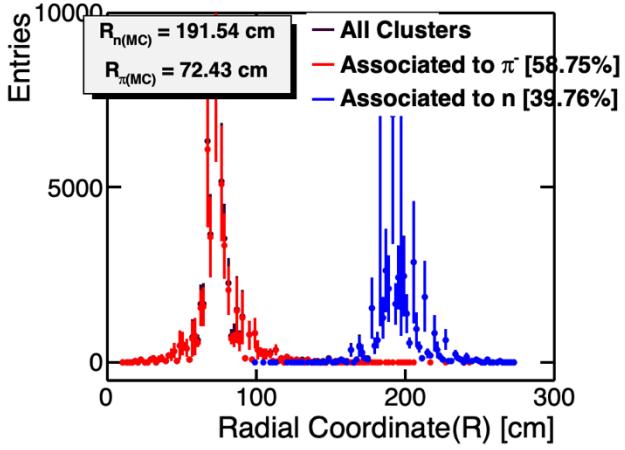












p = 1 GeV/c

~~~ 80% of the clusters associated with pions~~~

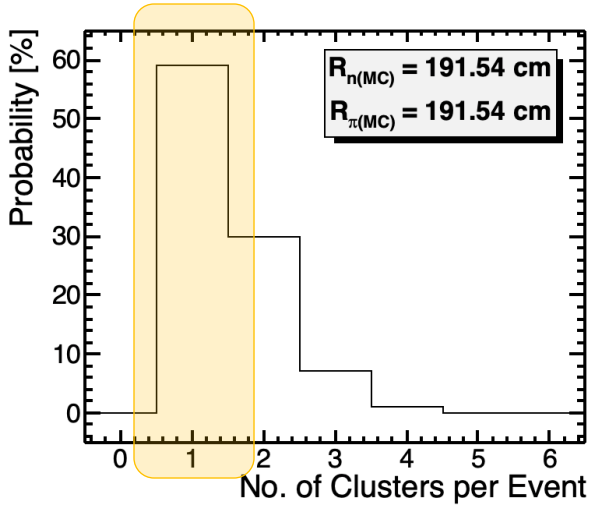
~~~ 20% of the clusters associated with neutrons~~~

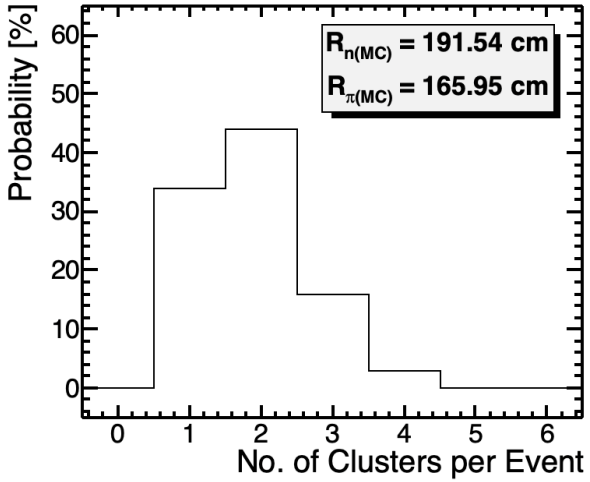
~~Neutron Clusters start to shift inwards as $(R_n - R_\pi)$ increases~~

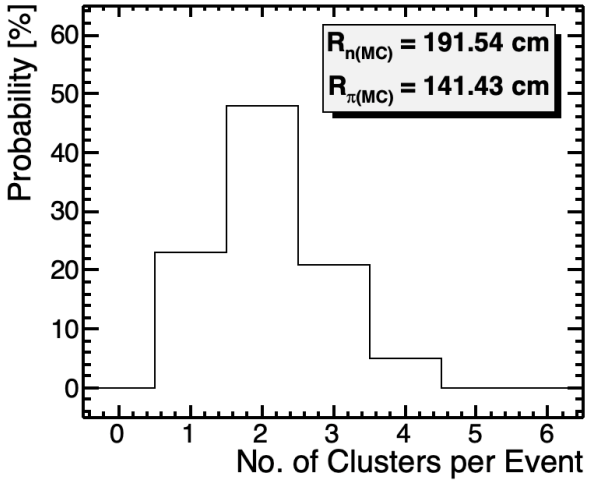
Percentages (fraction of clusters identified as π-/n clusters) are based on ClusterMCParticle associations [better performance as the π-n distance increases]

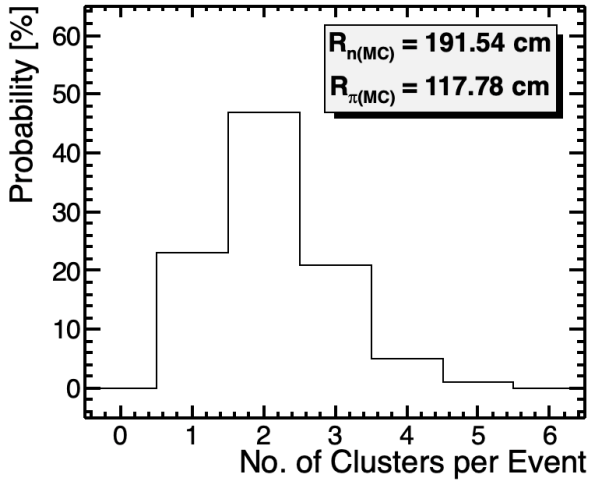
Clusters are in the expected positions

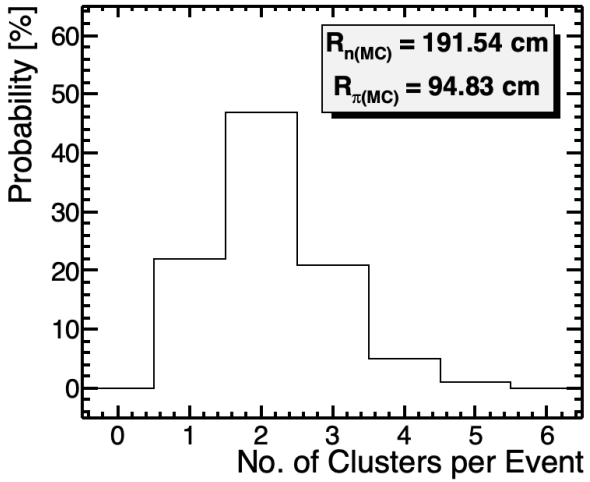
Cluster Reconstruction

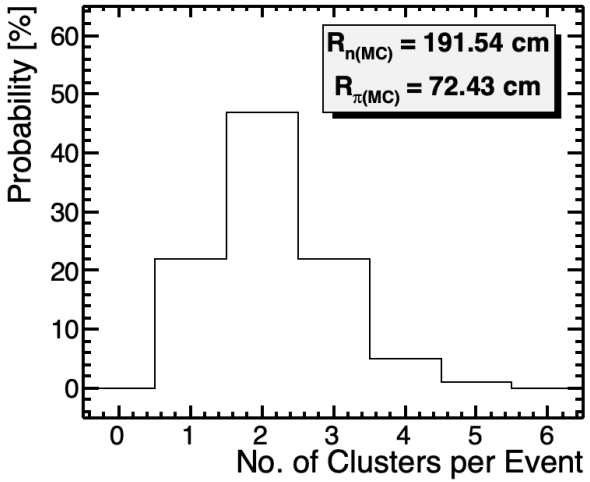




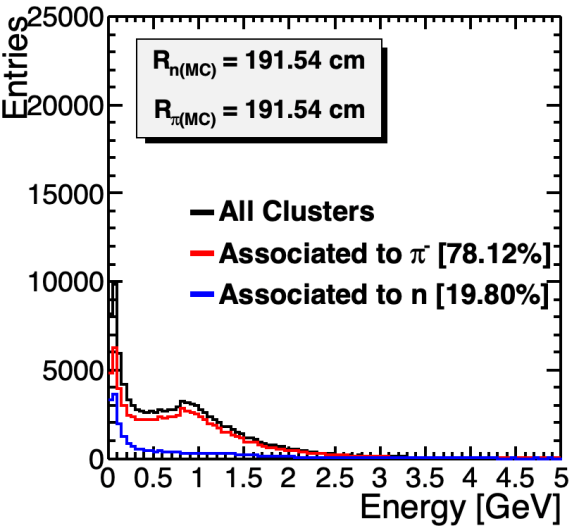


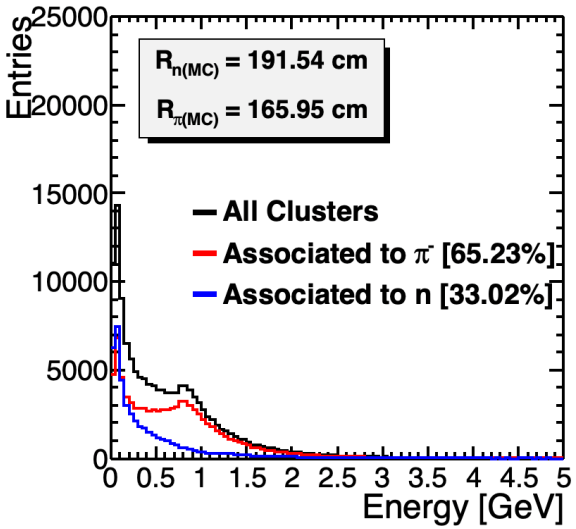


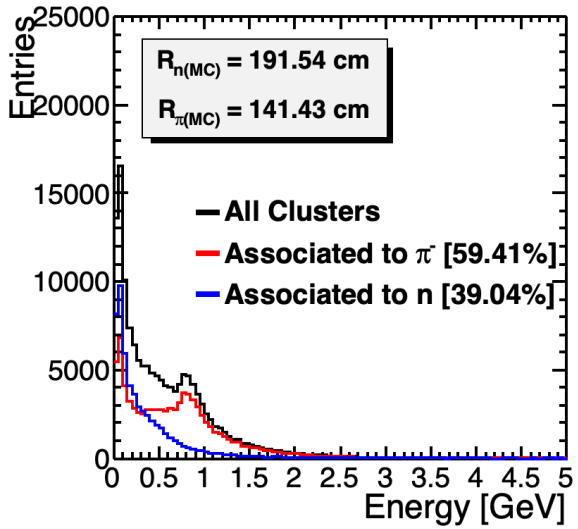


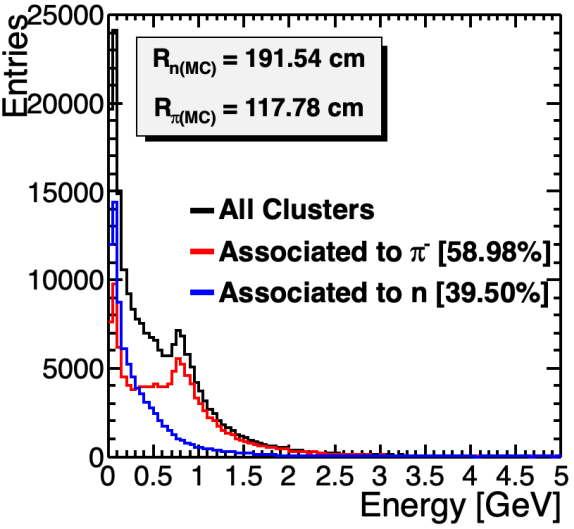


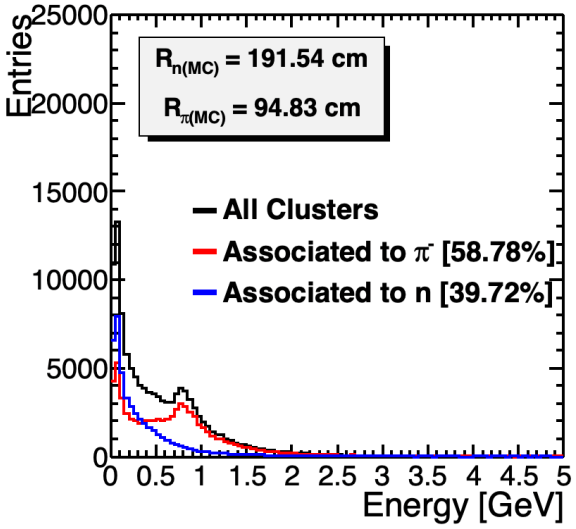
Cluster Reconstruction

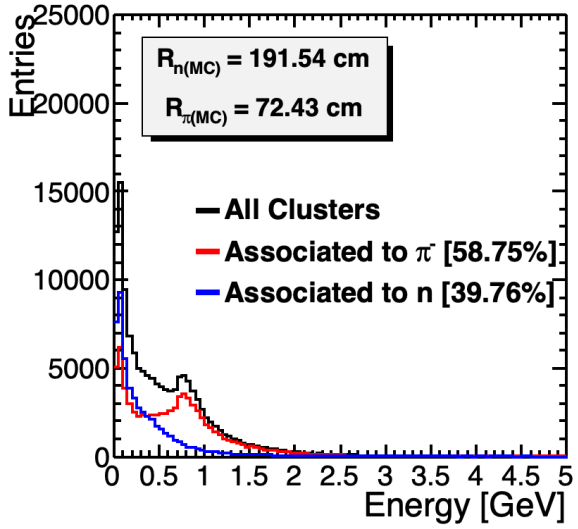




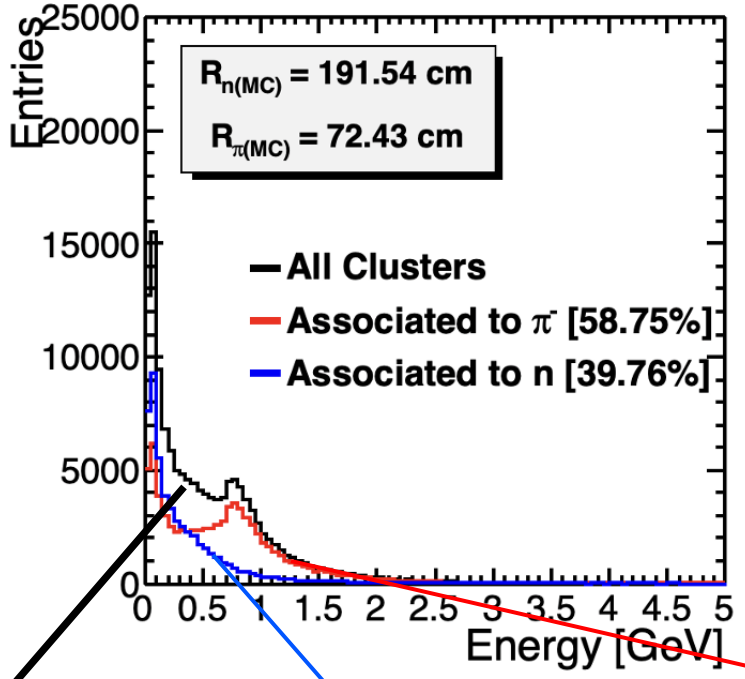




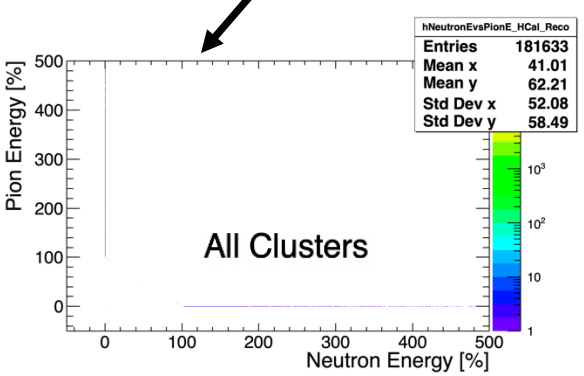


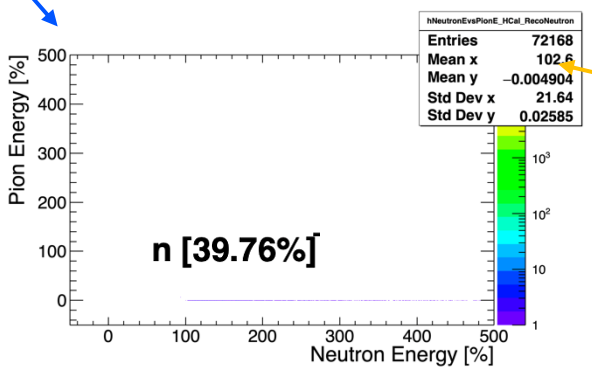


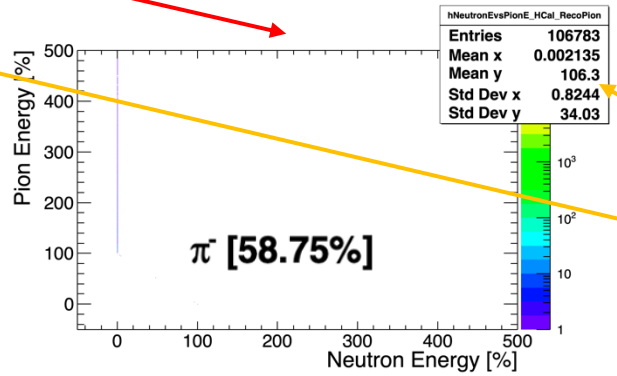
Cluster Reconstruction



- Cluster energies have been traced back to the constituent ~~recoHits~~ mergedRecoHits [can be accessed via cluster.getHits()] which were tagged as pion/neutron hits based on the most energetic hit contribution of the mapped simHit [can be accessed by comparing cellIDs] of the mergedRecoHits.







Cluster-MCparticle Association works well.

$$Pion(Neutron)Energy\% = \frac{\sum Pion(Neutron)RecohitEnergy}{ClusterEnergy} \times 100$$

Cluster Reconstruction

Processing event 84959/85000... # **Event containing 2 clusters**

[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 0, 16, 59, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.0263415, time = 17.3, pos.z() = -4107.5
Sim Hit: energy = 0.000220031
Contrib: energy = 0.000220031, time = 17.303
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 1, 24, 89, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.132992, time = 14.29, pos.z() = -4107.5
Sim Hit: energy = 0.00127383
Contrib: energy = 0.00121976, time = 14.2872
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 2, 23, 84, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.462582, time = 13.83, pos.z() = -4107.5
Sim Hit: energy = 0.00295112
Contrib: energy = 0.000721806, time = 14.039
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 3, 30, 102, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.0424034, time = 14.62, pos.z() = -4107.5
Sim Hit: energy = 0.000395054
Contrib: energy = 3.9479e-06, time = 68.6456
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 4, 35, 132, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.0841643, time = 14.22, pos.z() = -4107.5
Sim Hit: energy = 0.000807706
Contrib: energy = 0.000807706, time = 14.2187
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (0, 5, 37, 134, 3)
Cluster: energy = 0.721966, nHits = 6
Rec Hit: energy = 0.090589, time = 14.8, pos.z() = -4107.5
Sim Hit: energy = 0.000865865
Contrib: energy = 0.00016734, time = 14.7966
Particle: energy = 1.00969, pdg = -211, gen status = 1

[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (1, 0, 16, 59, 3)
Cluster: energy = 0.117107, nHits = 6
Rec Hit: energy = 0.0263415, time = 17.3, pos.z() = -4107.5
Sim Hit: energy = 0.000220031
Contrib: energy = 0.000220031, time = 17.303
Particle: energy = 1.00969, pdg = -211, gen status = 1
[Contrib #0] (cluster, reco hit, sim hit, contrib, particle) ID = (1, 1, 24, 89, 3)
Cluster: energy = 0.117107, nHits = 6
Rec Hit: energy = 0.132992, time = 14.29, pos.z() = -4107.5
Sim Hit: energy = 0.00127383
Contrib: energy = 0.00121976, time = 14.2872
Particle: energy = 1.00969, pdg = -211, gen status = 1
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Cluster: energy = 0.117107, nHits = 6
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Particle: energy = 1.00969, pdg = -211, gen status = 1

Constituent RecHit energies can be > Cluster energies
**continued discussion on next slide*

Cluster 1:

cluster.getEnergy(): 0.721966
hcalreco_neutronE: 0
hcalreco_pionE: 0.839073

Pion energy contribution > cluster energy

Cluster 2:

cluster.getEnergy(): 0.117107
hcalreco_neutronE: 0
hcalreco_pionE: 0.839073

*Rec hits are mergedRechits [look at the pos.z()]

Cluster Reconstruction

Cluster energy is determined after doing a weighted sum of the mergedhits.
If the weight is too small, cluster energy can be < a constituent mergedhit energy.

```
for (unsigned i = 0; i < pcl.getHits().size(); ++i) {
const auto& hit = pcl.getHits()[i];
const auto weight = pcl.getWeights()[i];
debug("hit energy = {} hit weight: {}", hit.getEnergy(), weight);
auto energy = hit.getEnergy() * weight;
totalE += energy;
time += (hit.getTime() - time) * energy / totalE;
cl.addToHits(hit);
cl.addToHitContributions(energy);
const float eta = edm4hep::utils::eta(hit.getPosition());
if (eta < minHitEta) {
minHitEta = eta;
}
if (eta > maxHitEta) {
maxHitEta = eta;
}
}
cl.setEnergy(totalE / m_cfg.sampFrac);
cl.setEnergyError(0.);
cl.setTime(time);
cl.setTimeError(timeError);
```

If a mergedRecoHit is far away from a local maxima; it will have a less weight to the cluster corresponding to that local maxima.

```
for (std::size_t idx : group) {
size_t j = 0;
// calculate weights for local maxima
for (std::size_t cidx : maxima) {
double energy = hits[cidx].getEnergy();
double dist = edm4hep::utils::magnitude(transverseEnergyProfileMetric(hits[cidx], hits[idx]));
weights[j] = std::exp(-dist * transverseEnergyProfileScaleUnits / m_cfg.transverseEnergyProfileScale) * energy;
j += 1;
}

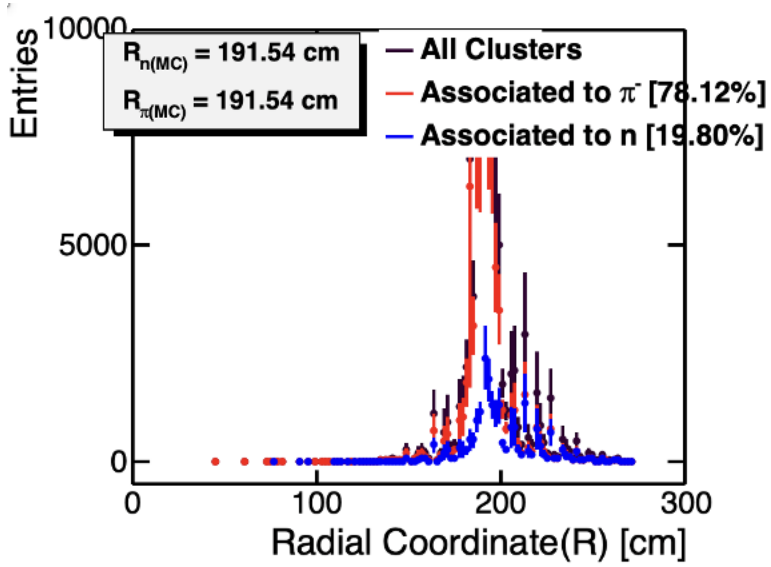
// normalize weights
vec_normalize(weights);

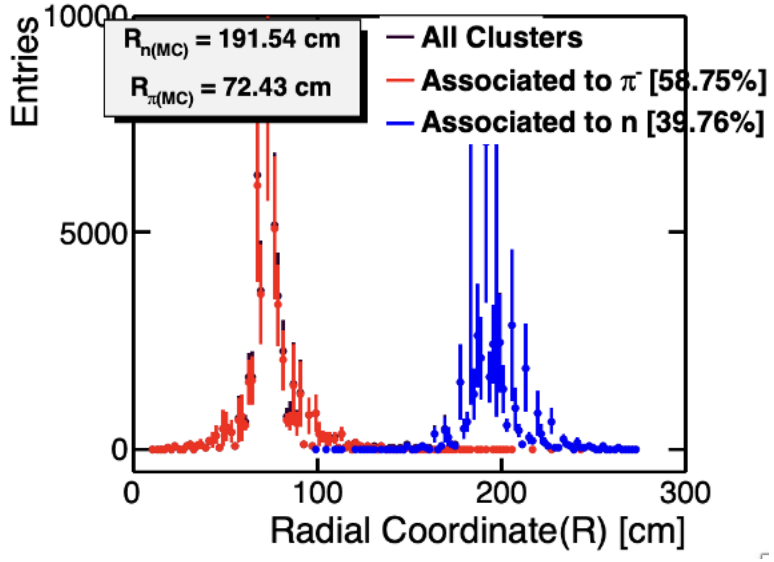
// ignore small weights
for (auto& w : weights) {
if (w < 0.02) {
w = 0;
}
}
vec_normalize(weights);

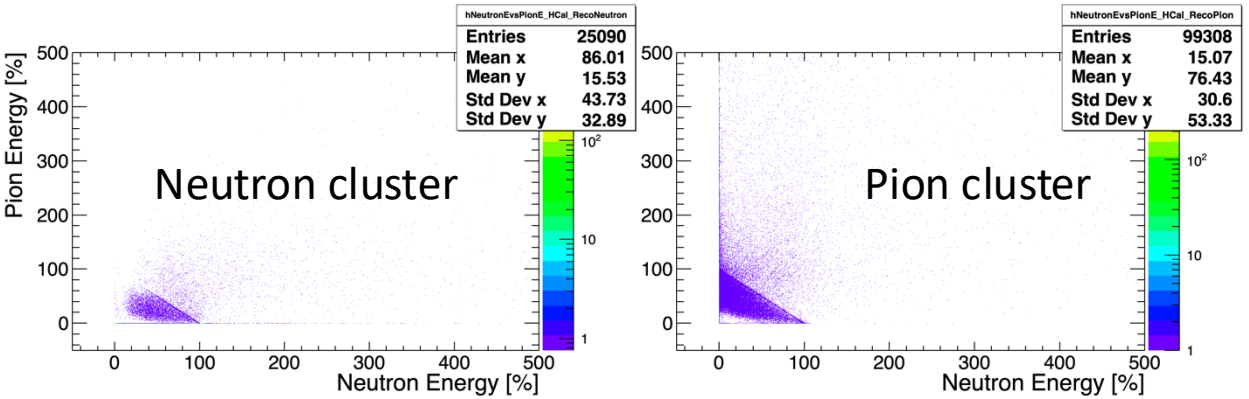
// split energy between local maxima
for (size_t k = 0; k < maxima.size(); ++k) {
double weight = weights[k];
if (weight <= 1e-6) {
continue;
}
pcls[k].addToHits(hits[idx]);
pcls[k].addToWeights(weight);
}
}
```

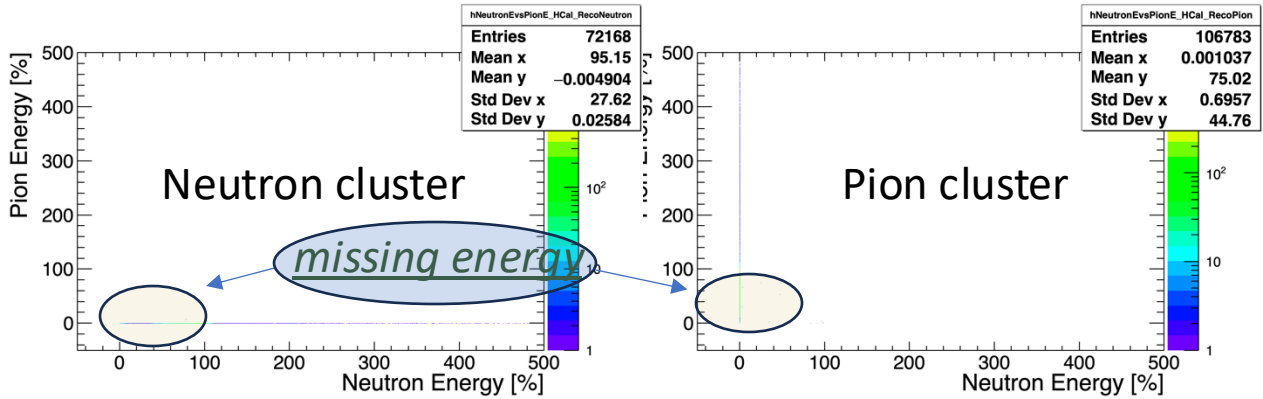
*no of local maxima = no of clusters

Cluster Reconstruction





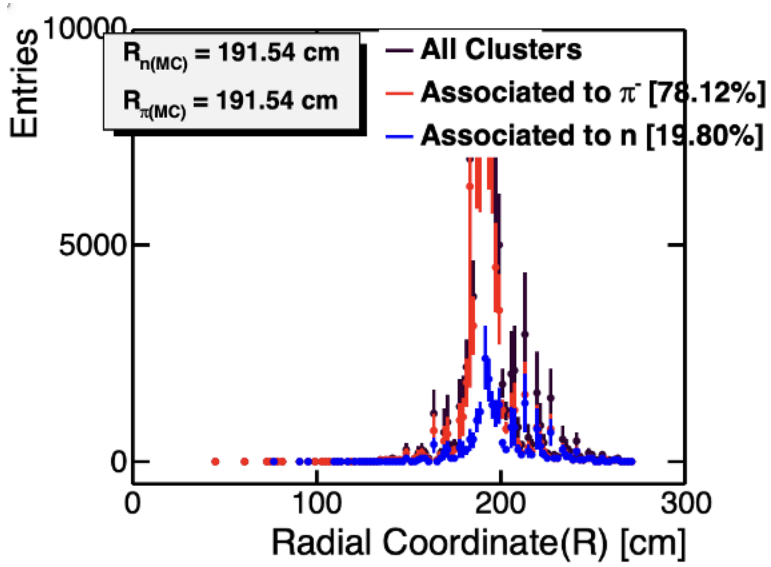


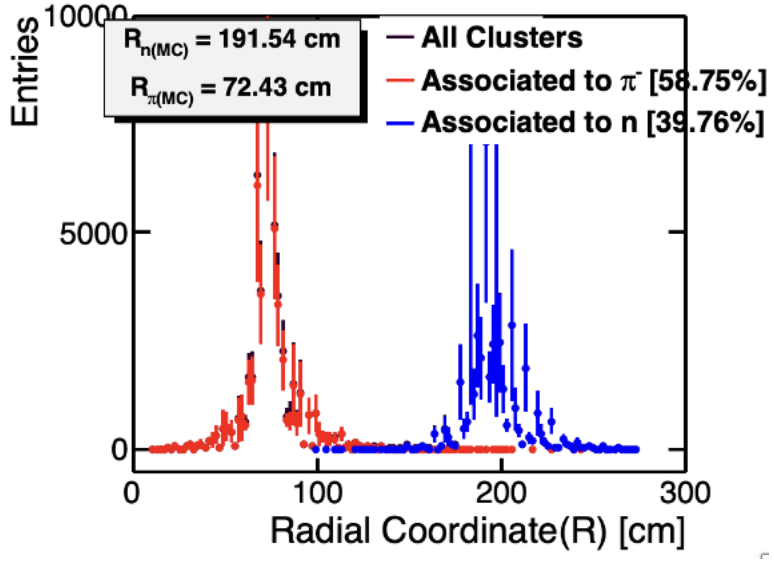


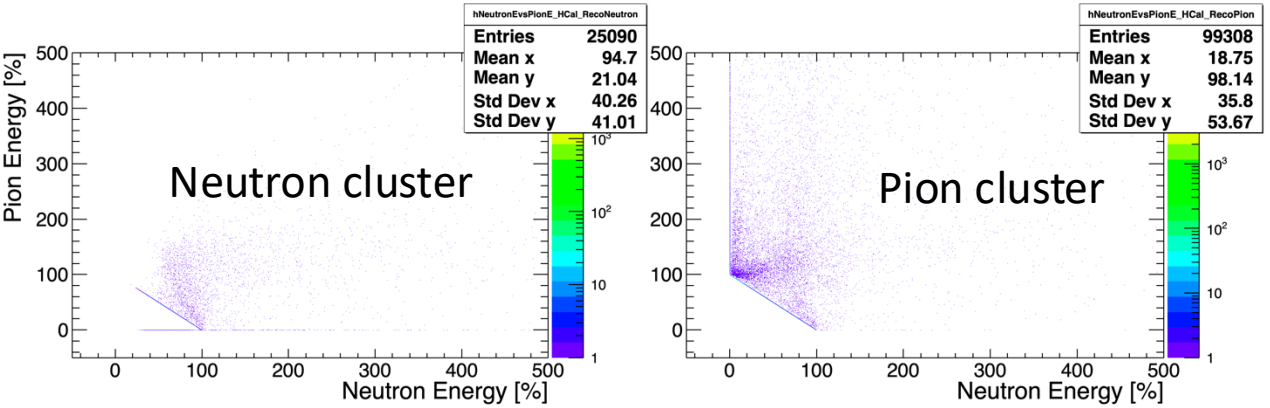
$$E_{Pion(Neutron)}\% = \frac{\sum E^{HitContribution}_{Pion(Neutron)} / sampling fraction}{ClusterEnergy} \times 100$$

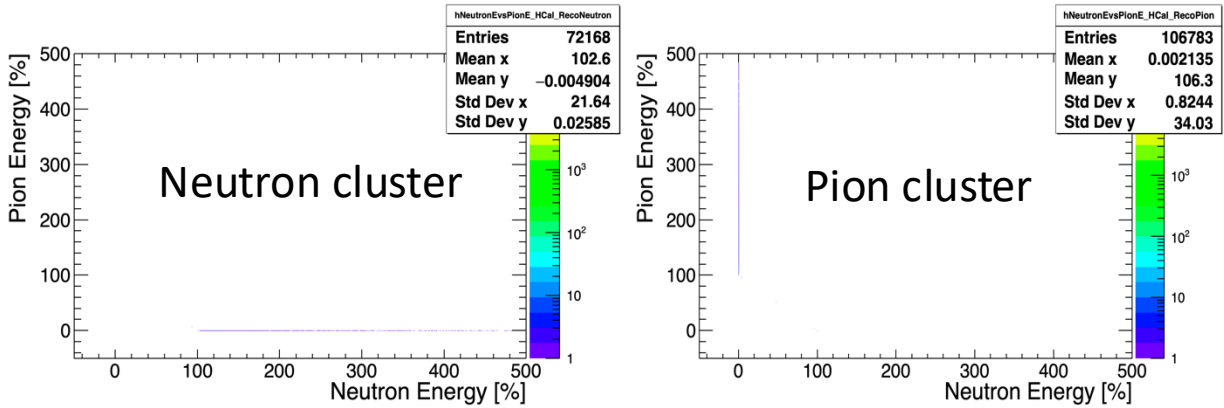
if (sim.getEnergy() < 0.1875e-3) continue; [time info not stored in simhits]
if (contrib.getTime() > 100) continue;

Cluster Reconstruction





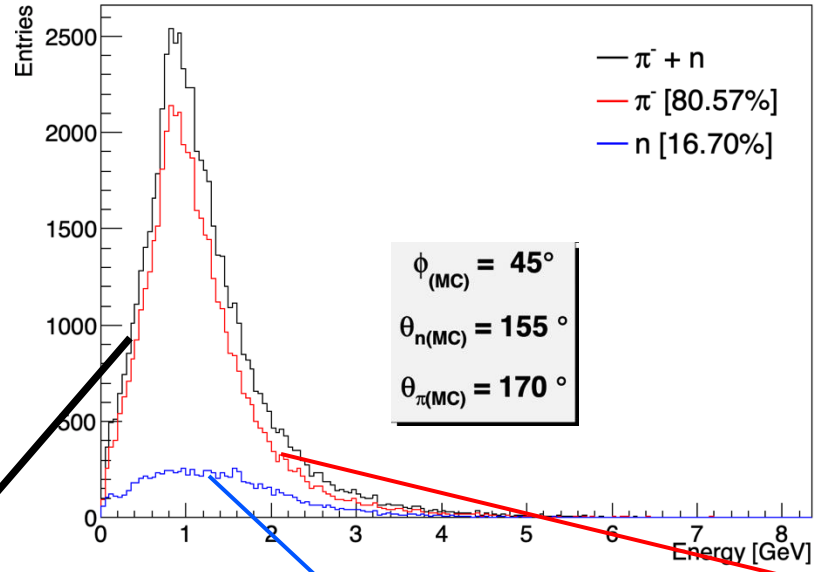




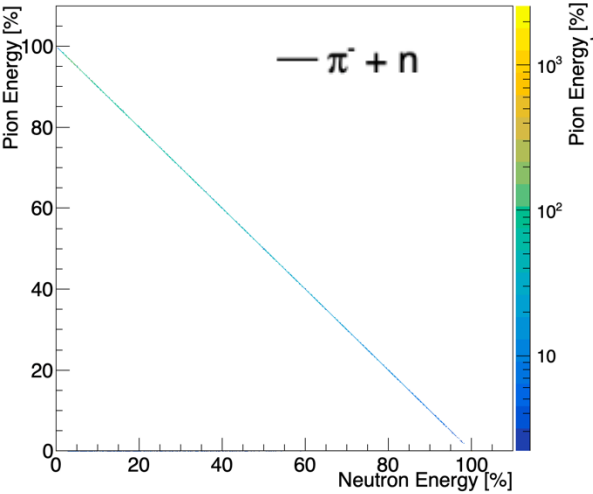
$$Pion(Neutron)Energy\% = \frac{\sum Pion(Neutron)RecohitEnergy}{ClusterEnergy} \times 100$$

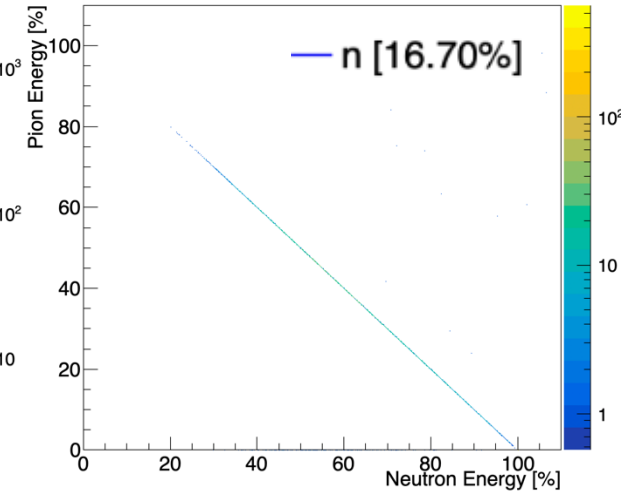
This definition of Pion(Neutron) Energy % works better. [no missing energy]

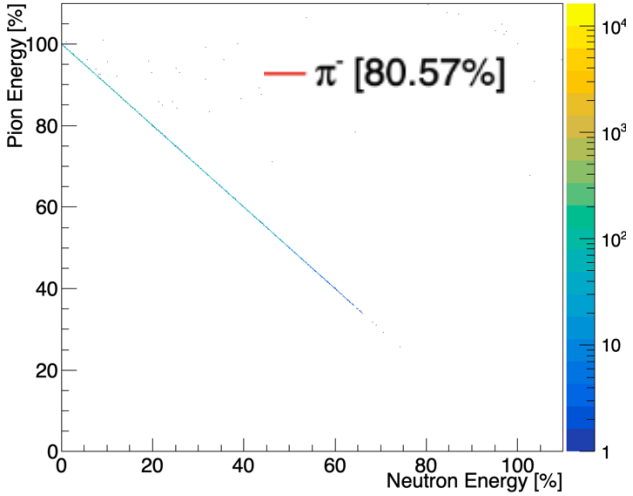
Cluster Reconstruction



old





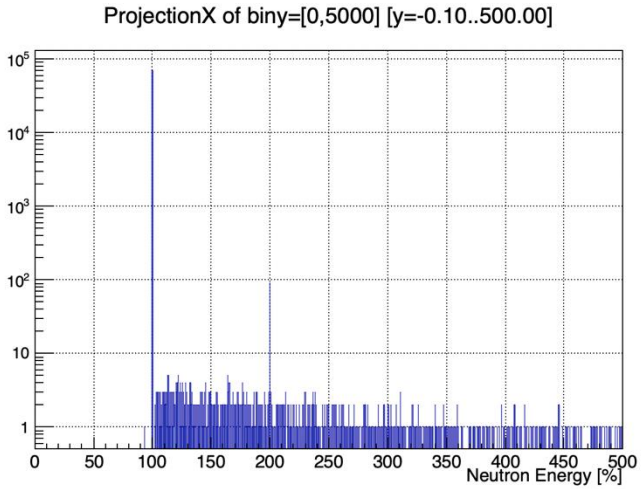


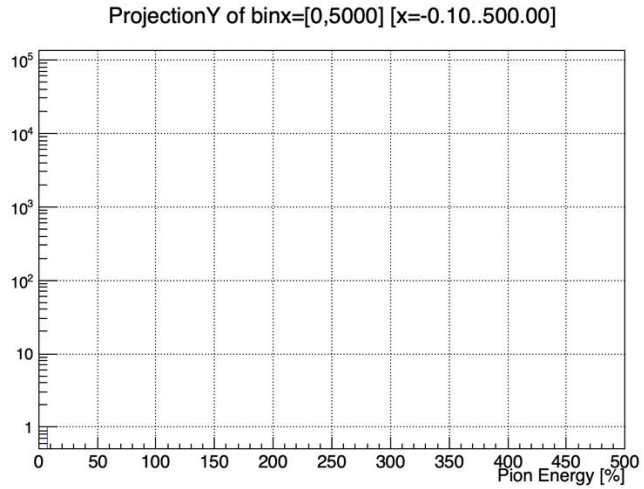
Thank You

backup

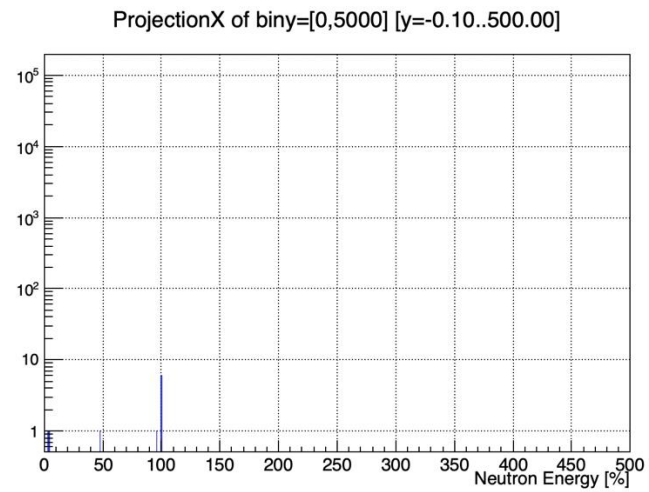
Cluster Reconstruction

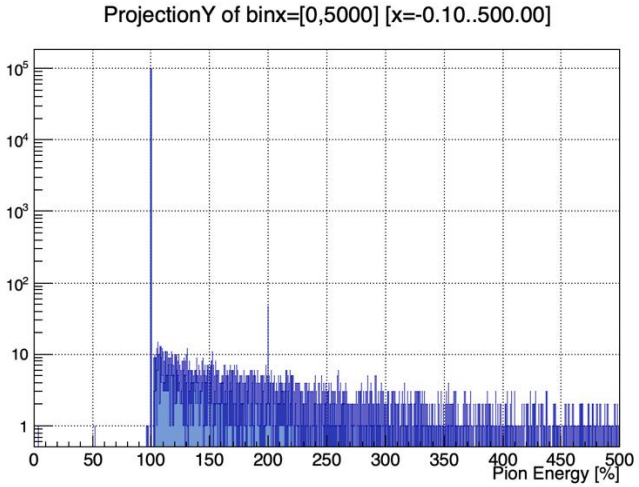
Neutron Clusters



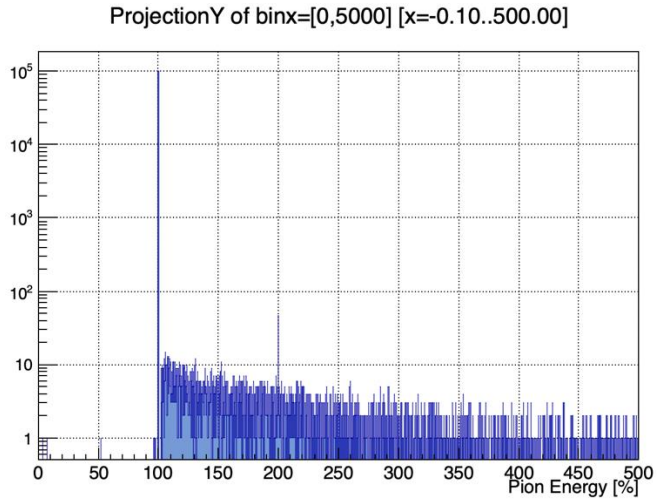


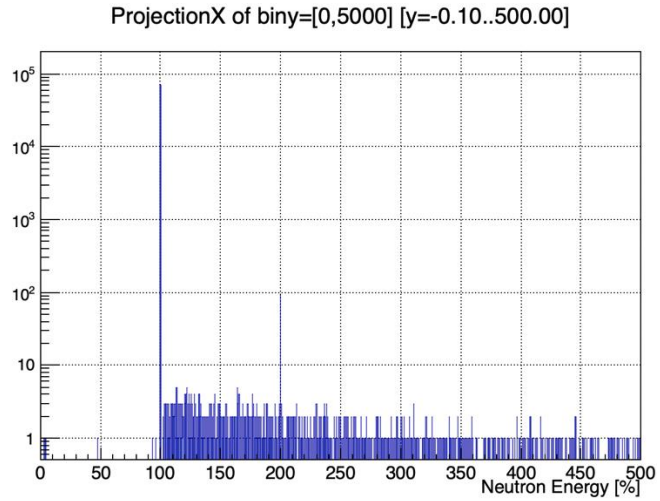
Pion Clusters





All Clusters

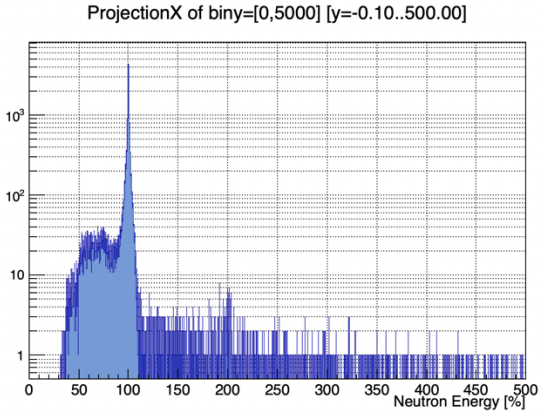


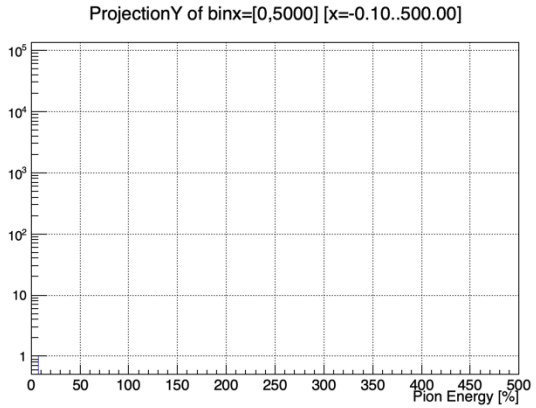


*discussion on next slides with an example

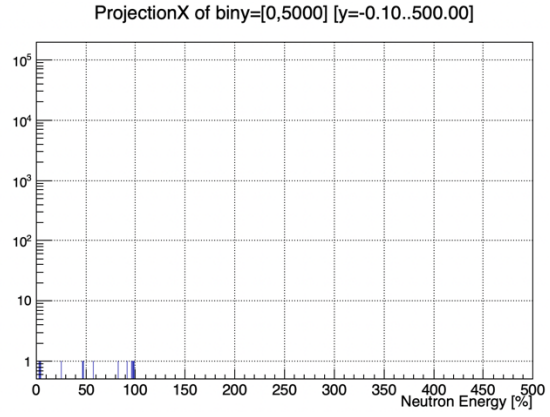
Cluster Reconstruction

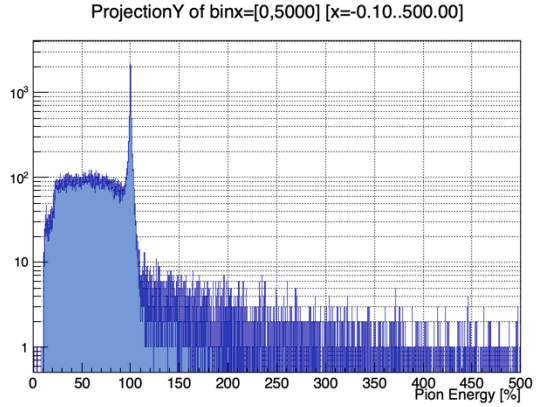
Neutron Clusters





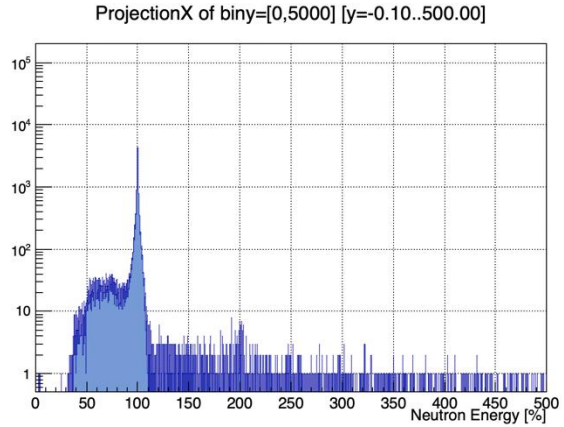
Pion Clusters

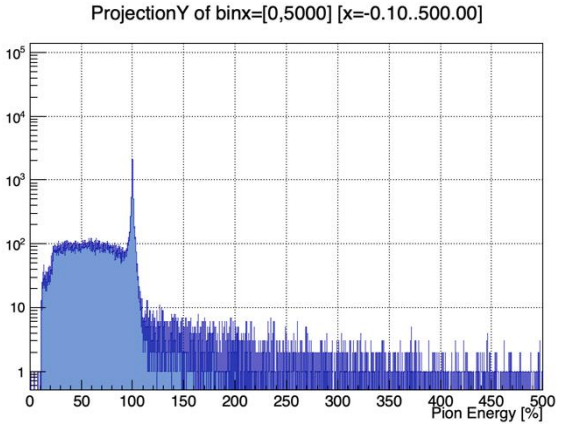




$$E_{Pion(Neutron)}\% = \frac{\sum E^{HitContribution}_{Pion(Neutron)} / sampling fraction}{ClusterEnergy} \times 100$$

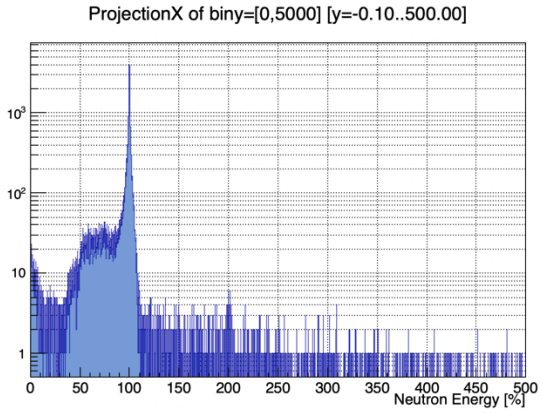
All Clusters

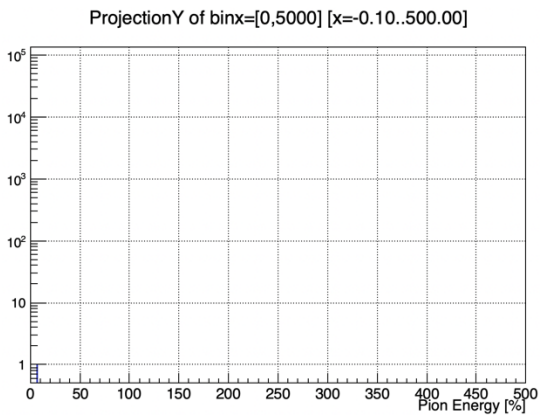




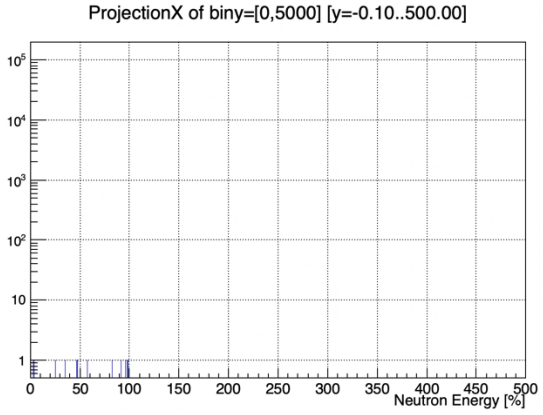
Cluster Reconstruction

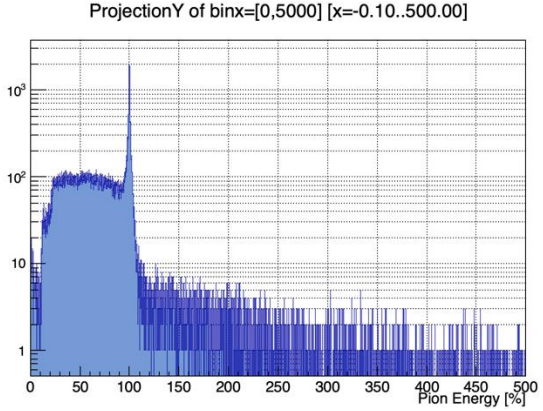
Neutron Clusters



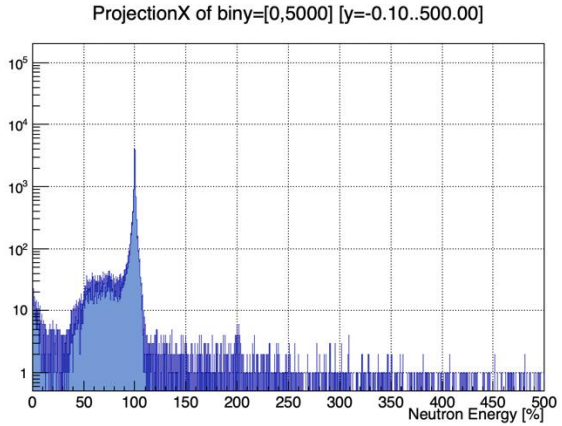


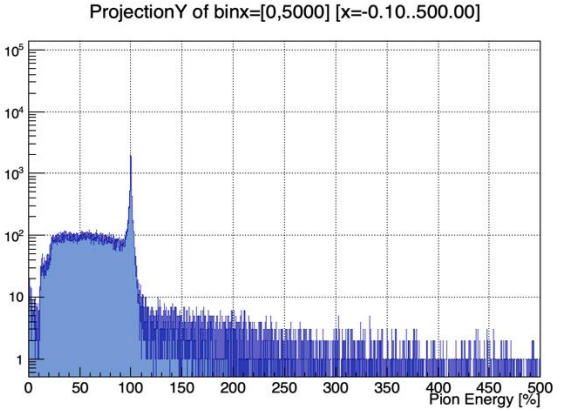
Pion Clusters





All Clusters





$$E_{Pion(Neutron)}\% = \frac{\sum E^{HitContribution}_{Pion(Neutron)} / sampling fraction}{ClusterEnergy} \times 100$$

if (sim.getEnergy() < 0.1875e-3) continue; [time info not stored in simhits]
if (contrib.getTime() > 100) continue;

Cluster Reconstruction

```
        app->Add(new JOmniFactoryGeneratorT<CalorimeterHitDigi_factory>(
          "HcalEndcapNRawHits",
          {"HcalEndcapNHits"},
#if EDM4EIC_VERSION_MAJOR >= 7
          {"HcalEndcapNRawHits", "HcalEndcapNRawHitAssociations"},
#else
          {"HcalEndcapNRawHits"},
#endif
          {
            .tRes = 0.0 * dd4hep::ns,
            .capADC = HcalEndcapN_capADC,
            .capTime = 100, // given in ns, 4 samples in HGCROC
            .dyRangeADC = HcalEndcapN_dyRangeADC,
            .pedMeanADC = HcalEndcapN_pedMeanADC,
            .pedSigmaADC = HcalEndcapN_pedSigmaADC,
            .resolutionTDC = HcalEndcapN_resolutionTDC,
            .corrMeanScale = "1.0",
            .readout = "HcalEndcapNHits",
          },
          app   // TODO: Remove me once fixed
        ));
        app->Add(new JOmniFactoryGeneratorT<CalorimeterHitReco_factory>(
          "HcalEndcapNRecHits", {"HcalEndcapNRawHits"}, {"HcalEndcapNRecHits"},
          {
            .capADC = HcalEndcapN_capADC,
            .dyRangeADC = HcalEndcapN_dyRangeADC,
            .pedMeanADC = HcalEndcapN_pedMeanADC,
            .pedSigmaADC = HcalEndcapN_pedSigmaADC,
            .resolutionTDC = HcalEndcapN_resolutionTDC,
            .thresholdFactor = 0.0,
            .thresholdValue = 41.0, // 0.1875 MeV deposition out of 200 MeV max (per layer) --> adc = 10 + 0.1875 / 200 * 32768 == 41
            .sampFrac = "0.0095", // from latest study - implement at level of reco hits rather than clusters
            .readout = "HcalEndcapNHits",
          },
          app   // TODO: Remove me once fixed
```

if (sim.getEnergy() < 0.1875e-3) continue;
if (contrib.getTime() > 100) continue;