Reconstruction of unconverted photons in the presence of high pileup with the CMS Phase-2 High Granularity Endcap Calorimeter

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The CMS Collaboration will soon start the construction of a novel endcap calorimeter, named **High-Granularity CALorimeter** (HGCAL), to sustain the harsher conditions of the **High-Luminosity LHC**. It will be predominantly a **Si-based sampling calorimeter**, with regions of the hadronic section also using small scintillator tiles read out by SiPMs where the dose permits . The electromagnetic section will have **26 active layers** and will extend for **27.7 X_0**. **The Iterative CLustering** (TICL) is a modular framework developed within the CMS reconstruction software to carry out an optimal Particle Flow (PF) reconstruction during the CMS Phase-2 together with all other subdetectors.

TICL workflow

Hits → 2D Layer Clusters (LCs) → Seeding region → Tracksters → Linking → PF reconstruction

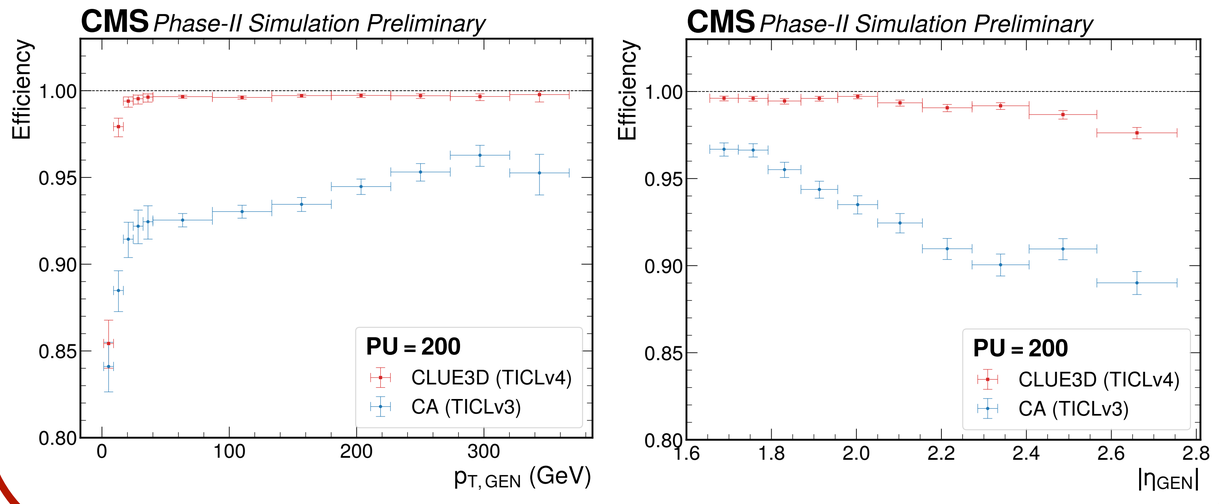
CLUE is an energy density based algorithm to cluster hits on each HGCAL layer and produce 2D LCs.

The **pattern recognition** algorithm aims at reconstructing the showers in 3D forming the ***trackster***.
The latest version TICLv4 is using **CLUE3D** as pattern recognition and replaces the Cellular Automaton (**CA**) used in the previous TICLv3.
CA is mainly a geometrical algorithm, whereas CLUE3D follows the energy flow to connect LCs together.

Comparison between CA (TICLv3) and CLUE3D (TICLv4) for unconverted photons

Reconstruction efficiency

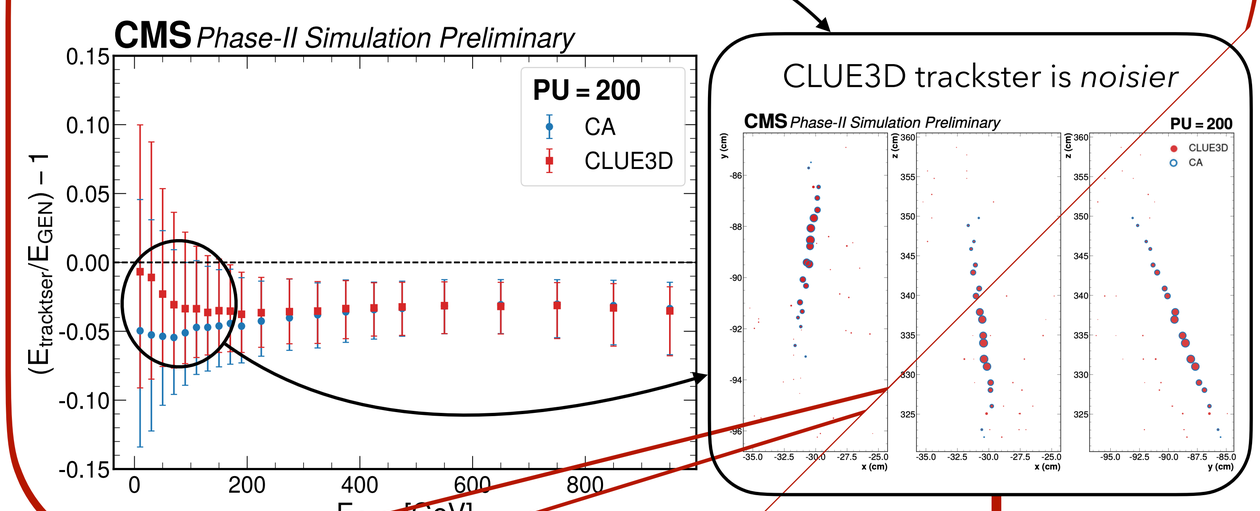
The CLUE3D longitudinal pattern recognition used in TICLv4 outperforms the cellular automaton (CA) of TICLv3 in reconstruction efficiency across all η and p_T bins



Unconverted photons generated with a gun in the flat energetic range [10, 1000] GeV and uniformly in radius within eta [1.65, 2.75]

Energy response

While CLUE3D seems to have a better response than CA at low energy, this is due to **CLUE3D picking up slightly more PU-induced LCs**



Cleaning of CLUE3D photon tracksters

Due to the high-PU environment at the HL-LHC, **spurious PU-induced LCs** can be picked-up by TICL and spoil the resulting trackster

The Cleaning algorithm in a nutshell

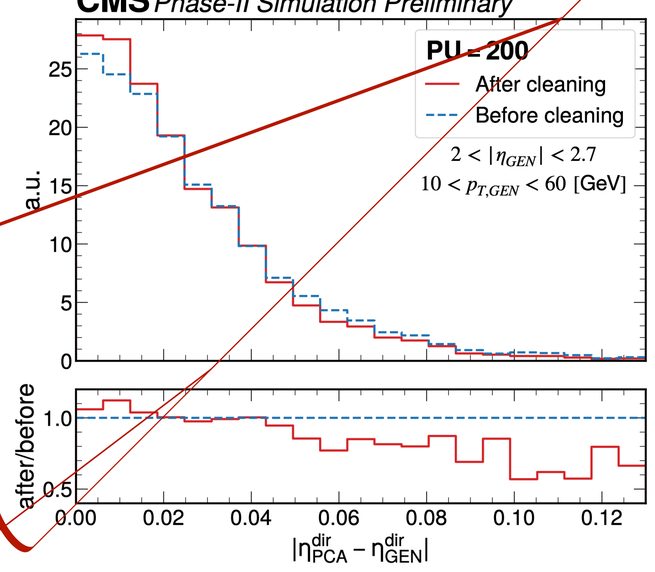
Ingredients

- *Centre of the shower* ➔ Most energetic LC of the trackster
- *Shower axis* ➔ Main axis in the **energy-weighed Principal Component Analysis** (PCA) computed by considering the most energetic LC per layer in the region between +15 and -10 layers from the centre

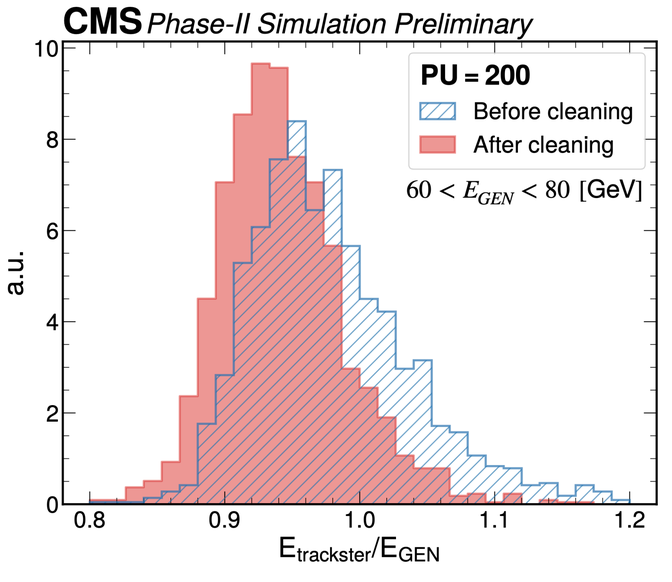
Cleaning

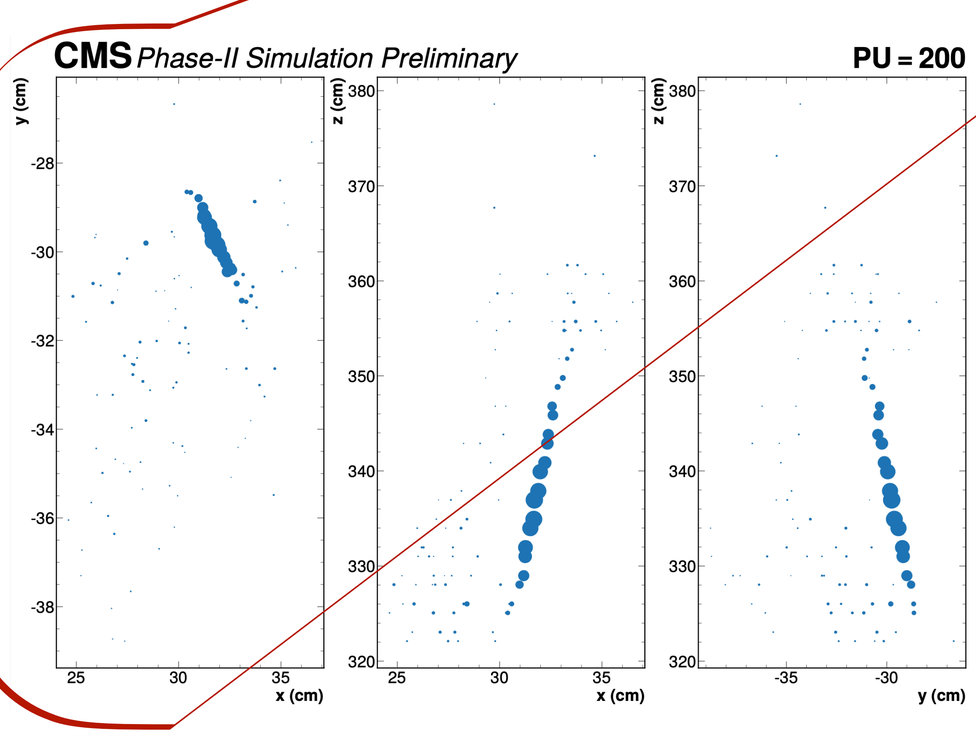
➡ Keeping **the closest LC to the shower axis** per layer in the region between +15 and -12 layers from the centre

Improvement in the estimation of the trackster direction



Energy response more symmetric, narrower, and more gaussian





PU is effectively discarded

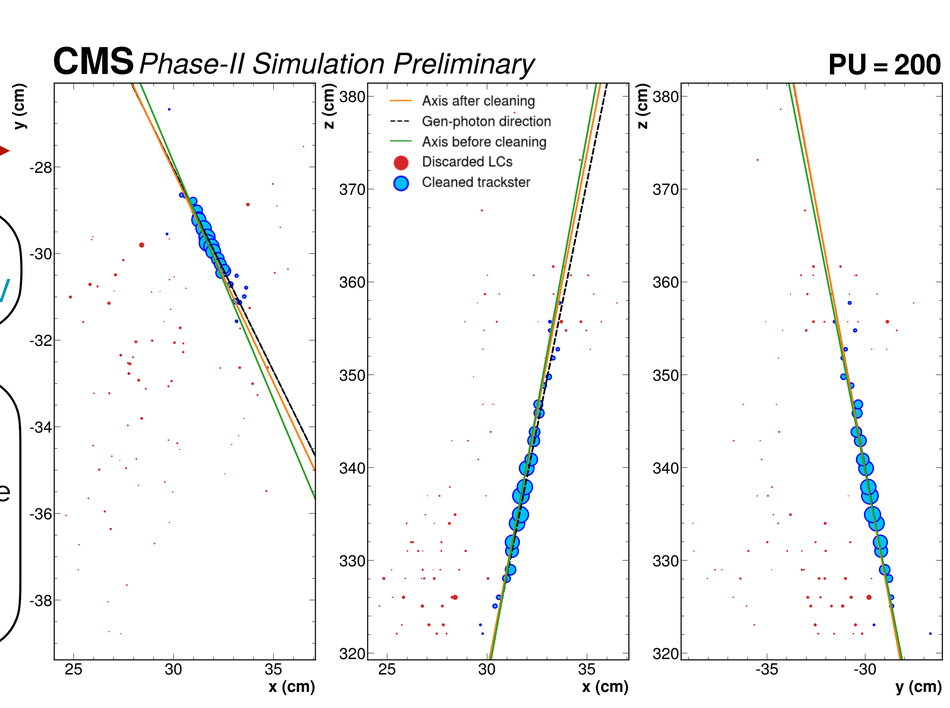
$E_{GEN} = 293$ GeV

$E_{RECO} = 361$ GeV $E_{CLEAN} = 288$ GeV

After the cleaning the estimated shower axis is closer the extrapolation of the direction of the generated photon

θ(before, gen) = 0.60°

θ(after, gen) = 0.28°



The current version of TICL shows an **excellent performance in reconstructing electromagnetic objects** even in the high pileup environment expected at the HL-LHC. The cleaning algorithm provides better-quality tracksters by **removing PU contribution** that is mistakenly associated to the electromagnetic shower. Currently working to improve the hadronic reconstruction and PF-objects interpretations. The plan for the future is to extend TICL to the barrel region to have a uniform PF framework for the entire detector.

F. Beaudette, S. Bhattacharya, S. Ghosh, K. Hatakeyama , A. Reddy K., B. Maier, A. Nandi, F. Pantaleo, W. Redjeb, M. Rovere, A. Savona, A. Schmidt, A. Tarabini

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