

ImagingTopoClustering on Combined Collection of ScFi and Img RecHits

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```
app->Add(new J0mniFactoryGeneratorT<ImagingTopoCluster_factory>(
    "EcalBarrelScFiProtoClusters_Topo", {"EcalBarrelScFiRecHits"},
    {"EcalBarrelScFiProtoClusters_Topo"},
    {
        .readout          = "EcalBarrelScFiHits",
        .neighbourLayersRange = 2, // # id diff for adjacent layer
        .sameLayerDistXYZ   = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .diffLayerDistXYZ   = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .sameLayerMode      = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .diffLayerMode      = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .sectorDist         = 5.0 * dd4hep::cm,
        .minClusterHitEdep  = 0,
        .minClusterCenterEdep = 0,
        .minClusterEdep     = 100 * dd4hep::MeV,
        .minClusterNhits    = 10,
    },
    app // TODO: Remove me once fixed
));
```

Subdir: XYZ_8_8_4_xyz_8_8_4

Theta	Avg SciFi Penalty	Avg Topo Penalty	#Events
10	1.006	0.419	1000
20	0.991	0.183	1000
30	1.003	0.175	1000
40	0.997	0.186	1000
50	0.996	0.197	1000

**Penalty score for ScFiClusters based on
ImagingTopoClustering is ~ 0**

Next Step:

ImagingTopoClustering on combined collection of ScFi and Imaging RecHits :

```
app->Add(new J0mniFactoryGeneratorT<CollectionCollector_factory<edm4eic::CalorimeterHit>>(
    "EcalBarrelRecHits_Topo", {"EcalBarrelScFiRecHits", "EcalBarrelImagingRecHits"},
    {"EcalBarrelRecHits_Topo"},
    app
));
```

ImagingTopoClustering : System based clustering of EcalBarrelRecHits_Topo

```
// helper function to group hits
bool ImagingTopoCluster::is_neighbour(const edm4eic::CalorimeterHit& h1,
                                      const edm4eic::CalorimeterHit& h2) const {

    // Get the "system" field from the ID specification
    auto* sys_field = m_idSpec.field("system");
    if (!sys_field) {
        error("Field 'system' not found in IDSpec for readout ", m_cfg.readout);
        return false;
    }
    // Extract system IDs for both hits
    int sys1 = sys_field->value(h1.getCellID());
    int sys2 = sys_field->value(h2.getCellID());

    if (sys1 != sys2) {
        debug("is_neighbour: different systems {} vs {}, returning false", sys1, sys2);
        return false;
    }
}
```

SystemID = 105 (ScFi):

sameLayer and DiffLayer grouping:

ScFi_sameLayerMode &
ScFi_diffLayerMode:
xy,xyz,etaphi,tz

SystemID = 101 (Img):

sameLayer and DiffLayer grouping:

Img_sameLayerMode &
Img_diffLayerMode:
xy,xyz,etaphi,tz

```
app->Add(new J0mniFactoryGeneratorT<ImagingTopoCluster_factory>(
    "EcalBarrelProtoClusters_Topo", {"EcalBarrelRecHits_Topo"},
    {"EcalBarrelProtoClusters_Topo"},
    {
        .readout = "EcalBarrelScFiHits",
        // we need a readout name to connect the cell ID to a system ID only,
        // so it does not matter that this is more specific than the hits we feed here
        .neighbourLayersRange = 2, // # id diff for adjacent Layer
        .ScFi_sameLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .Img_sameLayerDistTZ = {2.0 * dd4hep::mm, 2.0 * dd4hep::mm},
        .ScFi_diffLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .Img_diffLayerDistEtaPhi = {10.0 * dd4hep::mrad, 10.0 * dd4hep::mrad},
        .ScFi_sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .Img_sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::tz,
        .ScFi_diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .Img_diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::etaphi,
        .ScFi_sectorDist = 5.0 * dd4hep::cm,
        .Img_sectorDist = 3.0 * dd4hep::cm,
        .minClusterHitEdep = 0,
        .minClusterCenterEdep = 0,
        .minClusterEdep = 100 * dd4hep::MeV,
        .minClusterNhits = 10,
    }
),
app // TODO: Remove me once fixed
));
```

3 cases : ImagingTopoClustering on ScFi, Img and the combined collection

1.

```
app->Add(new JOmniFactoryGeneratorT<ImagingTopoCluster_factory>(  
    "EcalBarrelScFiProtoClusters_Topo", {"EcalBarrelScFiRecHits"},  
    {"EcalBarrelScFiProtoClusters_Topo"},  
    {  
        .readout = "EcalBarrelScFiHits",  
        .neighbourLayersRange = 2, // # id diff for adjacent layer  
        .sameLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},  
        .diffLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},  
        .sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,  
        .diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,  
        .sectorDist = 5.0 * dd4hep::cm,  
        .minClusterHitEdep = 0,  
        .minClusterCenterEdep = 0,  
        .minClusterEdep = 100 * dd4hep::MeV,  
        .minClusterNhits = 10,  
    },  
    app // TODO: Remove me once fixed  
));
```

2.

```
app->Add(new JOmniFactoryGeneratorT<ImagingTopoCluster_factory>(  
    "EcalBarrelImagingProtoClusters", {"EcalBarrelImagingRecHits"},  
    {"EcalBarrelImagingProtoClusters"},  
    {  
        .readout = "EcalBarrelImagingHits",  
        .neighbourLayersRange = 2, // # id diff for adjacent layer  
        .sameLayerDistTZ = {2.0 * dd4hep::mm, 2.0 * dd4hep::mm},  
        .diffLayerDistEtaPhi = {10.0 * dd4hep::mrad, 10.0 * dd4hep::mrad},  
        .sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::tz,  
        .diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::etaphi,  
        .sectorDist = 3.0 * dd4hep::cm,  
        .minClusterHitEdep = 0,  
        .minClusterCenterEdep = 0,  
        .minClusterEdep = 100 * dd4hep::MeV,  
        .minClusterNhits = 10,  
    },  
    app // TODO: Remove me once fixed  
));
```

3.

```
app->Add(new JOmniFactoryGeneratorT<ImagingTopoCluster_factory>(  
    "EcalBarrelProtoClusters_Topo", {"EcalBarrelRecHits_Topo"},  
    {"EcalBarrelProtoClusters_Topo"},  
    {  
        .readout = "EcalBarrelScFiHits",  
        // we need a readout name to connect the cell ID to a system ID only,  
        // so it does not matter that this is more specific than the hits we feed here  
        .neighbourLayersRange = 2, // # id diff for adjacent layer  
        .ScFi_sameLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},  
        .Img_sameLayerDistTZ = {2.0 * dd4hep::mm, 2.0 * dd4hep::mm},  
        .ScFi_diffLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},  
        .Img_diffLayerDistEtaPhi = {10.0 * dd4hep::mrad, 10.0 * dd4hep::mrad},  
        .ScFi_sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,  
        .Img_sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::tz,  
        .ScFi_diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,  
        .Img_diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::etaphi,  
        .ScFi_sectorDist = 5.0 * dd4hep::cm,  
        .Img_sectorDist = 3.0 * dd4hep::cm,  
        .minClusterHitEdep = 0,  
        .minClusterCenterEdep = 0,  
        .minClusterEdep = 100 * dd4hep::MeV,  
        .minClusterNhits = 10,  
    },  
    app // TODO: Remove me once fixed  
));
```

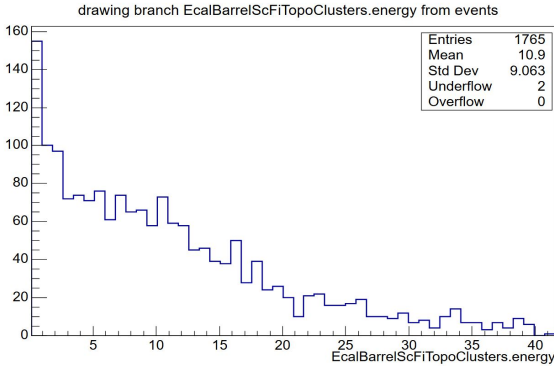
Here, for **Case 3**, we expect to have same ScFiClusters and ImgClusters since the clustering in this case is based on the systemID.

Two Photon Simulation

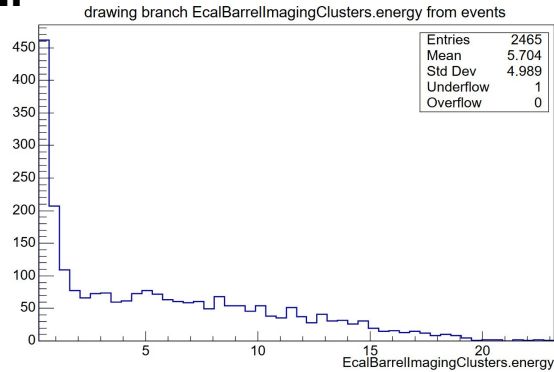
- Energy of Photon : uniformly random energy between 0 and 20 GeV
Both Photons have same Phi and different theta ($\theta_{\text{diff}} = 10$ deg)

3 cases : ImagingTopoClustering on ScFi, lmg and the combined collection

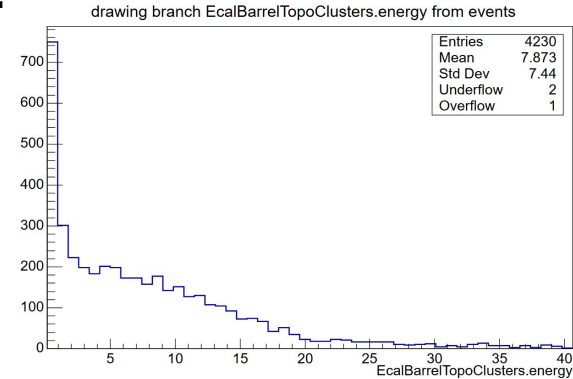
1.



2.



3.



Event	System	1 ScFiProto_Topo [Nhits,Cluster_energy]	2 ImagingProto [Nhits,Cluster_energy]	3 Proto_Topo [Nhits,Cluster_energy]
1	101		[58, 2.6583], [22, 0.9215], [14, 0.7880]	[58, 2.6583], [22, 0.9215], [14, 0.7880]
	105	[32, 3.1402], [29, 3.0545]		[32, 3.1402], [29, 3.0545]
2	101		[67, 2.8800], [41, 2.1399], [10, 1.0360]	[67, 2.8800], [41, 2.1399], [10, 1.0360]
	105	[47, 5.7402], [29, 1.8112]		[47, 5.7402], [29, 1.8112]
3	101		[274, 13.6912], [213, 12.1679], [14, 0.5946] [14, 0.5000]	[274, 13.6912], [213, 12.1679], [14, 0.5946] [14, 0.5000]
	105	[49, 23.6263], [31, 3.8452], [20, 7.6845]		[49, 23.6263], [31, 3.8452], [20, 7.6845]
4	101		[141, 7.5607], [131, 6.1113], [10, 0.3107]	[141, 7.5607], [131, 6.1113], [10, 0.3107]
	105	[33, 9.8753], [24, 0.6192], [19, 4.8223]		[33, 9.8753], [24, 0.6192], [19, 4.8223]
5	101		[285, 14.2571], [114, 6.1309]	[285, 14.2571], [114, 6.1309]
	105	[48, 10.7488], [30, 23.9112]		[48, 10.7488], [30, 23.9112]

ImagingTopoClustering : Cross-System clustering of EcalBarrelRecHits_Topo

```
// helper function to group hits
bool ImagingTopoCluster::is_neighbour(const edm4eic::CalorimeterHit& h1,
                                      const edm4eic::CalorimeterHit& h2) const {

    // different sectors, simple distance check
    if (h1.getSector() != h2.getSector()) {
        return std::hypot((h1.getPosition().x - h2.getPosition().x),
                          (h1.getPosition().y - h2.getPosition().y),
                          (h1.getPosition().z - h2.getPosition().z)) <= sectorDist;
    }
}
```

Since in this case we let the ScFi hits to consider as a neighbour of the Imaging hits, Layer based grouping is not required..

```
app->Add(new JOmniFactoryGeneratorT<ImagingTopoCluster_factory>({
    "EcalBarrelProtoClusters_Topo", {"EcalBarrelRecHits_Topo"},
    {"EcalBarrelProtoClusters_Topo"},
    {
        .readout = "EcalBarrelScFiHits",
        // we need a readout name to connect the cell ID to a system ID only,
        // so it does not matter that this is more specific than the hits we feed here
        .neighbourLayersRange = 2,

        .sameLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .diffLayerDistXYZ = {80.0 * dd4hep::mm, 80.0 * dd4hep::mm, 40.0 * dd4hep::mm},
        .sameLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .diffLayerMode = eicrecon::ImagingTopoClusterConfig::ELayerMode::xyz,
        .sectorDist = 5.0 * dd4hep::cm,

        .minClusterHitEdep = 0,
        .minClusterCenterEdep = 0,
        .minClusterEdep = 100 * dd4hep::MeV,
        .minClusterNhits = 10,

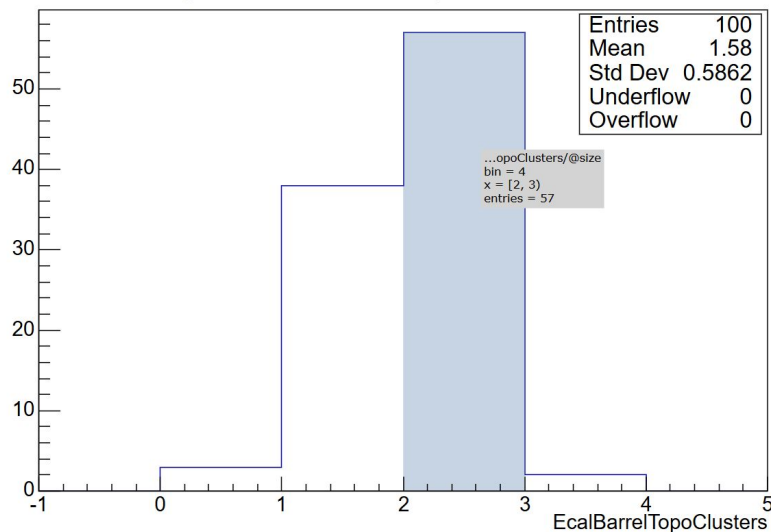
    },
    app // TODO: Remove me once fixed
));
```

In this case, we expect only two clusters due to cross system clustering

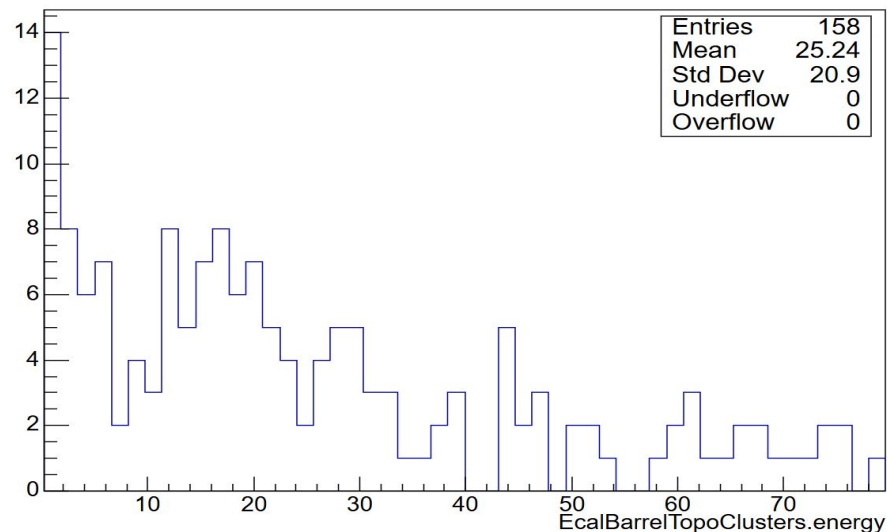
Two Photon Simulation

- Energy of Photon : uniformly random energy between 0 and 20 GeV
Both Photons have same Phi and different theta (theta_diff = 10deg)

drawing branch EcalBarrelTopoClusters from events



drawing branch EcalBarrelTopoClusters.energy from events



Summary :

- Two ways of ImagingTopoClustering on EcalBarrelRecHits_Topo: System Based Clustering and Cross system Clustering.
 - System based clustering : The Clustering matched with separate clustering of ScFi Hits and Imaging Hits
 - Cross System Clustering : Most of the events showed 2 clusters as expected. But still need to adjust the clustering parameters for better clustering.

Next Steps:

- Fix the doubling of energy in th Cross system case.
- In the Cluster Reconstruction of the Cross System clustering, need to work on to get Position info completely based on the AstroPixand Energy info based on ScFi