The L1 e/γ trigger algorithm and performance using 2018 data at CMS

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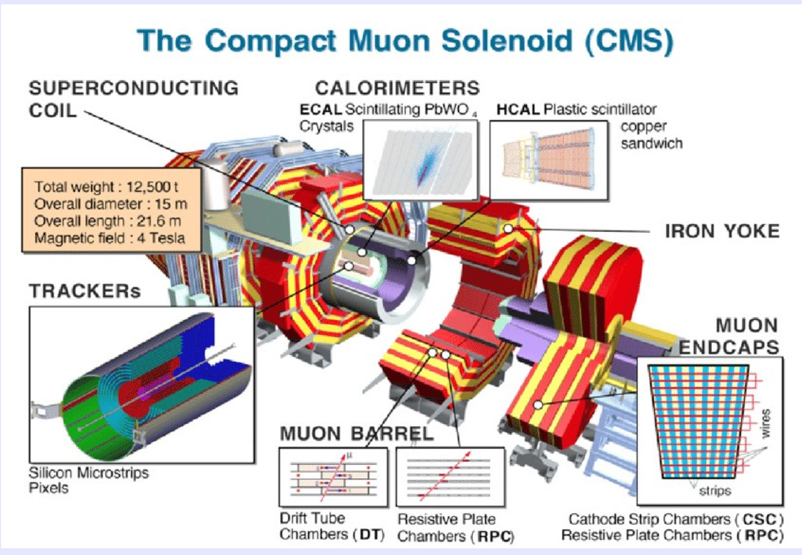
On behalf of the CMS Colaboration

The CMS experiment at the LHC

The **Large Hadron Collider (LHC)** in Geneva, Switzerland, is the most powerful collider built to date. It consists of two proton rings that run to collide in four different interaction points, including one where the CMS experiment is located.

During Run-2, the LHC has successfully delivered ~140 fb^{-1} of p-p collision data, under harsh experimental conditions, that include of a peak lumnosity of $2.1x10^{34}$ $cm^{-2}s^{-1}$ as well as a PU of up to 80.

- The CMS detector is a general purpose instrument with a broad physics programme.
- The L1 e/γ trigger user information from the Electromagnetic (ECAL) and the Hadronic (HCAL) calorimeters.



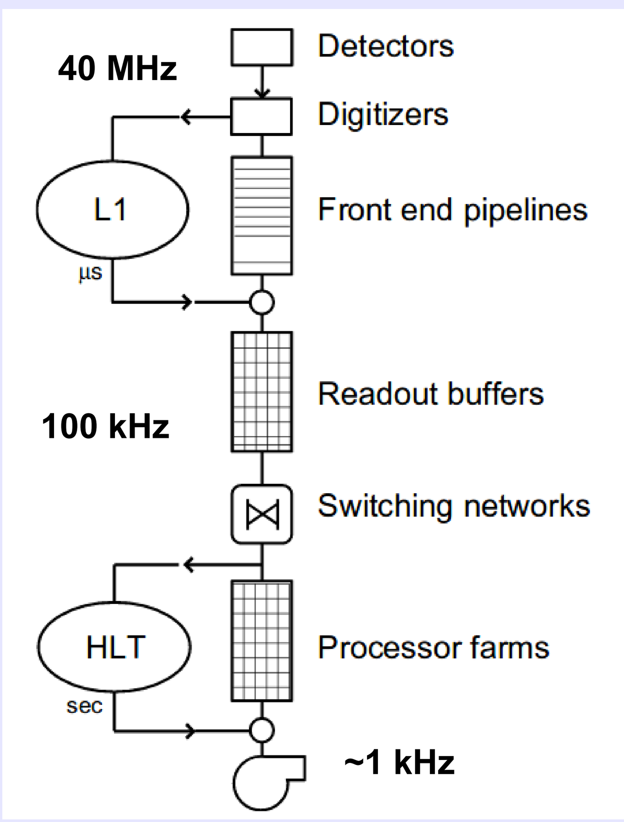
The CMS Triggering System

CMS uses a two-level triggering system to achieve a rejection of ~10^5.

- The triggering system is composed of the **Level-1 Hardware Trigger** (L1T), and the software **High-Level-Trigger** (HLT).
- The L1T uses as inputs trigger primitives (TP) from the calorimeters (ECAL and HCAL) and muon detectors and has a fixed latency of ~4μs.
- The HLT processing is based on offline-like reconstruction algorithms and has a latency of ~ 200 ms

The ***L1 e/γ trigger*** is a two – layer calorimeter based trigger:

- **Layer-1** : Combines inputs from ECAL (5x5 crystals) and HCAL into trigger towers (TT) and applies position and energy - dependent calibrations.
- **Layer-2** : Uses Layer-1 information to reconstruct objects such as jets, muons & e/γ and to compute global quantities such as missing transverse energy. Pileup subtraction and object-based calibrations are applied.

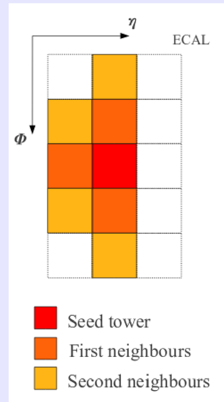


L1 e/γ Trigger Algorithm

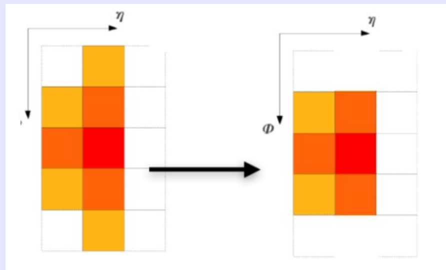
The L1 e/γ Algorithm is responsible for the identification of L1 e/γ candidates and is implemented in four main steps:

Dynamic Clustering

- The Trigger Tower (TT) with local energy maximum (E_T ≥ 2GeV) is used as the seed for clustering.
- Neighboring energy deposits (E_T ≥ 1GeV) are then added to the cluster.
- The energy distribution within a cluster is used to compute a refined position of the L1 e/γ candidate.



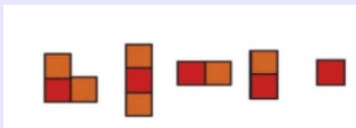
Trimming of L1 e/γ cluster



Trimming

- Some TTs are removed from the raw shape in order to obtain less PU induced clusters.

e/γ-like cluster shapes

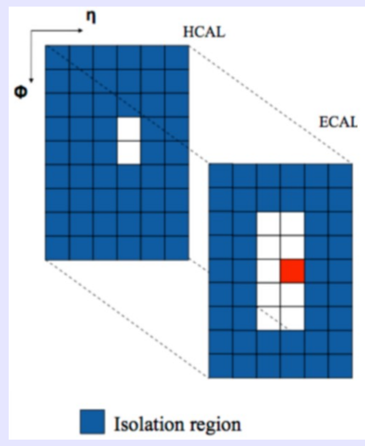


Calibration

- Energy corrections are used to correct the L1 e/gamma candidate energy. They depend on η, ET and shape information and are encoded into a Look-Up Table (LUT)

Criteria for rate reduction

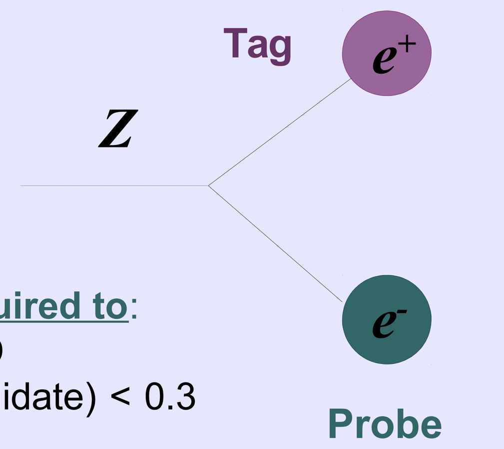
- Fine-grain veto (FG) uses the energy distribution within the seed to reject e/γ candidates with a shower profile not compatible with electromagnetic objects.
- Cut on the H/E (E_T^{HCAL} /E_T^{ECAL}) ratio, that rejects candidates with a large hadronic energy deposit, that usually are QCD-induced jets
- Shape identification based on LUT using η, E_T and shape information.
- Isolation requirements (vs. jets) which depend on PU and η and are relaxed with E_T for maximal efficiency.



L1 e/γ efficiency via Tag & Probe

A data-driven **Tag and Probe method** is used to measure the L1 e/γ trigger efficiency : it utilizes the characteristic signature of Z→ee decays in order to yield a clean and unbiased sample of electrons.

- All electrons must reside inside the ECAL fiducial volume
- T&P electron invariant mass 60 < m_{ee} < 120 GeV
- Electrons must have opposite charge (OS)
- $\Delta R(e_{Tag}, e_{Probe}) > 0.6$



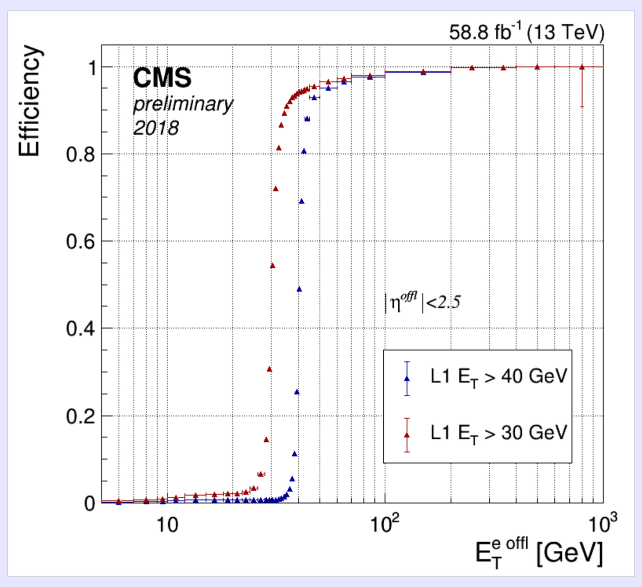
Tag electron is required to:

- Pass medium electron ID
- E_T > 30 GeV
- Be matched to the HLT electron triggering the event

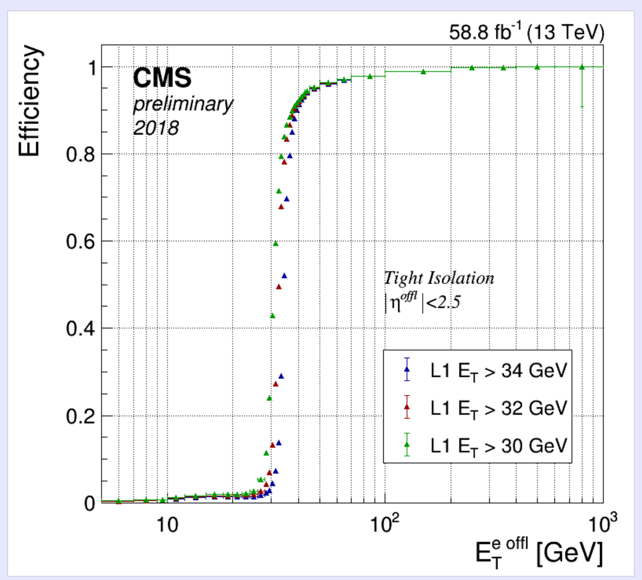
Probe electron is required to:

- Pass Loose electron ID
- ΔR(Probe, L1 e/γ candidate) < 0.3

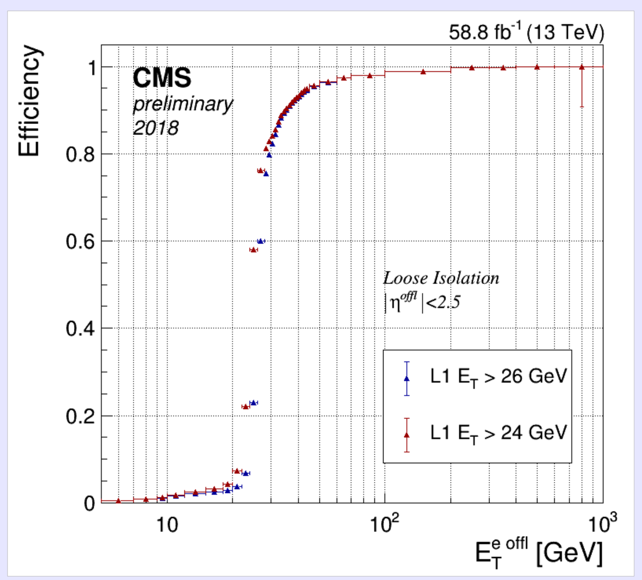
L1 e/γ Trigger Performance of the 2018 data



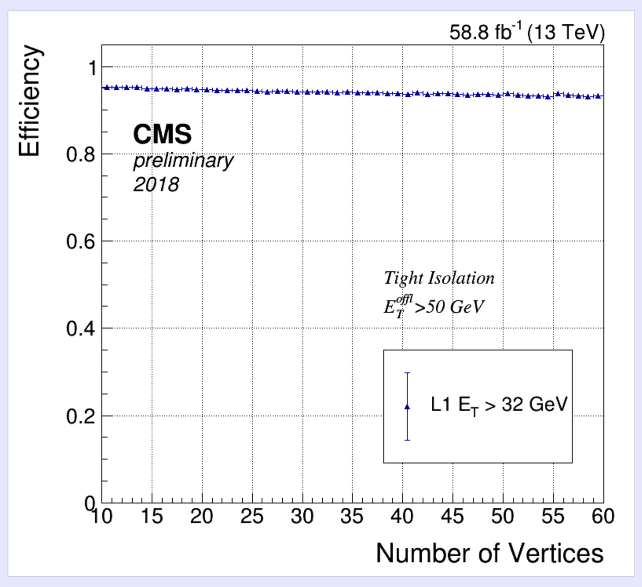
The L1 e/γ trigger efficiency turn-on is sharp and the plateau reaches 1.



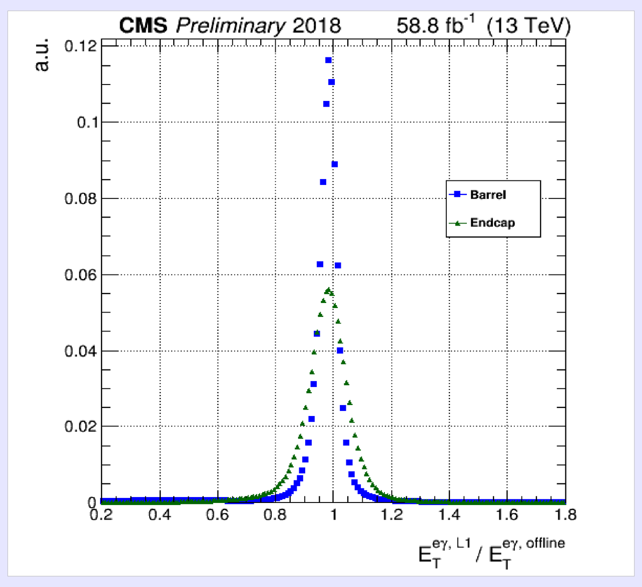
Requiring the L1 e/γ candidates to be tightly isolated allows to reduce the trigger rate and hence to reduce the trigger E_T threshold, ensuring better efficiency for the analyses.



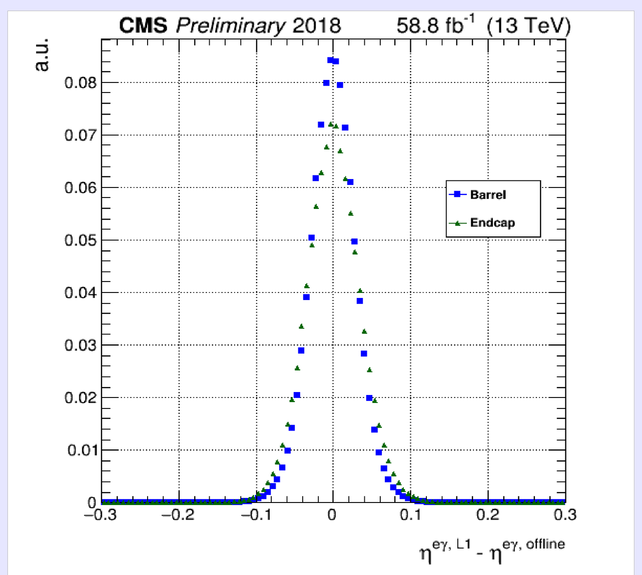
Similarly, requiring L1 e/γ candidates to be loosely isolated allows to reduce the trigger rate and hence to reduce the Double e/gamma trigger E_T threshold(s).



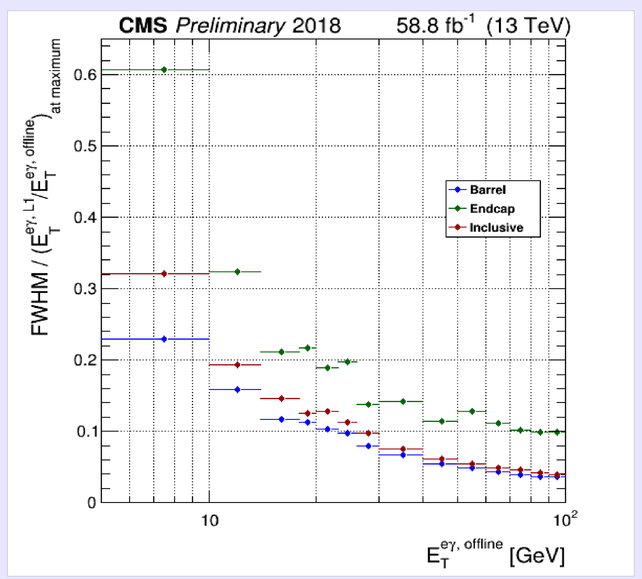
The efficiency of the Level-1 e/γ algorithm is stable versus PU.



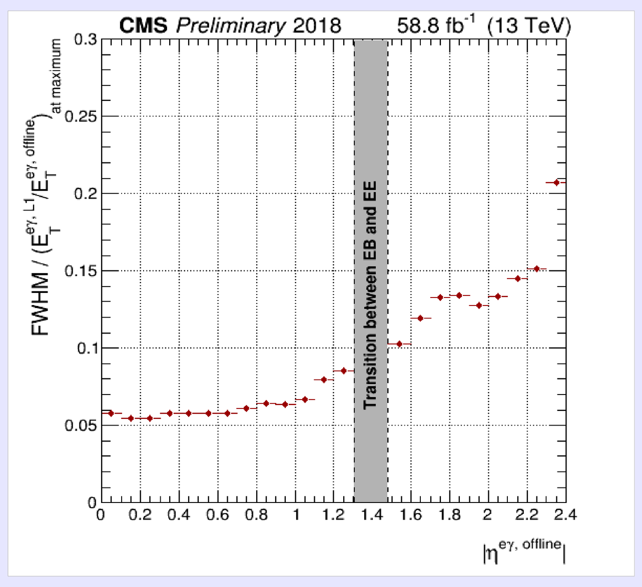
The energy resolution of the electrons in the barrel region is better by a factor of 2, compared to the energy resolution of the EE electrons.



Good |η| resolution is observed for the electrons in both the barrel and the EE region.



The L1 e/γ trigger E_T resolution as a function of the offline reconstructed electrons E_T. We observe that the resolution improves as a function of E_T.



The L1 e/γ trigger E_T resolution as a function of the offline electron |η|. The resolution deteriorates as |η| becomes larger.

Outlook

The CMS Level-1 e/γ trigger has delivered high performance during Run-2.

Its performance measured in the 2018 dataset, corresponding to an integrated luminosity of 58.8 fb^{-1}, has been shown.

Intense work ongoing for further improvements on efficiency, resolution and monitoring for Run III

References: [1] CMS Collaboration, A.Zabi, The CMS Level-1 Calorimeter Trigger for LHC Run II, CMS-CR-2016-360 (2016)
[2] CMS Collaboration,The CMS Level-1 electron and photon trigger: for Run II of LHC, JINST 12 (2017) C02014
[3] CMS Collaboration,The CMS trigger system, CMS-TRG-12-001