Performance of the CMS Level-1 Trigger during Run 2

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The CMS Level-1 (L1) Trigger system was upgraded in 2016 in order to cope with the threefold increase in peak luminosity of Run 2 compared to Run 1. The upgraded trigger features advanced clustering, calibration, and particle identification techniques. More sophisticated algorithms, for example involving the invariant mass of pairs of L1 candidates, were also implemented. The upgrades reduced the trigger rate from background processes and increased the efficiency for a variety of physics signals. This poster highlights a number of improvements that the upgraded L1 trigger provided during the Run 2 program at CMS.

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1. The CMS Level-1 trigger architecture

The CMS experiment [1] implements a sophisticated two-level trigger system which reduces event rates by a factor of 10^5. It consists of the Level-1 (L1) trigger and the High Level Trigger (HLT). The L1 trigger is a hardware trigger which collects the information from the calorimeter and muon chambers. The L1 trigger selects up to 100 kHz of the most interesting events with a latency of 4μs.

Figure 1 shows the CMS L1 trigger system during Run 2. The muon trigger system includes three muon track finders for each geometrical region. It reconstructs muons in the barrel (BMTF), overlap (OMTF), and endcap (EMTF) regions of the detector, and sends them to the global moun trigger for final muon selection. The calorimeter trigger consists of two layers. The Layer-1 receives and calibrates the local energy deposits which are sent by the electromagnetic calorimeter (ECAL) and hadron calorimeter (HCAL). The Layer-2 uses these trigger primitives (TPs) to reconstruct and calibrate the physics objects such as electrons, tau leptons, jets. Lastly, the global trigger combines the information from global muon trigger and calorimeter trigger.
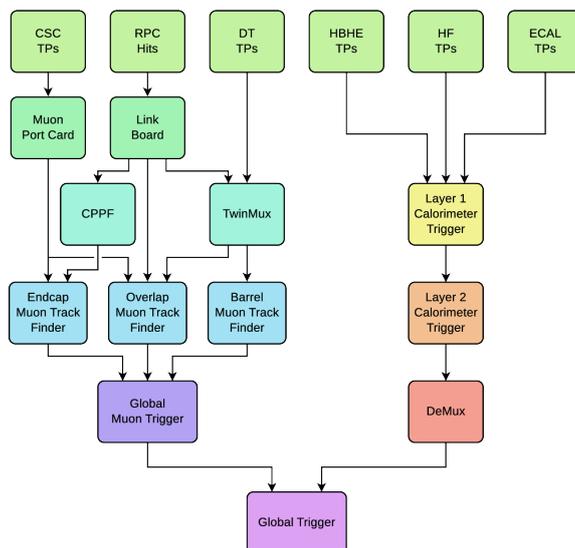
Figure 1: Diagram of the upgraded CMS Level-1 trigger system during Run 2.

2. Performance of the Level-1 muon trigger

The CMS muon system consists of three types of muon detectors: Drift Tube (DT) chambers, Resistive Plate Chambers (RPC) and Cathode Strip Chambers (CSC). Using distinct regions, the L1 muon trigger improved its resolution and redundancy. The BMTF in the barrel region uses a road search extrapolation track finder. The OMTF and the EMTF use a pattern based track finder and the EMTF also uses a boosted decision tree (BDT) based p_T assignment. In Figure 2, a single muon trigger efficiency for the typical L1 threshold 22 GeV is shown for each region. High efficiency on the plateau and sharp turn-on curves represent a good performance of the L1 muon trigger system.
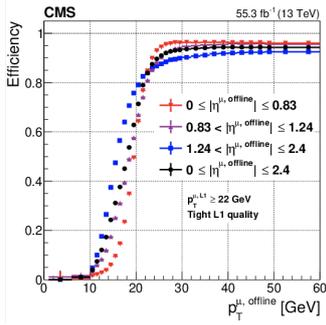
Figure 2: The L1 muon trigger efficiency for data as a function of the offline reconstructed muon p_T for each region: barrel region in red, overlap region in purple, endcap region in blue, and the total in black.
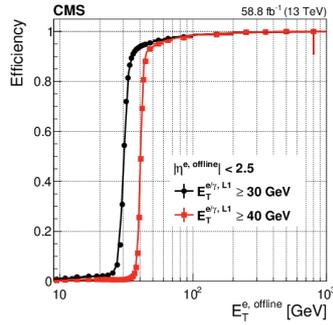
Figure 3: The L1 e/γ trigger efficiency as a function of the offline reconstructed electron E_T: an E_T threshold of 30 GeV in black, and of 40 GeV in red.
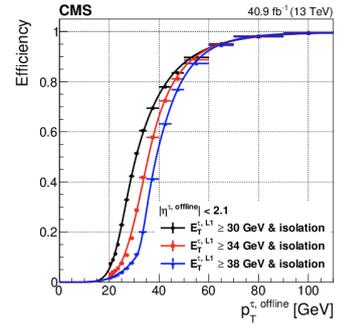
Figure 4: The L1 isolated τ trigger efficiency as a function of the offline reconstructed τ p_T: a p_T threshold of 30 GeV in black, 34 GeV in red, and of 40 GeV in blue.

3. Performance of the Level-1 calorimeter trigger

The e/γ trigger uses a dynamic clustering algorithm around the seed (local energy maximum). Calibration is done depending on E_T, η and shape of the cluster. Figure 3 shows the e/γ trigger efficiency as a function of the offline reconstructed electron E_T for thresholds of 30 and 40 GeV. It shows high plateau efficiency and its sharp turn-on reflects a good energy resolution. The τ trigger uses the e/γ clustering as a baseline. A τ candidate is considered as isolated if the E_T in the isolation area is smaller than a chosen value. Figure 4 shows the isolated τ trigger efficiency for several thresholds. It also shows a good performance. The jet trigger clustering uses a 9x9 trigger tower sliding window centered on the jet seed. The pileup subtraction is applied to the jets.

References

[1] CMS Collaboration, "The CMS experiment at the CERN LHC", JINST 3 (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

[2] CMS Collaboration, "Performance of the CMS muon detector and muon reconstruction with proton-proton collisions at $\sqrt{s}$=13 TeV", JINST 13 (2018) P06015, doi:10.1088/1748-0221/13/06/P06015, arXiv:1804.04528.

[3] CMS Collaboration, "Performance of the CMS Level-1 trigger in proton-proton collisions at $\sqrt{s}$= 13 TeV", JINST 15 (2020) P10017, doi:10.1088/1748-0221/15/10/P10017, arXiv:2006.10165.