The CMS Level-1 tau lepton and Vector Boson Fusion triggers for the LHC Run II

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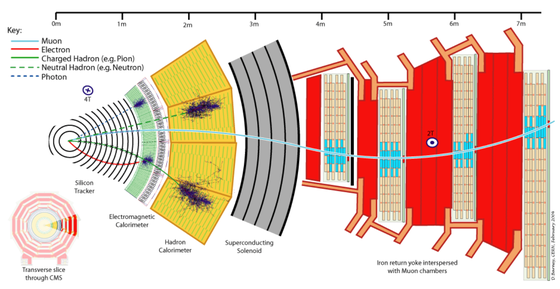
THE LHC RUN II

After a long shutdown, the LHC started the Run II in 2015 at a centre-of-mass energy of **13 TeV**. In 2017, it reached typical instantaneous luminosities of **1.5x10^{34} cm^{-2} s^{-1}** and an average pileup of **57** collisions per bunch crossing.

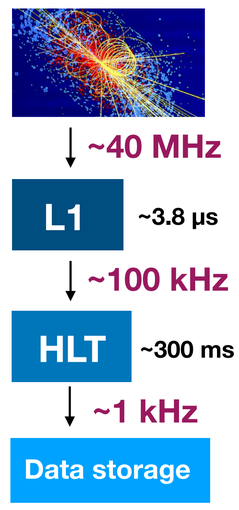
THE CMS DETECTOR



CMS is a **multi-purpose detector**, consisting of sub-detectors installed concentrically with respect to the interaction point and designed specifically to characterize different kinds of particles. In 2017, it recorded **41 fb^{-1}** of data for Physics analysis.

THE CMS TRIGGER SYSTEM

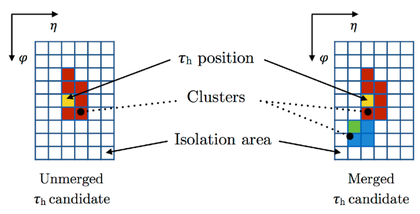
The CMS detector implements a sophisticated two-level trigger architecture composed a **Level-1 (L1)** and a **High-Level-Trigger (HLT)**, achieving 10^5 rate reduction. The **L1** operates at hardware level and uses the information of the calorimeters and the muon chambers. The software **HLT** uses more sophisticated algorithms exploiting the full detector information. The CMS L1 trigger architecture underwent a full **upgrade in 2016** in order to maintain and improve the trigger performance in the challenging experimental conditions of Run II.



THE LEVEL-1 TAU TRIGGER

THE L1 TAU ALGORITHM

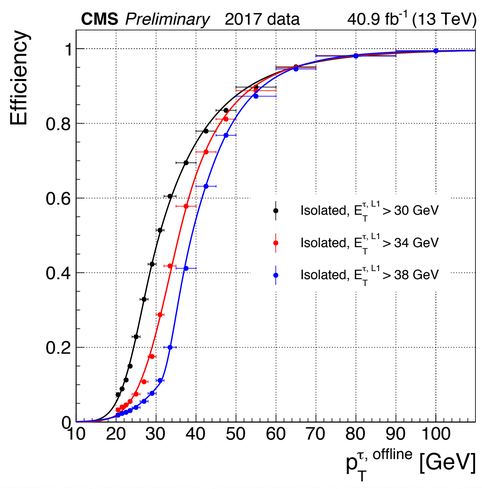
- The τ_h localized energy deposits in the calorimeters are identified through **dynamic clustering**.
- Secondary clusters from τ_h decays are **merged** into a single candidate.
- The energy is **calibrated** to improve the τ_h's scale and resolution.
- **Isolation** criterion is applied to reject quark and gluon background.
- **Pileup** is estimated and subtracted based on the energy deposition in the central part of the detector.



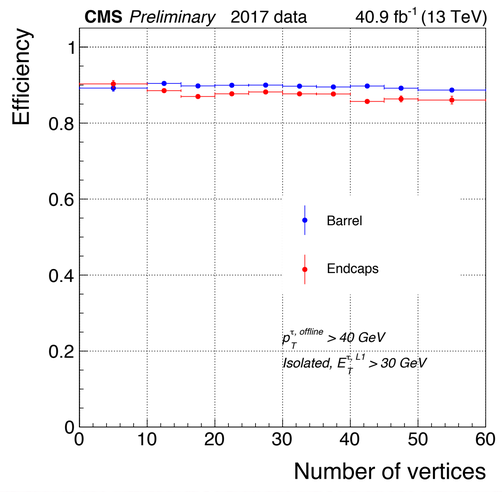
PERFORMANCE IN 2017 (1)

The τ_h trigger allowed to **observe the Higgs in $\tau\tau$ final state** in 2017 (3)

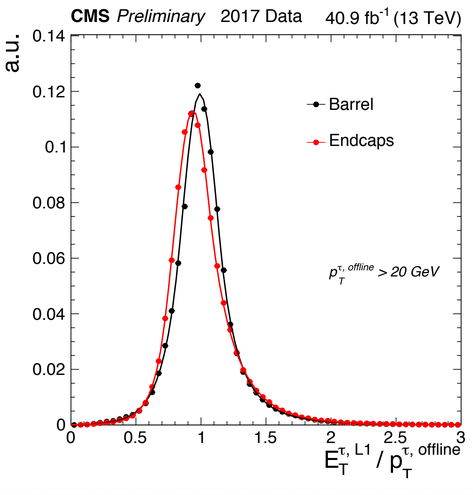
Outstanding **performance** for the typical L1 thresholds, reaching **95%** efficiency at **50 GeV**, threshold used in $H\rightarrow\tau_h\tau_h$ analysis.



Excellent **pileup resilience** throughout 2017 data-taking thanks to the pileup estimator already present at L1.

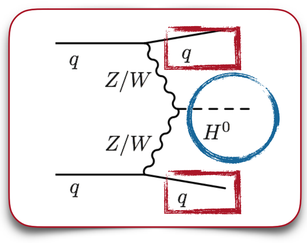


Very good **energy resolution** as a result of the *in-situ* calibration of the τ_h performed at L1.



THE LEVEL-1 VECTOR BOSON FUSION TRIGGER

THE L1 VBF STRATEGY



The VBF process contributes as ~10% to the Higgs boson production and has a very **characteristic signature**:

- **VBF jets** with high invariant mass and large angular separation.
- **Higgs boson** decay products in central region.

- Thanks to the trigger upgrade, **invariant masses** can be computed at L1 and, while the usual trigger strategies target the decay mode, the VBF trigger is specific for the **production mode**.

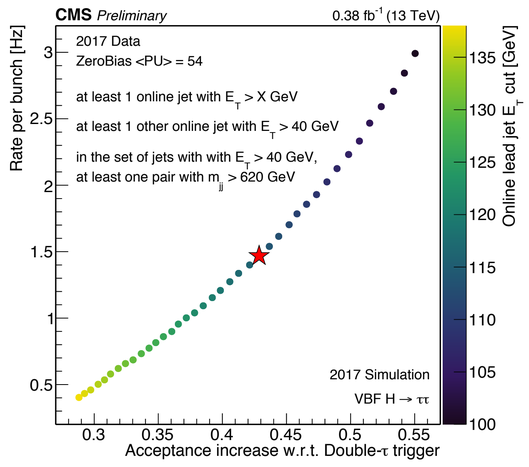
- Using the VBF trigger as a complement to the classic triggers, the **phase-space is expanded** and the **sensitivity to VBF** is improved.

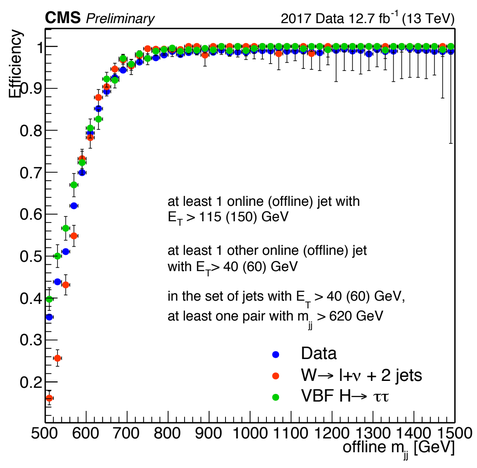
L1 trigger selection for VBF production

- at least one jet with $E_T > X$
- at least two jets with $E_T > Y$ and $m_{jj} > Z$

PERFORMANCE IN 2017 (2)

The X = 115 GeV, Y = 40 GeV, and Z = 620 GeV selection, used throughout 2017, provided **43% additional VBF $H \rightarrow \tau\tau$ events** with an **excellent efficiency** that matches that predicted by simulations.





CONCLUSIONS

During Run II, CMS has benefited from a new L1-trigger architecture that has enabled the design of high performance τ_h seeds as well as L1 algorithms directly targeting the VBF Higgs boson production mode. Both demonstrated outstanding performance in 2017 and have already been updated to cope with the harsh experimental conditions of the LHC in 2018.

REFERENCES: **(1)** CERN-CMS-DP-2018-006; **(2)** CERN-CMS-DP-2018-005; **(3)** *Observation of the Higgs boson decay to a pair of τ leptons with the CMS detector*, Phys. Lett. B779 (2018) 283-316