Jet Energy Corrections in CMS

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Outline

- Introduction
- Jet Energy Corrections in CMS: Results with 2016 Data and Simulation.
- Conclusions/Ongoing work

CMS detector

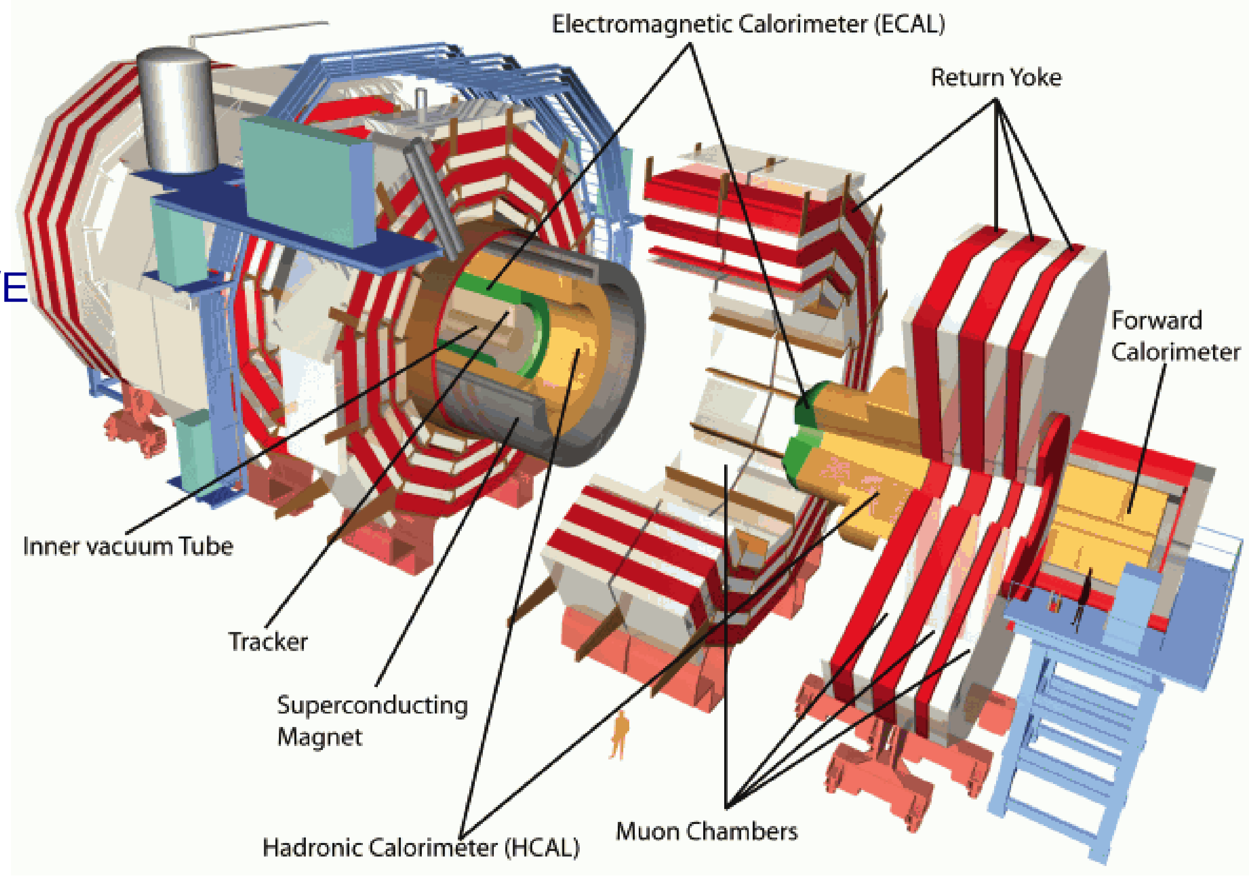
3.8 T

Pixels
$\sigma/p_T \sim 1.5 \cdot 10^{-4} p_T(\text{GeV}) \oplus 0.005$

Electromagnetic Calorimeter
$\sigma E/E \approx 2.9\%/\sqrt{E(\text{GeV})} \oplus 0.5\% \oplus 0.13\text{GeV}/E$

Hadronic Calorimeter
$\sigma E/E \approx 120\%/\sqrt{E(\text{GeV})} \oplus 6.9\%$

Muon Spectrometer
$\sigma p_T/p_T \approx 1\%$ for low pT muons
$\sigma p_T/p_T \approx 5\%$ for 1 TeV muons

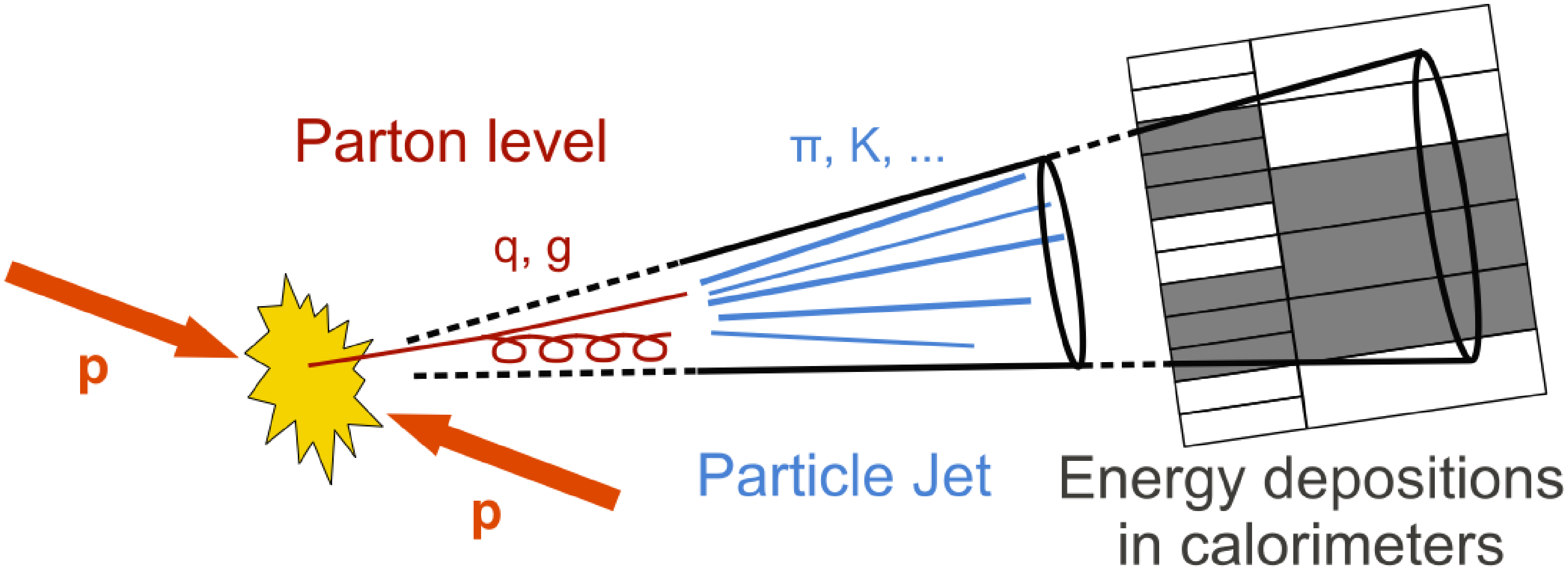


Jet Energy Corrections in CMS

•Jets are experimental signatures of quarks and gluons in high energy processes.

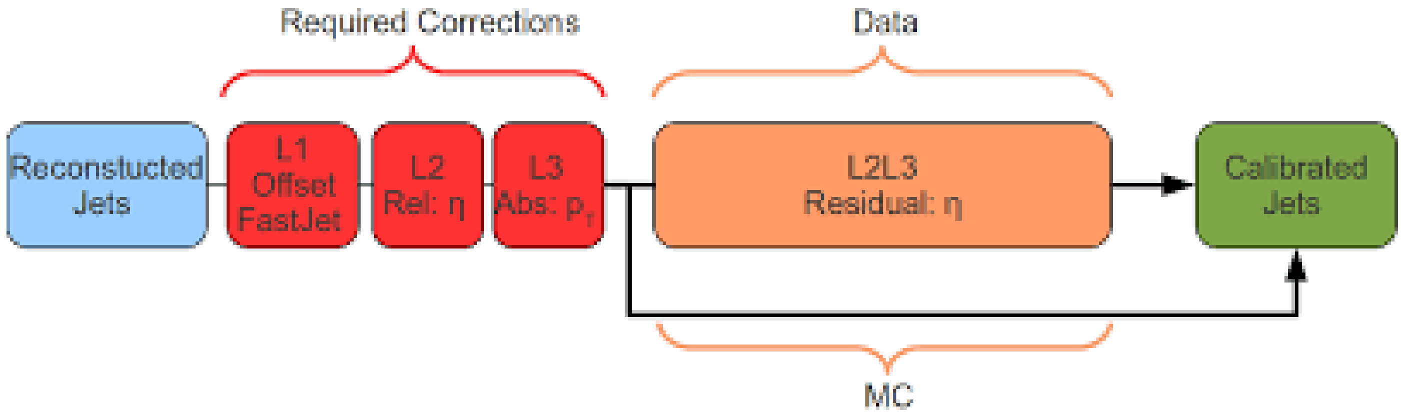
• The energy of the jet that is measured at the detector level and the one that is obtained at particle level are different.

•This is why Jet Energy Corrections (JEC) to the measured jet energy are necessary in order to approximate, as best as we can, the jet energies at the generator (particle) level.



Jet Energy Corrections at CMS: Overview

- L1 correction subtracts the average extra energy inside the jet cone due to pileup.
- L2 is a relative correction using balanced dijet events.
- L3 is an absolute correction using γ+jet events, Z+jets and multijet events.
- Baseline L2 and L3 corrections are obtained from simulation matching reconstructed with generated jets using dijet events. Then, residual ones are obtained from the data, using data-driven methods, to account for remaining differences between data and simulation.



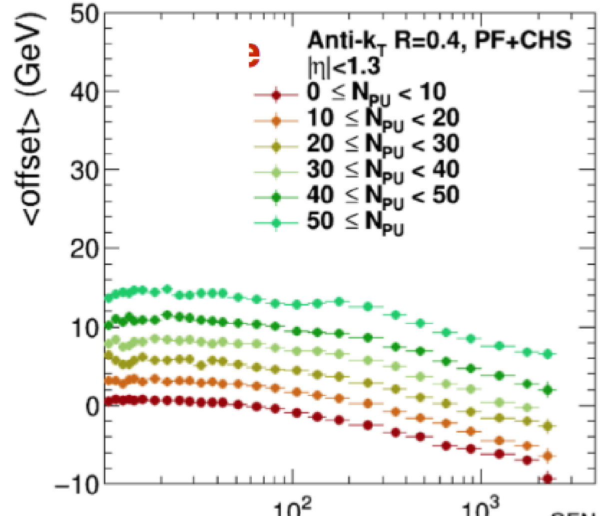
L1 offset

- The aim of this step is to estimate and subtract the energy that is not coming from the high pT scattering (due to Pile Up).

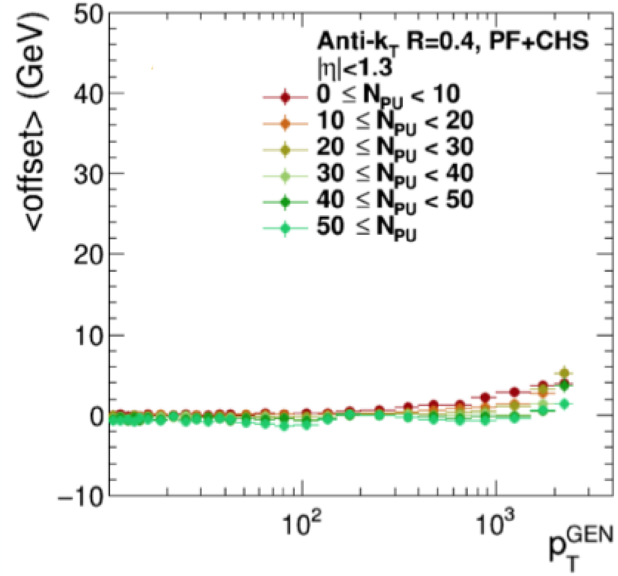
- L1 corrections derived by comparing same jets reconstructed in the same event with and without PU:

$$\langle \text{offset} \rangle = \langle p_{T,\text{jet(event with PU)}} - p_{T,\text{jet(event w/o PU)}} \rangle$$

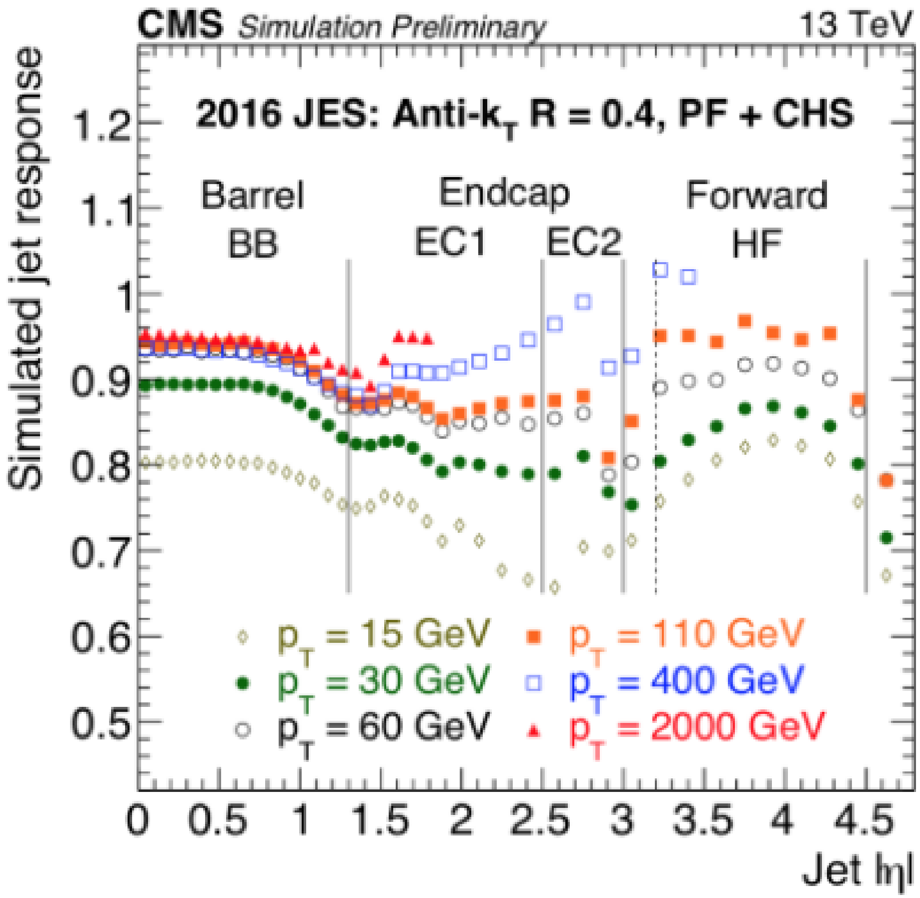
Before L1 corrections



After L1 corrections



Response Corrections

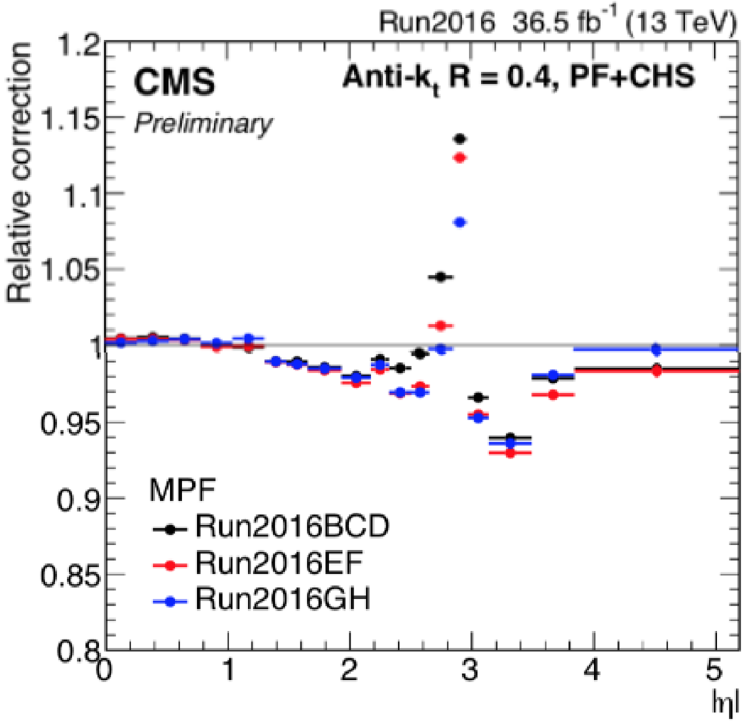


- The relative response is stable in the region |η|<1.3.

- Outside the tracker coverage, |η|>2.5, the relative response show large variation.
  - 3.0<|η|<3.2 due to detector transition
  - |η|>4.5 due to acceptance

Residual Corrections, Relative (η)

- The goal of this set of corrections, is to make the jet response flat as a function of jet η.
- We correct jet η in arbitrary η relative, to a jet in the central (|η|<1.3) region.
- In the region 2.5< |η| <3.0, the residual corrections are high.

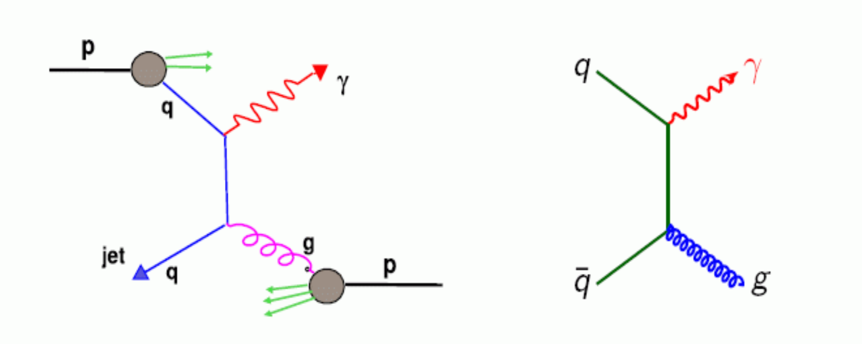


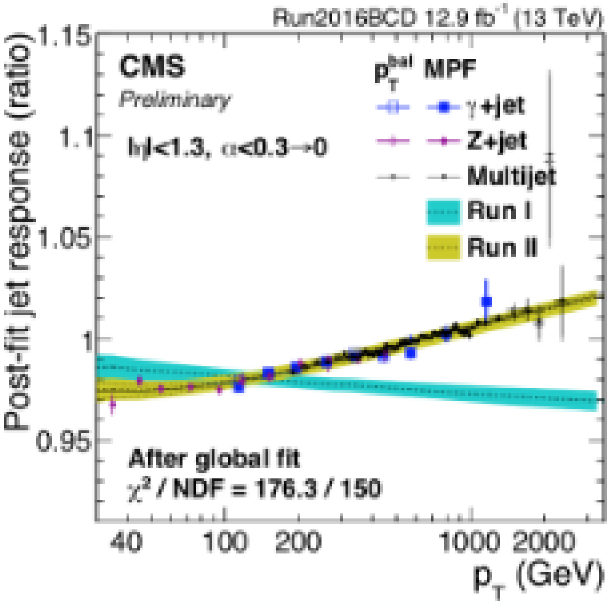
Residual Corrections, Absolute (pT)

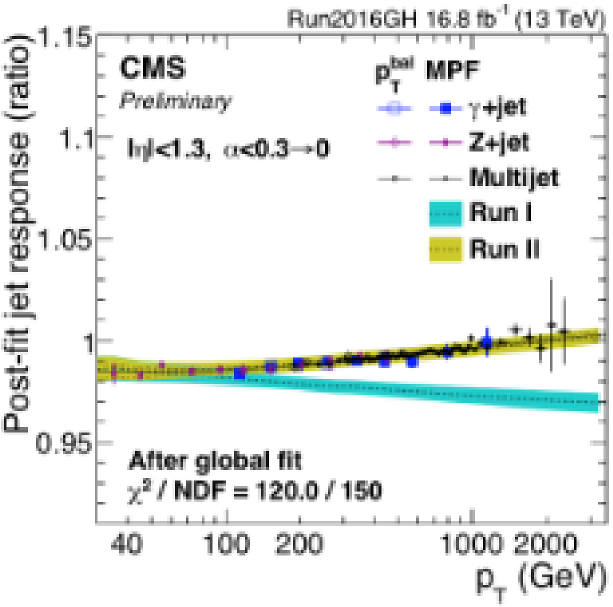
- The goal of this set of corrections, is to make the jet response flat as a function of jet pT

- We use events where a photon or Z boson is produced back-to-back to one or more jets.

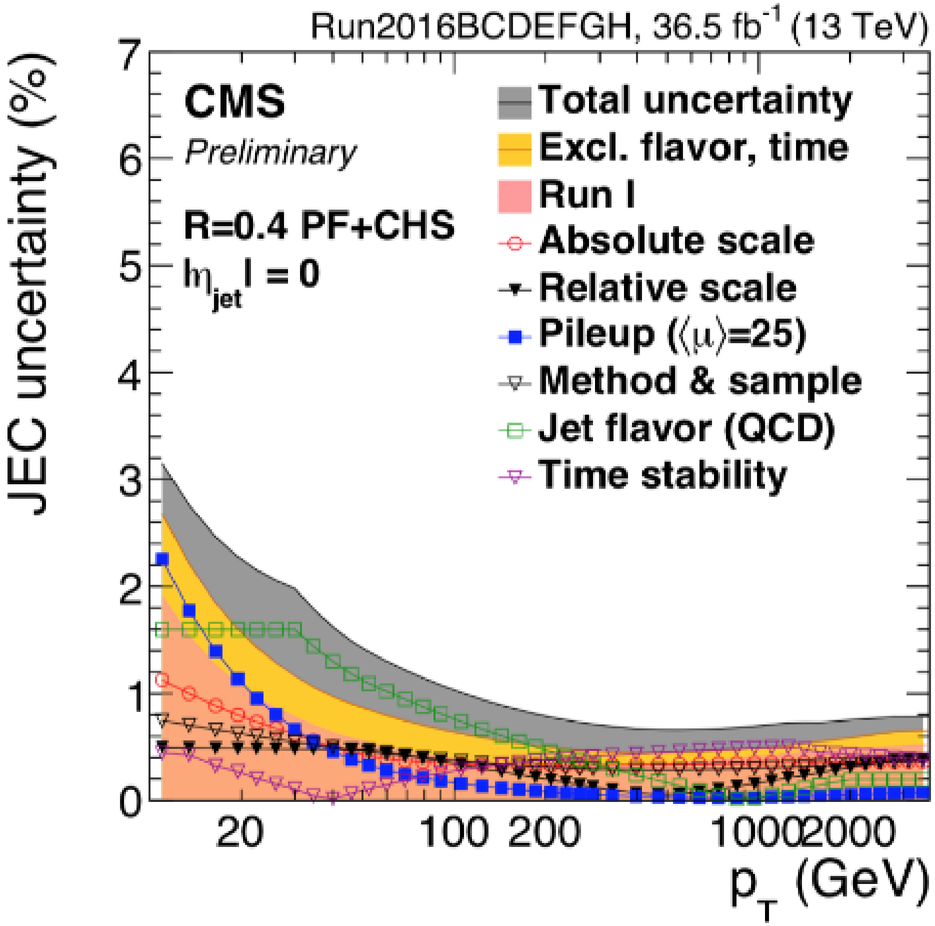
- The pT resolution of the photon or Z boson is much better than the jet resolution.







JECs: Uncertainties

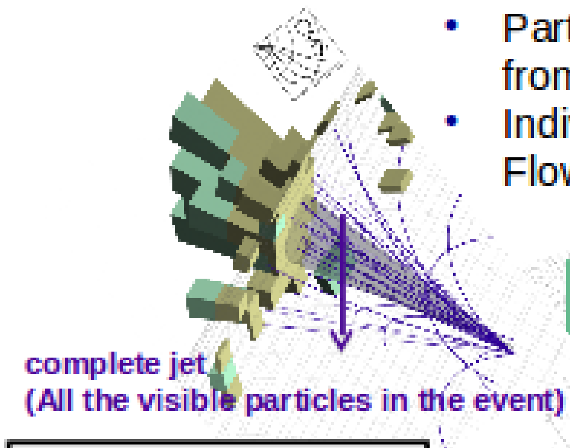


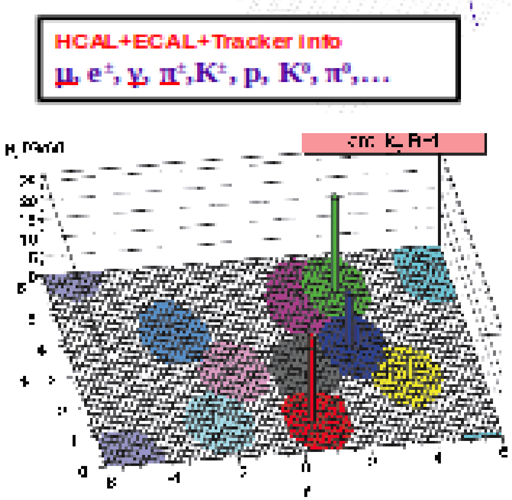
- At low pTs, pile up uncertainty dominates.

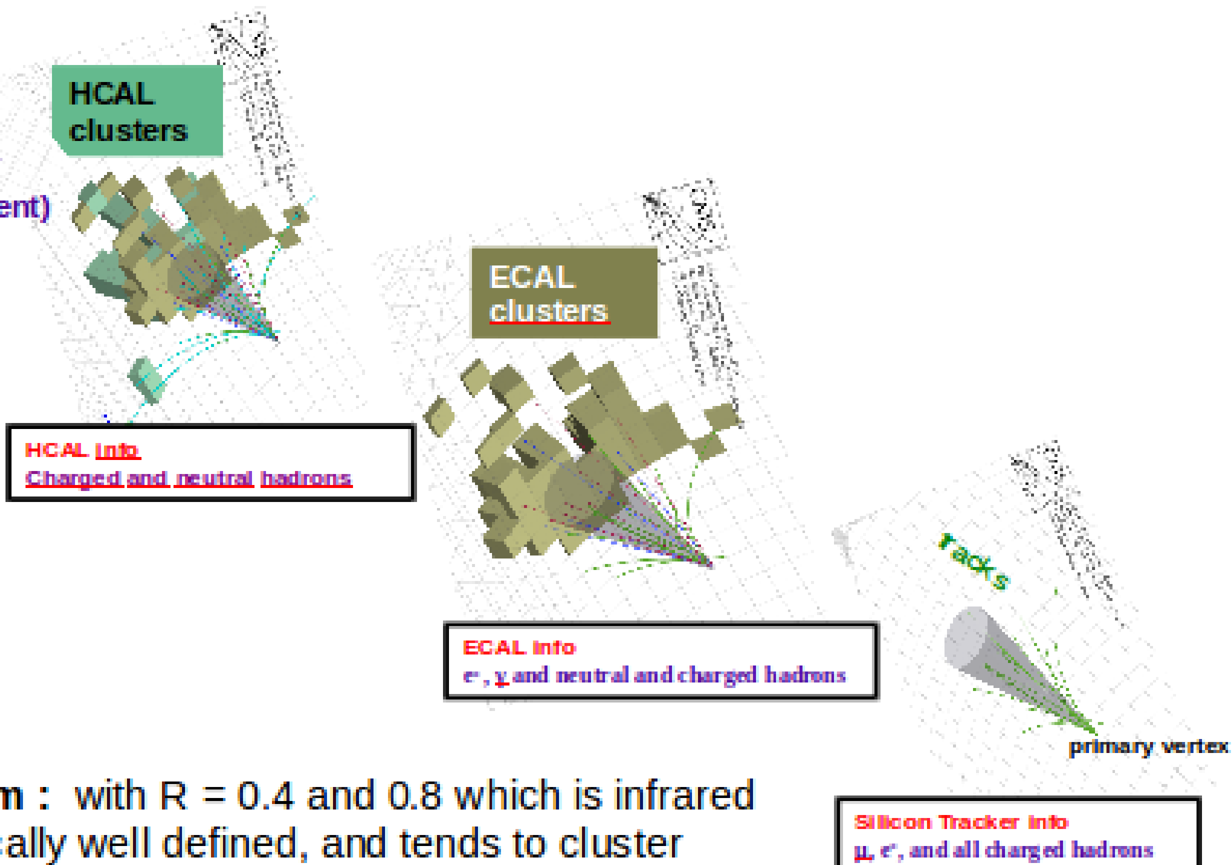
Jet Reconstuction

CMS

- Particle Flow Algorithm combines all information from several sub-detector systems
- Individual particles are reconstructed with Particle Flow Algorithm and then clustered into jets.







Anti-kt clustering algorithm : with R = 0.4 and 0.8 which is infrared and collinear safe, geometrically well defined, and tends to cluster around the hard energy deposits.

PUPPI algorithm

- PileUp Per Particle Identification

- It takes as input particle flow objects and it gives weight for each of them.

- Defines discriminating variable α, of each particle (i) using other particles

$$\alpha_i = \log \sum_{i \neq j, \Delta R_{i,j} < 0.4} \left(\frac{p_{Tj}}{\Delta R_{ij}} \right)^2$$

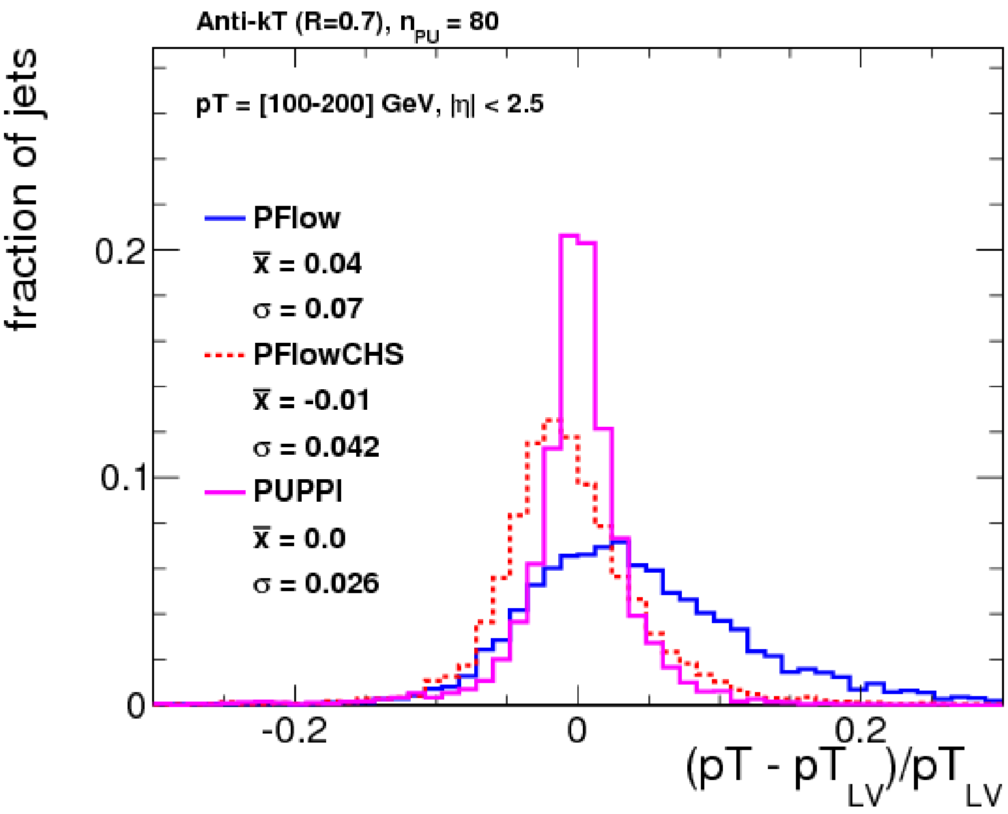
- Transforms the distribution of a in a weight (1 for particle from LV, 0 for particles from PU) .

$$w_i = f(\alpha_i)$$

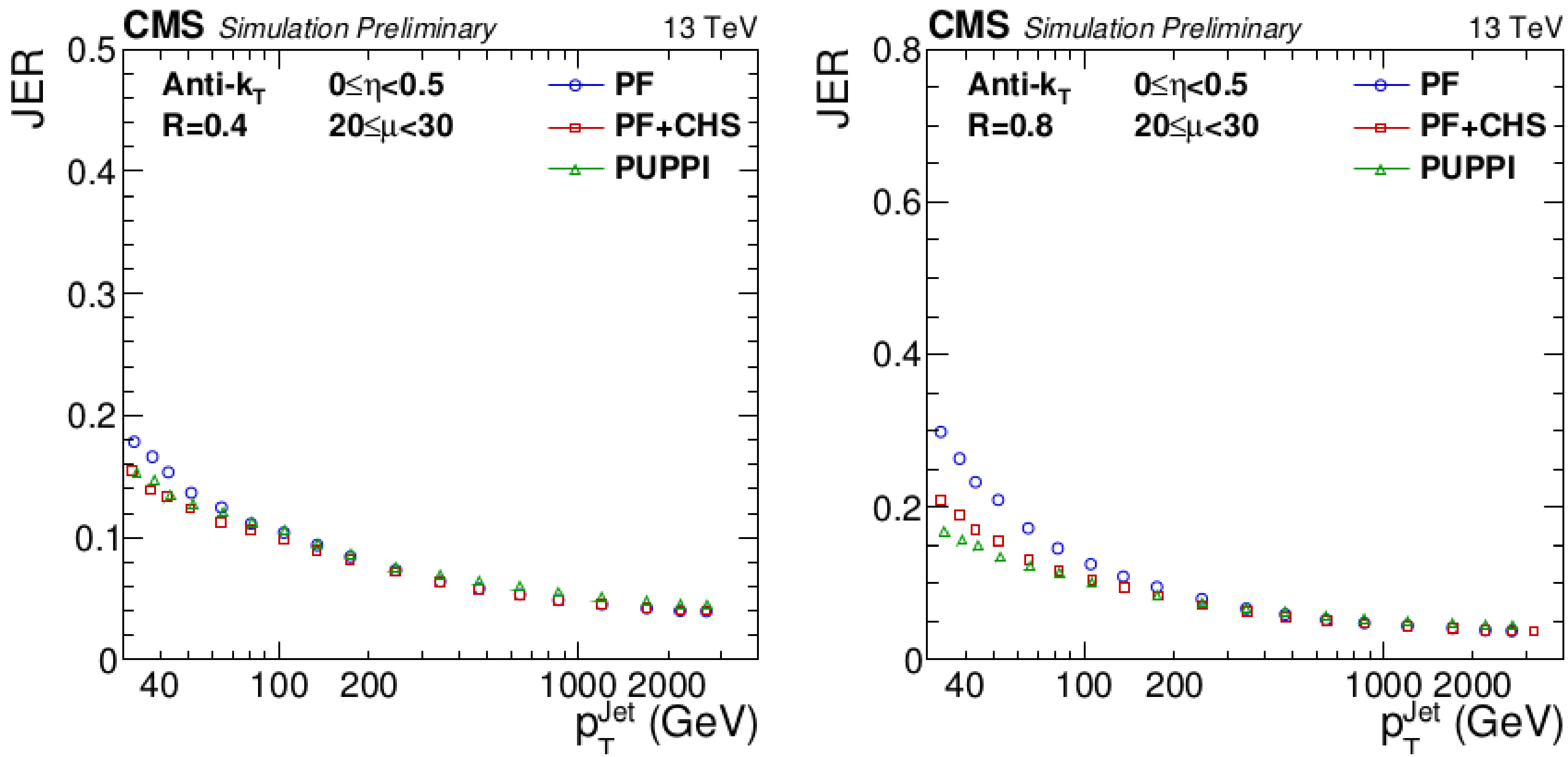
- The weight rescales the particle four-momentum.

- Despite the lack of tracking in the forward region, PUPPI is able to identify pileup particles there as well .

- This procedure leads to PileUp corrected PF Jets.



Jet pT resolution: PF CHS vs PUPPI



- For PF jets with a 0.4 cone-size, for 20-30 pileup interactions, the jet p_T resolution of CHS and PUPPI jets is similar.
- For PF jets with a larger 0.8 cone-size, for 20-30 pileup interactions,PUPPI jets have better resolution than CHS ones

General Stategy of L2L3 MC Truth Corrections on PUPPI Jets

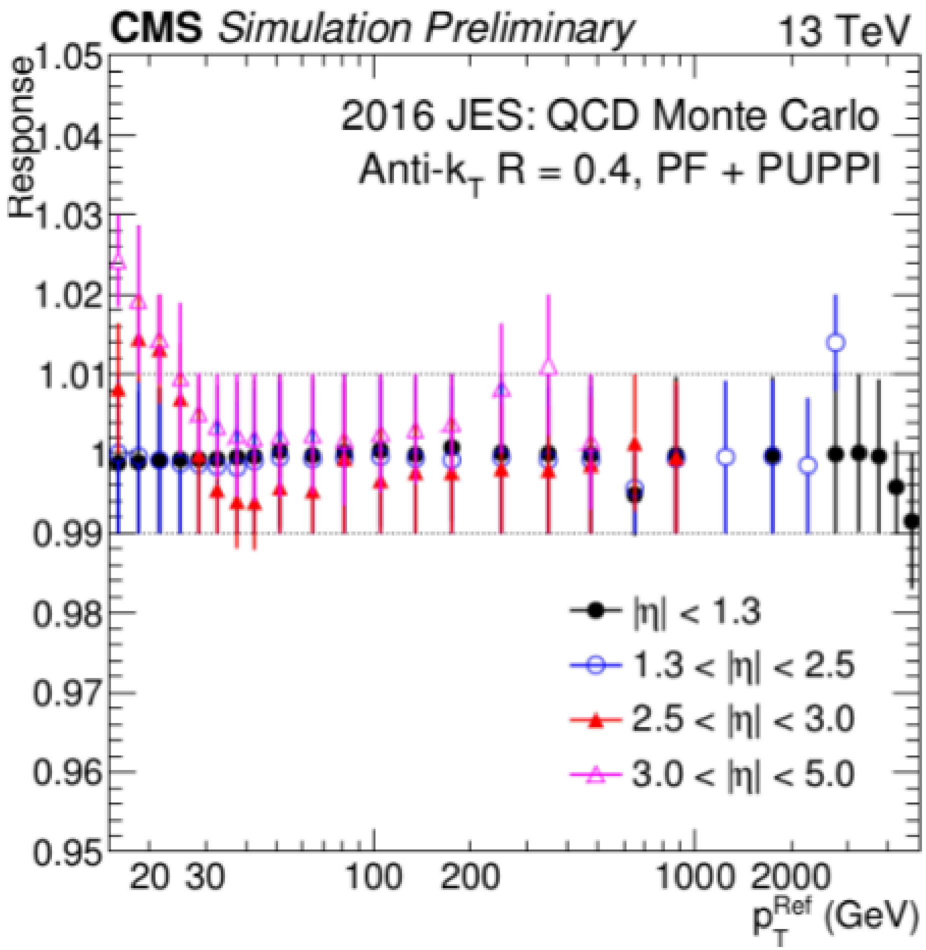
- For PUPPI PF Jets only L2L3 corrections are needed.

- Jet response p_T^{reco} / p_T^{gen} is determined in fine bins of p_T^{gen} and $|\eta|$ for generated and reconstructed jets that spatially matched with $\Delta R < 0.2$.

- Correction factor is the inverse of the mean response as a function of p_T^{gen} for each fine $|\eta|$ bin.

- Then, we examine the closure of the derived MC Truth Corrections, by applying them in the same sample from which we derived them: corrected response is 1 ± 0.01.

Relative Response vs Generated pT after the application of corrections



- The relative response p_T^{reco} / p_T^{gen} , after the application of L2L3 correction, is 1+/-0.01.

Conclusions

- In CMS the procedure of Jet Energy Corrections is factorized and each factor corrects for a different source:
  - Offset: removal of pile-up and residual electronic noise.
  - Relative (η): to equalize the response from different subdetector systems
  - Absolute (p_T): to correct the reconstructed jet energy to the true one.

- Pileup per particle identification (PUPPI) is a very promising pileup-rejection method being implemented in CMS. PUPPI PF jets in CMS have improved jet pT resolution for low jet pTs where pileup plays an important role.

- PUPPI PF jets in CMS do not need pileup (L1) JEC corrections down to PF jet pTs of 15 GeV, due to successful pileup handling. The performance of MC Truth JECs show that the corrected response is 1 +/0 0.01.

- Studies on PUPPI PF jets are ongoing to further improve their performance on CMS, as they will be becoming more and more important with the foreseen increase in instantaneous luminosity in Run III and HL-LHC.

- BACK UP

- Time stability: Accounts for the differences seen in residual corrections in different eras after applying corrections and comparing to JEC derived on the full sample

- Method & Sample:Accounts for the biases (large pT dependences) seen in the residual measurements