中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Photon Reconstruction Test

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2021年1月组会

Review of the last meeting

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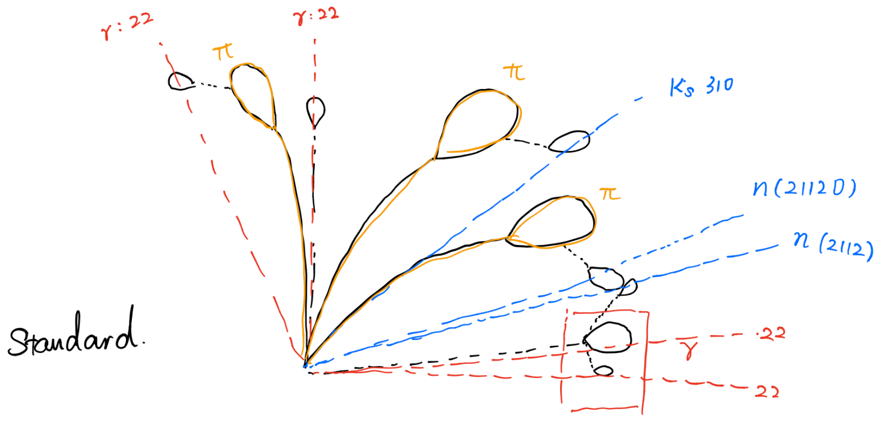
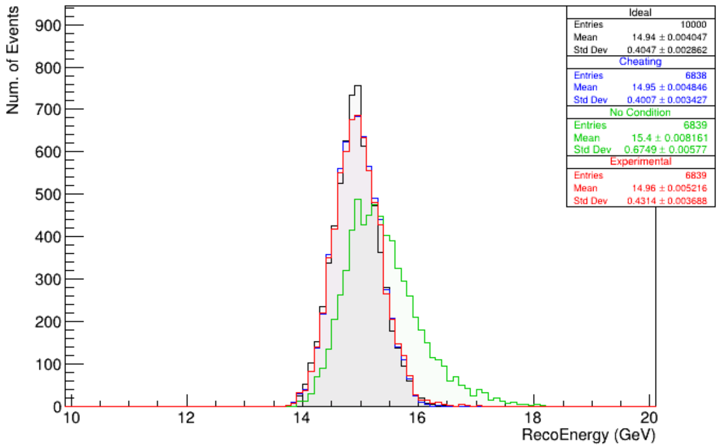
Motivation

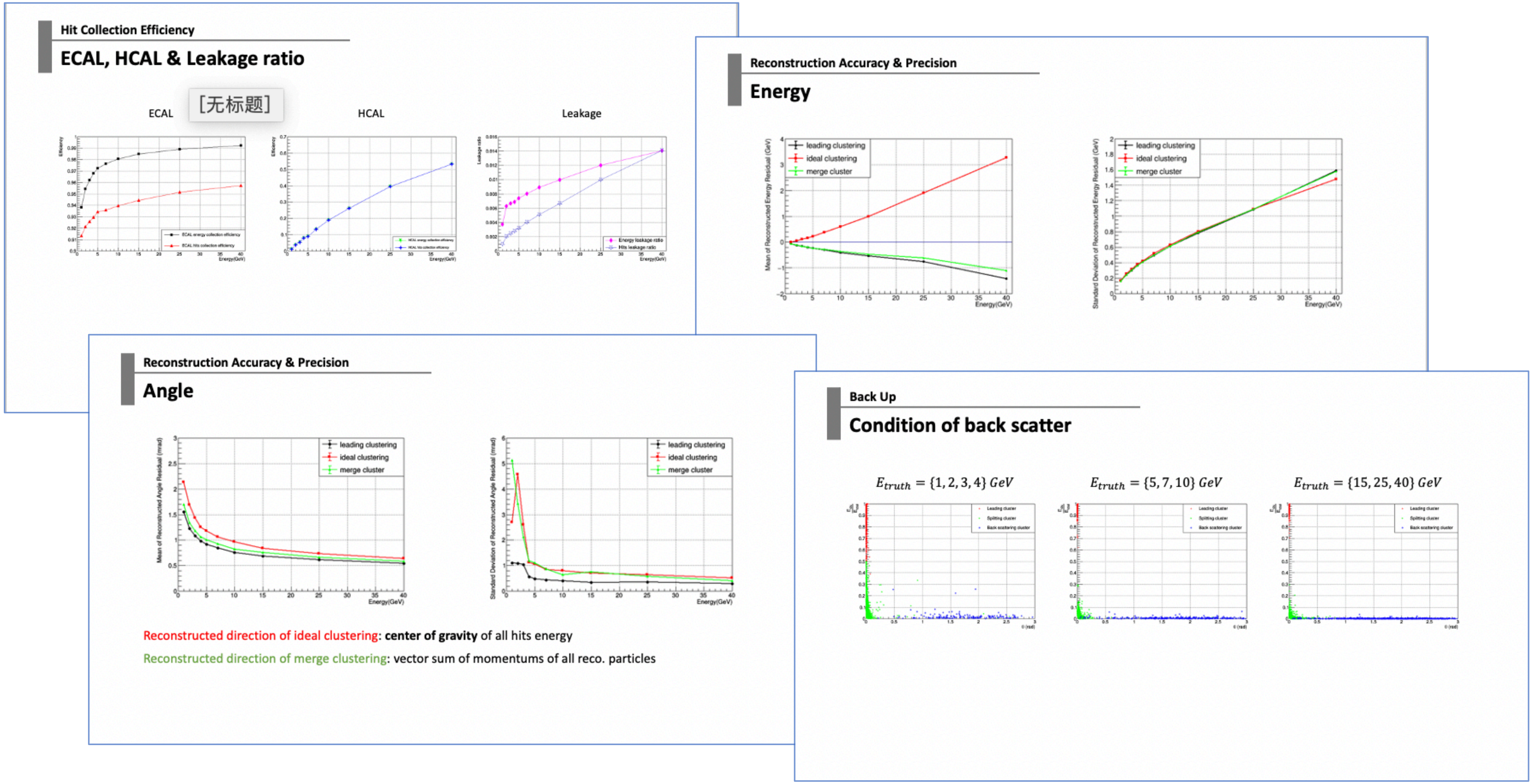
- Arbor
- Merge clusters
- Link cluster & track
- Reconstruct particles
  - Charged particle
  - Photon id
  - Fragment veto





Review of the last meeting

Rough statistics



Hit Collection Efficiency

ECAL, HCAL & Leakage ratio

[无标题]

ECAL

HCAL

Leakage

Reconstruction Accuracy & Precision

Energy

Reconstruction Accuracy & Precision

Angle

Reconstructed direction of ideal clustering: **center of gravity** of all hits energy

Reconstructed direction of merge clustering: vector sum of momentums of all reco. particles

Back Up

Condition of back scatter

$E_{truth} = \{1, 2, 3, 4\}\ GeV$ $E_{truth} = \{5, 7, 10\}\ GeV$ $E_{truth} = \{15, 25, 40\}\ GeV$

Motivation

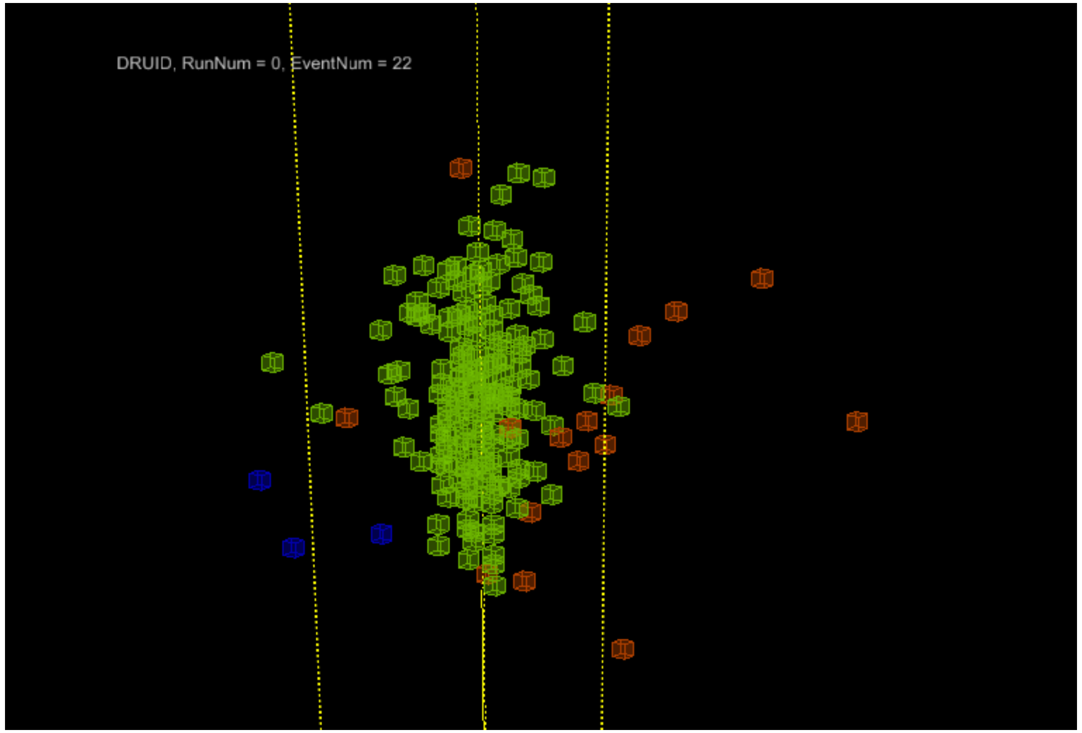
A test of photon reconstruction algorithm

- Hit collection efficiency
- Overview of split: #cluster vs. photon energy
  - *1-1* Reconstruction:
    - Energy accuracy & resolution
    - Position (angular) distribution
  - *1-N* Reconstruction:
    - Leading cluster: similar with 1-1 case
    - Sub-leading cluster: energy & position distribution

Sample

0. Sample

- **Single γ** in every event
- 10 energy points:
  {1, 2, 3, 4, 5, 7, 10, 15, 25, 40} GeV
- 10k events at each energy
- **Remove pre-interacted events** before analyze



Statistics without pre-interaction

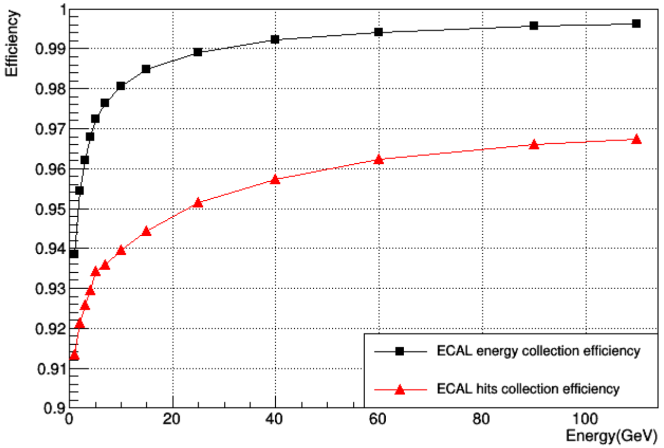
E(GeV)	1.0	2.0	3.0	4.0	5.0	7.0	10.0	15.0	25.0	40.0	60.0	90.0	110.0
N	9288	9208	9197	9175	9133	9084	9036	9001	8819	8525	8296	7961	7740

Hit Collection Efficiency

1. Hit Collection Efficiency

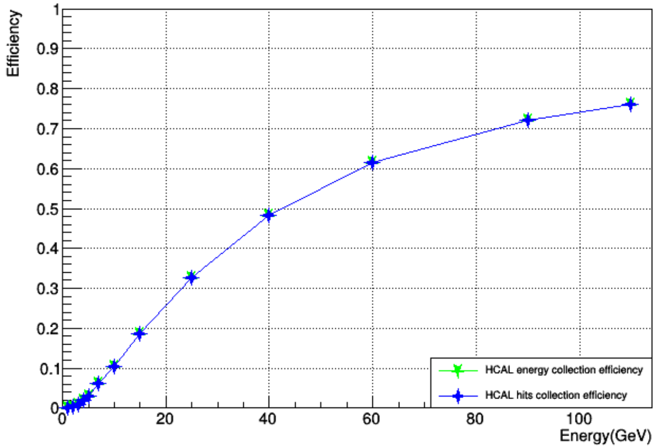
ECAL, HCAL & Leakage ratio

ECAL



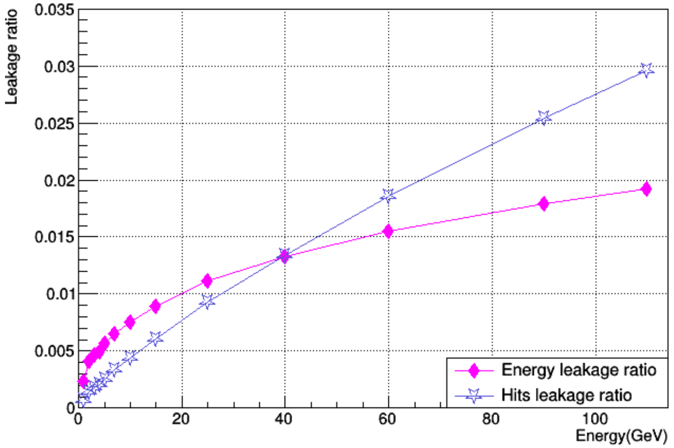
$$\epsilon_{ECAL} = \frac{\sum_{clu} E_{hit}^{in\ ECAL}}{\sum E_{hit}^{in\ ECAL}}$$

HCAL



$$\epsilon_{HCAL} = \frac{\sum_{clu} E_{hit}^{in\ HCAL}}{\sum E_{hit}^{in\ HCAL}}$$

Leakage



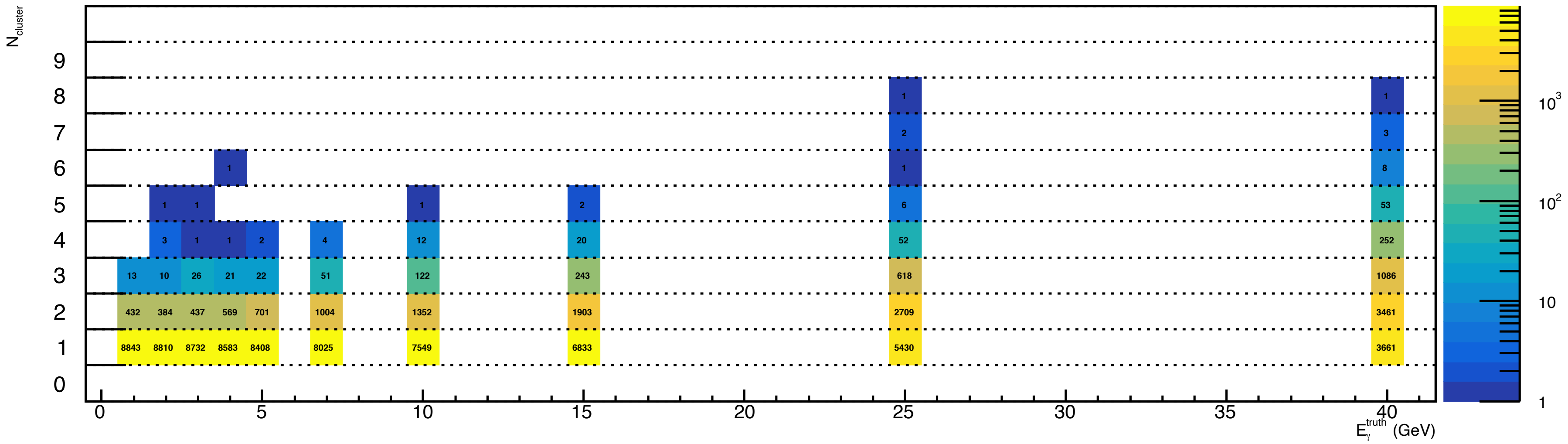
$$R_{leakage} = \frac{\sum E_{hit}^{in\ HCAL}}{\sum E_{hit}^{in\ ECAL} + \sum E_{hit}^{in\ HCAL}}$$

Cluster Split

- Overview: Number of Cluster
- *1-1* Reconstruction
  - Accuracy of Energy & Angular
- *1-N* Reconstruction
  - Leading Cluster
  - Sub-leading Cluster

2. Cluster Split

Num. of Cluster vs. Energy

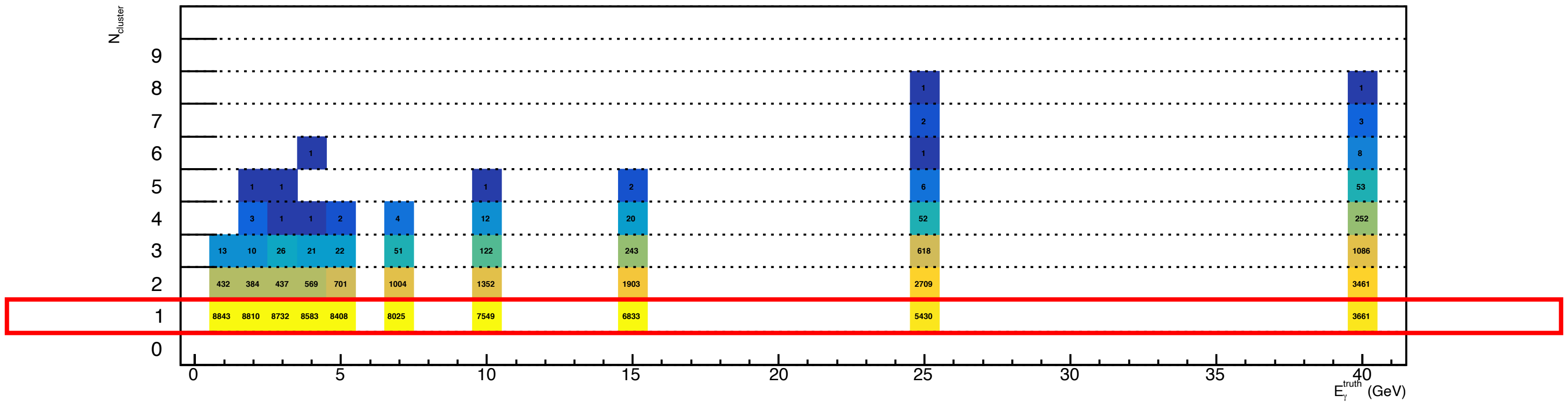


Statistics without pre-interaction

Energy	1.0	2.0	3.0	4.0	5.0	7.0	10.0	15.0	25.0	40.0
Statistic	9288	9208	9197	9175	9133	9084	9036	9001	8819	8525

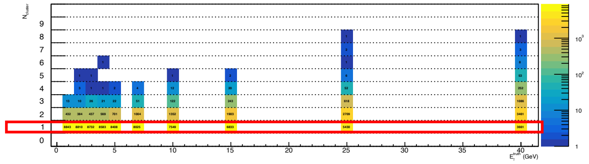
Cluster Split

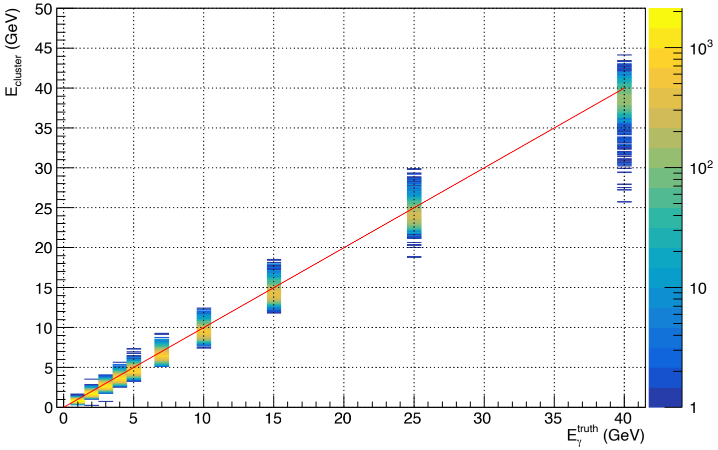
1-1 Reconstruction

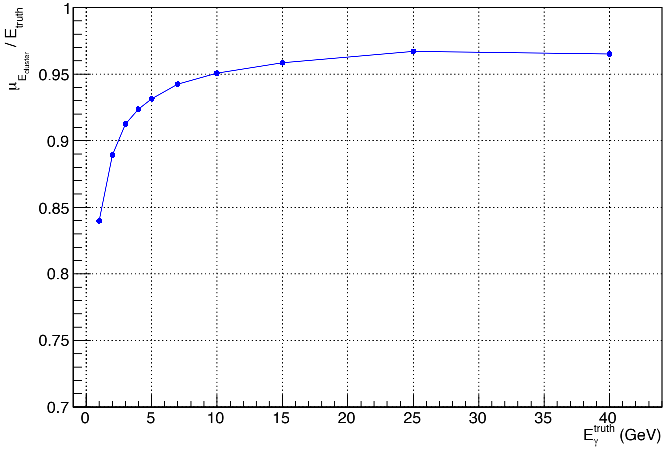


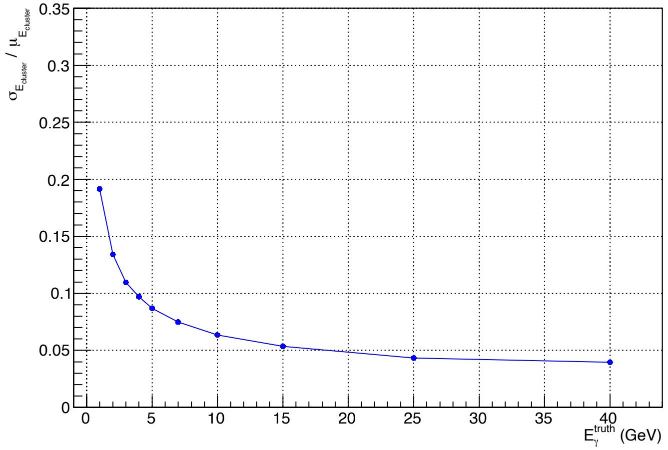
2.1. *1-1* Reconstruction

Energy Resolution & Accuracy



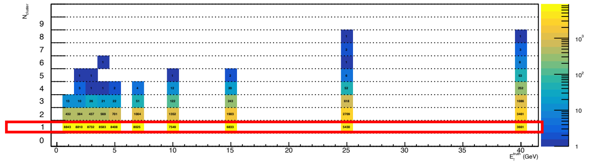


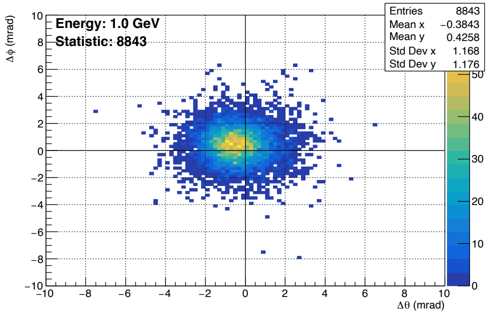


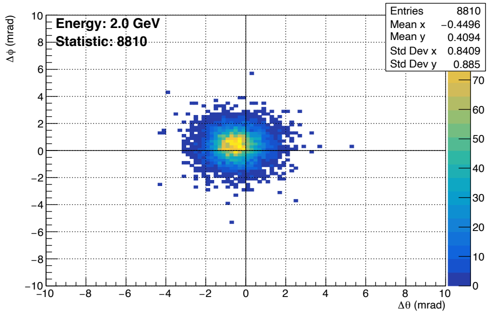


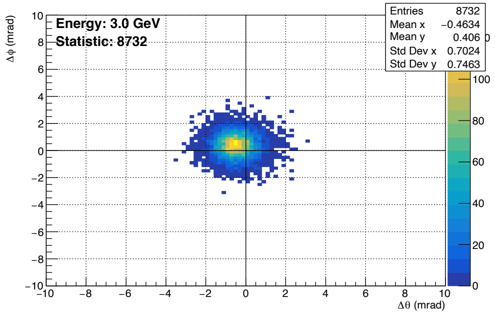
2.1. *1-1* Reconstruction

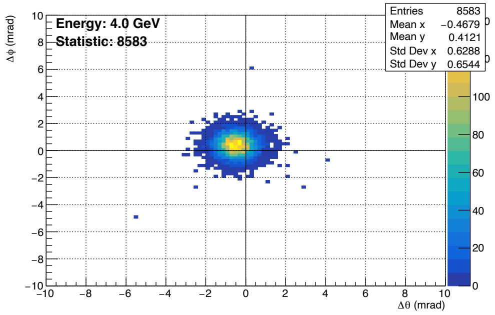
Angular Accuracy

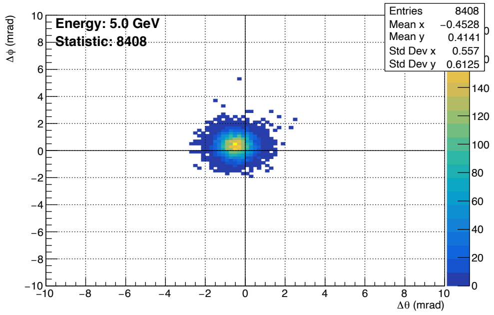


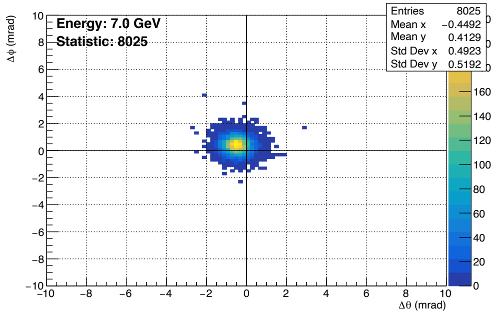


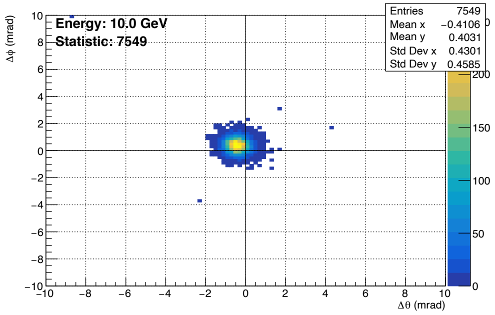


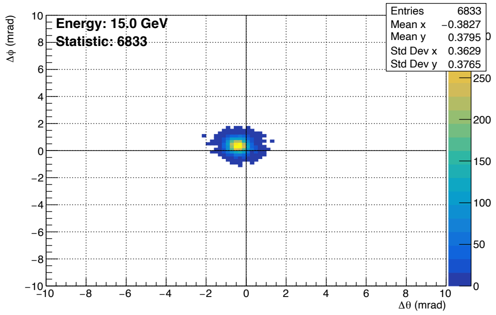


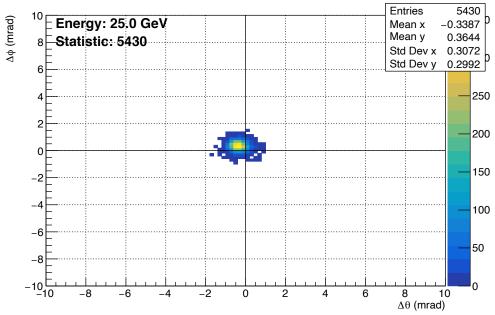






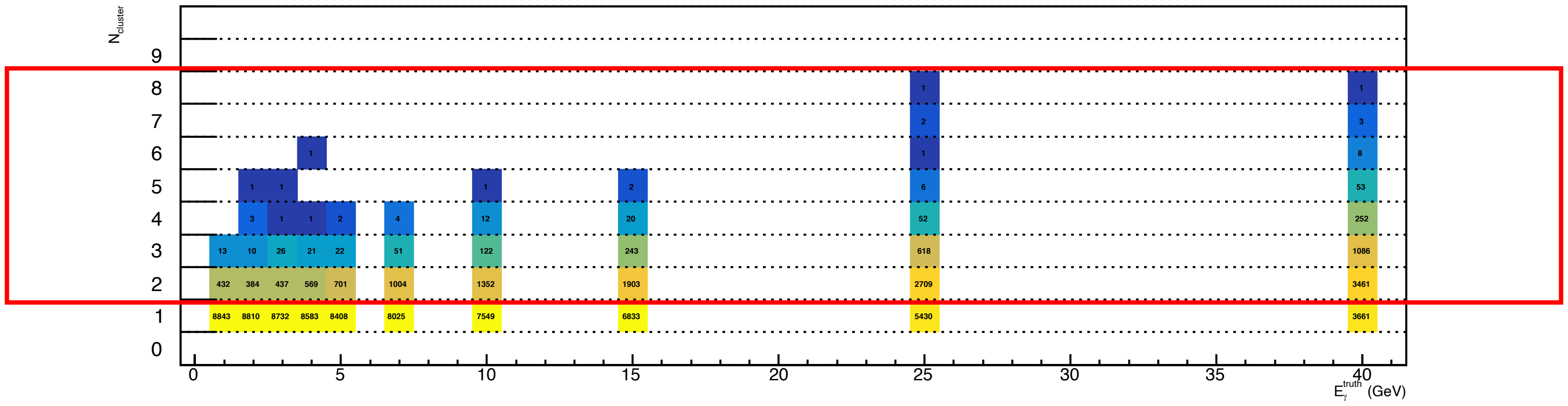




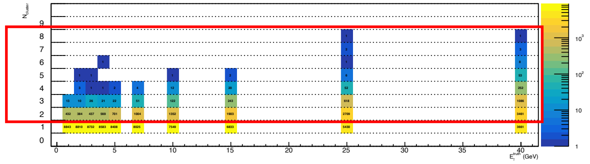


Cluster Split

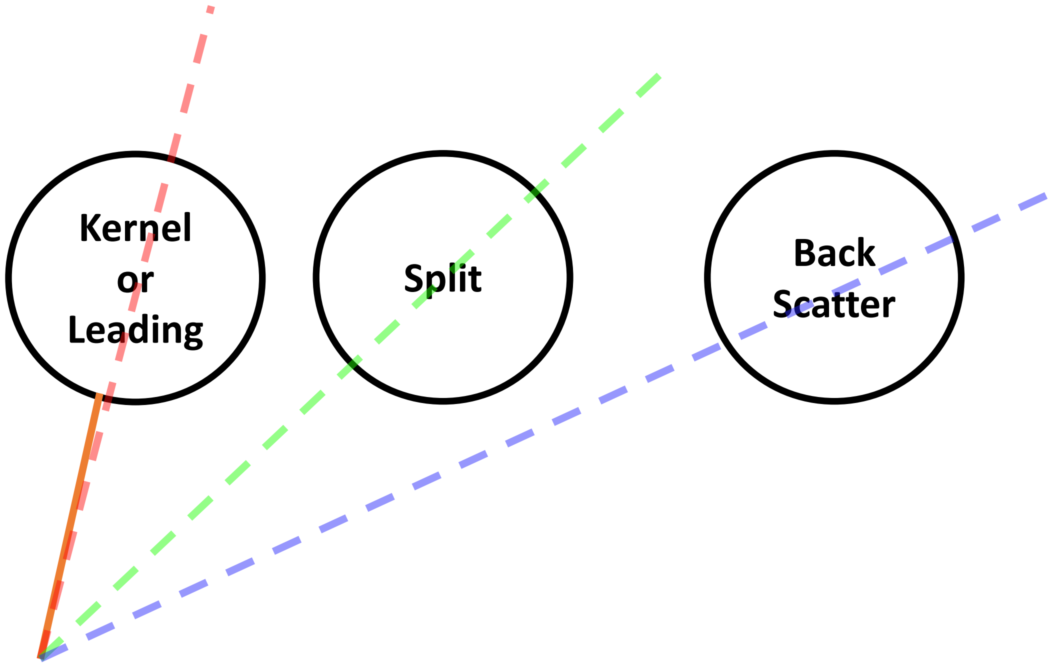
1-N Reconstruction



Split & Back Scatter



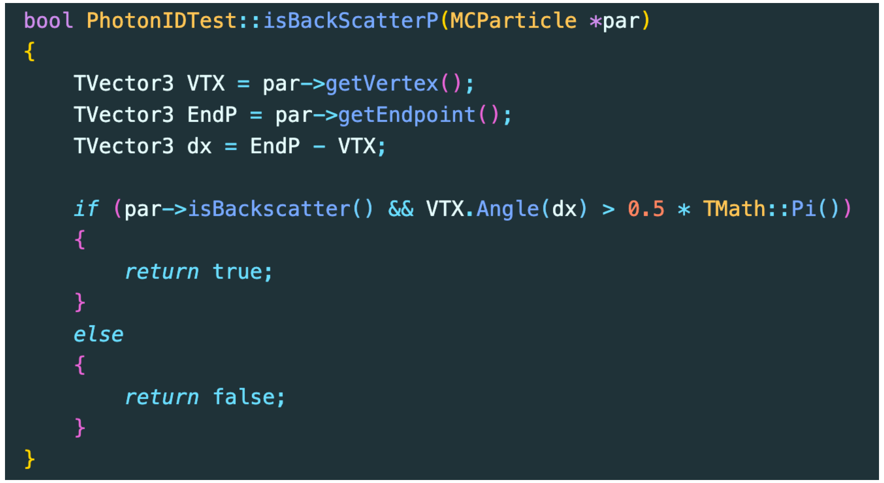
- **Leading Cluster**: The clusters with highest energy
- **Split**: The clusters that split from leading cluster because of Arbor algorithm
- **Back Scatter**: The clusters that created by back scattering particles, such as photon or neutron.



Condition of back scatter

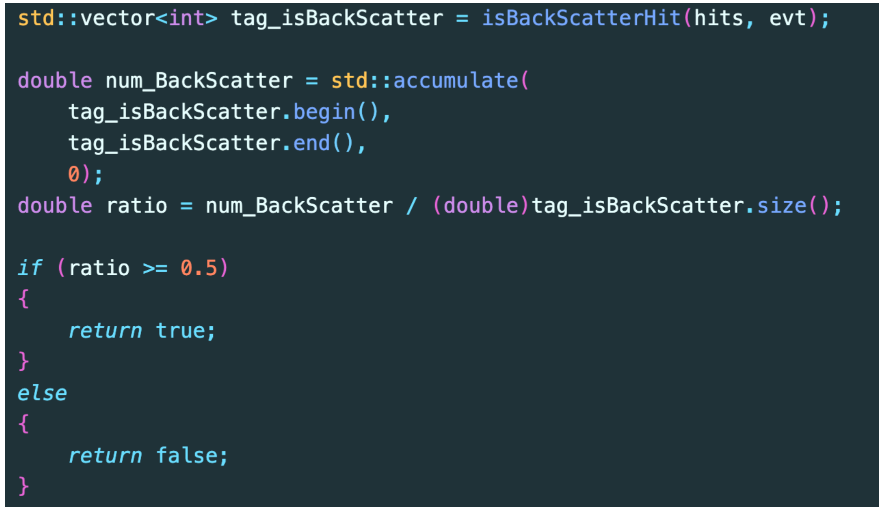
Identify back scatters from **MC Truth**:

- Back scatter hit:
    - cased by a back scatter particle
    - obtuse angle between fly direction and born direction of this particle
- Back scatter cluster or reco. particle:
    - **include >50% back scattering hits**



```
bool PhotonIDTest::isBackScatterP(MCParticle *par)
{
    TVector3 VTX = par->getVertex();
    TVector3 EndP = par->getEndpoint();
    TVector3 dx = EndP - VTX;

    if (par->isBackscatter() && VTX.Angle(dx) > 0.5 * TMath::Pi())
    {
        return true;
    }
    else
    {
        return false;
    }
}
```



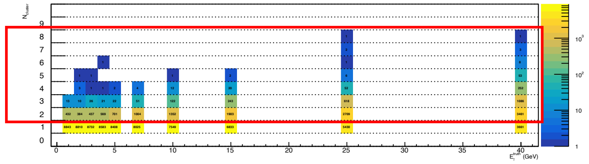
```
std::vector<int> tag_isBackScatter = isBackScatterHit(hits, evt);

double num_BackScatter = std::accumulate(
    tag_isBackScatter.begin(),
    tag_isBackScatter.end(),
    0);
double ratio = num_BackScatter / (double)tag_isBackScatter.size();

if (ratio >= 0.5)
{
    return true;
}
else
{
    return false;
}
```

2.2. *1-N* Reconstruction

Split & Back Scatter Chance



$$P(Split) = \frac{N_{event}^{split}}{N_{event}^{all}}$$

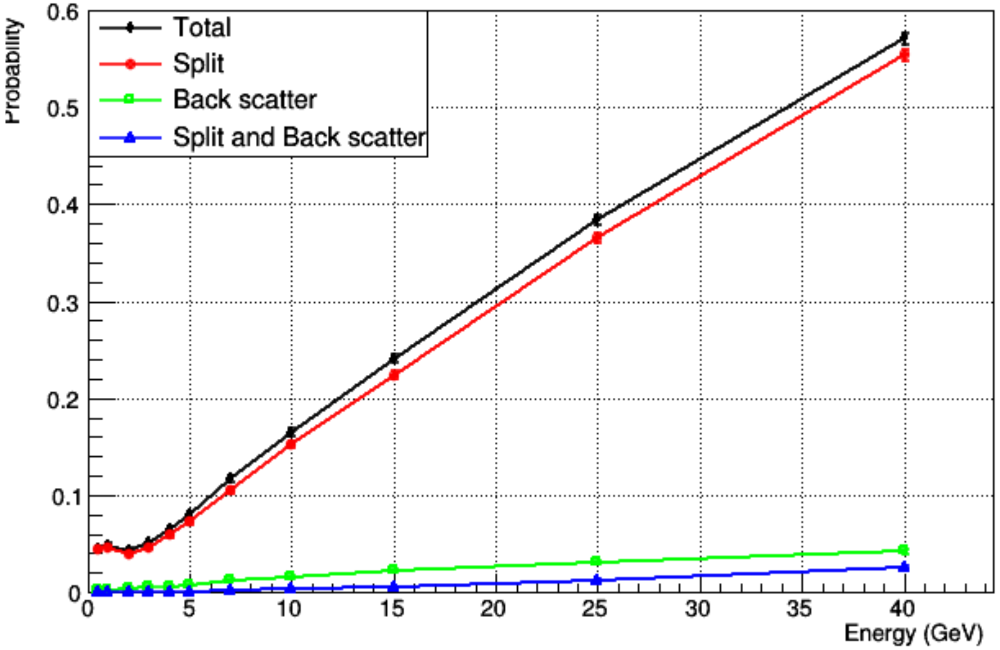
- $P(Back\ Scatter) = \frac{N_{event}^{back}}{N_{event}^{all}}$

- $P(Split\ and\ Back\ Scatter) = \frac{N_{event}^{split\ \&\&\ back}}{N_{event}^{all}}$

- $P(Total) = \frac{N_{event}^{split\ or\ back}}{N_{event}^{all}}$

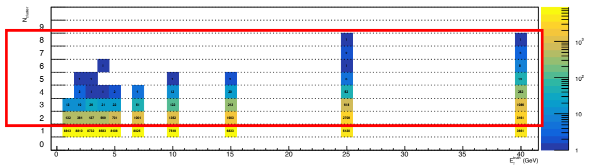
$$= P(Split) + P(Back\ Scatter)$$

$$- P(Split\ and\ BackScatter)$$

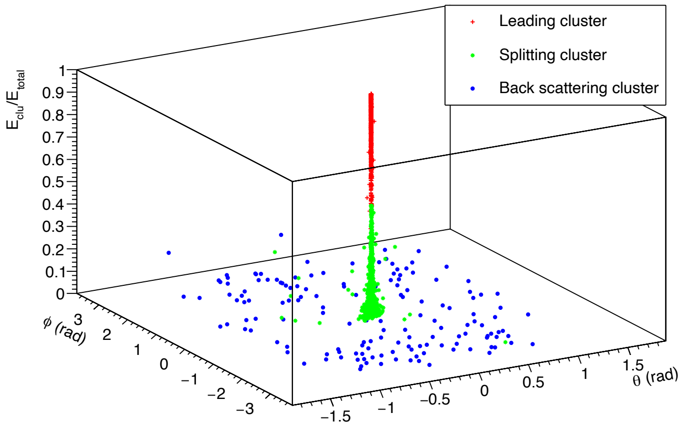


2.2. *1-N* Reconstruction

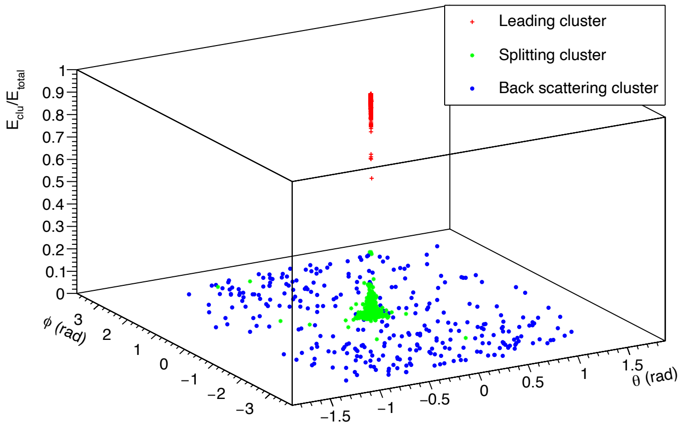
Angle of Split apart from Truth



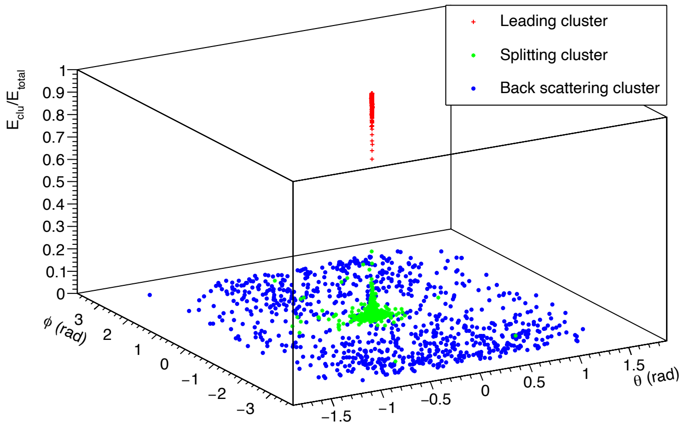
$E_{truth} = \{1, 2, 3, 4\}\ GeV$



$E_{truth} = \{5, 7, 10\}\ GeV$



$E_{truth} = \{15, 25, 40\}\ GeV$

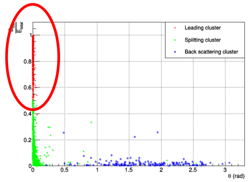


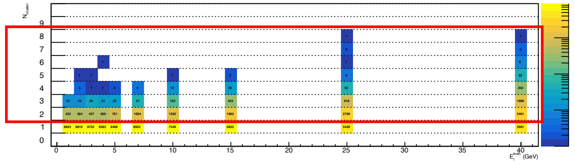
In *1-N* events, leading cluster always include **most of energy** and be **close to the truth photon**, while sub-leading clusters carry less energy and be farther from the truth photon.

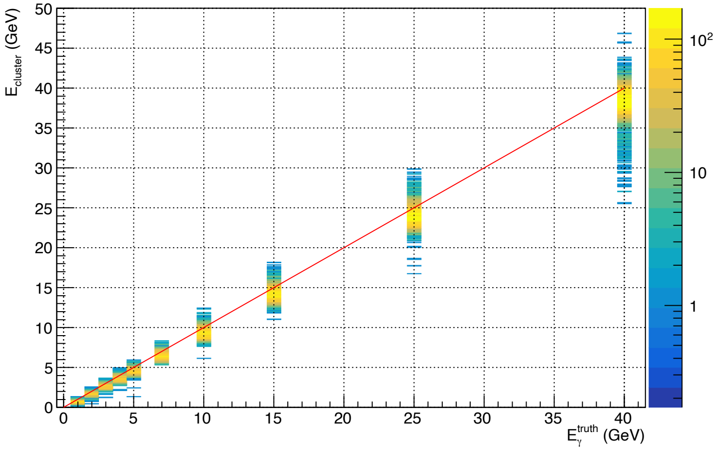
- back scattering cluster can be considered as sub-leading cluster together with splitting cluster since its small statistic and the arbitrary condition.

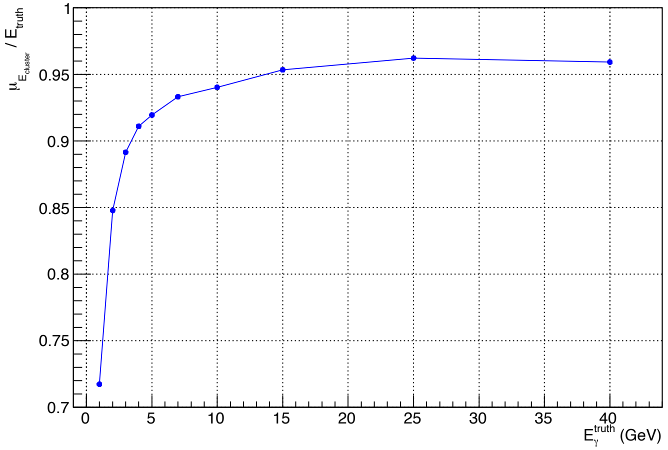
2.2. *1-N* Reconstruction: Leading cluster

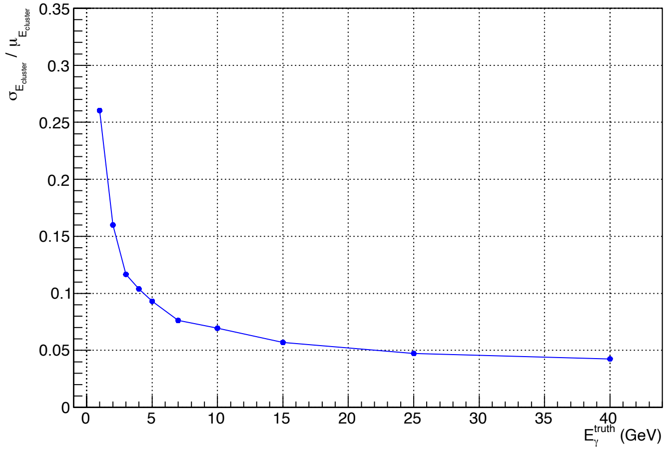
Energy Distribution











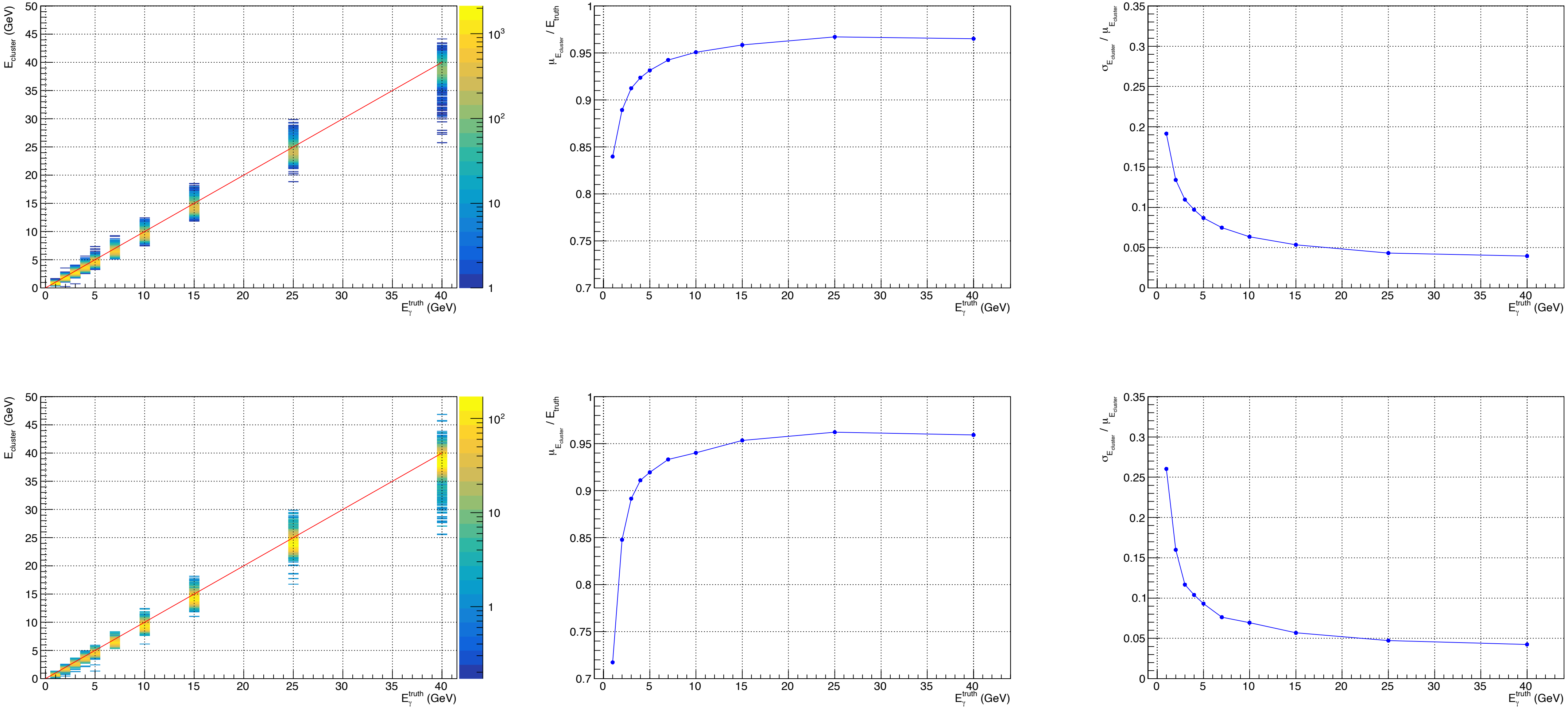
Comparing to *1-1* reconstruction,

1-N reconstruction (leading cluster) gives lower energy & worse energy resolution,

but these differences disappear with photon energy grows to 40 GeV

Back Up

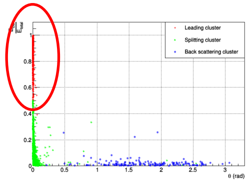
Energy Reconstruction

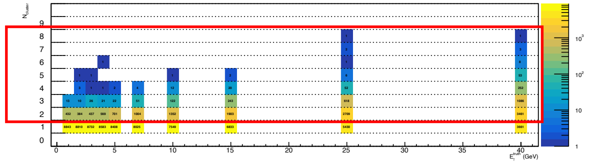


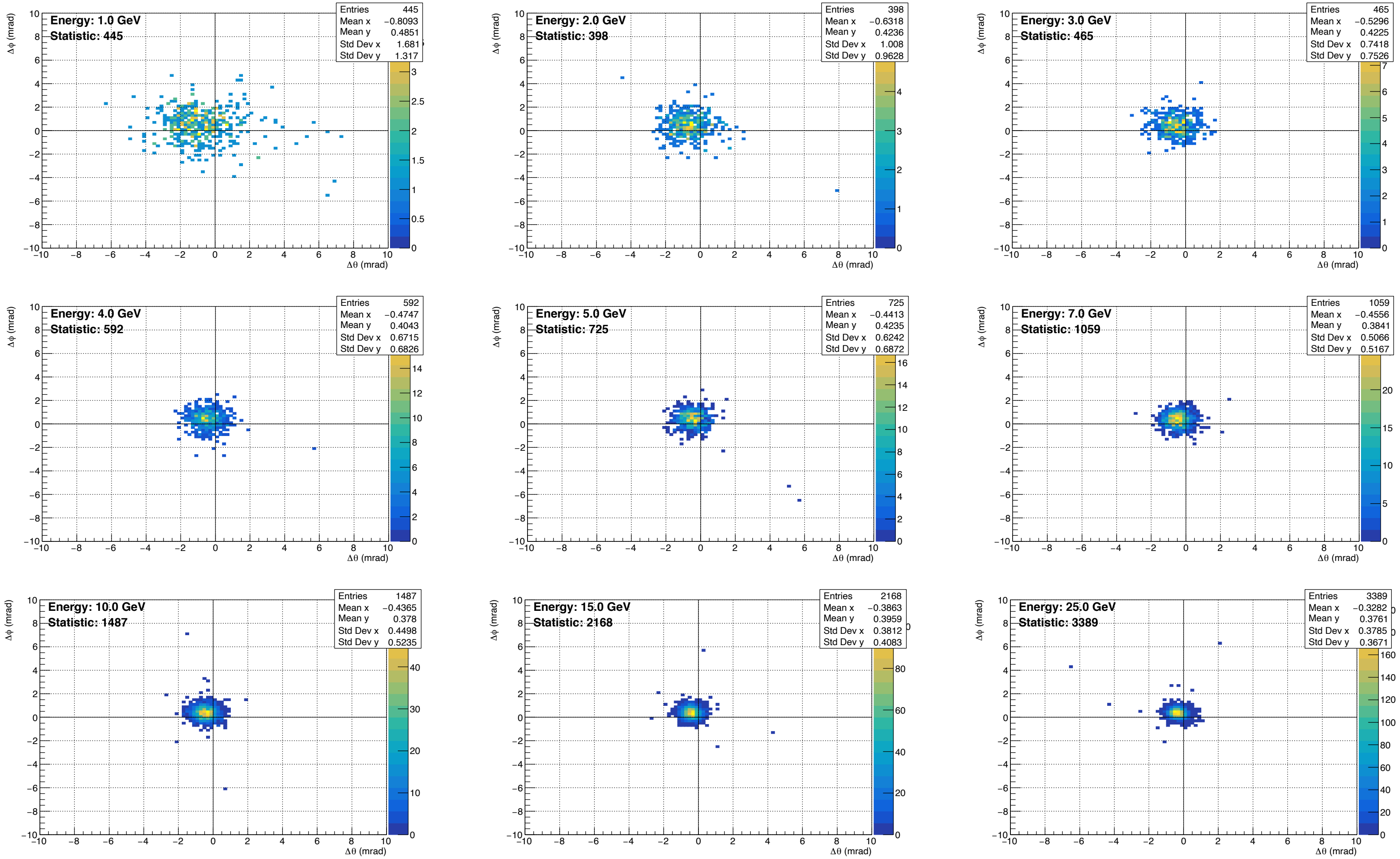
1^{st} line represents performance of clusters in 1-1 case while 2^{nd} line represents that of leading cluster in 1-N case

2.2. *1-N* Reconstruction: Leading cluster

Angular Distribution

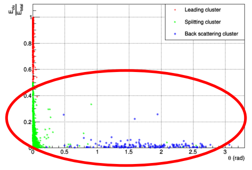


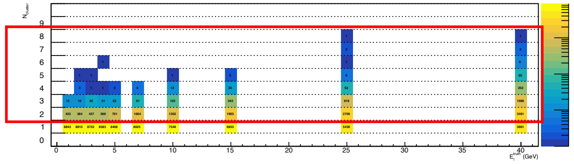




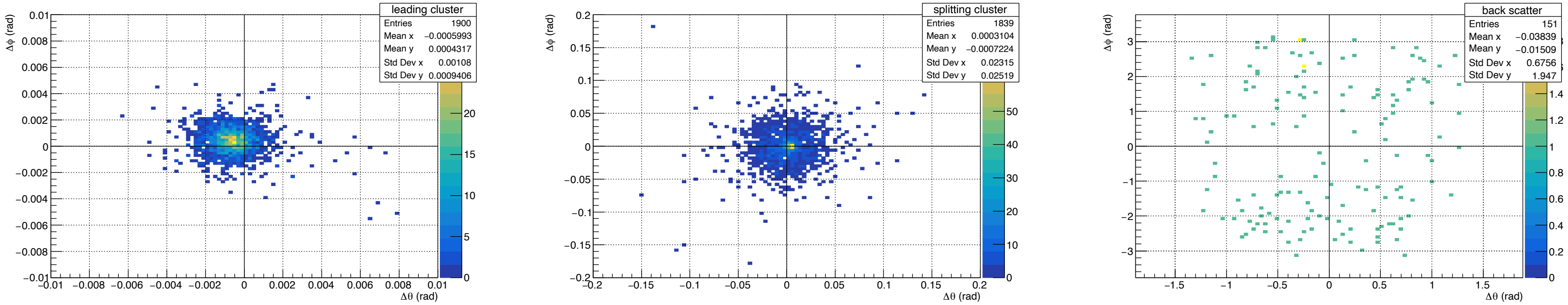
2.2. *1-N* Reconstruction: Split & Back Scatter

Angular Distribution

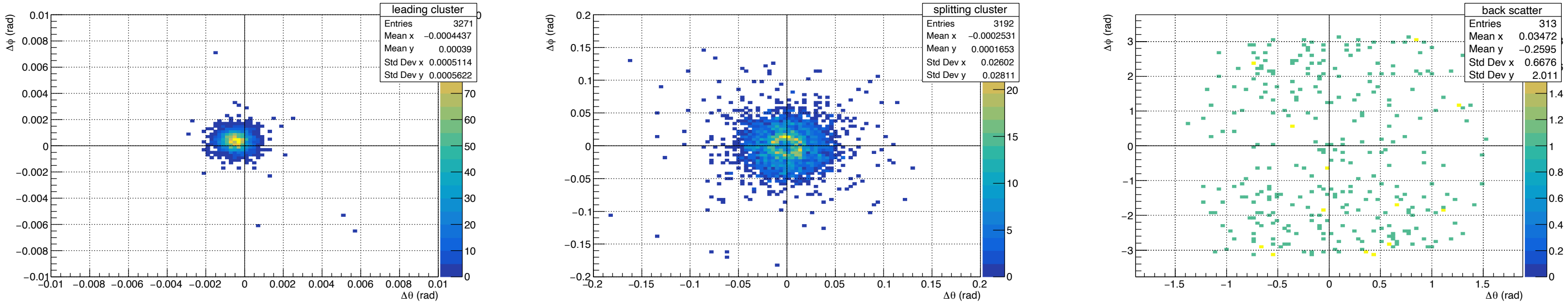




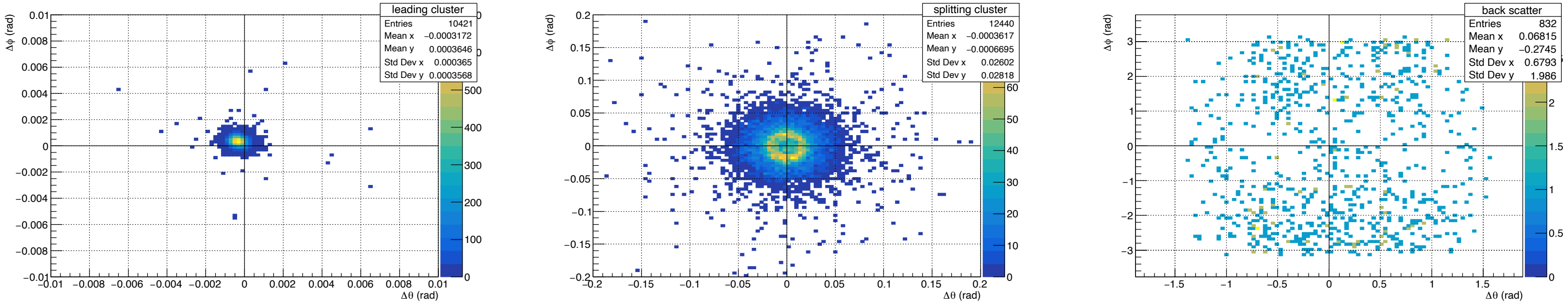
E_{truth}
$= \{1, 2, 3, 4\}\ GeV$



E_{truth}
$= \{5, 7, 10\}\ GeV$



E_{truth}
$= \{15, 25, 40\}\ GeV$

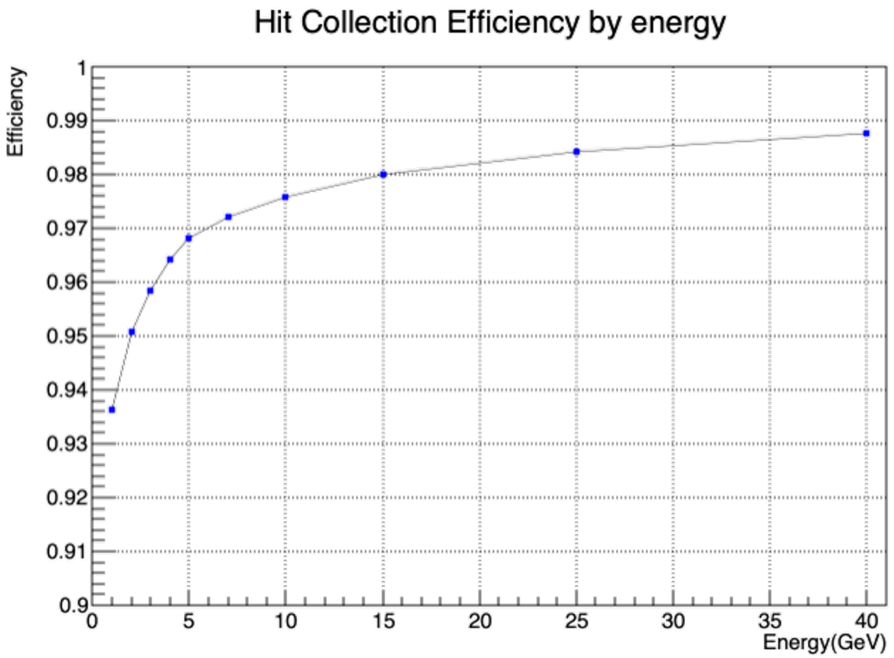


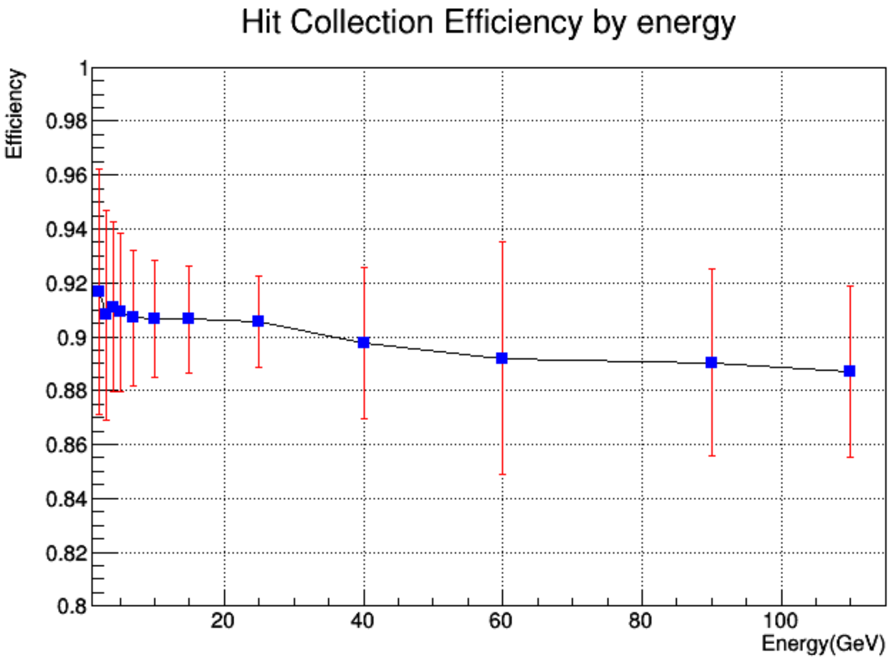
Future

- Single gamma with different direction or move to $Z \rightarrow \tau\tau$ sample
  - split probability as a function of polar angle
  - energy resolution as a function of polar angle
  - angle resolution as a function of polar angle

Back Up

Photon Energy Correction



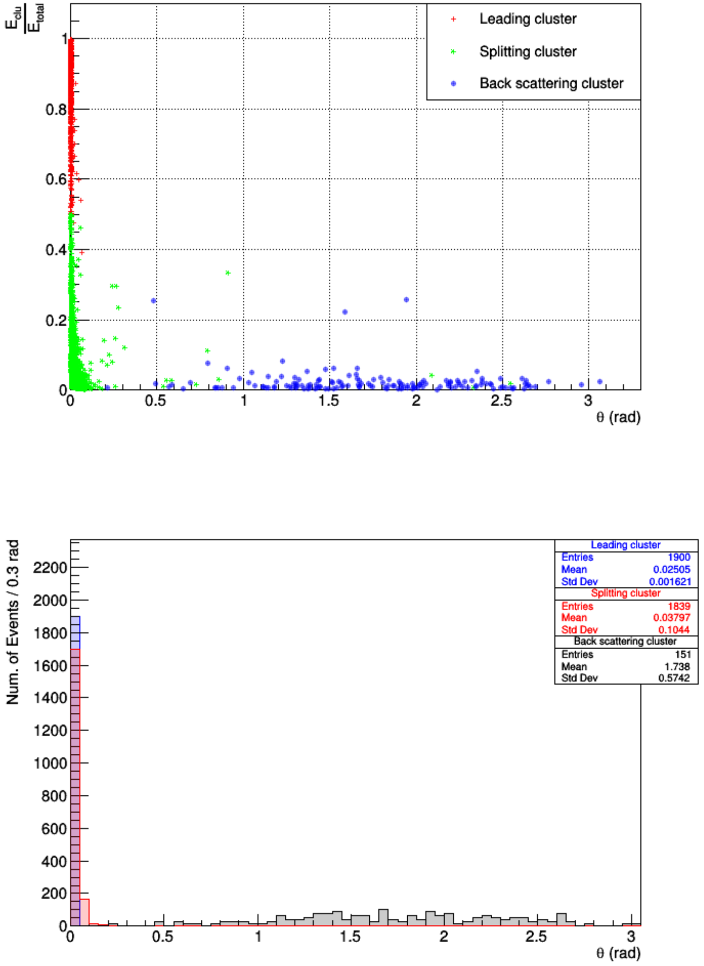


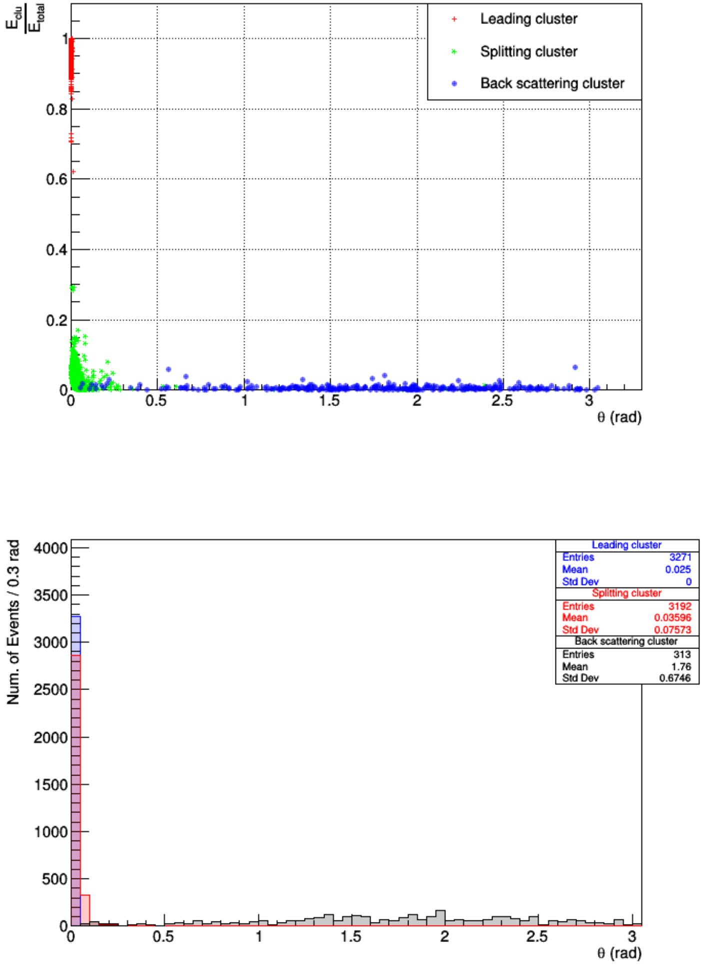
left: $\epsilon_l = \frac{\sum_{clu} E_{hit}}{\sum E_{hit}}$; **right**: $\epsilon_r = \frac{\sum E_{clu}}{\sum E_{hit}}$

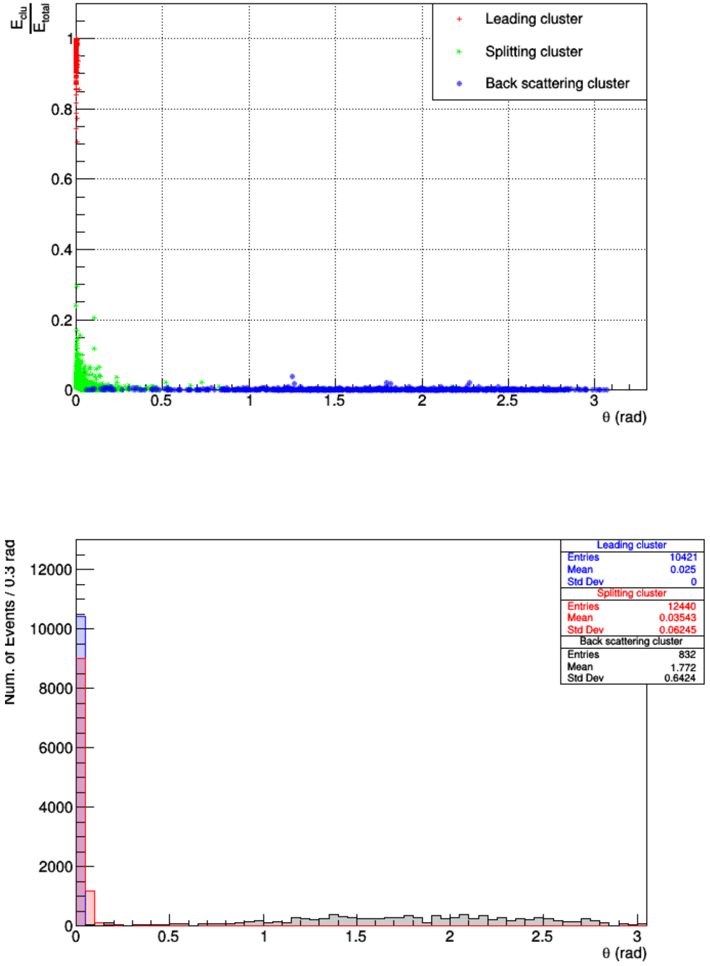
Is photon energy correction OK?

2.2. *1-N* Reconstruction

Angle of Split apart from Leading


$E_{truth} = \{1, 2, 3, 4\}\ GeV$

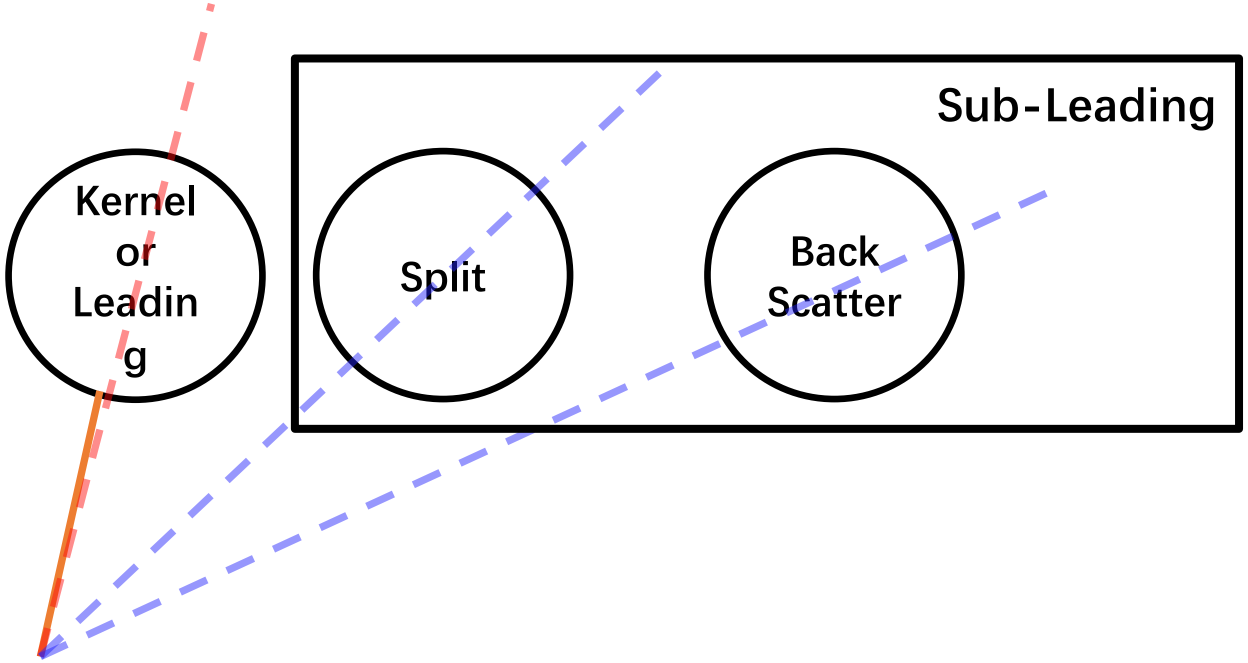

$E_{truth} = \{5, 7, 10\}\ GeV$


$E_{truth} = \{15, 25, 40\}\ GeV$

2nd line: every histogram has been normalized to the number of leading cluster.

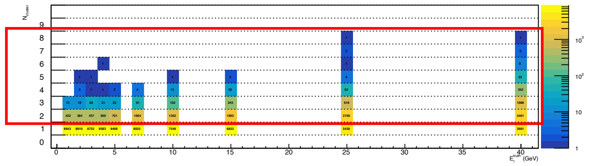
2.2. *1-N* Reconstruction: Sub-Leading cluster

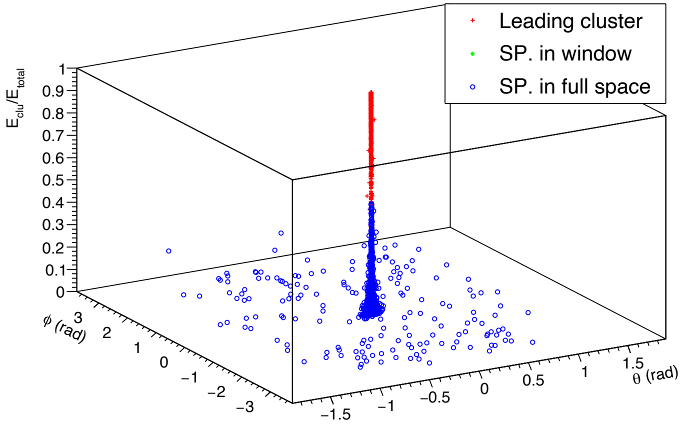
Angular Distribution



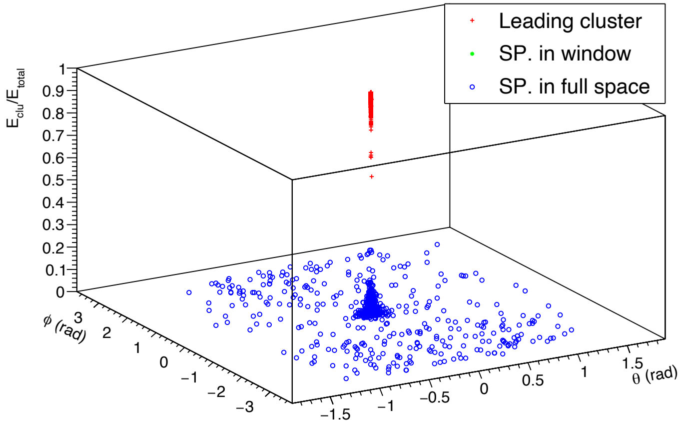
2.2. *1-N* Reconstruction

Angle of Split apart from Truth

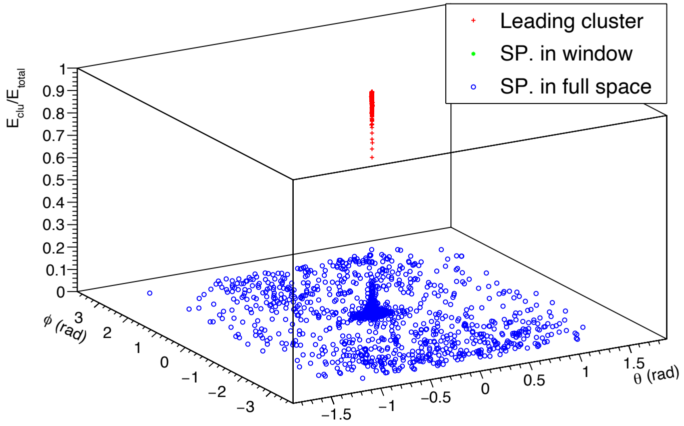




$E_{truth} = \{1, 2, 3, 4\}\ GeV$



$E_{truth} = \{5, 7, 10\}\ GeV$

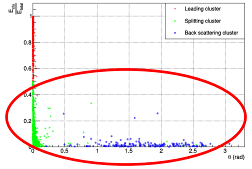


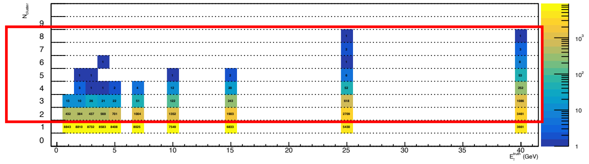
$E_{truth} = \{15, 25, 40\}\ GeV$

In *1-N* events, leading cluster always include **most of energy** and be **close to the truth photon**, while sub-leading clusters carry less energy and be farther from the truth photon.

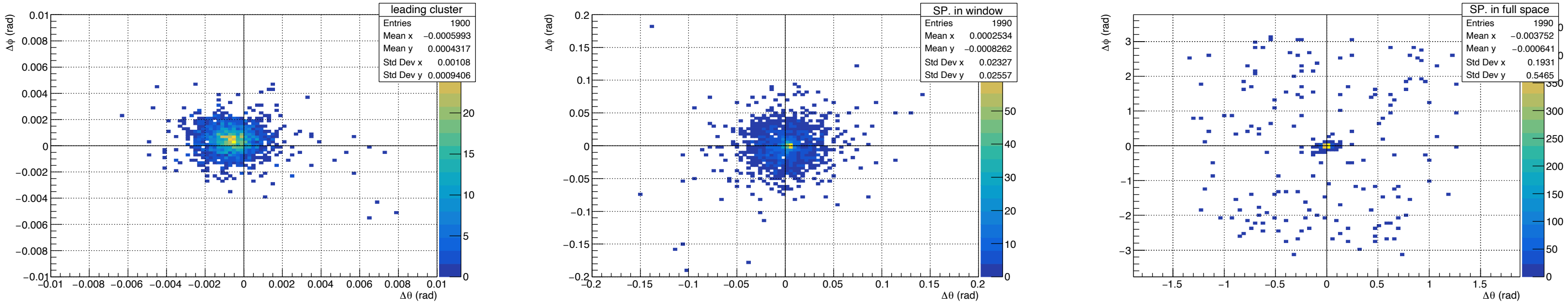
- 2nd line: every histogram has been normalized to the number of leading cluster.
- back scattering cluster can be considered as sub-leading cluster together with splitting cluster since its small statistic and the arbitrary condition.

Angular Distribution

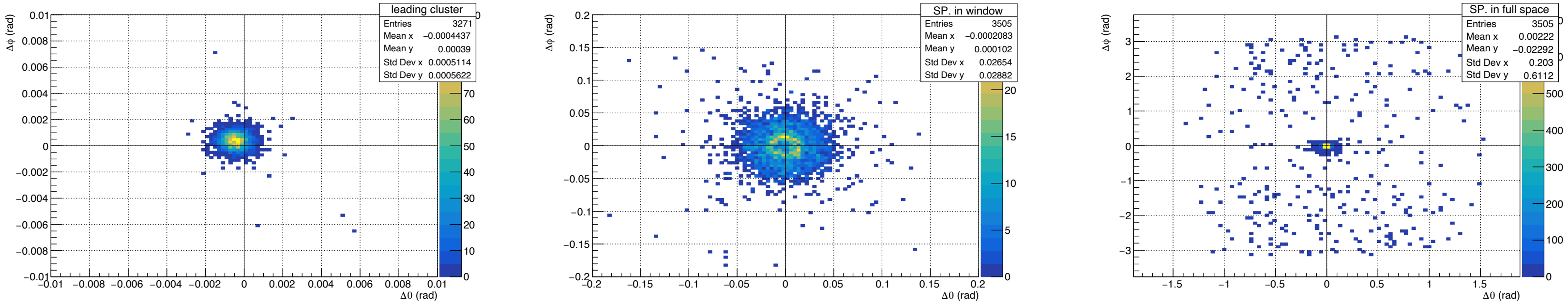




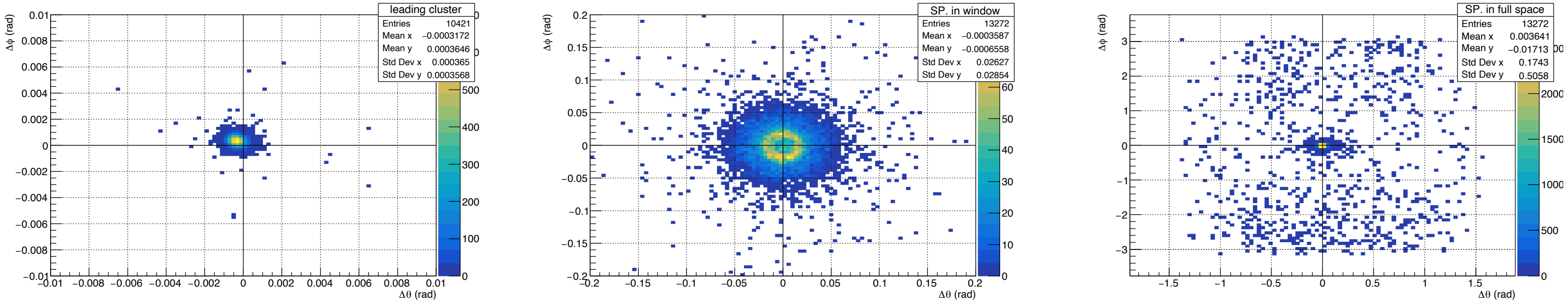
E_{truth}
$= \{1, 2, 3, 4\}\ GeV$



E_{truth}
$= \{5, 7, 10\}\ GeV$

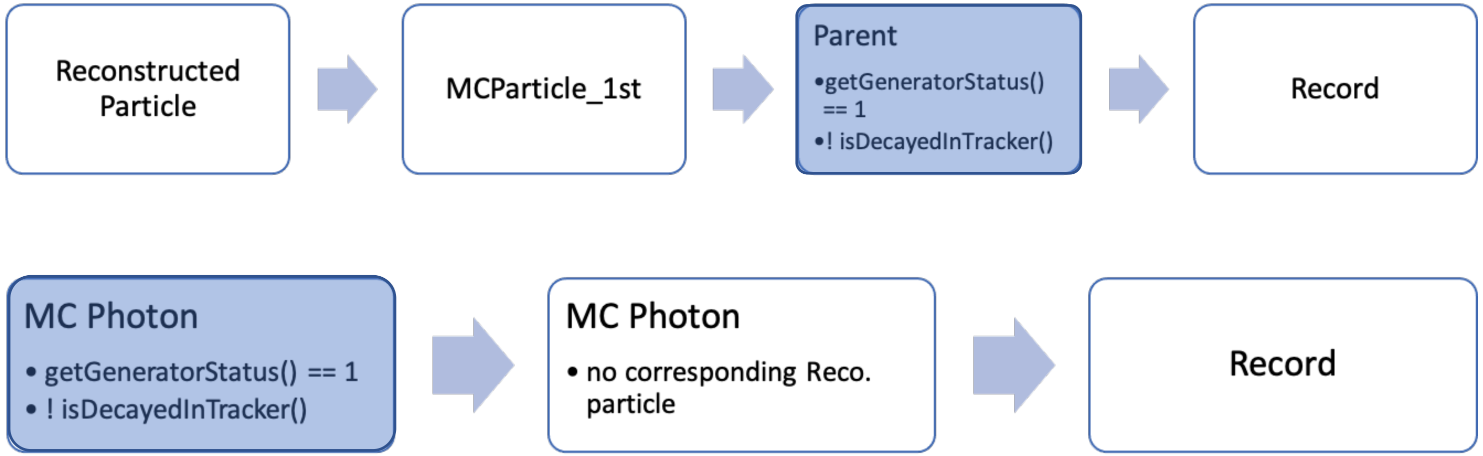


E_{truth}
$= \{15, 25, 40\}\ GeV$



Back Up

Check Generator Status



Reconstructed Particle

MCParticle_1st

Parent

- getGeneratorStatus() == 1
- ! isDecayedInTracker()

Record

MC Photon

- getGeneratorStatus() == 1
- ! isDecayedInTracker()

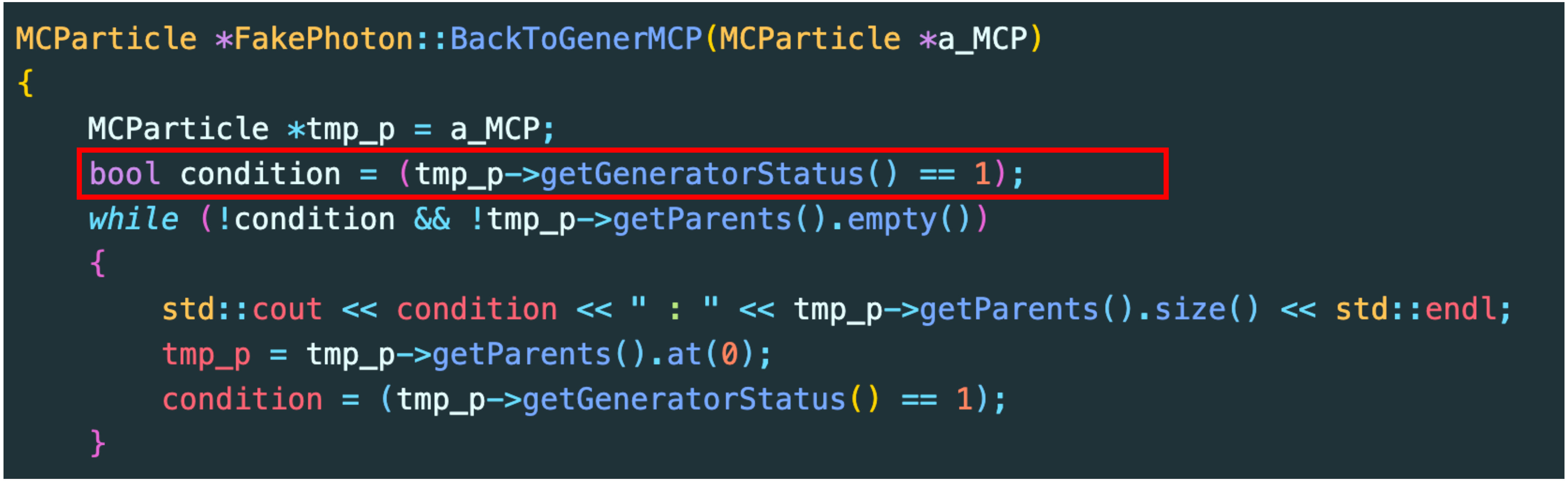
MC Photon

- no corresponding Reco. particle

Record

Check Generator Status

Final State Selection



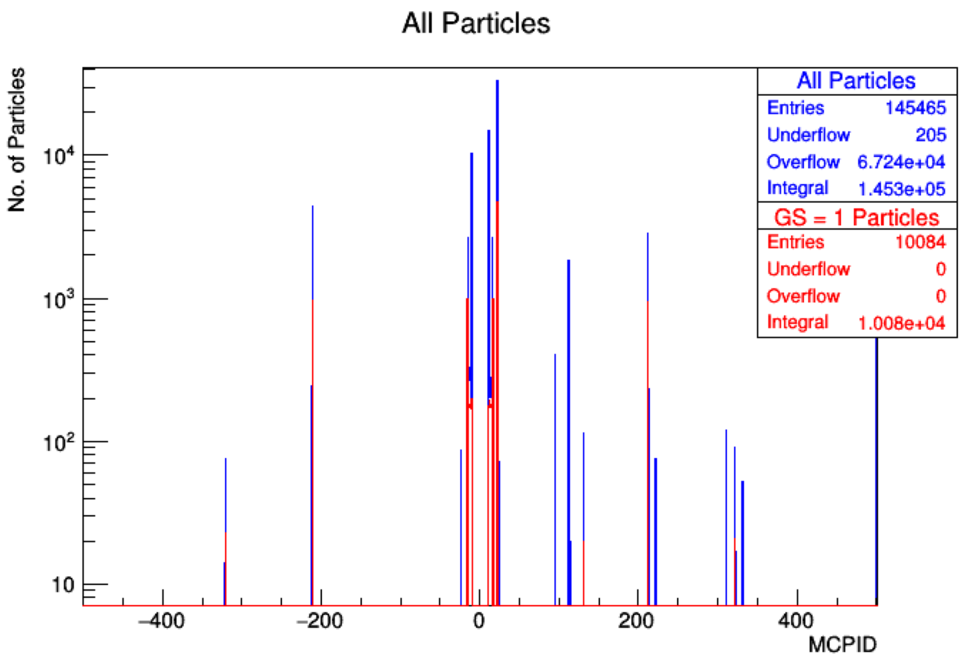
```
MCParticle *FakePhoton::BackToGenerMCP(MCParticle *a_MCP)
{
    MCParticle *tmp_p = a_MCP;
    bool condition = (tmp_p->getGeneratorStatus() == 1);
    while (!condition && !tmp_p->getParents().empty())
    {
        std::cout << condition << " : " << tmp_p->getParents().size() << std::endl;
        tmp_p = tmp_p->getParents().at(0);
        condition = (tmp_p->getGeneratorStatus() == 1);
    }
```

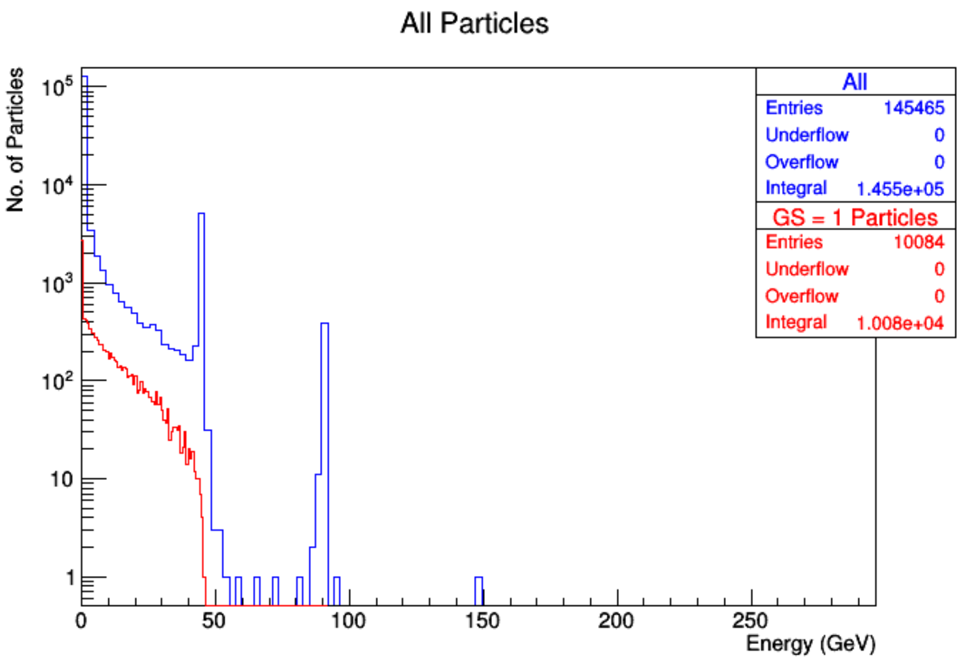
From the particle which directly contributed energy to a specific hit, *getGeneratorStatus()* leads us to find the final state particle on generator level.

Using $Z \to \tau\tau$ Sample (~ 1000 events) to check the reliability of this member function of class *MCParticle*.

Check Generator Status

Overview of Particle ID in Simulation Sample

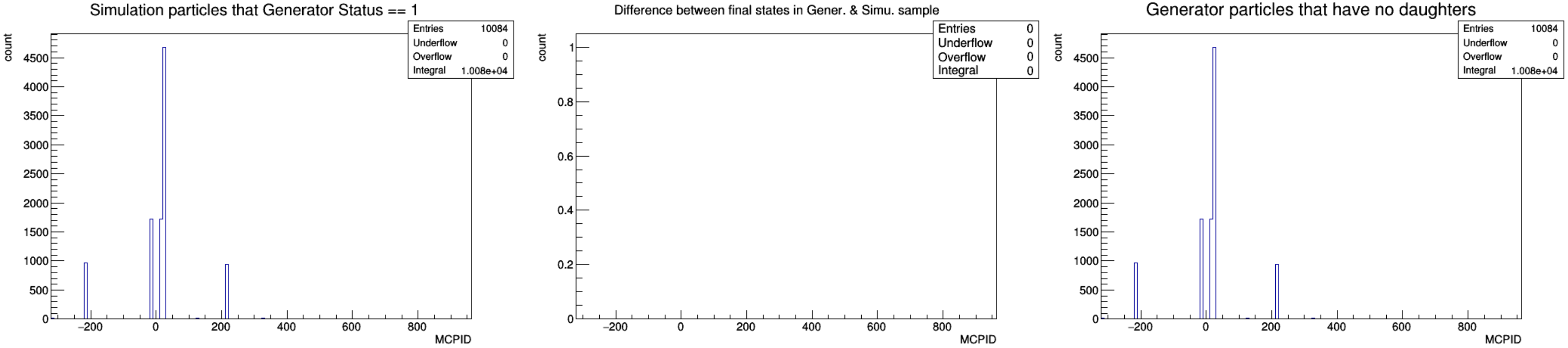




After setting *GS(Generator Status) == 1*, about 6.8% particles has been selected as final state particle.

Check Generator Status

Particle ID


Simulation particles that Generator Status == 1

Difference between final states in Gener. & Simu. sample

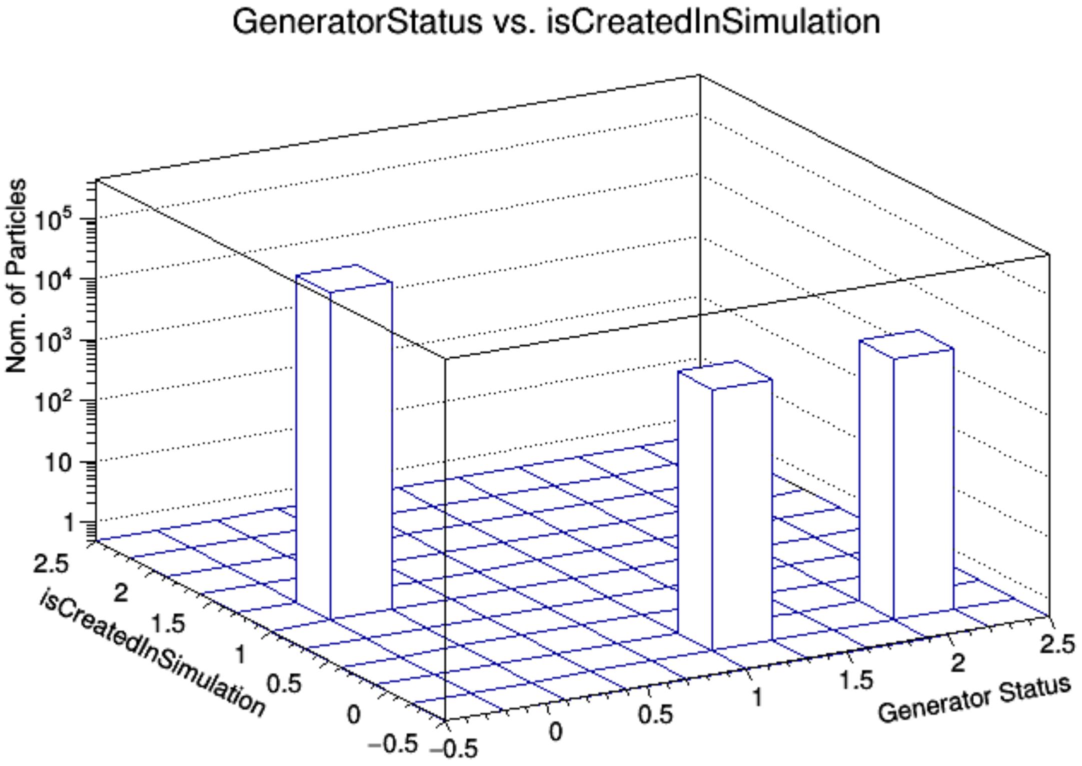
Generator particles that have no daughters

Left: Selected final state candidates in simulation sample

Middle: Left - Right

Right: Final state particles in generator sample

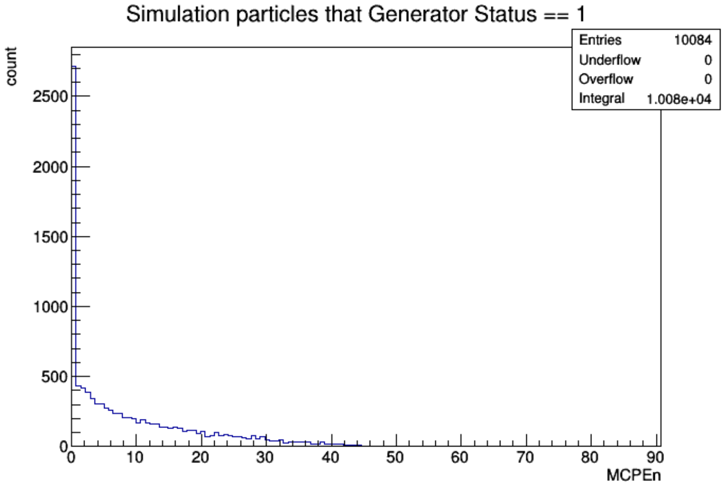
Generator Status vs. isCreatedInSimulation

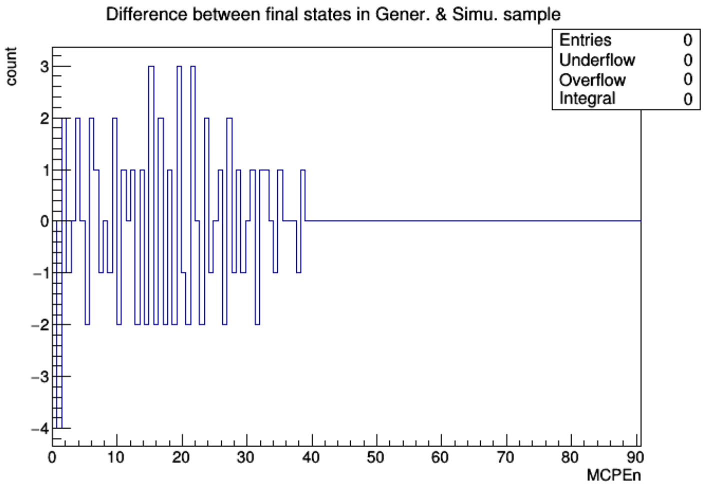


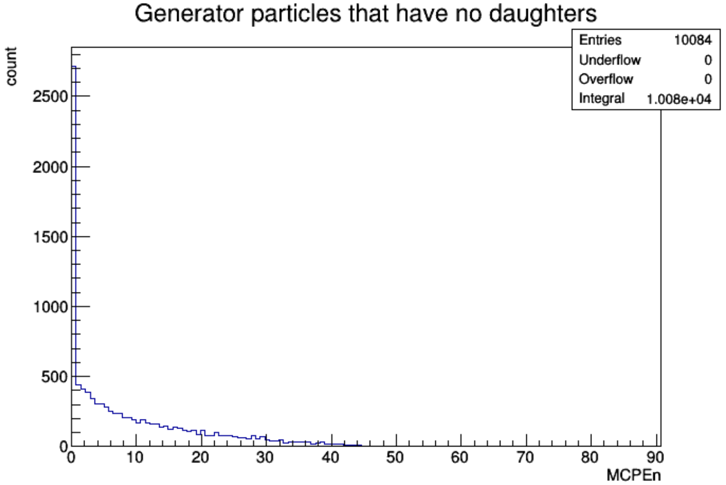
GeneratorStauts = !(isCreatedInSimulation)

Check Generator Status

Energy Distribution







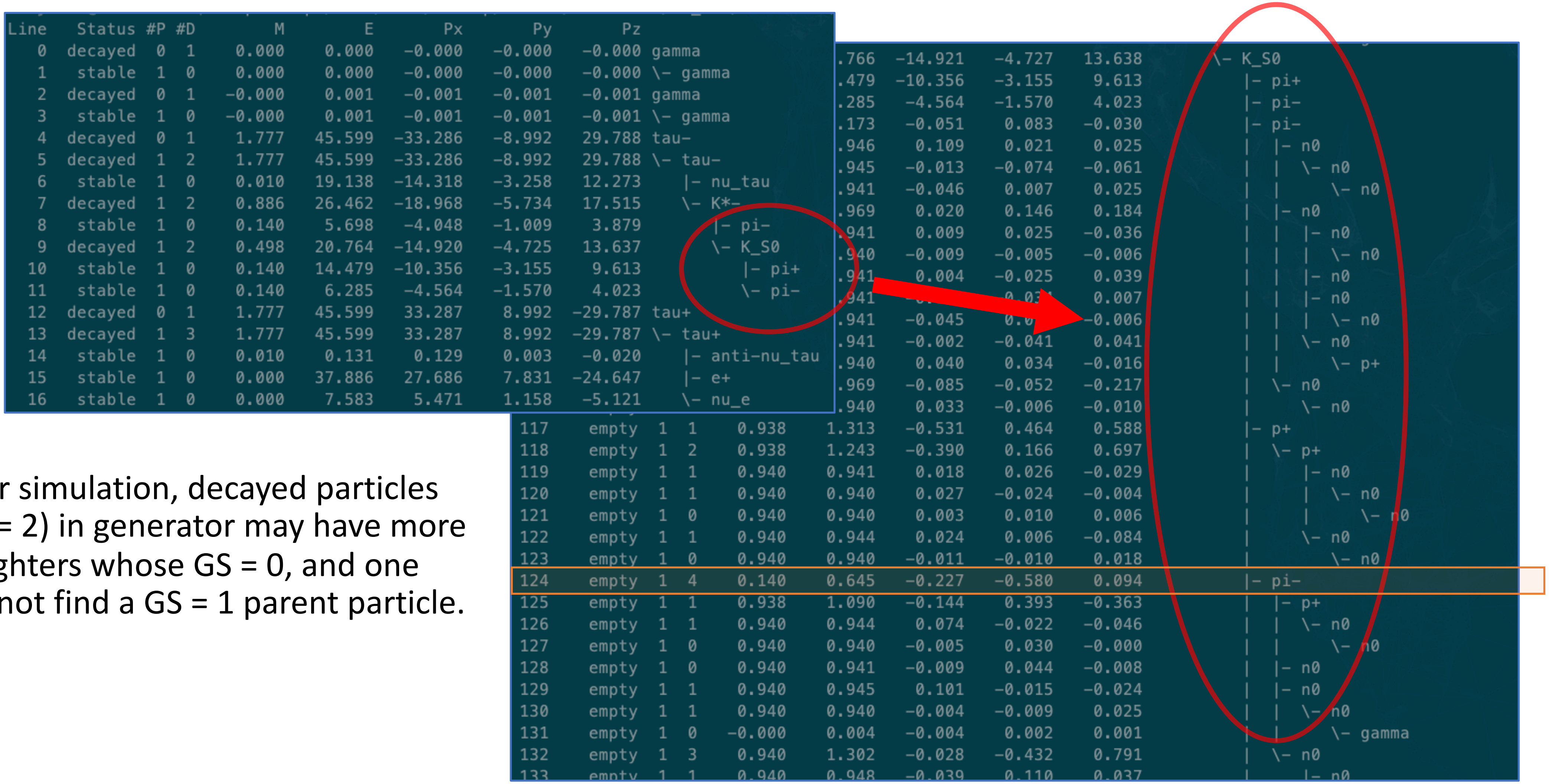
Left: Selected final state candidates in simulation sample

Middle: Left - Right

Right: Final state particles in generator sample

getGeneratorStatus() is reliable ☺

One can not always find final state using this function



```
Line   Status #P #D         M        E       Px       Py       Pz
   0  decayed  0  1     0.000    0.000   -0.000   -0.000   -0.000 gamma
   1   stable  1  0     0.000    0.000   -0.000   -0.000   -0.000 \- gamma
   2  decayed  0  1    -0.000    0.001   -0.001   -0.001   -0.001 gamma
   3   stable  1  0    -0.000    0.001   -0.001   -0.001   -0.001 \- gamma
   4  decayed  0  1     1.777   45.599  -33.286   -8.992   29.788 tau-
   5  decayed  1  2     1.777   45.599  -33.286   -8.992   29.788 \- tau-
   6   stable  1  0     0.010   19.138  -14.318   -3.258   12.273    |- nu_tau
   7  decayed  1  2     0.886   26.462  -18.968   -5.734   17.515    \- K*-
   8   stable  1  0     0.140    5.698   -4.048   -1.009    3.879       |- pi-
   9  decayed  1  2     0.498   20.764  -14.920   -4.725   13.637       \- K_S0
  10   stable  1  0     0.140   14.479  -10.356   -3.155    9.613          |- pi+
  11   stable  1  0     0.140    6.285   -4.564   -1.570    4.023          \- pi-
  12  decayed  0  1     1.777   45.599   33.287    8.992  -29.787 tau+
  13  decayed  1  3     1.777   45.599   33.287    8.992  -29.787 \- tau+
  14   stable  1  0     0.010    0.131    0.129    0.003   -0.020    |- anti-nu_tau
  15   stable  1  0     0.000   37.886   27.686    7.831  -24.647    |- e+
  16   stable  1  0     0.000    7.583    5.471    1.158   -5.121    \- nu_e
```

```
                                .766  -14.921   -4.727   13.638        \- K_S0
                                .479  -10.356   -3.155    9.613           |- pi+
                                .285   -4.564   -1.570    4.023           |- pi-
                                .173   -0.051    0.083   -0.030           |- pi-
                                .946    0.109    0.021    0.025           |  |- n0
                                .945   -0.013   -0.074   -0.061           |  |  \- n0
                                .941   -0.046    0.007    0.025           |  |     \- n0
                                .969    0.020    0.146    0.184           |  |- n0
                                .941    0.009    0.025   -0.036           |  |  |- n0
                                .940   -0.009   -0.005   -0.006           |  |  |  \- n0
                                .941    0.004   -0.025    0.039           |  |  |- n0
                                .941   -0.       0.03     0.007           |  |  |- n0
                                .941   -0.045    0.0     -0.006           |  |  |  \- n0
                                .941   -0.002   -0.041    0.041           |  |  \- n0
                                .940    0.040    0.034   -0.016           |  |     \- p+
                                .969   -0.085   -0.052   -0.217           |  \- n0
                                .940    0.033   -0.006   -0.010           |     \- n0
117    empty  1  1    0.938    1.313   -0.531    0.464    0.588           |- p+
118    empty  1  2    0.938    1.243   -0.390    0.166    0.697           |  \- p+
119    empty  1  1    0.940    0.941    0.018    0.026   -0.029           |     |- n0
120    empty  1  1    0.940    0.940    0.027   -0.024   -0.004           |     |  \- n0
121    empty  1  0    0.940    0.940    0.003    0.010    0.006           |     |     \- n0
122    empty  1  1    0.940    0.944    0.024    0.006   -0.084           |     \- n0
123    empty  1  0    0.940    0.940   -0.011   -0.010    0.018           |        \- n0
124    empty  1  4    0.140    0.645   -0.227   -0.580    0.094           |- pi-
125    empty  1  1    0.938    1.090   -0.144    0.393   -0.363           |  |- p+
126    empty  1  1    0.940    0.944    0.074   -0.022   -0.046           |  |  \- n0
127    empty  1  0    0.940    0.940   -0.005    0.030   -0.000           |  |     \- n0
128    empty  1  0    0.940    0.941   -0.009    0.044   -0.008           |  |- n0
129    empty  1  1    0.940    0.945    0.101   -0.015   -0.024           |  |- n0
130    empty  1  1    0.940    0.940   -0.004   -0.009    0.025           |  |  \- n0
131    empty  1  0   -0.000    0.004   -0.004    0.002    0.001           |  |     \- gamma
132    empty  1  3    0.940    1.302   -0.028   -0.432    0.791           |  \- n0
133    empty  1  1    0.940    0.948   -0.039    0.110    0.037           |     |- n0
```

After simulation, decayed particles (GS = 2) in generator may have more daughters whose GS = 0, and one can not find a GS = 1 parent particle.