# Triggering on electrons and photons with CMS at the LHC


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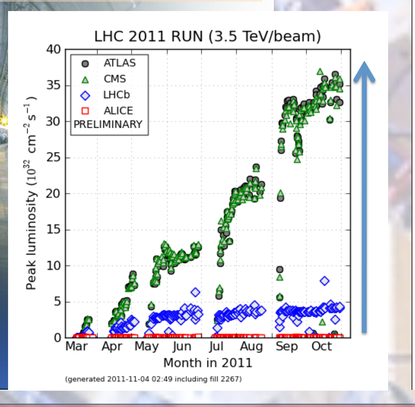
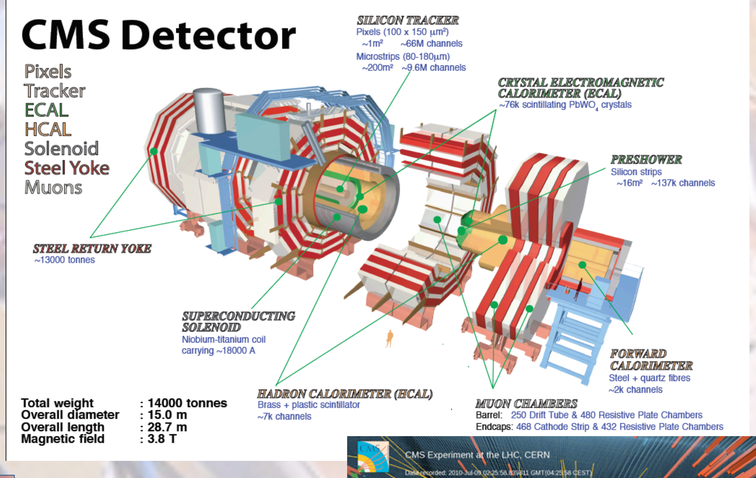
*On behalf of the CMS Collaboration*



**Record: 3.7x10$^{33}$ cm$^{-2}$ s$^{-1}$**
**Data recorded: 5.2 fb$^{-1}$**





## CMS Event Selection

The CMS trigger system is organized in 2 stages to achieve a reduction of the input data rate of the order of 4.10$^5$. The L1 trigger decision is based on coarsely segmented data from the calorimeters and muon systems. Custom made hardware is implemented at L1 while the second stage (HLT) reconstructs partially the event with full sub-detector readout using a farm of computers.

**Bunch crossing 40 MHz**

*1000TB/s*

**L1 Trigger 100kHz**

*2.5GB/s*

**High Level Trigger 300Hz**

*225MB/s*

## Level-1 Electron and Photon trigger

- 4 isolated E.M objects
- 4 non-iso E.M objects
- 4 central, forward, τ jet

Per regional RCT crate:
- 4 highest isolated E.M objects
- 4 highest non-iso E.M objects
- 4 highest central, forward, τ jet

**RCT** Regional Calorimeter Trigger

**GCT** Global Calorimeter Trigger

**GT** Global Trigger

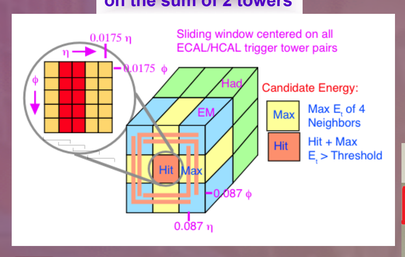
**L1 Accept**

Trigger Decision must be made within 3.2 us

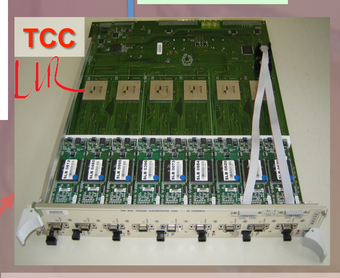
Hcal Trigger Primitives

Ecal Trigger Primitives

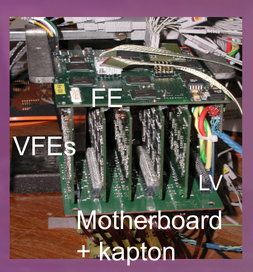
EM Objects: Based on the sum of 2 towers

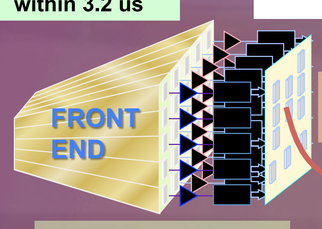



**TCC**



Trigger Concentrator Card
Synchro Link Board




*Trigger Tower (TT)*
*5x5 crystals in EB*

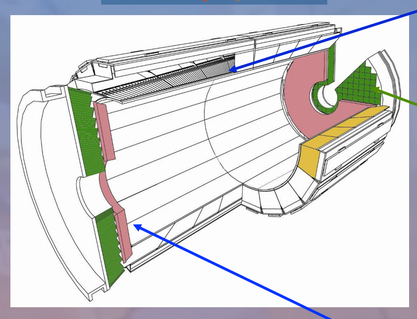
*@ 40 MHz, 800 Mb/s optical fibers (70m)*

The 25 crystals transverse energies are summed into a trigger primitive (TP) in the Front End boards (3072 total) and sent to the TCC boards (108 total) for further processing. Pairs of trigger primitives are combined by the RCT to form Isolated or Non-Isolated Level-1 EM objects.

## CMS ECAL

*CMS Electromagnetic Calorimeter (ECAL)* is optimized to reconstruct the energy of electrons and photons in Higgs events. It is made of scintillating crystals (26 $X_0$) organized in a compact and hermetic structure. It has a 0.5% constant term, it is highly segmented , radiation tolerant and equipped with fast electronics.

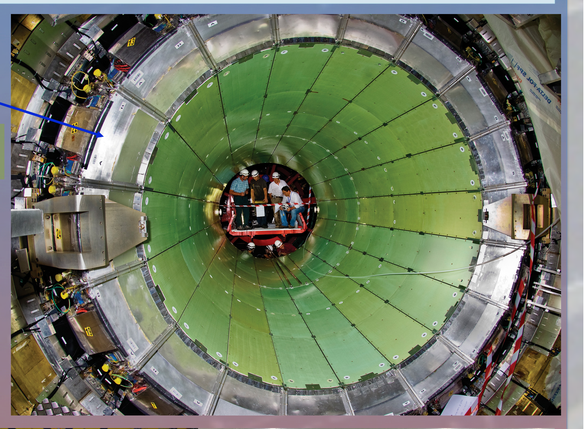
ECAL: 75848 $PbWO_4$ crystals

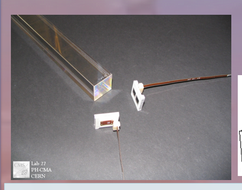


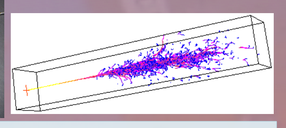
Barrel (EB)
36 Super Modules
(61200 crystals)

Endcap (EE) 4 "Dees"
(14648 crystals)

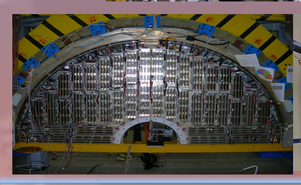
Pb/Si preshower

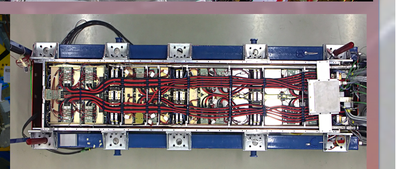






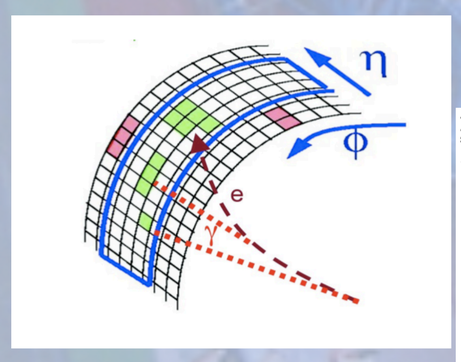
Crystal PbWO4 + APD (Avalanche photo-diode)
VPT are used in the endcaps (Vaccum photo-triode)



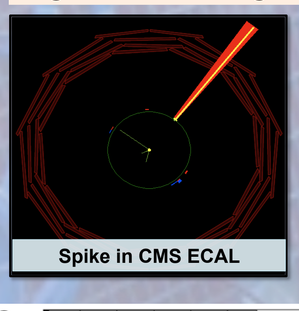


## From ECAL to the Level-1 trigger

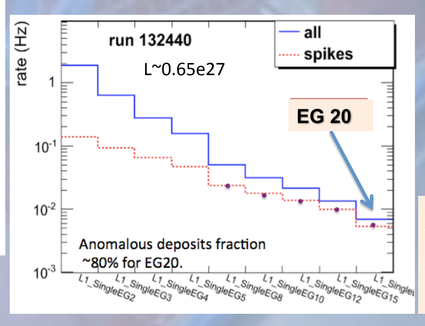
**Triggering on electron signal**: Electrons in CMS are reconstructed using the ECAL and the Tracker information. However only ECAL information is used at the level-1 trigger. As an electron can spread its energy due to bremshtralung, the cluster is extended in phi (supercluster)



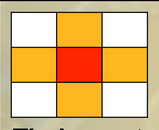

**Anomalous signals**: particles passing through Barrel APDs can cause direct ionization resulting in the generation of a large anomalous signal in a single crystal, so called "spike".



Spike in CMS ECAL




**OFFLINE IDENTIFICATION**

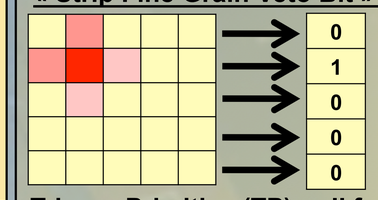


« **SwissCross** » : (1 - $E_4$ / $E_1$)
→ EM shower energy : ~80% in 1 xtal
→ Spike : single crystal

**Timing cut**
→no decay constant of scintillation light (~10ns)
→spike pulses appear earlier than shower pulses

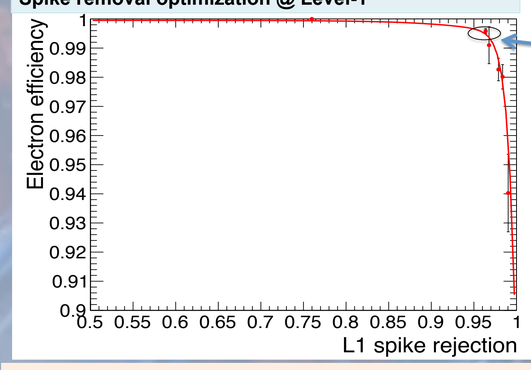
**ONLINE REMOVAL**

« **Strip Fine Grain Veto Bit** » (sFGVB)




**Trigger Primitive (TP) null for spike**
if $E_T$ (TP)>killing thresh. & sFGVB(TP)=0 → TP = 0

**Spike removal optimization @ Level-1**

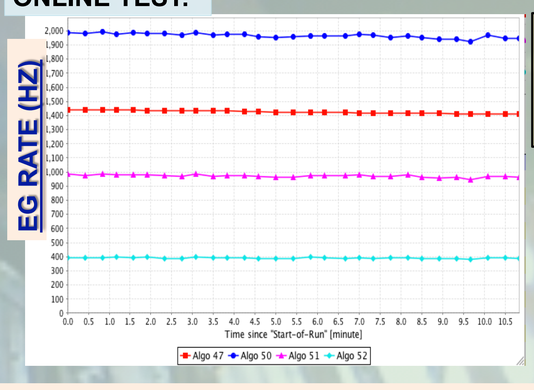



sFGVB (281 MeV) & ET(TP)>8GeV

**L1 spike rejection**: the spike removal has been optimized to reject 96% of these anomalous signals while maintaining 99.6% triggering efficiency for electrons (pT > 20 GeV)

**Finding a working point**
Using data recorded with various sFGVB and killing thresholds
Electron efficiency: fraction of electrons that keep triggering after spike removal applied at Level-1
L1 spike rejection: fraction of spikes trigger suppressed at Level-1

**ONLINE TEST:**




**L1 BANDWIDTH OPTIMIZED FOR PHYSICS:**

| Threshold (GeV) | 12 | 15 | 20 | 30 |
|---|---|---|---|---|
| Rate reduction | 3.4 | 4.3 | 6.0 | 9.6 |

Factor of 10 rate reduction of sum ET triggers (HT)

## Level-1 electron trigger performance

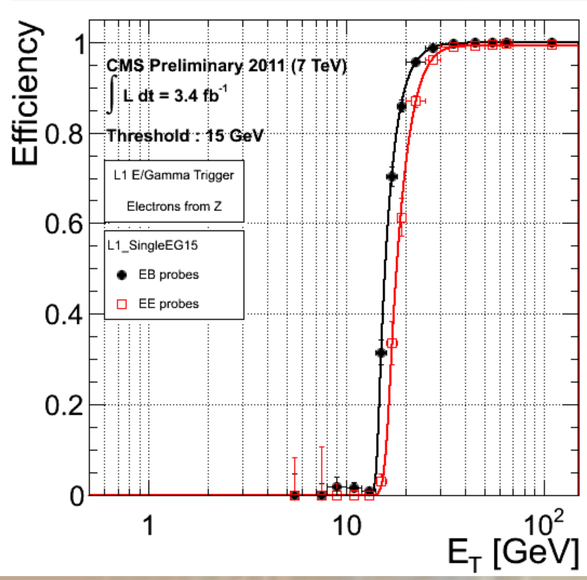
**Measuring the electron trigger efficiency using 2011 data recorded at CMS (3.4 fb$^{-1}$)**

**Method**: using the Tag&Probe on Zee selected events:
Tag: Electron ID&Isolation cuts + L1trigger seed
Probe: ElectronID&Isolation cuts
➔ Pure electron sample (negligible background)

**Matching**: matching of offline reconstructed electron with L1 candidate.
Looking for the trigger tower with the highest ET within the electron supercluster. The coordinate of that tower is used to find the Region of Interest (RCT region = 4x4 trigger towers) where the L1 candidate is produced.

**Definition:** the trigger is considered efficient if a L1 candidate is found above the studied threshold
L1_SingleEG15 : L1 EG candidate pT > 15 GeV

**L1 Electron trigger efficiency (15 GeV threshold)**



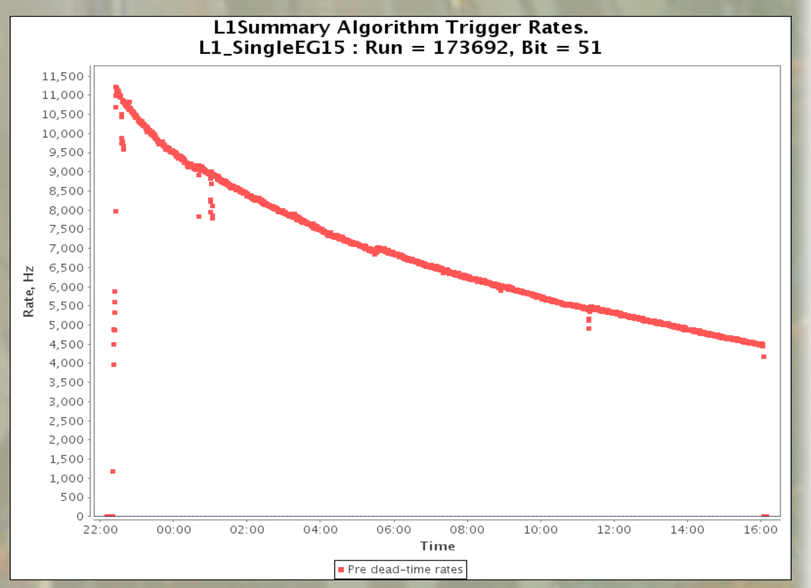

**Excellent triggering efficiency performance in 2011**

| EG15 efficiency | EB GeV | EE GeV |
|---|---|---|
| 50% | 15.8 | 18.0 |
| 95% | 22.1 | 26.1 |
| 99% | 28.3 | 35.7 |
| 100 GeV electron | 99.9% | 99.3% |

**Sources of inefficiency**
Electrons spread their energy over many TT while L1 candidate only gather 2 TT.

EE turn-on point displaced due to preshower energy not included in the trigger

Masking of Trigger Primitive at ECAL level due to hardware failure or noise:
0.2% in the Barrel
1.3% in the Endcaps




**Trigger rate under control over 18 hours of running!**
Instantaneous luminosity: 2.1x10$^{33}$cm$^{-2}$s$^{-1}$
Deadtime < 2%; L1 Rate = 53kHz
Efficiency: 98.6%
Total lumi: 83pb$^{-1}$ (Fill 2040)