Usage of tracking in the CMS Level-1 trigger for the High Luminosity LHC Upgrade

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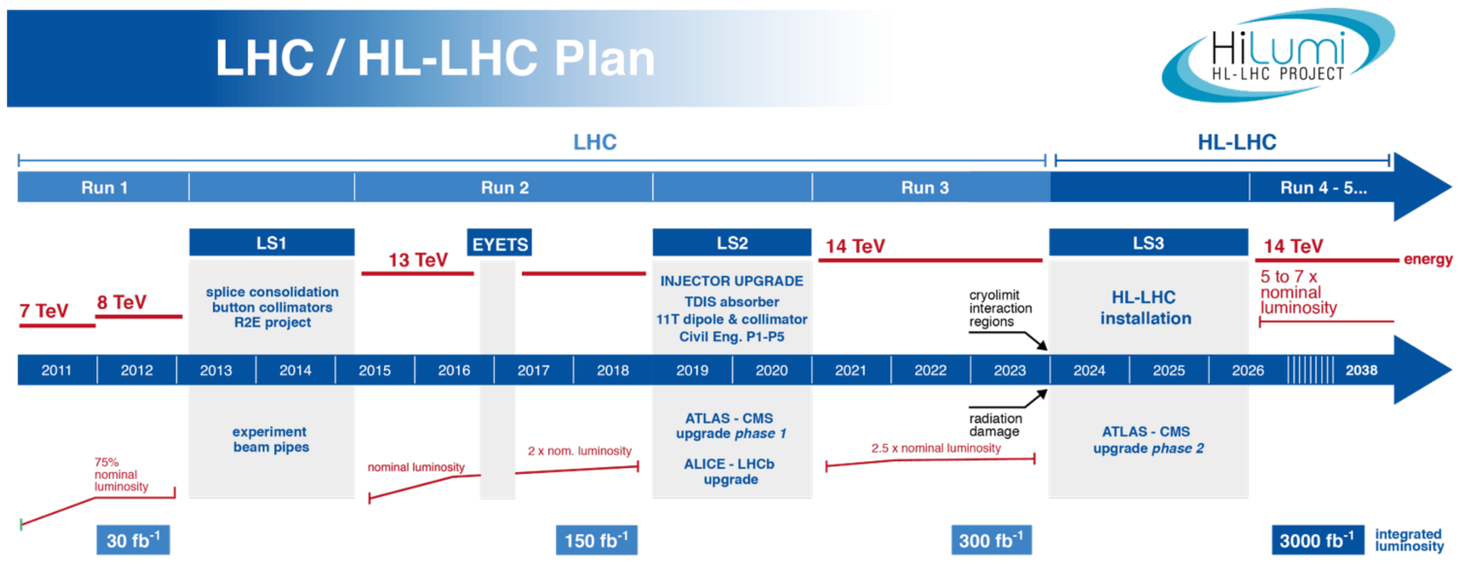
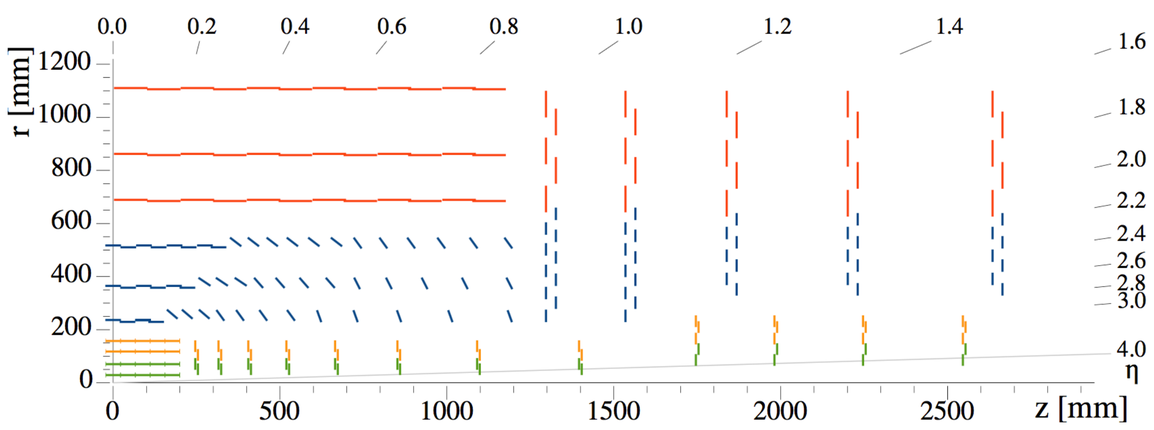
Introduction

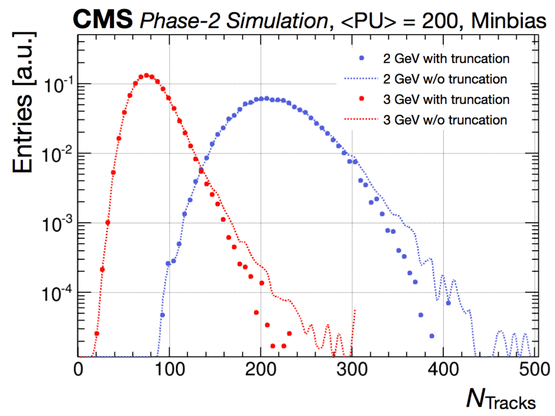
At the High Luminosity LHC (HL-LHC), the CMS experiment will face a harsh environment with a high instantaneous luminosity up to 5×10^{34}/cm^2/s corresponding to an average of 140-200 multiple proton-proton collisions per bunch crossing. The main goal of the CMS Level 1 trigger (L1T) upgrade for the HL-LHC is to maintain trigger thresholds that are as low as possible and comparable to those currently in use at the LHC, and to possibly include new triggers that were not feasible at the LHC. This will be achieved by upgrading the detector readout electronics, to allow a much larger L1T rate, and by including, for the first time, tracking information in the L1 trigger. Examples of how this tracking information can be used to reduce the L1 trigger rates are presented.



CMS Tracker upgrade for the HL-LHC

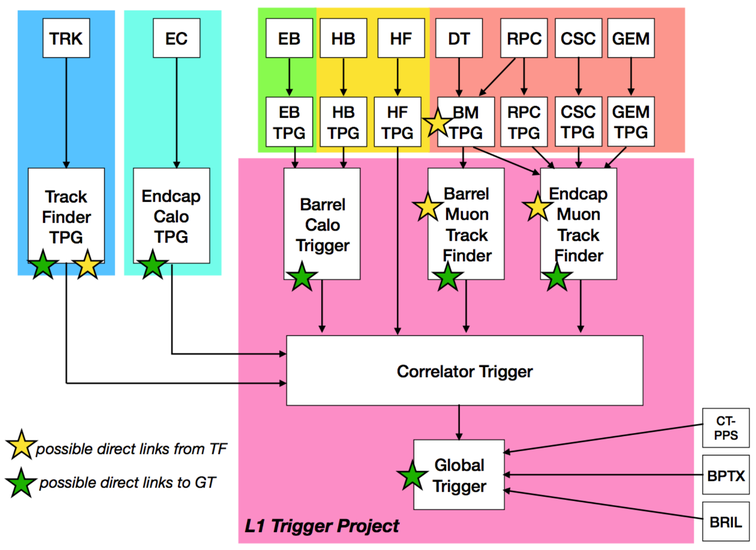


- High radiation tolerance to operate efficiently up to 3000 fb^{-1}
- Tracking information to the L1 trigger
- Outer tracker tilted barrel geometry
  - Optimized stub reconstruction efficiency
  - Reduced its material budget
- High granularity of pixel layers to keep a low occupancy in the inner tracker
  → smaller pixels are considered



Tracks filtered for p_T>2 GeV in front-end
→ 97% tracks are rejected minimum-bias events

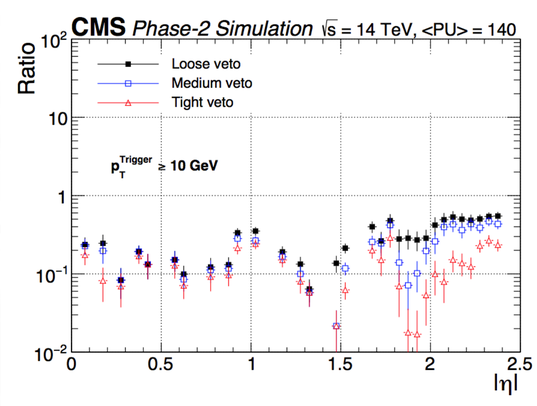
CMS Phase-2 L1 trigger



Targets for L1 trigger data processing latency

Processing step	Time (μs)
Input data received by CT	5
Trigger objects received by GT	7.5
L1A received by TCDS	8.5
L1A received by front-ends	9.5

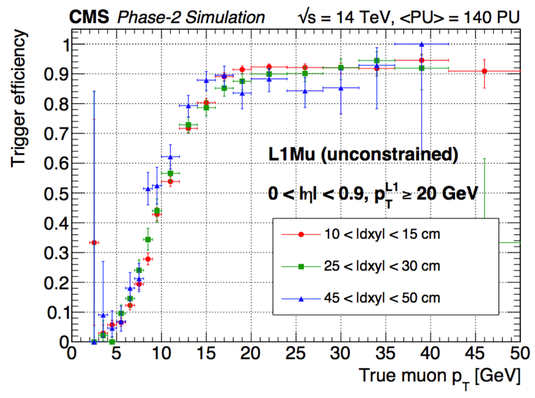
Displaced Muons



Barrel and endcap displaced muon trigger rate reduction factor versus pseudorapidity after applying

- *lose (solid black squares)*
- *medium (open blue squares)*
- *tight (open red triangles)*

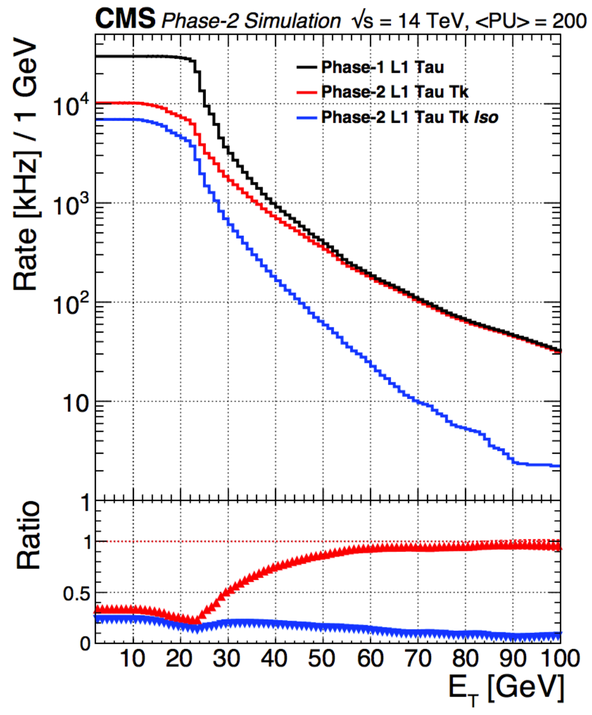
track-veto requirements.



Efficiencies of the displaced muon algorithm in the barrel for impact parameters between

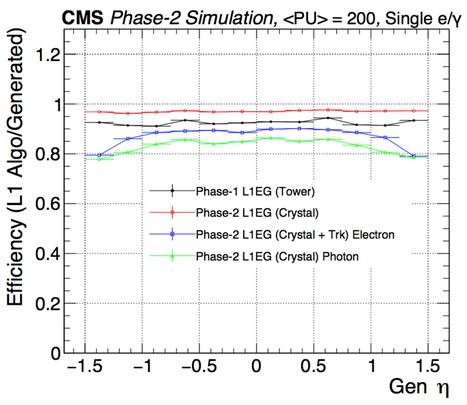
- *10-15 cm (solid red circles)*
- *25-30 cm (solid green squares)*
- *45–50 cm (solid blue triangles)*

taus



The expected rate for Phase-1 L1 Tau, Phase-2 TauTk and Phase-2 TauTk Iso single-τ triggers, as a function of Phase-1 L1 Tau E_T, for ⟨PU⟩ = 200.

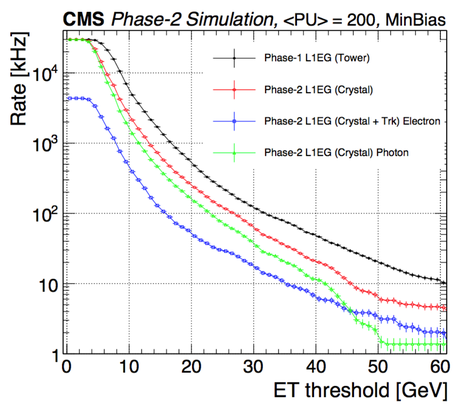
Electrons / Photons



Expected efficiency of the single electron trigger for the barrel region with

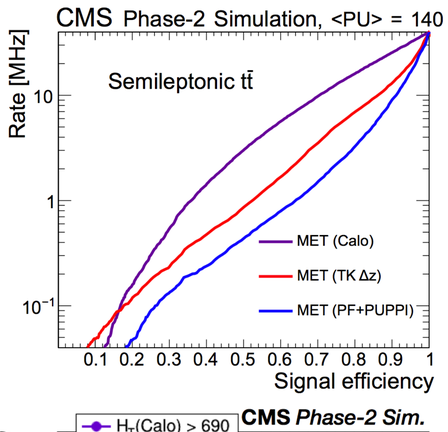
- *current trigger*
- *calorimeter only*
- *calorimeter matched to the track*
- *calorimeter photon tuned trigger*

as a function of simulated |η| of the electrons/photons for a trigger threshold of 20 GeV.



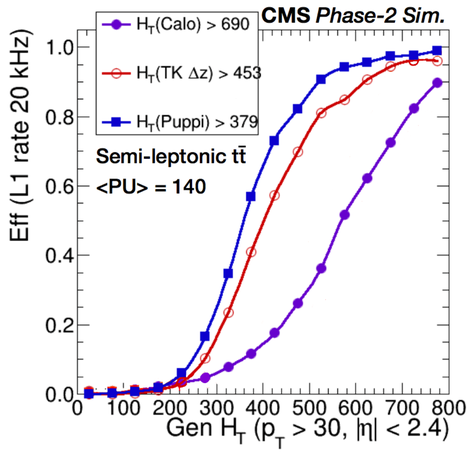
Expected rate for minimum-bias events using the single electron calorimeter trigger (for the barrel region only) as a function of trigger threshold.

Particle Flow (PF) Reconstruction



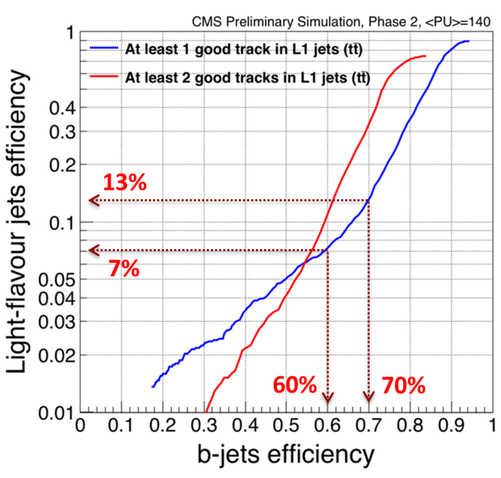
(Top) Efficiency for selecting signal and background for three different E_T^{miss} trigger algorithms and (Bottom) efficiency turn-on curves for three different H_T trigger working points:

- *calorimeter-only algorithm (purple)*
- *track-only trigger algorithm using tracks consistent with the primary vertex (red)*
- *PF+PUPPI trigger algorithm (blue).*



The H_T thresholds were chosen so that each H_T trigger path corresponds to a rate of 20 kHz. The study was conducted using a background sample of minimum-bias collisions and a signal sample from simulated top quark pair events decaying semileptonically, corresponding to an average PU of 140.

b-tagging at L1



- Use of inner pixel detector information at L1 as a "option"
- Combined inner pixel with outer tracker for L1 b-tagging studies.
- **~65%** b-tagging efficiency for a light jet missing rate of **~10%** for jet p_T > 20 GeV

Acknowledgment

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