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The CMS Electromagnetic Trigger: commissioning and performance toward the start of operation

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The CMS electromagnetic calorimeter (ECAL) has been designed to precisely measure electron and photon energy. 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 implements a sophisticated online selection system that achieves a rejection factor of nearly 10^6. In the intense hadronic environment, the ECAL trigger system provides a powerful tool to select interesting physics events which may contain electrons or photons in their final states. Comic ray data recorded by the CMS experiment have been analyzed in order to estimate the ECAL 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. The interaction rate at nominal luminosity (10^{34} $cm^{-2}s^{-1}$) will reach approximately 10^9 inelastic event/s leading to tremendous experimental challenges. CMS must be equipped with an online selection system able to reduce the rate of 1 billion event/s to a rate of 100 event/s. 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. The barrel has an inner radius of 129 cm and covers a range of $|\eta| < 1.48$. It is structured as 36 identical supermodules each containing 1700 crystals. The barrel 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. A trigger tower is a matrix of 5×5 crystals corresponding to the size of a Hadronic calorimeter (HCAL) trigger tower.

During the months of October and November 2008, CMS recorded 270 million cosmic events with the goal of commissioning the experiment in preparation for LHC collisions. These events have been used to study the performance of the ECAL trigger chain [1]. In the following, first the ECAL trigger chain and then the results of this analysis will be presented.

2. The Level-1 ECAL trigger

The CMS Level-1 ECAL trigger decision is based on trigger candidates such as electrons/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) before being sent to the Regional Calorimeter Trigger (RCT). The RCT implements the algorithm which combines pairs of trigger primitives into Level-1 trigger candidates. The Global Calorimeter Trigger (GCT) is then responsible for sorting the candidates from all regions according to their transverse energy. Only the 4 most energetic are sent to the global trigger (GT) which generates the final decision (L1 accept).

3. ECAL trigger performance

During the CMS cosmics data taking period, the barrel ECAL trigger was fully deployed and operational. ECAL trigger primitive were produced and sent to the RCT. In order to minimize the contribution from noise, a threshold of 750 MeV was applied to the TPG. Noisy or absent ECAL channels were masked. Only the simplest trigger object algorithms were enabled at the GT level, with no threshold for muons, and the lowest energy threshold allowed by the noise rate for calorimeter objects. The e/γ trigger required a calorimeter deposit above a configurable cut:

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L1_SingleEG1 for a candidate with E_T >1 GeV. The total rate for triggers was about 475 Hz, 300Hz for the open single muon trigger alone. The single e/γ trigger ran at 23 Hz or at 0.5 Hz in coincidence with the single muon trigger.

The performance of the barrel e/γ trigger was evaluated in terms of efficiency by selecting events with large energy deposits originating from muon Bremstrahlung signal in the ECAL. Reconstruction of superclusters was performed offline. The superclusters were used as tags to probe for the production of L1 trigger candidates. Both the trigger primitive efficiency as well as the full L1 e/γ efficiency were determined. A coherent configuration of the entire trigger chain was required and regions with electronics and powering problems were excluded. Due to the requirement of an energy deposit on ECAL this measurement evaluated the trigger efficiency only in the active part of the detector and was relative to the detector efficiency to detect muons and electromagnetic energy.

In order to reject asynchronous cosmic muon signals, only selected superclusters with their timing falling within 3.75 ns of the trigger were retained in the analysis. A matching between the ECAL superclusters and the offline-reconstructed muons was performed. It was based on the distance ΔR between the supercluster (SC) position and the linear extrapolation of the muon track to the ECAL inner surface starting from the tracker. The selection required $\Delta R(SC,\mu) < 0.1$.

The trigger primitive generator is considered efficient if an ECAL supercluster has an associated TPG above threshold in the same trigger tower. The TPG efficiency is displayed on Fig. 1 (left) as a function of the supercluster E_T. The turn-on point measured is compatible with the set threshold of 750 MeV. The systematics errors were evaluated by varying the cuts in the selection. The L1 e/γ trigger is considered efficient if an L1 candidate with E_T above the threshold under study, can be associated with the ECAL supercluster. The association procedure uses the distance between the L1 candidate and the muon-tagged supercluster: ΔR(L1,SC). This distance is required to be less than 0.5. Fig. 1 (right) shows the trigger efficiencies for three algorithms.

4. Conclusion

Events with electromagnetic radiation from muons have been used to evaluate the performance of the Level-1 trigger chain. They are consistent with expectations. A 100% efficiency of the electron/photon trigger is achieved down to E_T values of 3 GeV, well below the requirements for data taking with beam collisions at the LHC.

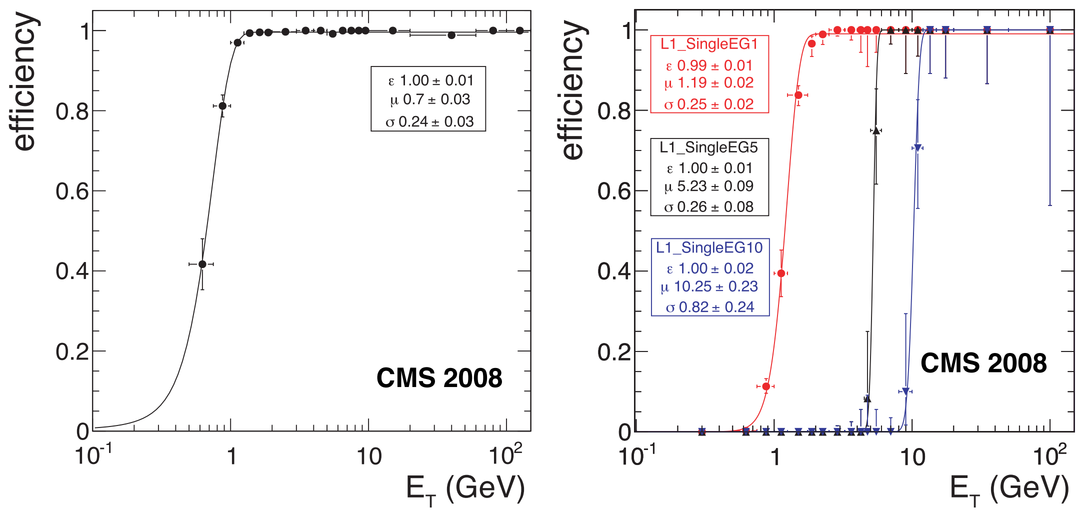

Figure 1: The ECAL trigger primitive production efficiency (left) and the full Level-1 e/γ trigger efficiency (right) as a function of the E_T reconstructed offline in ECAL. Parameters are obtained from fits of error functions to the data. In the case of the right figure, an unbinned fit was used.

References

[1] L. Agostino *et al.* [CMS Collaboration], “Performance of the CMS Level-1 Trigger during Commissioning with Cosmic Ray Muons”,arXiv:0911.5422v1 Nov 2009 JINST 4 P10005.