The CMS electromagnetic calorimeter (ECAL) is a homogenous scintillating crystal calorimeter, mounted in a Barrel and closed up by two Endcaps. It plays a key role in the energy reconstruction of the particles [1].

The ECAL clustering refers to the series of algorithms that reconstruct the energy of a particle by aggregating the energy deposits in the different crystals into clusters and super-clusters, while mitigating the noise and pile-up contributions.

- Particle Flow Clustering algorithm (PFClustering)
- Particle Flow SuperClustering algorithm (SuperClustering)

The ageing of the ECAL manifests itself in an increase of the electronic noise and a loss of the crystal transparency due to radiation damage. A direct consequence is the enhancement of the overall noise level with the accumulated luminosity.

**Objective**

Tune the parameters of the ECAL clustering algorithms in order to get optimal performance against the enhanced noise expected during the LHC Run 3 of data taking.

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**Algorithm**

Reconstruction of the energy deposits originating from a particle into a cluster, while mitigating the case where the particles overlap.

The application of energy thresholds aims at excluding noise when forming the clusters.

1. Inputs
2. Seeding
3. Clustering

1. The algorithm takes as input the energy deposits from the different crystals that are greater than the crystal energy threshold.
2. The seed of the cluster is identified as the crystal having the largest energy with respect to its neighbors, provided that it is greater than the seeding energy threshold.
3. The clusters are formed by gathering the neighboring crystals around the seed and computing the energy fraction of a crystal in a given cluster.

**Resolution**

Relative width of the ratio between reconstructed and simulated energy

**Efficiency**

Ratio between the number of reconstructed clusters and simulated particles

**Noise Rate**

Percentage of clusters originated from noise

The resolution, efficiency and noise rate with respect to the different thresholds multipliers. The tuning is performed with a MC photon sample simulated on the front face of the ECAL, while mitigating the case where the particles overlap.

The optimal thresholds were found to be both set to 3σ for |η| ≤ 2.5 and 4σ for |η| > 2.5.

**SuperClustering algorithm**

A particle that showers gives rise to multiple clusters. Super-clusters are formed out of clusters to recover the energy of the shower.

Geometrical reconstruction taking into account the bend induced by the CMS magnetic field.

- **Moustache algorithm**
  - yields the region delimited by an upper and lower parabola.

- **Dynamic Δϕ-window algorithm**
  - adjusts the Δϕ window width.

The Δη and Δϕ represent the relative position between a given cluster and the seed of the super-cluster. Any cluster falling in the region delimited by the algorithms is included in the super-cluster.

**Performance of the tuning**

The validity of the tuning is evaluated by comparing the performance as obtained with the tuned or reference (i.e. as per Run 2) parameters.

- Resolution and efficiency as a function of |η| for clusters associated to a simulated particle of transverse energy between 5 and 10 GeV. At large |η|, the tuning improves the resolution, but affects the efficiency.

The thresholds will be updated once a year based on the expected luminosity at mid-year.