Jet Energy Calibration and Resolution at CMS experiment

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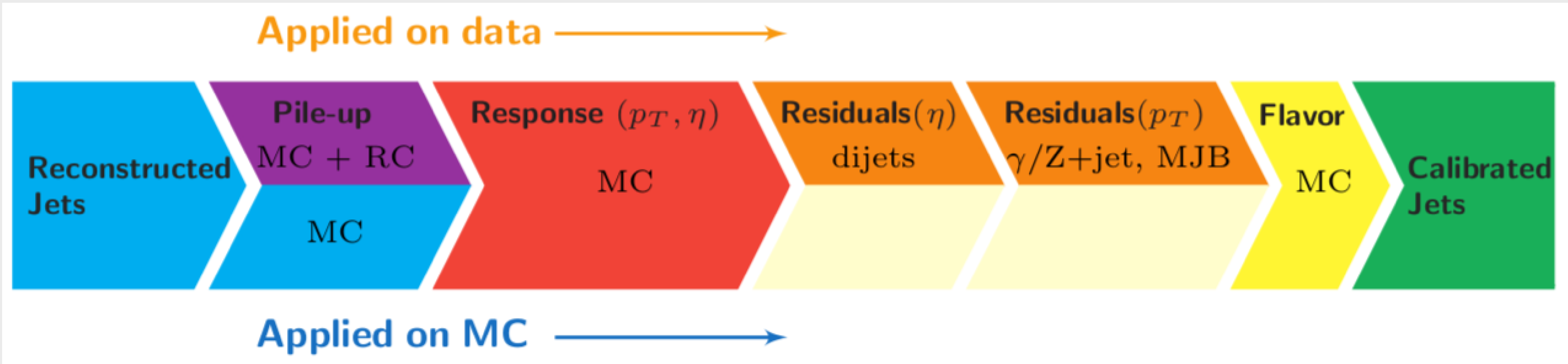
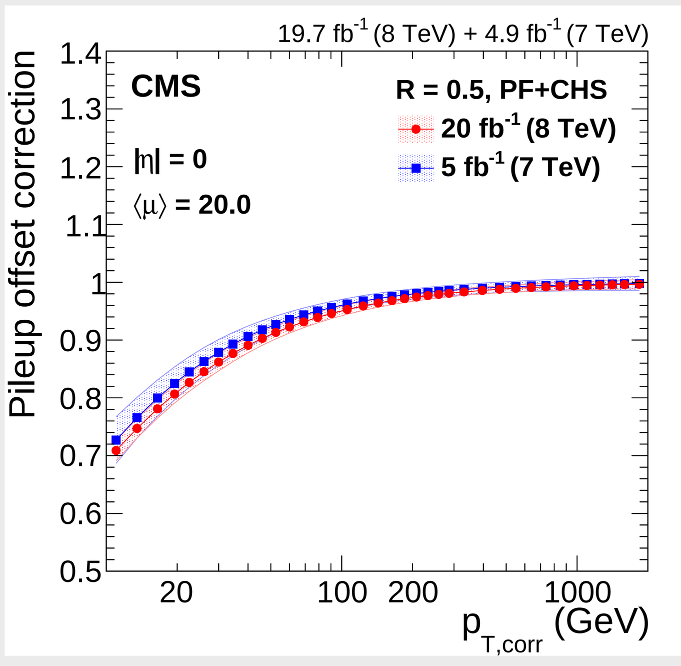
Jet energy calibration chain in the CMS experiment



Jets are experimental signatures of energetic quarks and gluons produced in high-energy processes. The jets are reconstructed from energy deposits in various CMS subdetectors (energy clusters in electromagnetic and hadronic calorimeters, and tracks in tracker). This makes them complex objects, and challenging to calibrated to infer four-momenta of the original quarks and gluons. A **factorized approach** is employed to correct the jet energy scale (JES) for various physics and detector effects. The first step corrects for the effect of pileup in hadronic collisions. In the second step, transverse momenta of reconstructed jets are corrected to match that of particle level jets using simulated multijets events . The third step is applied on data only and corrects for any residual differences with respect to simulated energy scale as a function of η and p_T of the jet. On top of that, the jet energy resolution (JER) is also used to smear the jets p_T in simulation to correct for any differences between data and MC.

Pileup offset correction

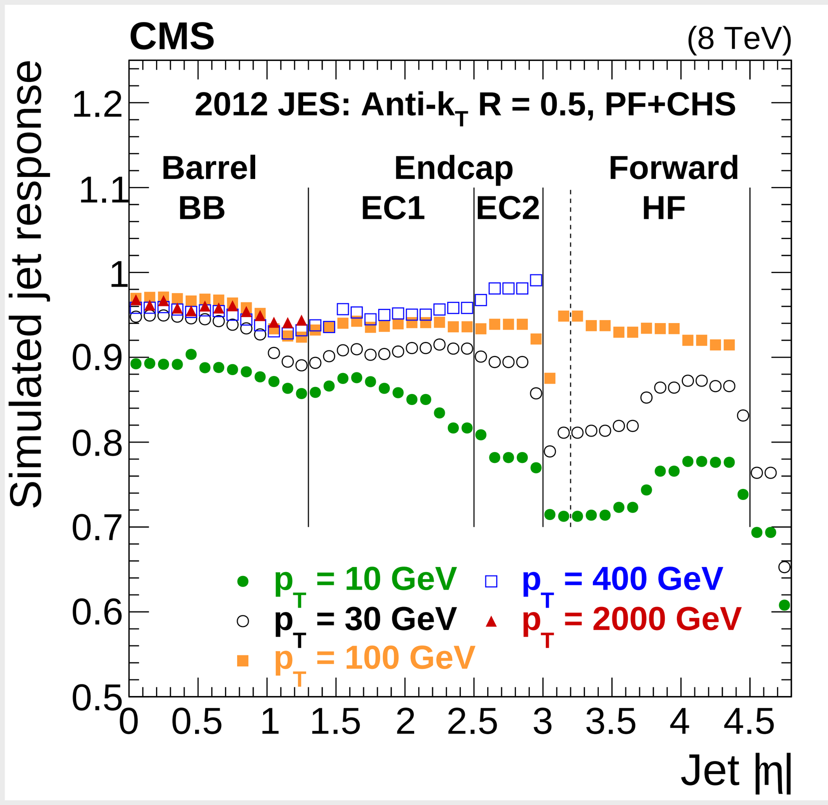
Given the LHC high instantaneous luminosities, multiple collisions happen in a single beam crossing (pileup). This extra activity results in an energy offset in the jets that the jet energy correction should account for.



The hybrid jet area method uses the effective area (A) of the jets multiplied by the average energy density (ρ) in the event to calculate the offset energy to be subtracted from the jet. The correction, per jet, is given by :

$$C_{\text{hybrid}}(p_\mathrm{T}, \eta, A, \rho) = 1 - \frac{[\rho_0 + \rho\beta(\eta)(1+\gamma(\eta)log(p_\mathrm{T}))]A}{p_\mathrm{T}}$$

Simulated responses correction



The simulated response corrections are extracted from multijets MC samples that have been reconstructed with a detailed model of the CMS detector which takes into account detector geometry, data-based alignment and calibration of the detector elements. The use of simulation based corrections allows us to avoid biases inherent to data based methods and derive the corrections in areas of the phase space which are not accessible using only data.

The simulated response is defined as :

$$R_{\text{ptcl}}(<p_\mathrm{T}>, \eta) = \frac{<p_\mathrm{T}>}{p_{\mathrm{T,ptcl}}}[p_\mathrm{T}, \eta]$$

The response is the ratio between the reconstructed transverse jet momentum p_T and the particles-level one $p_{\mathrm{T,ptcl}}$. The response is derived in bins of p_T and η. The main uncertainties arise from the detector calibration.

Residual correction for data

The residual corrections are derived from events where a reference object is **balanced** by a jet , with no real missing transverse energy ($\vec{\not{E}}_\mathrm{T}$). Two methods are used to constrain the corrections :

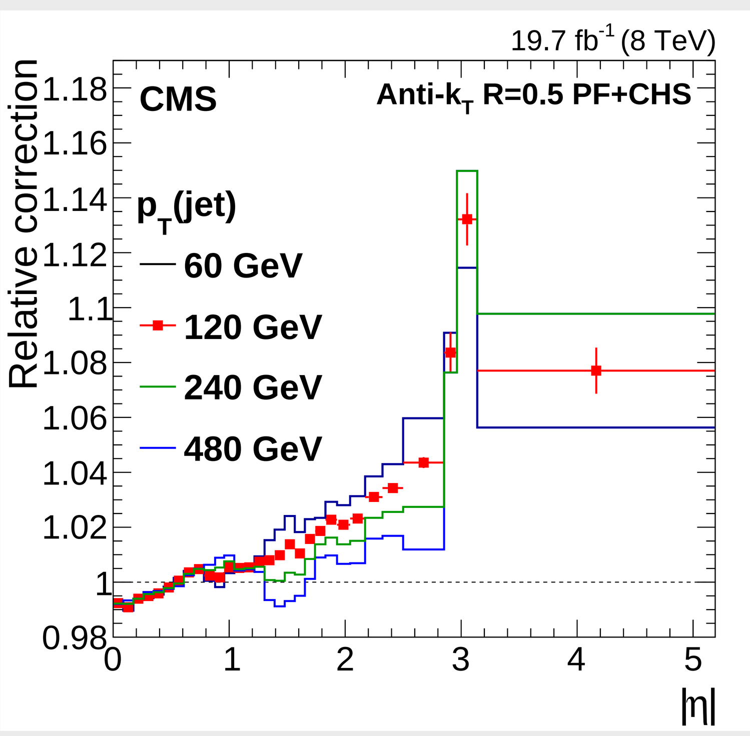
$$R_{\text{balancing}} = \frac{p_\mathrm{T}^{\text{jet}}}{p_\mathrm{T}^{\text{ref}}} \quad \text{and} \quad R_{\text{mpf}} = 1 + \frac{\vec{\not{E}}_\mathrm{T} . \vec{p}_\mathrm{T}^{\text{ref}}}{p_\mathrm{T}^{\vec{\text{ref}}\,2}}$$

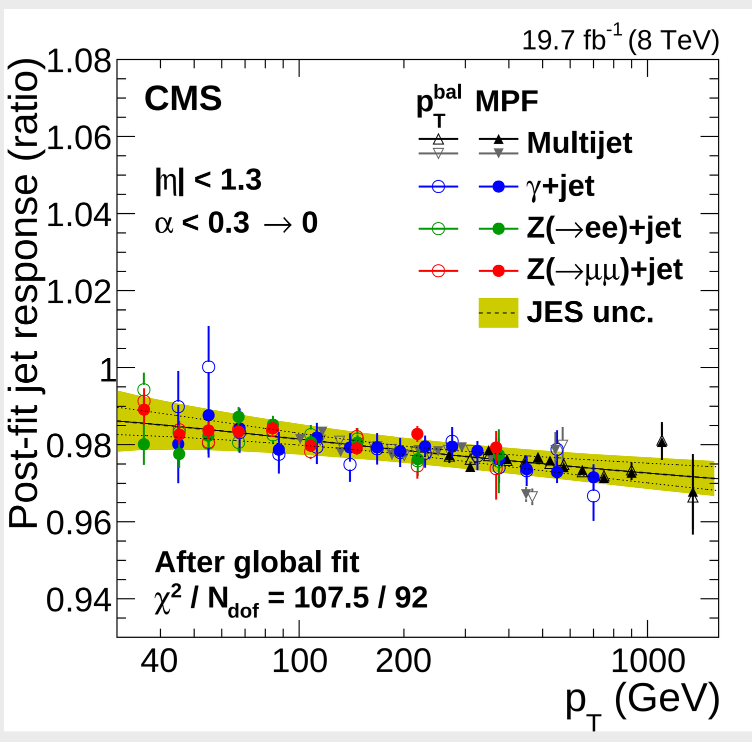
$R_{balancing}$ measures the balance of the two most energetic objects in the transverse plane. R_{mpf} balances the reference object against the whole hadronic recoil. Part of the imbalance originates from additional jets from initial/final state radiation (ISR/FSR) or pileup. To mitigate these effects, we extrapolate the responses to the limit of no additional jet in the event.

The corrections vs η are derived from dijets events where the reference jet must be in the barrel region and the probe jet η is not constrained.

The corrections vs p_T are derived with γ/Z + jets and multijets events, and combined into a global fit to better constrain the JES.

The dominant uncertaintity sources are : ISF+FSR, reference object scales and statistical uncertainties.





Jet energy resolution

The jet energy resolution is quite large compared to the resolution of other physical objects. Applying the proper smearing to the jets energy in simulation is therefore capital in numerous analysis to avoid biases.

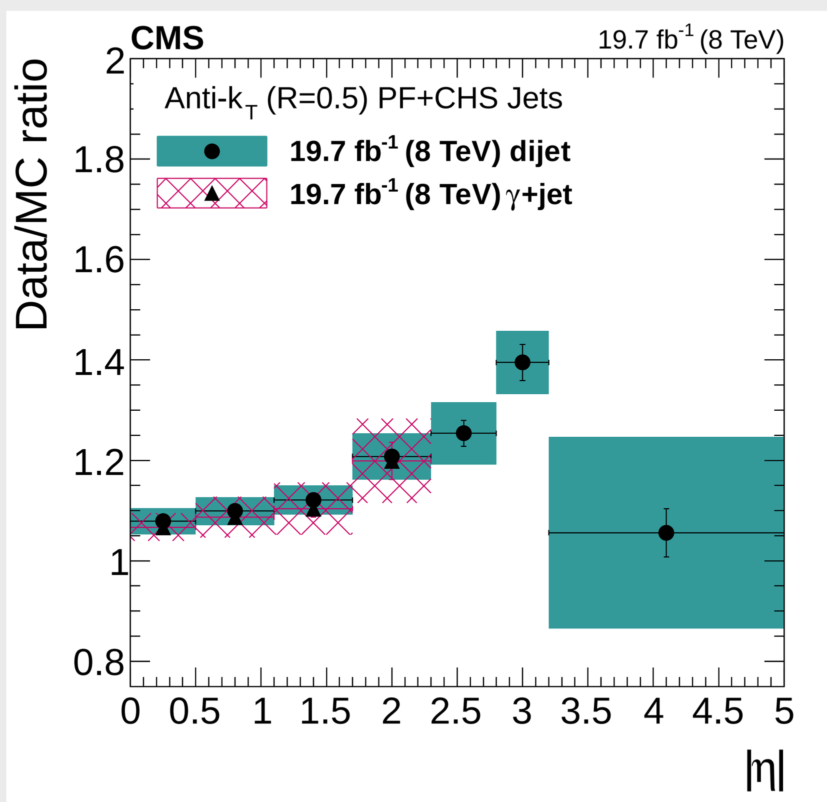
We define the particle level JER (σ_{JER}) as the width of $\frac{p_\mathrm{T}^{\text{jet}}}{p_{\mathrm{T,\,ptcl}}^{\text{jet}}}$.

The JER is measured from the width of the responses distribution, after extrapolation to zero additional activity:

$$R_{\text{balancing}} = \frac{p_\mathrm{T}^{\text{jet}}}{p_{\mathrm{T,ptcl}}^{\text{jet}}} \times \frac{p_{\mathrm{T,\,ptcl}}^{\text{jet}}}{p_{\mathrm{T,\,ptcl}}^{\gamma}} \times \frac{p_\mathrm{T}^{\text{jet}}}{p_{\mathrm{T},\gamma}} \qquad \rightarrow \qquad \sigma_{\text{JER}} = \sqrt{\sigma^2_{R_{\text{balancing}}} - \sigma^2_{\text{PLI}} - \sigma^2_{\gamma}}$$

We also define the particle-level imbalance, extracted from simulation, as $\text{PLI} = \frac{p_{\mathrm{T,\,ptcl}}^{\text{jet}}}{p_{\mathrm{T,\,ptcl}}^{\gamma}}$ which accounts for underlying event and out of time pileup effects.

The main sources of uncertainties in the JER computation arise from ISR and FSR correction, particle-level imbalance, and non-Gaussian tails in the responses.



References

JINST 12 (2017) P02014 (arXiv:1607.03663v2 [hep-ex] 26 Feb 2017)