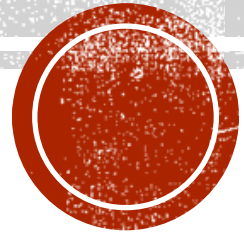
bHCAL Meeting – Neutron Calibration Update



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08/14/2026

OVERVIEW

- QA of bHCAL energy deposition
  - Determine why we see large total energy deposition for neutrons
- Number of hits and cluster sizes in bHCAL for neutrons
  - Understanding of:
    - Where is energy from neutrons deposited
    - Sampling fraction
    - Clustering algorithm
- QA of bECAL energy deposition
  - Identification of events with badly reconstructed energy from clusters
- Global vs. SciFi bECAL clusters
  - Independent study to all above
  - Comparison of different cluster collections in EICRecon
  - Important for ongoing calibration studies (both manual and AI/ML)

SIMULATION SETUP

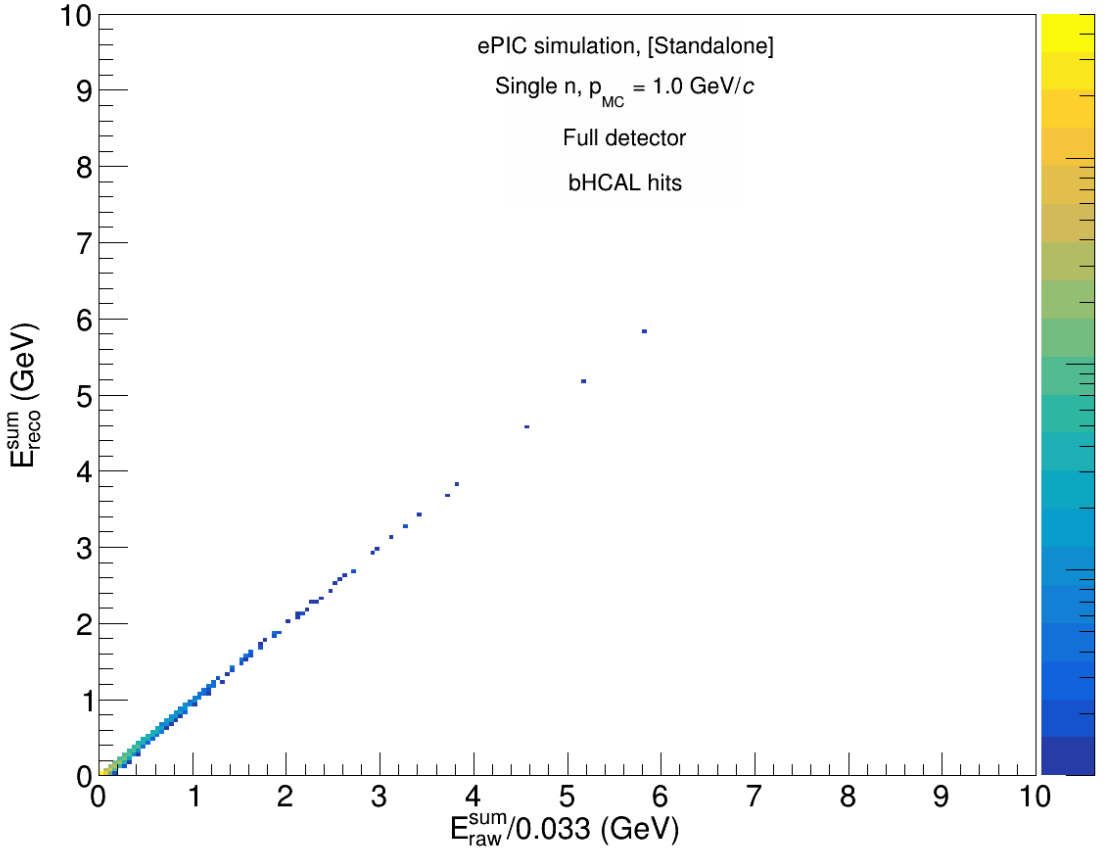
- Standalone simulation with default setup
  - Latest detector geometry, EICRecon, etc. inside the EIC shell container
  - Motivation: Central simulations do not contain raw bHCAL hits needed for part of this study

- Single neutrons
  - Energies: $1\ \mathrm{GeV}$, $2\ \mathrm{GeV}$, $5\ \mathrm{GeV}$
  - Uniform in ϕ
  - $\cos\theta$ distribution in range $33.5 < \theta < 146\ \mathrm{deg}$

bHCAL QA

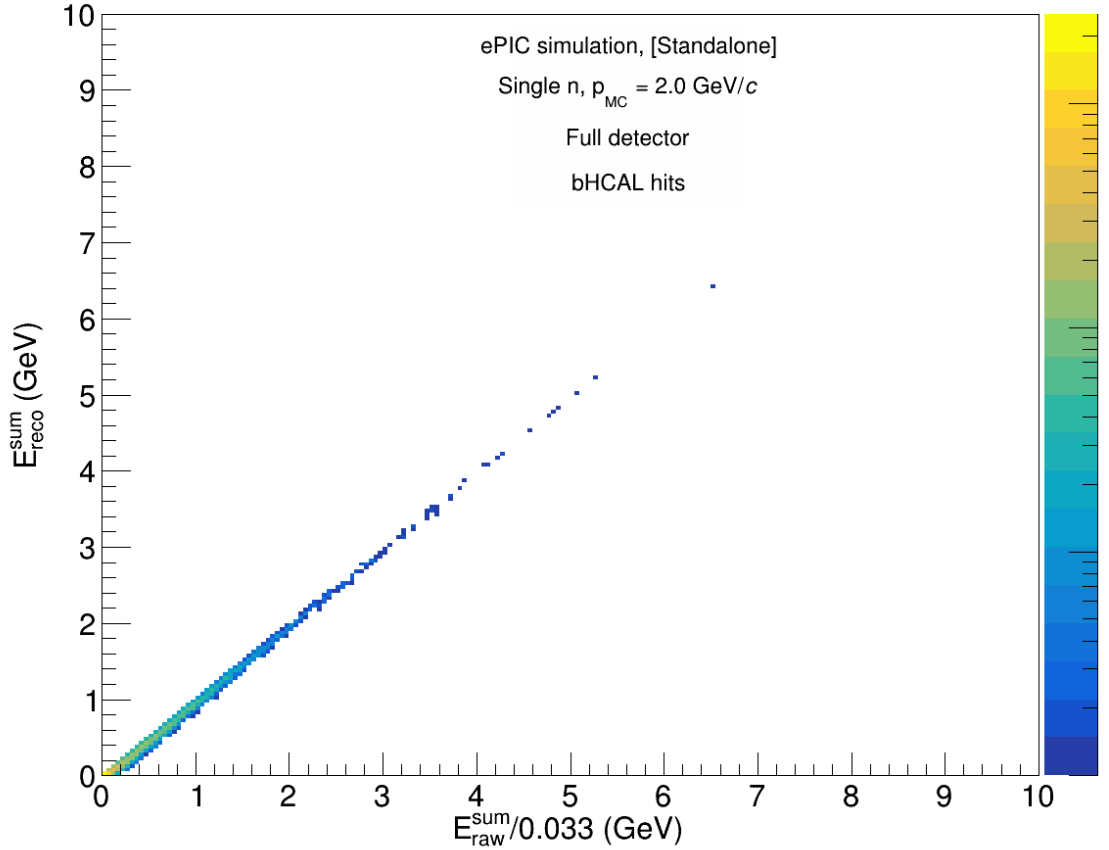
QA OF bHCAL ENERGY DEPOSITION

- Comparison of energy deposition from raw bHCAL hits and reconstructed bHCAL hits for $1\ \mathrm{GeV}$ neutrons
  - **Horizontal axis:** Sum of raw tile energy deposition, scaled by the sampling fraction (1/0.033)
    - HcalBarrelHits
  - **Vertical axis:** Sum of reconstructed tile energy deposition from EICRecon
    - HcalBarrelRecHits
- Large reconstructed bHCAL energies directly from raw hits scaled by sampling fraction
- **Is this sampling fraction correct for low energy neutrons?**



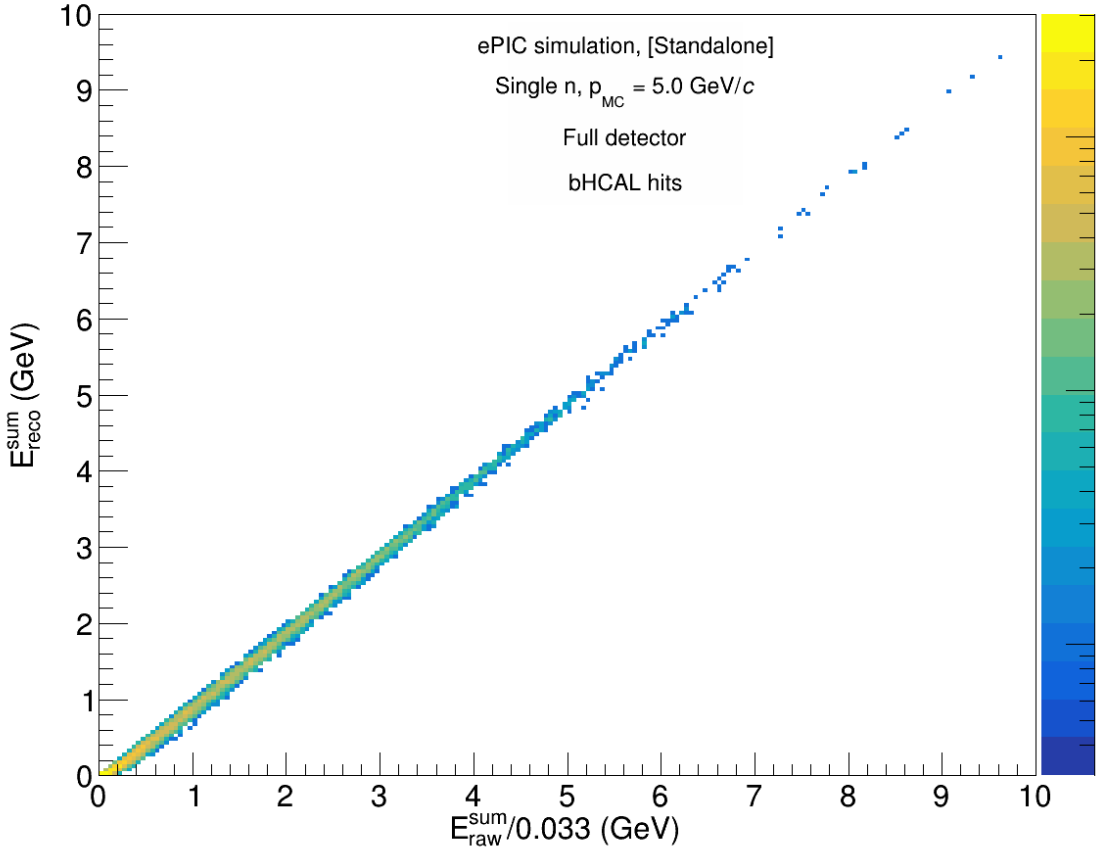
QA OF bHCAL ENERGY DEPOSITION

- Comparison of energy deposition from raw bHCAL hits and reconstructed bHCAL hits for 2 GeV neutrons
  - **Horizontal axis:** Sum of raw tile energy deposition, scaled by the sampling fraction (1/0.033)
    - HcalBarrelHits
  - **Vertical axis:** Sum of reconstructed tile energy deposition from EICRecon
    - HcalBarrelRecHits
- Large reconstructed bHCAL energies directly from raw hits scaled by sampling fraction
- **Is this sampling fraction correct for low energy neutrons?**



QA OF bHCAL ENERGY DEPOSITION

- Comparison of energy deposition from raw bHCAL hits and reconstructed bHCAL hits for 5 GeV neutrons
  - **Horizontal axis:** Sum of raw tile energy deposition, scaled by the sampling fraction (1/0.033)
    - HcalBarrelHits
  - **Vertical axis:** Sum of reconstructed tile energy deposition from EICRecon
    - HcalBarrelRecHits
- Large reconstructed bHCAL energies directly from raw hits scaled by sampling fraction
- **Is this sampling fraction correct for low energy neutrons?**
  - Attempt to answer in following slides
- **Following slides:** Number of hit tiles and cluster sizes in bHCAL

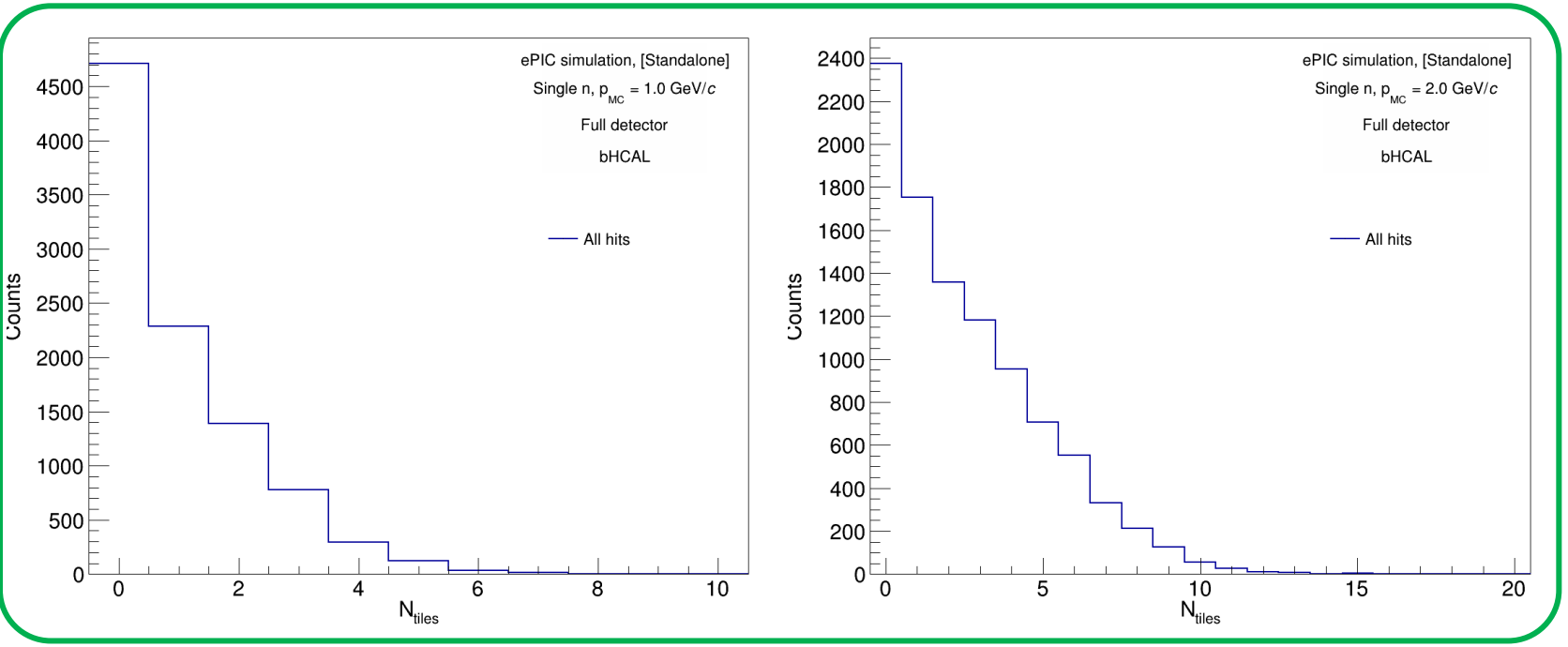


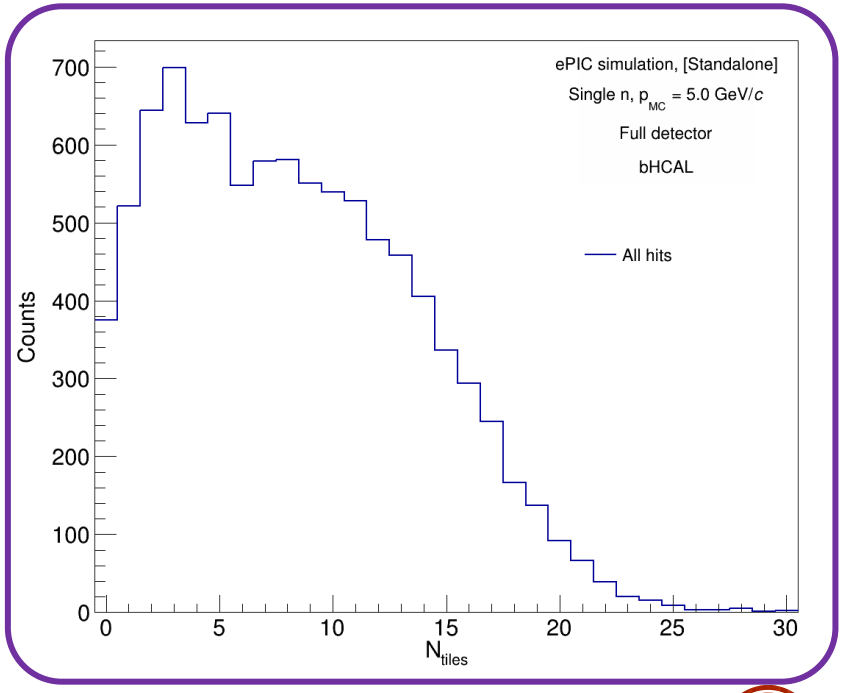
NUMBER OF INDIVIDUAL HITS IN bHCAL

- Number of hits per neutron in bHCAL
  - Hit = tile with non-zero energy deposition

- **Low energy** ($E < 2$ GeV)
  - Many events have very low number of hit tiles
  - **Often only single tile is hit**
    - Does our sampling fraction work here?

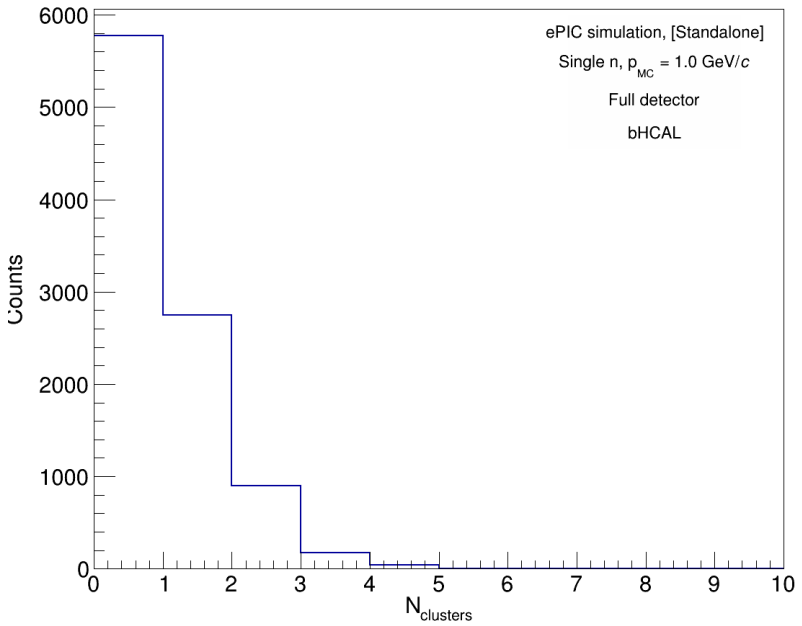
- **High energy** ($E > 5$ GeV)
  - More likely to have multiple tiles hit at the same time

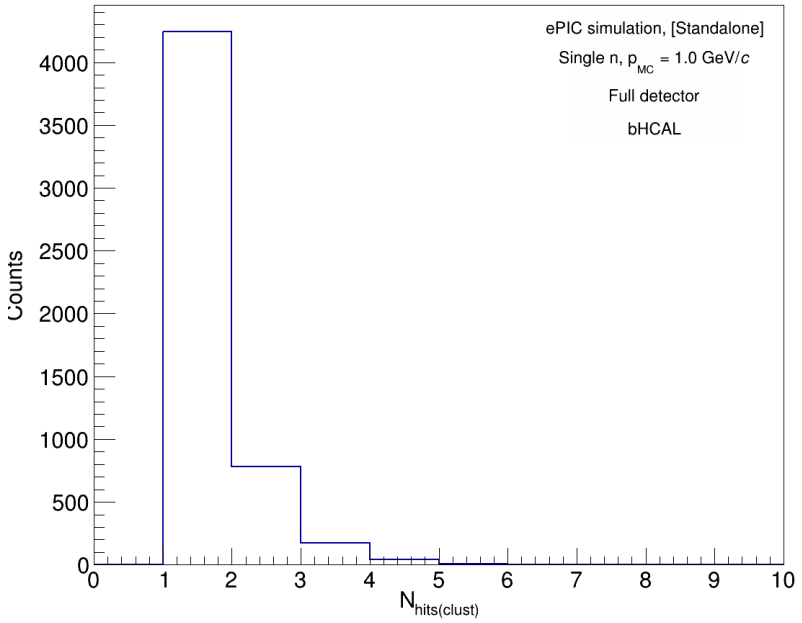




CLUSTER SIZE IN bHCAL

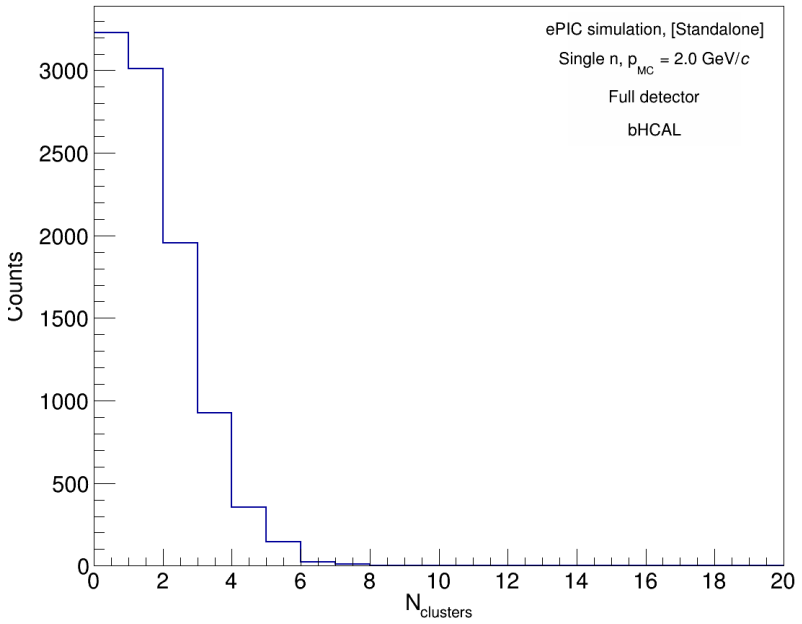
- Cluster size in bHCAL for 1 GeV neutrons
- (top) Number of clusters per neutron
  - Most 1 GeV neutrons have one cluster
- (bottom) Number of hits (tiles) per cluster
  - **Most clusters consist of a single tile**
- Clustering algorithm likely still based on sPHENIX
  - Possible issues because of single tile (ePIC) vs. tower, 5-tile readout (sPHENIX)

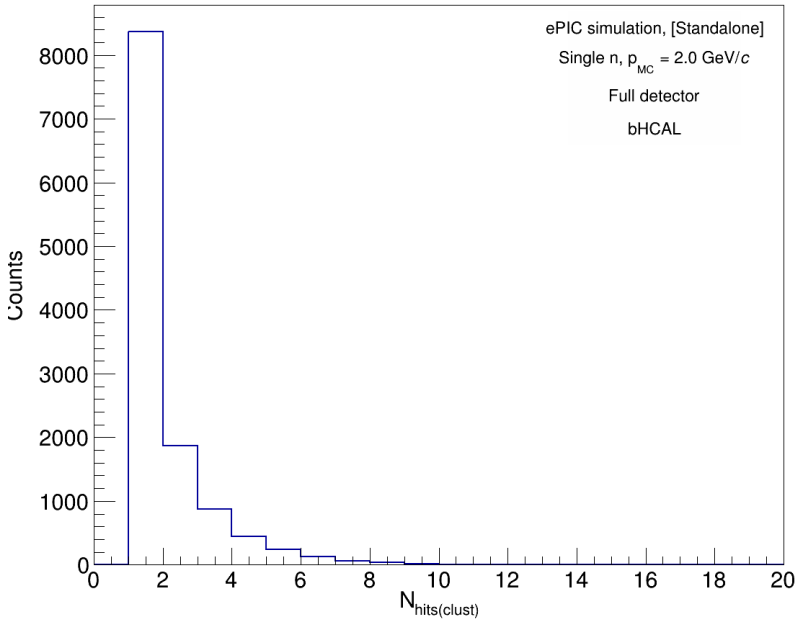




CLUSTER SIZE IN bHCAL

- Cluster size in bHCAL for 2 GeV neutrons
- (top) Number of clusters per neutron
  - Most 2 GeV neutrons have one cluster
- (bottom) Number of hits (tiles) per cluster
  - **Most clusters consist of a single tile**
- Clustering algorithm likely still based on sPHENIX
  - Possible issues because of single tile (ePIC) vs. tower, 5-tile readout (sPHENIX)

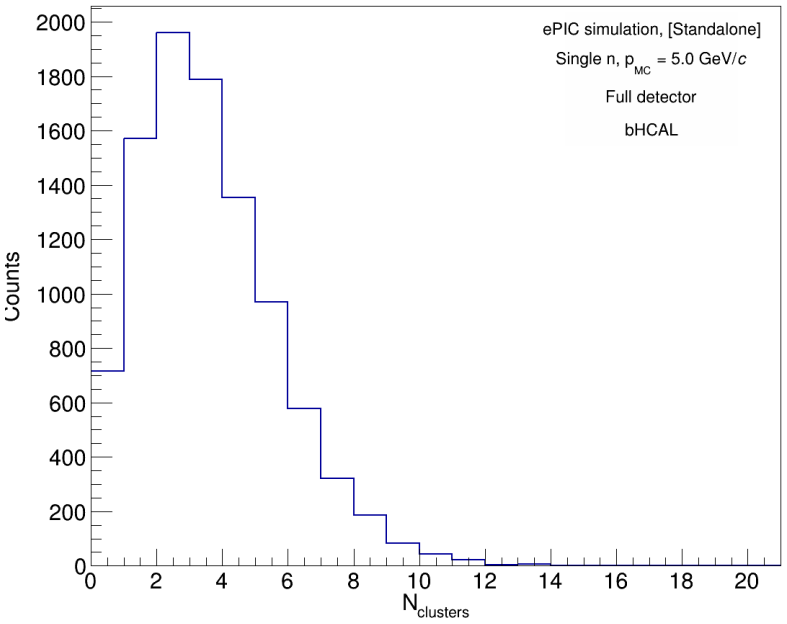


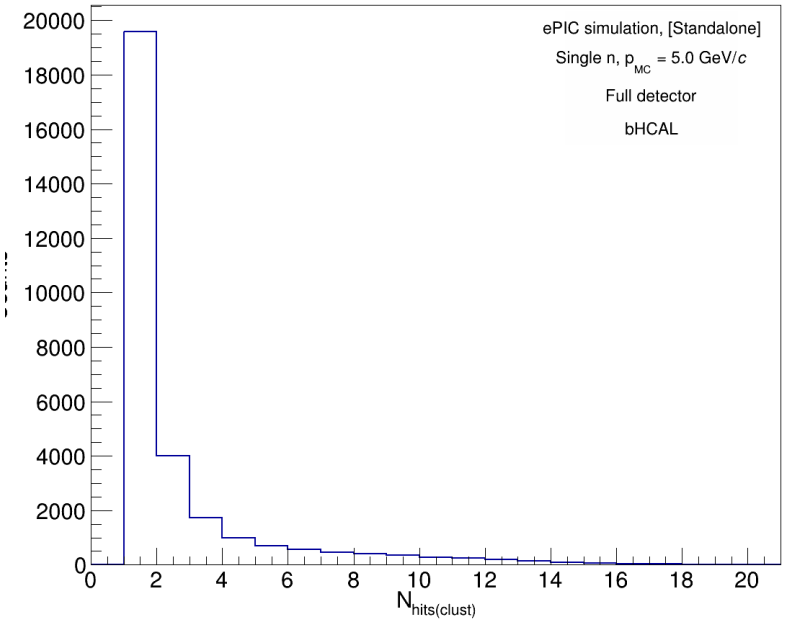


CLUSTER SIZE IN bHCAL

- Cluster size in bHCAL for 5 GeV neutrons
- (top) Number of clusters per neutron
  - High energy neutrons seem to have more clusters
- (bottom) Number of hits (tiles) per cluster
  - **Most clusters consist of a single tile**
- Clustering algorithm likely still based on sPHENIX
  - Possible issues because of single tile (ePIC) vs. tower, 5-tile readout (sPHENIX)

- **Section conclusions:**
  - High reconstructed energy in bHCAL directly from scaling raw deposited energy by constant sampling fraction
    - Potential issue due to very small cluster sizes for low *E* neutrons
  - Clustering algorithm possibly needs to be updated for ePIC single tile readout

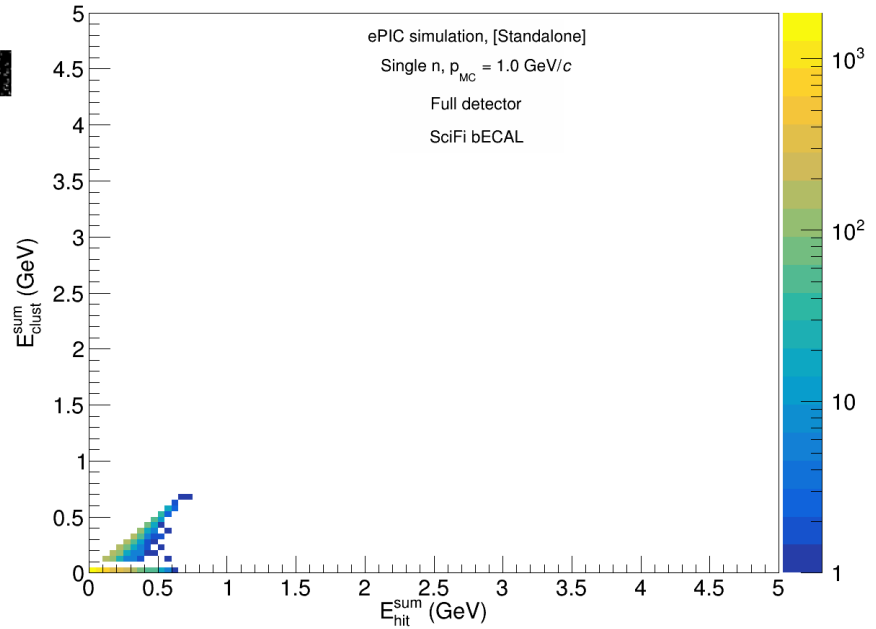


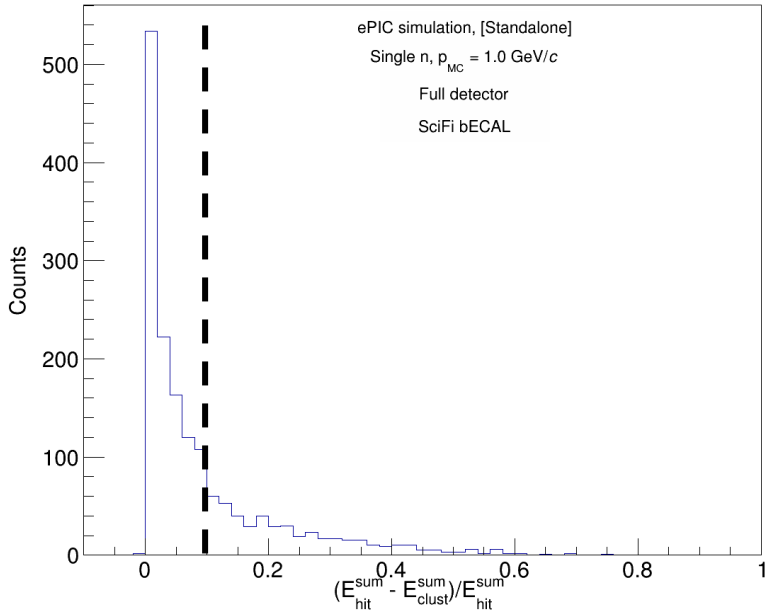


bECAL QA

ENERGY DEPOSITION IN bECAL

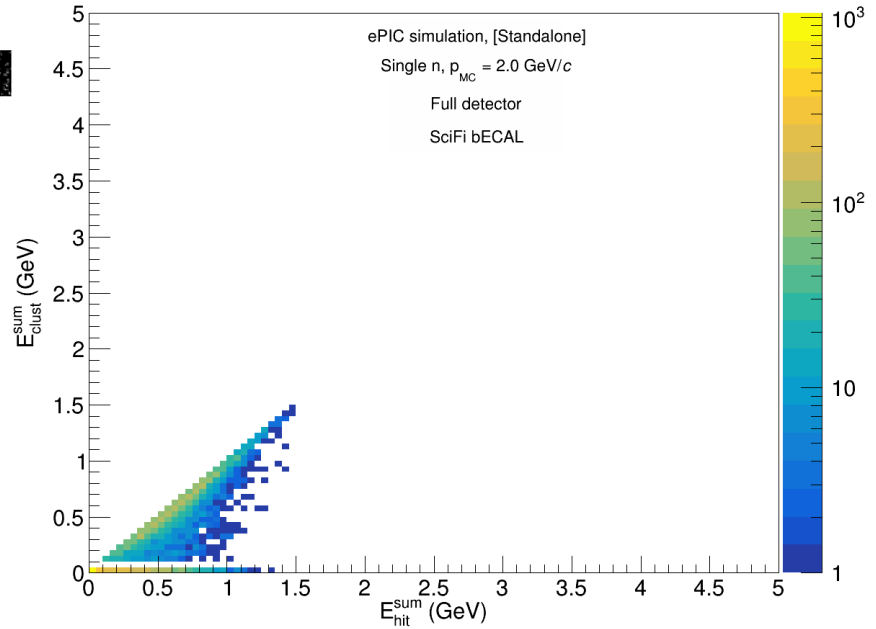
- (top) Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $1\ \mathrm{GeV}$ neutrons
  - **Issue:** Quite many clusters with low reconstructed energy
- (bottom) Same comparison as in top figure, but plotted as 1D distribution: $R = (E_{hit}^{sum} - E_{clust}^{sum})/E_{hit}^{sum}$
- Divide bECAL hit sample in two categories:
  - Good: $R < 0.1$
  - Bad: $R > 0.1$

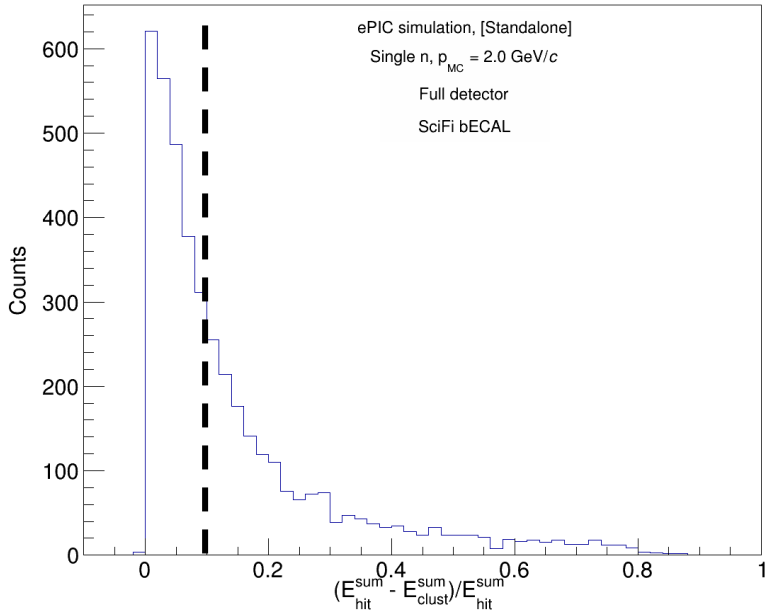




ENERGY DEPOSITION IN bECAL

- (top) Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $2\ \mathrm{GeV}$ neutrons
  - **Issue:** Quite many clusters with low reconstructed energy
- (bottom) Same comparison as in top figure, but plotted as 1D distribution: $R = (E_{hit}^{sum} - E_{clust}^{sum})/E_{hit}^{sum}$
- Divide bECAL hit sample in two categories:
  - Good: $R < 0.1$
  - Bad: $R > 0.1$





ENERGY DEPOSITION IN bECAL

- (top) Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $5\ \mathrm{GeV}$ neutrons
  - **Issue:** Quite many clusters with low reconstructed energy
- (bottom) Same comparison as in top figure, but plotted as 1D distribution: $R = (E_{hit}^{sum} - E_{clust}^{sum})/E_{hit}^{sum}$
- Divide bECAL hit sample in two categories:
  - Good: $R < 0.1$
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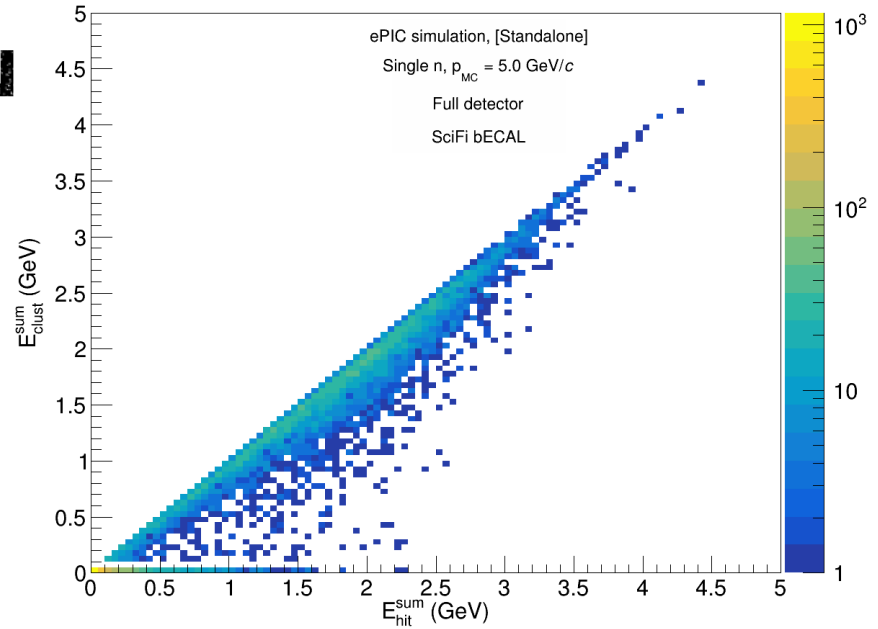
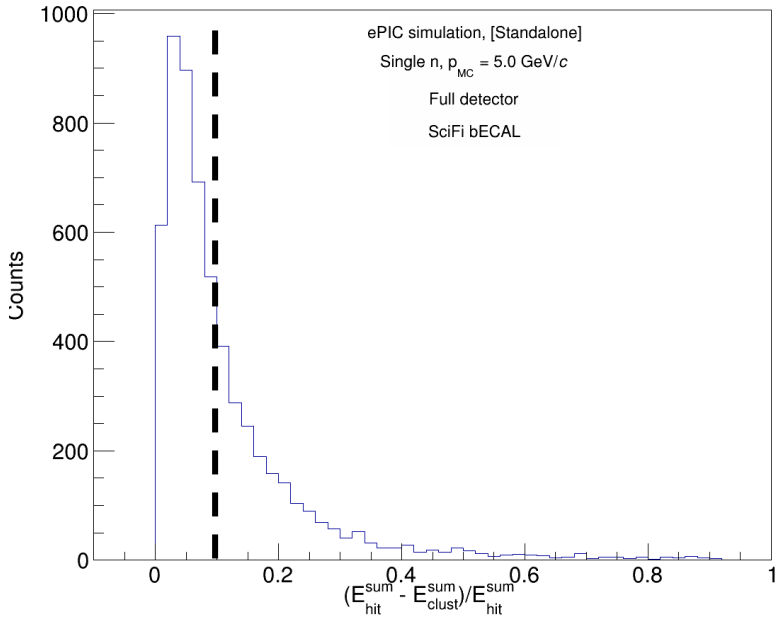
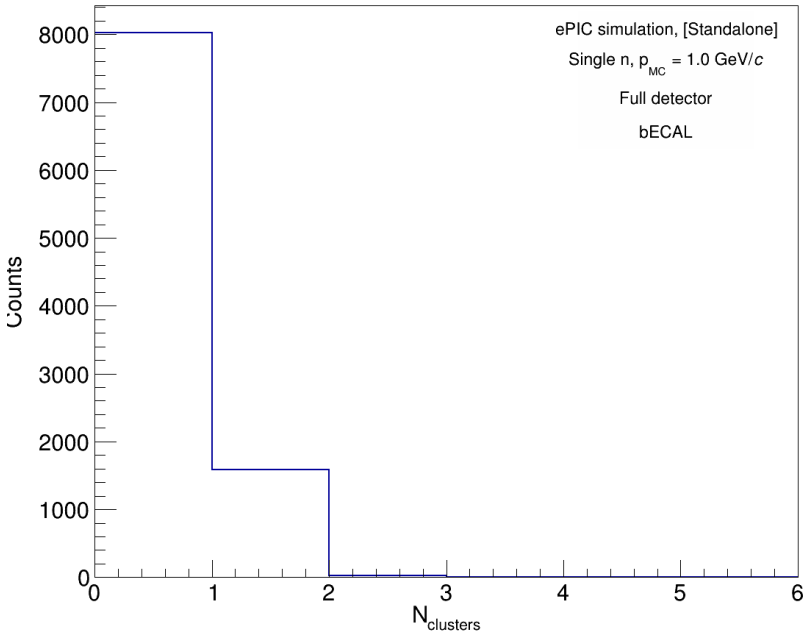


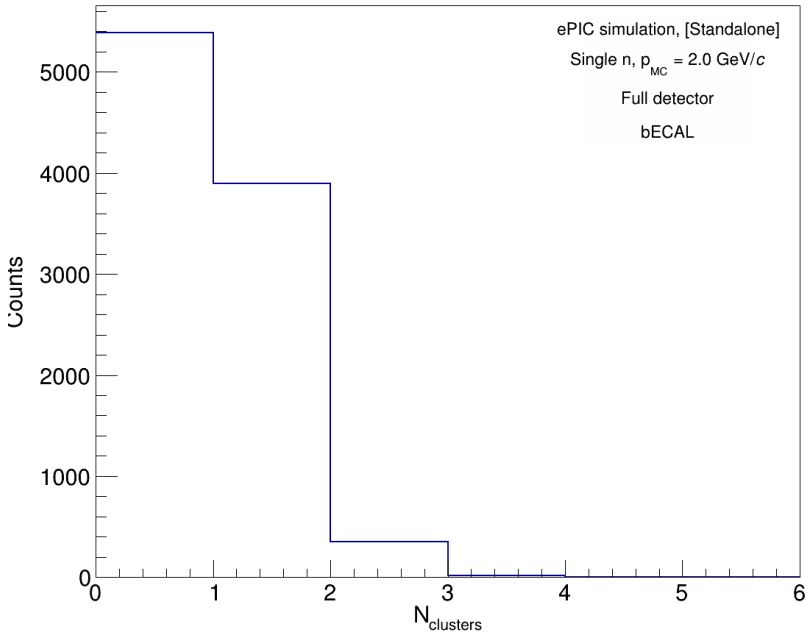


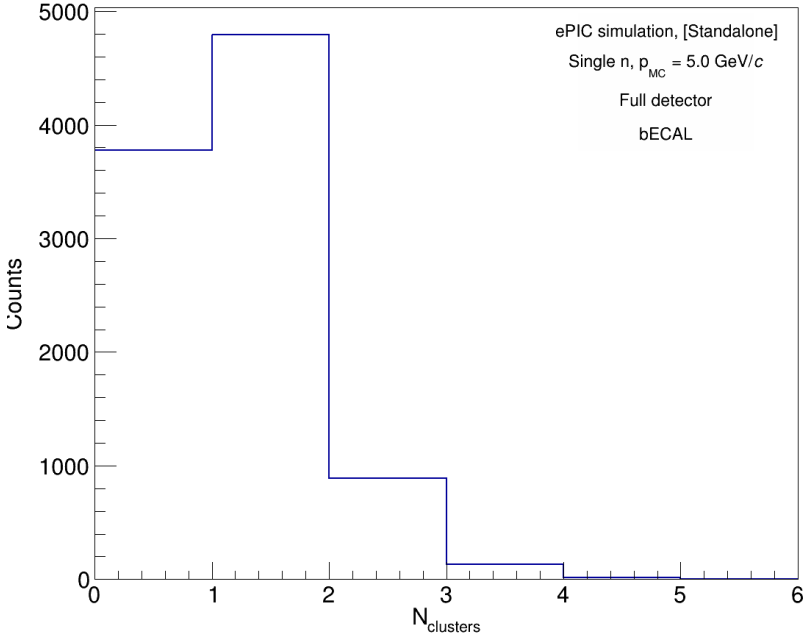
NUMBER OF CLUSTERSIN bECAL

- **Number of SciFi clusters** in bECAL for single neutrons

- **Most events have only one bECAL SciFi cluster**

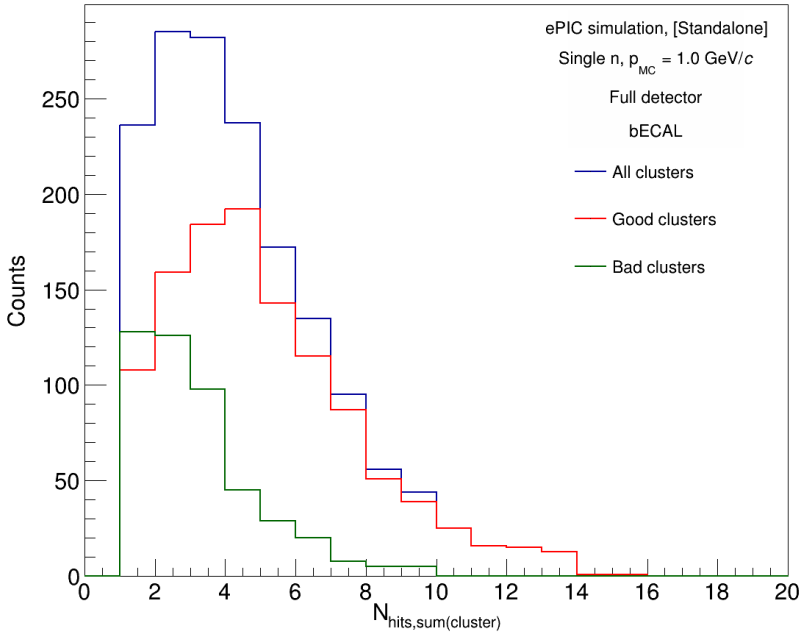


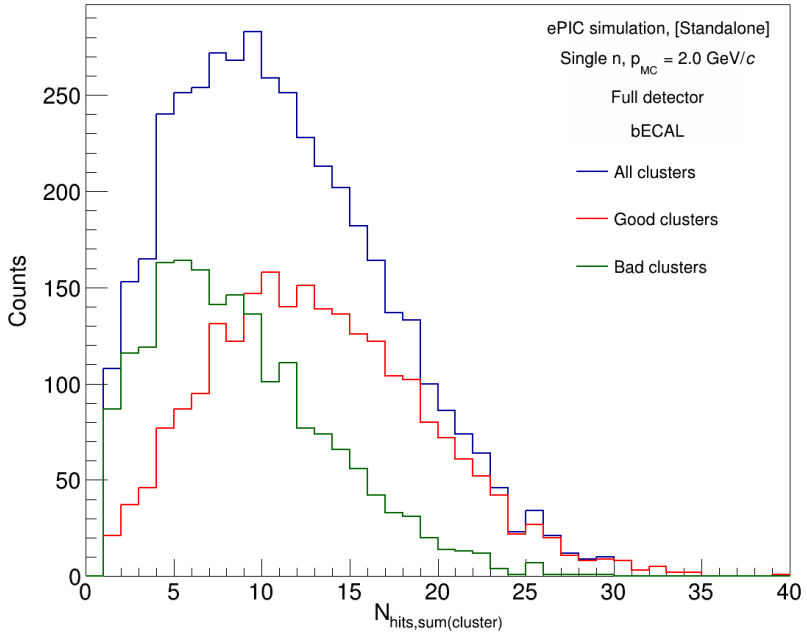


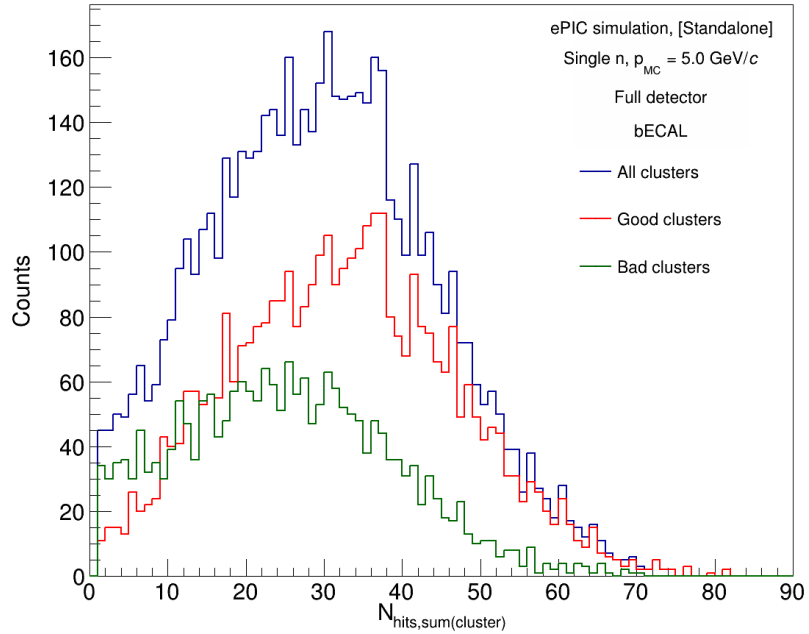


CLUSTER SIZE IN bECAL

- **Sum of hits for all SciFi clusters** in bECAL for neutrons
  - Summing all hits, as energy depositions calculated from sum of all clusters
  - Most events have one bECAL cluster, so should be a good approximation
- Comparison for all, good, and bad clusters
  - Definition of good/bad from Slides 13-15
- Reasonable separation between good/bad based on sum of hits







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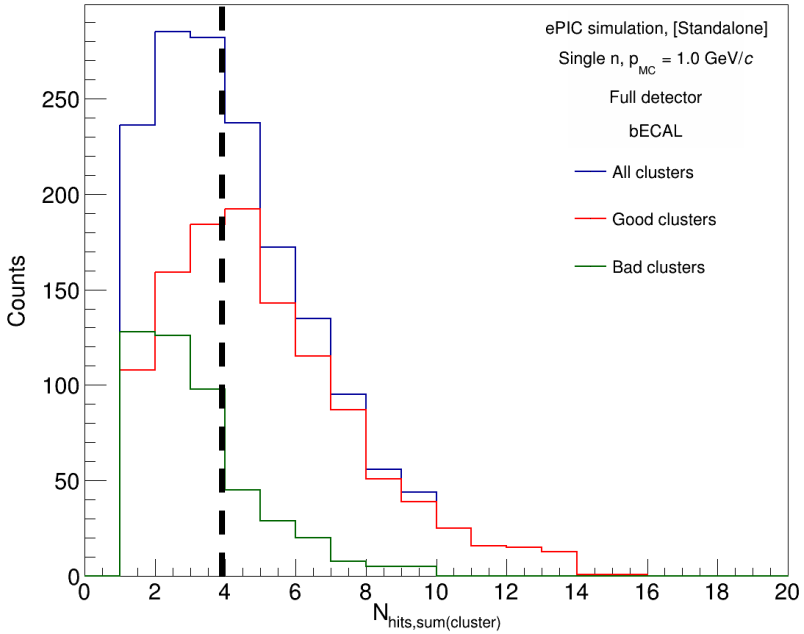
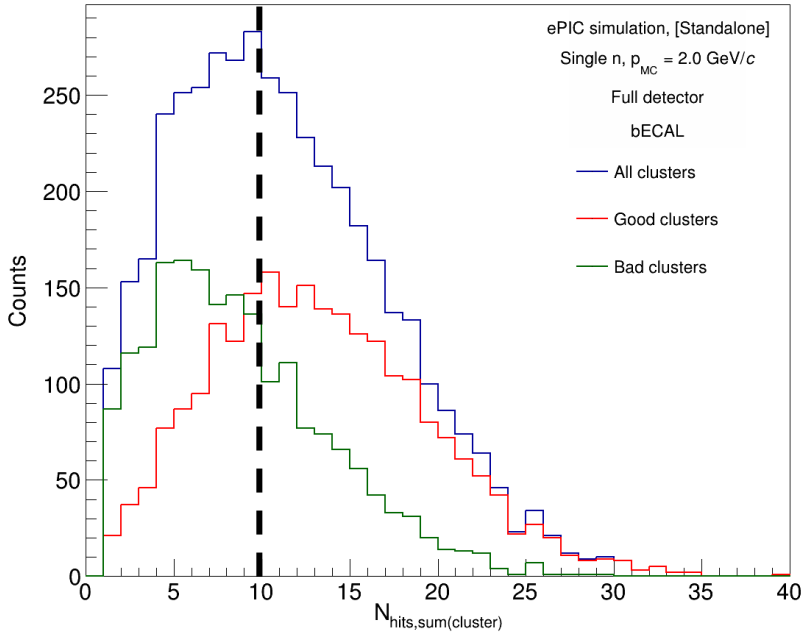
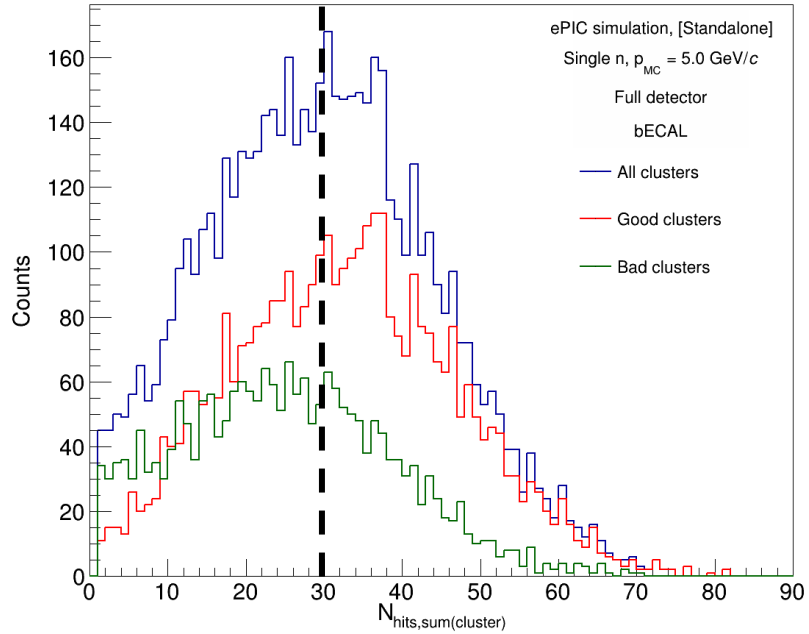


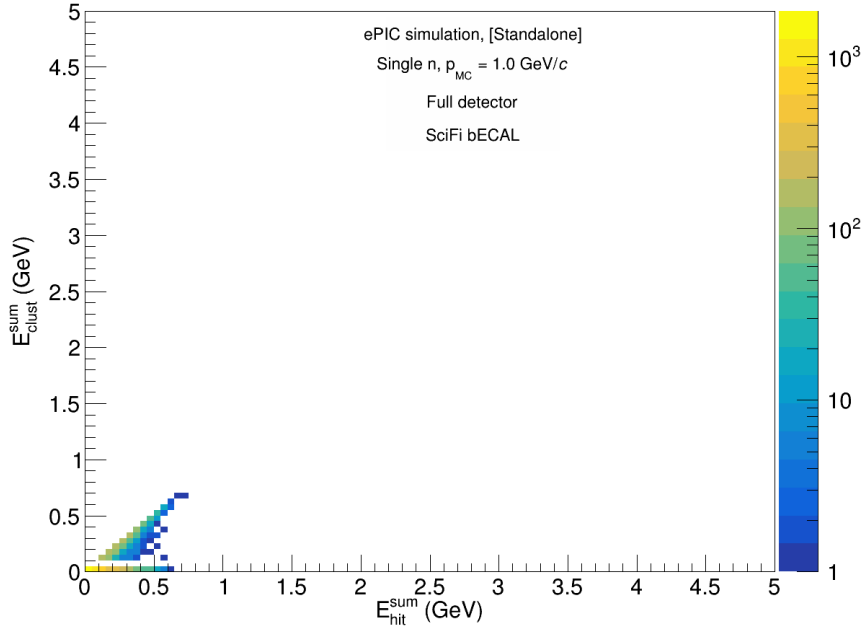


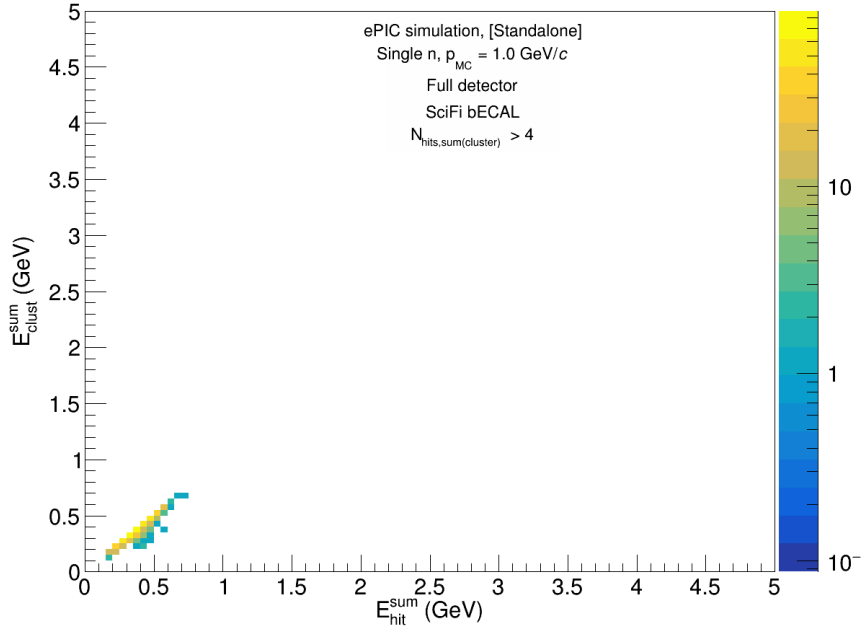


ENERGY DEPOSITION IN bECAL AFTER CUT

- Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $1\ \mathrm{GeV}$ neutrons
- (left) Before $N_{hits,sum(cluster)}$ cut
- (right) $N_{hits,sum(cluster)} > 4$ (see Slide 18)

- **Possibility to remove bad bECAL clusters based on cluster size/number of hits**
  - Not perfect, but seems to be working OK

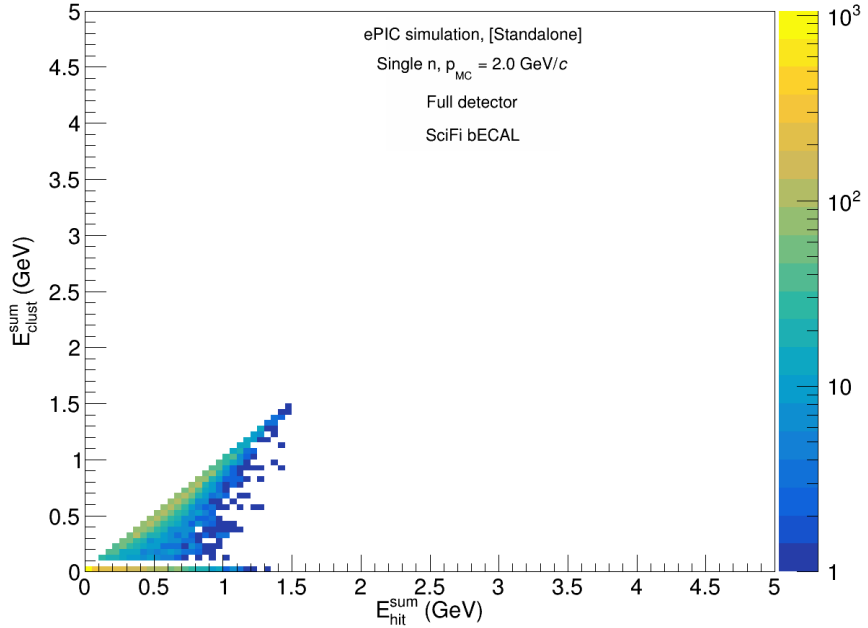


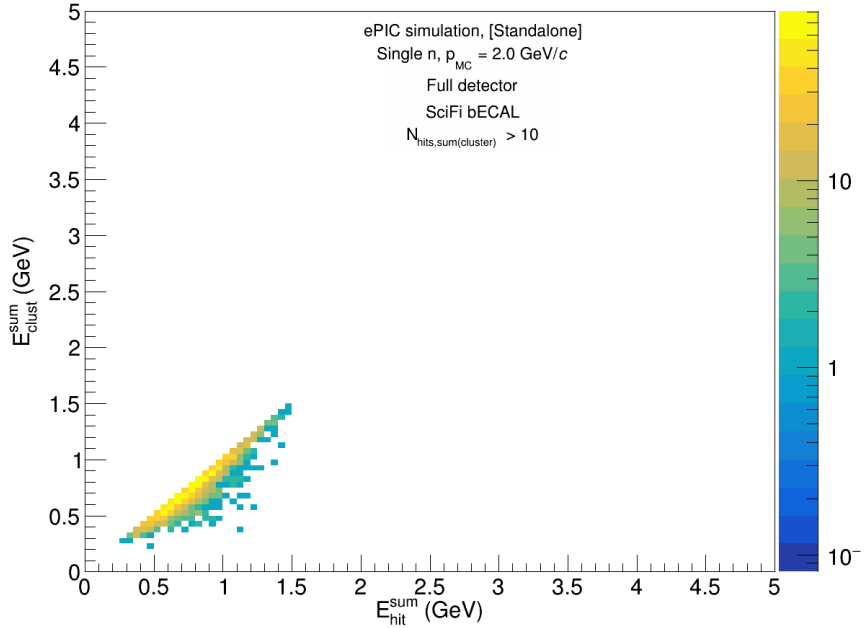


ENERGY DEPOSITION IN bECAL AFTER CUT

- Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $2\ \mathrm{GeV}$ neutrons
- (left) Before $N_{hits,sum(cluster)}$ cut
- (right) $N_{hits,sum(cluster)} > 10$ (see Slide 18)

- **Possibility to remove bad bECAL clusters based on cluster size/number of hits**
  - Not perfect, but seems to be working OK

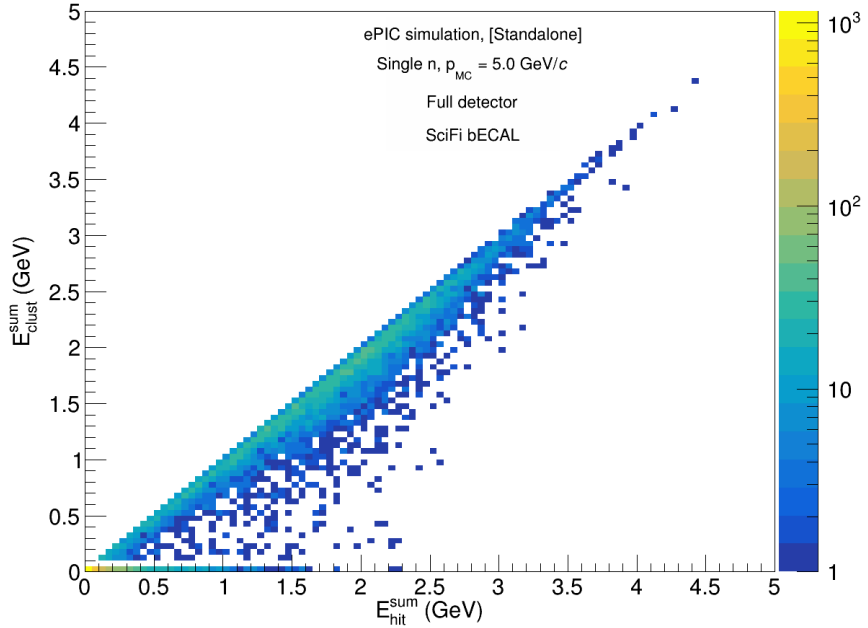


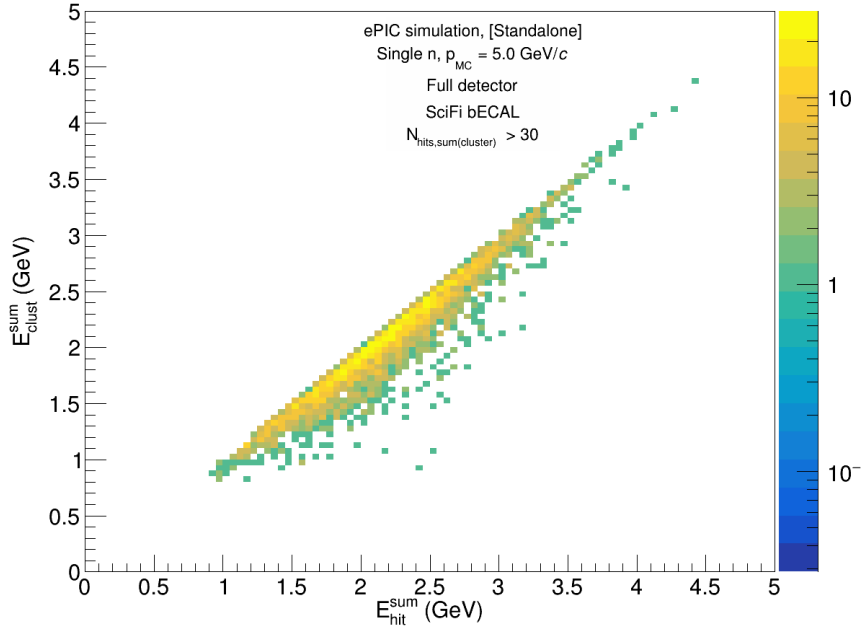


ENERGY DEPOSITION IN bECAL AFTER CUT

- Sum of energy from hits vs. sum of energy from SciFi clusters in bECAL $5\ \mathrm{GeV}$ neutrons
- (left) Before $N_{hits,sum(cluster)}$ cut
- (right) $N_{hits,sum(cluster)} > 30$ (see Slide 18)

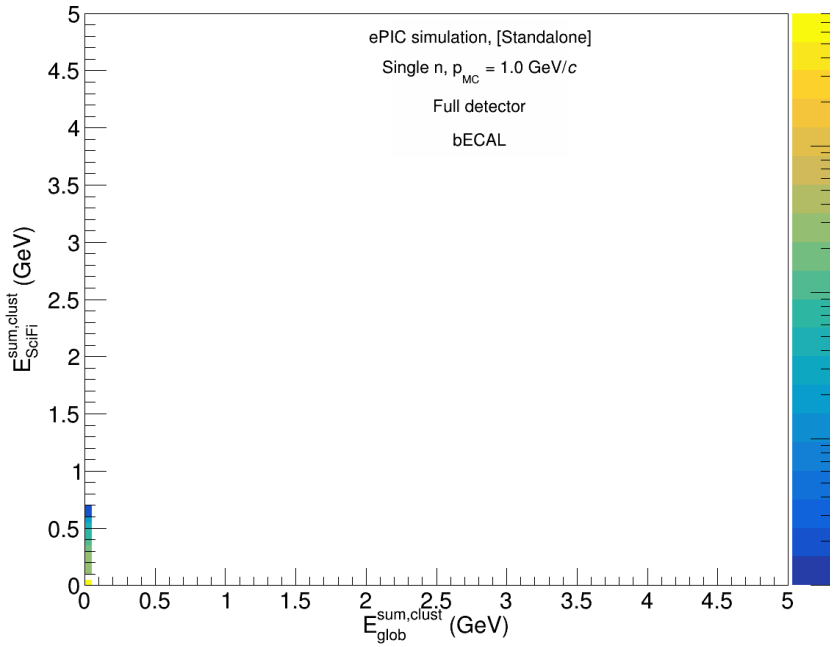
- **Possibility to remove bad bECAL clusters based on cluster size/number of hits**
  - Not perfect, but seems to be working OK

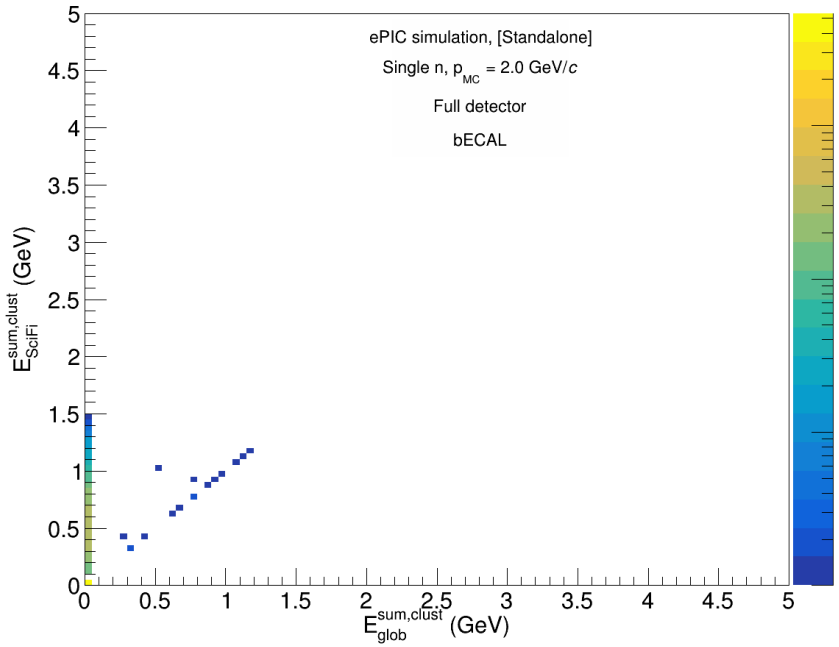


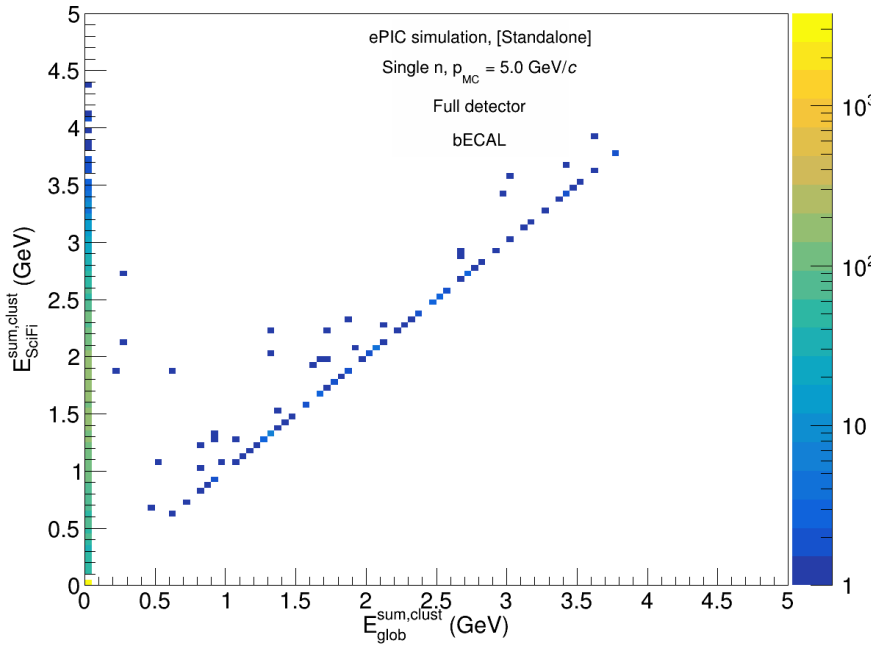


GLOBAL VS. SciFi CLUSTERS IN bECAL

- Comparison of energy from sum of global bECAL clusters and SciFi bECAL clusters
  - Global clusters: EcalBarrelClusters
  - SciFi clusters: EcalBarrelScFiClusters
- **Global clusters seem to have very poor efficiency compared to the SciFi clusters**
  - Important for ongoing ML/AI studies







SUMMARY AND OUTLOOK

- Simple bHCAL sampling fraction may not work well for low energy neutron
  - Often only all energy deposited in single tile
  - Very small shower size?
- Clustering in bHCAL may need updating to work properly with single tile readout
- Badly reconstructed energy from bECAL clusters correlated with small total number of hits in all clusters
  - Possible, but not perfect mitigation by selecting large enough total number of hits in all clusters
- Possible issues with global bECAL clusters (EcalBarrelClusters)
  - Better use SciFi clusters (EcalBarrelScFiClusters) for any studies for now
- **Outlook:**
  - Evaluate energy dependent sampling fraction for neutrons?
    - Make absorber sensitive in simulation and evaluate fraction of energy seen by tiles
  - Update of clustering in bHCAL?

THANK YOU FOR ATTENTION