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The Compact Muon Solenoid Experiment

CMS Performance Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

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Towards a GPU compatible electron seeding algorithm

CMS Collaboration

Abstract

This note presents first results on the development of a parallelizable algorithm for building tracking seeds in the reconstruction of electrons.

Towards a GPU compatible electron seeding algorithm

CMS Collaboration

cms-trigger-coordinator@cern.ch

Electron seeding in CMS

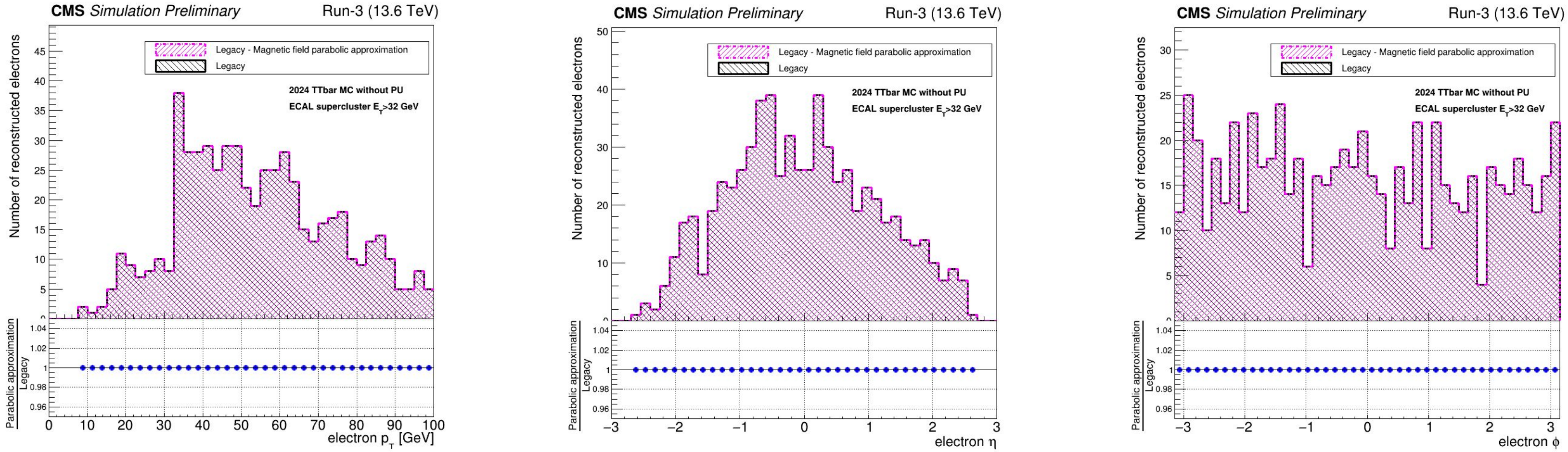
Electrons in CMS [1] are reconstructed via a series of dedicated reconstruction algorithms combining information from the electromagnetic calorimeter (ECAL) and the tracker detectors. One crucial step for the timely reconstruction of electrons is to reduce the collection of tracker hits that are used as inputs to the Gaussian Sum Filter (GSF)[2] track fitting algorithm since the latter is CPU intensive. This procedure, known as electron seeding, is currently the most time consuming part of the electron reconstruction [3]. Electron seeding is done in two steps, one being the dedicated doublet and triplet electron seed building algorithm and the second being the pixel matching algorithm. The pixel matching algorithm uses the information from the ECAL and the beamspot and propagates the electron track through the tracker volume according to the two electron charge hypotheses, searching for compatible tracker hits.

Towards a parallelizable electron seeding algorithm

Since the start of Run 3, several reconstruction algorithms have already been redesigned to follow a parallelized logic and are now able to run on GPUs [3]. It is crucial to explore whether further algorithms, such as the time consuming pixel matching algorithm, can also be redesigned to exploit the massive parallelization GPUs can offer. In this note, preliminary results from the initial steps towards a parallel pixel matching algorithm will be described. In order to achieve this, several changes have to be implemented both at algorithmic level as well as in various utility functions used by the algorithm. With the current state of developments, the parallelized approach achieves comparable efficiency as the legacy algorithm, while ongoing work aims to match its fake rate as well, which is currently slightly higher. In the following, the impact of two very basic changes will be showcased:

- In the current (legacy) pixel matching implementation, the magnetic field is described using a parabolically parameterized approximation within the tracker while a full magnetic field description is used in the ECAL. Since it is not straightforward to have a full description of the magnetic field on the GPU, the procedure is simplified by extending the parametrized parabolic approximation to the ECAL.
- In the current (legacy) approach, the order in which the pixel matching is performed does not exploit the parallelism of the GPU. In the legacy implementation, the matching starts from the ECAL supercluster collection (~O(10) candidates) and then loops through the collection of electron seeds (~$O(10^4)$ candidates). In the parallelized approach, the order in which the loop over the ECAL supercluster and electron seed collection is performed has been reversed, with the goal of assigning each electron seed to a separate GPU software thread, thus largely increasing the level of parallelization of the algorithm.

Comparison of reconstructed electrons with different magnetic field parametrizations

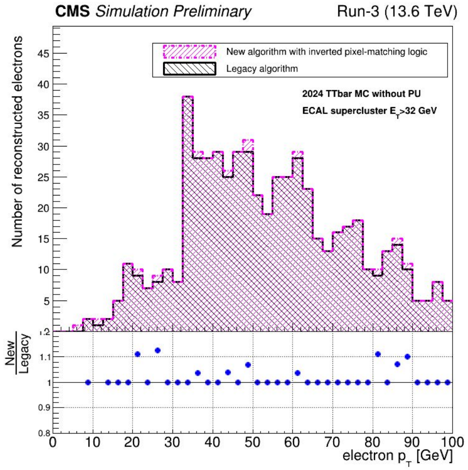


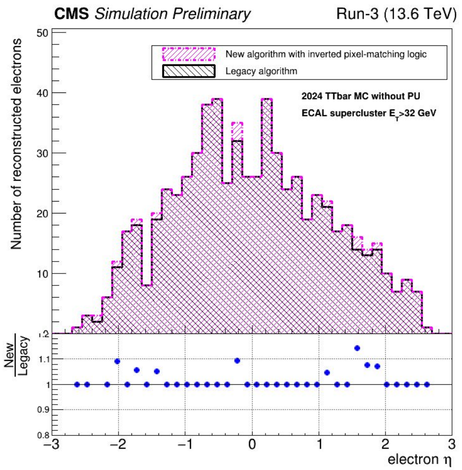
The number of reconstructed electrons matched to a generator level electron is shown as a function of the electron p_T (left), η (middle) and φ (right) in two different cases:

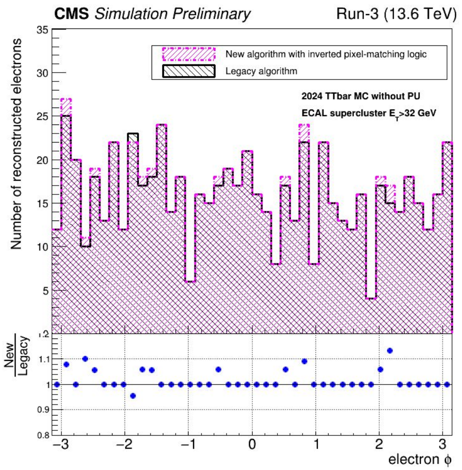
- The current (legacy) pixel matching algorithm with the legacy approach for the magnetic field (black line)
- The current (legacy) pixel matching algorithm with the simplified approach for the magnetic field (magenta line)

The ratio between the distributions obtained with the legacy approach and the simplified approach for the magnetic field is displayed in the lower panels and shows excellent agreement. The results have been produced using 1800 simulated no pileup tt-bar di-leptonic events.

Comparison of reconstructed electrons with different matching logic







The number of reconstructed electrons matched to a generator level electron is shown as a function of the electron p_T (left), η (middle) and φ (right) in two different cases:

- The current (legacy) pixel matching algorithm (black line)
- The new pixel matching algorithm with the inverted matching logic, using the simplified approach for the magnetic field (magenta line)

The ratio between the distributions obtained with the legacy and the new algorithm is displayed in the lower panels and shows good agreement. Slight differences in the number of reconstructed electrons can be attributed to some quality cuts that are not applied in the new algorithm and the different structure of the electron seed and ECAL supercluster association map. The results have been produced using 1800 simulated no pileup tt-bar di-leptonic events.

References

[1] CMS Collaboration, *Electron and photon reconstruction and identification with the CMS experiment at the CERN LHC*, doi:10.1088/1748-0221/16/05/P05014, arXiv:2012.06888v2, [hep-ex], 2021

[2] W. Adam, R. Fruhwirth, A. Strandlie, and T. Todorov, "*Reconstruction of electrons with the Gaussian-sum filter in the CMS tracker at the LHC*", J. Phys. G 31 (2005) 9, doi:10.1088/0954-3899/31/9/n01, arXiv:physics/0306087

[3] CMS Collaboration, *Commissioning CMS online reconstruction with GPUs,* CMS Detector Performance Note CMS DP-2023/004, 2023