BIC Simulation Meeting

Hybrid Clustering Algorithm for the Barrel Imaging Calorimeter (BIC) at the Electron Ion Collider (EIC)

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Hybrid Clustering For BIC

- **Topological clustering:**
  - **On Imaging Hits**
  - **On Scfi Hits**
- **Cross System Clustering**

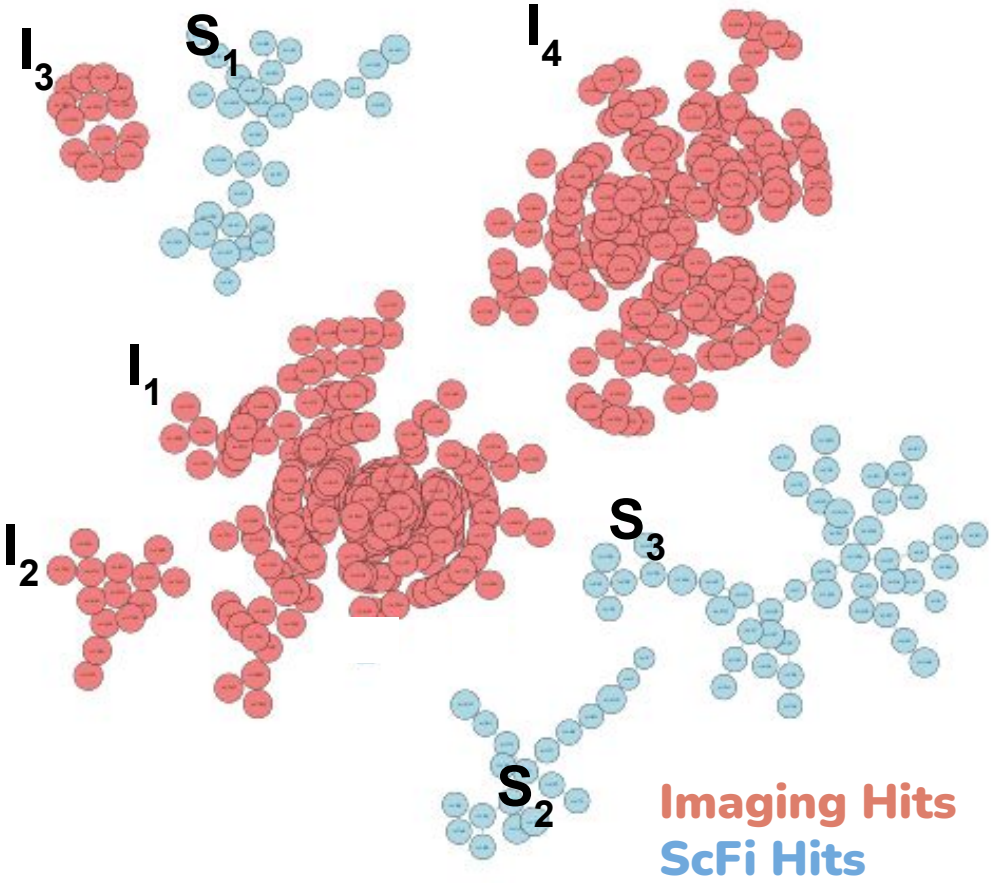
Imaging Topo Clustering for ScFi

ElayerMode	sameLayerMode	diffLayerMode
xy	sameLayerDistXY	diffLayerDistXY
etaphi	sameLayerDistEtaPhi	diffLayerDistEtaPhi
tz	sameLayerDistTZ	diffLayerDistTZ
xyz	**sameLayerDistXYZ**	**diffLayerDistXYZ**

```
case ImagingTopoClusterConfig::ELayerMode::xyz:
  return (std::abs(h1.getLocal().x - h2.getLocal().x) <= sameLayerDistXYZ[0]) &&
         (std::abs(h1.getLocal().y - h2.getLocal().y) <= sameLayerDistXYZ[1]) &&
         (std::abs(h1.getLocal().z - h2.getLocal().z) <= sameLayerDistXYZ[2]);
```

Cross-System Clustering

- **Start from an Imaging cluster**
- **Search for neighboring ScFi clusters**
- If a neighbour is found → combines Imaging and ScFi clusters
- Check whether other Imaging clusters connect to the same ScFi cluster
- Repeat the neighbour checks for all Imaging clusters
- Keep unused clusters unchanged



This is just for demonstration and are not real detector hits and clusters

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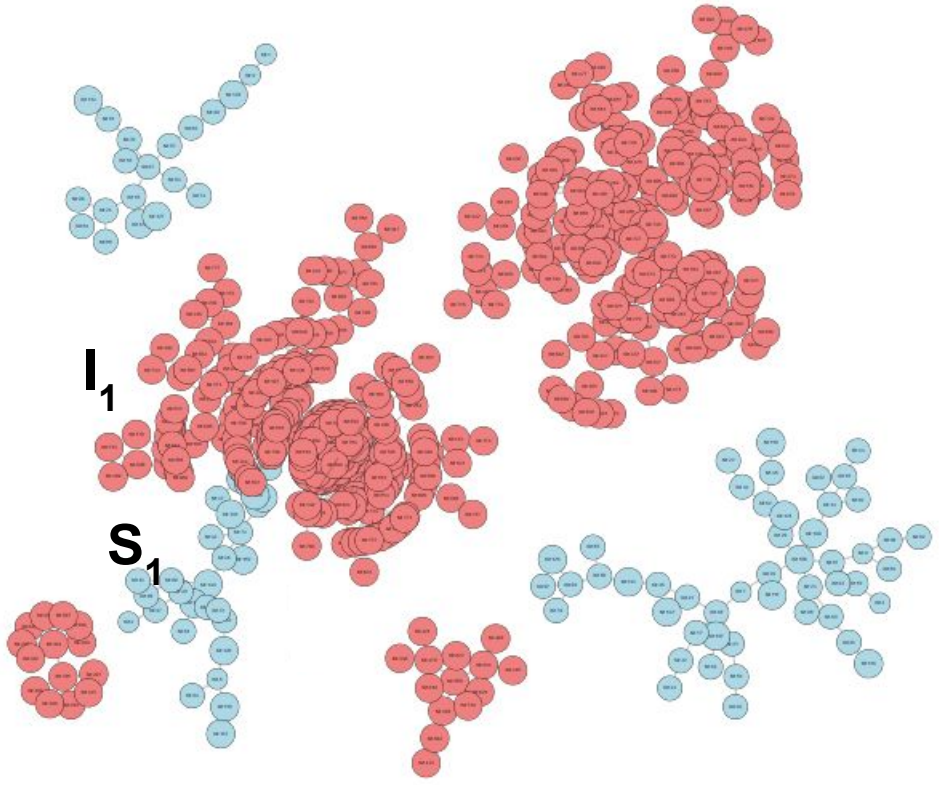

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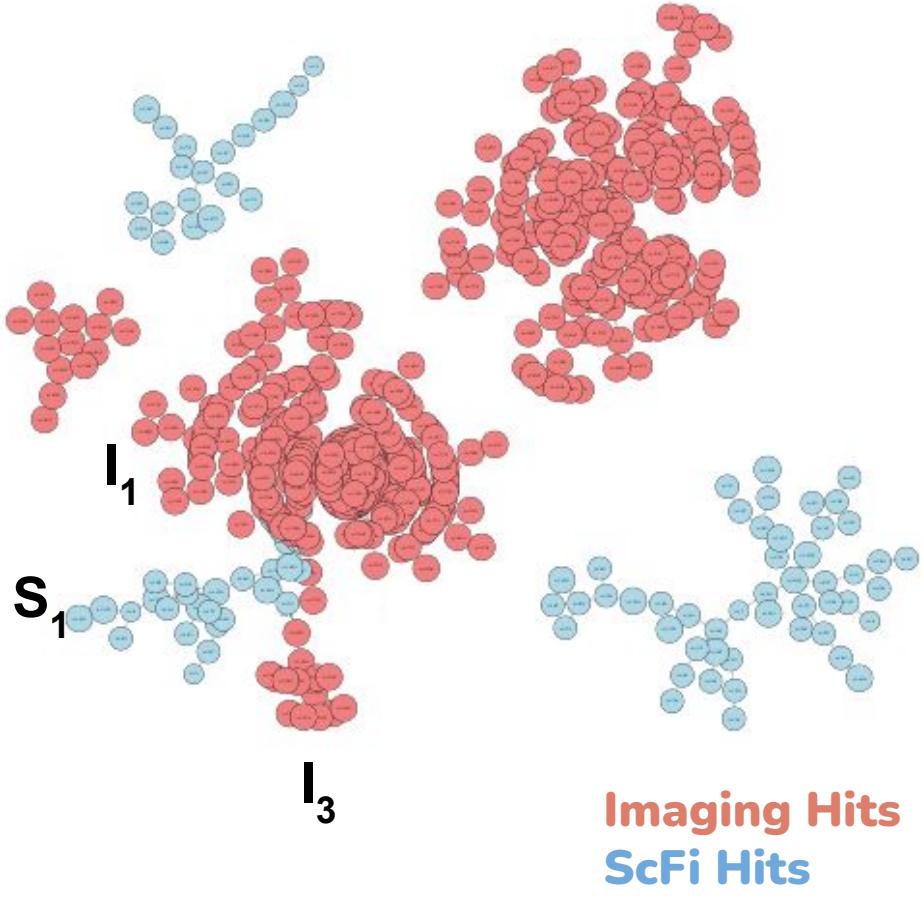

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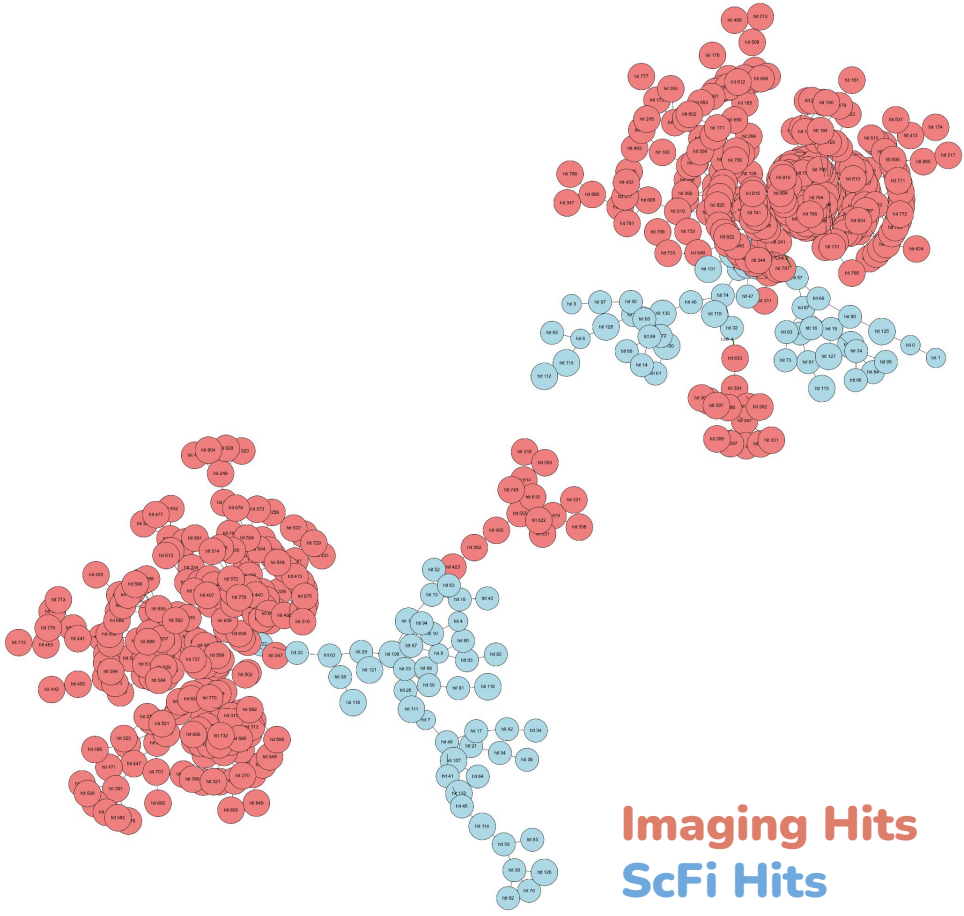

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Optimizing the Hybrid clustering : based on simulation of 2 Photon at different opening angles and with energy of 500 MeV.

Penalty score :

Cluster Count : $P_{\text{count}} = |N_{\text{clusters}} - N_{\text{true}}|$

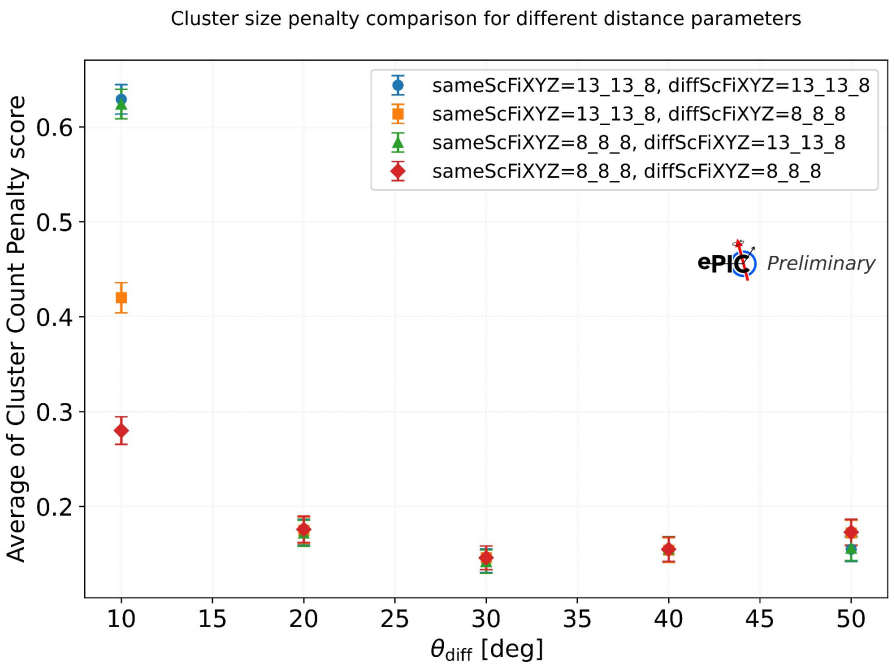
Cluster Energy : $P_{\text{energy}} = \frac{1}{N} \sum_{i=1}^{N} \frac{|E_{\text{cluster}} - E_{\text{true}}|}{E_{\text{true}}}$

Distance parameters are optimized by minimizing the penalty score; lower values indicate better clustering performance.

For now only the parameters used for Topological clustering on ScFi hits at the initial stage of Hybrid Clustering are optimized. They are:

1) **ScFisameLayerXYZ**
2) **ScFidiffLayerXYZ**

Hybrid Clustering (2 photons of 500 MeV)



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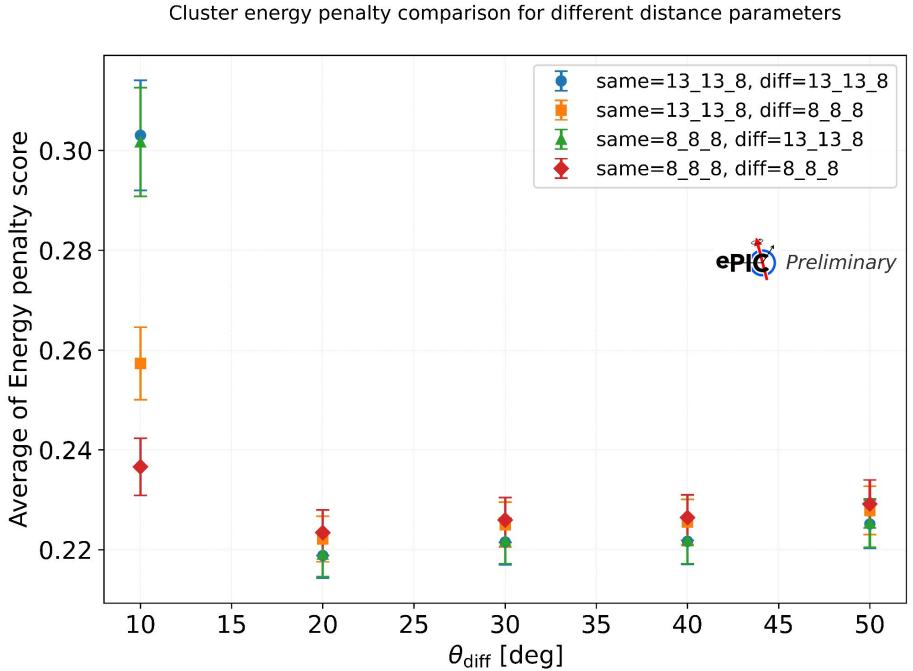


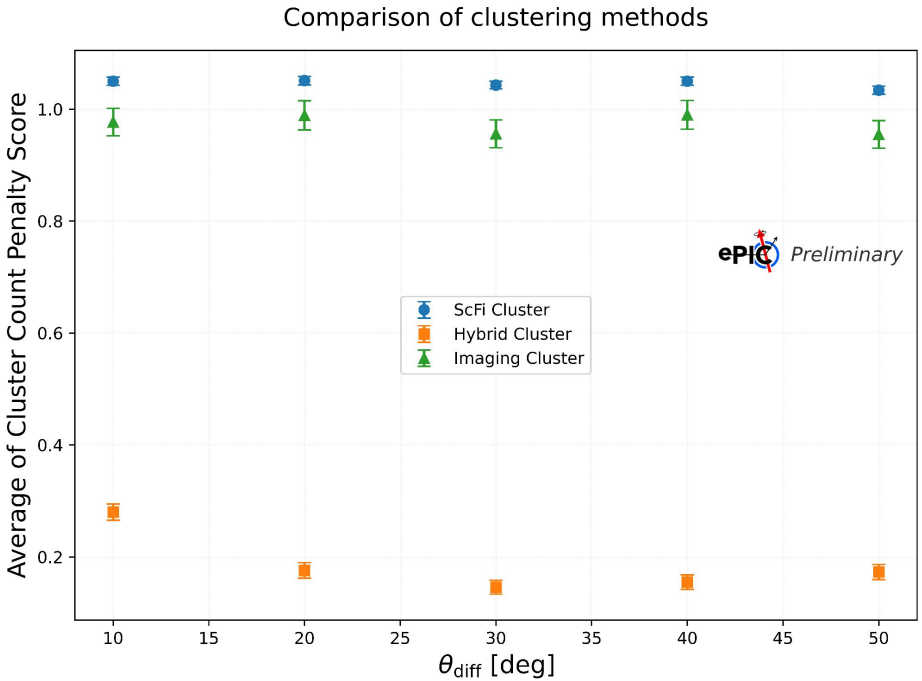
$$P_{\text{energy}} = \frac{1}{N}\sum_{i=1}^{N}\frac{|E_{\text{cluster}} - E_{\text{true}}|}{E_{\text{true}}}$$

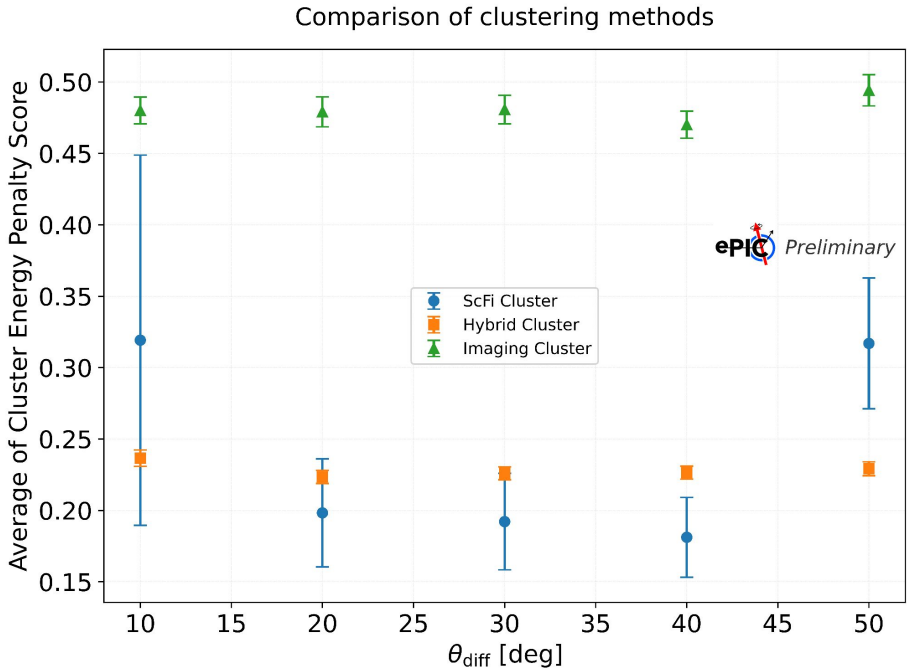
Distance parameter with low penalty is the best choice :
ScFisameLayerXYZ - 8,8,8
ScFidiffLayerXYZ - 8,8,8

Comparing the 3 Clustering Algorithms:

ScFisameLayerXYZ - 8,8,8

ScFidiffLayerXYZ - 8,8,8





Lower penalty → better clustering

Future Goal :

Study the physics-performance by applying the hybrid clustering algorithm to neutral pion reconstruction and evaluating how it improves photon separation, merging probability etc.

(Energy Position Merger Algorithm)Current Version:

Starts from an Imaging cluster
finds best matching ScFi cluster (each can be used only once):

Relative Energy of Imaging and ScFi < energy_Tolerance
del_eta < eta_Tolerance
del_phi < phi_Tolerance

If more than 1 best match : choose the one with closest energy to ScFi

For eg: Imaging = 4.0 GeV :

ScFi 0 = 3.8 GeV ΔE = 0.2
ScFi 1 = 4.1 GeV ΔE = 0.1 ← selected
ScFi 2 = 4.5 GeV ΔE = 0.5

The hybrid energy comes entirely from ScFi .

Merged Cluster stores subdetector energies energy of the the merged cluster is from ScFi

(Energy Position Merger Algorithm)New Version:

Compare each ScFi cluster with ALL Imaging clusters

Check Spatial matching : $\Delta\eta$, $\Delta\varphi$

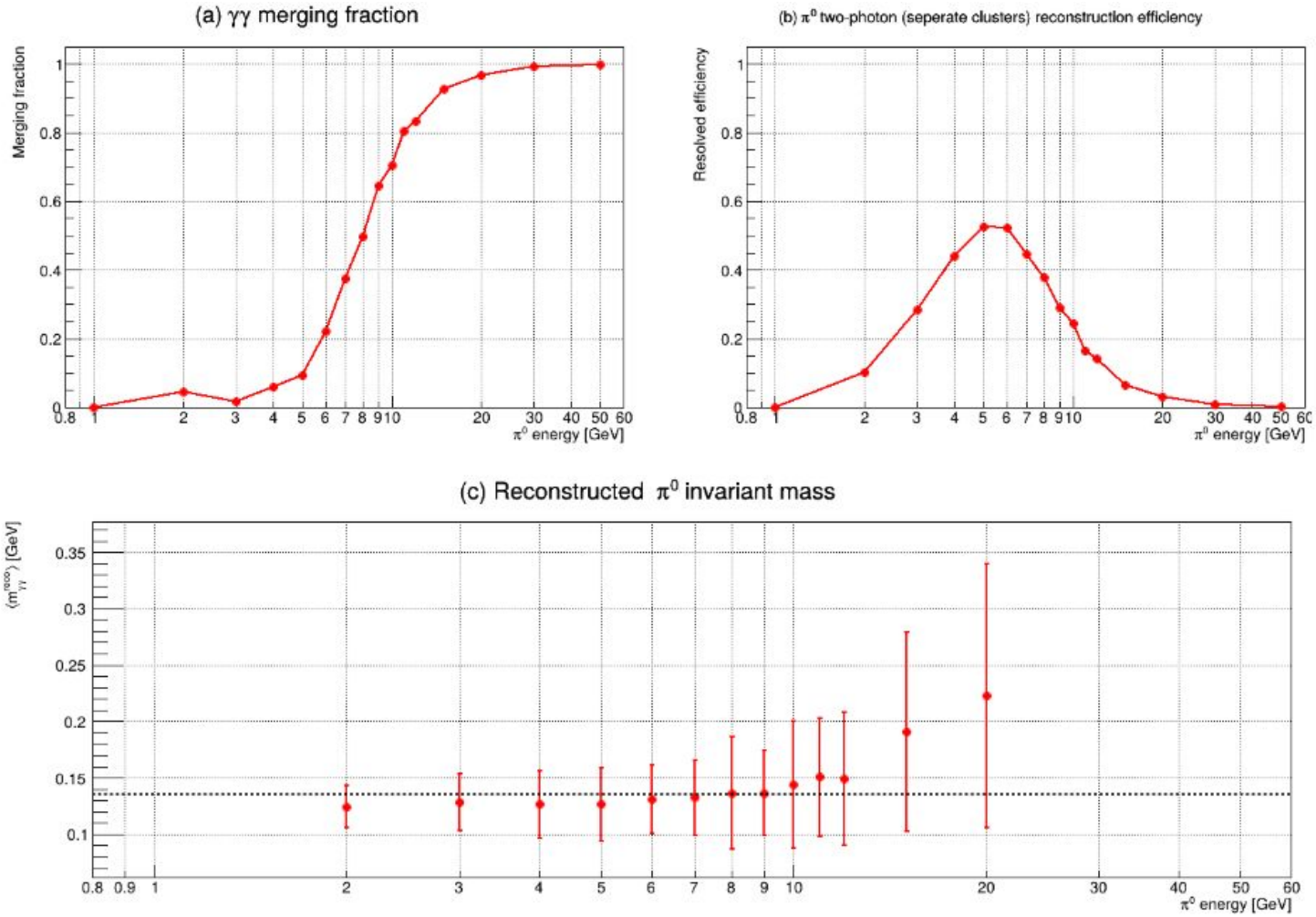
Find compatible Imaging clusters and calculate weight factor :

$$W_i = E_{img,i} / \text{Sum}\,(E_{img})$$

Distribute Scfi Energy : $E_i = W_i \times E_{scFi}$

```
Merging energy and position clusters for new event
Input clusters: 1 ScFi, 2 Imaging
  Energy cluster 0 matched 2 position cluster(s)
  Energy cluster 0 total assigned weight: 1
   --> ScFi cluster 0 -> Imaging cluster 0 -> merged cluster 0
       ScFi energy              = 10.150336 GeV
       Imaging energy           = 6.4409866 GeV
       sharing weight           = 0.9110789478148251
       assigned ScFi energy     = 9.247757684796678 GeV
       final merged energy      = 9.247758 GeV
       ScFi cluster 0 contains 88 hits

   --> ScFi cluster 0 -> Imaging cluster 1 -> merged cluster 1
       ScFi energy              = 10.150336 GeV
       Imaging energy           = 0.6286385 GeV
       sharing weight           = 0.08892105218517493
       assigned ScFi energy     = 0.9025785807672869 GeV
       final merged energy      = 0.9025786 GeV
       ScFi cluster 0 contains 88 hits
```


(a) γγ merging fraction
Merging fraction
π⁰ energy [GeV]
(b) π⁰ two-photon (seperate clusters) reconstruction efficiency
Resolved efficiency
π⁰ energy [GeV]
(c) Reconstructed π⁰ invariant mass
⟨m^reco_γγ⟩ [GeV]
π⁰ energy [GeV]

Next Step :

-> Improve the association logic in the Energy Position Merger Algorithm.

-> Study the 2 photon separation for pi0 decay and thereby compare the invariant mass of pi0.

Thank You