Jet energy scale and resolution measurements at CMS

Anastasia Karavdina on behalf of CMS collaboration

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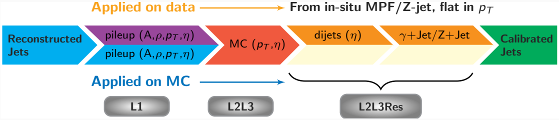
University of Hamburg

Jet energy scale corrections

JEC corrects reconstructed jets back to particle level



$$\frac{<p_T^{RECO}>}{<p_T^{ptcl}>}(p_T^{ptcl}, \eta, \mu) = 1$$

Factorized approach:

- Pileup corrections to correct for offset energy
- Correction to particle level jet vs. (p_T,η) from simulation
- Small residuals correction to data: pile-up, relative vs η, absolute vs p_T
  Although corrections are small, these are full physics analyses!

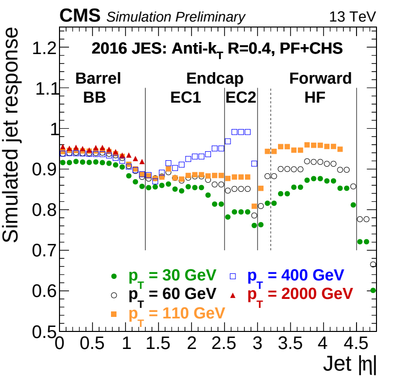
Jet Energy Resolution:

- Measured in MC vs (p_T^{ptcl},η,μ)
- Data/MC Scale factors from dijet events

Accuracy of JES has impact on all measurements with jets in final state

Jet energy scale from simulation

Matching particle-level and reconstructed jets in QCD MC



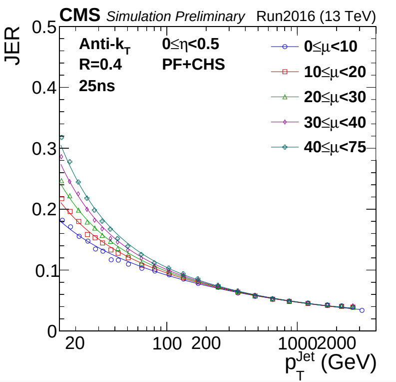
$$R_{ptcl}(<p_T>, \eta) = \frac{<p_T>}{<p_T^{ptcl}>}[p_{T,ptcl}, \eta]$$

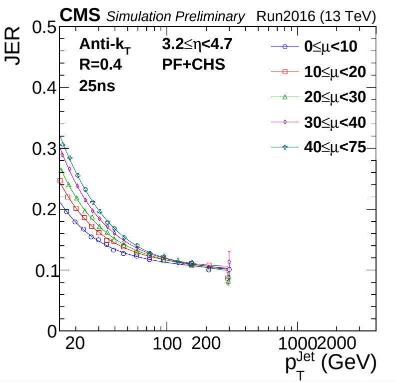
- Adressing the non-uniformity of the detector response
- Stable response in barrel
- Stronger p_T-dependence in Endcaps and HF
- Drop in response
  - at $3<|\eta|<3.2$ due to gaps
  - at $|\eta|>4.5$ due to acceptance

Jet energy resolution (JER) from simulation

$$\text{JER} = \sigma\left(\frac{<p_T>}{<p_T^{ptcl}>}\right)$$

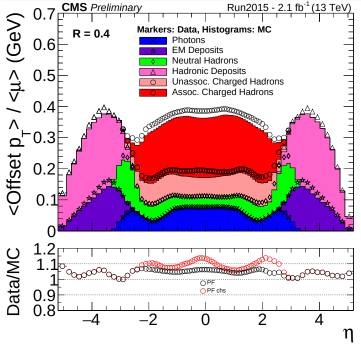
- Resolution stable against pileup above jet p_T=100 GeV
- Better than 10% (5%) resolution above p_T=100 GeV (1 TeV)
- Degradation of 50% at p_T=20 GeV for very high pileup of up to μ=75





Offset scale factor

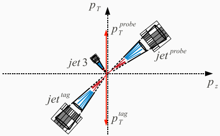
- Offset correction aims to remove IT and OOT pileup
- For simulation derived with QCD multijet events with/without pileup overlay



Residual correction to data: Random Cone method with zero-bias data and single-neutrino MC

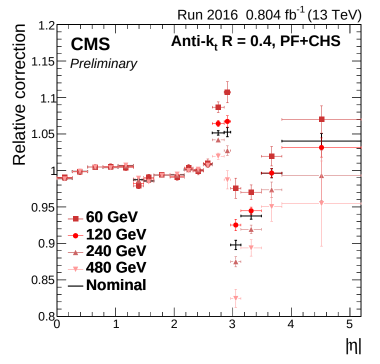
- No contribution from hard scattering → only noise and pileup
- Data/MC comparison for average offset per additional pileup interaction (μ)
- Different types of PF contributions monitored separately

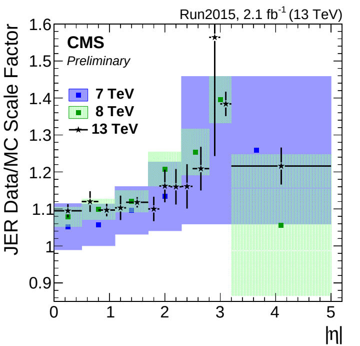
Relative η residual correction and JER SFs



- Disbalance in dijet events after MC based JEC applied
- Data/MC residual correction for the dependency of the jet response on the jet η

- Dijet events also used to measure JER SFs

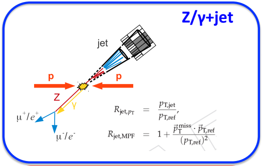


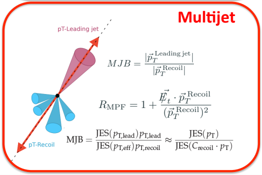


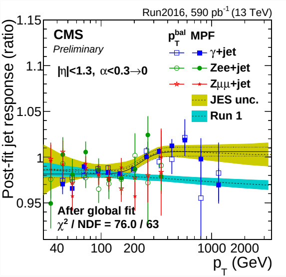
Absolute residual scale

Response in several channels to cover wide p_T range:

- $Z \to ll$ + jets
- γ + jets
- multijet

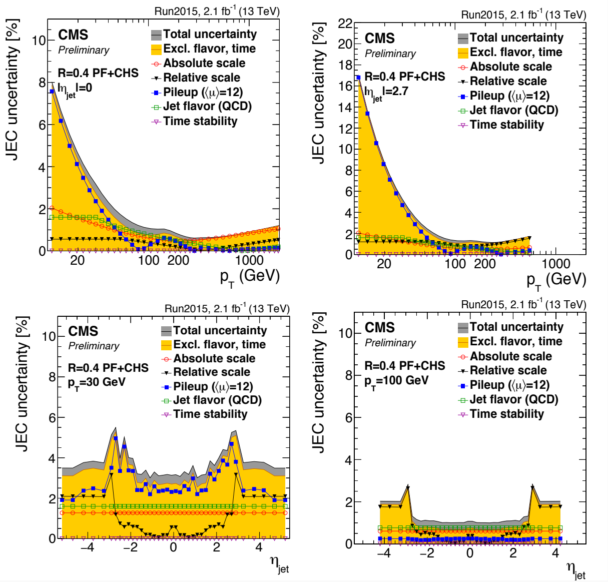






- Data/MC comparison for the jet response dependency on the jet p_T
- Global fit taking into account individual scales and uncertainties of reference objects (0.2% for μ, 0.2% for e, 0.5% for γ)
- Vulnerable to low-level/reference object instabilities

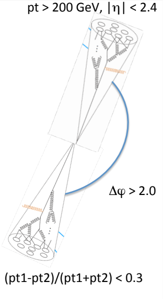
Jet energy correction uncertainties



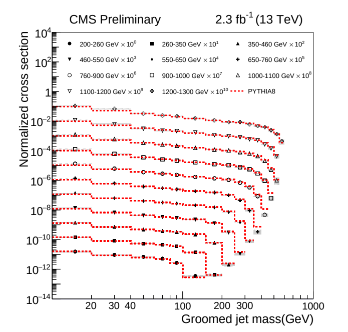
- Pileup uncertainty dominant below 50 GeV
- Important uncertainties: absolute scale at $|\eta|<3$ and relative scale at $|\eta|>3$
- Minimum uncertainty of 0.7% at p_T=300 GeV and $|\eta|<3$

The differential jet production cross section

- Jet mass is sensitive to the internal structure of jets, described by QCD parton showering
- Differential cross section of dijets with respect to p_T and mass
- Grooming technique to separate soft part and hard core of the jet
- First comparison to analytic calculations using soft drop jet grooming technique



- The uncertainties of the jet mass dramatically reduced after grooming is applied
- The physics modeling and pileup uncertainties are suppressed



CMS PAS SMP-16-010

Summary

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- Factorized approach:
  - Pileup corrections to correct for offset energy
  - Correction to particle level jet vs. (p_T,η) from simulation
  - Small residuals correction to data: pile-up, relative vs η, absolute vs p_T
- Understanding of both JEC and JER is of crucial importance for many physics analyses (e.g. the inclusive jet cross section and top quark mass)
- For first time at hadron collider a direct comparison is made between data and theoretical calculations for differential jet cross section with respect to p_T and mass
  $\rightarrow$ Sensitive observable to the physics modeling and could be used in future global fits for parameter tuning

Uncertainties estimate in RunI