The CMS Level-1 Trigger for Run-II

Costas Foudas

University of Ioannina Greece and CERN

On behalf of the CMS Level-1 Trigger Group

Goals of the Level-1 Trigger Upgrade for Run-II

- **Electron and Photon Triggers**
  - Better isolation for electron/photon triggers
  - Pile up subtraction
  - The new electron/photon algorithms is similar to offline
- **Jet triggers based on calorimeter towers (0.087x0.087)**
  - A factor of 16 better granularity and pile-up subtraction
  - Improvement of jet η and ϕ resolutions
- **Tau Trigger**
  - Much improved efficiency and modest rata reduction
  - Capability of triggering at hadronic taus
  - Pile-up subtraction
- **Muon Triggers**
  - Improvement of the muon P_T-Resolution
  - Significant reduction of background rates at high η
- **Capability for introducing new triggers**

Level-1 Trigger Strategy

- Build a very flexible trigger to adapt to the physics needs of CMS from LS1 to LS3, and provide basis for further development and expansion for beyond LS3

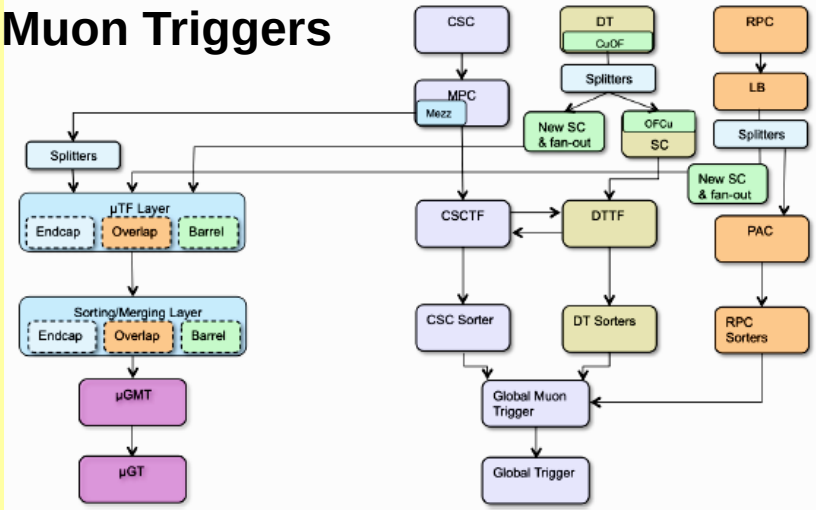
- CMS must have a functional trigger, appropriate to LHC running conditions, at all times

- Build up in parallel ready for running in 2016 to safeguard CMS physics, decouple from LHC schedule

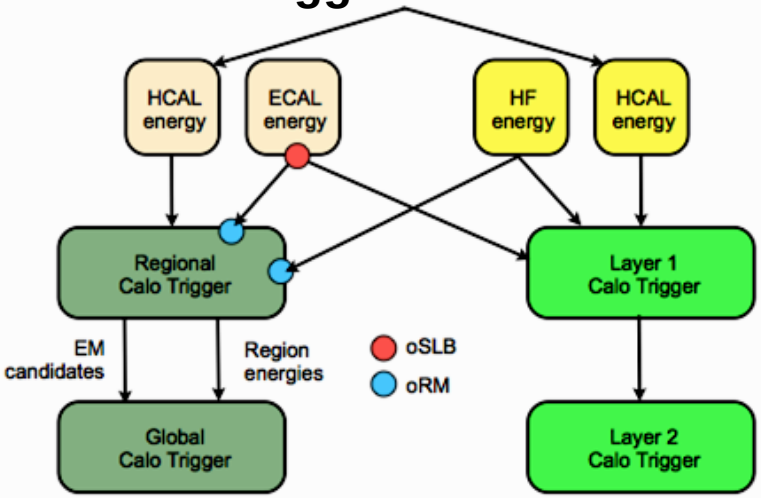
- Implement low-risk, modifications to the present trigger during LS1 to ensure improved performance at startup in 2015

- **See: http://cds.cern.ch/record/1556311/files/CMS-TDR-012.pdf**

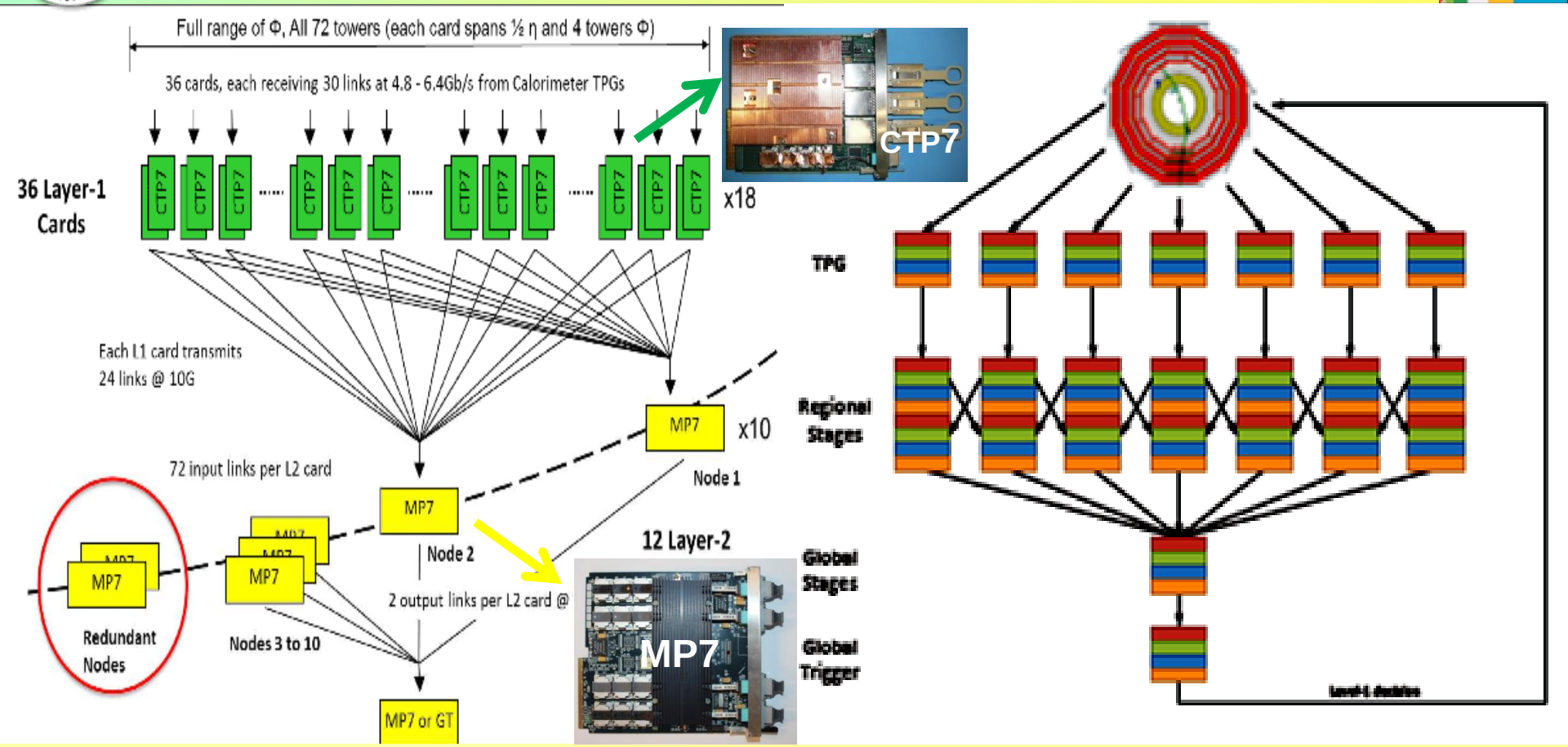
Muon Triggers



Calorimeter Triggers



Calorimeter : Time Multiplexed Trigger



TMT Design:

(1) Eliminates boundaries and can take data at full detector granularity

(2) Allows for more flexibility in algorithm design

(3) It can be upgraded in a 'straight-forward' way

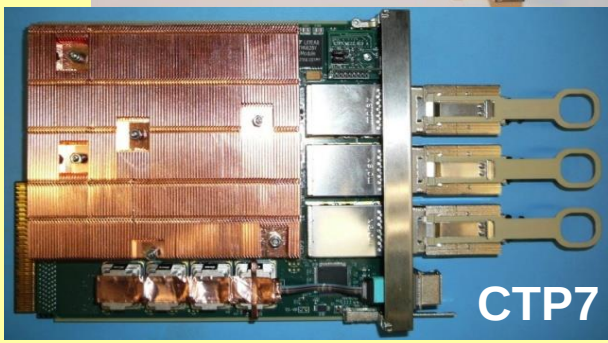
(4) It brings the Lvl-1 capabilities closer to HLT

CMS L-1 Trigger Hardware Platforms in µTCA

- **MP7 (Calo Trigger Layer-2):**
  - 72 I/O Optical Links at 10 G, Virtex-7 690 FPGA
  - Also used for, Global Trigger, Global Muon Trigger and the Barrel Muon Track Finder

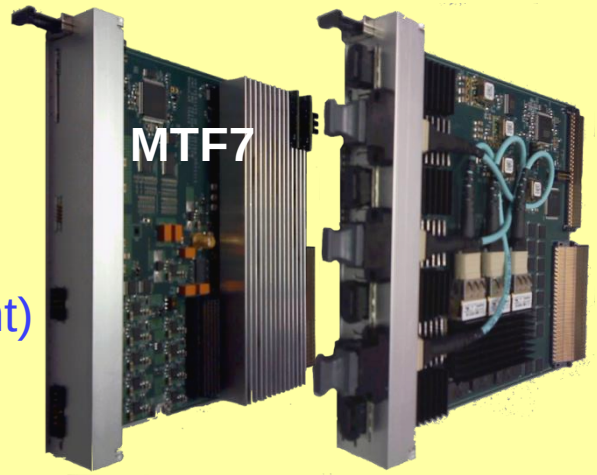
- **CTP7 (Calorimeter Trigger Layer-1):**
  - 67 Rx, 48 Rx Links at 10 G
  - Virtex-7 690 FPGA

Telecom Standard



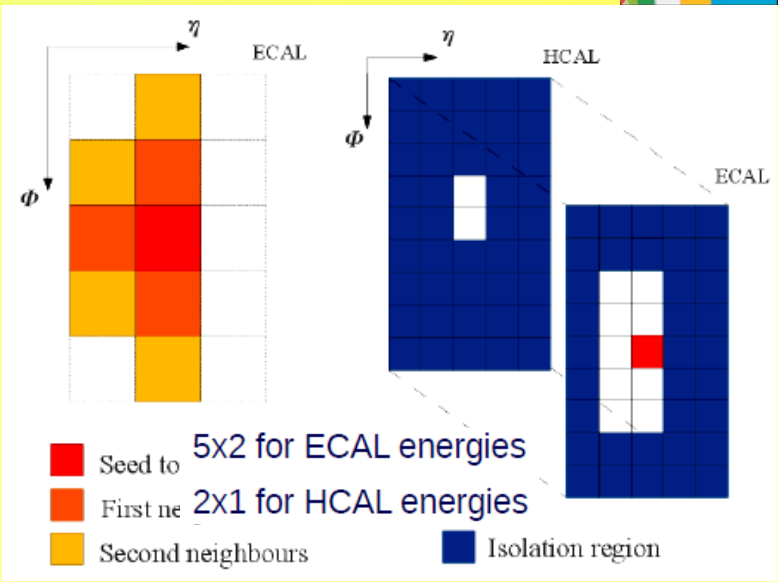
- **MTF7 (EndCap,Overlap Muon Track Finder):**
  - Optimized for maximum input from muon detectors (84 Rx, 28 Tx @ 10 Gbps)
  - Dual card with large capacity RAM (~1GB) for p_T assignment in track finding

- **Modular µTCA designs which allow for**
  - Different trigger architectures
  - Adding more processors as needed
  - Data exchange via the µTCA backplane (point-to-point)

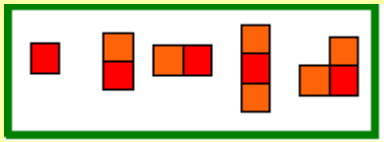


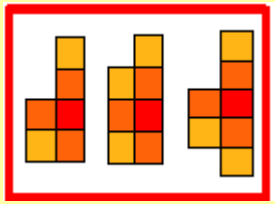
L1- Electron Finding Algorithms

- **Search for seeds with E_T>2 GeV threshold**
- **Form 3x3 calorimeter tower proto-clusters**
  - Dynamical Trimming (Brem., Posit., E_T resol.)
  - Towers with E_T > 1 GeV are clustered.
  - The side in η with the maximum E_T is kept.
  - Corners kept only if linked to the seed.
  - Extensions in ϕ are added if linked to the seed.



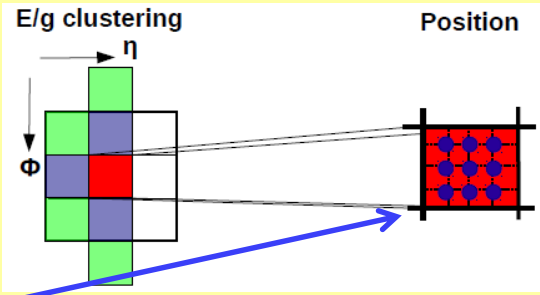
e/γ like



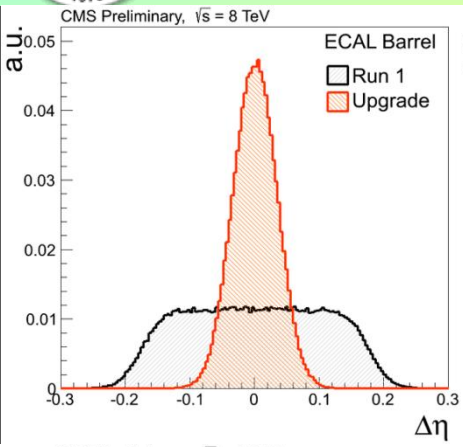


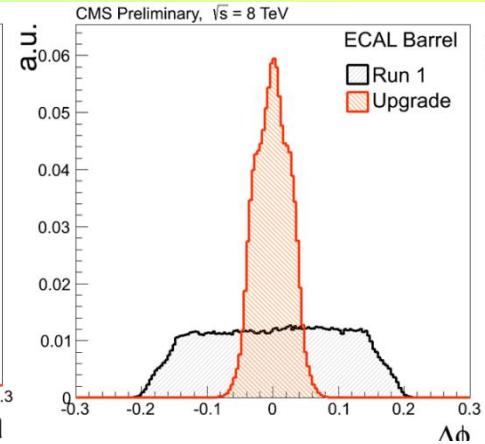
jet like

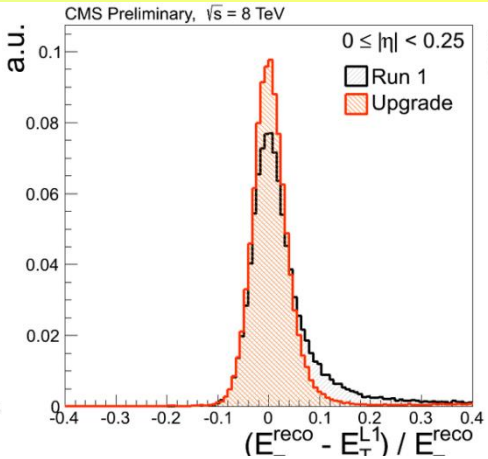
- **Require Fine Grain Bit and H/E cut**
  - The Fine Grain Bit requires that the energy deposition within a tower is consistent with that from an electron (ϕ band of crystals).
  - H/E < 0.040 in the EndCap and H/E < 0.015 in the Barrel
- **Require a 9x5 tower isolation window**
  - E(5x9)-H(1x2)-E(2x5) < Isol-cut (nTT, η)
- **9 Possible Impact points based on cluster shape**

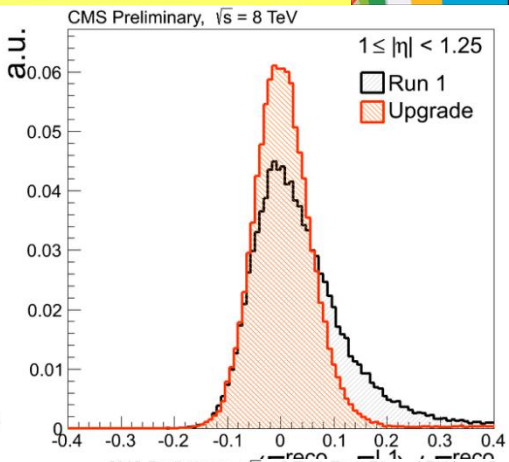


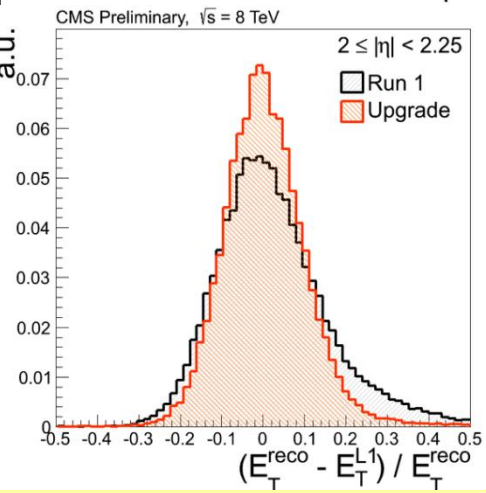
L1- Electron Finding Performance

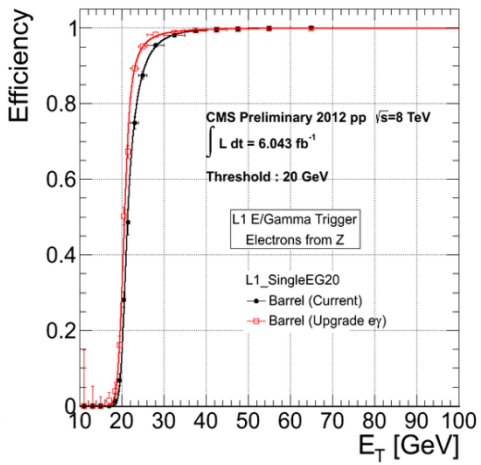


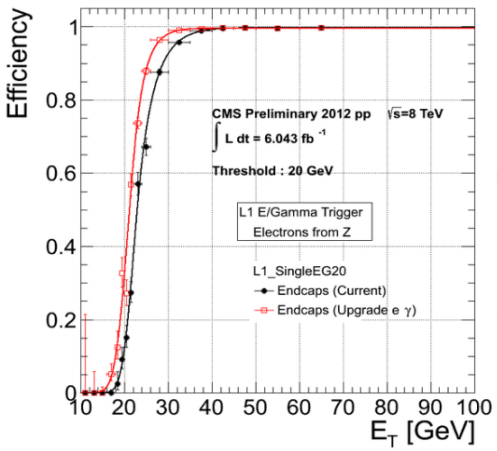


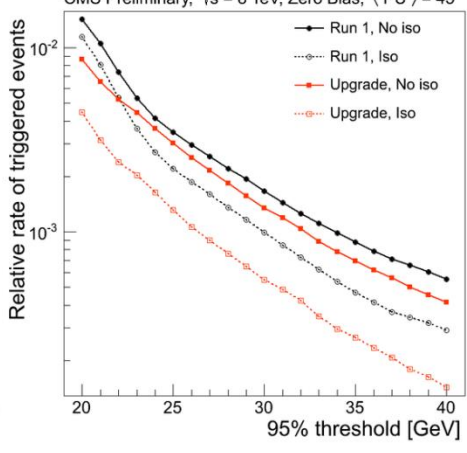






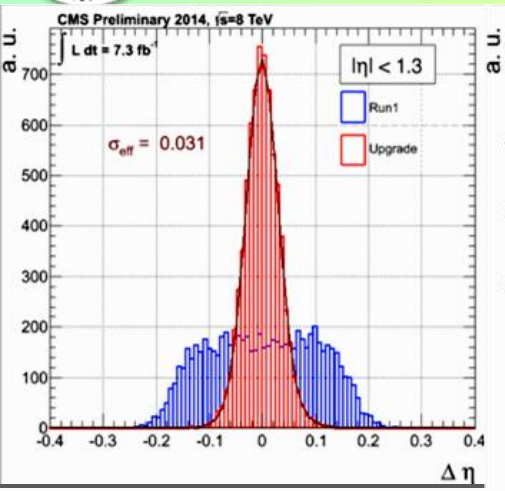


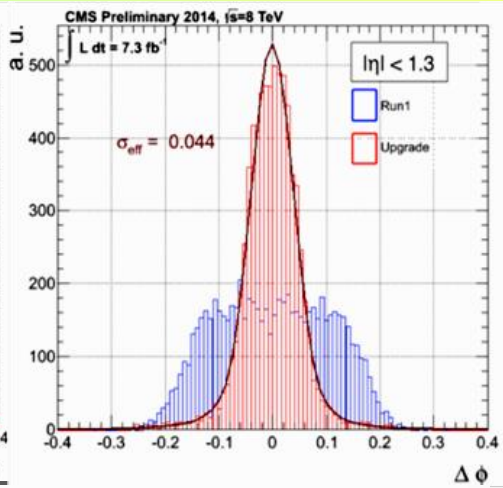


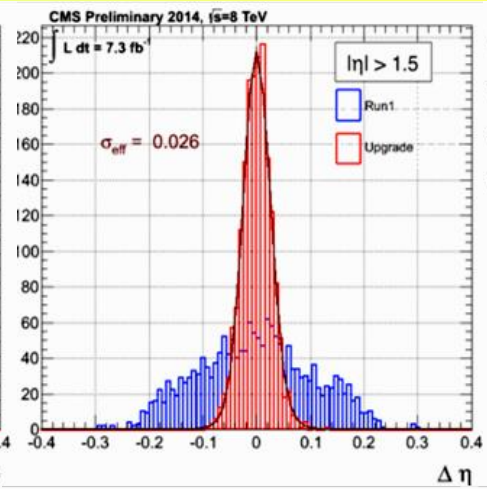


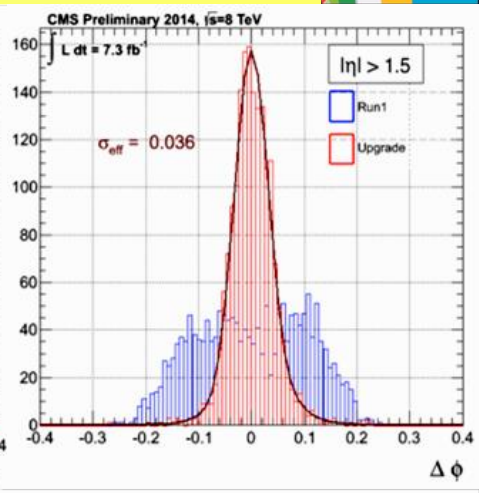
- **Market improvement in η, ϕ, and E_T resolutions.**
- **Sharper threshold curves to reduce backgrounds.**
- **Non Iso-e rates by ~2 lower for E_T <20 GeV and 10-20% lower for E_T >30 GeV.**
- **Iso-e rates 30% lower than before.**

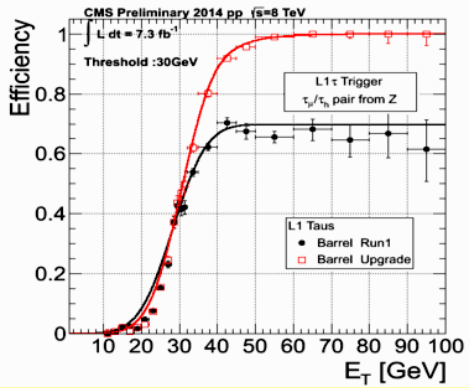
Level-1 Tau Triggers

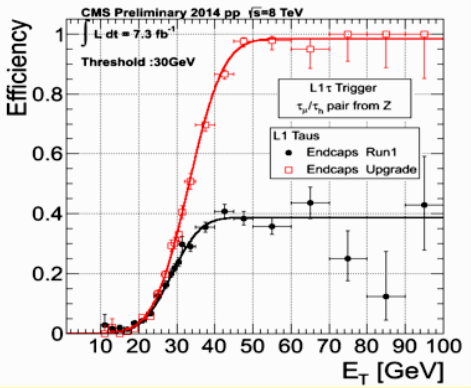


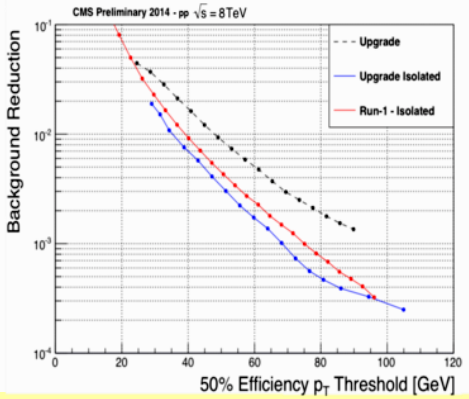


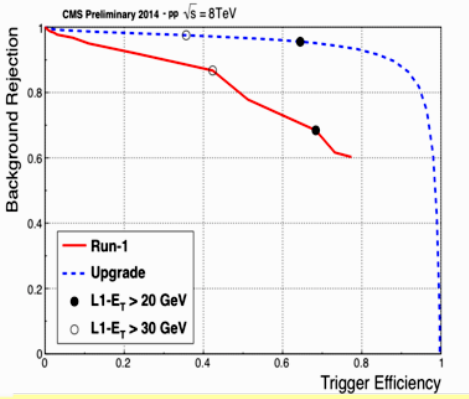








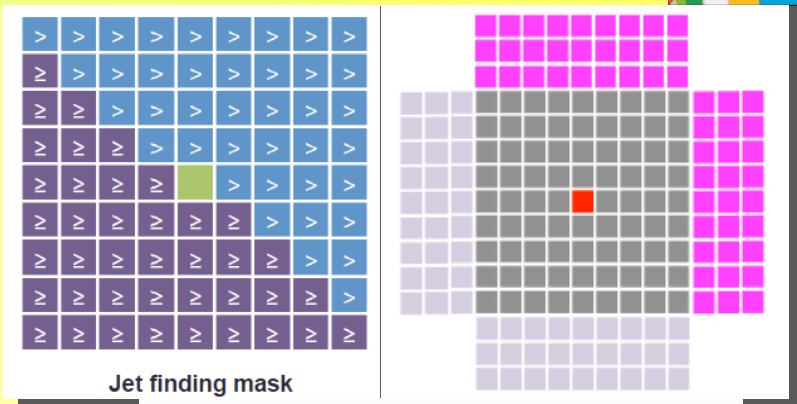


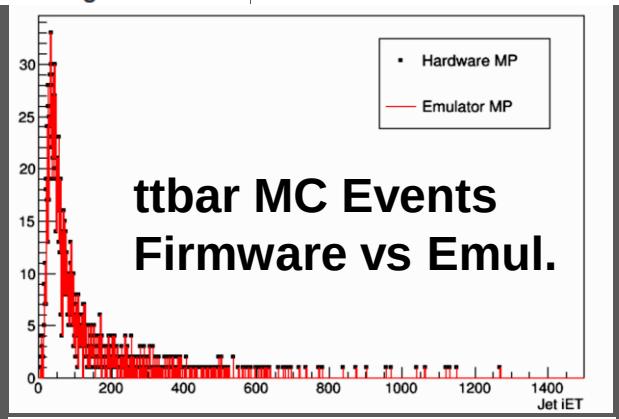


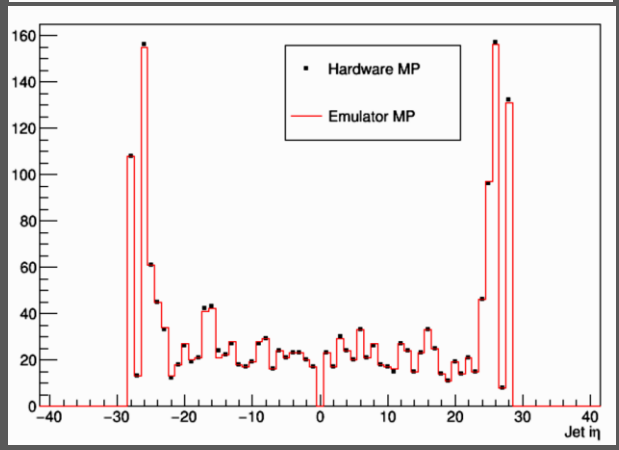
- 1-prong or 1-Prong + π^0 : Use e/gamma clusters with E+H and no H/E cut (2x3).
- 3-prong: Search for extra seed in the φ direction and if found combine clusters.
- Dynamically assign the tau footprint based on cluster shape (5x9, 3x5, 2x5).
- Isolation based on a 5x9 window.
- Dramatic improvement in efficiency; modest rate reduction; E_T>20 GeV possible.

CMS Level-1 Jet Trigger Performance

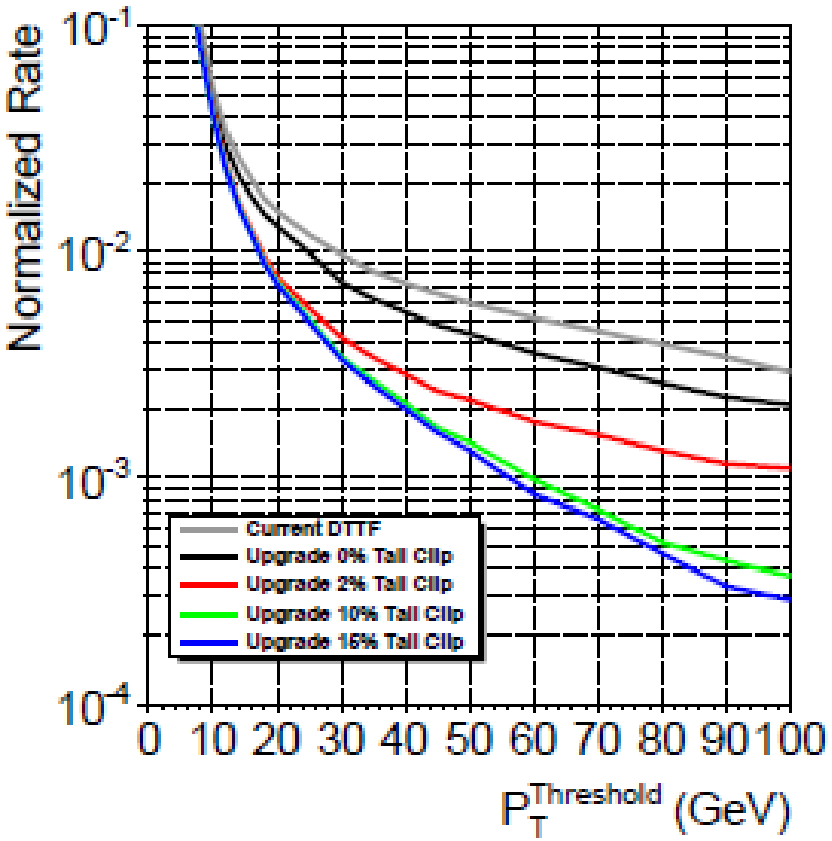
- Use a 9x9 tower mask which ~ R=0.4
- Compare all trigger tower depositions in the mask with the seed.
  - Use > for blue
  - Use ≥ for purple
- If the above statement is TRUE then veto the jet and move on to another seed.
- For Pile-up Subtraction two approaches:
  - Global jet based ρ subtraction: Estimate energy to subtract off jet using the median of calorimeter energy deposits, see arXiv:0707.1378v2
  - Local subtraction: Estimate energy to subtract off jet using a region local to the jet, see arXiv:1010.1759
  - The local is currently implemented but the global will also be tried

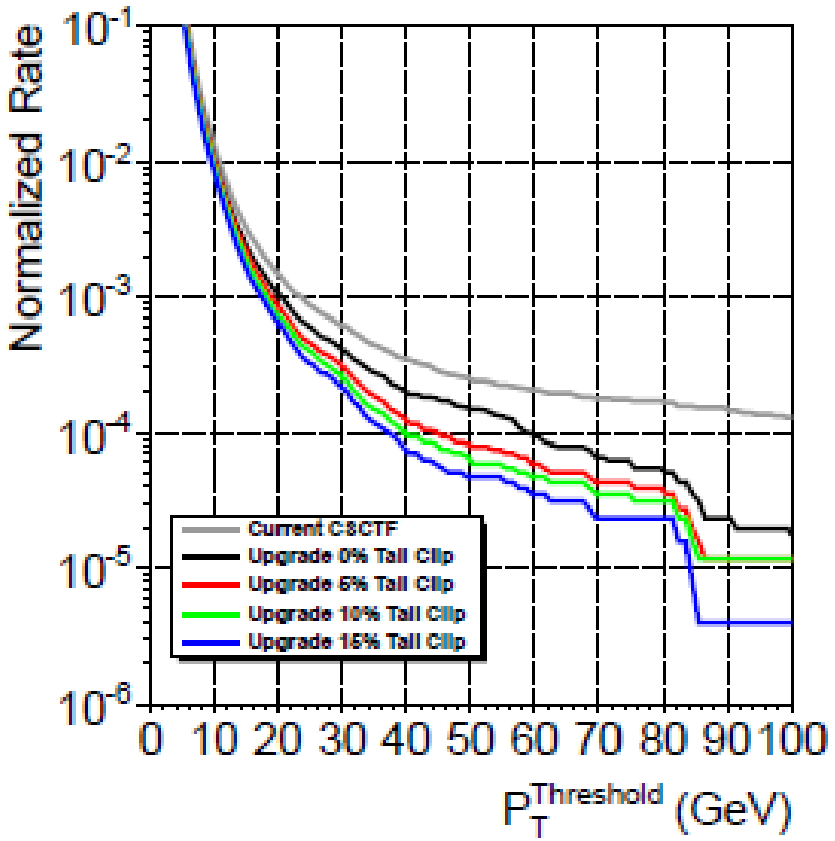






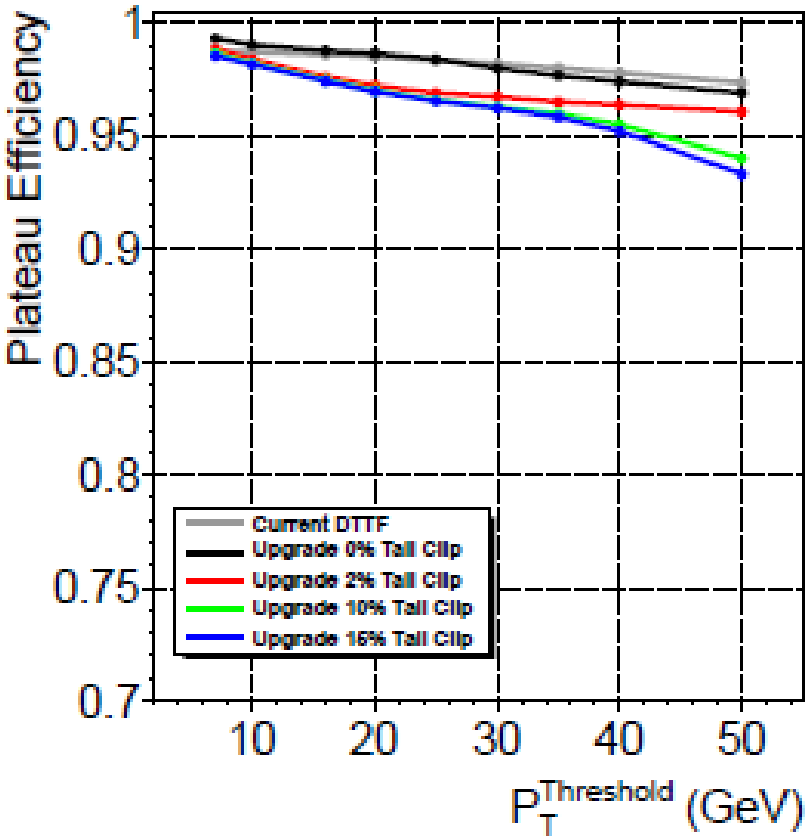
CMS L1 Muon Track Finder Rates

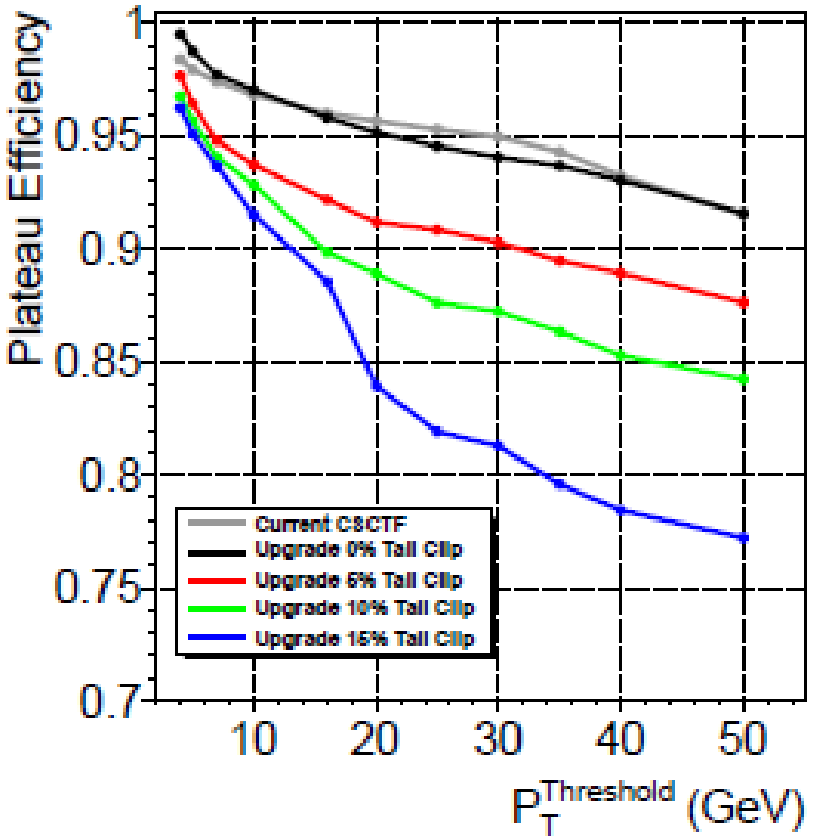




- **The new muon trigger aims mainly in increasing the muon P_T resolution. Hence to reduce the rate. It does this by using large LUTs (EndCap) and advanced pattern recognition (Overlap and Barrel).**
- **Three Muon track finders have been installed: Overlap, EndCap and Barrel.**
- **The first two consist of 12 MTF7 processors and the last of 12 MP7 processors.**

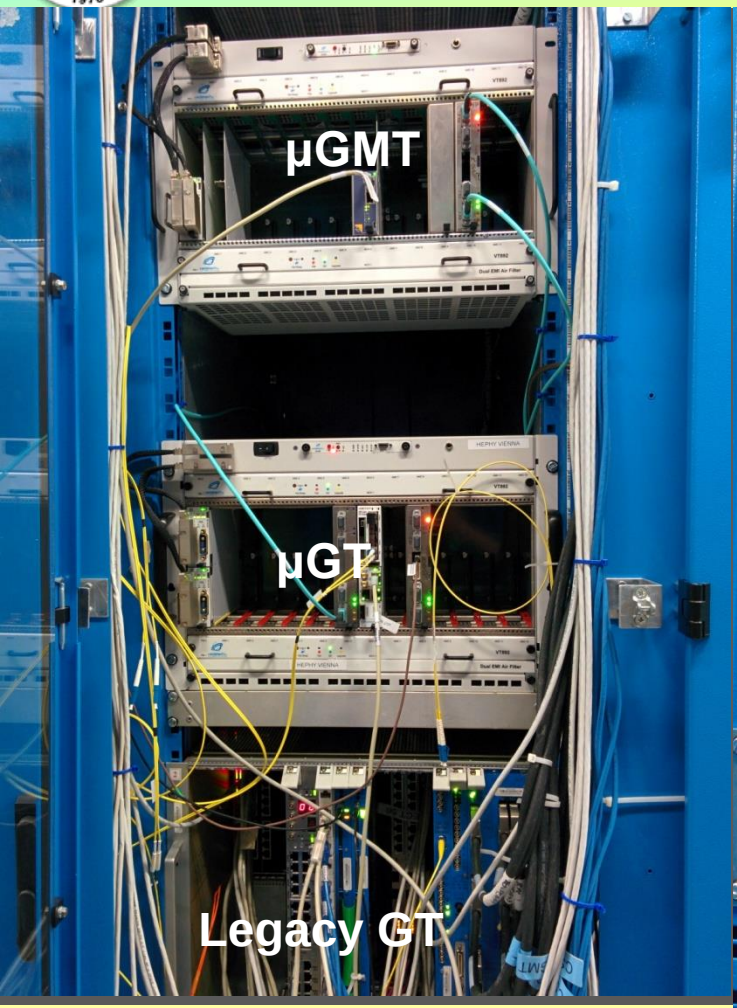
CMS L1-Muon Trigger Efficiencies

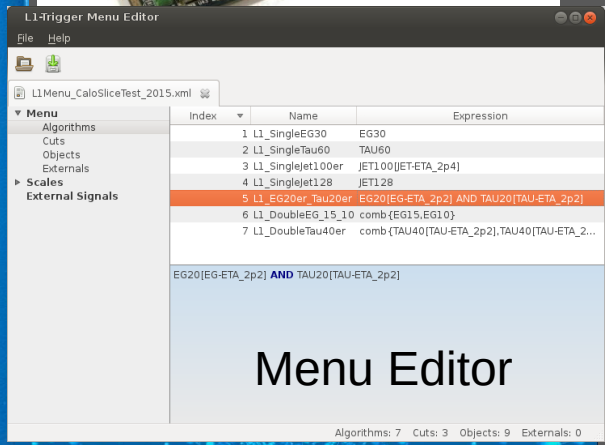




- **Modest loss of efficiency results to considerable reduction in rate.**
- **The efficiency loss in the Barrel (right) is minimal but it is larger in the EndCap**
- **All three track finders are undergoing testing at P5 and parallel running with the legacy system is to commence during September/October.**
- **The new muon Trigger will be operational in February 2016.**

CMS L1 Global and Global Muon Trigger

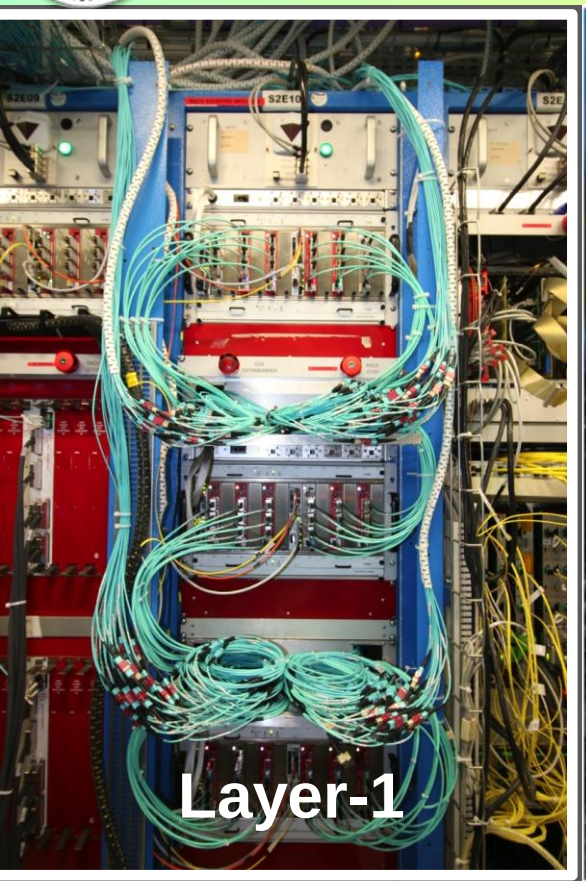


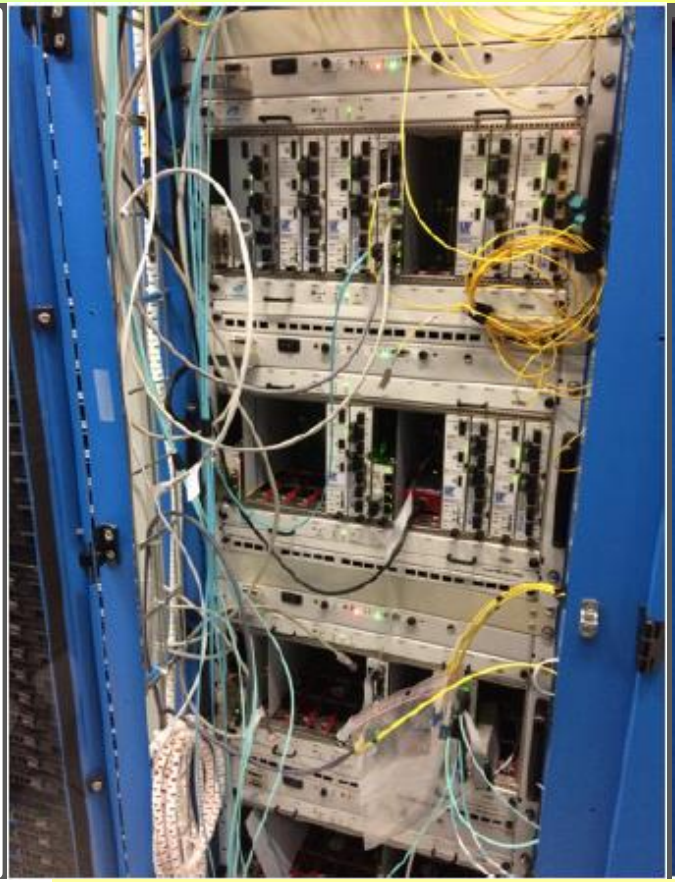


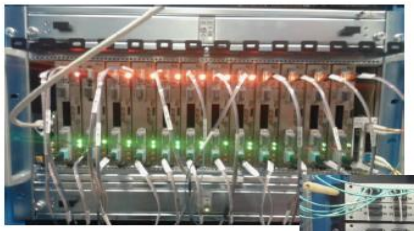
HEPHY
Institute of High Energy Physics

- Use the one MP7 trigger processor but has been designed to be expandable by adding more MP7s. Firmware for the basic trigger menu has been tested.
- **To be commissioned in September 2015**

Trigger Electronics at P5







- All trigger groups have installed electronics at P5 and testing has started.
- Calo. Trig., uGT, uGMT, EndCap Muon TF : Complete.
- Barrel and Overlap to be completed by Sep. 2015.
- **Parallel running with Legacy Trig. In the Fall 1025.**

CMS Level-1 Trigger Summary

- **CMS is Looking forward to the High Luminosity LHC runs and is confident that will be able to exploit the full physics potential of the data.**
- The new Level-1 trigger system will enable CMS to operate at high luminosity and high pile-up with a better selection efficiency.
- It is planned to start taking data with the new trigger early in 2016. However, a small scale upgrade of the calorimeter trigger has been commissioned and is ready to go in for the 25ns run. And this will give:
  - Improved isolation for electron triggers
  - Improved tau trigger
  - Pile-up subtraction
- We are getting ready for new discoveries starting in 2015.
- We feel confident that with the upgraded detector we will be able to measure the Higgs properties with increased precision.