The Level-1 CMS Electron and Photon Trigger for the LHC Run II

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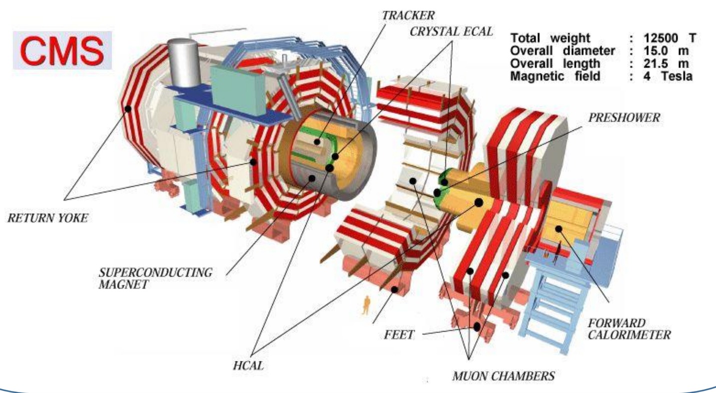
ΙΔΡΥΜΑ ΣΤΑΥΡΟΣ ΝΙΑΡΧΟΣ STAVROS NIARCHOS FOUNDATION

Introduction

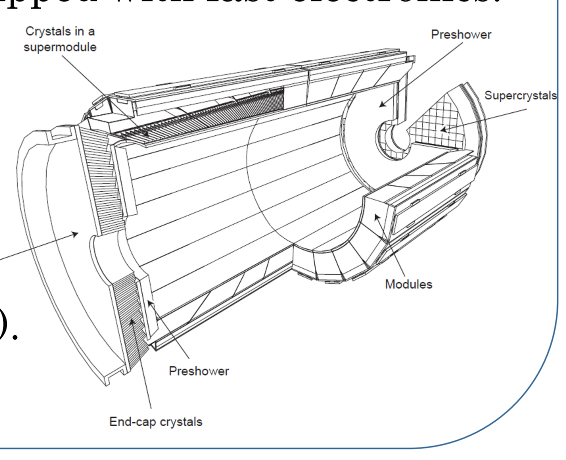
The CMS Detector

- The **Compact Muon Solenoid (CMS)** experiment is a general-purpose detector operating at the LHC (CERN, Switzerland).
- CMS was designed to study proton-proton and heavy ion collisions at $\sqrt{s}$ = **14 TeV**, primarily to search for new particles and physics processes.



The CMS Electromagnetic calorimeter (ECAL)

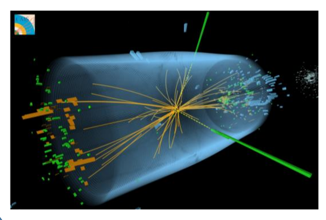
- The **CMS ECAL** is a hermetic system designed for measuring precisely the energies of electrons and photons.
- It is made of scintillating **lead tungstate crystals** and is equipped with fast electronics.
- The **L1 e/γ** trigger is based on **trigger towers (TT)** of the ECAL and the hadronic calorimeter (HCAL).



CMS Trigger System

- The CMS Detector has a sophisticated **two-level trigger system** that reduces the input data rate by a factor of 10^5. The CMS Trigger is designed for a fast selection of interesting physics events.
- The **Level-1 (L1)** trigger is implemented in custom hardware and its inputs are the data from the calorimeters and muon systems. The L1 trigger latency is 3.8 μs.
- The **High Level Trigger (HLT)** runs on a massive computer farm and uses refined algorithms exploiting the full detector granularity; its latency is 200 ms.

LHC Collisions

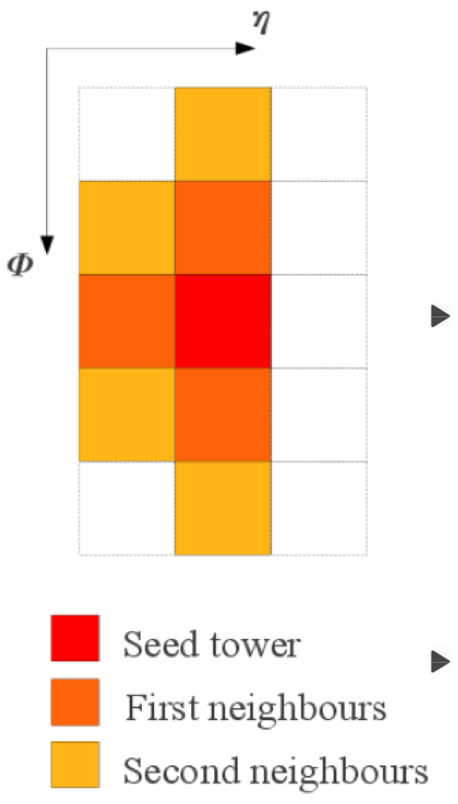


40 MHz → **L1** → 100 kHz → **HLT** → ~1 kHz → **Offline reconstruction and analyses**

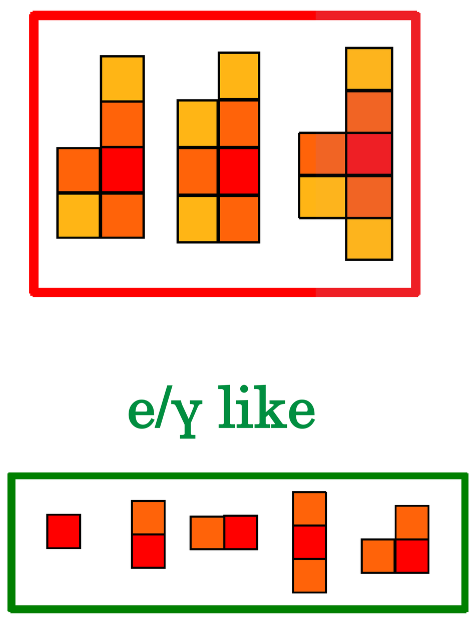
L1EG Trigger Algorithm

Identification of e/γ candidates

- **Dynamic clustering around a seed trigger tower (TT)**
  - Seed: A trigger tower with local energy maximum and $E_T \geq 2$ GeV.
  - Neighboring energy deposits with $E_T \geq 1$ GeV added to seed to form a cluster.
  - Energy distribution inside the cluster provides refined position of the e/γ candidate.
- **Calibration**
  - Energy correction computed from a LUT with E_T, η and shape as inputs.
- **Fine-Grain veto (FG)**
  - Uses energy distribution within the seed TT to reject e/γ candidates with a shower profile not compatible with electromagnetic objects.



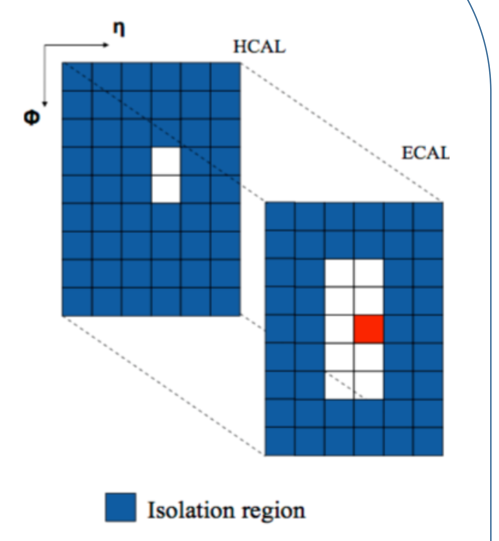
- **H/E requirement**
  - Based on E_T^{HCAL}/E_T^{ECAL} ratio for the seed TT.
  - Cut optimized to give high efficiency for T&P selected electrons.
- **Extended H/E**
  - Extension of H/E criteria including neighboring towers used in clustering.
  - Minimal loss of efficiency.
  - Rate decrease about 20%.
- **Shape identification**
  - Exploits full granularity of e/γ cluster.
  - Based on LUT with E_T, η and cluster shape as inputs.
  - Designed to have increasing efficiency with E_T (no requirement for E_T > 70 GeV).

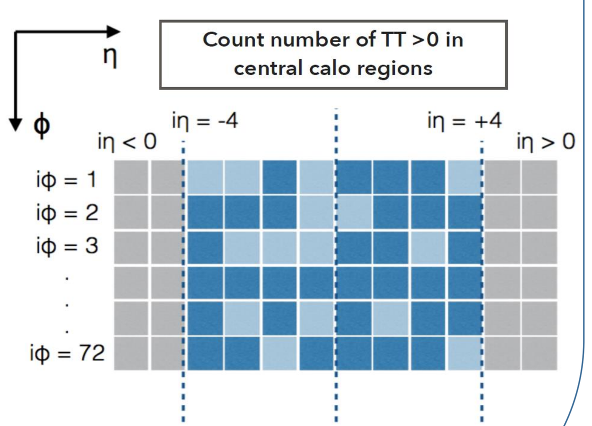


Examples of cluster shapes

Isolation

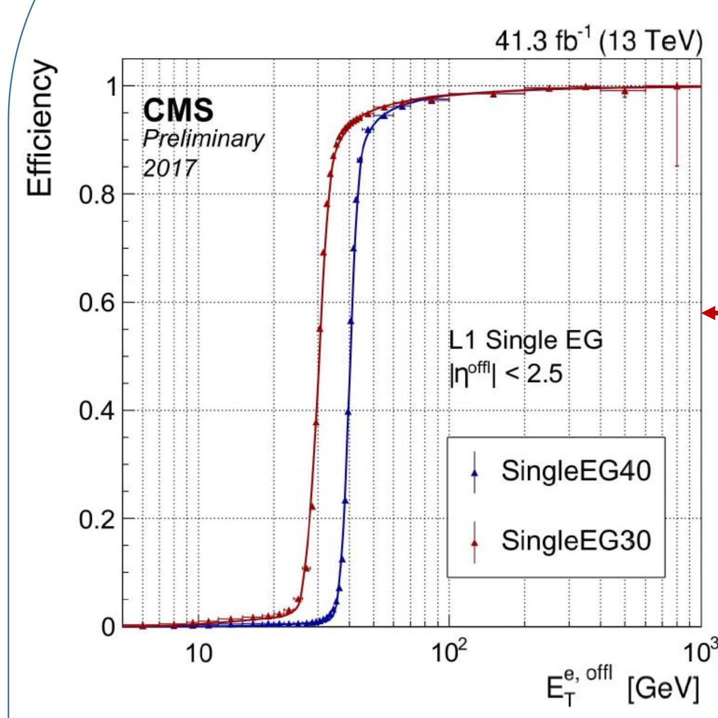
- Cut on energy in an isolation region around cluster: $E+H_{6x9}-E_{2x5}-H_{1x2}$ **< Iso.cut**
- The isolation cut value depends on E_T, η and a pile-up estimator.
- Pile-up is estimated from the number of TTs with $E_T > 0$ in the central calorimeter.
- Cut implemented via a LUT.
- Two Isolation working points are used; They correspond to two different relaxation schemes (Loose, Tight) as a function of E_T.





Performance of the L1 e/γ Trigger in 2017 data

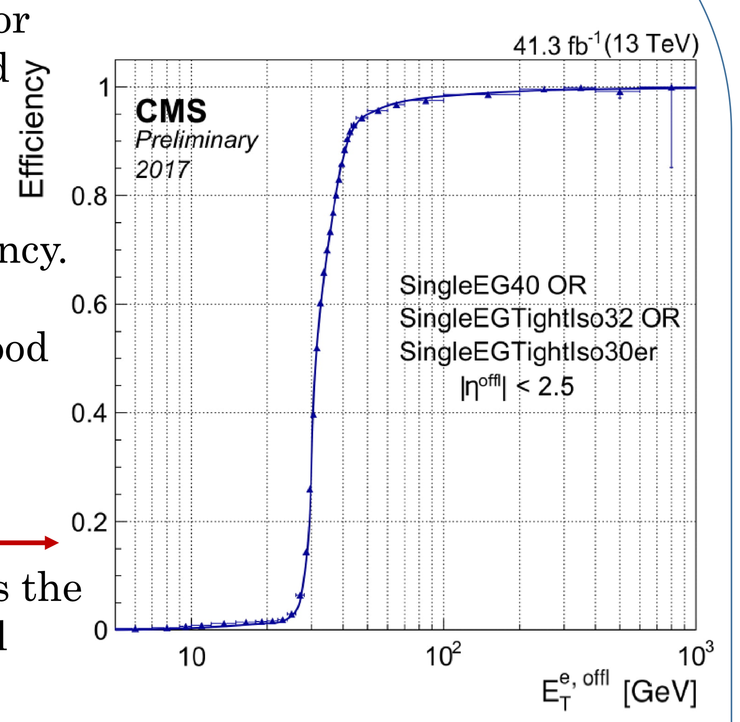
Efficiency

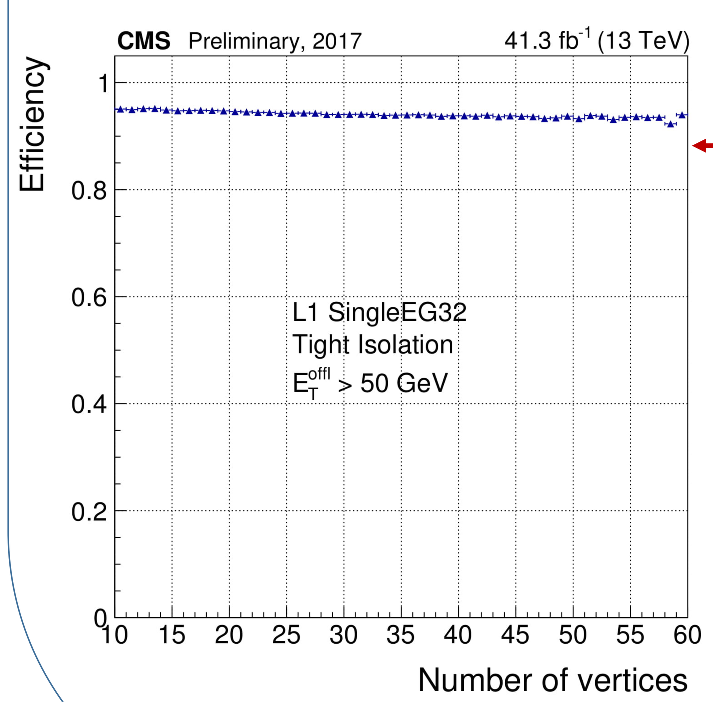


L1 Trigger efficiency for an **e/γ object** measured with **Tag&Probe.**

High plateau efficiency. **Sharp increase** in efficiency reflects good energy resolution.

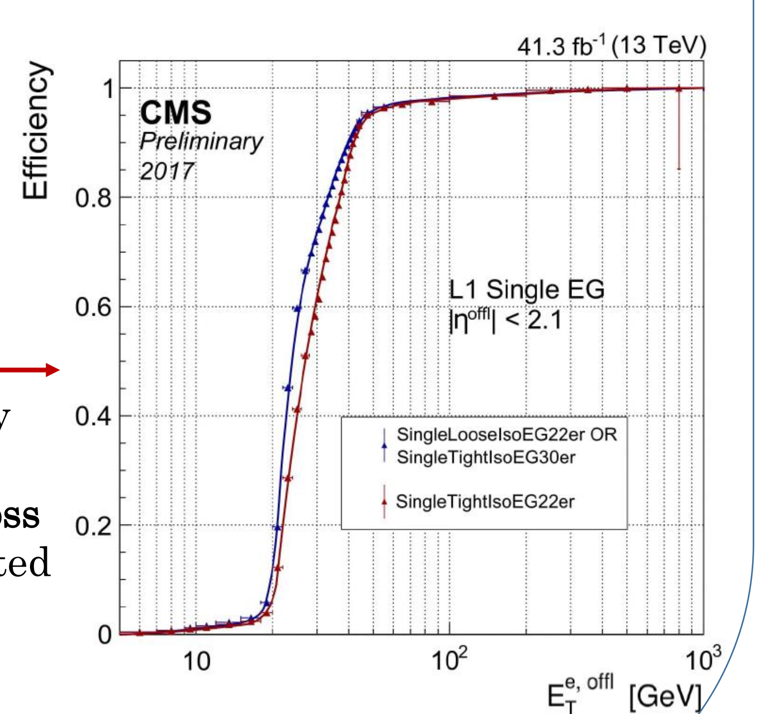
Combination of thresholds increases the acceptance for equal total rate.



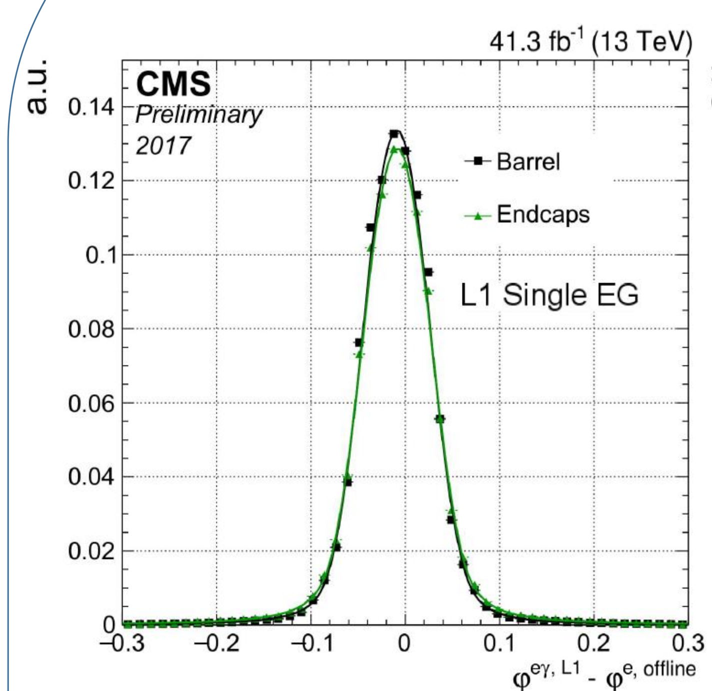


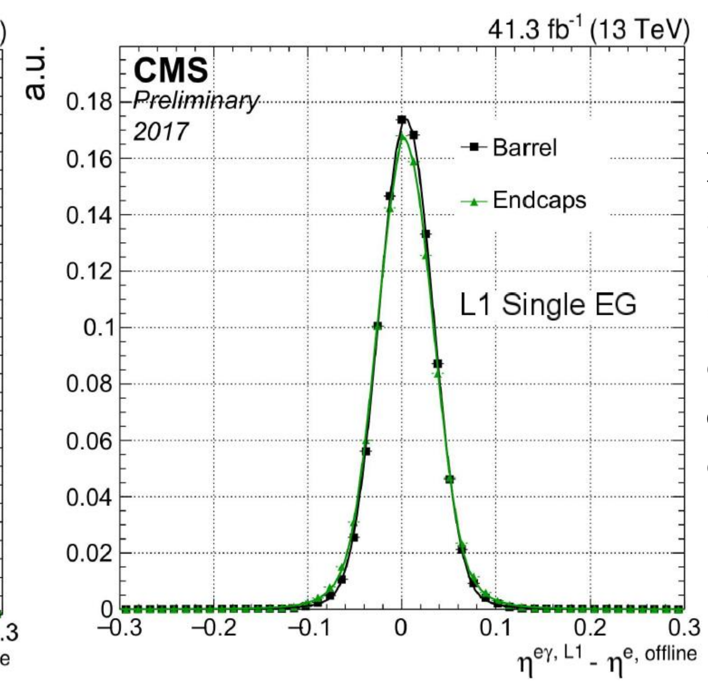
Isolation; High efficiency and **robust** with respect to pile-up.

Loose Isolation increases efficiency at low E_T. This is used in **Cross Triggers,** e.g. isolated e/γ plus μ, τ, or missing E_T.

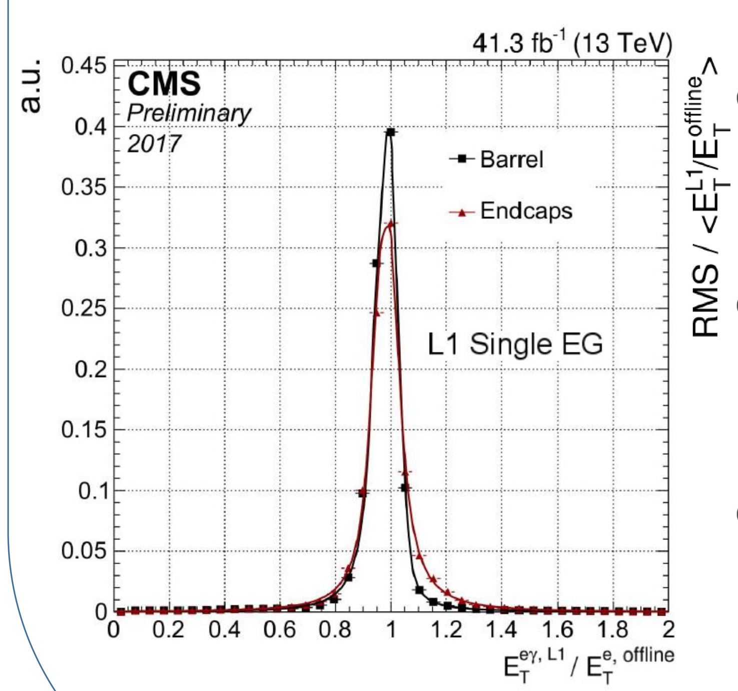


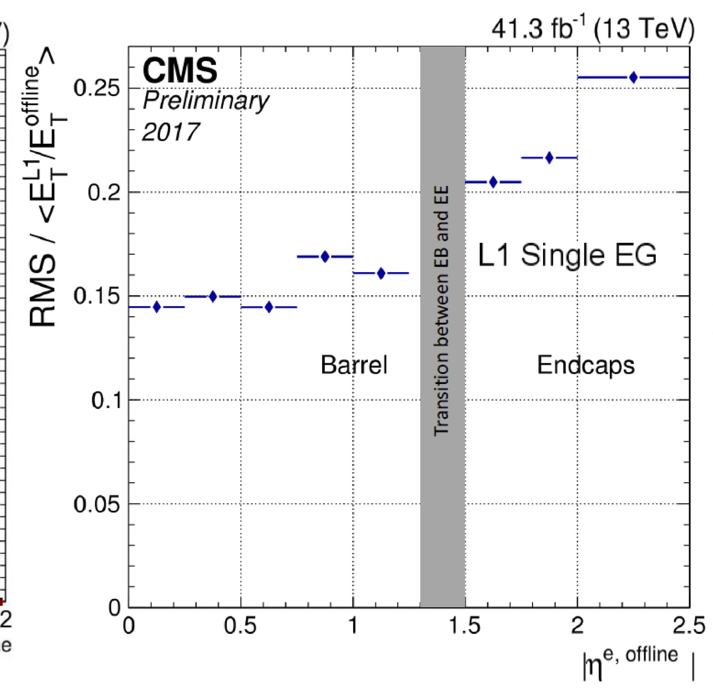
Resolution





Differences in azimuthal angle (**Left**) and pseudorapidity (**Right**) between the L1 e/γ candidates and the offline reconstructed electrons.





Left: Transverse energy E_T for L1 e/γ candidates with respect to the offline supercluster E_T.

Right: L1 e/γ trigger energy resolution with respect to offline electrons as a function of the supercluster pseudorapidity.

The CMS Level-1 trigger for electrons and photons has delivered very high performance at the high luminosity and associated pile-up conditions of 2017.

References
[1] CMS Collaboration, *CMS technical design report for the Level-1 Trigger Upgrade,* CERN-LHCC-2013-011, CMS-TDR-012 (2013)
[2] CMS Collaboration, *Level-1 E/Gamma performance on 2017 data,* CMS DP -2018/003 (2018)
[3] CMS Collaboration, A.Zabi, *The CMS Level-1 Calorimeter Trigger for LHC Run II,* CMS-CR-2016-360 (2016)

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