Level-1 Calorimeter Trigger Performance

CMS Collaboration

Abstract

By the end of 2017, the LHC achieved an instantaneous luminosity of $2.06 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with peak average pileup of more than 50. Till now LHC has delivered 23.16 fb$^{-1}$ of data for 2018. This document includes studies of the performance of the CMS Level-1 Calorimeter Trigger performance for electrons and photons, taus and jets and energy sums using the partial 2018 data.
Level-1 Calorimeter Trigger Performance

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Abstract

By the end of 2017, the LHC achieved an instantaneous luminosity of $2.06 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with peak average pileup of more than 50. Till now LHC has delivered 23.16 fb$^{-1}$ of data for 2018. This document includes studies of the performance of the CMS Level-1 Calorimeter Trigger performance for electrons and photons, taus and jets and energy sums using the partial 2018 data. The Level-1 trigger Calorimeter trigger algorithms are defined in the calorimeter trigger upgrade TDR.

Level-1 Trigger: Electron/Photon (EG)

Efficiency
• The Level-1 trigger efficiency is evaluated for e/γ objects used to seed the Single Electron High Level Trigger.
• The efficiency is computed with the Tag & Probe method as a function of the offline-reconstructed e/γ transverse energy.
• Two isolation criteria are applied at level-1: Loose and Tight Isolation.
• DPS Note with Level-1 E/Gamma performance on 2017 data can be found in http://cds.cern.ch/record/2305544.

Isolation
The level-1 isolation is implemented as a LUT encoding the isolation cut, which depends on ET, η and a pileup estimator based on the number of trigger towers with non-zero energy in the central region of the calorimeters.

Calibration
• L1EG objects are built by clustering of trigger towers.
• Dedicated calibrations are applied at tower and object level.

Tag & Probe Selection
• Electrons required to be in ECAL fiducial volume (|η|<1.4442 or (|η|>1.566 and |η|<2.5))
• 60 < Mee < 120 GeV
• Opposite charge requirement
• Tag required to pass medium electron ID and ET>30 GeV and to be matched to the HLT electron triggering the event.
• Probe required to pass loose electron ID
• ΔR(Tag,Probe) > 0.6
• ΔR(Probe, L1EG Candidate) < 0.3
Level-1 Efficiency: Single EG

L1 trigger efficiency curves for an e/γ object as a function of the offline reconstructed supercluster transverse energy $E_T$ of the electron, measured with Tag & Probe method on data. A geometrical matching between the electron supercluster and the L1 candidate is applied. The efficiency is drawn for an $E_T$ threshold of 40 (blue) and 30 (red) GeV. Offline reconstructed electrons are selected with $|\eta^{\text{off}}| < 2.5$. 

L1 $E_T > 40$ GeV
L1 $E_T > 30$ GeV

$\eta^{\text{off}} < 2.5$
L1 trigger efficiency curves for an e/γ object as a function of the offline reconstructed supercluster transverse energy $E_T$ measured with Tag & Probe method on data. A geometrical matching between the electron supercluster and the L1 candidate is applied. The efficiency is drawn for an $E_T$ threshold of 32 (blue), 30 (red) and 28 (green) GeV and the Tight Isolation requirement applied online. Offline reconstructed electrons are selected with $|\eta^{\text{off}}|<2.1$. 

CMS preliminary 2018

8.1 fb$^{-1}$ (13 TeV)
L1 trigger efficiency curves for an e/γ object as a function of the offline reconstructed supercluster transverse energy $E_T$ measured with Tag & Probe method on data. A geometrical matching between the electron supercluster and the L1 candidate is applied. The efficiency is drawn for an $E_T$ threshold of 26 (blue) and 24 (red) GeV with the Loose Isolation requirement applied online. Offline reconstructed electrons are selected with $|\eta^{\text{offl}}| < 2.1$. 
First feedback on the performance with 2018 data
Improving at forward Jet response

- Appears to be a significant change in energy scale between GEN and PF jets in HF
- 2018 HF JEC are < 1 for low pT, results in a very different energy scale for jets in BE & HF
  - Particularly problematic for VBF triggers
- Temporary solution is to set all HF JEC to unity, i.e. turn off JEC for HF jets
- Dramatically improves resolution, but reduces efficiency by a few percent
- Work ongoing to understand jet calibration in HF
Level-1 Trigger: Jets and Sums

By the end of 2017, the LHC achieved an instantaneous luminosity of $2.06 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$ with peak average pileup of more than 50. Till now LHC has delivered 23.16 fb$^{-1}$ of data for 2018.

Studies of the performance of the Level-1 jets and energy sum trigger using 11.0 fb$^{-1}$ of data is presented. Study of the performance of the Level-1 jets and energy sums algorithms as defined in the calorimeter trigger upgrade TDR [1] and DPS note [2].


The previous Level-1 jets and energy sum trigger performance report can be found in: http://cds.cern.ch/record/2305545

The efficiency of the Level-1 single jets and energy sums trigger is evaluated with the single muon event

Offline PF jets are required to have $p_T > 20$ GeV and are matched to L1 jets with $\Delta R < 0.4$ for the case of Level-1 single jet trigger

- Offline scalar sum of PF jet transverse momenta with $p_T > 30$ GeV is required for the case of Level-1 scalar sum of jet $p_T$ trigger
- These criteria are used for both in central region with $|\eta| < 3.0$ and for the forward region $|\eta| > 3.0$.
- Offline PF missing transverse energy, which is the magnitude of the negative vector sum of the transverse momenta of all calorimeter energy deposits, with $|\eta| < 5.0$ is required in case of MET trigger
Efficiency curves for the Level-1 single jet trigger using events collected with a single muon trigger as a function of offline PF jet transverse energy ET. Offline jets in the $|\eta| < 3.0$ region are reconstructed with the anti-$k_T$ (R=0.4) algorithm, and are matched to L1 jets with $\Delta R < 0.4$. 
Efficiency curves for the Level-1 single jet trigger using events collected with a single muon trigger as a function of offline PF jet transverse energy ET. Offline jets in the $3.0 < |\eta| < 5.0$ region are reconstructed with the anti-$k_T$ ($R=0.4$) algorithm, and are matched to L1 jets with $\Delta R < 0.4$. 
Level-1 Efficiency: Sum of Central Jet ET

Efficiency curves for the Level-1 scalar sum of jet pT trigger (HT) using events collected with a single muon trigger as a function of the offline scalar sum of PF jet transverse momenta, using jets with pT > 30 GeV and |η|< 2.4 both online and offline.
Level-1 Efficiency: Missing Transverse Energy

Efficiency curves for the Level-1 missing energy trigger using events collected with a single muon trigger as a function of offline PF missing transverse energy (MET), which is the magnitude of the negative vector sum of the transverse momenta of all particle flow candidates reconstructed in an event, excluding muons.
Level-1 Trigger: Hadronic Taus

The Level-1 trigger efficiency is evaluated for hadronically-decaying $\tau$’s used to seed the di-$\tau$ High Level Trigger. The previous Level-1 $\tau$ performance report can be found in https://cds.cern.ch/record/2305547?ln=es

Tag & Probe definition and cuts used

- The efficiency is computed per single-$\tau$-leg through the tag-and-probe method, as a function of the offline-reconstructed $\tau$ transverse momentum.
- Hadronically-decaying $\tau$’s from the $Z \rightarrow \tau_\mu \tau_h$ process are selected in events that fired single $\mu$ High Level Trigger and fulfill the baseline $H \rightarrow \tau\tau$ requirements of well identified and isolated $\mu\tau_h$ pairs, as well as $m(E_T^{\text{miss}, \mu} < 30 \text{ GeV}$ and $40 \text{ GeV} < m(\tau, \mu) < 80 \text{ GeV}$.
- An $\eta$ restriction of $|\eta| < 2.1$ is applied to the $\tau_h$ L1 objects.
- Passing L1 $\tau$’s probes must geometrically match selected offline $\tau$’s.
- In the following, $p_{T,\text{offline}}^{\tau}$ refers to the transverse momentum of the offline $\tau$ candidate.
- Integrated Luminosity: 11.11 fb$^{-1}$
Level-1 Efficiency: Hadronic Taus

Level-1 trigger efficiency of hadronically-decaying $\tau$ leptons, as a function of the offline $\tau$ transverse momentum, without any requirement on the isolation at Level-1.
Level-1 Efficiency: Isolated Hadronic Taus

Level-1 trigger efficiency of hadronically-decaying $\tau$ leptons, as a function of the offline $\tau$ transverse momentum, with an isolation requirement applied at Level-1.