The Level-1 muon trigger for CMS

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The Level-1 Muon Trigger at CMS

The hardware-based Level-1 Trigger (L1) is the first part of the CMS Trigger system. **Its main goal is to perform a physics selection** and as a result it reduces the bunch crossing rate of 40 MHz delivered by LHC down to 100 kHz.
Muons can be tracked from their ionization deposits in CMS

Goal of the L1 muon trigger:

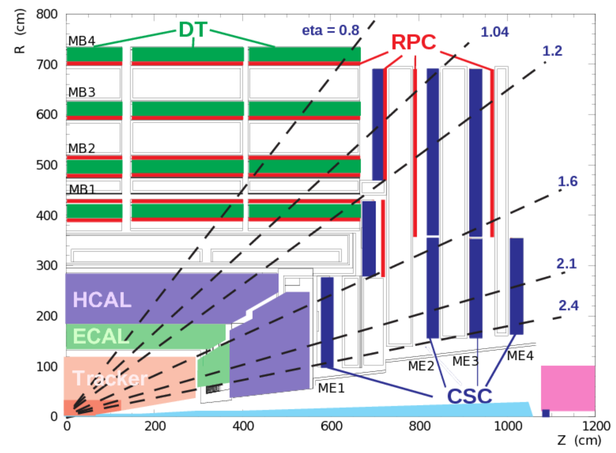
- Optimising muon reconstruction to achieve the highest efficiency and quick trigger decisions (<4 μs)

The L1 trigger algorithms:

- Identify muon tracks and assign p_T & quality.

The L1 muon trigger after the 2016 upgrade in a nutshell:

- Region based system: muon track finders combine info from subsystems to generate muon candidates
- The 3 TF: Barrel Muon TF (BMTF), Overlap Muon TF (OMTF), Endcap Muon Track Finder (EMTF)
- **The best 36 muons from every regional TF** are selected and sent to the Global Muon Trigger (GMT)
- GMT: **muon sorting** (p_T & quality), **duplicate removal**
- **8 best muons sent to the Global Trigger**



The L1 muon trigger Algorithms

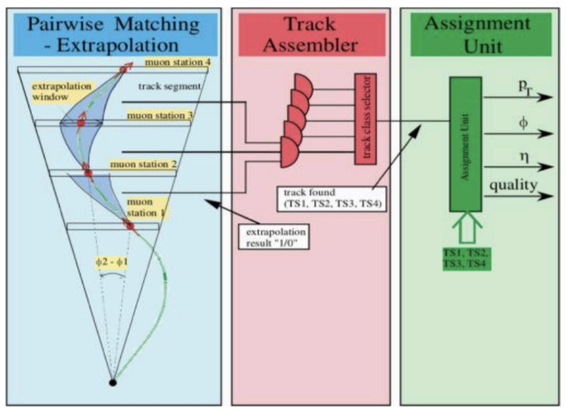
The BMTF algorithm

Combines **DT** & **RPC** information:

✓ **Extrapolator unit**: forms acceptance windows and super-primitive pairs

✓ **Tracker Assembler Unit**: Receives paired super-primitives and combines them to reconstruct a track. At the end a quality bit is assigned in every track based on its length

✓**Assignment unit**: Uses look-up tables (LUTs) to assign p_T, η and φ in a tracks.



The OMTF algorithm

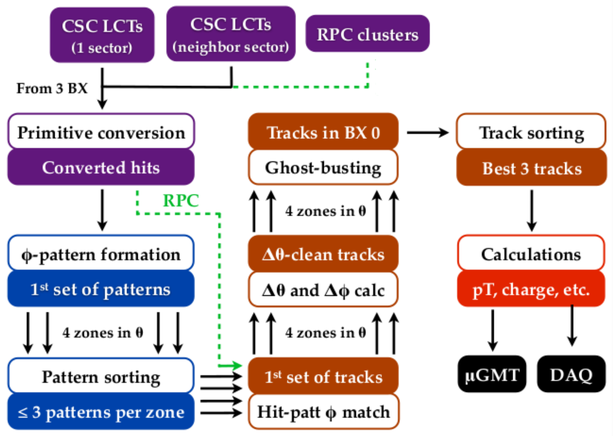
✓ Uses **DT** and **CSC** tracks and **RPC** hits

✓ Uses 52 Golden Pattern (GP) modules

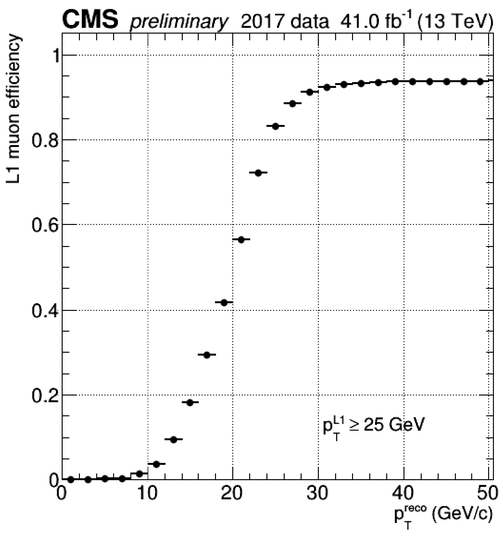
✓ Calculates **Δφ between hits and a reference hit, uses GPs to calculate log-likelihood of a p_T-sign hypothesis**

✓ Best GP based on the highest non-zero layers log-likelihood and highest sum of log-likelihood

The EMTF algorithm



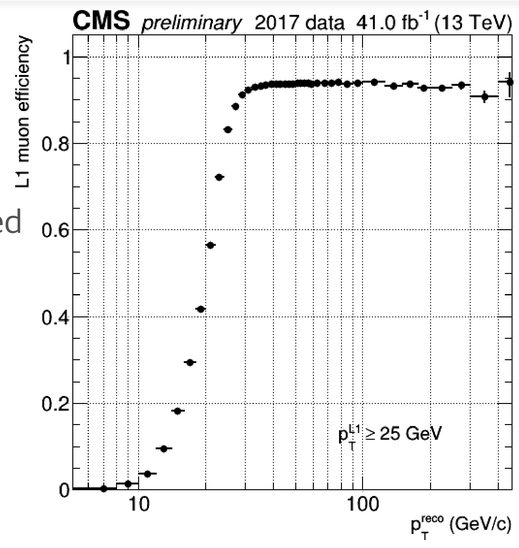
The L1 muon trigger performance in 2017

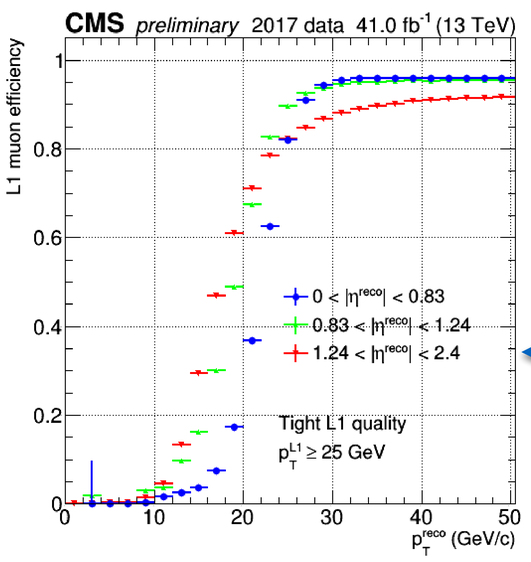


Efficiency vs. p_T for all muons (-2.4 < η < 2.4). The full single muon dataset from 2017 was used for these plots.

Left: Zoom in the region p_T<50 GeV

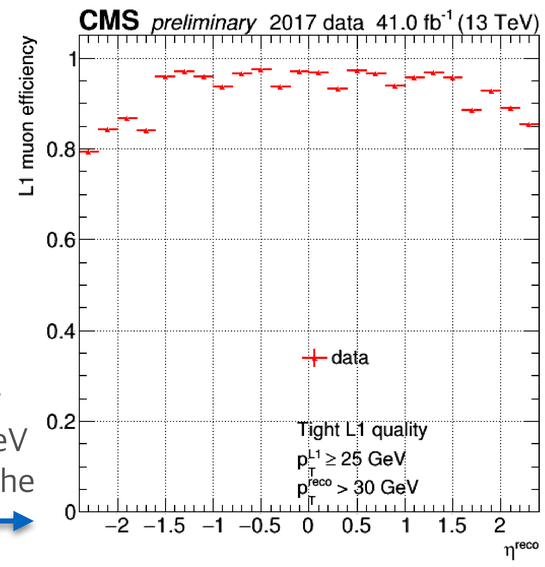
Right: Full p_T range.





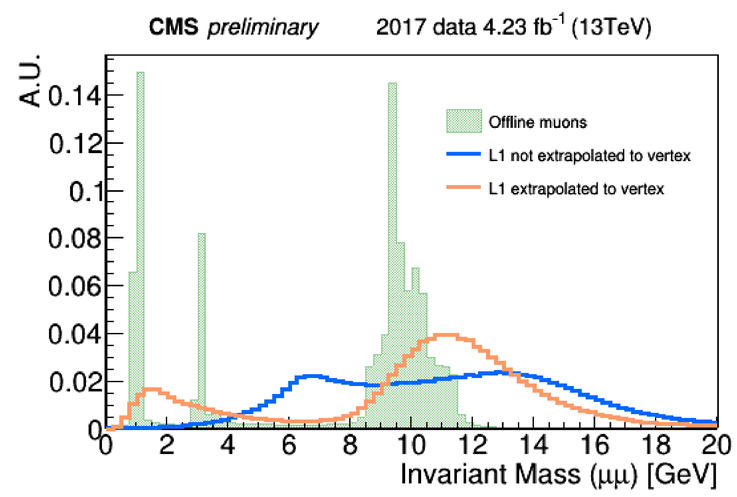
Left: Efficiency vs. p_T for all TFs. The three TFs use trigger primitives from different detectors. Blue BMTF, green OMTF, red EMTF. The full single muon dataset from 2017 was used for these plots.

Right: Efficiency vs. η for muons passing p_T > 25 GeV at L1 and p_T> 30 GeV in the offline reconstruction.



The L1 Dimuon Invariant Mass

The GMT is able to extrapolate the muon track reconstruction to the vertex by using a programmable LUT that has been optimised for 2017 data taking. This upgrade resulted in **improvement of the L1 muon trigger resolutions in p_T, η, φ and in the L1 dimuon invariant mass.** For the invariant mass spectrum below, part of the MuOnia sample collected in 2017 was used.



The M_{offl} spectrum compared to the M_{L1} spectrum with and without L1 track extrapolation to the vertex. M_{L1} appears shifted compared to M_{offl} due to p_T offsets designed to make the L1 muon trigger 90% efficient at any given p_T threshold. This result was **used successfully by a lot of b-Physics triggers** (e.g L1_DoubleMu4p5er2p0_SQ_OS_Mass7to18, L1_TripleMu_5_3p5_2p5_DoubleMu_5_2p5_OS_Mass_5to17 and others). **Data taking with high-level type of selection at the hardware level of the data acquisition system was achieved.**

The efficiency of the L1 muon trigger was measured using the tag and probe method and found to be greater the 90% for all the Track Finders

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References:

[1] CMS collaboration, The new Global Muon Trigger of the CMS experiment, CMS CR-2016/139
[2] CMS collaboration, Dimuon Level-1 invariant mass in 2017 data, CMS-DP-2018-002
[3] CMS collaboration, Level-1 muon trigger performance with the full 2017 dataset, CMS-DP-2018-008