Clustering algorithm for long crystal bar ECAL

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Introduction

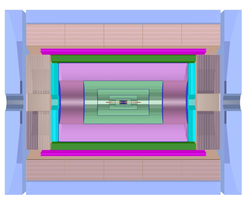
Circular electron positron collider (CEPC): Higgs and Z factory
- precise Higgs and EW measurement, flavor physics and BSM

The 4th CEPC conceptual detector:
- the physics motivations dictate our selection of detector technologies

Long crystal bar ECAL:
- optimal energy resolution and high cost-effectiveness
- 3-dimentional position and time information make particle flow possible

A dedicated reconstruction algorithm:
- feasibility study on this design concept

Key issues:
- ambiguity caused by matching of horizontal and vertical bars
- identification of energy deposits from each individual particle.



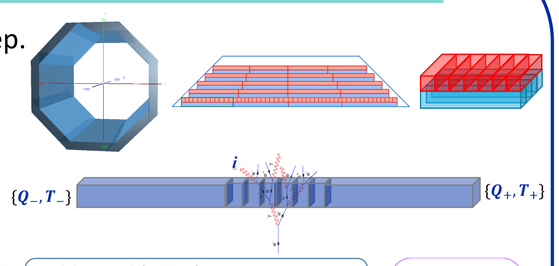
Clustering algorithm

Simulation, digitization and reconstruction

Geometry of ECAL is constructed using DD4hep.

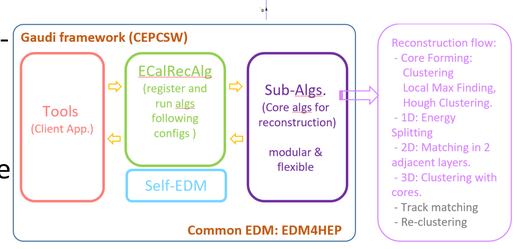
Simulation is performed using GEANT4.

Simplified digitization for one long crystal bar is considered as contribution of each G4step and time readouts are at both ends.



Reconstruction software is designed as a proto-PFA which follows the idea of PandoraSDK and develops in CEPCSW.

Clustering algorithm is the first one of the three main sub-algorithms subsequently by particle recognition and energy splitting.

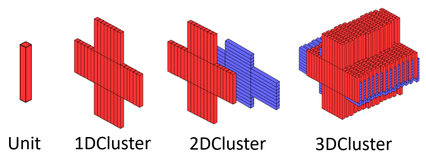


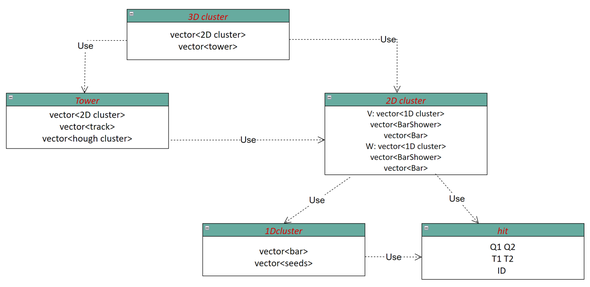
Clustering Algorithm: energy reconstruction

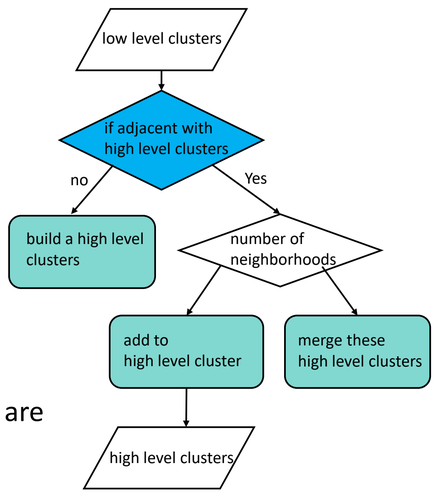
Cluster:
- a group of adjacent fired crystals whose energy is greater than threshold

Each detector unit has 3-dimentional labels:
- single layer
- bi-layer
- multi-layer

These labels are part of event data model for reconstruction software.

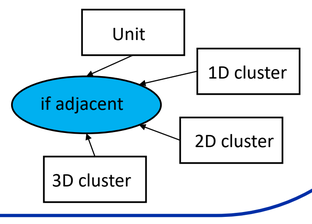






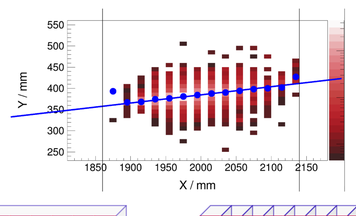
unit→1D cluster→2D cluster→3D cluster:
- for instant, unit will be added into 1D cluster if they are adjacent, otherwise a new 1D cluster will be constructed using this unit.

Features of algorithm:
1. abstraction: template technology
2. modularization and compatibility: neighborhood concept defined in terms of calorimeter designs is independent of algorithm

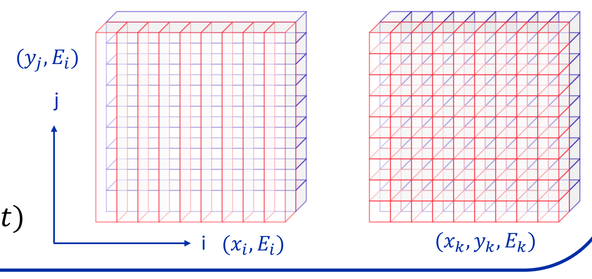


Position reconstruction

Method A:
1. in each layer: $\overline{x_j} = \frac{\sum_i E_i \times x_i}{\sum_i E_i}$
2. line fitting: $\chi^2 = \sum_{j=1}^{n} E_j \left[\overline{x_j} - g_j\right]^2$
3. "core of cluster": intersection between line and energetic layer



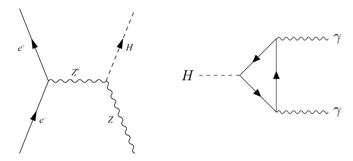
Method B:
1. vertical bars will be divided into several hits according to energy distribution of horizontal bars and vice versa.
2. "core of cluster": $\bar{x} = \frac{\sum_k E_k \times x_k}{\sum_k E_k}\ (k: hit)$



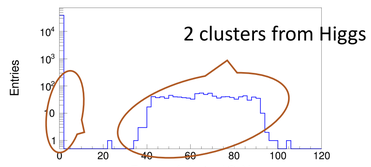
Performance

Efficiency and invariant mass distribution

Physics sample:
240GeV, $e^+ + e^- \rightarrow ZH \rightarrow \nu\nu\gamma\gamma$, without ISR

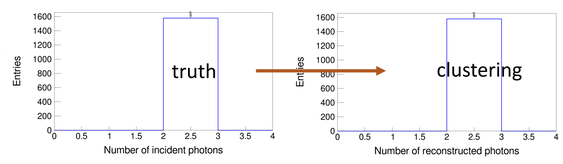


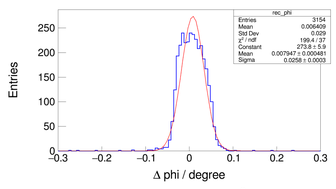
Besides 2 clusters from Higgs with high energy, there are many clusters with low energy in each event. "Isolated hits" is planned to be absorbed into clusters nearby.



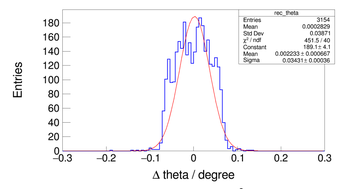
residual clusters caused by "isolated hits"

Efficiency of clustering: ε=1577/1577=100%





$\sigma_\phi = 0.026^\circ$
$\sigma_{position} = 0.84mm$

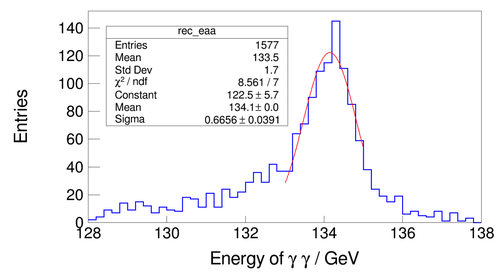


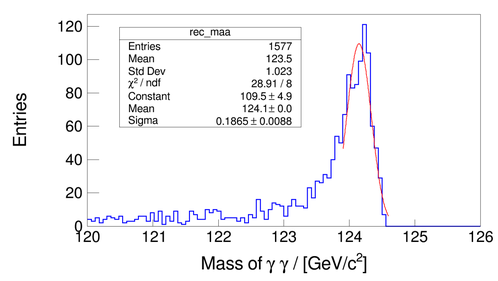
$\sigma_\theta = 0.034^\circ$
$\sigma_{position} = 1.10mm$

Position resolution is about $1mm$. Different methods for different incident position of photons are applied.

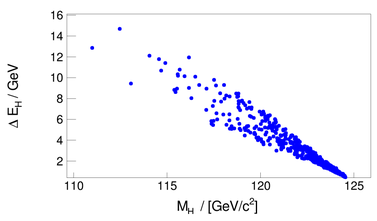
Energy distribution of H–>$\gamma\gamma$, $E = \gamma_1 + \gamma_2$, fit with gaussian function, $E_{mean} = 134.147 \pm 0.032\ GeV$

Invariant mass distribution of H–>$\gamma\gamma$, $M = \sqrt{2E_{\gamma_1}E_{\gamma_2}(1 - cos\theta_{\gamma_1\gamma_2})}$, fit with gaussian function, $M_{mean} = 124.148 \pm 0.011\ GeV/c^2$



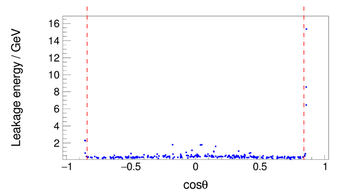


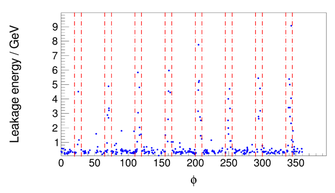
"Tail" and shift of MPV in the distribution is caused longitudinal energy leakage and will be corrected based on longitudinal profile.



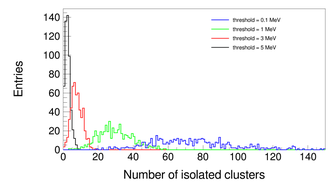
Energy leakage and threshold

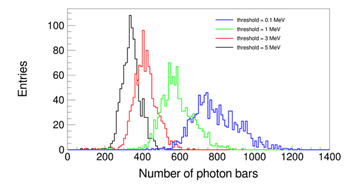
Energy leakage includes:
1. boundary effect ($cos\theta$)
2. geometric gap (ϕ)
3. longitudinal leakage (R)





A series of energy threshold will suppress "isolated hits" dramatically and remove some fluctuations





Conclusions

Design and implementation of clustering algorithm for long crystal bar ECAL
- ✓Algorithm is abstract and compatible

Performance check of clustering algorithm
- ✓clustering algorithm show good performance
- ✓threshold suppress "isolated hits" dramatically and study for detector threshold

Implementation of angle measurement for photons
- ✓position resolution meet the requirement
- ✓invariant mass distribution for $H \rightarrow \gamma\gamma$ meet the expectation

there is a talk in software session for more detail information

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