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Use of HGCAL and MTD timing information in TICL reconstruction

CMS Collaboration

Abstract

The High Granularity Calorimeter (HGCAL), planned for Phase 2 of the LHC, provides a measurement of the time of arrival (TOA) for all individual energy deposits above a few minimum ionizing particle (MIP)-equivalent. The precision of the TOA for reconstructed showers from high p_T particles is expected to be limited by a floor precision of about 20 ps. The TOA measurements can be exploited in the reconstruction to mitigate pileup contamination. They can, for instance, be used while combining the calorimeter information with that from tracks provided by the MIP Timing Detector (MTD). In the following, the first performance studies of the exploration of TOA-assisted reconstruction in HGCAL are shown.

Use of HGCAL and MTD timing information in TICL reconstruction

The CMS Collaboration

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Abstract

The High Granularity Calorimeter (HGCAL), planned for Phase 2 of the LHC [1], provides a measurement of the time of arrival (TOA) for all individual energy deposits above a few minimum ionizing particle (MIP)-equivalent. The precision of the TOA for reconstructed showers from high p_T particles is expected to be limited by a floor precision of about 20 ps.

The TOA measurements can be exploited in the reconstruction to mitigate pileup contamination. They can, for instance, be used while combining the calorimeter information with that from tracks provided by the MIP Timing Detector (MTD) [2].

In the following, the first performance studies of the exploration of TOA-assisted reconstruction in HGCAL are shown.

Glossary

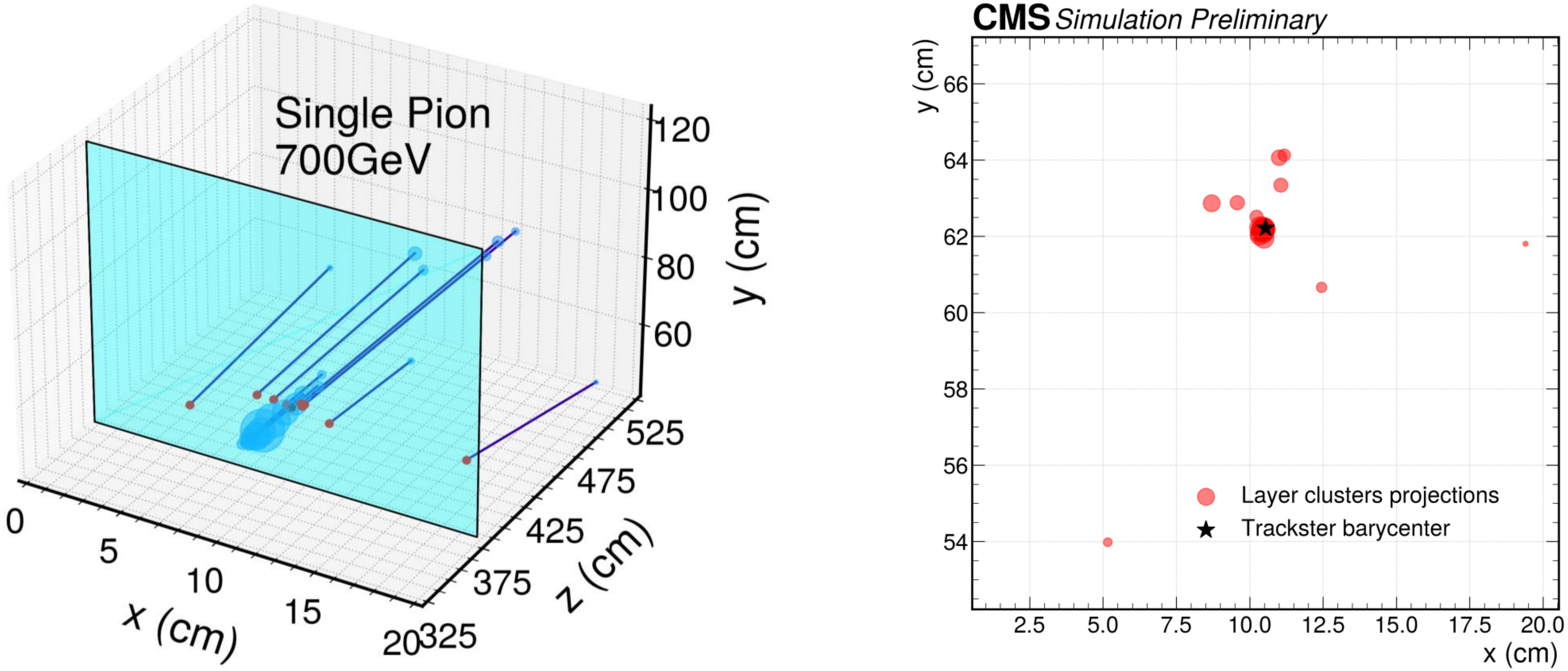
- TICL: stands for The Iterative CLustering, framework used to perform the HGCAL reconstruction and the linking with the tracks
- CLUE: shorthand for CLUstering of Energy, layer clustering algorithm used in HGCAL reconstruction
- CLUE3D: longitudinal association algorithm used in HGCAL reconstruction
- Layer cluster: cluster output by the CLUE algorithm, consisting of a set of reconstructed hits
- Trackster: cluster output by the CLUE3D algorithm, consisting of a set of layer clusters
- Trackster's barycentre: average of the positions of layer clusters in a trackster weighted on the energy of the layer clusters
- TICLCandidate: final output of the HGCAL reconstruction, is the result of the linking between different tracksters coming from the same particle and represents the candidate given in input to particle flow. It contains one or more tracksters, has a particle ID, the regressed energy, the time information, and the track linked to it.
- simTICLCandidate: reconstruction-like object built from Monte Carlo Truth, represents the best particle flow interpretation we can get with the reconstructed objects available
- PU: pileup
- PV: primary vertex

Reconstruction

The reconstructed hits are clustered with the CLUE layer clustering algorithm to obtain a set of layer clusters independently for each layer of the calorimeter [3]. The layer cluster time is computed as the average of the time of the hits weighted on the expected time resolution. Then, the CLUE3D longitudinal association algorithm is applied, clustering the layer clusters to form tracksters [4]. The TOA of the layer clusters are corrected by the time of flight between the cluster position and a common surface assuming the speed of light (c). The surface is defined as being perpendicular to the beam line and containing the (x, y) coordinates where the trackster barycentre lies. The trackster time is obtained with an average of the corrected TOA of the individual layer clusters weighted on the time resolution. The last stage of the TICL reconstruction is the creation of the TICLCandidates and the linking with the track. During the linking, the local HGCAL time, $t_{trackster}$, is compared to the track time as measured by the MIP timing detector (MTD), t_{MTD}, to check the time compatibility as follows:

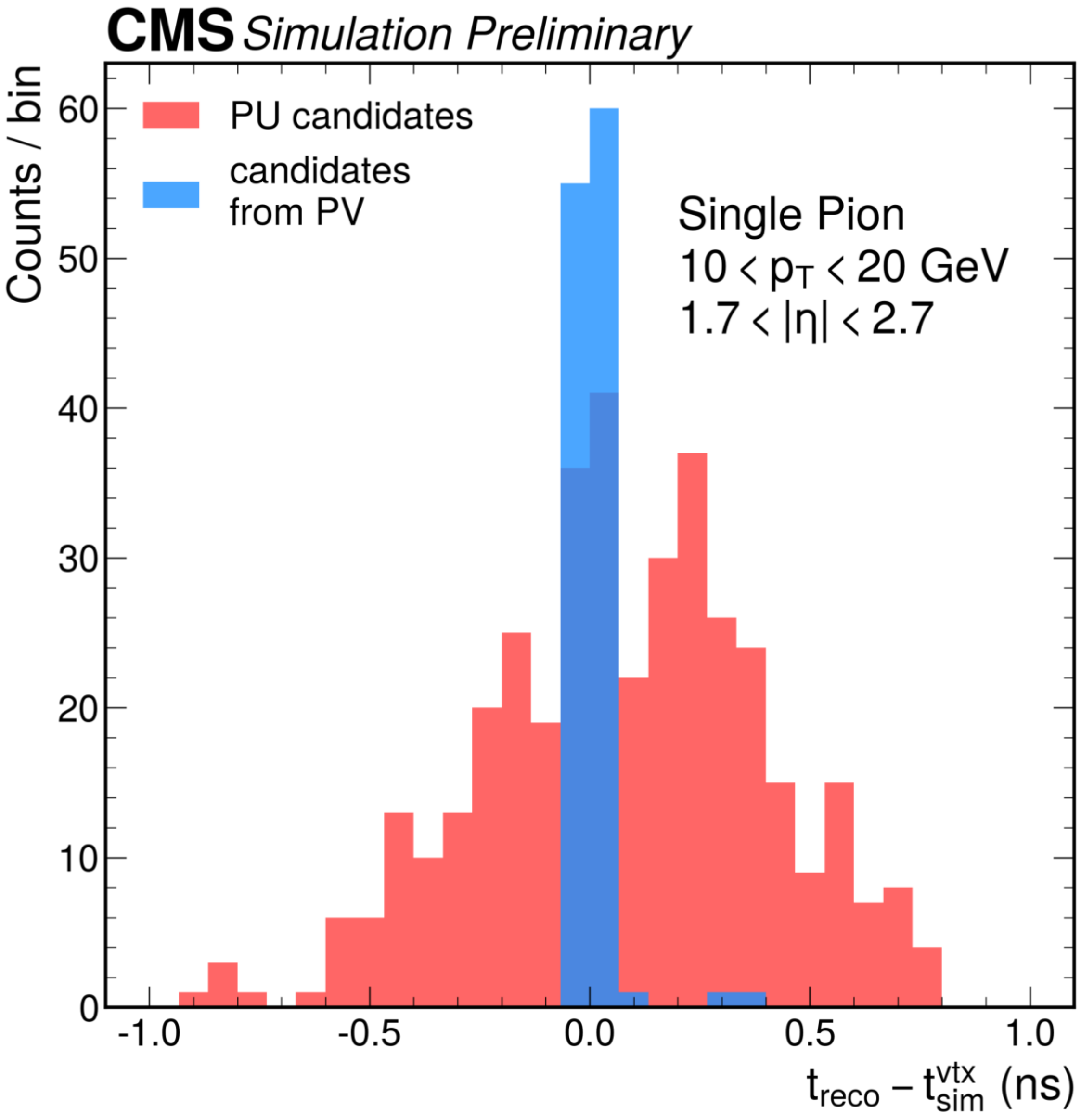
$$\left| \frac{distance(MTD\ cluster,\ trackster\ barycenter)}{c} - (t_{MTD} - t_{trackster}) \right| < 3\sqrt{\sigma_{t_{MTD}}^{2} + \sigma_{t_{trackster}}^{2}} \qquad (1)$$

The final TOA of the TICLCandidate is computed propagating the times of the tracksters to the vertex (or to the origin for neutral candidates), averaging them, and combining the result with the MTD time if available.

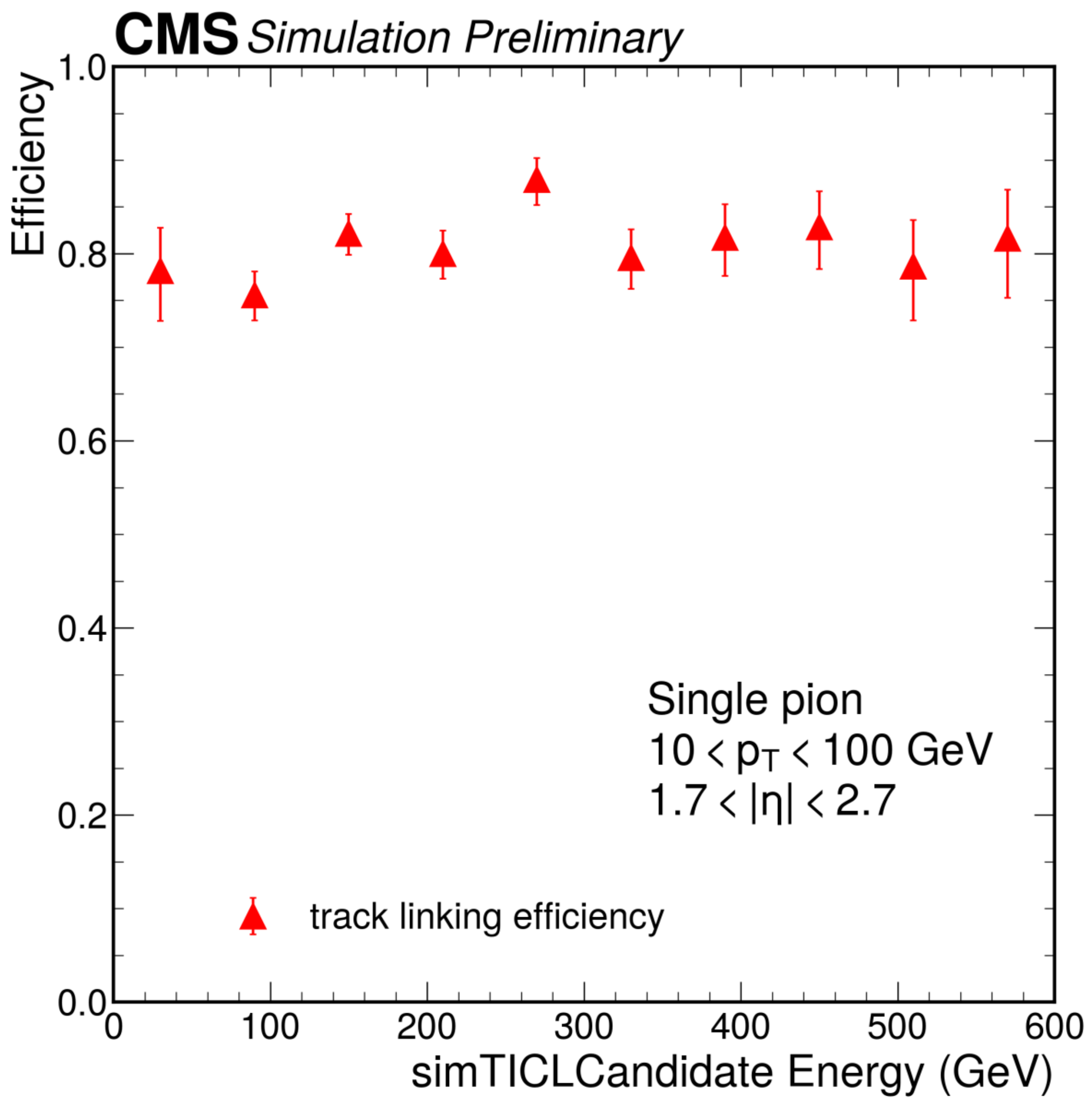


Left: illustration, using a simulated 700 GeV charged pion event, of how the trackster time is computed. The layer clusters (represented by blue circles whose area is proportional to their energy), are projected to the trackster barycentre plane through a straight line, connecting the hit position to the centre of the detector. The plane is represented by the light blue rectangle, perpendicular to the beam line, and the red points on it are the layer clusters projections. The individual layer cluster TOA are corrected by the time of flight to the plane, assuming a travel at the speed of light. The trackster TOA is computed based on a time-resolution weighted average.

Right: figure representing the position of the trackster barycentre (black star) and the projected layer cluster positions (red markers, dimension proportional to the logarithm of the layer clusters energy).



This plot shows the distribution of the difference between the reconstructed TICLCandidate time, t_{reco}, and the simulated time (i.e. referenced to the time of the primary interaction), t_{sim}^{vtx}, for a sample of charged pions uniformly sampled in the $10 < p_T < 20$ GeV and $1.7 < |\eta| < 2.7$ intervals. Track-only candidates, i.e. those made only of tracks not linked to a trackster in HGCAL, are not considered in this plot.
Only charged candidates are shown in this plot because the track is needed to propagate the time to the vertex.
Those in blue are TICLCandidates coming from the primary vertex, while in red there are the TICLCandidates produced from pileup interactions, with kinematics following the expected physical distribution of a Minimum Bias event.



This plot shows the efficiency in the linking between the tracksters in HGCAL and the tracker tracks.

The sample used are charged pions shot from the vertex uniformly sampled in the $10 < p_T < 100$ GeV and $1.7 < |\eta| < 2.7$ intervals and produced accordingly to the Phase 2 vertices distribution.

Tracker tracks are used in the linking if they have p_T >1 GeV, <5 missing outer hits and high quality [5].

Tracks and tracksters are projected onto two common surfaces, the first and the last layer of the electromagnetic section of the calorimeter, and geometric compatibility is performed (both in a 0.04 (first layer) – 0.06 (last layer) η window). In addition to that, also time and energy compatibility with the track are computed.

A track and a trackster are time compatible if they satisfy Eq. (1), while they are energy compatible if:

$$E_{trackster} < E_{track} + \min(10\ GeV, 0.2\ E_{trackster})$$

References

[1] CMS Collaboration, “The Phase-2 Upgrade of the CMS Endcap Calorimeter”, CMS-TDR-019

[2] CMS Collaboration, “A MIP Timing Detector for the CMS Phase-2 Upgrade”, CMS-TDR-020

[3] M. Rovere et al., “CLUE: A fast parallel clustering algorithm for high granularity calorimeters in high-energy physics” , Frontiers in Big Data 3 (2020)

[4] Felice Pantaleo et al., "The Iterative Clustering framework for the CMS HGCAL Reconstruction" , J. Phys.: Conf. Ser. 2438 012096 (2023)

[5] https://github.com/cms-sw/cmssw/blob/master/RecoTracker/PixelSeeding/plugins/alpaka/CAHitNtupletGenerator.cc#L277-L285

- p_T > 0.5 GeV
- |tranverse impact parameter| < 0.3 cm
- |z impact parameter| < 12 cm