PROCEEDINGS OF SCIENCE

Performance of the CMS jets and missing transverse energy trigger for the upgraded LHC RunII

Fengwangdong Zhang*
On behalf of the CMS Collaboration
IIHE - Université Libre de Bruxelles (BE), Peking University (CN)
E-mail: fengwangdong.zhang@cern.ch

In preparation for collecting the proton-proton (pp) collisions from the upgraded LHC at an unprecedented energy (13 TeV) and rate (40MHz), the CMS collaboration has prepared an array of triggers utilizing jets and missing transverse energy for standard model (SM) precision measurements and searches for new physics at the energy frontier. The CMS trigger system must be able to sift through the collisions in order to extract events of interest at a rate of 1kHz, applying sophisticated algorithms adapted for fast and effective operation. Particularly important is the calibration of the trigger objects, as corrections to the measured raw energy may be substantial. Equally important is the development of improved reconstruction algorithms to mitigate negative effects due to high numbers of overlapping pp collisions. Recent work by the CMS collaboration on upgrading the high-level trigger (HLT) for jets and missing transverse energy for the 25ns and 50ns LHC operation will be presented, along with the improved performance of these triggers.

The European Physical Society Conference on High Energy Physics
22–29 July 2015
Vienna, Austria

*Speaker.

PoS(EPS-HEP2015)290

1. Simulation of CMS detector performance in high pileup conditions

A consequence of the increase in the instantaneous luminosity and bunch crossing frequency is a large increase in the overlapping energy deposits in the detector from simultaneous interactions ("in-time pileup") and interactions from the previous bunch crossing ("out-of-time pileup"). This results in a large contribution of artificial jets not coming from the hard-scattering vertices. We aim to distinguish this kind of contamination and subtract such contribution from all the event candidates. Then we can concentrate on the physics events of interests.

For the RunII, with the central collision energy of 13 TeV, and the time separation of 25ns between bunches, we expect a luminosity such that the average number of pileup per bunch crossing is around 40. Figure 1 shows the ratio between number of pileup jets and number of all reconstructed jets for three different reconstruction scenarios. The RunII reconstruction is superior in suppressing pileup jets compared with RunI case. Regarding HLT, we finally choose the online scenario because it has optimal timing characteristics.

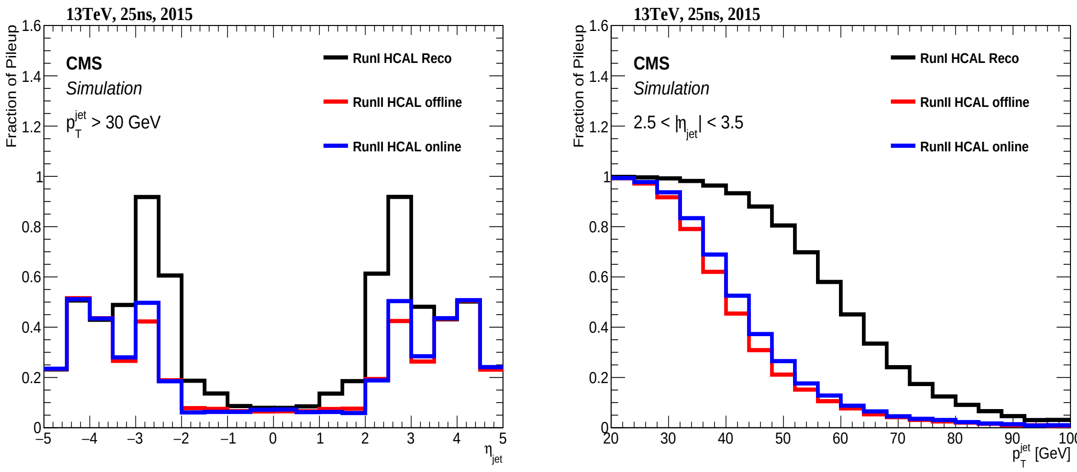

Figure 1: Pileup jets fraction with different reconstruction scenarios as a function of the reconstructed jets pseudorapidity η (left) and transverse momentum p_T (right), based on simulation. The central mass of collision is 13 TeV, and the time separation between each bunch is 25ns. The average number of pileup per bunch crossing is 40. "RunI HCAL Reco" is the default hadron calorimeter reconstruction pattern used during the last run of LHC. "RunII HCAL" is the new reconstruction method for upgraded LHC. While the "RunI HCAL Reco" simply integrates the signal in a certain time window, the "RunII HCAL" (both online and offline) separates "in-time" and "out-of-time" pulses.

The pileup offset is defined as the difference between the sum of p_T of all the jets and the p_T of jets coming from hard scattering. It is a relevant observable for monitoring the quality of reconstruction pattern. Figure 2 illustrates that the offset p_T is approximately the same for 25ns and 50ns of time separation between each bunch crossing in HLT and offline reconstruction, which is achieved by use of a dedicated local reconstruction to mitigate the effect of "out-of-time pileup". With the track and energy deposit of particles, we can distinguish different categories of objects. The offline case has abundant time to reconstruct robust vertices. In comparison, the HLT runs at much higher frequency to treat the events, and it can only reconstruct pixel vertices. Relatively, the pileup offset of offline method is more reasonable than that of online method, so we need to adjust HLT reconstruction to improve the confidence. Especially, the tracking at HLT is optimized to take into account only the primary vertex of the hard interaction, mimicking the behavior of removing charged hadrons from pileup vertices in the offline reconstruction.

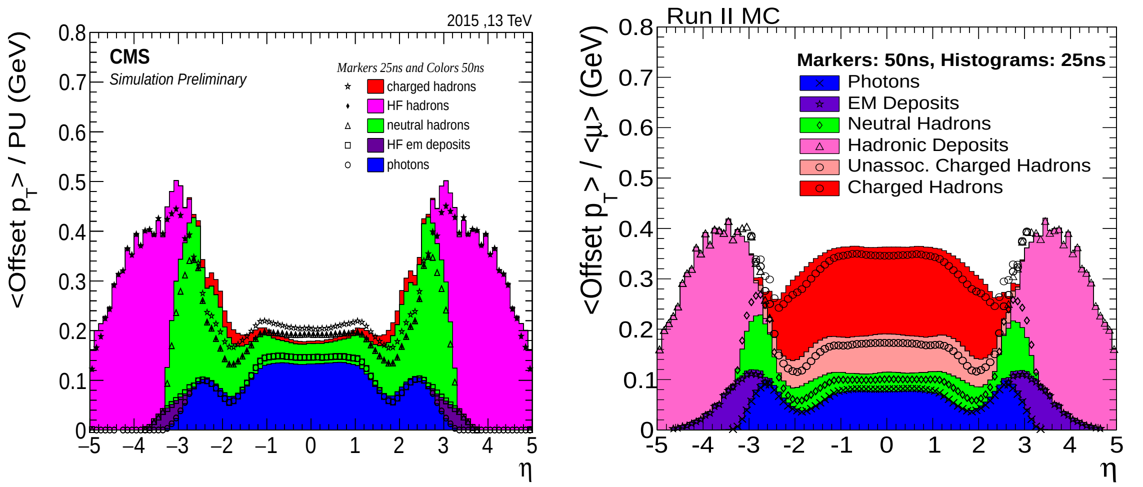

Figure 2: Average offset per pileup event ("PU" or "$< \mu >$") in the HLT reconstruction (left) and offline reconstruction (right) on different categories of jets, with the comparison of the 25ns and 50ns of separation time between each bunch crossing. Those kinds of jets are respectively: charged hadrons, neutral hadrons, forward hadrons("HF hadrons"(left) and "Hadronic Deposits"(right)), forward electrons("HF em deposits"(left) and "EM Deposits"(right)), photons. The "Unassoc.Charged Hadrons" in the right plot represents the charged hadrons without track.

2. Jet energy correction and resolution

Because of the finite resolution of the CMS detector, the p_T of reconstructed jets have systematic discrepancy corresponding to true p_T. It can be corrected using Jet Energy Corrections (JEC), which are:

- Pileup correction (L1)
- Relative (η) correction (L2)
- Absolute (p_T) correction (L3)

The JEC is determined by simulation, which contains both reconstructed jets and generated jets. According to the ratio between the generated jet p_T and the matched reconstructed jet p_T, we can obtain the correction factor, which is used to be multiplied to the reconstructed p_T and energy in data.

There are two categories of reconstructed jets used at HLT, which are:

- Calorimeter jet (CaloJet) - calorimetry only
- Particle flow jet (PFJet) - with both calorimetry and tracking information

Figure 3 shows the jet p_T resolution after applying JEC on HLT. The consistent application of JEC, specifically determined for the HLT objects with the latest RunII reconstruction, leads to the jet energy resolution similar to that of offline objects.

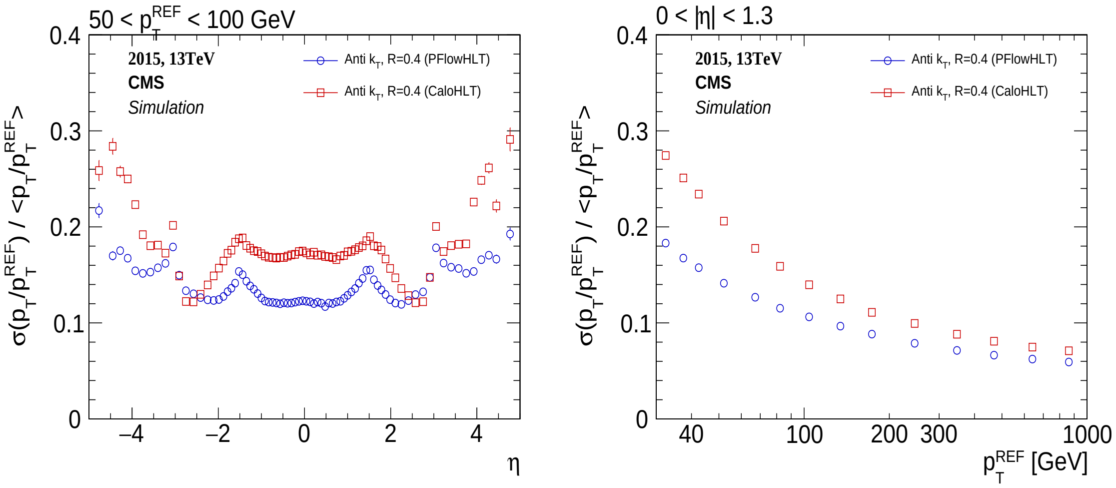

Figure 3: Jet p_T resolution as a function of η(left) and of p_T(right) in representative regions, for 25ns separation time of each bunch crossing. "p_T^{REF}" represents the transverse momentum of the generated jet, matched with the reconstructed jet coming from hard-scattering vertex. "Anti k_T" is a dedicated algorithm for reconstructing jets, and the "R" means the isolation cone of each jet.

3. Missing energy simulation

The missing transverse energy (MET) is a particularly important quantity for SM processes involving neutrinos and for searching for new physics. It is calculated as the negative absolute value of the vectorial sum of the transverse momenta of all the particles reconstructed with the particle flow algorithm. Figure 4 shows an example of the efficiency with a special cut on reconstructed MET p_T, by comparing the default reconstruction method and the new method. Regarding the similarity of the two curves, the new reconstruction scenario is reasonable to be used on RunII based on emulation level.

4. Trigger efficiency of data

With the first physics data being taken at 13TeV, the efficiency of triggers with respect to offline reconstructed jets can be evaluated. Figure 5 shows the efficiency of a specific HLT path, which triggers on the HLT particle flow jets with p_T larger than 40 GeV. Because the trigger path has been pre-scaled, the number of events passing the trigger selection has been multiplied by the global pre-scale factor. Due to statistical fluctuations, prescale corrected trigger efficiency can be estimated to be above unity. In general, the trigger path has good turn-on slope of efficiency on the new data.

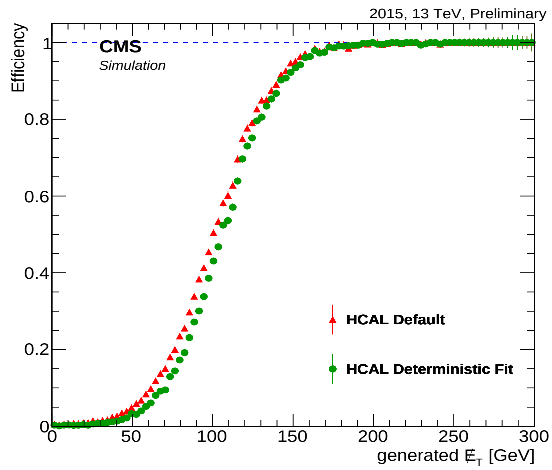

Figure 4: The MET efficiency of legacy RunI HCAL reconstruction ("HCAL Default") and the updated HCAL reconstruction to cope with the out-of-time pileup induced by the 25ns bunch spacing in RunII reconstruction("HCAL Deterministic Fit"), with the reconstructed MET $p_T > 100$ GeV. The efficiency is defined as the number of events which pass the given cut on the MET at HLT divided by the number of events as calculated at generator-level.

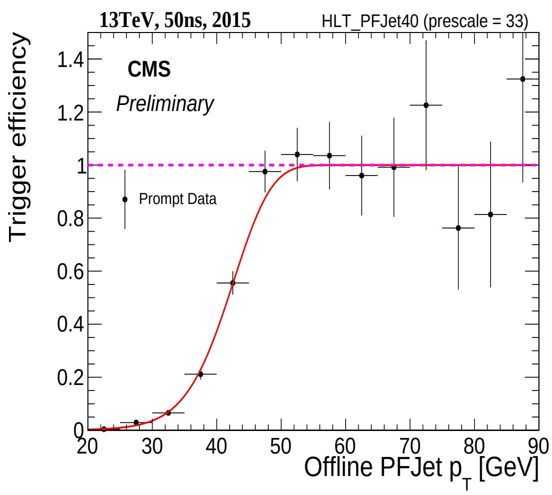

Figure 5: Turn-on curve of HLT efficiency of reconstructed jet on data with separation time of 50ns between each bunch crossing, for central proton-proton collision energy of 13 TeV. The specific trigger path name is "HLT_PFJet40", which requires the p_T of reconstructed particle flow jet on HLT larger than 40 GeV.

References

[1] CMS Collaboration, *The CMS experiment at the CERN LHC*, **JINST 3:S08004**, *2008*.

[2] CMS Collaboration, *Pileup Jet Identification*, **CMS-PAS-JME-13-005**.