Joint ePIC/EICUG Meeting

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

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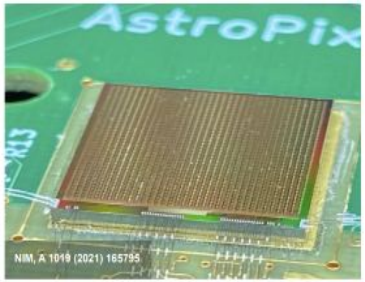
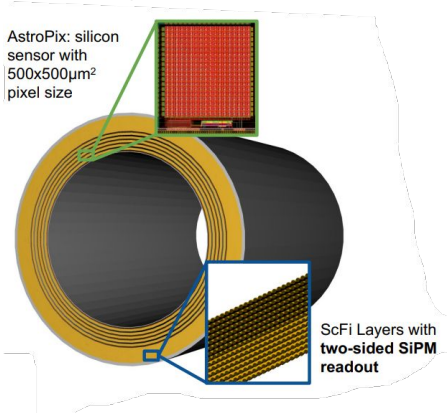
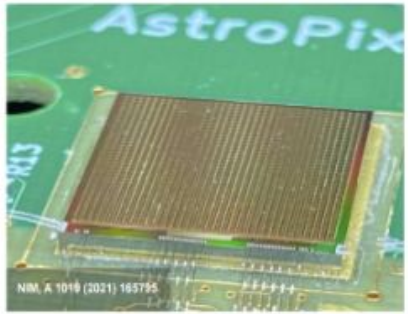
BARREL IMAGING CALORIMETER (BIC)

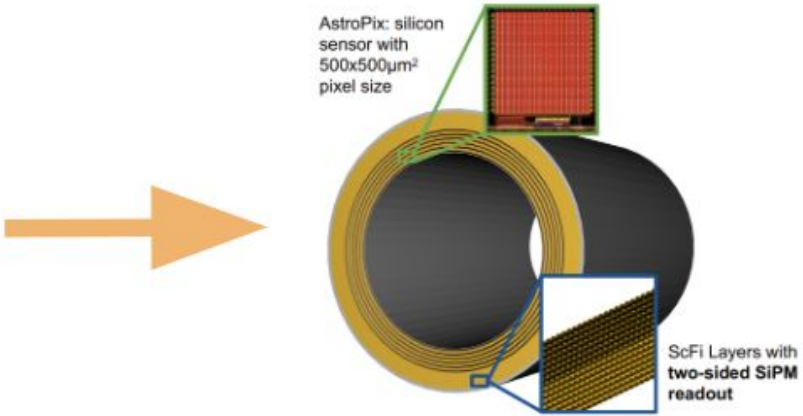
EIC will use the hybrid EM calorimeter by combining the Pb/ScFi technology used in the GlueX calorimeter and the AstroPix sensors developed for NASA's Amego-X Mission.





Longitudinal shower information from the ScFi system and fine spatial imaging from AstroPix measures 3D image of electromagnetic showers!





Clustering Methods :

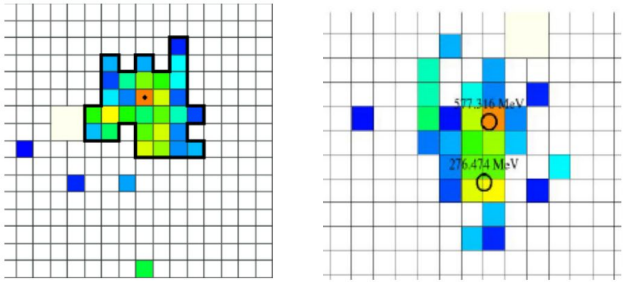
i. **ScFi system : Island Clustering Algorithm**
ii. **Imaging system : Topological Clustering Algorithm**

ScFi Hits : Island Clustering Algorithm

1. Identify the seed hit : (hits with energy above threshold)
2. Breadth-First Search (BFS)Grouping : Connects adjacent hits meeting a distance threshold
3. Find Local Maxima - Identifies energy peaks within each group:

    -If one maximum found: All hits form a single cluster

    -If multiple maxima found: splits clusters in the spatial distributions of energy



Plots by Chao Peng (ANL)

Island Clustering is 2D Clustering : Thus cannot be used for Imaging layers of BIC

Imaging Hits : Topological Clustering Algorithm

1. Starts with seed hit
2. Breadth-First Search (BFS) - Expands outward, adding neighboring hits to the cluster.
3. Neighbor criteria depend on the layer configuration:

    - Same layer Mode

    - Different layer Mode (within neighbour Layers Range)

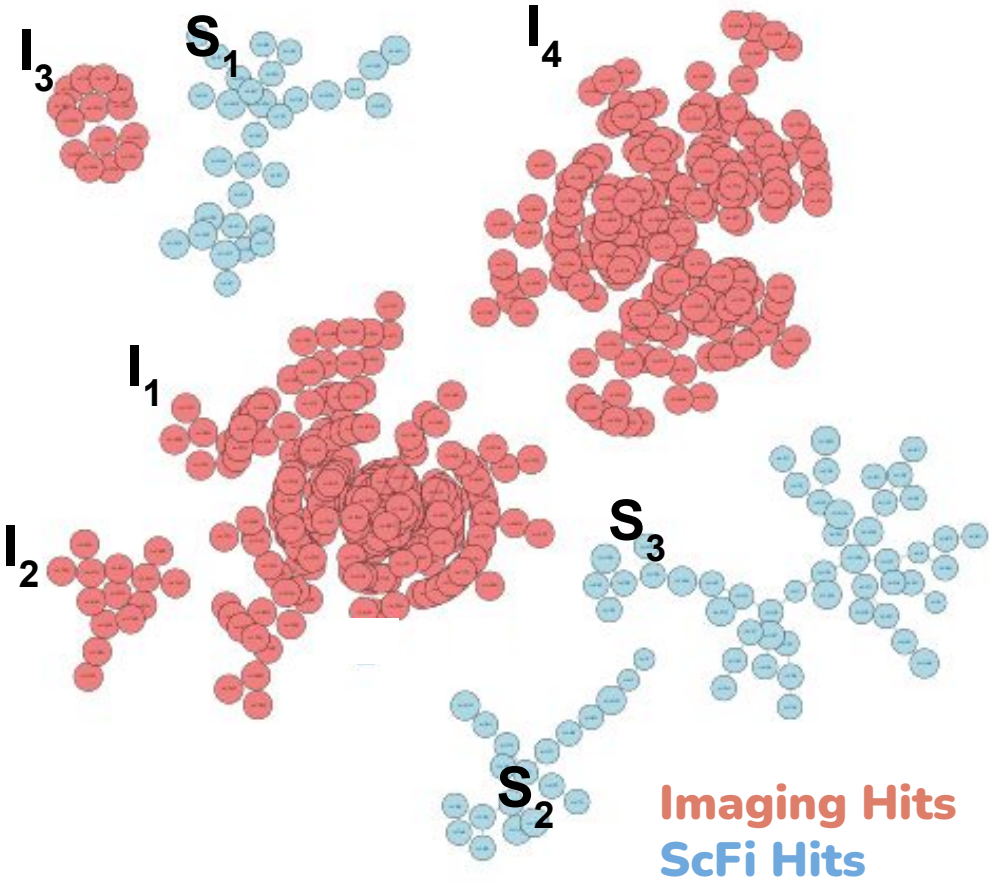
    - Different sectors

Hybrid Clustering For BIC

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

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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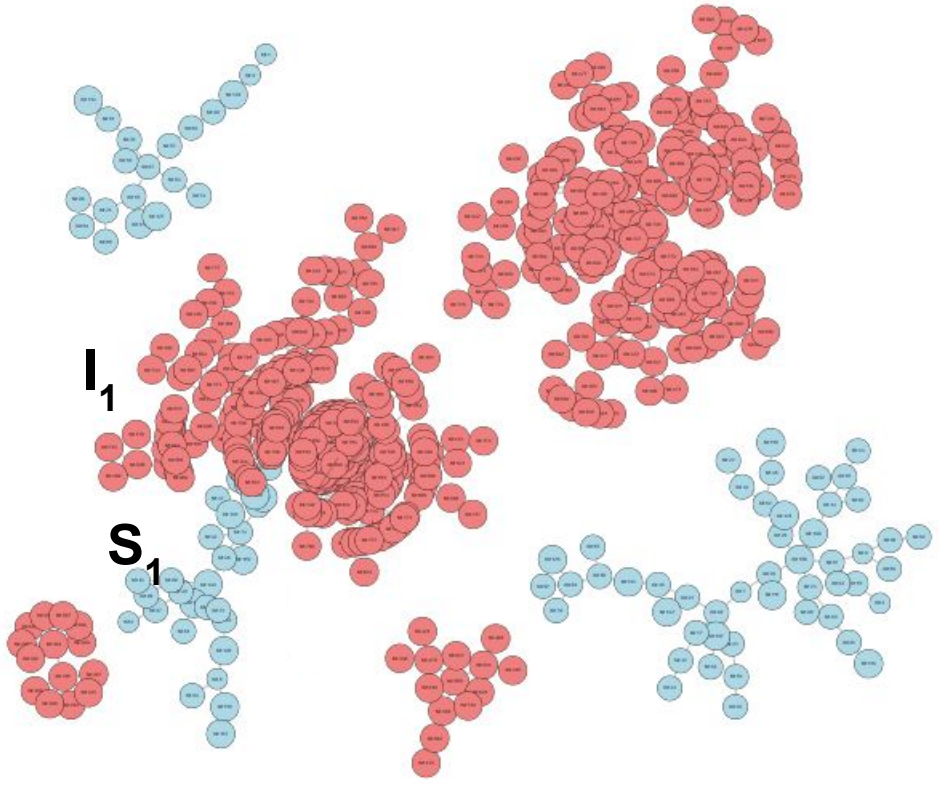

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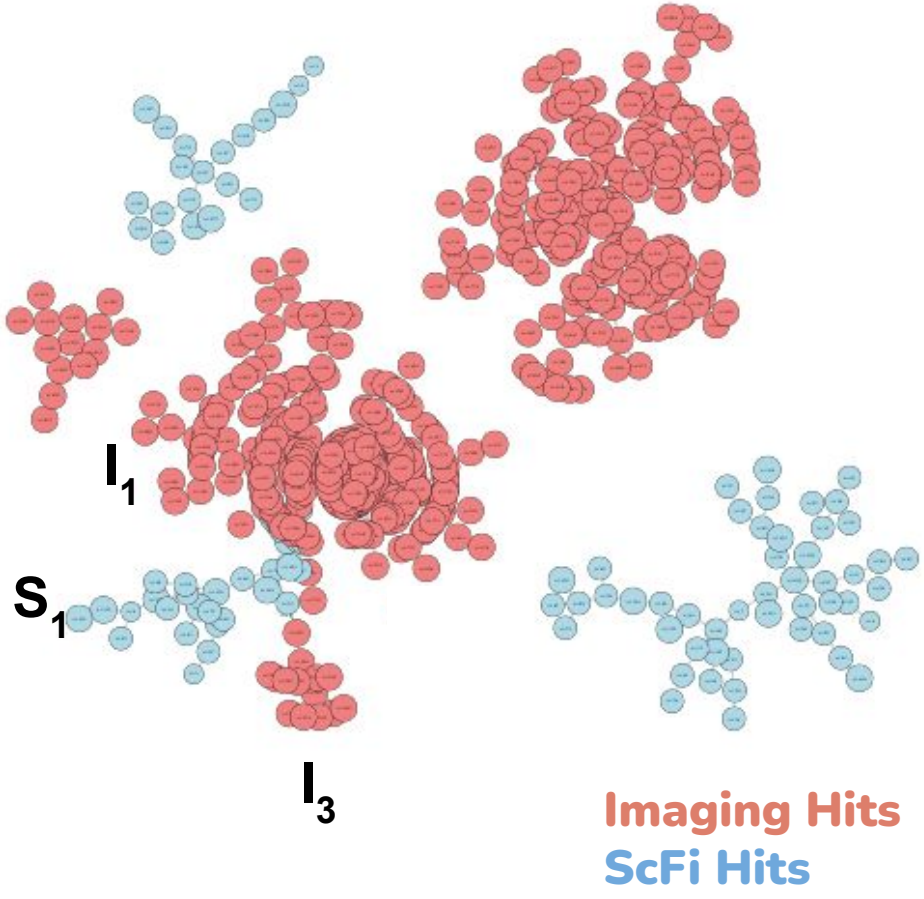

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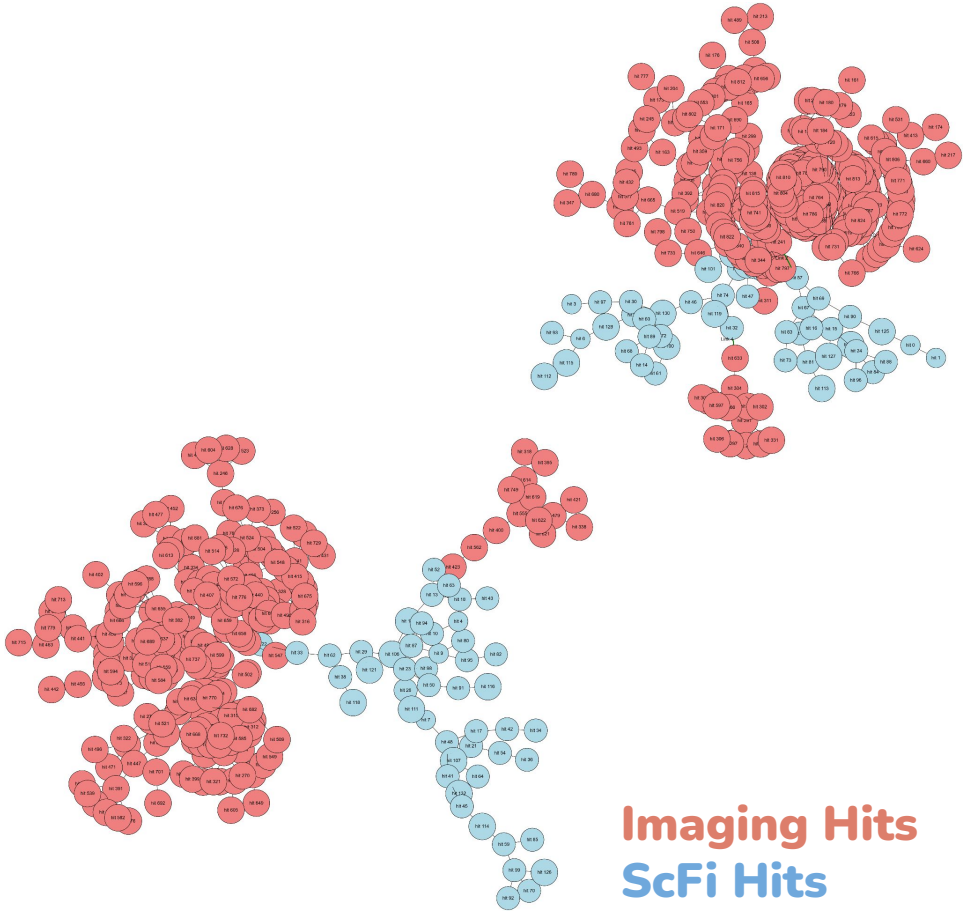

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Optimizing the Hybrid clustering : based on simulation of 2 Photon at different opening angles and with energy of 500 MeV.

Penalty score :

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

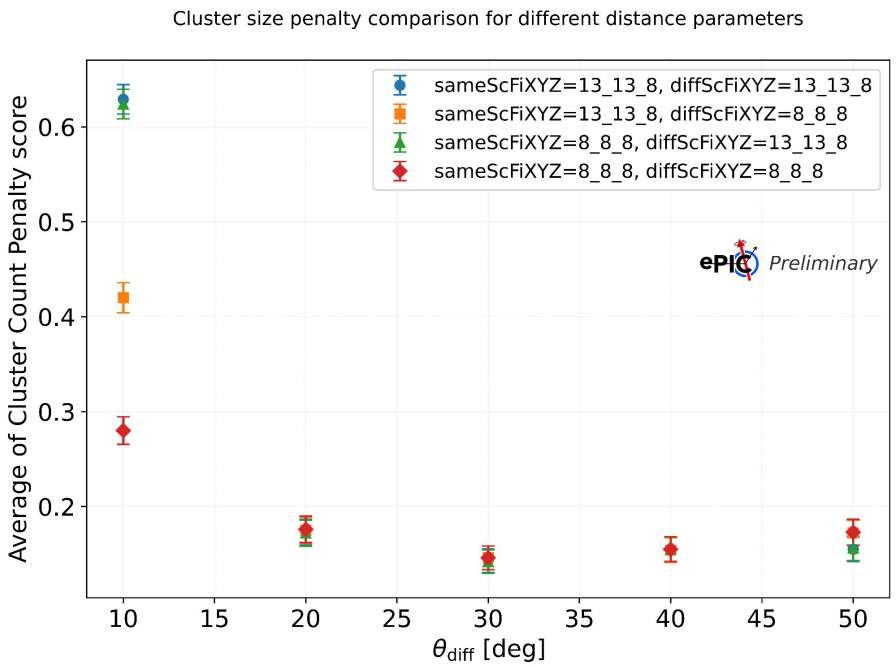
Cluster Energy : $P_{\text{energy}} = \frac{1}{N} \sum_{i=1}^{N} \frac{|E_{\text{cluster}} - E_{\text{true}}|}{E_{\text{true}}}$

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

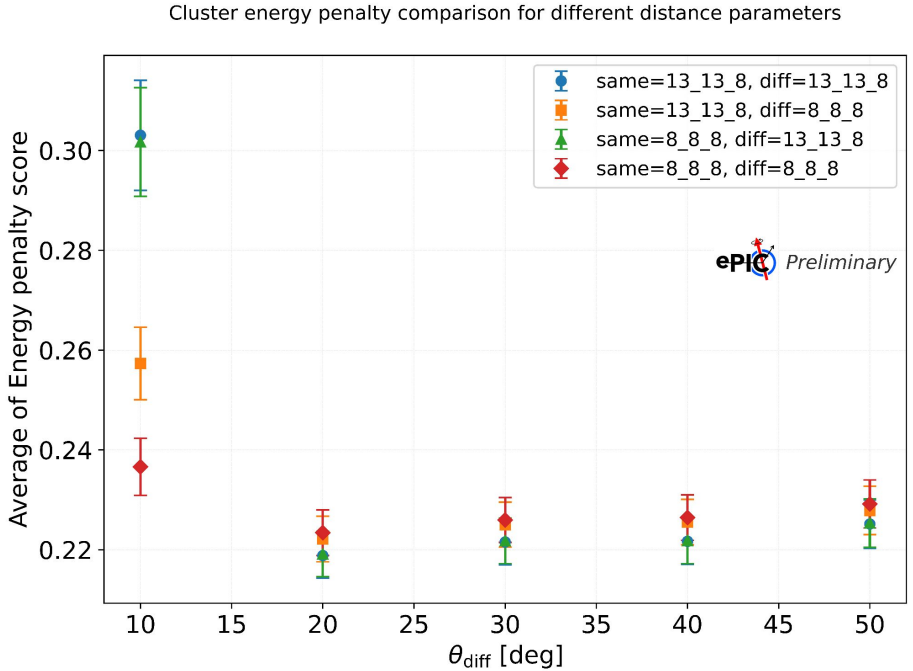
For now only the parameters used for Topological clustering on ScFi hits at the initial stage of Hybrid Clustering are optimized. They are:

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

Hybrid Clustering (2 photons of 500 MeV)



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



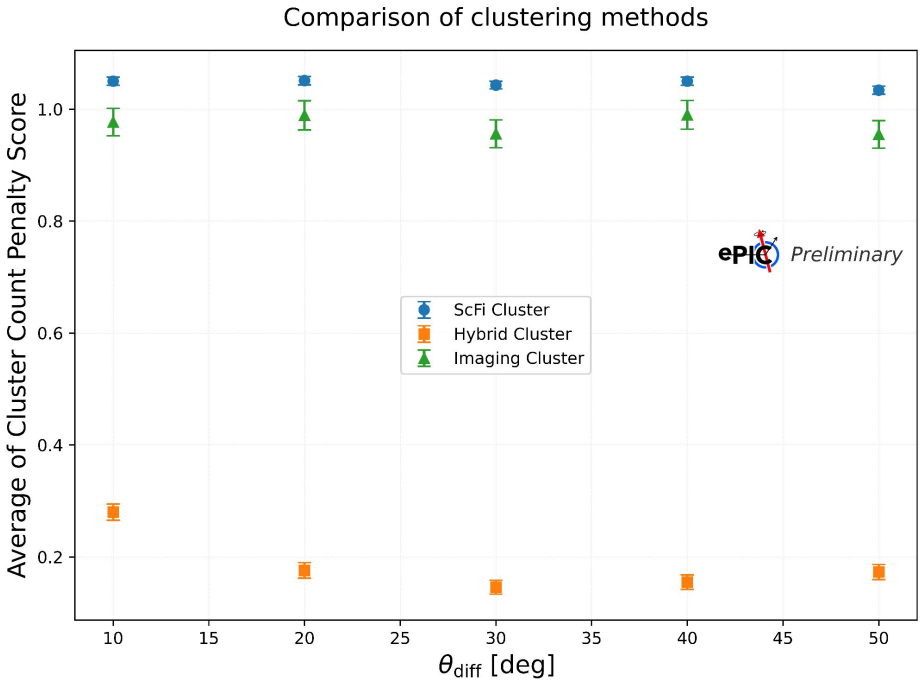
$$P_{\text{energy}} = \frac{1}{N}\sum_{i=1}^{N}\frac{|E_{\text{cluster}} - E_{\text{true}}|}{E_{\text{true}}}$$

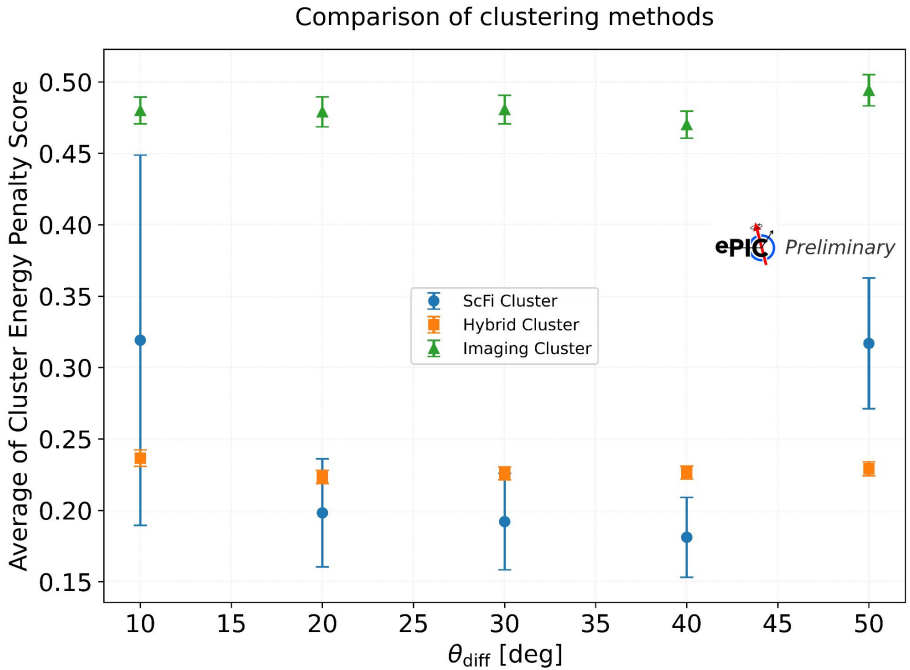
Distance parameter with low penalty is the best choice :
ScFisameLayerXYZ - 8,8,8
ScFidiffLayerXYZ - 8,8,8

Comparing the 3 Clustering Algorithms:

ScFisameLayerXYZ - 8,8,8

ScFidiffLayerXYZ - 8,8,8





Lower penalty → better clustering

Summary :

- **Currently the hybrid nature of the BIC uses two different clustering algorithm for each subsystem : Island Clustering, Topological Clustering.**
- **Developed a single clustering method for both subsystems at BIC : Hybrid Clustering Algorithm.**
- **Hybrid Clustering shows a low penalty score for both cluster count and cluster energy indicating a better performance than separate clustering method.**

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

Thank You