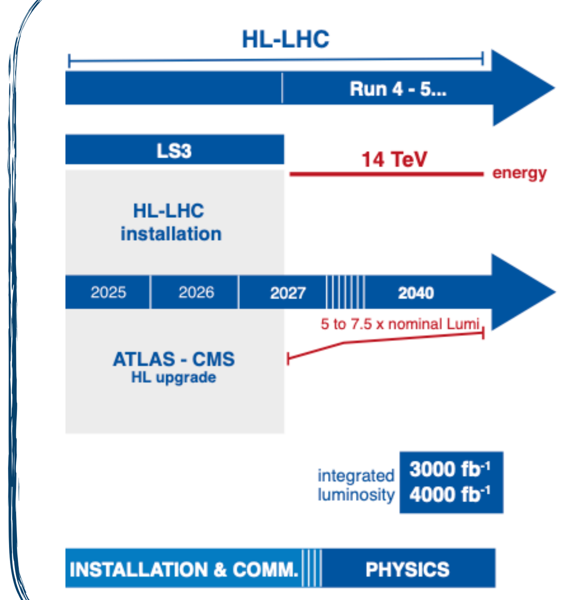
# Development of a L1 tau lepton trigger algorithm using the CMS high-granularity calorimeter information

**Jona Motta** on behalf of the CMS Collaboration
Laboratoire Leprince-Ringuet, IPP École Polytechnique, France
jona.motta@cern.ch

## HL-LHC AND THE CMS PHASE-2 UPGRADE



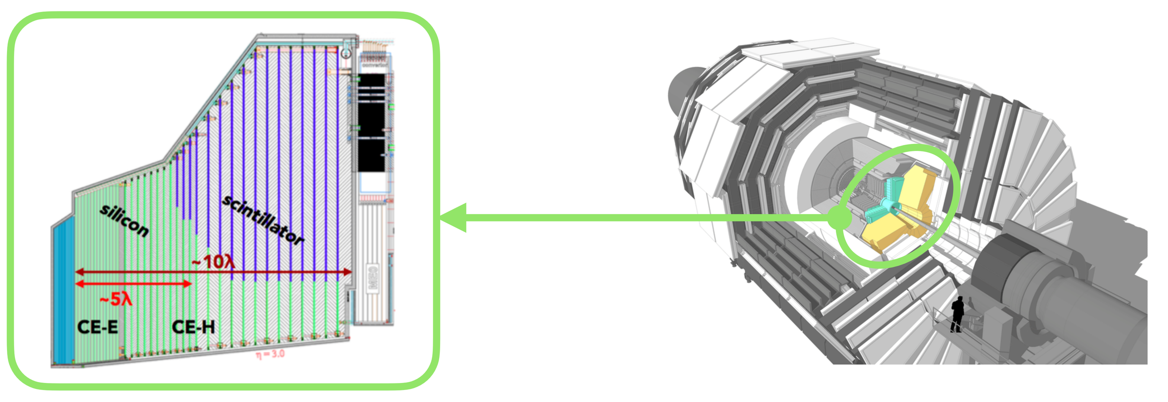

The **HL-LHC** will integrate 10 times the current LHC luminosity, and have an **instantaneous luminosity 3 times** the Run 2 peak value.

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




The **high-granularity calorimeter (HGCAL)** will be a **5D (x, y, z, E, t) sampling calorimeter**; its main features are:

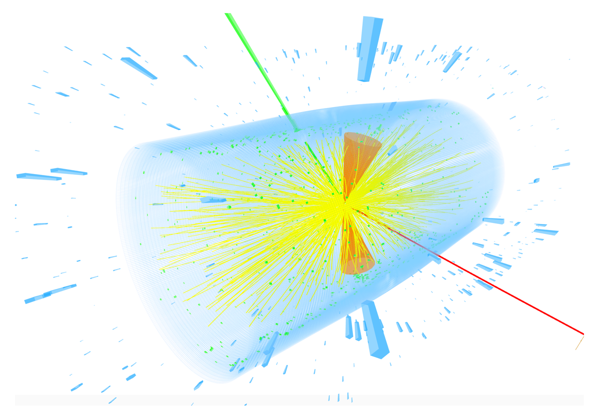
* silicon-based electromagnetic compartment ( **~25$X_0$** )
* silicon-based + scintillator tiles hadronic compartment ( **~10$\lambda$** )

## 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)**, targeting a **7.5 kHz** output rate.

The L1 trigger will operate at hardware level implementing custom processor boards and **FPGAs**, using the CMS detector enhanced granularity and fully reconstructed tracks.

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



rate 40 MHz → **L1** (latency 12.5 $\mu$s) → rate 750 kHz → **HLT** (latency 500 ms) → rate 7.5 kHz → **Data storage**

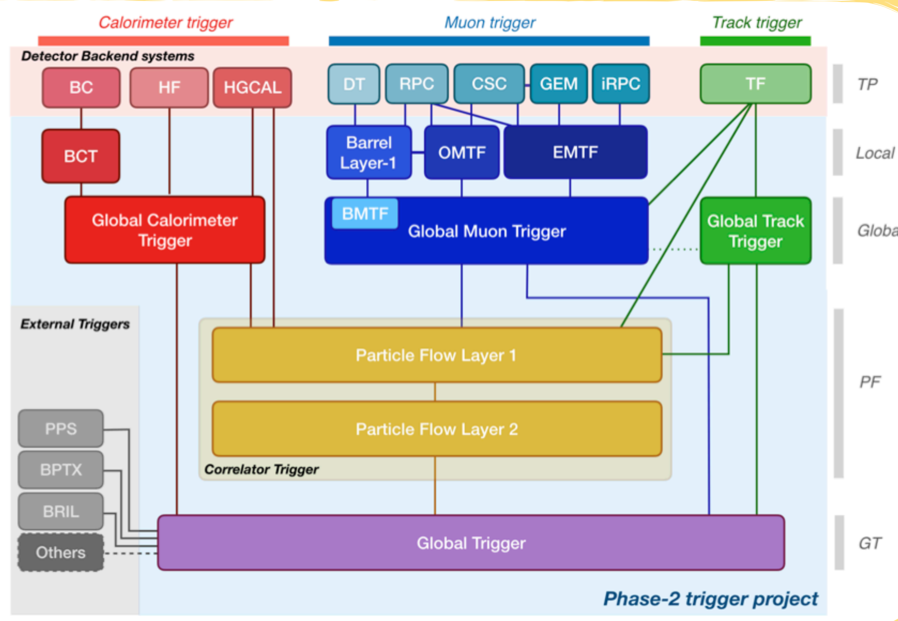
## THE PHASE-2 LEVEL-1 TRIGGER ARCHITECTURE

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 and processors for optimised reconstruction
* the use of **high-speed optical links** to facilitate the aggregation of data
* the implementation of a **highly modular architecture** to meet different HL-LHC running conditions

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

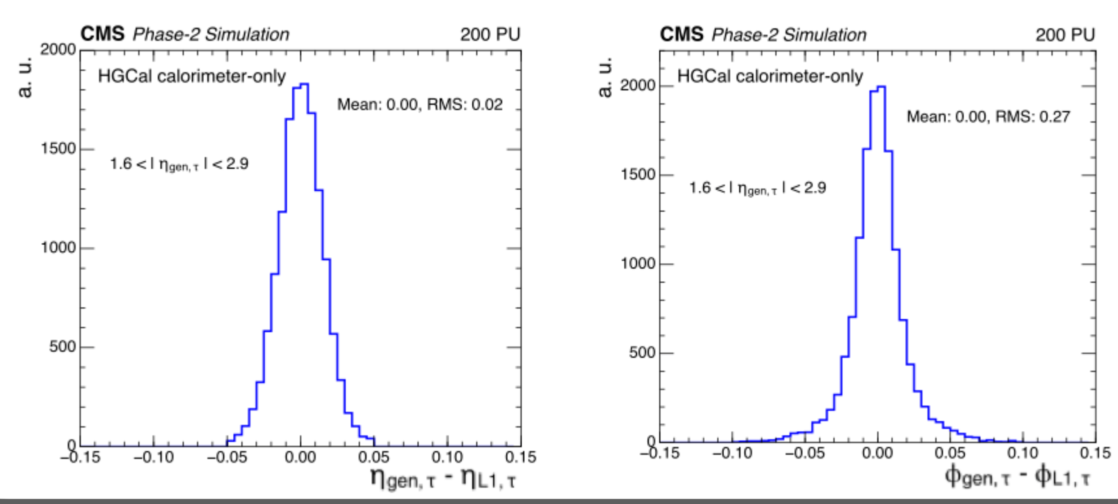
* the implementation of the **correlator trigger** where higher level variables can be computed to introduce PU mitigation and providing an L1 output with performance closer to offline reconstruction.
* the **first ever inclusion of tracker information**
* the inclusion of the **HGCAL trigger information**. Its trigger primitive generator takes trigger cells (sums of silicon/ scintillator tiles) as input and with a two-staged architecture clusters them in **3D-clusters** (HGCAL trigger primitives)




## THE HGCAL LEVEL-1 TAU TRIGGER ALGORITHM

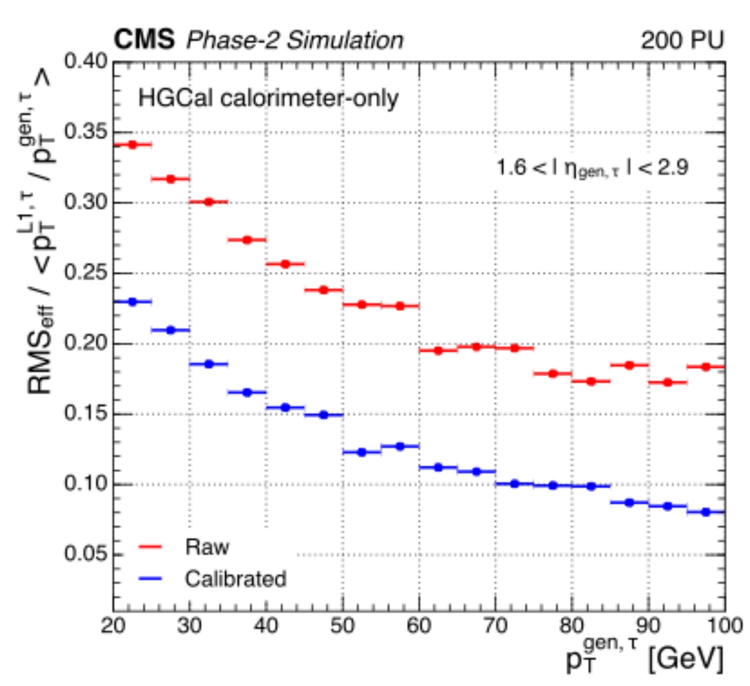
This algorithm targets **hadronically decaying tau leptons ( $\tau_h$ )** detected by HGCAL and it is developed foreseeing its implementation in the **calorimeter trigger** section of the L1.

The algorithm takes as an **input** the **3D-clusters** produced by the HGCAL trigger primitive generator and assumes a **tau-to-cluster one-to-one correspondence**. The minimal requirement $\mathbf{E_T^{clust.} \geq 4}$ **GeV** is applied to form the L1 candidates.

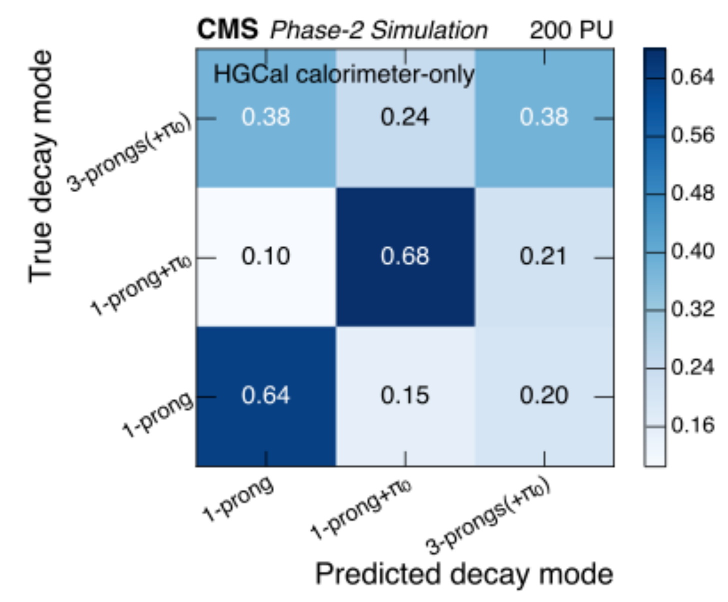



The first step is the application of a **boosted decision tree (BDT) for the rejection of PU** exploiting the clusters' shape variables. Clusters passing the 99% efficiency point are retained.

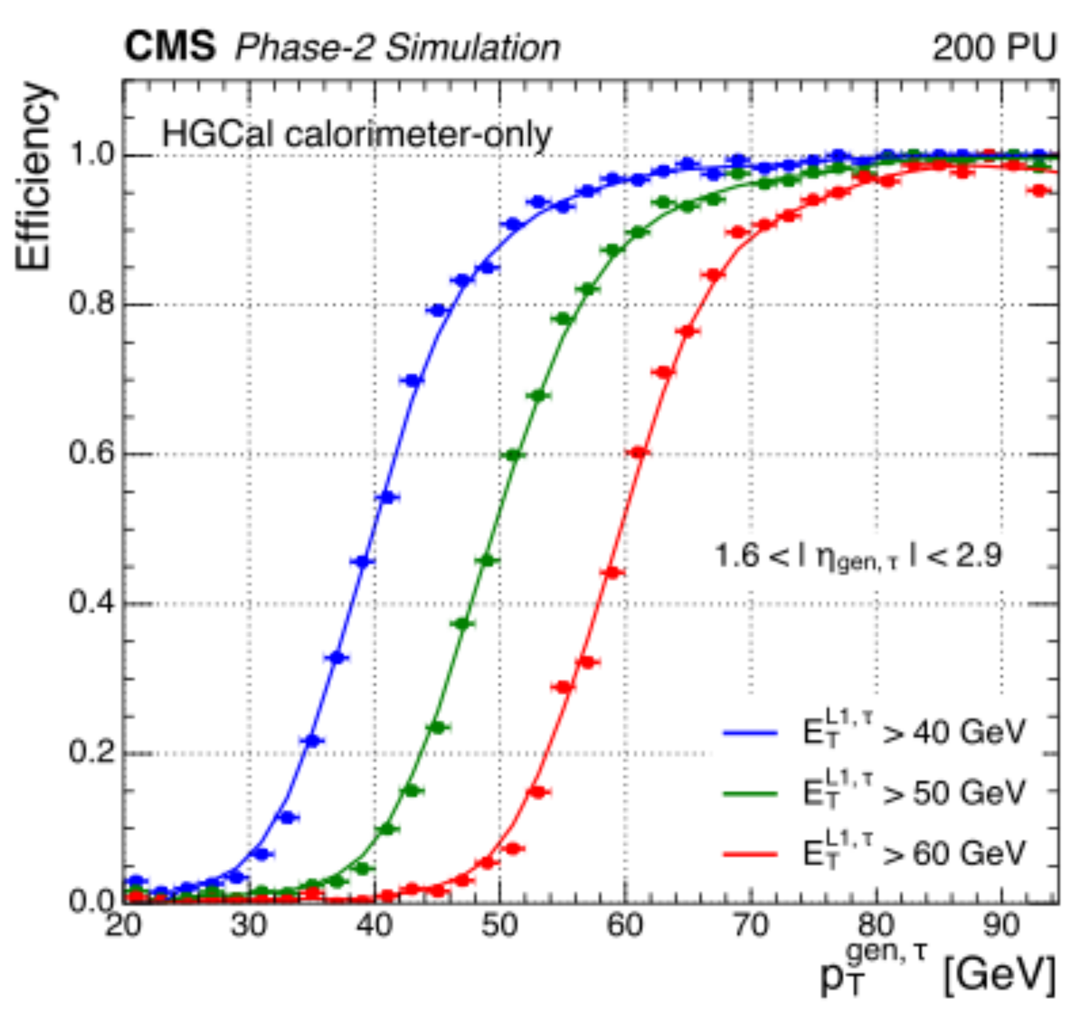
Next is a **clusters three stage calibration**:
→ $\eta$-dependent PU subtraction
↪ clusters' shape dependent correction
↪ energy dependent correction

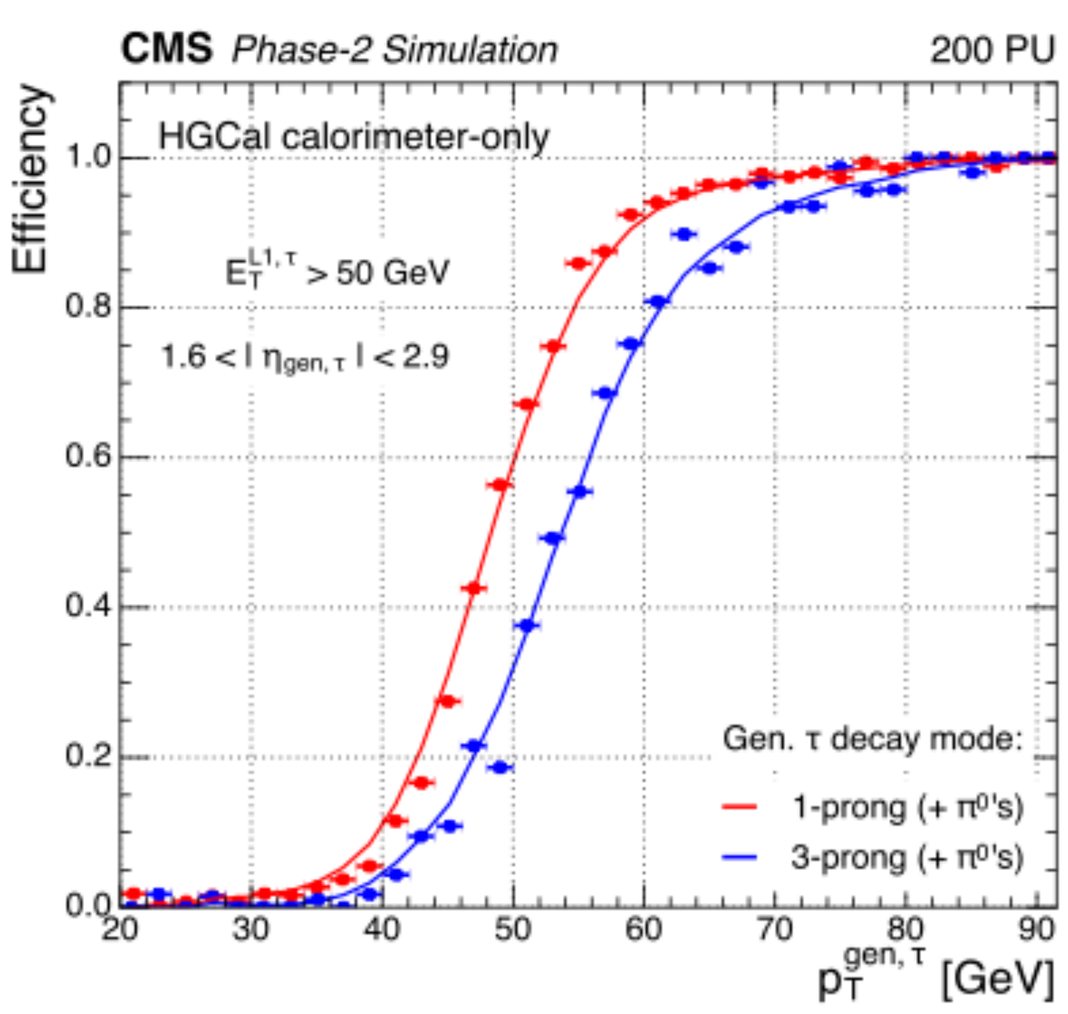


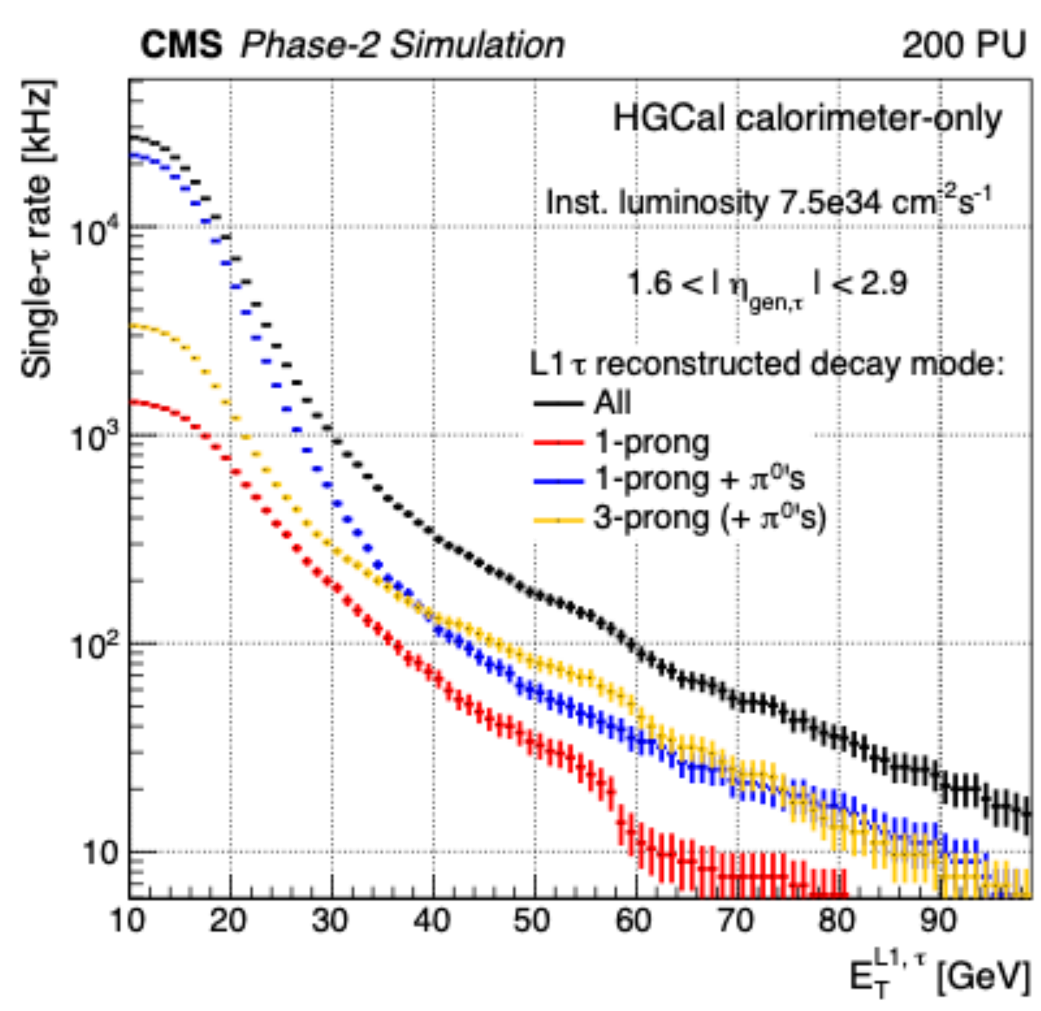

The last step is the identification of the **hadronic decay mode** in three categories using a **Random Forest Classifier** exploiting the clusters' shape variables.




## 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 $\tau_h$ lepton $p_T$ shows a **sharp turn-on**, both for the aggregated and split decay modes cases, that reaches 100% at plateau. The single-$\tau_h$ rate corresponding to different L1 threshold shows a large reduction for $p_T \geq 30$ GeV.

## CONCLUSIONS

The many L1 trigger upgrades permit substantial improvement in the implementation of $\tau_h$ trigger algorithms. A better knowledge of the shower features allows the use of sophisticated **BDT-based trigger primitive selection and calibration**.
The discussed algorithm shows great preliminary performance, namely:

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

## OUTLOOK

The main undergoing and future developments of the discussed $\tau_h$ algorithm are:

* the calculation and exploitation of quality and **isolation** variables **(undergoing)**
* the inclusion of **QCD-jet rejection (undergoing)**
* the exploitation of the L1 **track trigger information**
* the **firmware implementation (planned for this summer/autumn)**

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 )