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CMS Level-1 Electron and Photon Trigger Commissioning and Performance on 7 TeV Data

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The CMS electromagnetic calorimeter (ECAL) has been designed to precisely measure electron and photon energies. It is made of 75848 lead tungstate ($PbWO_4$) crystals and its characteristics have been optimized for the search of the Higgs boson in its two photons decay mode. In view of the high interaction rate at the Large Hadron Collider (LHC), CMS implemented a sophisticated online selection system that achieves a rejection factor of $O(4 \cdot 10^5)$. In the intense hadronic environment, the electron and photon trigger system provides a powerful tool to select interesting physics events containing electrons or photons in their final states. The first 7 TeV collision events recorded by the CMS experiment have been analyzed in order to estimate the electron and photon trigger performance in terms of efficiency.

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1. Introduction

The Compact Muon Solenoid (CMS) experiment has been designed to study the results of proton-proton interactions produced by the LHC. At the nominal luminosity of 10^{34} cm^{-2} s^{-1}, the LHC will reach a bunch-crossing rate of 40 MHz, leading to tremendous experimental challenges. CMS is equipped with an online selection system able to reduce the rate down to a value of 100 Hz [1][2]. The trigger system is organized in two consecutive stages: the Level-1 trigger implemented by custom hardware processors and the High Level Trigger (HLT) using a farm of standard commercial processors. The Level-1 trigger can provide a total rate of 100 kHz. Its decision is based on information gathered from the calorimeters and the muon systems. Reduced granularity and reduced resolution data are used to derive simple triggers on electromagnetic signals, muons and jets.

The CMS electromagnetic calorimeter (ECAL) is a high-resolution calorimeter made of 75848 crystals [3]. Its barrel is structured as 36 identical supermodules each containing 1700 crystals. These crystals have a front face cross-section of 2.2×2.2 cm^2 (corresponding to a coverage of 0.0174 in $\Delta\phi$ and $\Delta\eta$) and a length of 23 cm. The barrel has an inner radius of 129 cm and covers a range of $|\eta| < 1.48$. The two endcaps, structured as four "dees" of 3662 crystals each, extend the coverage up to $|\eta| < 3$.

A trigger tower is a matrix of crystals (5×5 in the barrel) corresponding to the size of a Hadronic Calorimeter (HCAL) trigger tower. In the endcaps, its size varies with pseudorapidity in order to follow approximately a projective geometry.

From April to July 2010, CMS has recorded the first LHC collision data at a center of mass energy of 7 TeV. These events have been used to study the performance of the electron and photon trigger system. The electron and photon trigger chain will first be presented, followed by the results of this analysis.

2. The Level-1 Electron and Photon Trigger

The CMS Level-1 e/γ trigger decision is based on trigger candidates corresponding to electrons or photons which use local energy deposits called trigger primitives as inputs. The trigger primitives each refer to a single trigger tower. They are computed by the front-end electronics as the summed transverse energy deposited in the tower, completed and then synchronized by the Trigger Concentrator Cards (TCC) [4] before being sent to the Regional Calorimeter Trigger (RCT) [5]. The RCT implements the algorithm which combines pairs of trigger primitives into Level-1 trigger candidates. The Global Calorimeter Trigger (GCT) [6] is then responsible for sorting the candidates from all regions according to their transverse energy. Only the most energetic four are sent to the global trigger (GT) [7] which generates the final decision (L1 accept).

3. Electron and Photon Trigger Performance

During the CMS data taking period, the e/γ trigger was fully deployed and operational. e/γ trigger primitives were produced and sent to the RCT. Noisy ECAL channels were masked. The e/γ trigger is made of different paths that each require a calorimeter deposit above a configurable threshold: the one with the lowest value, which was used unprescaled for that period, was

L1_SingleEG5: requiring a candidate with $E_T > 5$ GeV. The rate of this trigger on noise is below 5 Hz. For collisions at a luminosity of $1.4 \cdot 10^{30}$ cm^{-2}s^{-1}, the single L1_SingleEG5 trigger ran at an average rate of 400 Hz; the average rate for all Level 1 physics triggers was about 40 kHz.

The performance of the e/γ trigger was evaluated in terms of efficiency, on events selected by Minimum Bias triggers (based on LHC beam pick-up counters and CMS beam scintillators), with the additional requirement of a significant activity in the ECAL. Reconstruction of electromagnetic objects, like superclusters or electrons, was performed offline. These offline objects were used as tags to probe the production of L1 trigger candidates.

Due to the requirement of an energy deposit in the ECAL, this measurement evaluated the trigger efficiency only in the active part of the detector and was relative to the detector efficiency to detect electromagnetic energy.

The e/γ trigger efficiency was studied from two different points of view. On one hand, the intrinsic efficiency was measured on offline objects with the same geometry as L1 candidates, in adequate conditions for the trigger: synchronous signals of superclusters spread on 1 or 2 trigger towers, in a region where no trigger tower or region was masked. On the other hand, the absolute efficiency on electrons was measured on a sample of reconstructed electrons, selected using dedicated cuts suitable to enrich the sample in electrons from conversions, with a purity higher than 80%. No conditions were applied on the region or timing of the electron.

The L1 e/γ trigger is considered efficient if an L1 candidate with E_T above the studied threshold, can be associated with the ECAL supercluster. The association procedure identifies the ECAL trigger tower containing most of the energy of the offline object, and scans its trigger region for a L1 candidate. Figure 1 shows the intrinsic trigger efficiency on electromagnetic objects for three different pseudorapidity regions (left), and the trigger efficiency for electrons, separately in the barrel and in the endcaps (right). For the intrinsic efficiency, the third region (shown in red) corresponds to a very high pseudorapidity, where the calorimeter granularity is coarser, which explains the difference between this efficiency curve and the two other ones.

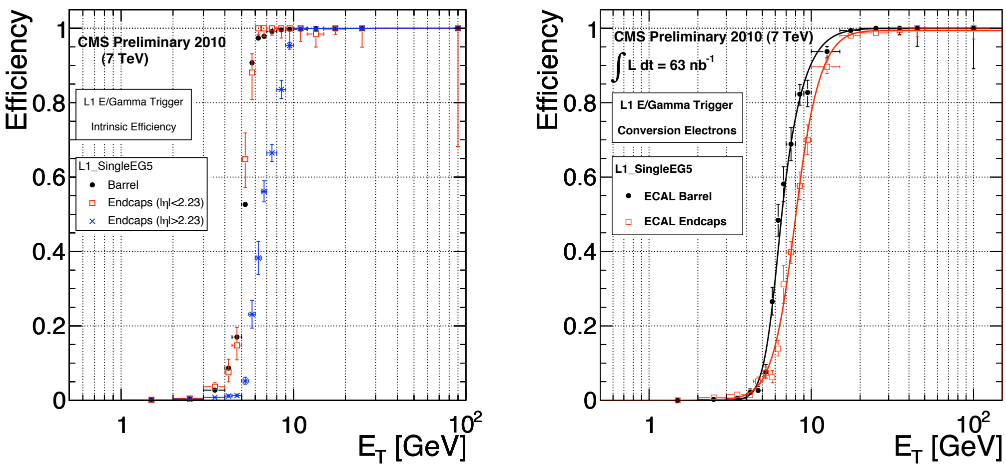

Figure 1: The e/γ L1_SingleEG5 trigger intrinsic efficiency on electromagnetic objects (left), and absolute efficiency on electrons (right).

4. Conclusion

An unbiased selection of electromagnetic objects has been used to evaluate the performance of the Level-1 trigger chain. Up to $|\eta| < 2.23$, 100% intrinsic efficiency is reached almost immediately at the 5 GeV threshold. Because of the typical spread of the electromagnetic shower over several towers, an absolute efficiency of 100%, on electrons from conversions, has been achieved at a larger threshold, E_T values of 20 GeV, corresponding to the requirements for the physics analyses at the LHC.

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