Gamma Finding procedure for GLD Detector

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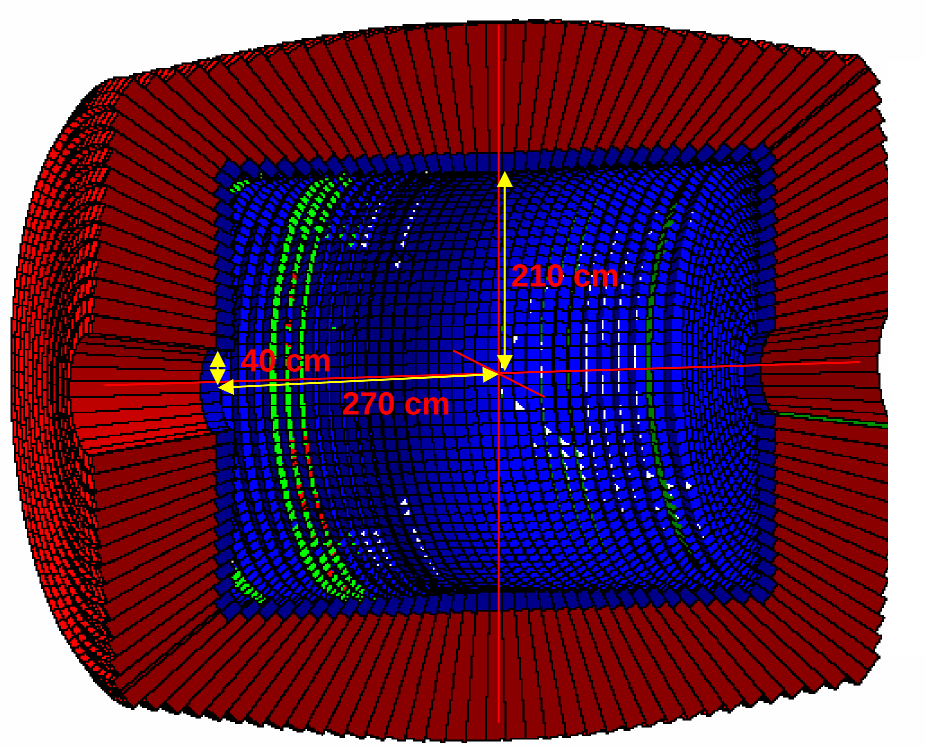
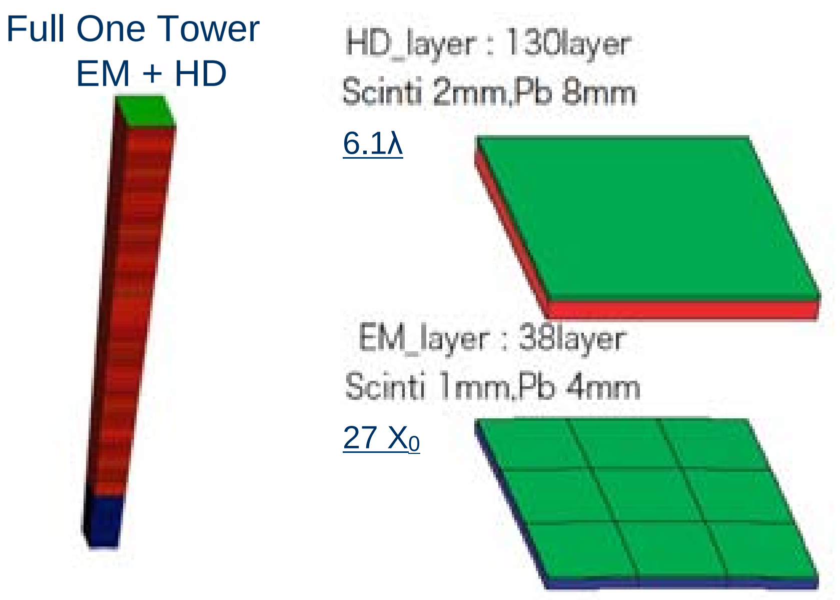
Motivation

To get high energy resolution in multi-jet event, we use the tracker information for charged particles and calorimeter hits information for neutral particles. (tracker resolution is much better than calorimeter's.)

Particle Flow Algorithm (PFA) is studied to achieve an event reconstruction. We studied part of PFA, "gamma finding method" for GLD detector, using full simulator (Jupiter).

Detector configuration





Y.Yamaguchi (Tsukuba Univ.)

In current Jupiter, calorimeter has tile type geometry. The default tile size is 4cmx4cm/12cmx12cm for ECAL/HCAL. We used this configuration mainly.

Flow of the gamma finding

As a first step of the clustering, we collect hit cells with its neighbors (at most with ~50MeV energy deposit). We call it "small cluster". Our gamma finding method is performed based on the small clusters.

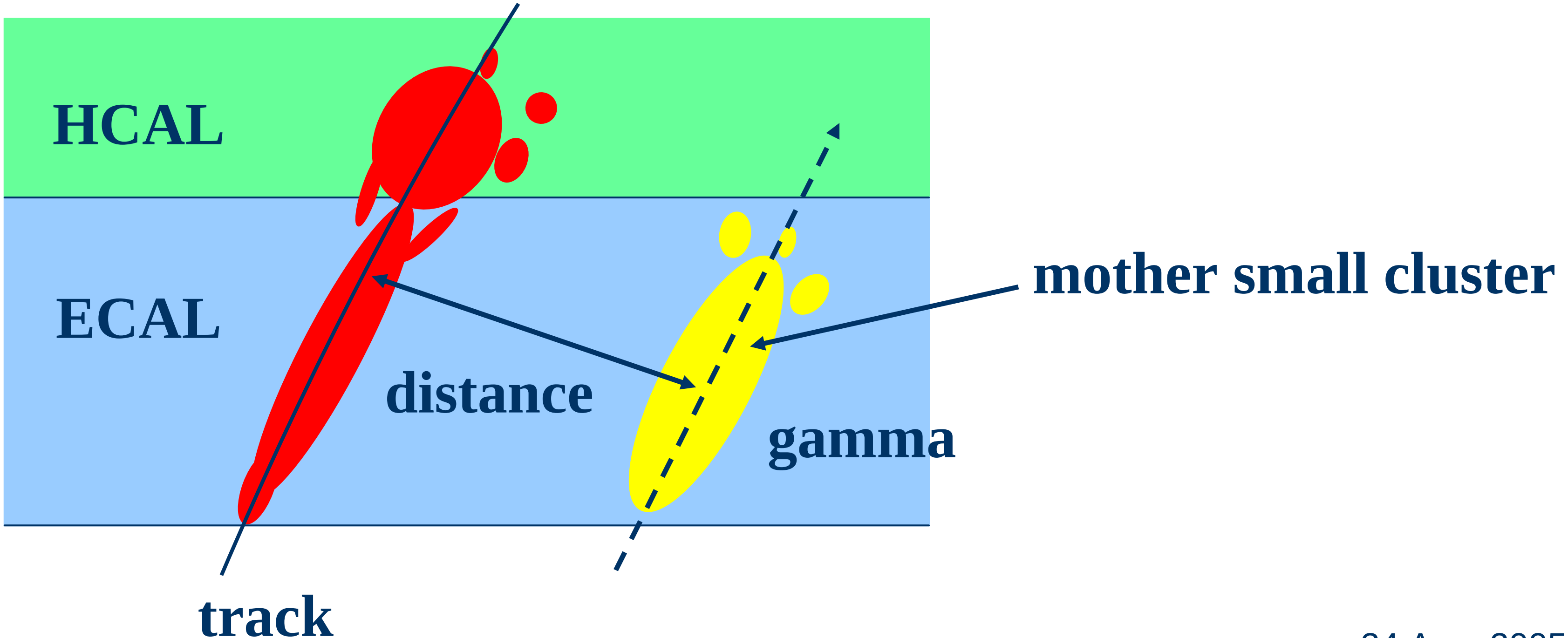
The flow of Gamma Finding

1. **Find "large" small cluster within ECAL region (we call it "mother small cluster").**
2. **Reject mother small clusters which are close to the track.**
3. **Collect small clusters within a tube.**
4. **Select gamma-like clusters using longitudinal shower profile.**

Gamma finding method

1. The distance from the nearest track

Calculate the distance between mother small cluster and its nearest track. The distance is used to separate gamma from charged particles.



Gamma finding method

2. Longitudinal shower profile

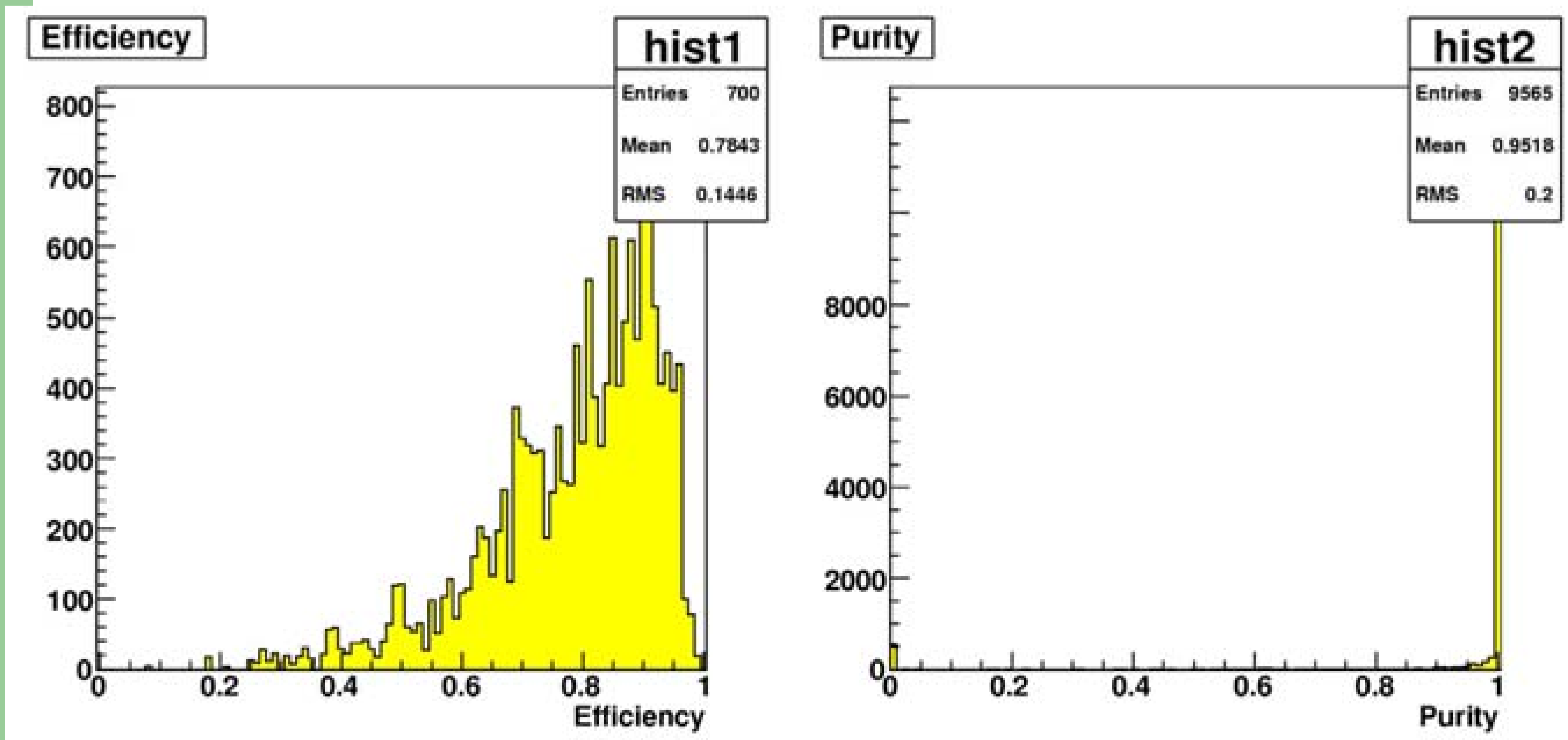
Make a small tube (**R = 5cm**) along mother small cluster's thrust axis in the ECAL region. (thrust axis is calculated using energy weighted fired cell position)

Check longitudinal shower profile within a tube.

1. Calculate mean shower depth from ECAL inner surface
2. Fit the shower profile by gamma distribution function.
3. Fit the shower profile by linear function. (reject MIP)
4. Calculate the layer ID which has maximum total energy deposit.

(please check slide in PFA session (22th Aug.))

Result of efficiency and purity

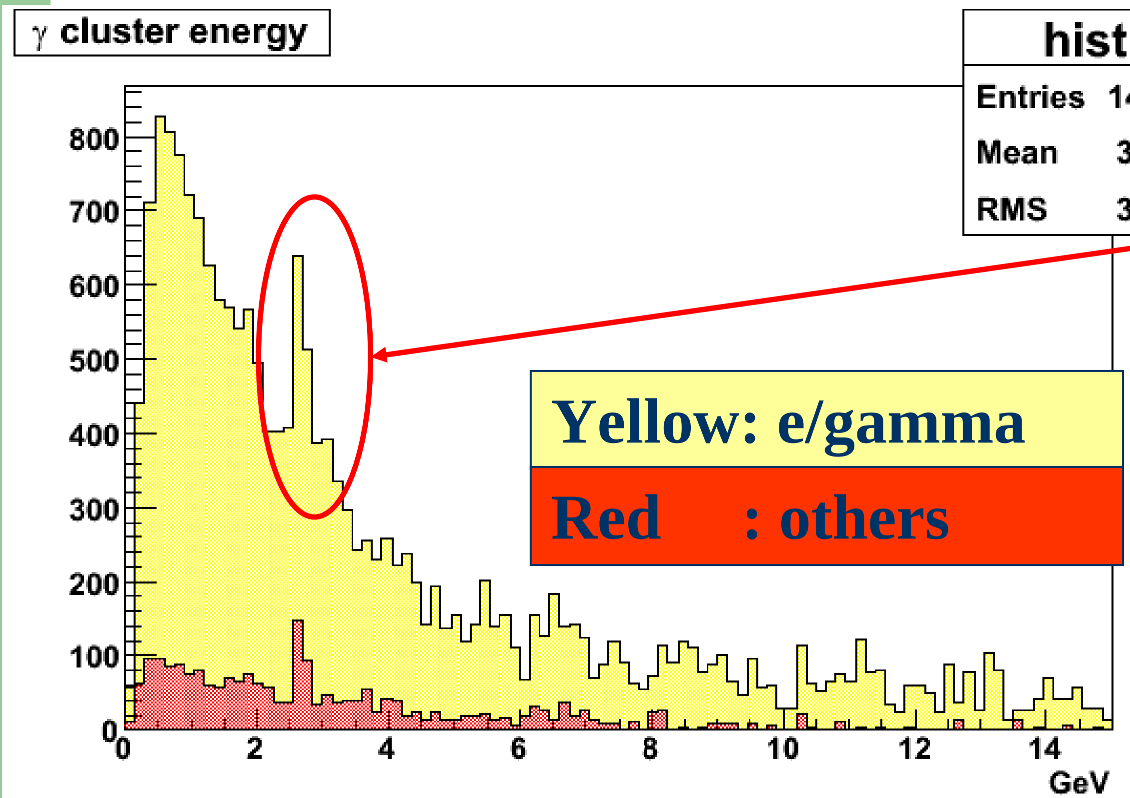


(Z->qqbar @ Ecm = 91.2 GeV)

e,gamma:Efficiency = 78.4%, purity = 95.2% (e-weighted)

Problem and Preliminary Idea

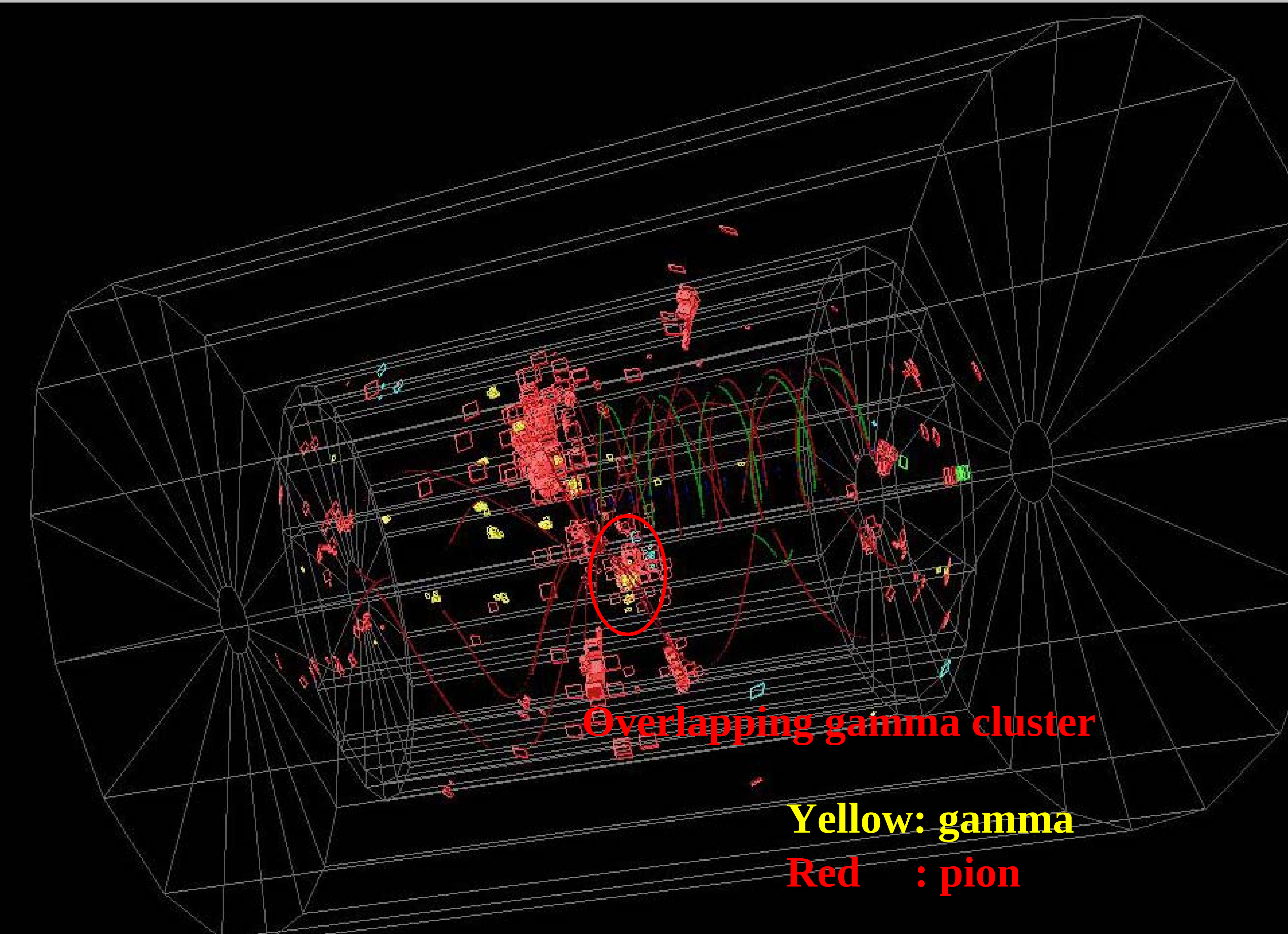
Cluster energy and purity

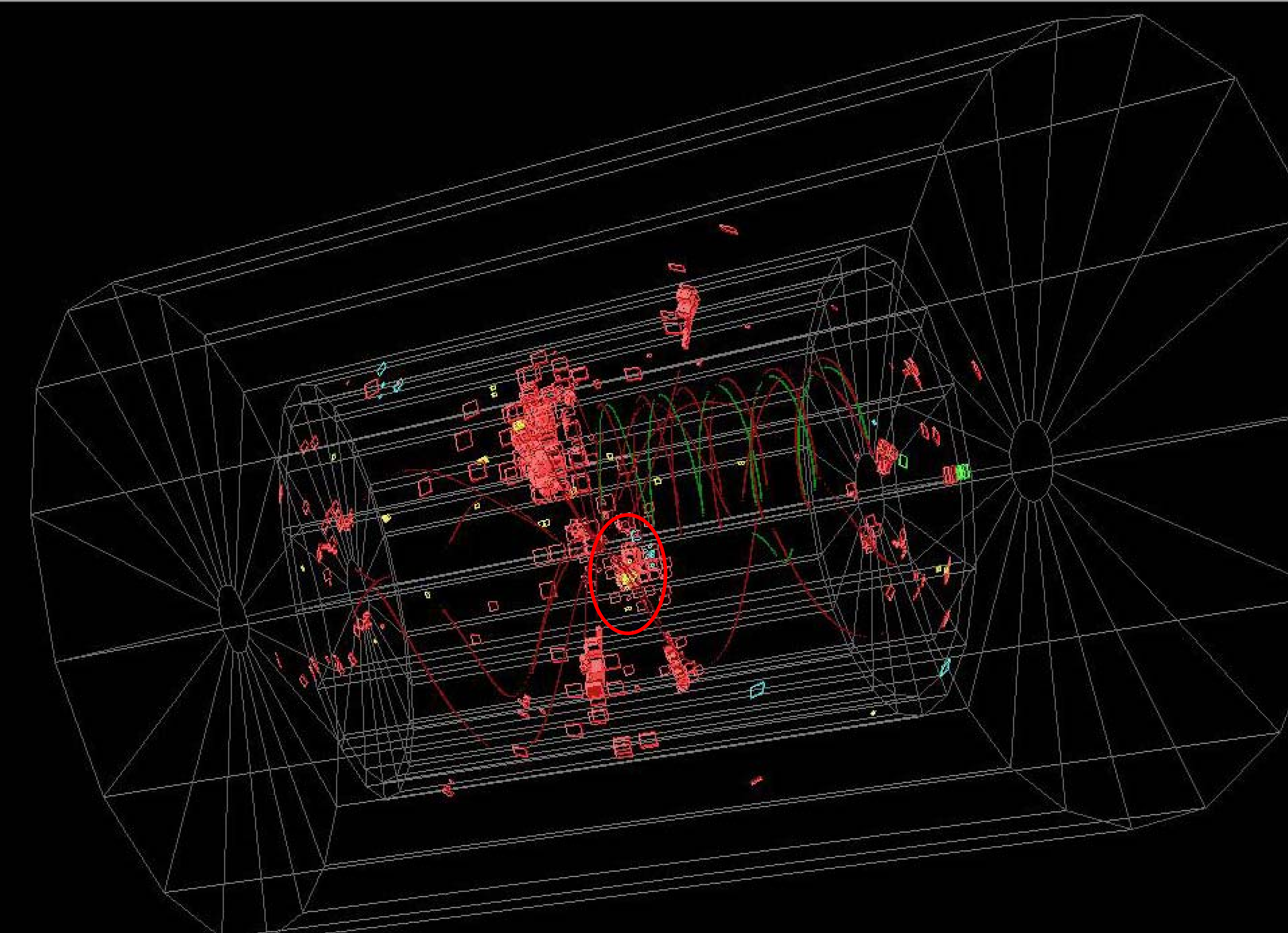


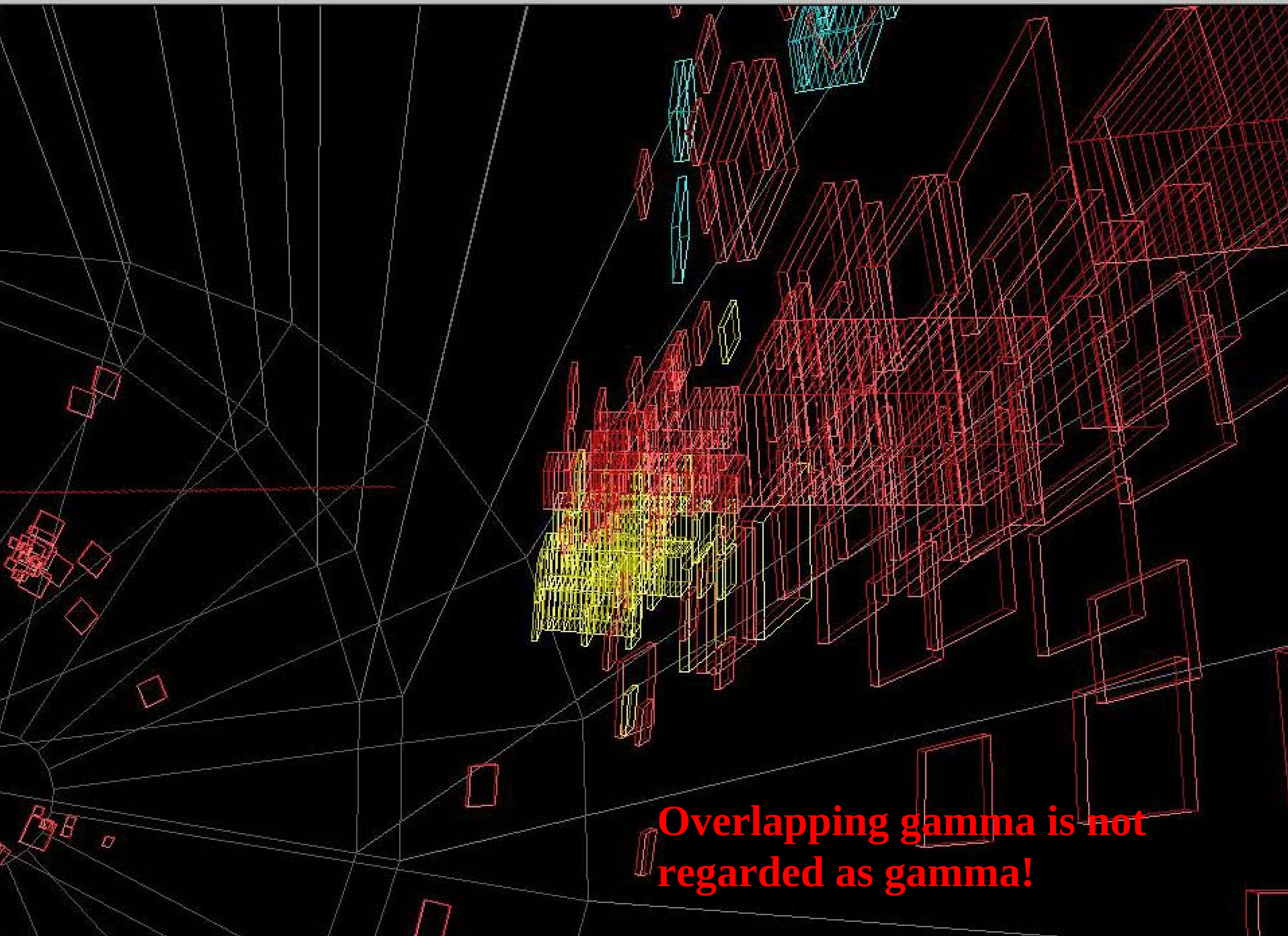
This peak consists to Small cluster's energy upper limit!

We can't contain enough small clusters within R=5cm tube.

Purity is worth at low energy region. It means low energy (charged) hadrons are regarded as gamma.


Overlapping gamma cluster
Yellow: gamma
Red : pion




Overlapping gamma is not
regarded as gamma!

Problem

1. **We can't collect gamma origin small clusters by R=5cm tube (with 4cm tile size configuration)**
2. **How to reduce low momentum hadrons contamination?**
3. **How to separate overlapping clusters?**

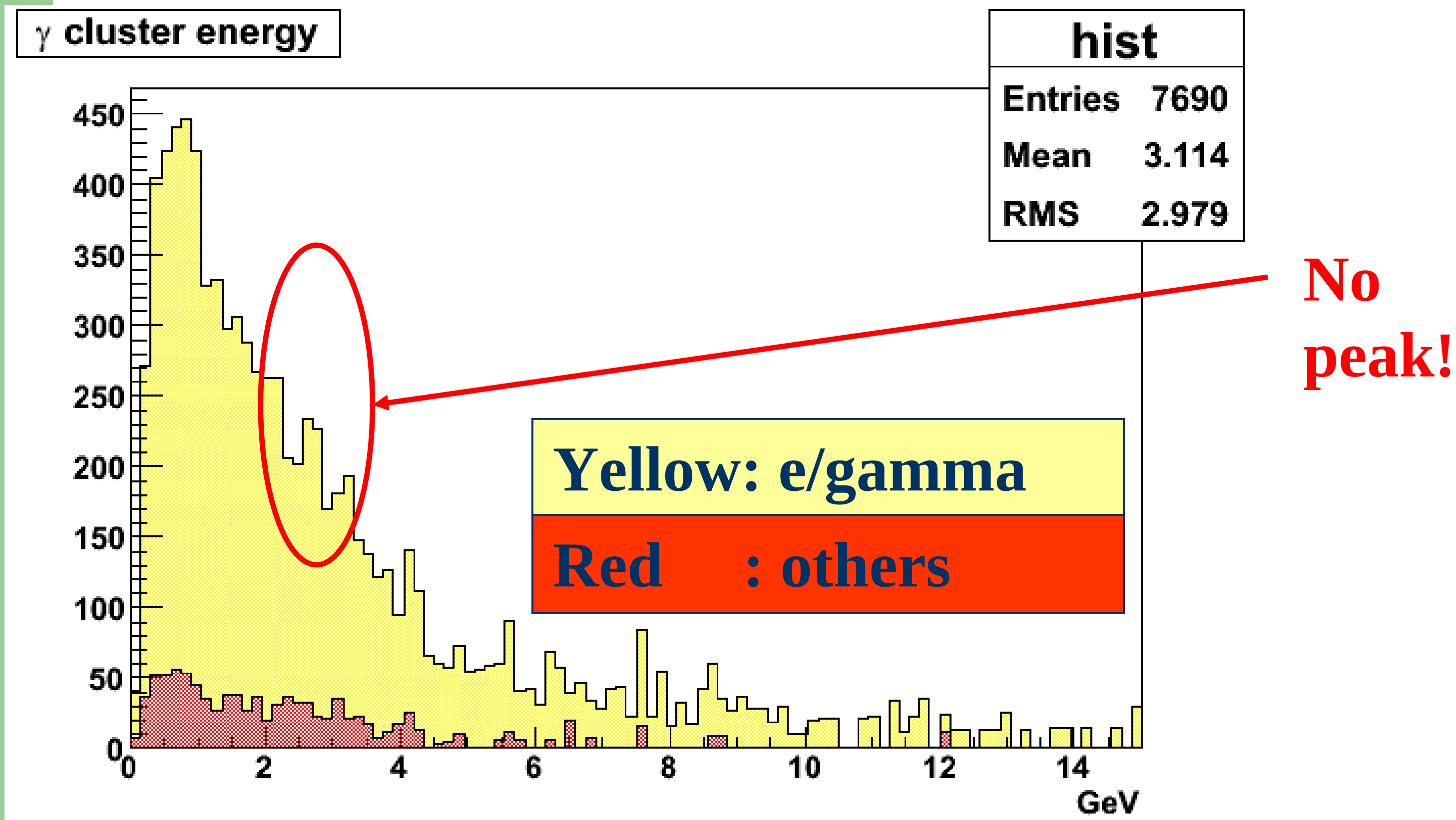
How to collect small clusters?

To collect enough small clusters…

1. **Make tube radius larger → purity become worth**
2. **Make tile size smaller (R_M ~ 2cm.→5cm is enough large)**
3. **Modify small clustering method**
4. **Do not use small clustering method → ??**

etc…

1cm x 1cm tile size case



We can collect small clusters by simple tube method.

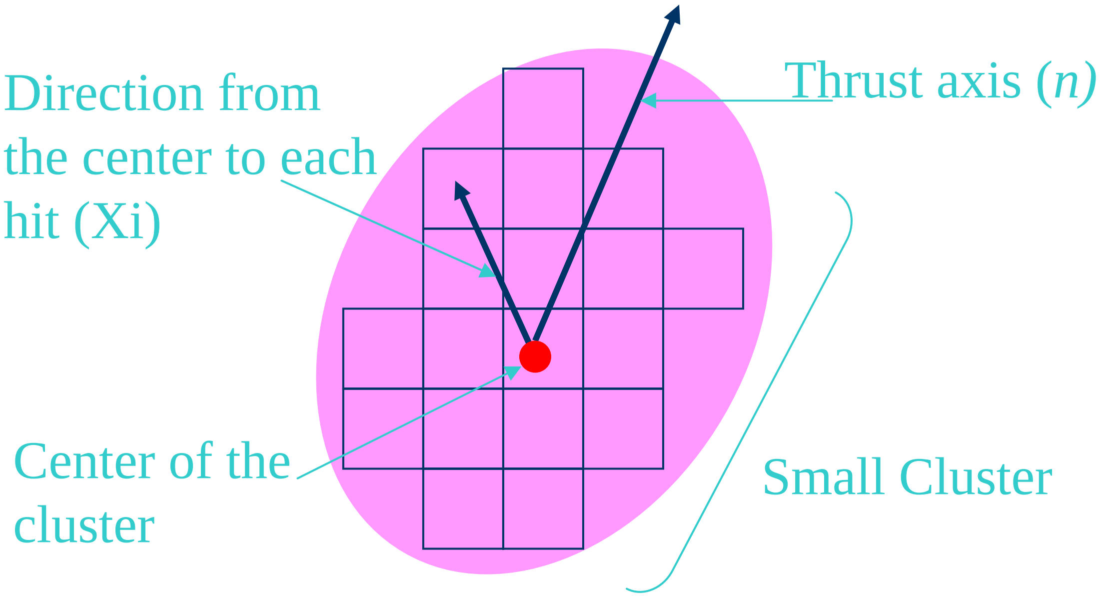
How to reject low momentum hadrons?

We have useful variables…

- *Energy-weighted Thrust & Broadening*

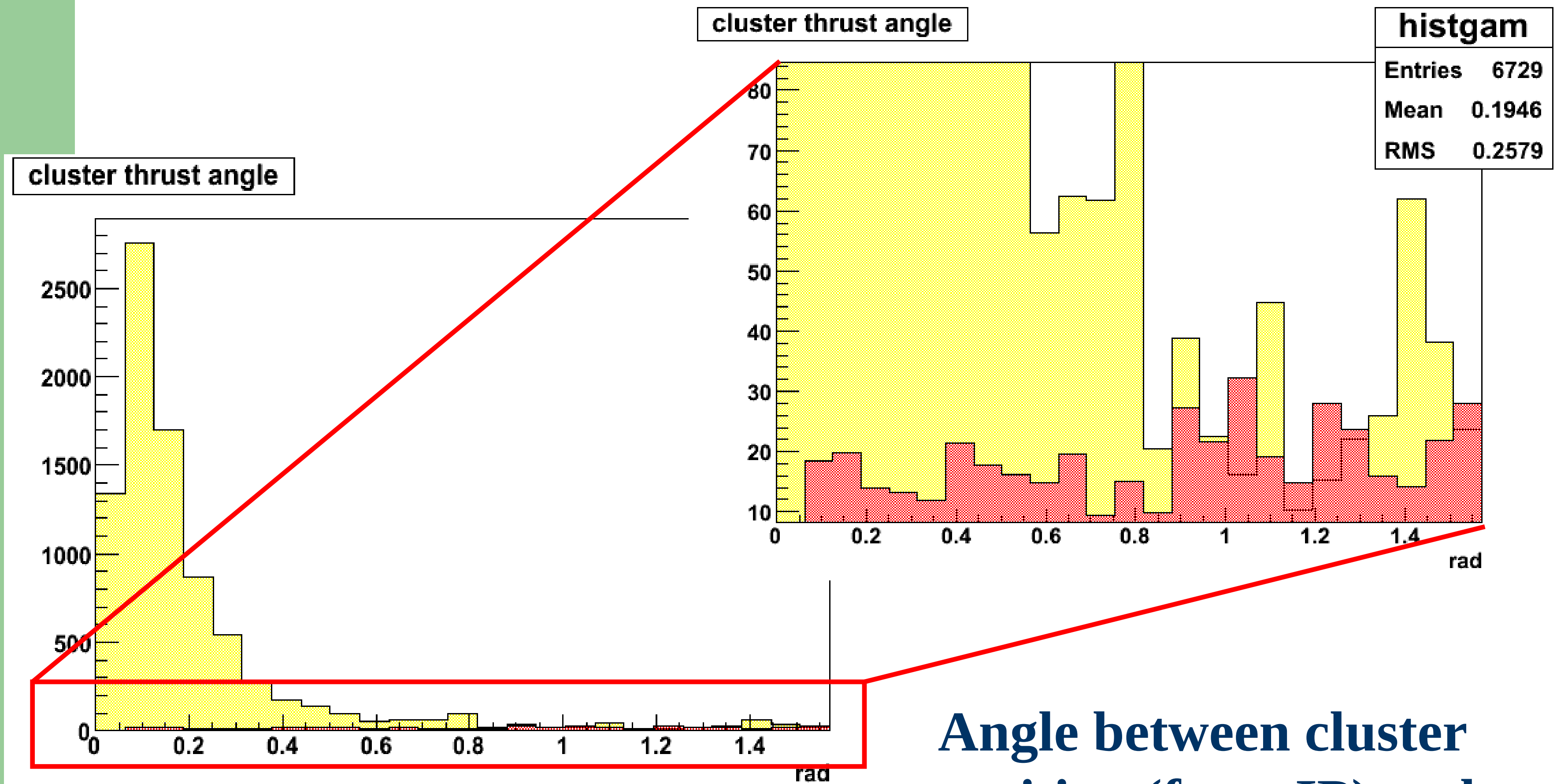
$$T \equiv \frac{\sum_i |\vec{X}_i \cdot \vec{n}| E_i}{E_{total} \sum_i |\vec{X}_i|}$$

$$B \equiv \frac{\sum_i |\vec{X}_i \times \vec{n}| E_i}{E_{total} \sum_i |\vec{X}_i|}$$



- Thrust axis *n* is defined as to maximize the T.

Cluster direction



with 1cm x 1cm tile size configuration

Angle between cluster position (from IP) and thrust axis.

How to separate overlapping clusters?

We need to modify small clustering algorithm…

Current small clustering algorithm:

1. Find the most energetic hit cell
2. Collect its fired neighbors from the closest one (spherical)

(upper limit for total energy deposition ~50MeV)

Idea (Not studied yet)

1. Collect neighbor cells using tube?? (set tube radius larger and larger)
2. Set high energy threshold → small clustering → Set energy threshold lower → small clustering → …. (use energy density)
3. Do not set energy upper limit??

Summary

- We got ~78% efficiency and ~95% purity using the nearest track distance requirement + longitudinal shower profile search.

- Current gamma finding method has low purity at low energy region.

- Need modification for our current small clustering method and/or tube size for gamma-clustering.

Next step

- **Study energy/angle dependent clustering method (change tube size depend on energy etc.) and re-consider small clustering method.**
- **Reject low momentum hadrons. (which related to low momentum track matching)**
- **Study other cell size configuration and other physics event case.**
- **Try to use H-matrix (SiD group proposal)**

Backup Slides

Clustering flow for GLD detector

- Procedure of the GLD-PFA

1. Small Clustering and Gamma Finding
   - Collect fired cells with its neighbors.
   - Separate gamma from hadrons.

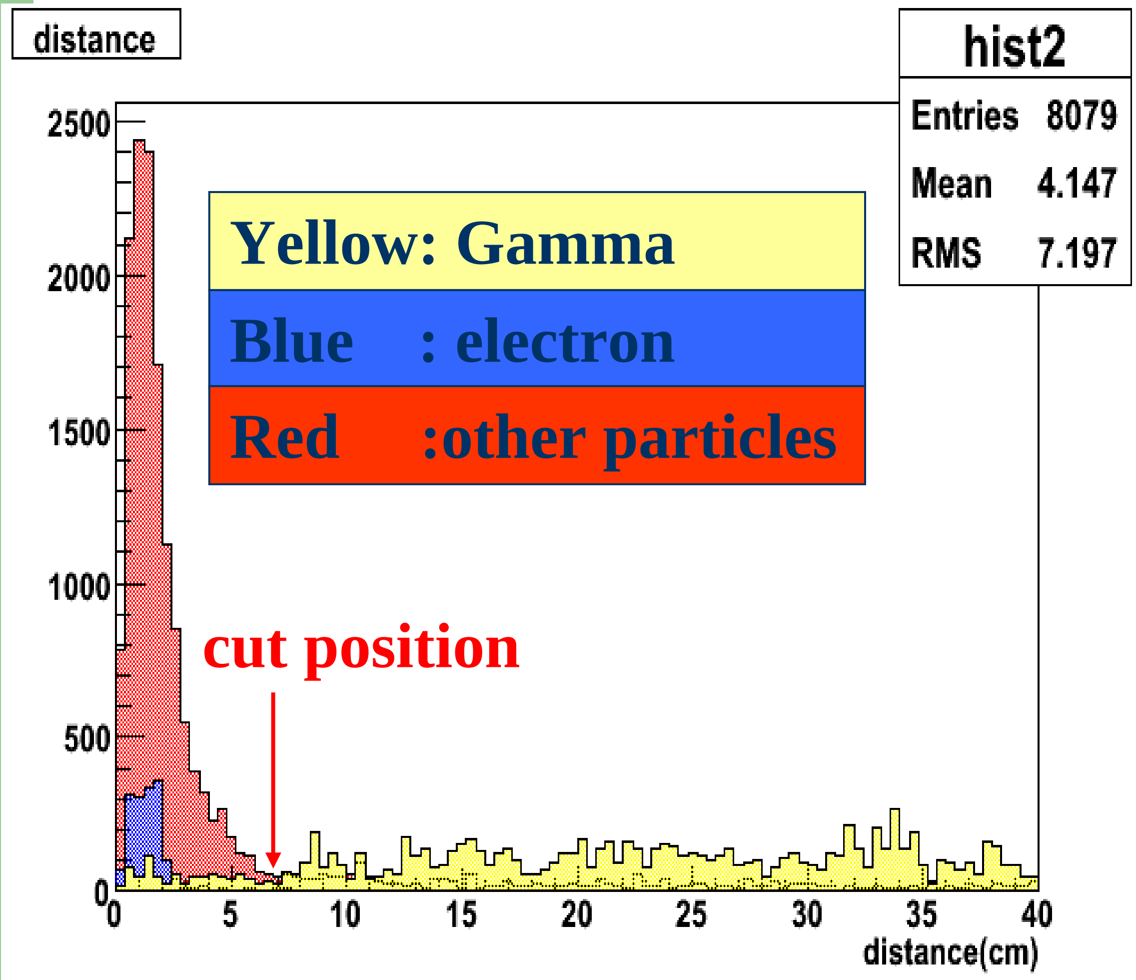
2. Cluster-Track Matching
- Separate charged particles from neutral particles.

3. Assuming the remaining hits are neutral hadrons.

Flow to make PFO

Note. Muon is rejected by cheated method at first

Distance from the nearest track



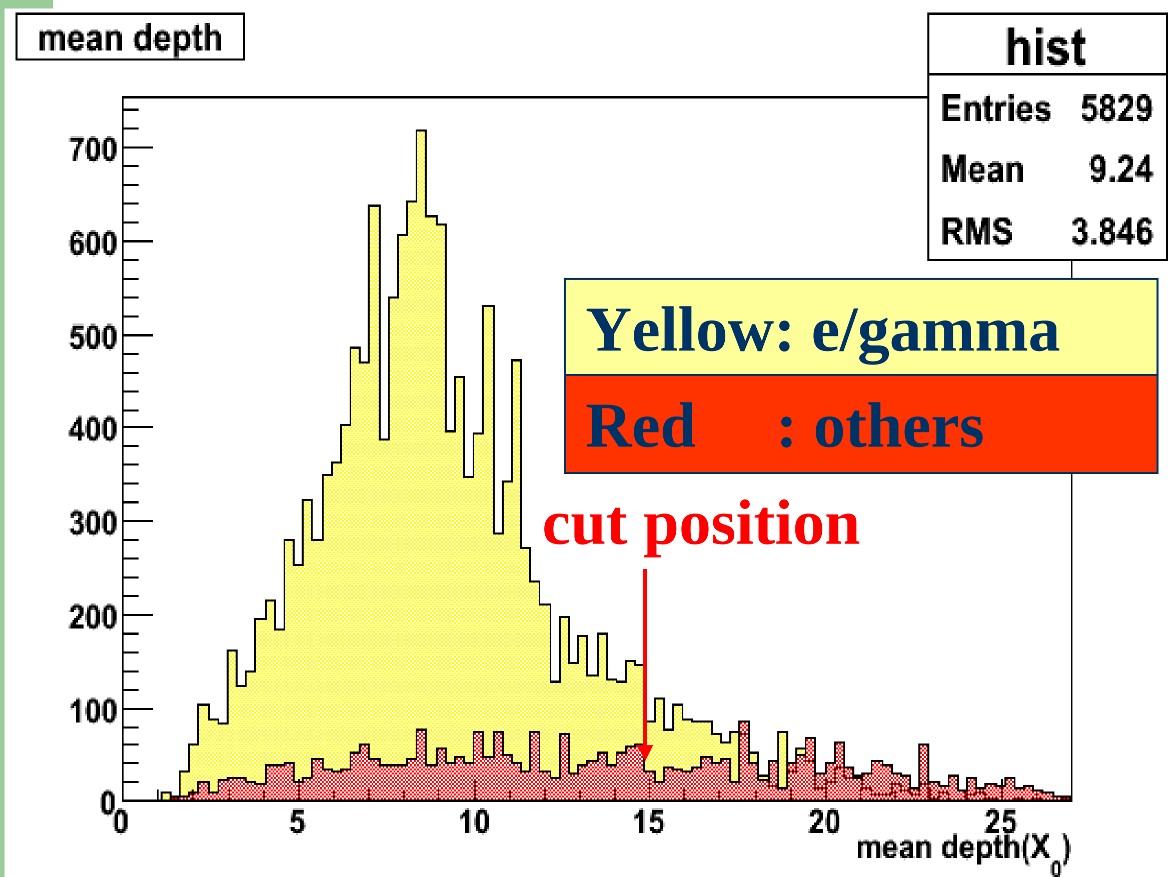
(Z->qqbar @ Ecm = 91.2 GeV)

This plot shows distributions of the distance from the nearest track for all "mother" small clusters within ECAL region. (energy-weighted)

We set a cut at 7cm.

Longitudinal shower profile

1. Mean shower depth (energy-weighted)



This plot shows a calculated mean shower depth from first layer (in unit of X0).

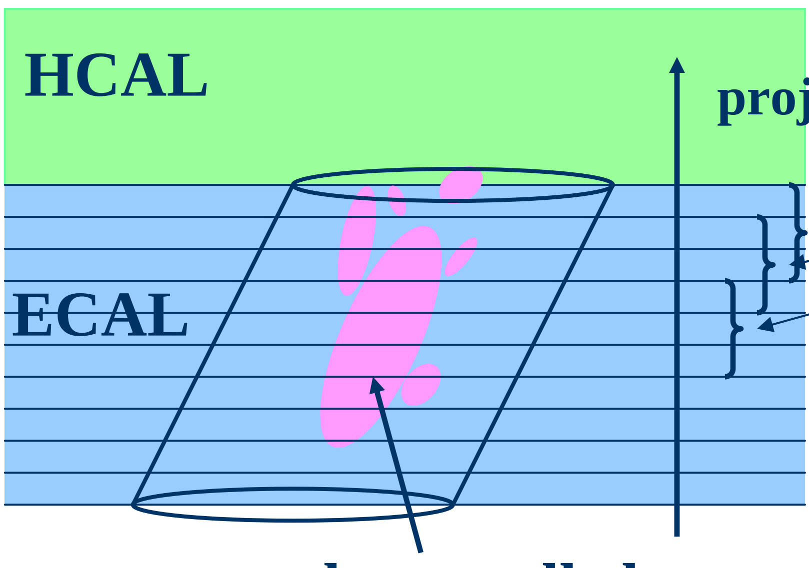
We set a cut position at **X0 = 15**.

(Z->qqbar @ Ecm = 91.2 GeV)

Longitudinal shower profile

2. Fit by gamma-distribution

Fit the longitudinal shower profile of the energy deposition within a tube as an electromagnetic cascade (gamma-distribution function).



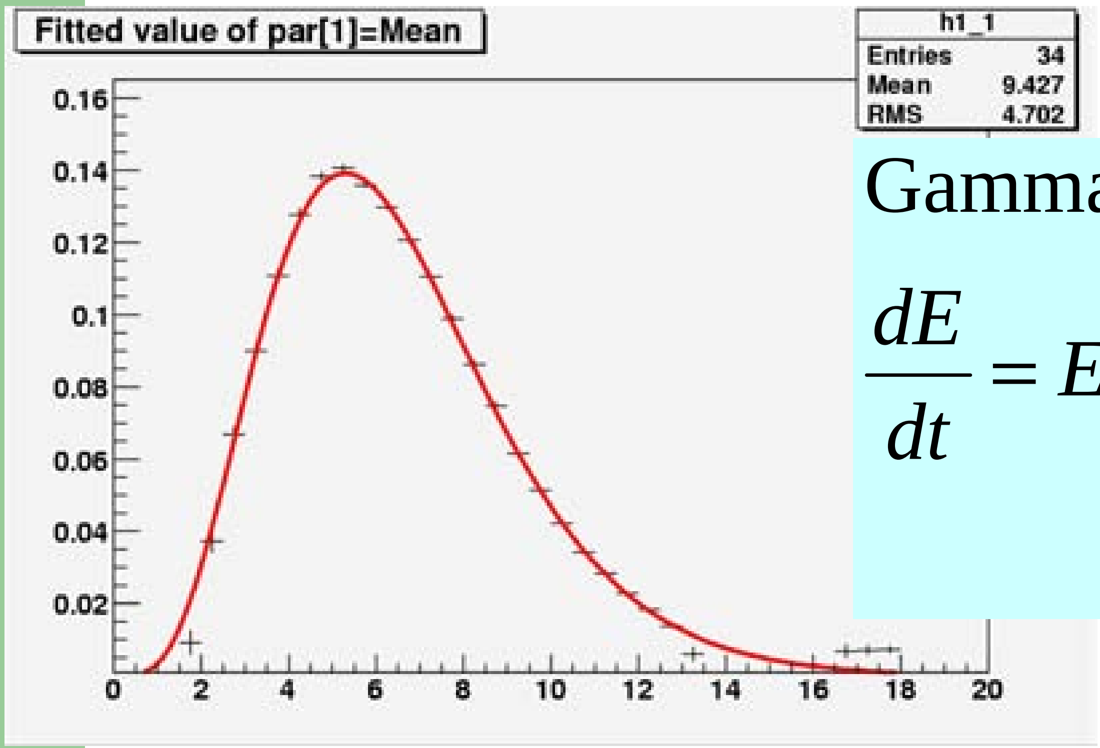
take an average energy deposit for each 3-layers

Energy deposit in three layers are merged to reduce fluctuation.

Longitudinal shower profile

2. Fit by gamma-distribution

The result of fitting for a single particle case (gamma at 3GeV)

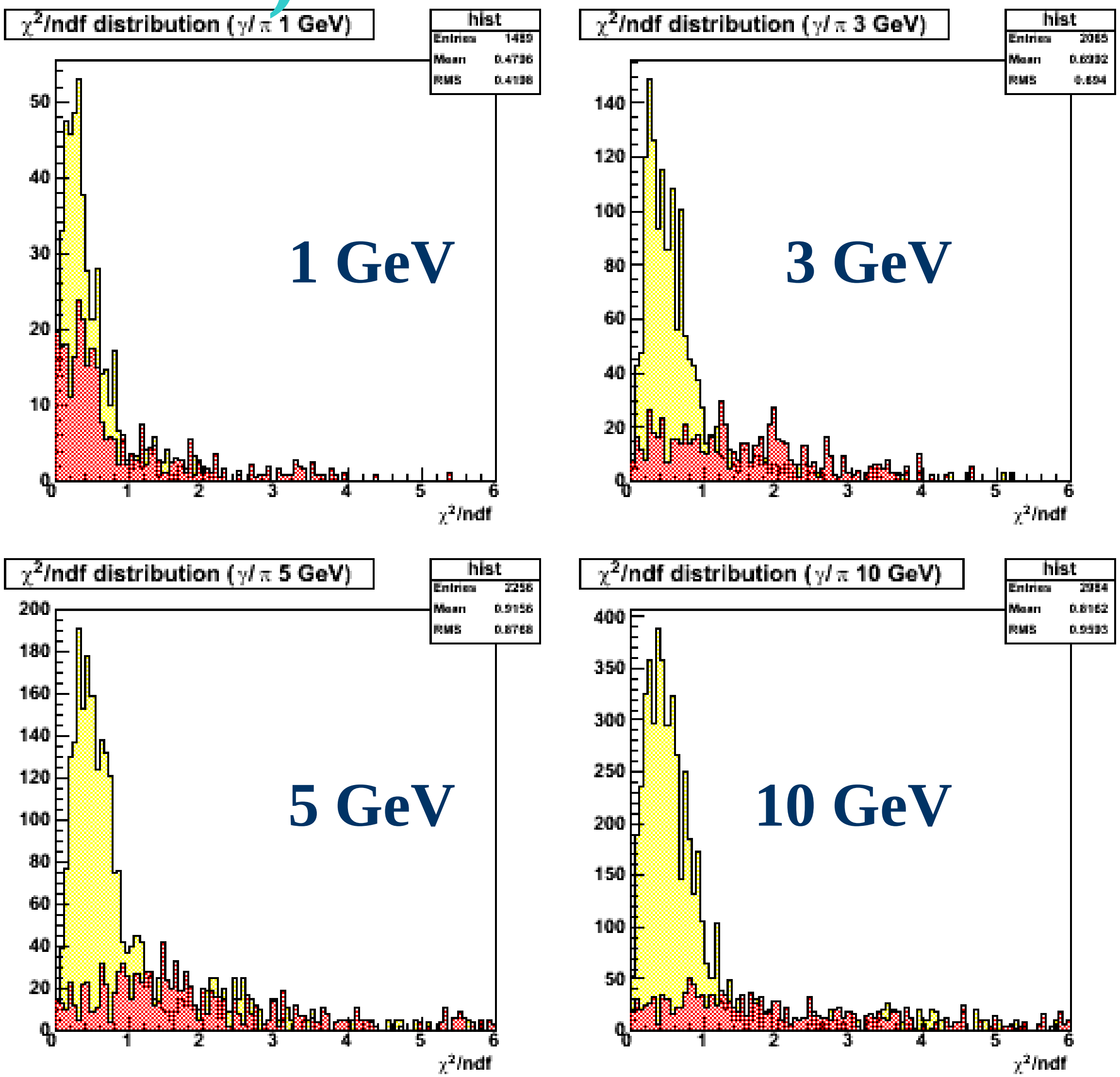


Gamma Distribution Function

$$\frac{dE}{dt} = E0 \cdot b \frac{(bt)^{a-1} \exp(-bt)}{\Gamma(a)}$$

where $t = x / X_0, b \cong 0.5$

Fit by gamma distribution (single particle)

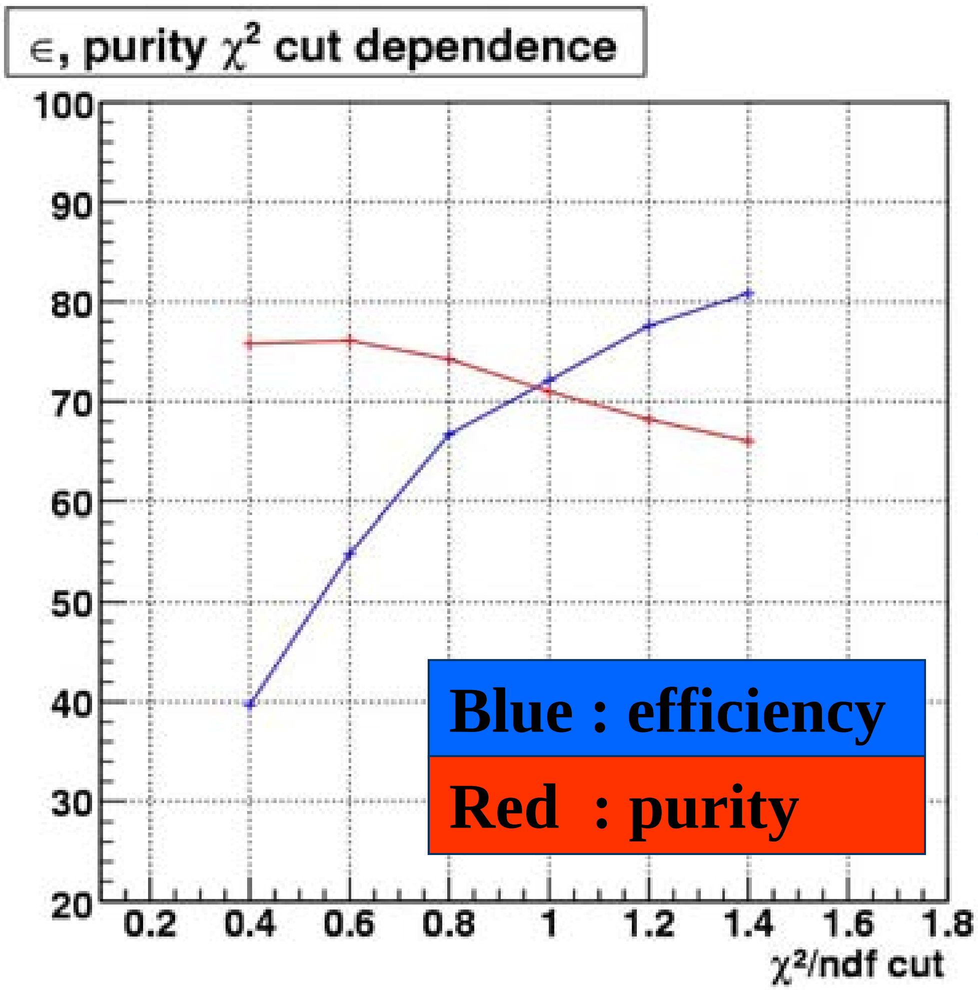


Yellow: gamma

Red : pion

In low momentum case, we can not separate pion from gamma effective.

Fit by gamma distribution

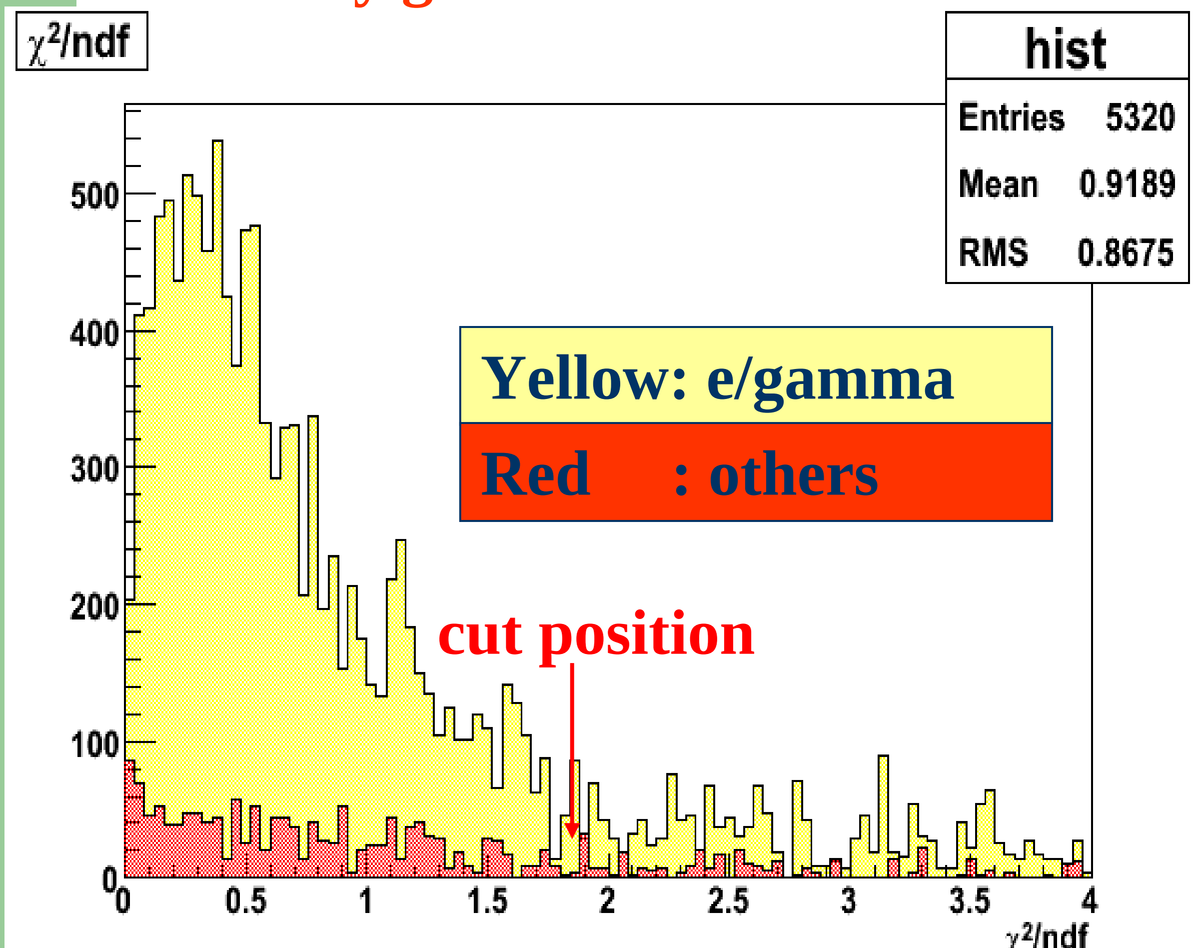


If we set a cut using a result of fit by gamma-distribution, it doesn't have high efficiency for electron/gamma finding. (maximum ~ 90%)

(Z->qqbar @ Ecm = 91.2 GeV)

Longitudinal shower profile

2. Fit by gamma-distribution



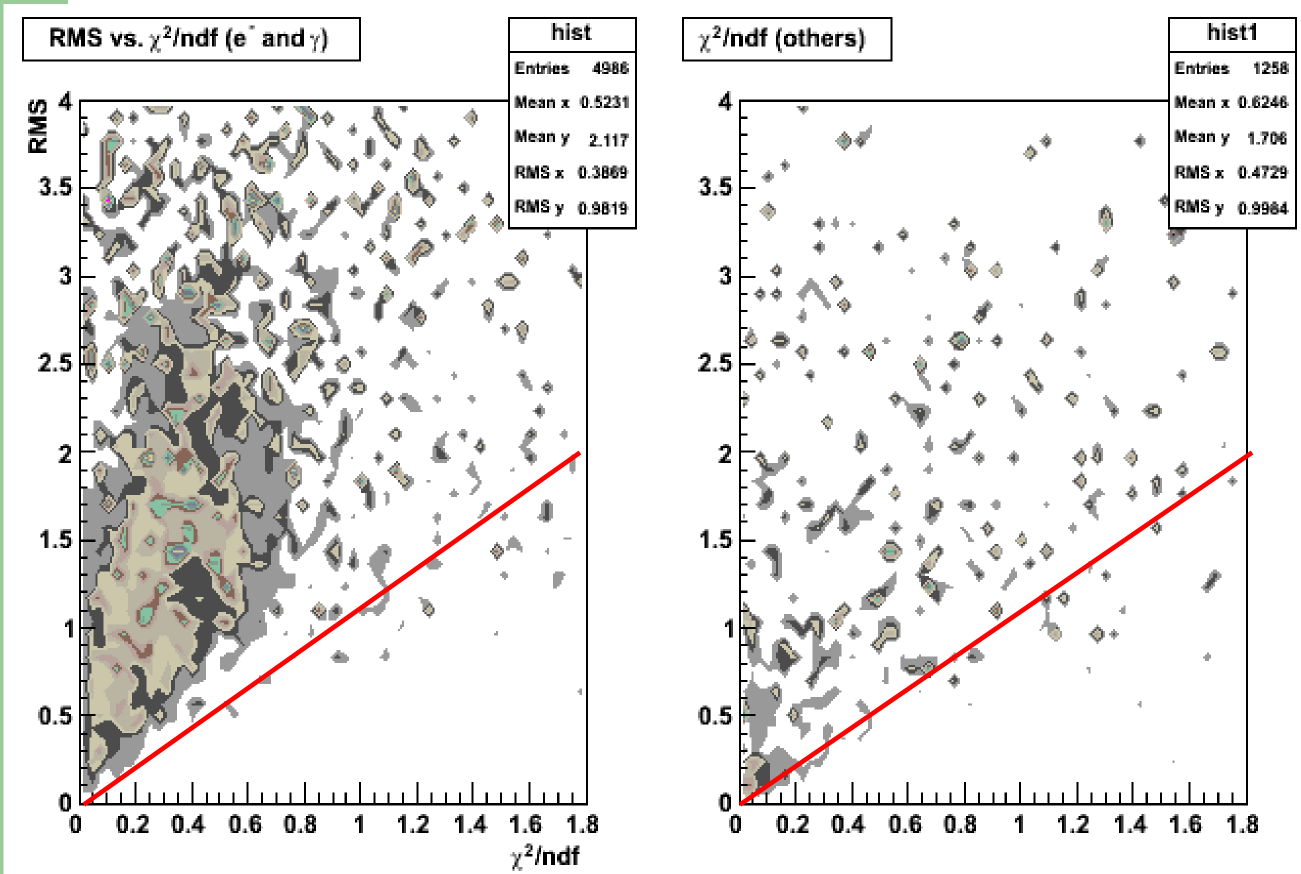
(Z->qqbar @ Ecm = 91.2 GeV)

This plot shows a chi2/ndf result of fit. Fit is performed for longitudinal shower profile (energy deposit) by gamma-distribution.

We set a cut for chi2/ndf at 1.8.

Longitudinal shower profile

3. Fit by linear function (to reject MIP)



This plot shows a RMS vs. Chi2/ndf distribution.

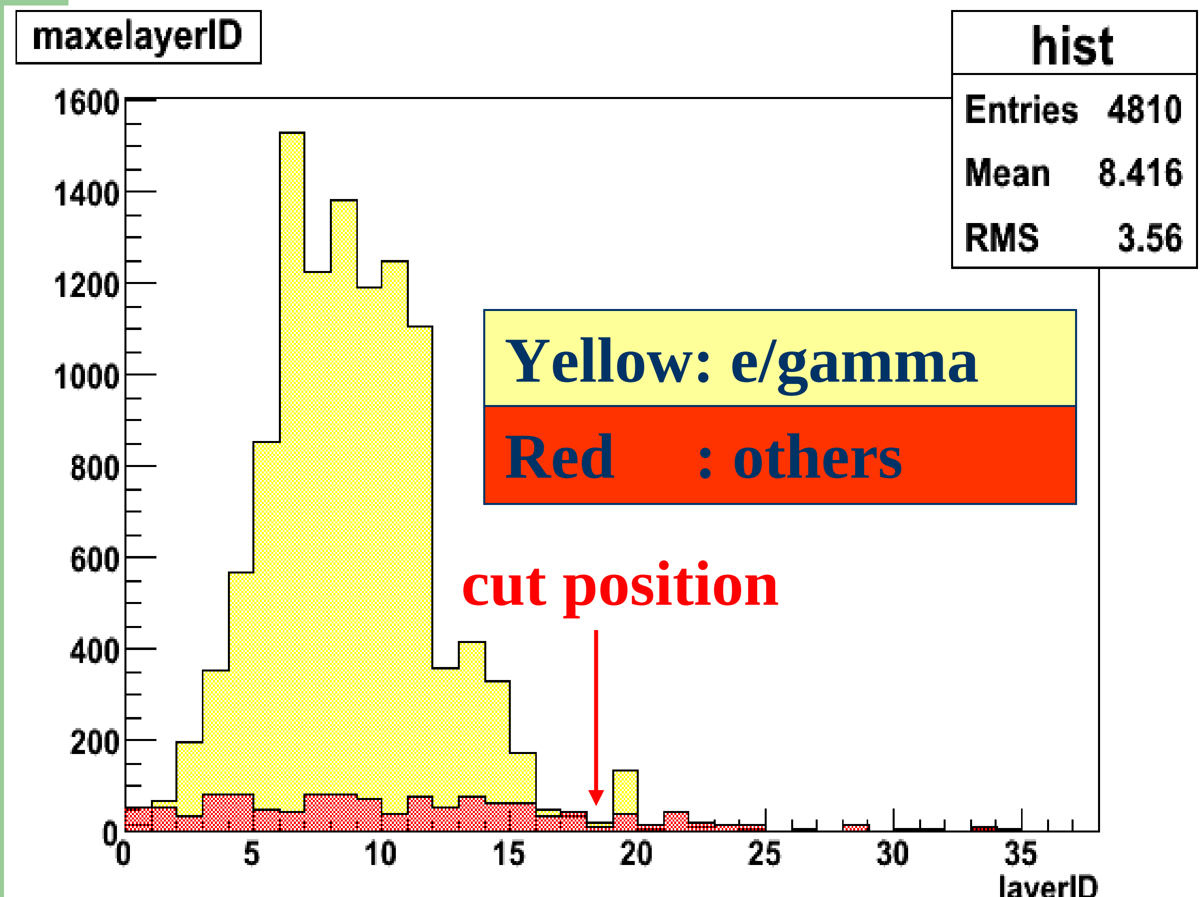
The fit result of RMS is used for the cut.

(RMS > chi2/ndf)
Because of some MIP cluster pass the chi2/ndf cut…

(Z->qqbar @ Ecm = 91.2 GeV)

Longitudinal shower profile

4. Maximum energy deposition layer

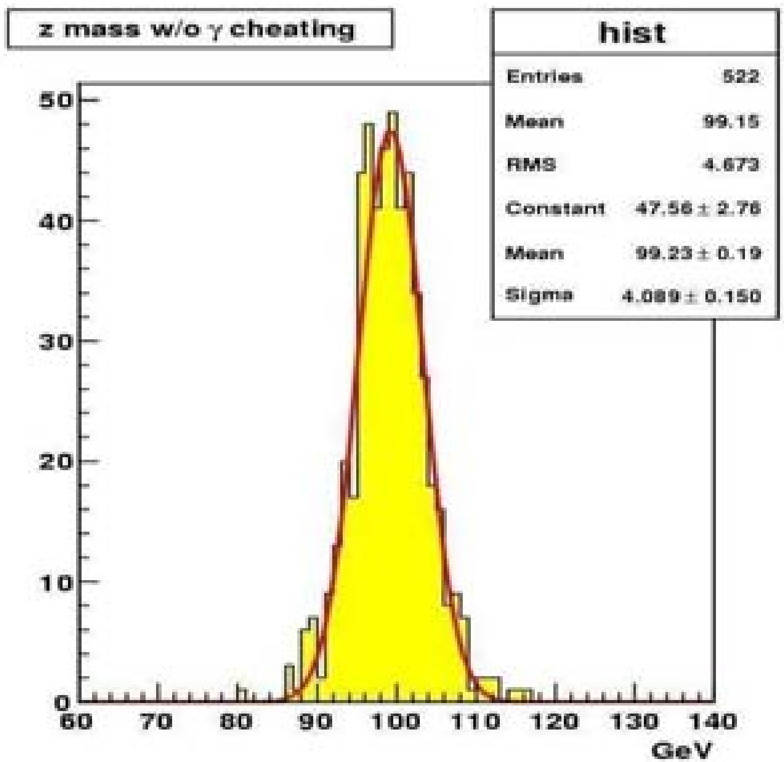


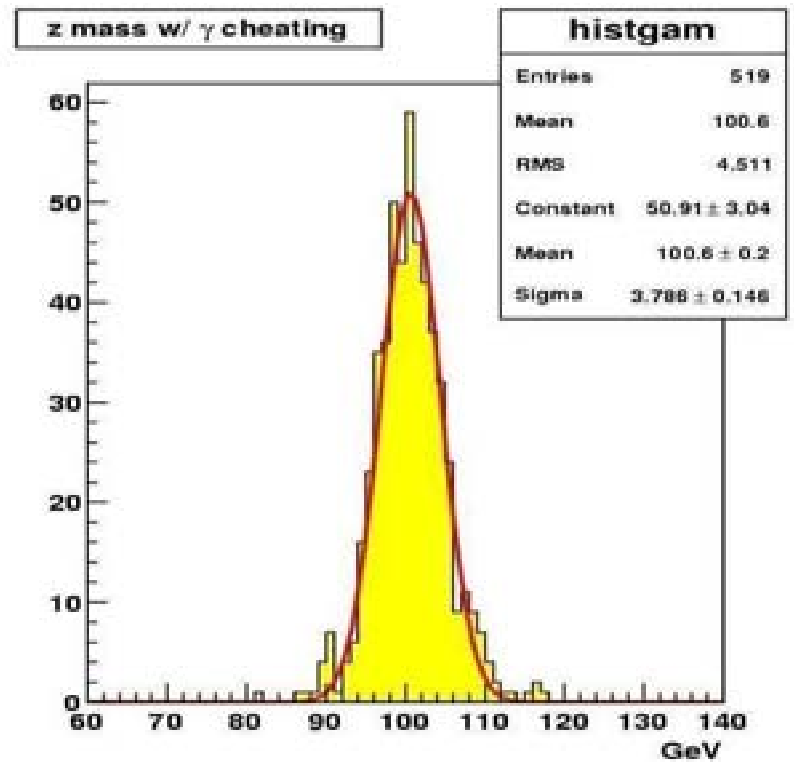
This plot shows a calculated layer ID which has maximum total energy deposit.

We set cut at 19.

(Z->qqbar @ Ecm = 91.2 GeV)

The result of energy sum





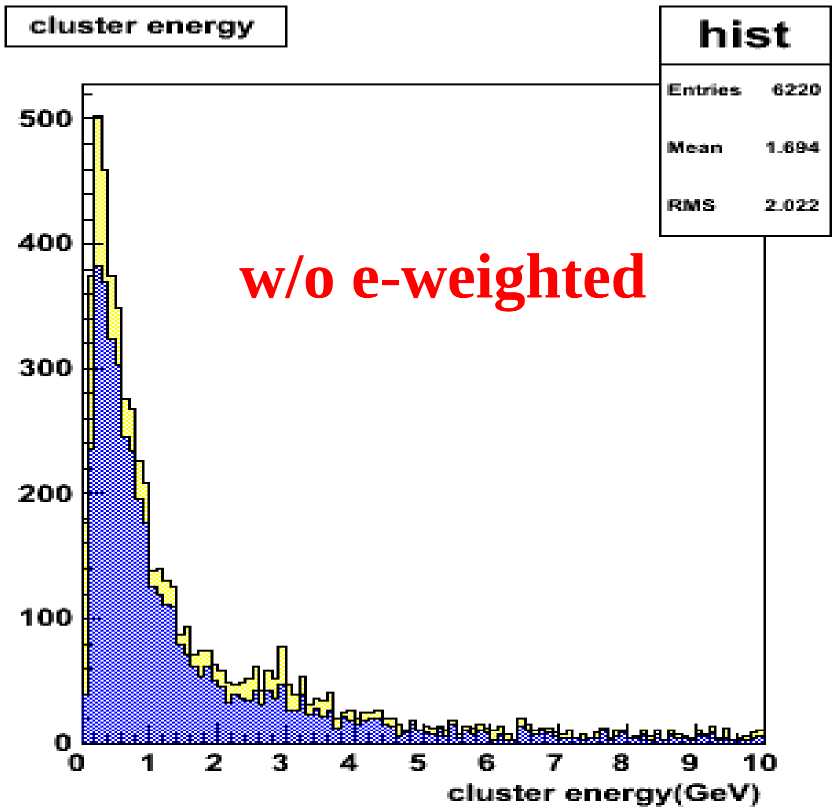
Realistic gamma finder

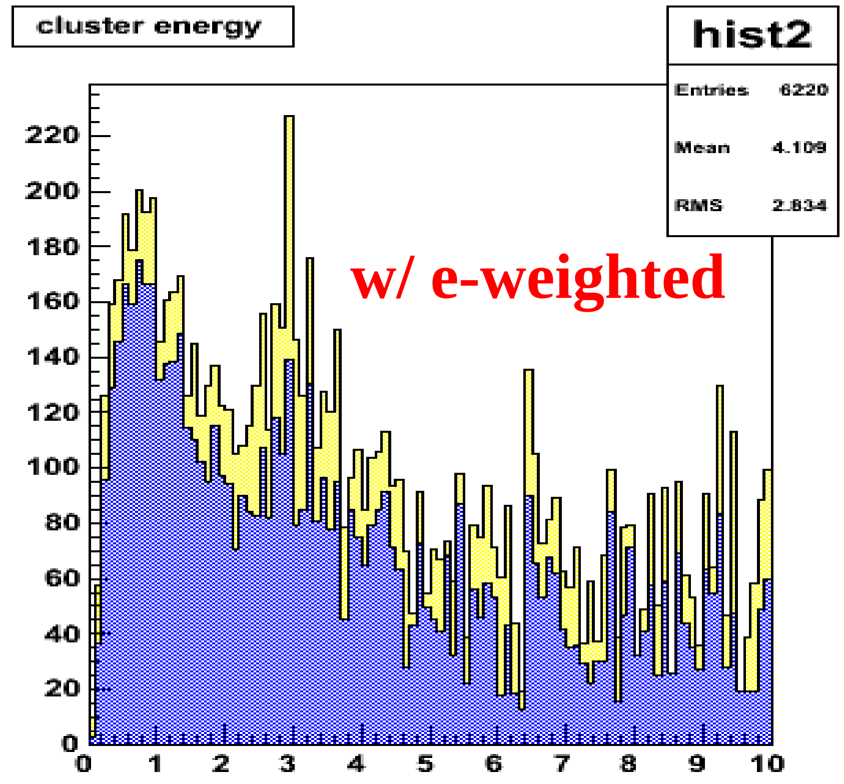
Cheated gamma finder

$$\sim 40.9\% / \sqrt{E} \qquad \sim 37.9\% / \sqrt{E}$$

track matching : $\varepsilon \sim 84.2\%$, $purity \sim 91.2\%$, missing energy (neutrino etc.) cheated

Cluster energy and efficiency



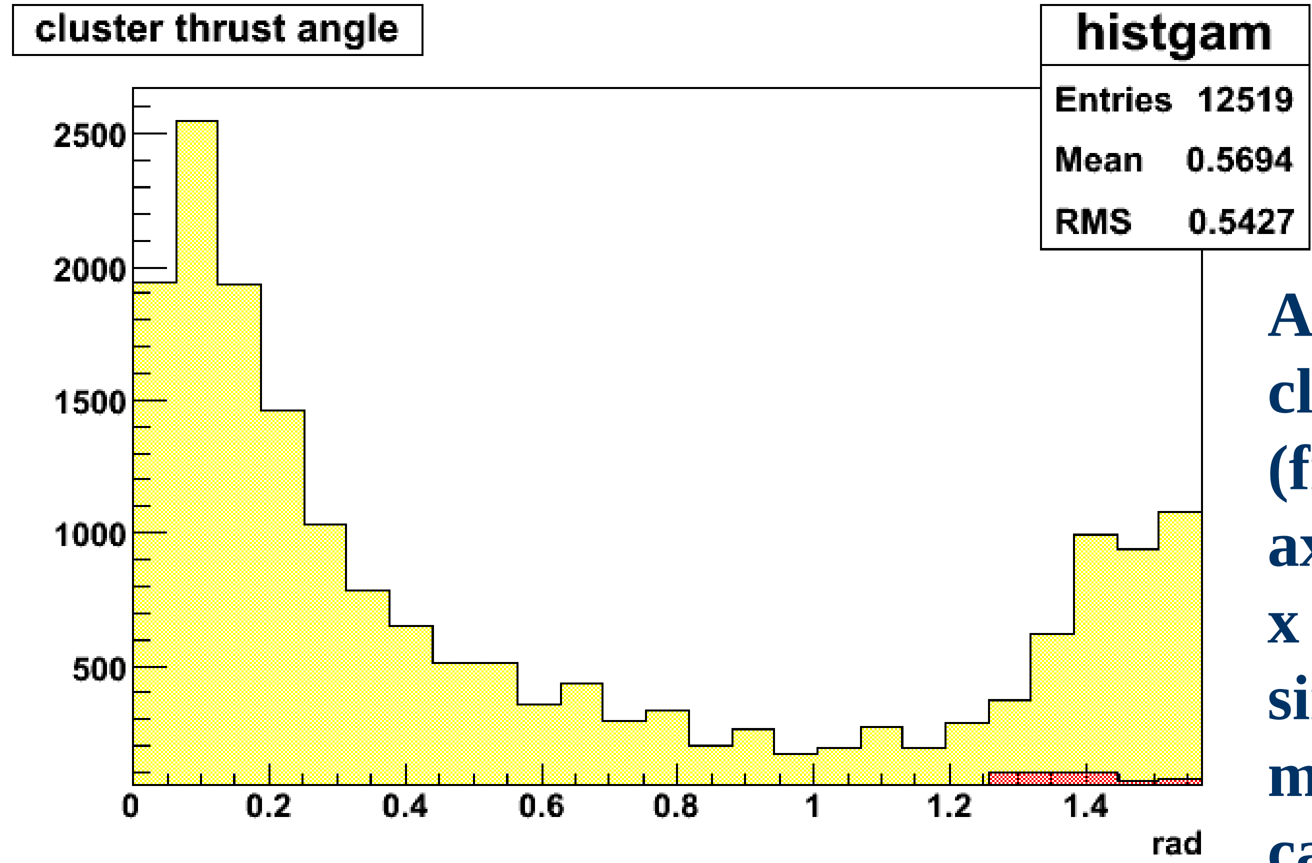


In low energy region, an efficiency of "Number of cluster" is low, but "Energy" efficiency is not so bad.

Yellow:Total

Blue :Regard as gamma

Cluster direction



with 4cm x 4cm tile size configuration

Angle between cluster position (from IP) and thrust axis. (If we use 4cm x 4cm tile and simple calculation method, we cannot calculate thrust correctly)