The CMS Level-1 τ algorithm for the LHC Run II

Luca Mastrolorenzo – Laboratoire Leprince-Ringuet (Ecole Polytechnique)

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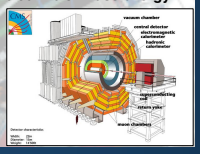
On Behalf of the CMS Collaboration

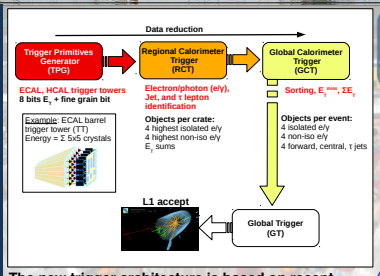
The challenge of triggering on τ-lepton

After the recent evidence of the H->ττ decay [1], its 5 sigma observation will be a priority of the run 2. In addition, the tau lepton is a privileged tool to search for new physics. The CMS experiment implements a sophisticated two-level online selection system that achieves a rejection factor of nearly 10^5. During Run II, the centre of mass energy of the LHC collisions will be increased up to 13 TeV and an instantaneous luminosity of $2x10^{34}$ $cm^{-2}s^{-1}$. In order to guarantee a successful physics program under this Intense environment, the CMS Trigger and Data acquisition system must be consolidated

[1] Nature Phys. "Evidence for the direct decay of the 125 GeV Higgs boson to fermions"- CMS Collaboration, 2014/06/22 and JHEP 1405 (2014) 104 arXiv:1401.5041

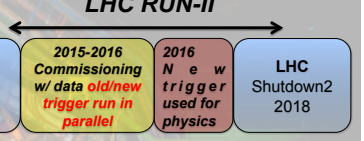


CMS Trigger Structure

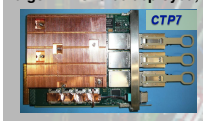


The new trigger architecture is based on recent microTCA standard from Vadatech Custom made AMC boards for layer 1&2 implementing Virtex-7 Xilinx FPGAs

Overall Schedule

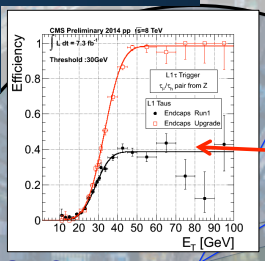


The L1 calorimeter Trigger hardware and architecture will be upgraded, benefiting from the recent microTCA technology allowing sophisticated algorithms to be deployed, better exploiting the calorimeter granularity.

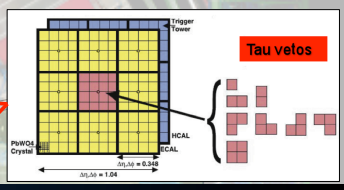


Layer-1 CPT7 board (36 boards in total)
Receiving ECAL and HCAL trigger primitives
Data formatting and pre-processing

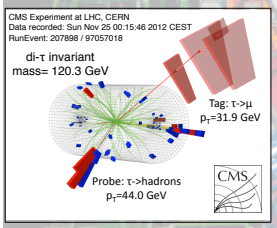
Layer-2 MP7 board (12 boards in total)
Trigger object reconstruction and identification
72+72 10 Gb/s optical links



Trigger Turn On: The limited efficiency (~70%) of the Run-I algorithm comes from the presence of a shape vetos and isolation criteria used to control the rate.



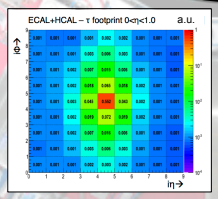
Conceiving a working L1 τ algorithm



Studies performed on real data:

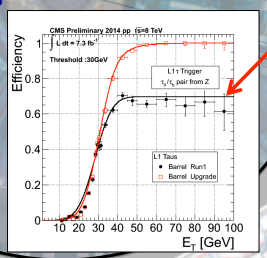
Dataset:	pp collision - 2012 data
Integrated Luminosity	7.3 fb^{-1}
Energy in the C.O.M	8 TeV
Events triggered by a mu with pT> 15 GeV	
Tag and Probe selection:	
Z->tau(->mu)tau(->had) events	
Tag (muon):	p_T > 24 GeV, |η| < 2.3
Probe (tau_had):	p_T > 20 GeV, |η| < 1.3
Visible invariant mass:	[42.5 ,72.5] GeV

Detailed studies on the tau footprint have been performed. The dynamic clustering is able to adapt to the large variety of tau energy deposit patterns

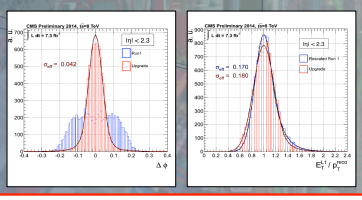


Turn On Curves

Level-1 tau trigger efficiency as a function of the offline tau calorimetric transverse energy for taus in the barrel (black) and in the endcaps (red) for a level-1 transverse energy threshold of 30 GeV.

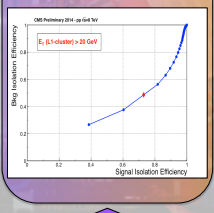


New τ Trigger Performance

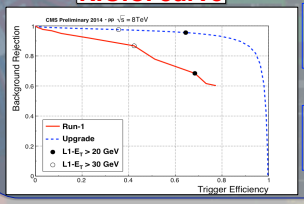


→ ANGULAR RESOLUTION 4-TIMES BETTER THAN RUN-1
→ COMPARABLE ENERGY RESOLUTION WITH RUN-1 WHILE USING A 90% SMALLER AREA

Isolation ROC Signal vs Bkg



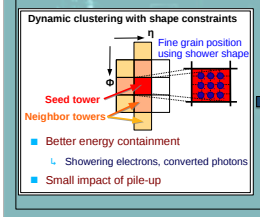
R.O.C. curve



+ 30% background rejection for trigger W.P 20

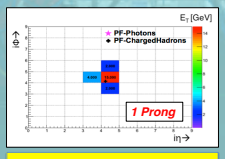
Possibility to trigger on low p_T τ-lepton

Dynamic clustering algorithms



E/G algo: building brick for the new L1-τ

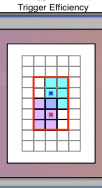
- E+H instead of E only
- No H/E VETO



For the 1 Prong's decay modes the new EG algorithm should be adequate modulo some modifications

DYNAMIC ISOLATION

The isolation is computed summing the energy in a 5x9 region in the (iη,iφ) plane after the subtraction of the energy assigned to the L1-τ

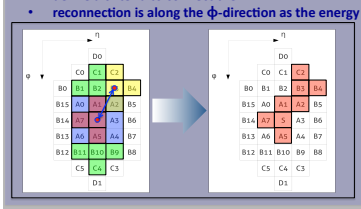


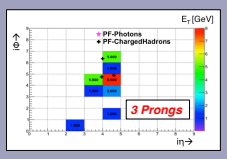
L1-τ region dynamically assigned:
→ Cluster shape information
→ Cluster relative positions

Merging more clusters

For the 3 Prong case, two clusters of the type "EG" might be found:

- define a criteria to connect them
- reconnection is along the ϕ-direction as the energy deposits of the 3 Prongs are spread only along ϕ





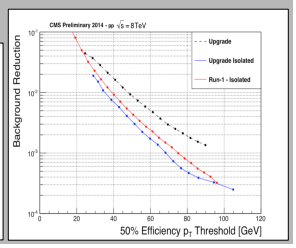
Cluster Calibration Procedure:

- E_T-dependent calibration: $E_{T\text{-Calibrated}} = [a(E_T)E_{T\text{-ECAL}} + b(E_T)E_{T\text{-HCAL}} + \text{Offset}] \times f(\eta)$
- η-dependent calibration on top of the E_T-dependent one

Conclusion

A new L1-trigger system entirely dedicated to the τ–lepton has been developed for the LHC phase II

MicroTCA Technology → Finer granularity (From RCT→TT (Information reduction of a factor ~10)) → • Dynamic clustering • Merging of clusters • Sophisticated calibration

Dynamic Isolation → Rate Control

- Excellent performance in term of efficiency and angular resolution in a wide range of W.P.
- Comparable energy resolution with current system using ~90% less trigger towers
- Using a tight isolation in the upgraded system, for the same efficiency as in Run-I, ~30% more background is killed
- The possibility to trigger efficiently on τ lepton in a wide range of energy will increase the sensitivity of the H->ττ and new physics searches performed in CMS