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Search for Z' bosons decaying into tau pairs in p-p Collisions at $\sqrt{s}$ =13 TeV with the CMS Detector

Thesis presented by

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The PF technique [1] takes the information collected by the CMS subdetectors in order to identify and reconstruct all the vissible final-state particles (electrons, muons, photons, charged hadrons and neutral hadrons) produced in the hard interaction. The PF technique reconstructs the jet constituents individually from the combination of tracks and calorimeter clusters. Then, the jet reconstruction is performed with the anti$-k_T$ algorithm [2] iterating over all the PF objects, using a distance parameter of $\Delta R = 0.4$ in the $\eta - \phi$ plane, where $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$.

The four-momentum of the reconstructed jet is the addition of the four-momenta of all the PF objects associated to the jet. However due to detector responses and experimental effects, the PF jet four-momentum does not correspond to the four-momentum at parton or hadron level; therefore, jet energy corrections (JEC) are required. Figure 3.1 shows the different levels of corrections which are applied in a fixed sequence. Each correction corresponds to a multiplicative factor C on the PF jet four-momentum (p_μ^{raw}):

$$p_\mu^{corrected} = C \times p_\mu^{raw} \tag{3.1}$$

The first step in the chain is the "L1 corrections" (also refered as "pileup offset"). It attends the additional tracks and the excess of energy deposits in the

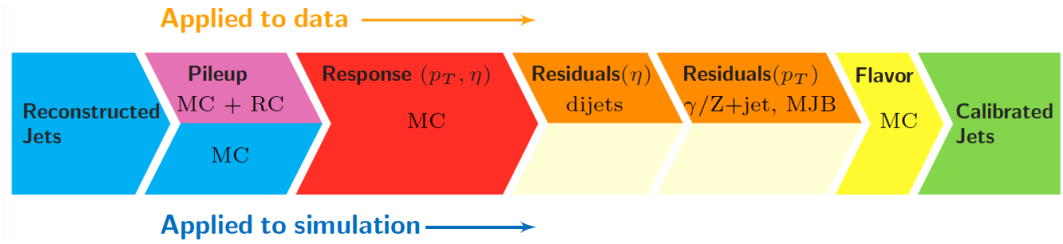

Figure 3.1: Levels of corrections for PF jet four-momentum. Figure taken from [3]

calorimeters due pile-up events . The amount of the pile-up contribution to the jet energy can be estimated from the global per-event $p_{T,offset}$ density ρ and the jet area [4]. This amount is obtained from simulated dijet events with and without PU.

The second level of JEC is related with the detector response to hadrons (L2L3 MC-truth corrections), correcting the non-uniformity in η and the non-linearity in p_T. The simulated jet response is determinated with QCD-multijet events generated with Pythia and with a simulation of the CMS detector based on Geant4.

After these steps, the L2L3 Residual corrections are applied in order to address the remaining difference between the jet response on data and MC (of the order of 1%). This corrections are achieved with data-driven methods, using dijet samples for η-dependent corrections and γ/Z+jets samples for the corrections to p_T. The last stage of the JEC (L5) is optional and it accounts the jet-flavor corrections.

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Bibliography

[1] *Particle-Flow Event Reconstruction in CMS and Performance for Jets, Taus, and MET*. Tech. Rep. CMS-PAS-PFT-09-001, CERN, 2009. Geneva (Apr 2009).

[2] M. Cacciari et al. *The Anti-k(t) jet clustering algorithm*. *JHEP* 04 (2008), 063. arXiv:0802.1189.

[3] V. Khachatryan et al. (CMS). *Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV*. *JINST* 12 (2017)(02), P02014. arXiv:1607.03663.

[4] T. C. collaboration. *Determination of jet energy calibration and transverse momentum resolution in CMS*. *Journal of Instrumentation* 6 (2011)(11), P11002.

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