PROCEEDINGS OF SCIENCE

CMS: Jet and missing E_T reconstruction

Milos Dordevic[a,*] **on behalf of the CMS Collaboration**

[a] *Vinca Institute of Nuclear Sciences, University of Belgrade, Mike Petrovica Alasa 12-14, 11351 Vinca, Belgrade, Serbia*

E-mail: milos.dordevic@cern.ch

The performance of jet and missing transverse energy (MET) reconstruction at the CMS experiment in LHC Run 2 data will be shown. The efficiencies of the reconstruction at the High Level Trigger will be discussed first, followed by the performance of the pileup mitigation techniques used in the jet and MET selection. The jet energy scale corrections used at the CMS experiment will be described, as well as the MET cleaning and reconstruction performance. The conclusions will be outlined with respect to the performance of jet and MET objects, with prospects for future studies.

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1. Introduction

Jets are experimental signatures of quarks and gluons produced in high-energy processes such as proton-proton collisions at the LHC. Jet production cross-sections are several orders of magnitude higher than those of other processes. Particles such as photons, electrons, muons and tau leptons can be mis-reconstructed as jets. The reconstruction of jets and missing transverse energy (MET) objects starts at the online (Trigger) level and this will be presented first. The high event pileup represents a challenge to reconstruct and calibrate jets at the LHC, which will be discussed next. The measurements of jet energy scale, resolution and the uncertainties at the CMS experiment [1] at the center-of-mass energy of 13 TeV, are discussed, followed by the performance of MET cleaning and of the pileup removal algorithms.

1.1 Jet and MET reconstruction at the High Level Trigger

The customized jet and MET reconstruction, with respect to the offline level, is executed at the High Level Trigger (HLT), optimized to be within the overall rate budget of the CMS Trigger and also to maintain the high reconstruction efficiency. The Particle Flow algorithm [2] is about hundred times faster than at the offline and the tracking algorithm at the HLT is reduced to three iterations. The jet energy corrections at the HLT are derived solely from the Monte Carlo (MC) simulated events.

The jet HLT efficiency is measured as a function of the offline jet transverse momentum (p_T) using a single-muon sample, for the thresholds ranging from 40 to 500 GeV, as presented in Fig. 1, showing good overall performance of the HLT selection. The MET HLT efficiency as a function of the offline MET is measured in single-electron sample and presented in Fig. 2, with good efficiency.

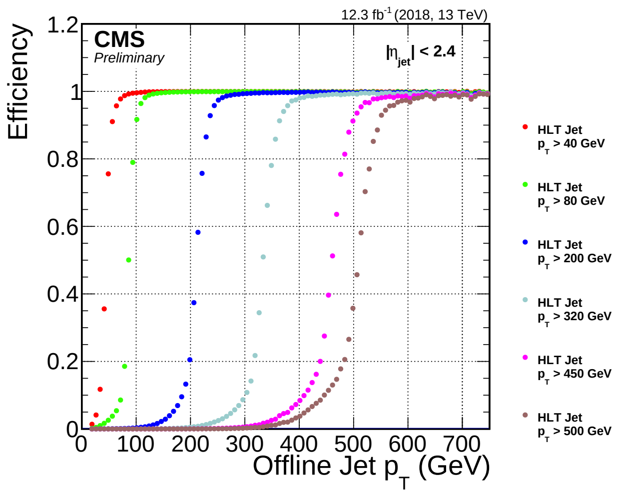

Figure 1: Jet HLT efficiency at 13 TeV for jets from 40 to 500 GeV [3].

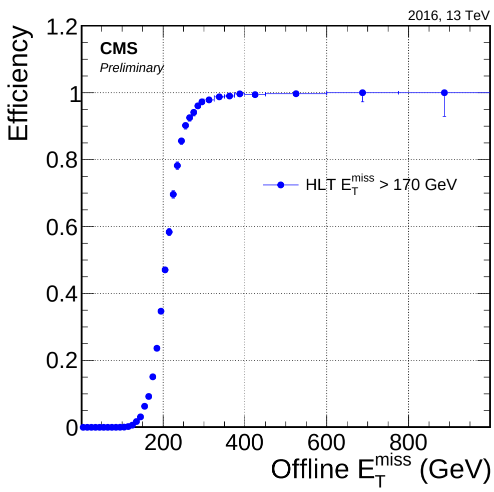

Figure 2: MET HLT efficiency at 13 TeV for MET above 170 GeV [3].

1.2 Pileup mitigation techniques at CMS

The Pileup is an ever growing challenge in LHC physics, where the average (expected) number of pileup interactions in LHC Run 2 (Run 3) is 29 (50). The most commonly used algorithm at CMS

PoS(LHCP2020)048

is Charged Hadron Subtraction (CHS) [2] which relies on the tracking information for removing the particles associated to the pileup vertices. After the CHS some pileup jets still remain, hence the PU Jet ID algorithm [4] is applied, which is a multivariate technique used to reject pileup jets. Pile Up Per Particle ID (PUPPI) algorithm [5] uses a distribution of neighboring particles to estimate the probability of neutral particle to be from pileup (effectively CHS plus weighting neutrals). The efficiency and purity of the pileup mitigation algorithms is measured in MC events, comparing CHS (+PU Jet ID) with PUPPI, as shown in Fig. 3 and Fig. 4, respectively. PUPPI has an improved efficiency, higher purity and the best overall performance in the central region of the CMS detector.

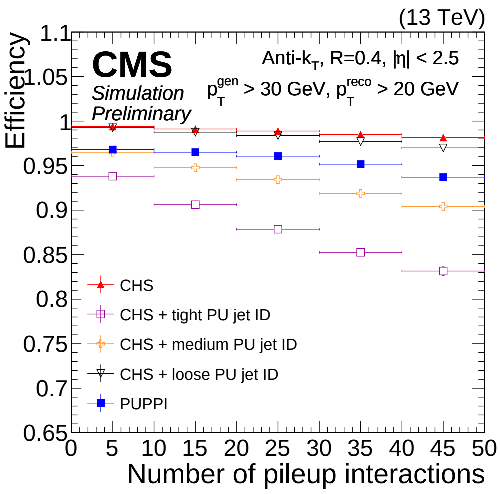

Figure 3: Jet efficiency in MC as function of number of interactions for PUPPI and CHS+PU Jet ID [6].

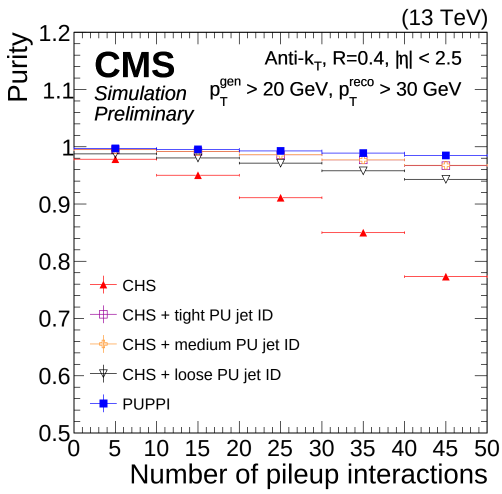

Figure 4: Jet purity in MC as function of number of interactions for PUPPI and CHS+PU Jet ID [6].

1.3 Jet energy scale corrections at CMS

At the CMS experiment, jets are calibrated using a factorized approach that, on average, restores the jet energy scale to the particle jet level. The pileup correction step (L1) accounts for an offset energy coming from pileup. The next, L2L3 step applies the correction versus the p_T and pseudorapidity, as obtained from the MC. The residual corrections are applied to data in order to account for data to MC differences. The jet response is shown in Fig. 5 and is stable in the barrel region, with a drop for lower p_T due to the limited HCAL acceptance. A stronger dependence on the jet p_T is found in the endcap and forward region, as well as some degradation in the transition region. The jet energy scale uncertainties are divided into sub-components: flat absolute scale uncertainties, the relative scale dijet uncertainties, the uncertainties due to pileup offset, the jet flavor uncertainties, the uncertainties due to differences per epoch and due to method and sample.

1.4 MET reconstruction, cleaning and performance

The most commonly used algorithm for MET reconstruction at CMS is the Particle Flow (PF) MET. The PUPPI MET is obtained by weighting the PF candidates. There exists also the "Type-1" MET that is obtained by propagating the jet energy corrections into the MET calculation.

PoS(LHCP2020)048

Anomalous MET events occur mostly due to the detector noise and a dedicated cleaning algorithms are applied at the first instance to remove such events. In terms of pileup mitigation, the PUPPI MET has around 20% better resolution for an average Run 2 pileup of 29, as shown in Fig. 6 (blue) when compared to the PF MET reconstruction (red) and it is also more stable as the pileup increases.

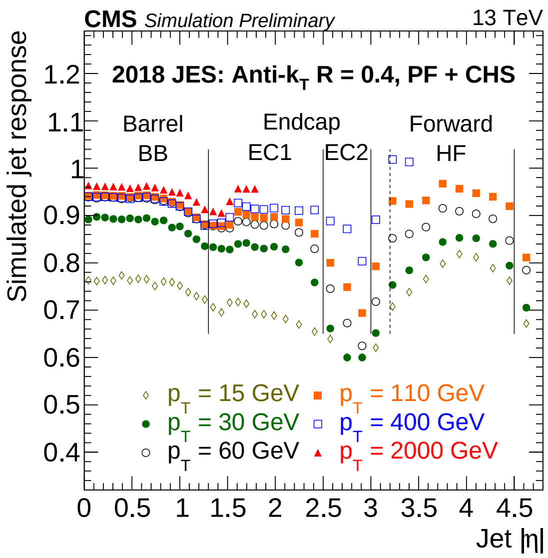

Figure 5: Simulated jet response versus η, presented in bins of p_T [7].

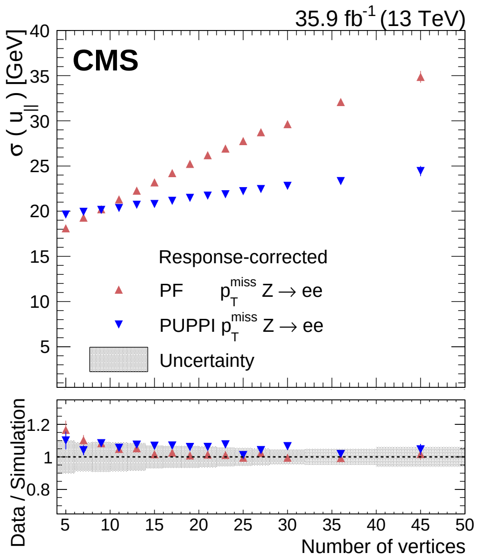

Figure 6: MET resolution comparison, versus a number of vertices [8].

1.5 Summary

The CMS Collaboration has demonstrated the ability to deal with the pileup conditions expected in the LHC Run 3, with the mitigation techniques exercised in LHC Run 2. Significant gain in MET reconstruction performance is obtained using the new pileup mitigation techniques such as PUPPI.

References

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