Development of a L1 tau lepton trigger algorithm for the HL-LHC using the CMS high-granularity calorimeter information

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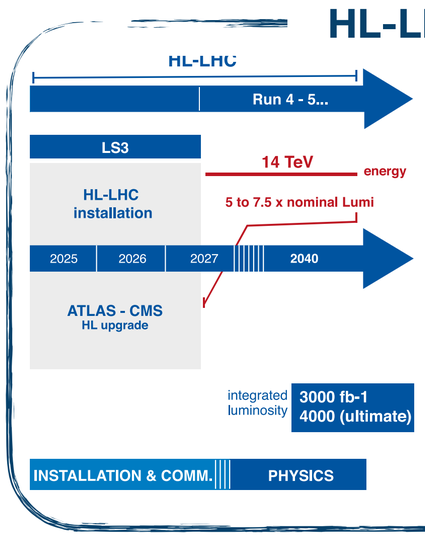
HL-LHC AND THE CMS PHASE-2 UPGRADE



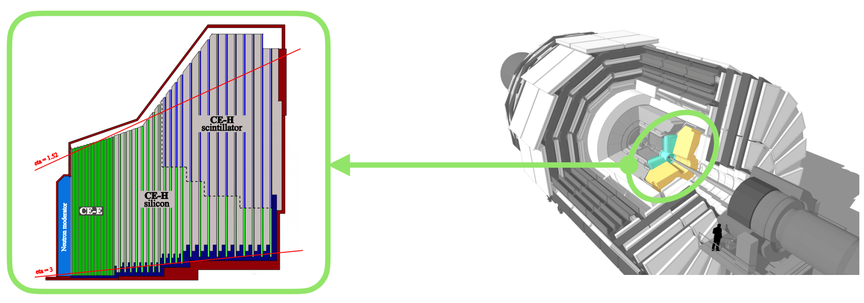
HL-LHC will integrate 10 times the LHC luminosity, and have an **instantaneous luminosity 3 times** the Run 2 peak value.

This will result in unprecedented levels of radiation and **high pileup** (PU) collision rate.

The CMS Collaboration will replace:

- the tracking detectors
- the barrel backend electronics
- the muon detectors
- the endcap calorimeter

THE HGCAL DETECTOR



HGCAL, the High-Granularity CALorimeter, will be a **5D (x, y, z, E, t) sampling calorimeter** with:

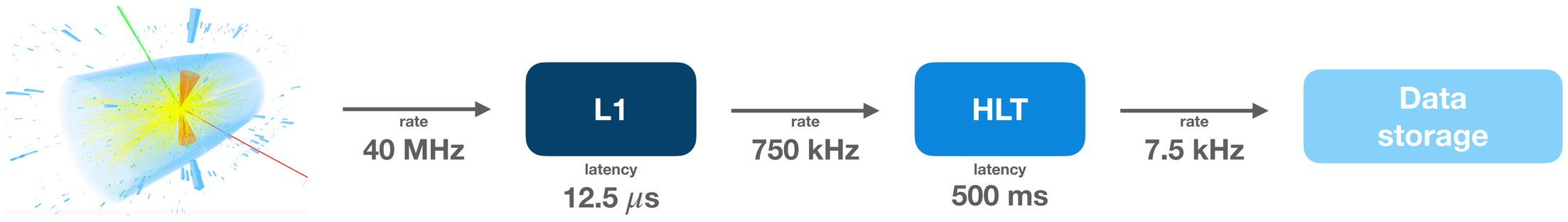
- silicon-based electromagnetic compartment
- silicon-based + scintillator tiles hadronic compartment

THE PHASE-2 CMS TRIGGER SYSTEM

The Phase-2 trigger system implements the well-established **two-level trigger architecture** with **Level-1 (L1)** and **High-Level-Trigger (HLT)**

The L1 trigger will operate at hardware level implementing **custom processor boards** and **FPGAs**

The HLT will operate at software level using as input the CMS detector **full-granularity information** and more sophisticated algorithms.

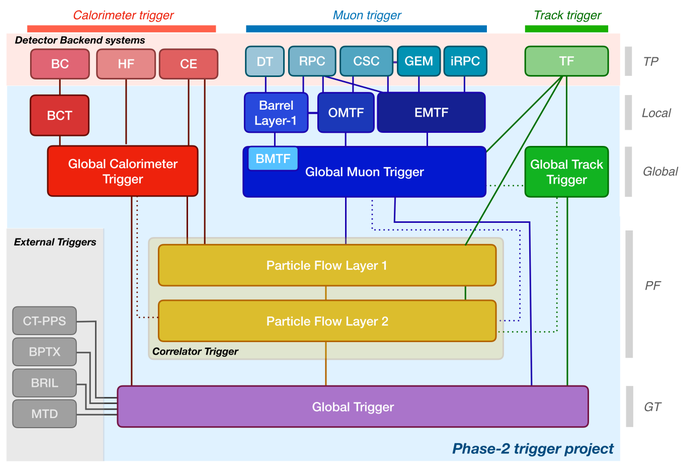


The **main hardware improvements** for the L1 Phase-2 system, w.r.t. the current system, will be:

- the extensive use of **state-of-the-art FPGA** boards
- the use of **high-speed optical links**
- the implementation of a **highly modular architecture**

The **main new features** of the L1 Phase-2 system will be:

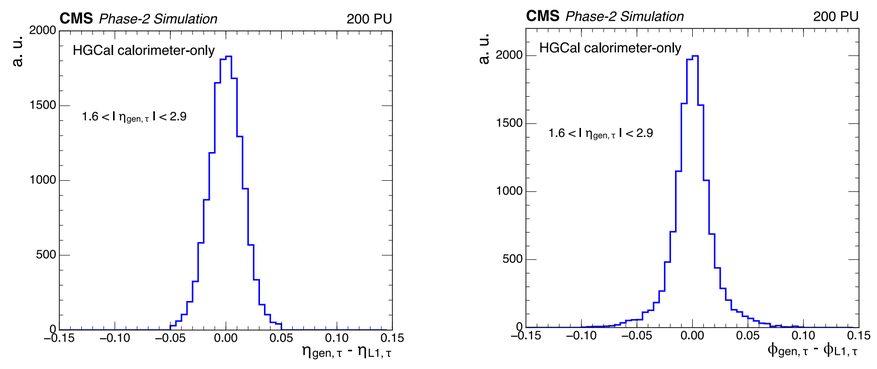
- the implementation of the **correlator trigger**
- the **first ever inclusion of tracker information**
- the inclusion of **HGCAL information** in the form of **3D-clusters** (HGCAL trigger primitives)



THE HGCAL LEVEL-1 TAU TRIGGER ALGORITHM

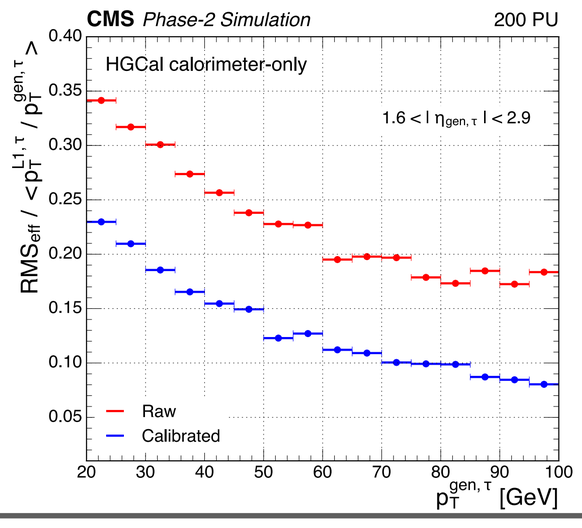
This algorithm targets **hadronically decaying tau leptons (τ_h)** detected by HGCAL and it is developed foreseeing its implementation in the **calorimeter trigger** section of the L1

The algorithm takes as **input** the **3D-clusters** from HGCAL and assumes a **tau-to-cluster one-to-one correspondence**

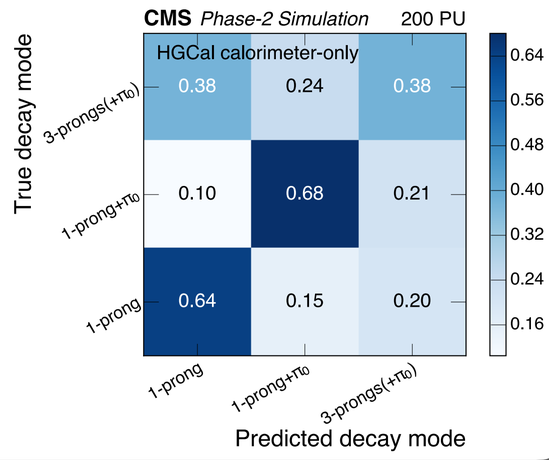


The first step is the application of a **boosted decision tree (BDT) for the rejection of PU** exploiting the clusters' shape variables

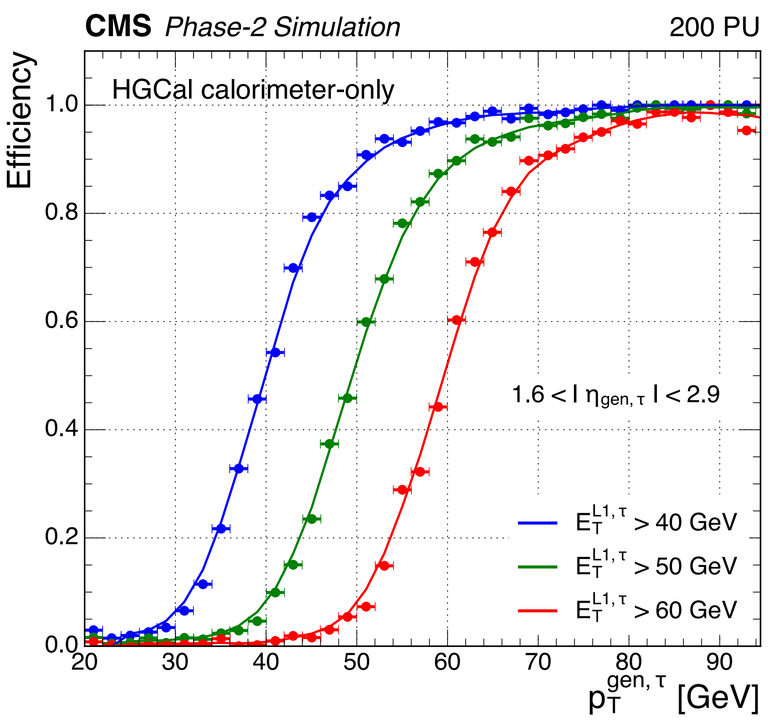
Next is a **cluster three stage calibration**:
→ η-dependent PU subtraction
↪ clusters' shape dependent correction
↪ energy dependent correction

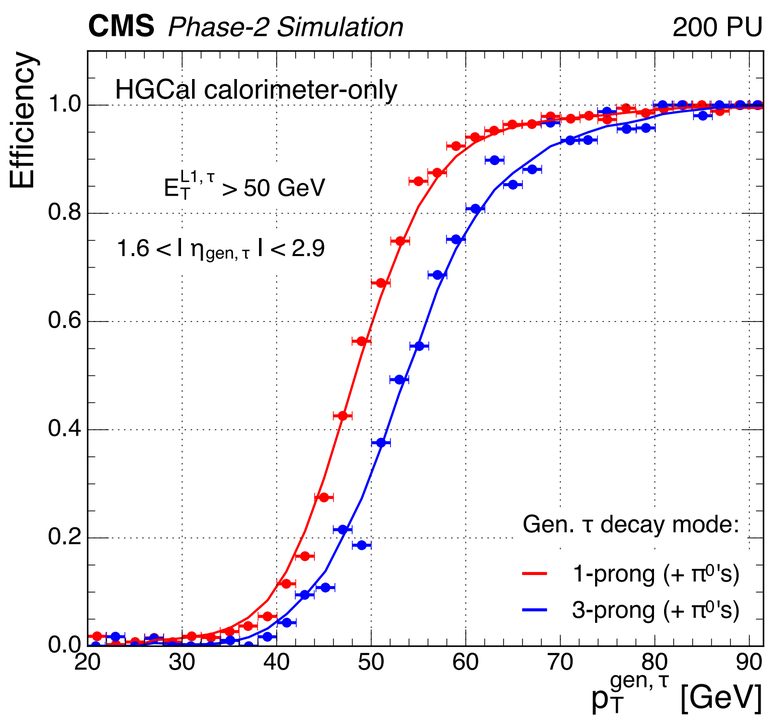


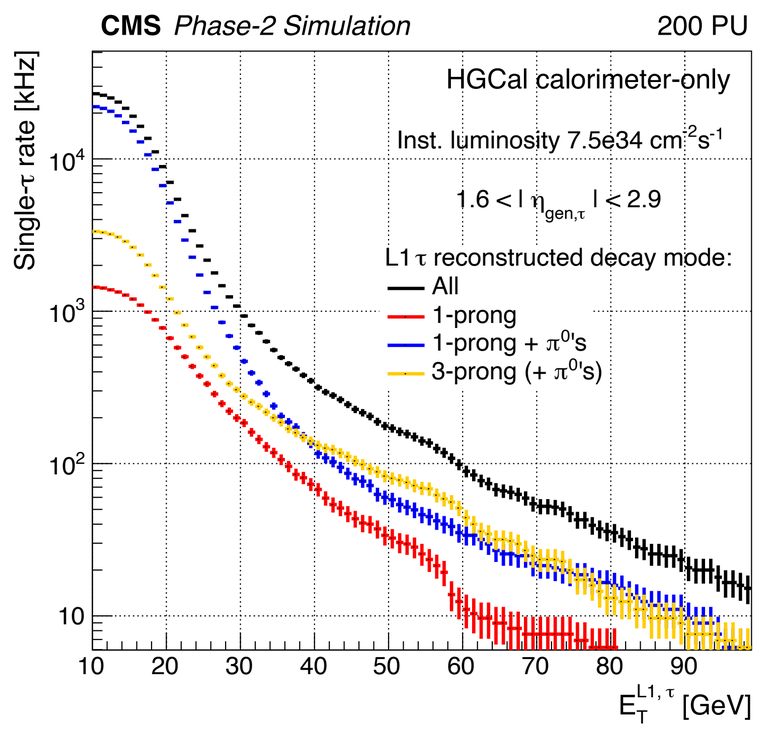
The last step is the identification of the **hadronic decay mode** using a **Random Forest Classifier** exploiting the clusters' shape variables



PERFORMANCES







The efficiency of the L1 algorithm is evaluated with simulated collisions with **200 average PU events**. The efficiency as a function of the generated visible τ_h lepton p_T shows a **sharp turn-on**, both for the aggregated and split decay modes cases, that reaches 100% at plateau.
The single-τ_h rate corresponding to different L1 threshold shows a large reduction for $p_T \geq 30$ GeV.

CONCLUSIONS

The many L1 trigger upgrades permit a better knowledge of the τ_h shower features thus allowing the use of sophisticated **BDT-based trigger primitive selection and calibration**.
The discussed algorithm shows great preliminary performance:

- 19% energy resolution (~14% better than Run 2 performance)
- **sharp selection efficiency** that reaches 100% at plateau
- the possibility to separate the **decay modes at L1 level**

OUTLOOK

The undergoing developments of the discussed algorithm are:

- the calculation and exploitation of **isolation** variables
- the inclusion of **QCD-jet rejection**
- the exploitation of the L1 **track trigger information**
- the **firmware implementation**

REFERENCES: The Phase-2 Upgrade of the CMS endcap calorimeter (CMS-TDR-019) ; The Phase-2 Upgrade of the CMS Level-1 Trigger (CMS-TDR-021)