Cluster Splitting and Merging For ScFi

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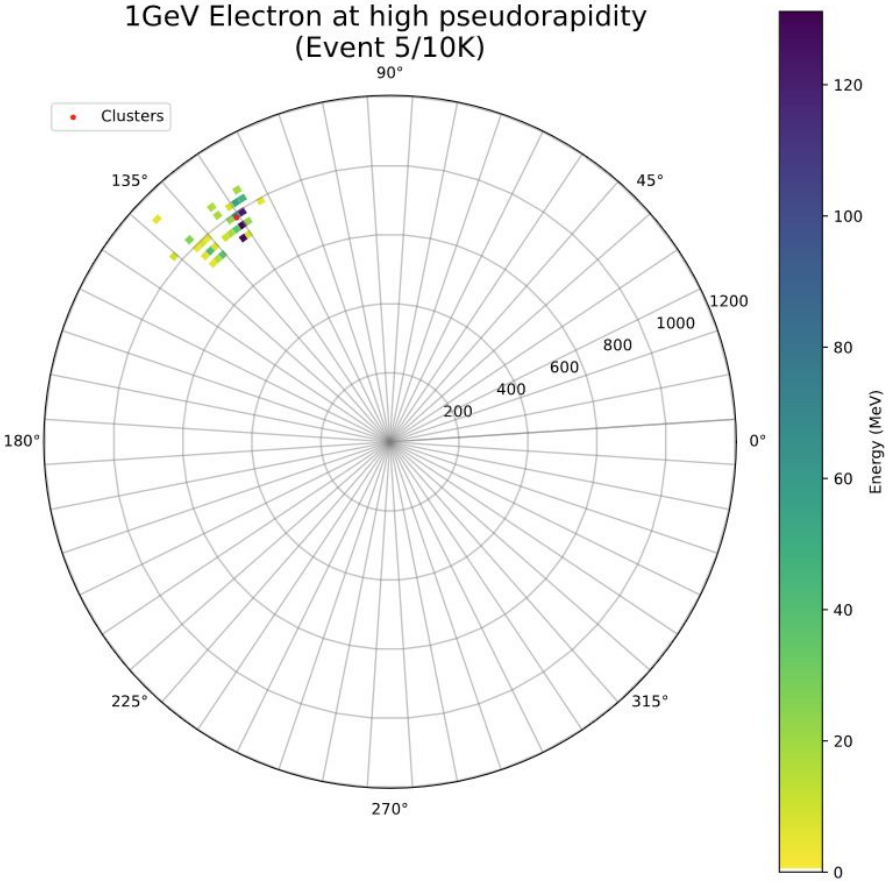
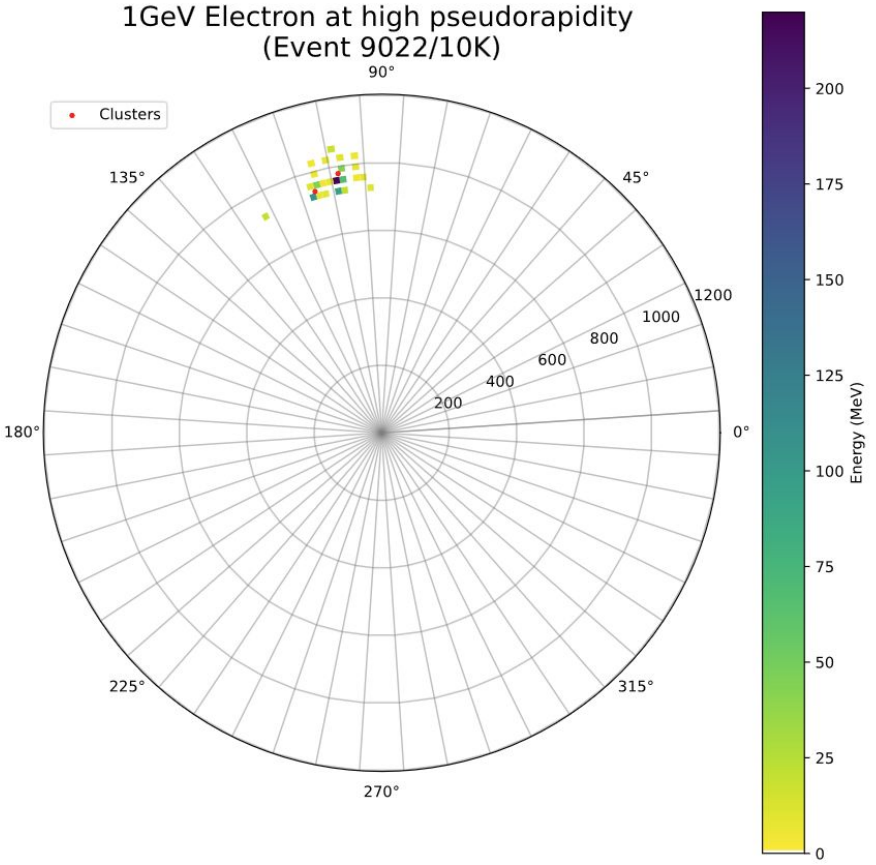
1 GeV Electron Simulation :

```
from DDSim.DD4hepSimulation import DD4hepSimulation
from g4units import mm, GeV, MeV, deg
SIM = DD4hepSimulation()

SIM.gun.etaMin = -2
SIM.gun.etaMax = -0.8
SIM.gun.distribution = "cos(theta)"
SIM.gun.energy = 1*GeV
SIM.gun.particle = "e-"
SIM.gun.phiMin = 90*deg
SIM.gun.phiMax = 150*deg
```

Clustering Parameters:

```
app->Add(new JOmniFactoryGeneratorT<CalorimeterIslandCluster_factory>(
  "EcalBarrelScFiProtoClusters", {"EcalBarrelScFiRecHits"}, {"EcalBarrelScFiProtoClusters"},
  {
    .sectorDist = 50. * dd4hep::mm,
    .localDistXZ = {80 * dd4hep::mm, 80 * dd4hep::mm},
    .splitCluster = false,
    .minClusterHitEdep = 5.0 * dd4hep::MeV,
    .minClusterCenterEdep = 100.0 * dd4hep::MeV,
  },
  app
));
```





Should we split it into two separate clusters?

Should we merge it into single cluster?

Event

Cluster

Hits contribution to the cluster

Particle contributing to the Hit

Trace back to its parent particles
(recursively until the initial particle)

From the Parent hierarchy :

Find the decay within the calorimeter -- Valid Decay

Corresponding decay radius -- minimum decay radius

```
============================================================
Processing Event 8/9999
============================================================

Clusters size: 1
Sim hits size: 171
Processing Cluster 0 in Event 8
Complete Parent Hierarchy for Cluster 0 in Event 8:
------------------------------------------------
    Particle ID: 233, PDG Code: -11, Decay Vertex: (182.094, 864.382, -2384.51), Decay Radius: 883.354, Phi: 78.1038
    Particle ID: 231, PDG Code: 22, Decay Vertex: (180.691, 866.008, -2380.04), Decay Radius: 884.657, Phi: 78.2144
    Particle ID: 226, PDG Code: -11, Decay Vertex: (179.014, 864.369, -2368.11), Decay Radius: 882.712, Phi: 78.2992
    Particle ID: 1, PDG Code: 22, Decay Vertex: (25.1572, 392.933, -1049.93), Decay Radius: 393.737, Phi: 86.3367
    Particle ID: 0, PDG Code: 11, Decay Vertex: (0, 0, 0), Decay Radius: 0, Phi: 0
------------------------------------------------
Complete Parent Hierarchy for Cluster 0 in Event 8:
------------------------------------------------
    Particle ID: 232, PDG Code: 11, Decay Vertex: (182.094, 864.382, -2384.51), Decay Radius: 883.354, Phi: 78.1038
    Particle ID: 231, PDG Code: 22, Decay Vertex: (180.691, 866.008, -2380.04), Decay Radius: 884.657, Phi: 78.2144
    Particle ID: 226, PDG Code: -11, Decay Vertex: (179.014, 864.369, -2368.11), Decay Radius: 882.712, Phi: 78.2992
    Particle ID: 1, PDG Code: 22, Decay Vertex: (25.1572, 392.933, -1049.93), Decay Radius: 393.737, Phi: 86.3367
    Particle ID: 0, PDG Code: 11, Decay Vertex: (0, 0, 0), Decay Radius: 0, Phi: 0
------------------------------------------------
Complete Parent Hierarchy for Cluster 0 in Event 8:
------------------------------------------------
    Particle ID: 185, PDG Code: 11, Decay Vertex: (296.991, 904.539, -2488.53), Decay Radius: 952.047, Phi: 71.8232
    Particle ID: 130, PDG Code: 22, Decay Vertex: (261.791, 825.586, -2299.53), Decay Radius: 866.099, Phi: 72.4063
    Particle ID: 128, PDG Code: -11, Decay Vertex: (261.729, 825.45, -2299.21), Decay Radius: 865.95, Phi: 72.4075
    Particle ID: 121, PDG Code: 22, Decay Vertex: (261.164, 824.361, -2296.6), Decay Radius: 864.742, Phi: 72.4214
    Particle ID: 116, PDG Code: -11, Decay Vertex: (147.126, 649.936, -1820.95), Decay Radius: 666.38, Phi: 77.2449
    Particle ID: 5, PDG Code: 22, Decay Vertex: (142.082, 641.327, -1793.38), Decay Radius: 656.877, Phi: 77.5082
    Particle ID: 0, PDG Code: 11, Decay Vertex: (0, 0, 0), Decay Radius: 0, Phi: 0
------------------------------------------------
Complete Parent Hierarchy for Cluster 0 in Event 8:
------------------------------------------------
    Particle ID: 197, PDG Code: -11, Decay Vertex: (266.059, 831.507, -2420.71), Decay Radius: 873.035, Phi: 72.2568
    Particle ID: 119, PDG Code: 22, Decay Vertex: (165.608, 679.687, -1913.06), Decay Radius: 699.572, Phi: 76.3065
    Particle ID: 116, PDG Code: -11, Decay Vertex: (147.126, 649.936, -1820.95), Decay Radius: 666.38, Phi: 77.2449
    Particle ID: 5, PDG Code: 22, Decay Vertex: (142.082, 641.327, -1793.38), Decay Radius: 656.877, Phi: 77.5082
    Particle ID: 0, PDG Code: 11, Decay Vertex: (0, 0, 0), Decay Radius: 0, Phi: 0
------------------------------------------------
```

Valid Decay

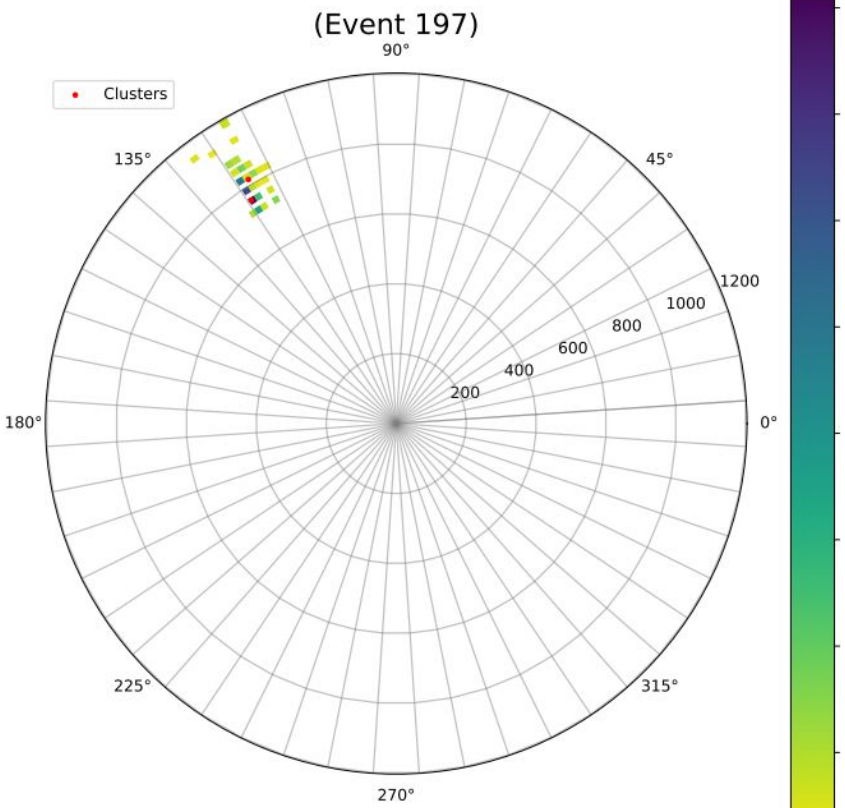
Clusters that need to be Merged:

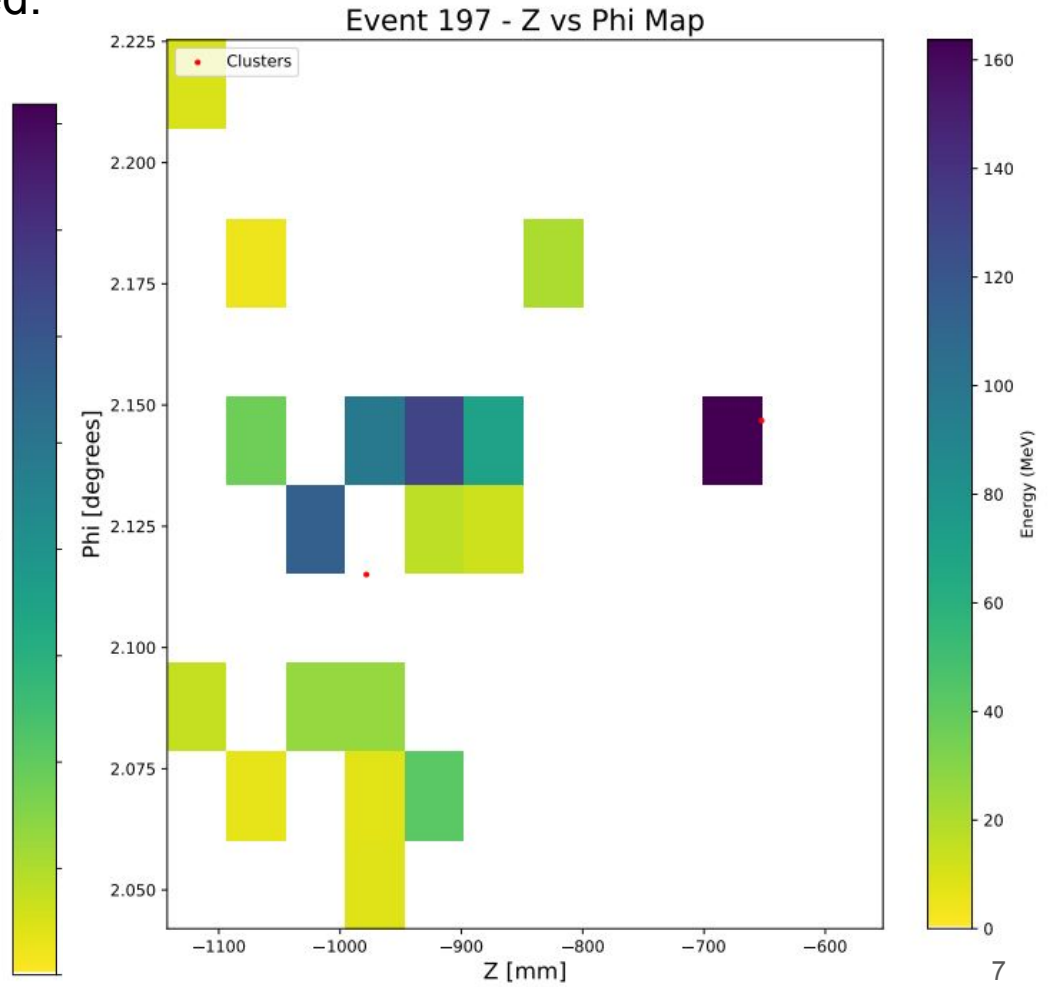
```
------------------------------------------------------------------------
                    Processing Cluster 0 in Event 197
------------------------------------------------------------------------
Total Energy of Cluster (cluster.getEnergy()) 0.633965 GeV
Total Energy of Cluster (sum of contribution energy): 0.0586887 GeV

=======================Grouped Particles by Decay Radius=================

Group with Decay Radius: 0

Energy Percentage (Cluster) in the Group with radius: 0 is 9.15774 %
Energy Percentage (Calculated) in the Group with radius: 0 is 98.9234 %

Group with Decay Radius: 750

Energy Percentage (Cluster) in the Group with radius: 750 is 0.0996697 %
Energy Percentage (Calculated) in the Group with radius: 750 is 1.07665 %


------------------------------------------------------------------------
                    Processing Cluster 1 in Event 197
------------------------------------------------------------------------
Total Energy of Cluster (cluster.getEnergy()) 0.163667 GeV
Total Energy of Cluster (sum of contribution energy): 0.0152852 GeV

=======================Grouped Particles by Decay Radius=================

Group with Decay Radius: 0

Energy Percentage (Cluster) in the Group with radius: 0 is 9.33919 %
Energy Percentage (Calculated) in the Group with radius: 0 is 100 %
```

Group the valid decays with minimum decay radius within +/-25 cm together

Group with Maximum Energy contribution is common to both the clusters : This clusters need to be merged.

Splitted Clusters that need to be Merged:





Total number of Events Simulated : 10000

```
==========================================
Total Events With Zero Clusters: 1224
Total Events With One Cluster: 8116
Total Events With More Than One Cluster: 659
Total Events needed Merging: 123
==========================================
```

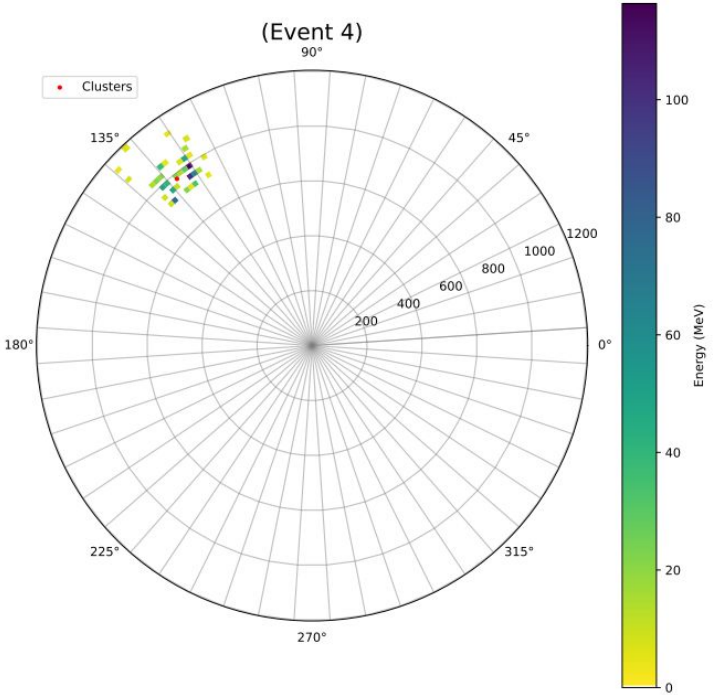
Clusters that need to be Splitted:

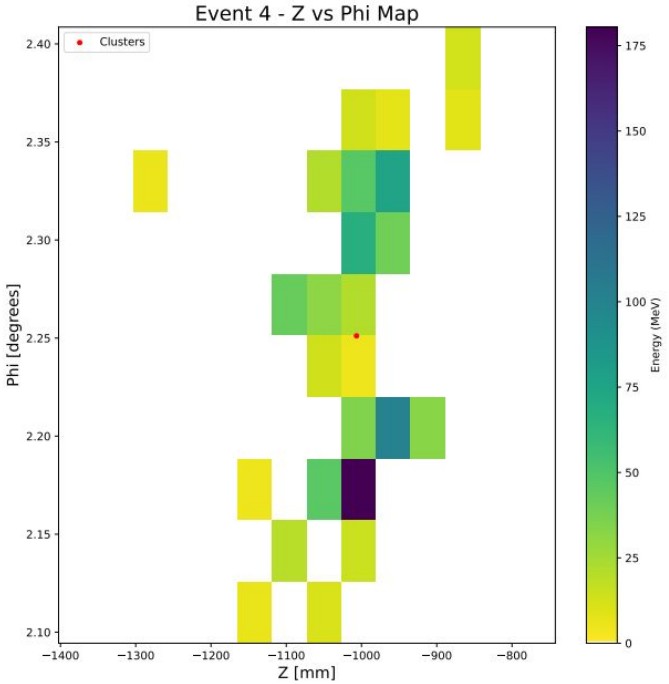
```
------------------------------------------------------------------
                    Processing Cluster 0 in Event 4
------------------------------------------------------------------
Total Energy of Cluster (cluster.getEnergy()) 0.801576 GeV
Total Energy of Cluster (sum of contribution energy): 0.0742484 GeV

================= Grouped Particles by Decay Radius ======

Group with Decay Radius: 0
Minimum Radius in this group: 0


Total Energy of Particles in this group: 0.0342881 GeV

Energy Percentage to cluster energy): 4.27758 %
Energy Percentage to total contribution energy: 46.1803 %

.........................
Group with Decay Radius: 450
Minimum Radius in this group: 451.12


Total Energy of Particles in this group: 0.0350074 GeV

Energy Percentage to cluster energy): 4.36732 %
Energy Percentage to total contribution energy: 47.1491 %

.........................
Group with Decay Radius: 750
Minimum Radius in this group: 773.193


Total Energy of Particles in this group: 0.0049529 GeV

Energy Percentage to cluster energy): 0.617895 %
Energy Percentage to total contribution energy: 6.67072 %
```

Comparable energy Contribution from different Group radius

Single Clusters that need to be Splitted:

```
================= Cluster Needs to be Split =================
Event 4, Cluster 0 needs to be split.
  Group with Decay Radius: 0 cm, Energy Percentage: 46.1803%
  Group with Decay Radius: 450 cm, Energy Percentage: 47.1491%
```





Total number of Events Simulated : 10000

```
==========================================
Total Events With Zero Clusters: 1224
Total Events With One Cluster: 8117
Total Events With More Than One Cluster: 659
Total Events That Need to be Split: 1959

==========================================
```

Clusters that needs both Splitting and Merging

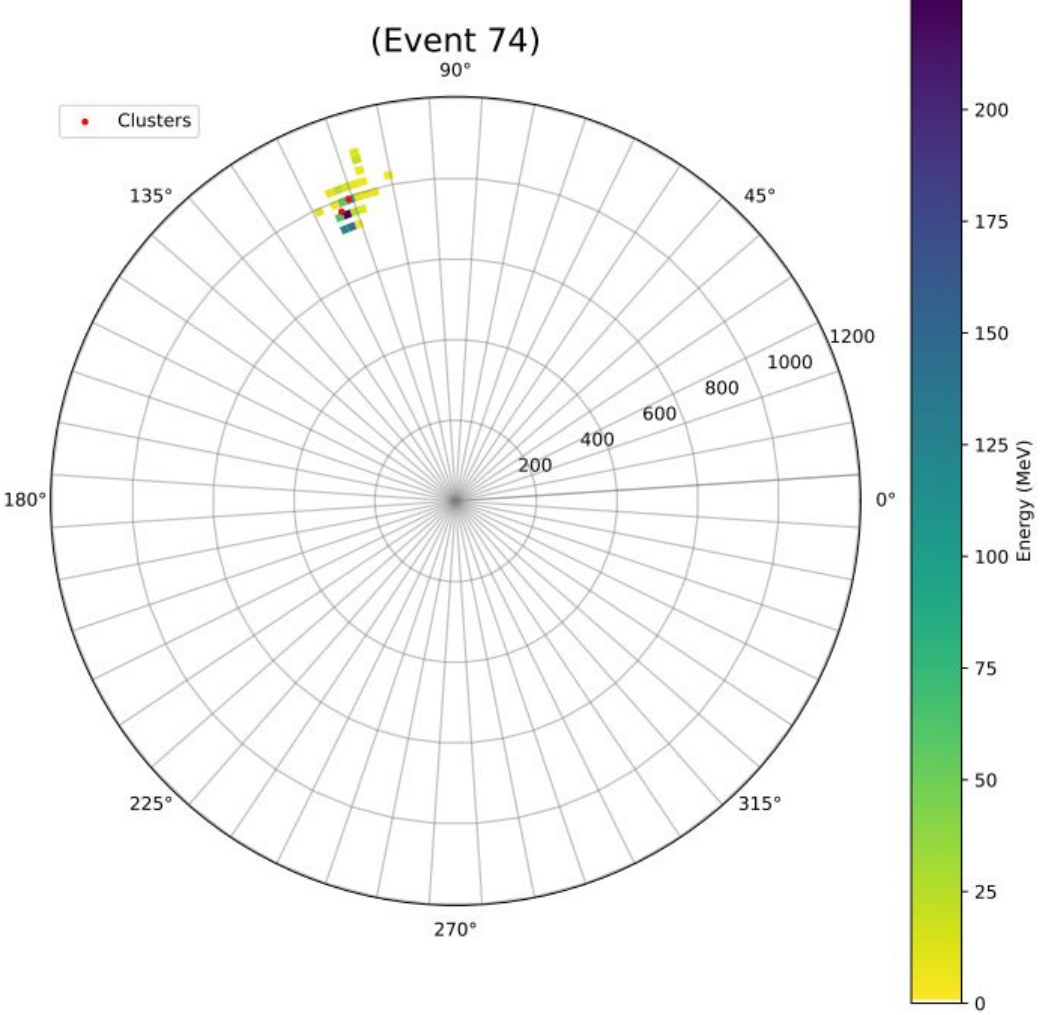
```
--------------------------------------------------------------------------------
                        Processing Cluster 0 in Event 74
--------------------------------------------------------------------------------
Total Energy of Cluster (cluster.getEnergy()) 0.687206 GeV
Total Energy of Cluster (sum of contribution energy): 0.063687 GeV

=======================Grouped Particles by Decay Radius=======================

Group with Decay Radius: 0

Energy Percentage (Cluster) in the Group with radius: 0 is 4.83179 %
Energy Percentage (Calculated) in the Group with radius: 0 is 52.1367 %

Group with Decay Radius: 725

Energy Percentage (Cluster) in the Group with radius: 725 is 0.159218 %
Energy Percentage (Calculated) in the Group with radius: 725 is 1.71801 %

Group with Decay Radius: 750

Energy Percentage (Cluster) in the Group with radius: 750 is 4.25408 %
Energy Percentage (Calculated) in the Group with radius: 750 is 45.903 %

Group with Decay Radius: 775

Energy Percentage (Cluster) in the Group with radius: 775 is 0.0224521 %
Energy Percentage (Calculated) in the Group with radius: 775 is 0.242267 %
```

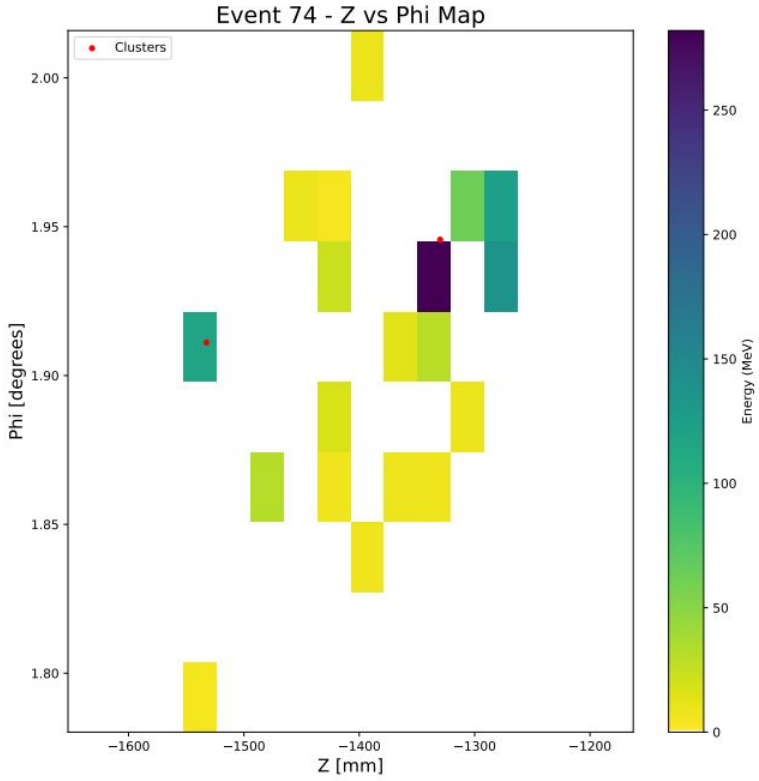
Comparable energy Contribution from different Group radius

Clusters that needs both Splitting and Merging

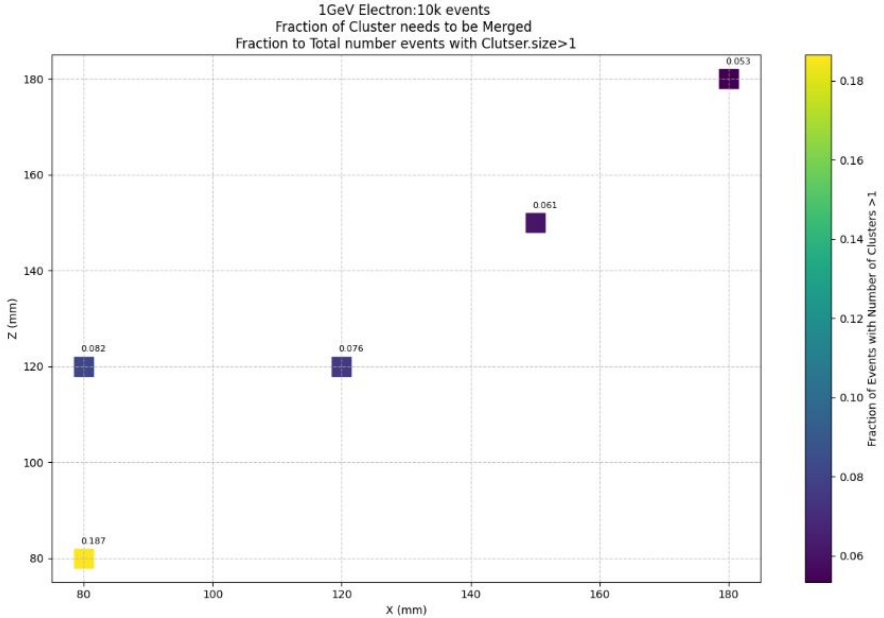
```
--------------------------------------------------------------------------------
                        Processing Cluster 1 in Event 74
--------------------------------------------------------------------------------
Total Energy of Cluster (cluster.getEnergy()) 0.116342 GeV
Total Energy of Cluster (sum of contribution energy): 0.0107496 GeV

=======================Grouped Particles by Decay Radius=======================

Group with Decay Radius: 0

Energy Percentage (Cluster) in the Group with radius: 0 is 8.34656 %
Energy Percentage (Calculated) in the Group with radius: 0 is 90.3341 %

Group with Decay Radius: 725

Energy Percentage (Cluster) in the Group with radius: 725 is 0.769145 %
Energy Percentage (Calculated) in the Group with radius: 725 is 8.32439 %

Group with Decay Radius: 750

Energy Percentage (Cluster) in the Group with radius: 750 is 0.123953 %
Energy Percentage (Calculated) in the Group with radius: 750 is 1.34154 %
```

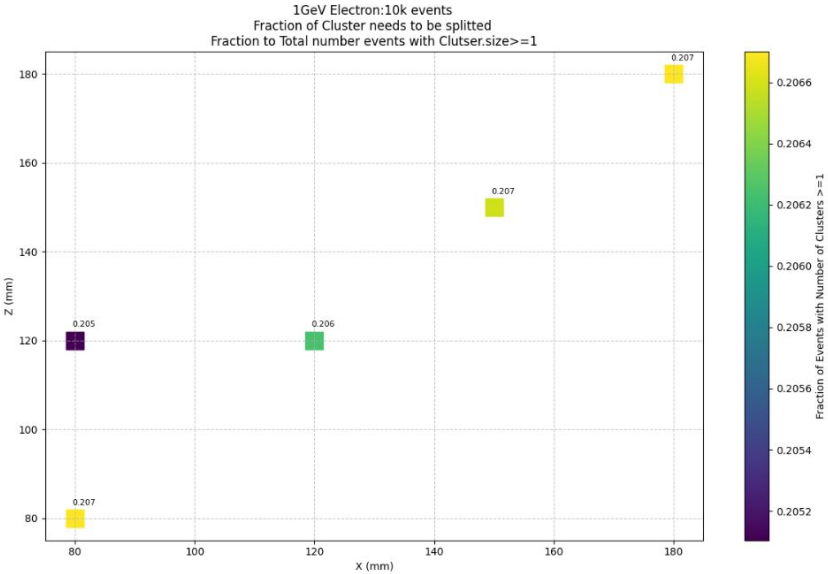
Group with Maximum Energy contribution is common to both the clusters


(Event 74)
Clusters
90°
135°
45°
180°
0°
225°
315°
270°
200
400
600
800
1000
1200
Energy (MeV)
0
25
50
75
100
125
150
175
200


Event 74 - Z vs Phi Map
Clusters
Phi [degrees]
2.00
1.95
1.90
1.85
1.80
Z [mm]
−1600
−1500
−1400
−1300
−1200
Energy (MeV)
0
50
100
150
200
250

Cluster Splitting and Merging Fraction For Different Local Distance Parameter





Local Distance Parameter **(x,z)**	**Number of events with Clusters Marked For Merging**	**Fraction to Total number of events with multiple cluster**	**Number of events with Clusters Marked For Splitting**	**Fraction to Total number of events with both single and multiple cluster**
(80, 80)	123	(123/659) **=0.1866**	1814	1814/(8117+659)) **= 0.2067**
(80, 120)	44	(44/539) **=0.0816**	1800	1800/(8237+539) **= 0.2051**
(120, 120)	40	(40/527) **=0.0759**	1810	1810/(8249+527) **= 0.2062**
(150, 150)	31	(31/509) **=0.0609**	1813	1813/(8267+509) **= 0.2065**
(180,180)	27	(27/506) **= 0.0533**	1814	1814/(8270+506) **=0.2067**

NEXT STEP …

Repeat Similar study for 10x100 GeV Q^2>1 datasets

[pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc]