Simulation Study of the Gen-II CALI prototype

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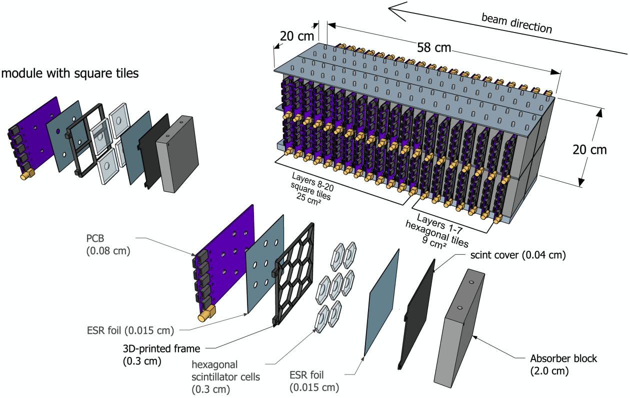
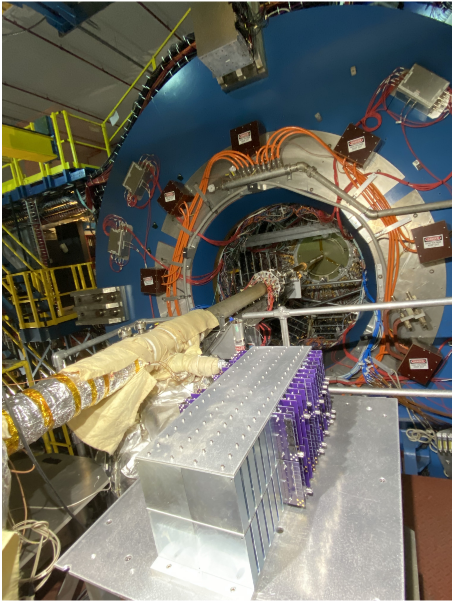
Gen-II Prototype

- Beam test of Gen-I prototype in Hall D at JLab on Jan 23, 2023 Instruments 2023, 7(4), 43
- 40 channels in Gen-I prototype
- 300 channels in Gen-II prototype
- 4 hexagonal layers + 10 square layers

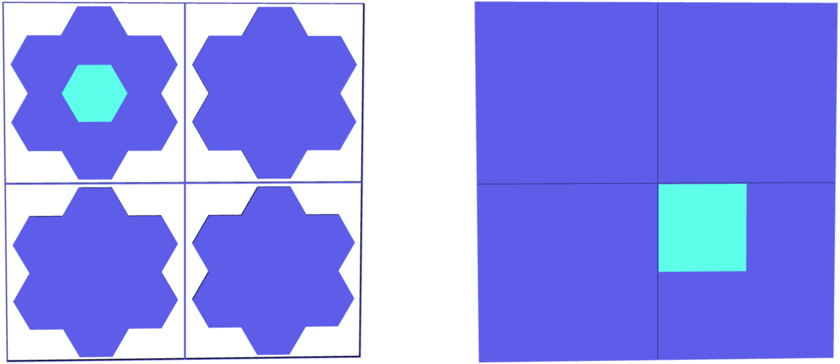


Test Position



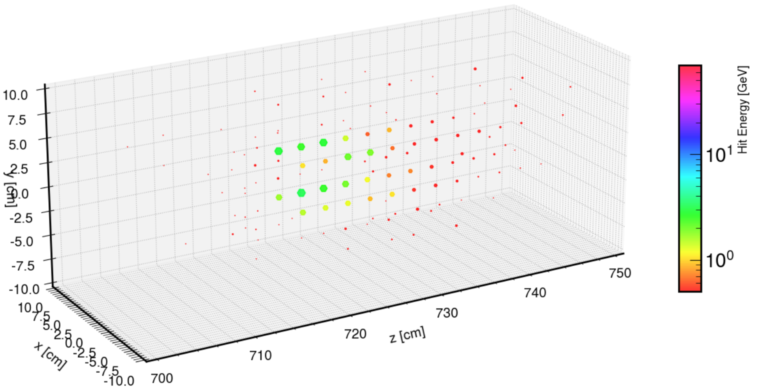
- $\gtrsim 7$ m away from the IP
- North of the beampipe, ~ 47 cm away from the beampipe center ($3.2 < \eta < 3.6$)
- Roughly alighted in height
- Be parallel to the beampipe

Simulation

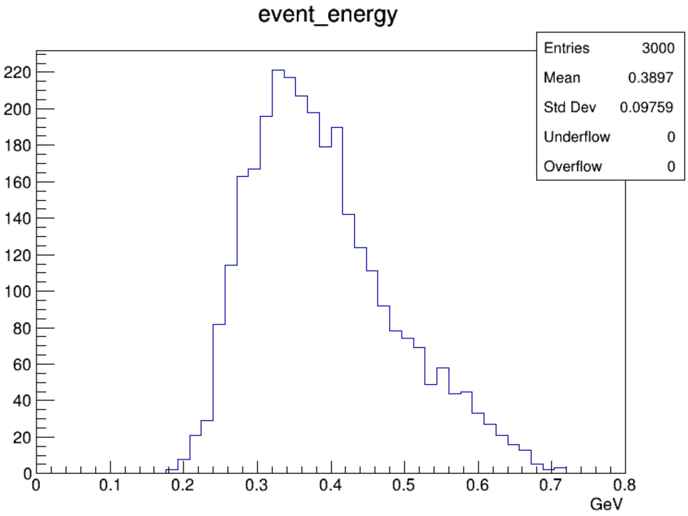


- DD4HEP framework
- 7 layers of hexagonal cell (7.9 cm^2), 13 layers of square cell (22.5 cm^2)
- 7 m away from the beam source, $0 < \theta < 0.001$
- Hepmc3 file for π^0 events, making sure the 2 photons hit the prototype

Event Display: 40 GeV Photon

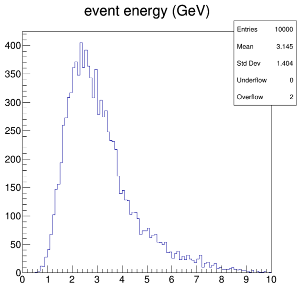


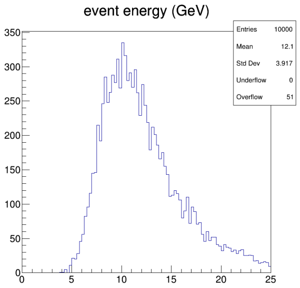
Sampling Fraction

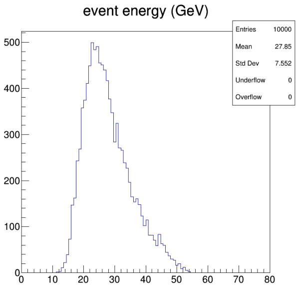


- sf = 0.01

Event Energy







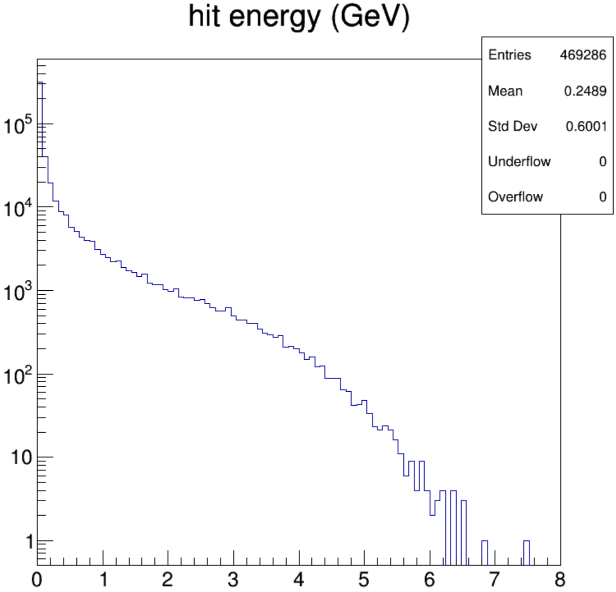
5 GeV photon
$3.145/5 \sim 60\%$

15 GeV photon
$12.1/15 \sim 80\%$

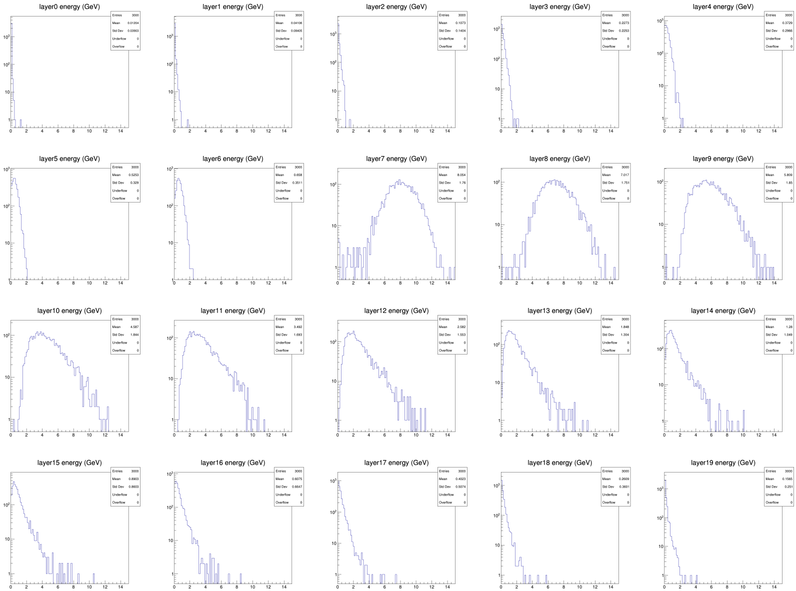
30 GeV photon
$27.85/30 \sim 93\%$

- sf is energy dependent

Hit Energy Distribution



Layer Energy Distribution

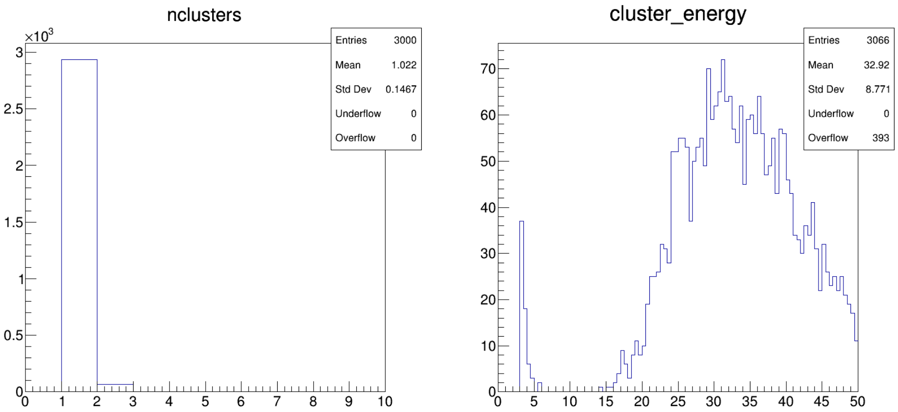


Reconstruction: Eicrecon

Imaging topological cluster algorithm

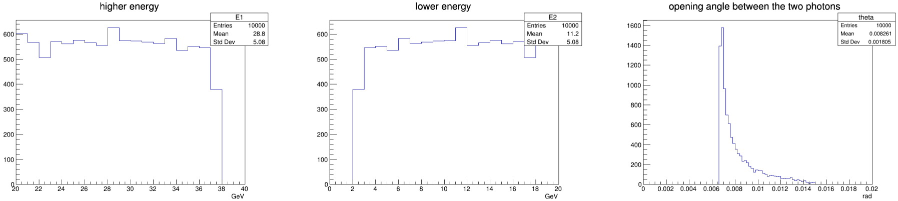
```
app->Add(new JOmniFactoryGeneratorT<ImagingTopoCluster_factory>(
    "CALIImagingTopoClusters",
   {"CALIRecHits"},
   {"CALIImagingTopoClusters"},
   {
      .neighbourLayersRange = 1,
      .localDistXY = {55*dd4hep::mm, 50*dd4hep::mm},
      // .layerDistEtaPhi = {0.9, 0.5},
      // .sectorDist = 10.0 * dd4hep::cm,
      .minClusterHitEdep = 10.0 * dd4hep::MeV,
      .minClusterCenterEdep = 1000.0 * dd4hep::MeV,
      .minClusterEdep = 3000.0 * dd4hep::MeV,
      .minClusterNhits = 1,
   },
   app    // TODO: Remove me once fixed
));
```

Cluster



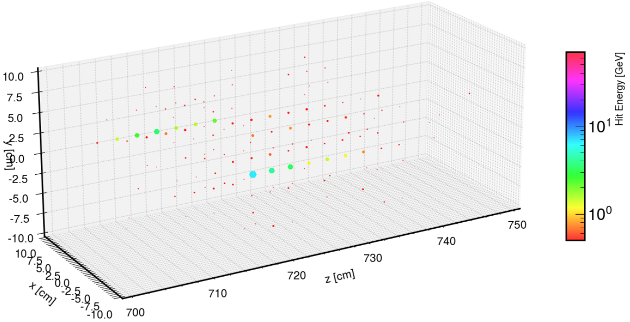
nclusters
×10^3
Entries 3000
Mean 1.022
Std Dev 0.1467
Underflow 0
Overflow 0
3
2.5
2
1.5
1
0.5
0
0 1 2 3 4 5 6 7 8 9 10
cluster_energy
Entries 3066
Mean 32.92
Std Dev 8.771
Underflow 0
Overflow 393
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35 40 45 50

π^0: Photon Distributions



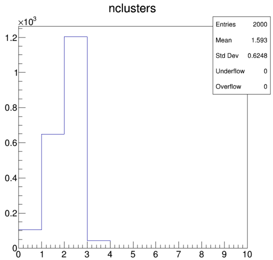
- The larger the opening angle, the larger the energy difference
- The lower energy photon can go to very low energy
- The higher the π^0 energy, the smaller the minimum opening angle, the harder to distinguish the decay photons

Event Display: 40 GeV π^0

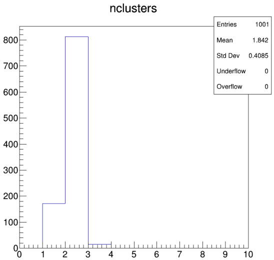


π^0: Number of Clusters

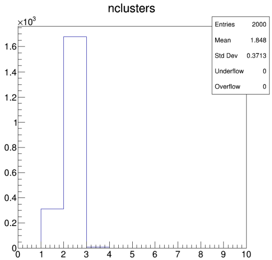
$\Delta\theta = 6 - 7$ mrad



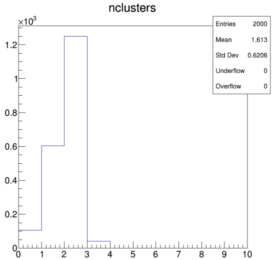
$\Delta\theta = 7 - 8$ mrad



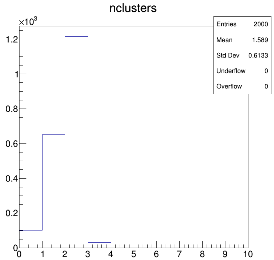
$\Delta\theta = 8 - 9$ mrad



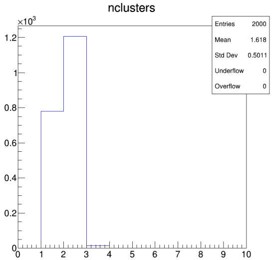
$\Delta\theta = 9 - 10$ mrad



$\Delta\theta = 10 - 11$ mrad

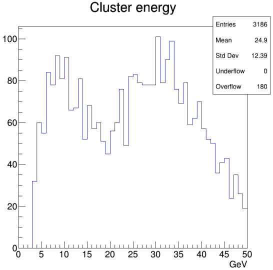


$\Delta\theta = 11 - 12$ mrad

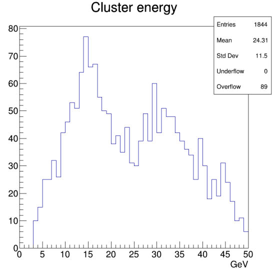


π^0: Cluster Energy

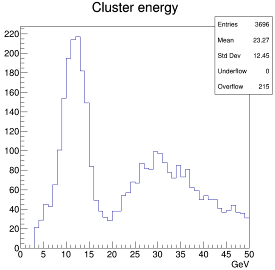
$\Delta\theta = 6 - 7$ mrad



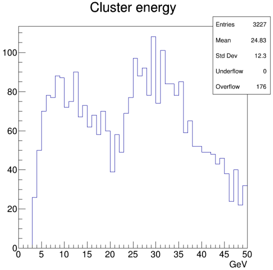
$\Delta\theta = 7 - 8$ mrad



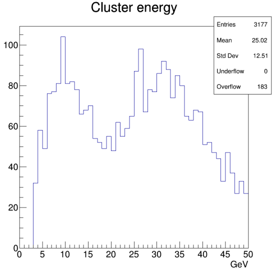
$\Delta\theta = 8 - 9$ mrad



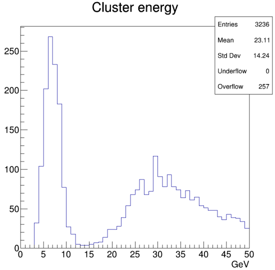
$\Delta\theta = 9 - 10$ mrad



$\Delta\theta = 10 - 11$ mrad

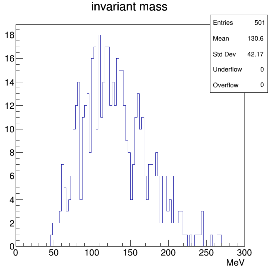


$\Delta\theta = 11 - 12$ mrad

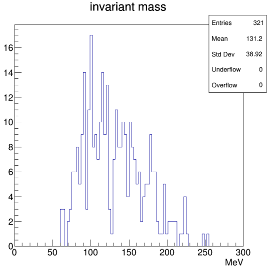


π^0: Invariant Mass

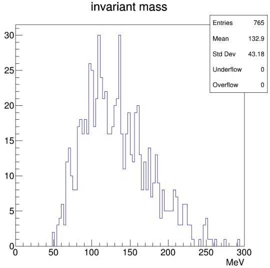
$\Delta\theta = 6 - 7$ mrad



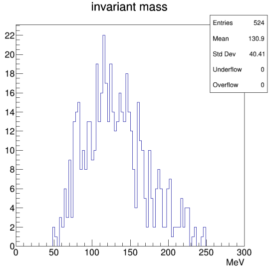
$\Delta\theta = 7 - 8$ mrad



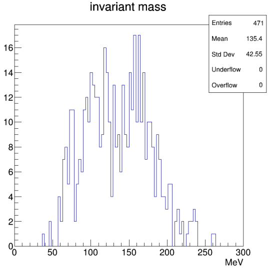
$\Delta\theta = 8 - 9$ mrad



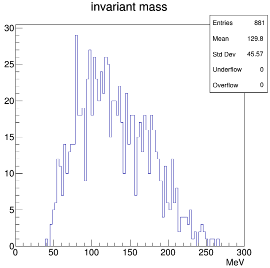
$\Delta\theta = 9 - 10$ mrad



$\Delta\theta = 10 - 11$ mrad



$\Delta\theta = 11 - 12$ mrad



Summary

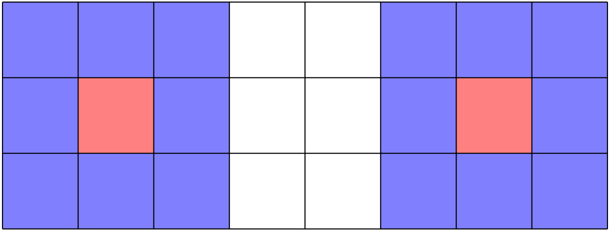
- Simulation of high energy photon and π^0 with the Gen-II prototype
- Cluster reconstruction with the ImagingTopological algorithm
- Reconstruct the π^0 events
- Next step: rate study in STAR pp collision environment

Backup

Invariant Mass

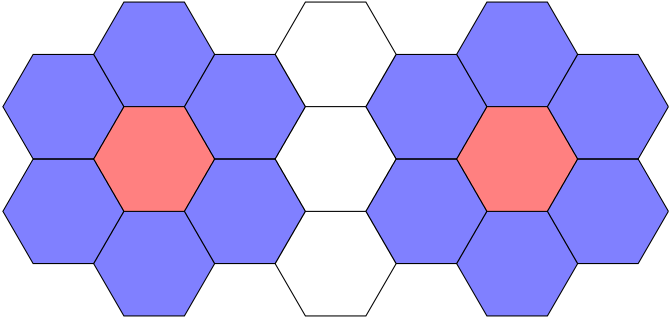
$$m = \sqrt{(e_1 + e_2)^2 - \sum_{i=x,y,z} \left(e_1 \frac{i_1}{l_1} + e_2 \frac{i_2}{l_2} \right)^2}$$

Seperating Clusters In Square Cells



- Need a thin cluster: high minClusterHitEdep
- A large seperation between the two decayed photons

Seperating Clusters



- Hexagon side: $s = 1.74$ cm
- Seperation length: $dx = 6 \times s = 10.44$ cm