HPS@L1 algorithm for the upgraded CMS level-1 hadronic tau trigger for the HL-LHC

From:
National Institute of Chemical Physics and Biophysics
Tallinn, Estonia
sandeep.bhowmik@cern.ch

Dr. Sandeep Bhowmik
On behalf of the CMS collaboration

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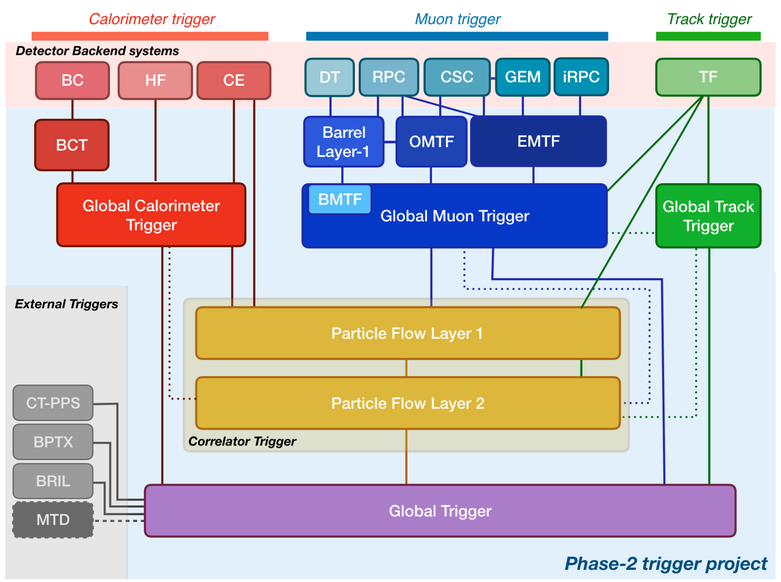
Introduction

Abstract

The High-Luminosity LHC will open an unprecedented window on the weak-scale nature of the universe, providing high-precision measurements of the Standard Model as well as searches for new physics beyond the standard model. The Compact Muon Solenoid (CMS) experiment is planning to replace entirely its trigger and data acquisition system to achieve this ambitious physics program. Efficiently collecting those datasets will be a challenging task, given the harsh environment of 200 proton-proton interactions per LHC bunch crossing. The new Level-1 trigger architecture for the HL-LHC will improve performance with respect to Phase I through the addition of tracking information and updates of the trigger electronics, which will allow to run a simplified particle-flow (PF) event reconstruction on the first trigger level (L1).

In this poster, we present the development of an algorithm, which is one of many developed algorithms, to select events containing hadronic tau decays on L1 during LHC Phase II. The algorithm is inspired by the "hadrons-plus-strips" (HPS) algorithm, which has been used for the reconstruction of hadronic taus in offline analyses performed by CMS during LHC Runs 1 and 2. It takes advantage of the capability of the upgraded trigger to perform tracking and PF event reconstruction on L1 and is referred to as the HPS@L1 algorithm. The performance of the algorithm is studied in terms of efficiency and rate expected for a single hadronic tau and for a tau pair (di-tau) trigger, using simulated events. For a tau isolation selection that yields a plateau efficiency of 85% per tau, the algorithm achieves a tau pT threshold of about 20 GeV for the di-tau trigger, which is lower than the pT threshold (32 GeV) achieved by the di-tau trigger (using calorimeter-only information) used by CMS during LHC Phase I (with luminosity $2\times10^{34}cm^{-2}s^{-1}$).

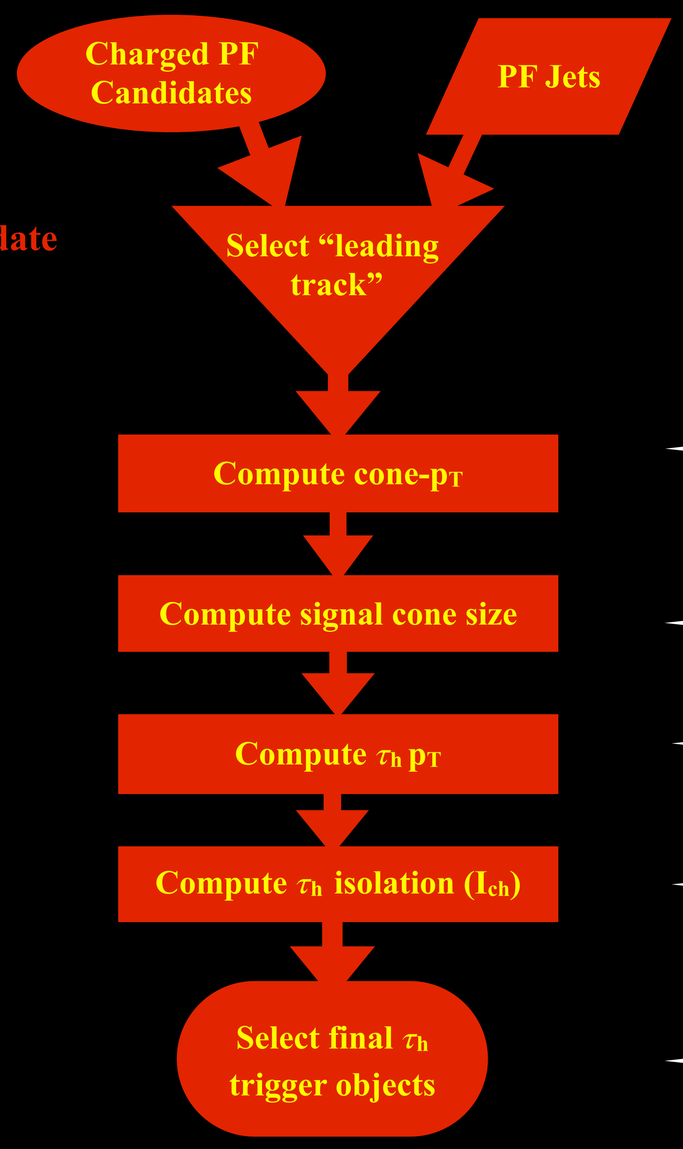
CMS L1 Phase-2 upgraded trigger design



CMS L1 Phase-2 upgraded trigger

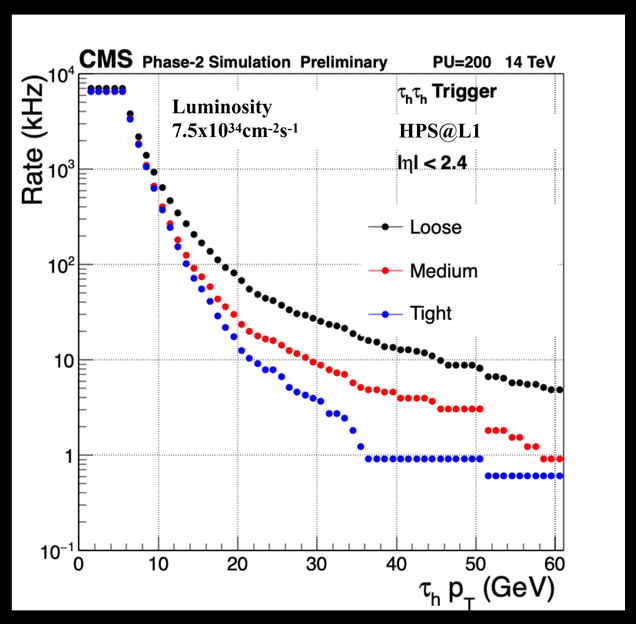
- The CMS will implement the sophisticated two-level triggering system composed of Level-1 (L1), instrumented by generic hardware processor boards (based on ATCA technology), and software High Level Trigger (HLT)
- The Phase-2 upgrade of the trigger and DAQ system will increase the L1 maximum rate to 750 kHz, to maintain the physics acceptance, and increasing the total latency to 12.5 ms to allow, for the first time, the inclusion of the tracker and high-granularity calorimeter information.
- Moreover, a longer latency is adequate to perform higher-lever object reconstruction and identification as well as evaluating global event quantities and correlation variables to optimize physics selectivity. The implementation of sophisticated algorithms using particle-flow reconstruction techniques or machine-learning based approaches can now be contemplated.
- The envisaged L1 system will more closely replicate the full offline object reconstruction, in stead of making use of simple subsystem variables, to make a better optimized selection.

Hadrons Plus Strips Algorithm at Level-1 (HPS@L1) in a Nutshell

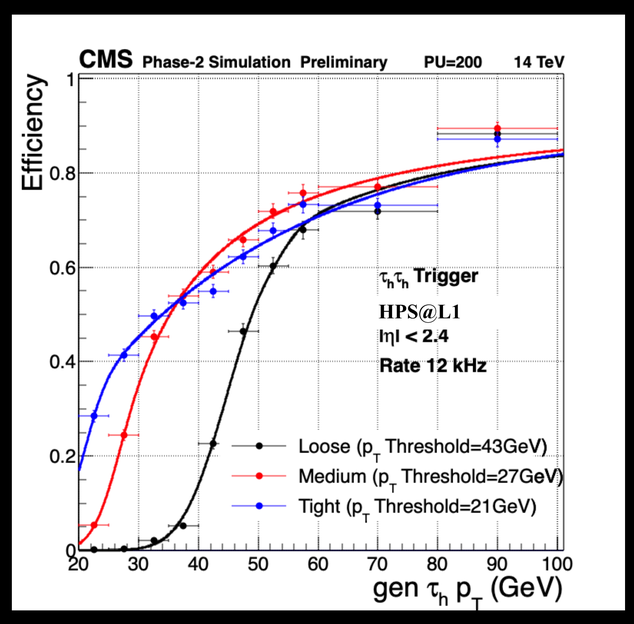


Performance of HPS@L1 algorithm in simulated events

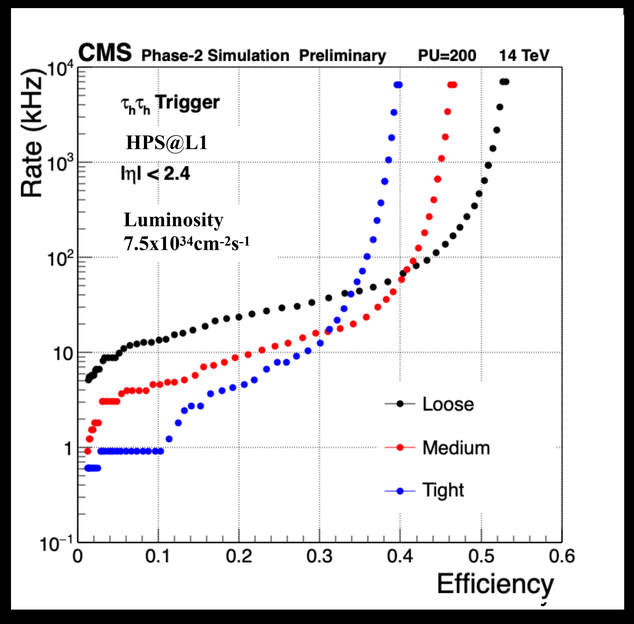
- Rates and efficiencies are shown for Loose, Medium, and Tight selections on the isolation of τ_h. These correspond to the conditions $I_{ch} < 0.20\ p_T$, $I_{ch} < 0.10\ p_T$ and $I_{ch} < 0.05\ p_T$, where p_T refers to the transverse momentum of τ_h



- Rate of the τ_h τ_h trigger for the HPS@L1 in proton-proton collisions with 200 pileup interactions per LHC bunch crossing.
- The rate is shown as a function of L1 τ_h p_T threshold.
- The same threshold is applied to both τ_h
- The algorithm achieves a trigger rate of 12 kHz for L1 τ_h p_T threshold of 43, 27 and 21 GeV for Loose, Medium, and Tight τ_h isolation selections.
- The rate is reduced by requiring both τ_h to be isolated and to be compatible with originating from the same vertex.



- Efficiency of the τ_h τ_h trigger for the HPS@L1 algorithm to select SM H→$\tau_h\tau_h$ signal events produced via the gluon fusion process.
- The efficiency is shown per τ_h and as function of generator-level τ_h p_T.
- The algorithm achieves a plateau efficiency of 85%.
- As Loose isolation has highest L1 τ_h p_T threshold it shows smallest efficiency than others.



- Rate of the τ_h τ_h trigger as a function of trigger efficiency for SM H→$\tau_h\tau_h$ events produced via gluon fusion.
- The efficiency is computed for events containing two generator-level τ_h of $p_T > 20$ GeV and $|\eta| < 2.4$.
- Points along each curve are obtained by varying the L1 τ_h p_T threshold, which is applied to both τ_h.
- For a trigger rate of 12 kHz, the Tight τ_h isolation selection achieves a trigger efficiency of 30% for the SM H→$\tau_h\tau_h$ signal.

[1] CMS Collaboration, "The Phase-2 Upgrade of the CMS L1 Trigger Interim Technical Design Report", Technical Report CERN-LHCC-2017-013

[2] CMS Collaboration, Reconstruction and identification of τ lepton decays to hadrons and ντ at CMS, *JINST* 11 (2016) 01, P01019