Karlsruher Institut für Technologie

Bundesministerium für Bildung und Forschung

Jet Energy Calibration in CMS

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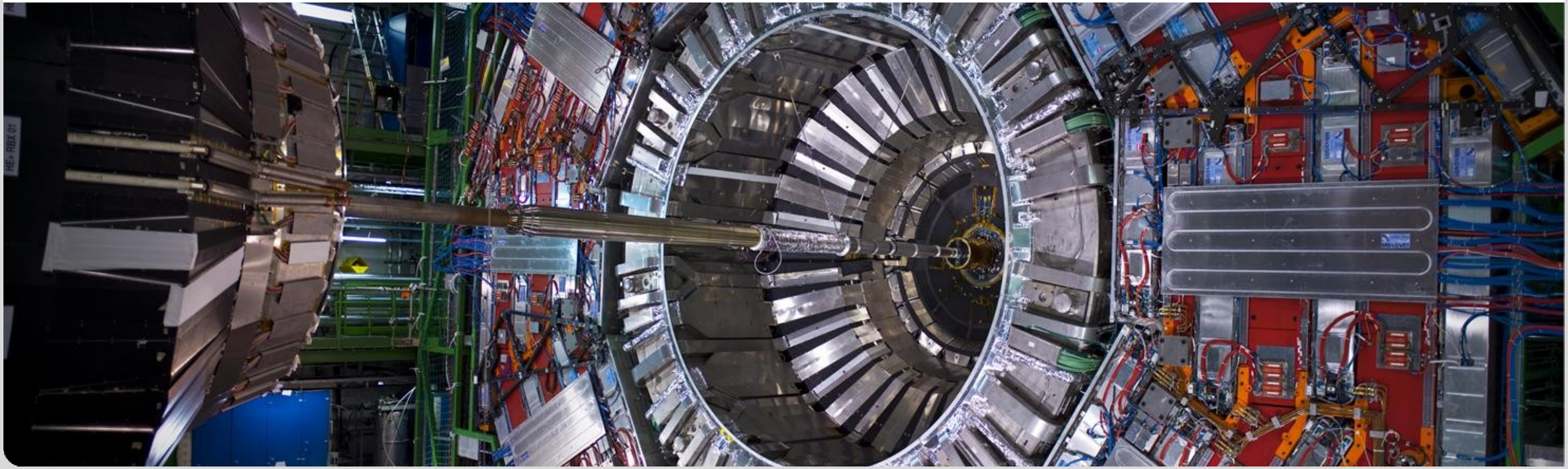

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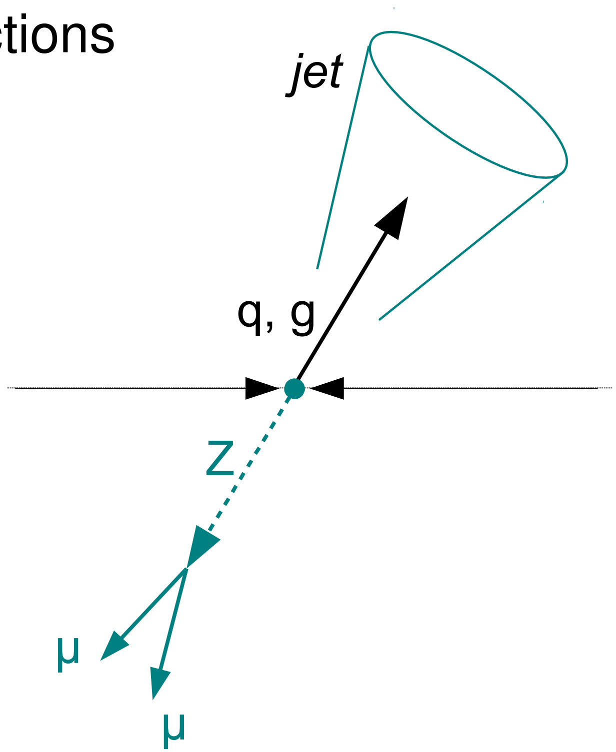
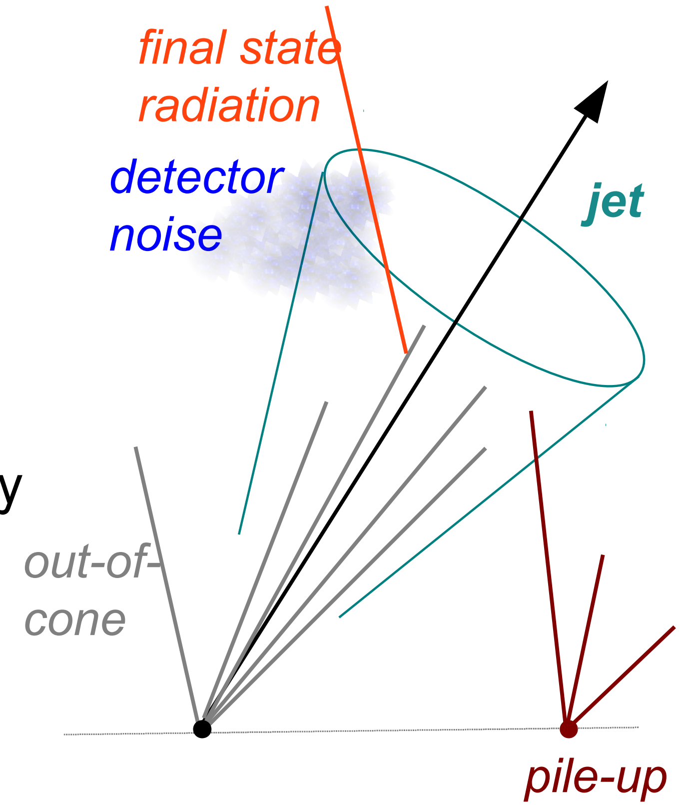


The Need for Jet Energy Corrections

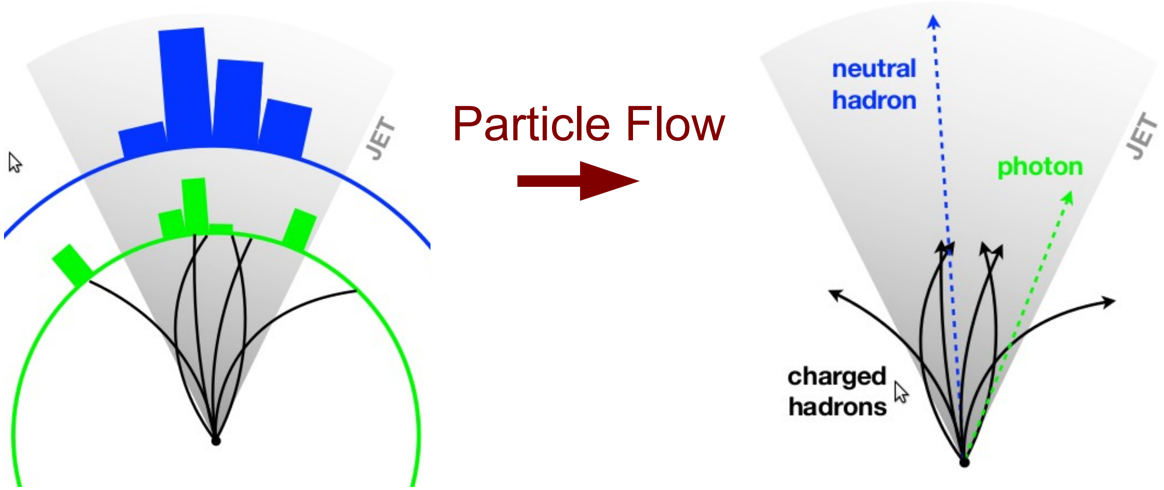
- A precisely calibrated jet energy is <u>important for almost all LHC analyses</u>
- Jet energy uncertainties are often the <u>largest contribution to total uncertainties</u>
- Jet energy measurements are <u>complicated</u> by effects such as out-of-cone particles, pile-up energy, coarse detector resolution, …



- **Precise corrections of the jet energy and an understanding of the uncertainties and correlations are mandatory**

Particle Flow (PF) and Jet Reconstruction

- CMS uses the Particle Flow approach
  - Combine information from all detector subsystems to reconstruct individual particle candidates
  - Jet clustering and MET calculation are done with PF candidates



http://moriond.in2p3.fr/QCD/2011/ThursdayMorning/Pandolfi.pdf

- In the following, I will refer to jet clustered with the anti-k_T algorithm with R=0.5

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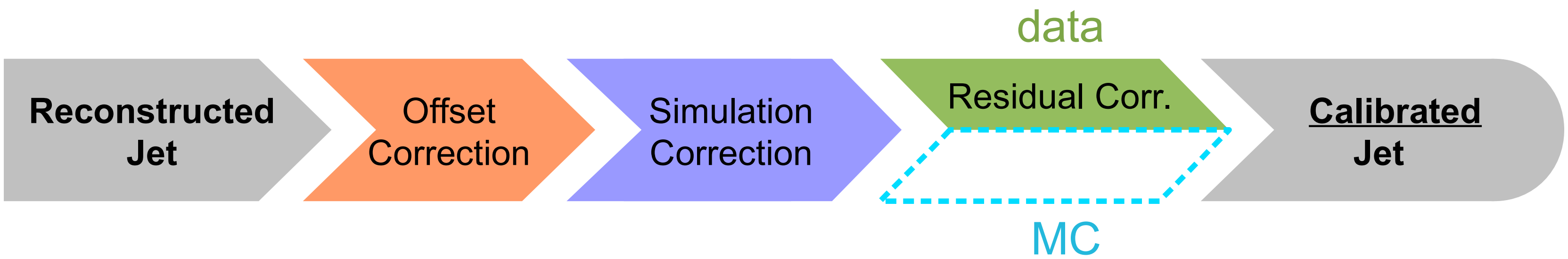


Factorized jet energy correction approach:

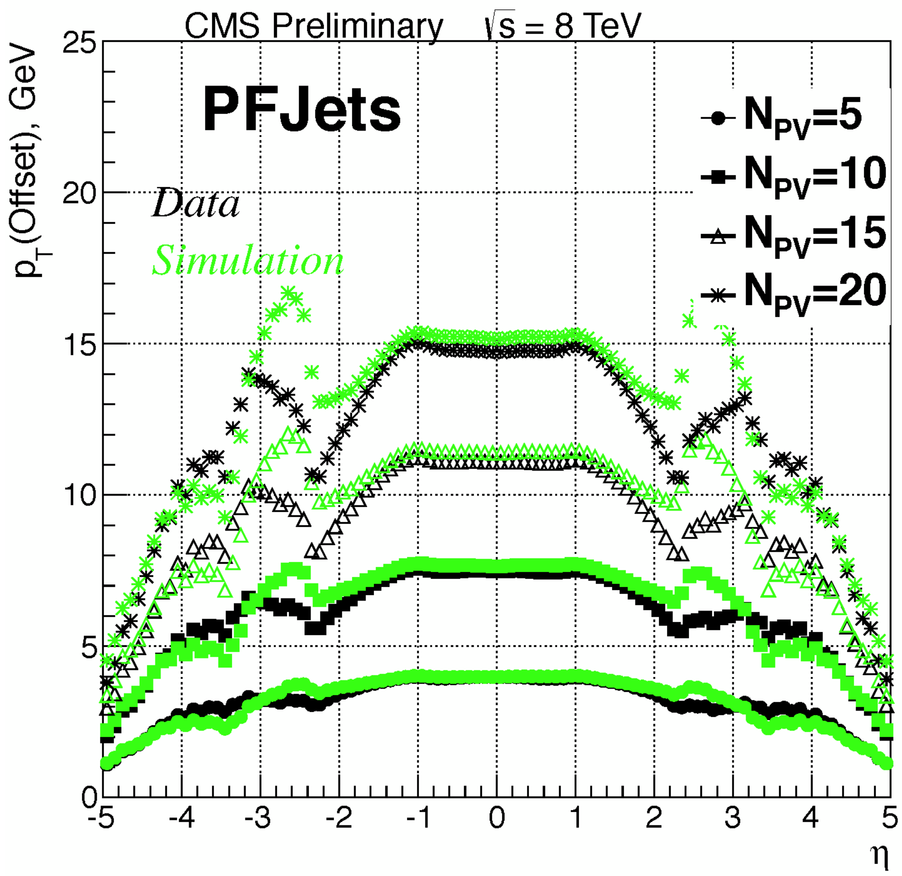
1) Remove *pile-up effects* and *detector noise*
→ derived from data and simulation

2) Correct for *response differences between* η / p_T *regions*
→ derived from simulation

3) Correct for *residual data/simulation differences* (applied on data only)
→ relative: derived from dijet balancing
→ absolute: derived from Z/photon+jet balancing

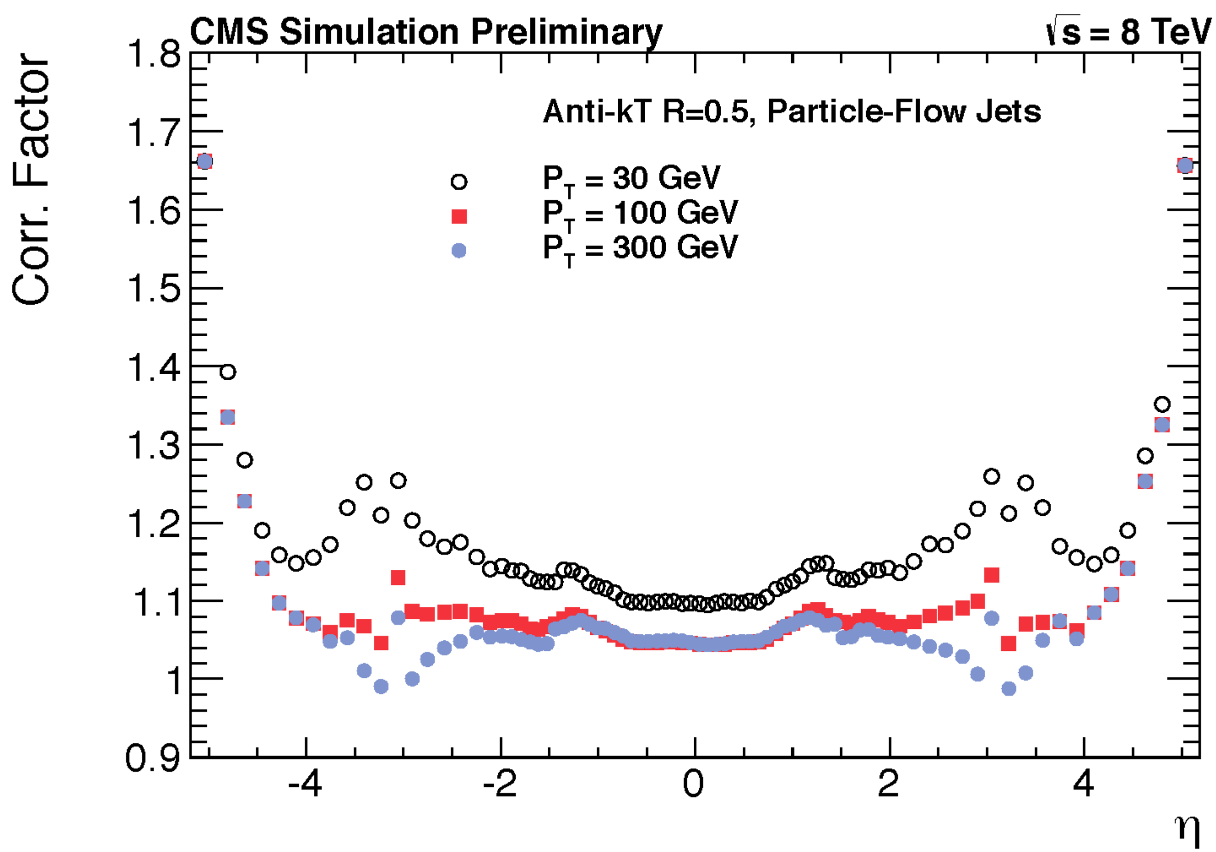
1) Offset Corrections

- p_T offset calculated depending on
  - Jet area in η-φ-space
  - Average p_T density (per event)
  - Jet p_T and η
- Event-level (p_T density) and jet-level (area) information are combined for <u>precise offset estimation</u>
- Prior to jet clustering, charged hadrons from pileup-vertices are removed



2) Baseline Corrections (From Simulation)

- Approximative η, p_T-dependent correction factor from simulation
- Derived by comparing p_T of reconstructed jet to p_T of matching simulated jet



3) Residual Corrections (From Data)

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- Simulation-based corrections need to be completed with data-based residual corrections
- Approach: Compare jet with well-measured reference object (e.g. Z)
- Two methods to measure the jet response in data:

p_T balance

$$R_{balance} = \frac{p_T^{Jet}}{P_T^Z}$$

MPF

(Missing E_T Projection Method)

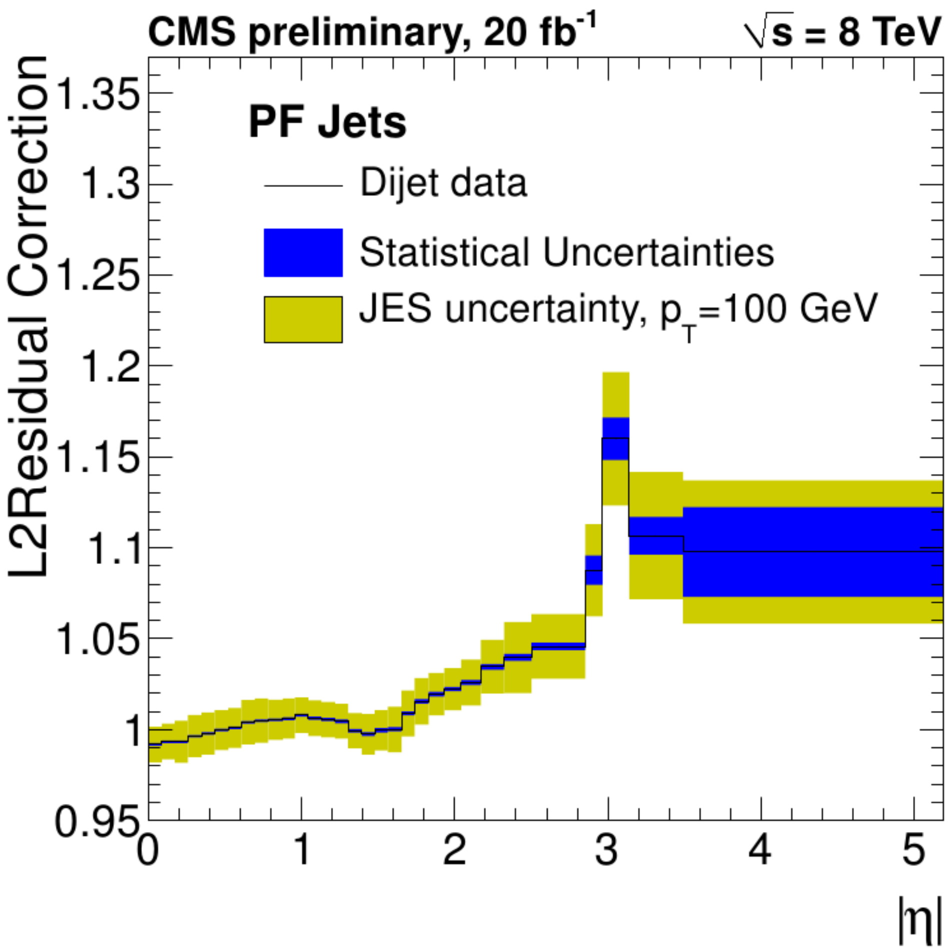
$$R_{MPF} = 1 + \frac{\vec{E}_T^{miss} \cdot \vec{p}_T^Z}{(p_T^Z)^2}$$

- p_T balance has stronger bias from initial and final state radiation
- MPF takes into account hadronic recoil in all detector regions

3) *Relative* Residual Corrections

- Method: Dijet balancing
  - Precisely measured tag jet in central detector region
  - Probe jet in other η region (encap/forward)

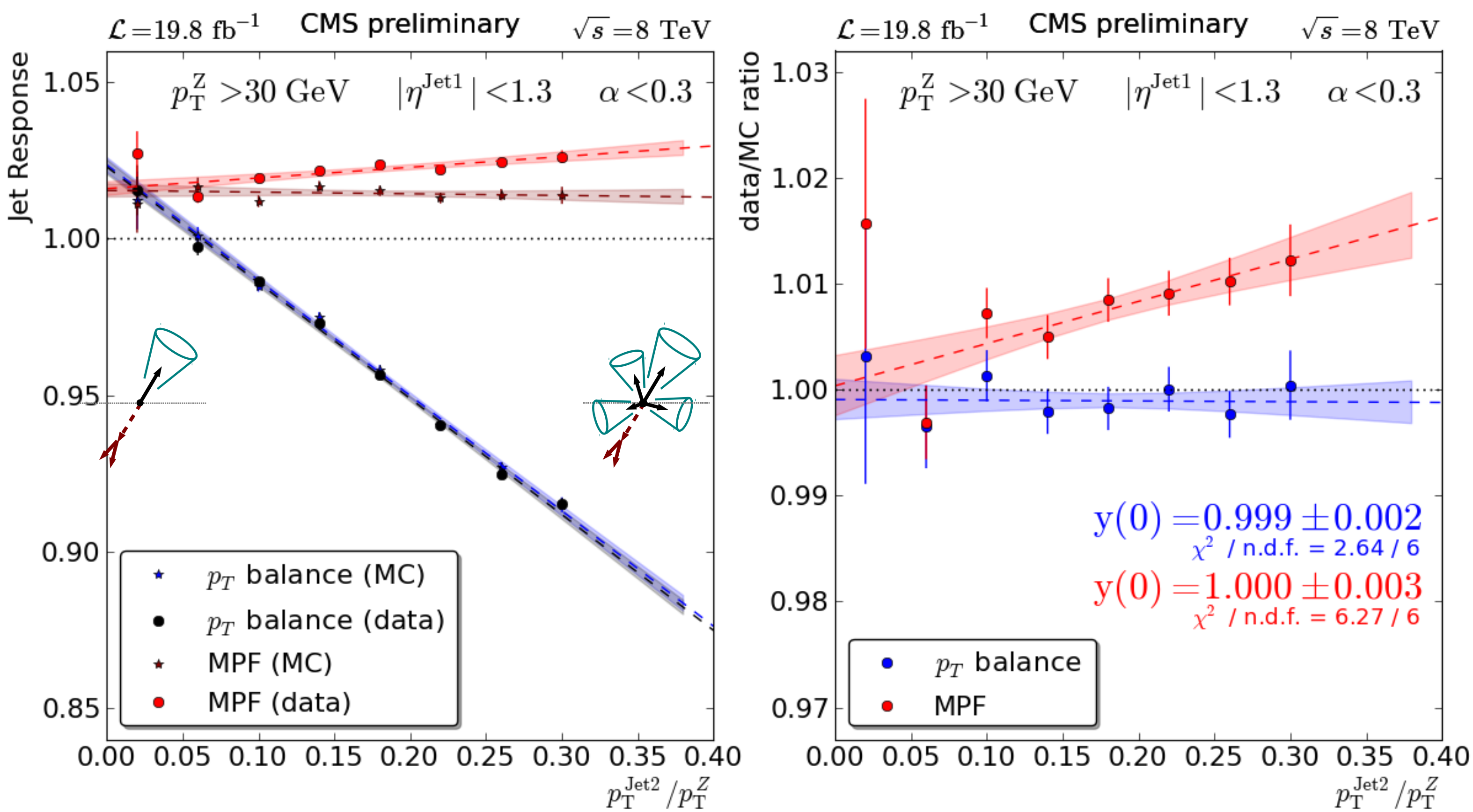
- Correction factor derived with the MPF method as a function of η



3) *Absolute* Residuals Corrections

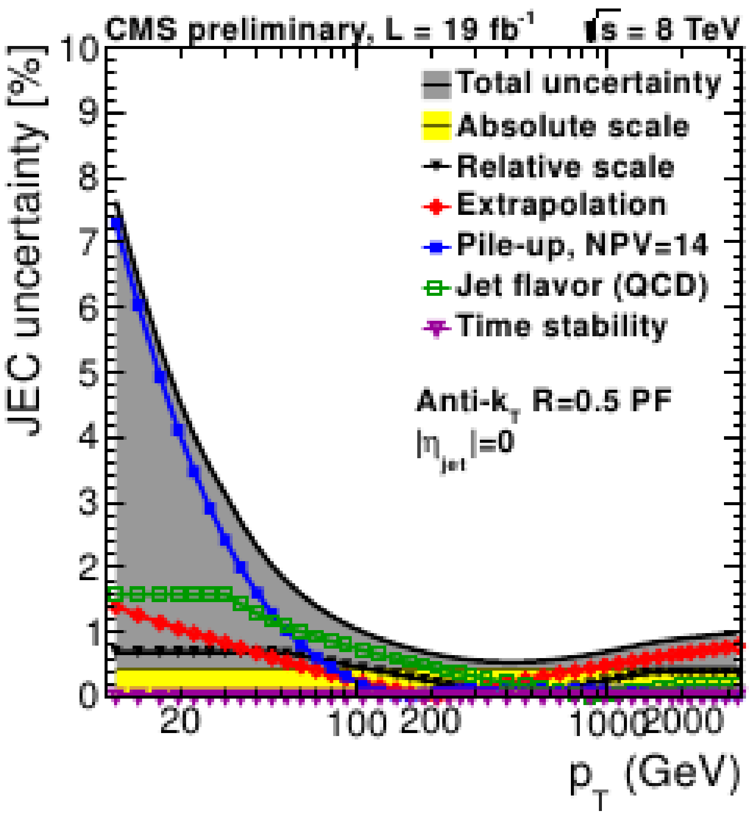
- Absolute correction factor in barrel derived from Z→ μμ+jet events
- MPF and p_T balance agree after extrapolation

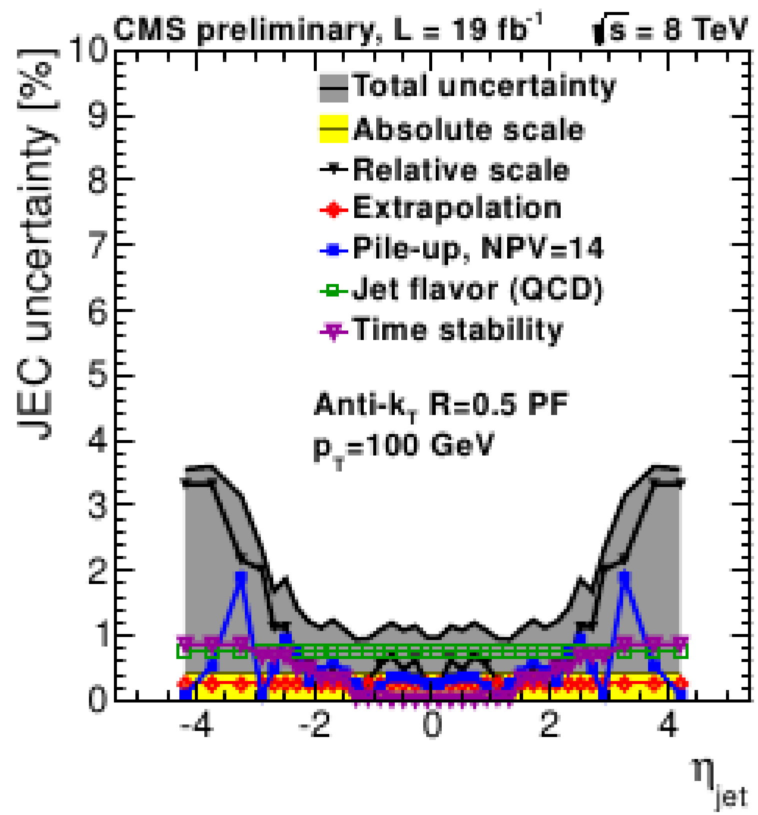
Data/Simulation RATIO



Jet Energy Uncertainty Sources

- <u>Uncertainy as small as 0.55%</u>
- Pileup uncertainty dominating at lower p_T, relative uncertainty at high η





Getting Ready for 13 TeV

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- Changes in LHC Run2:
  - Higher energy
  - More (out of-time) pileup
- CMS develops techniques to prepare for these challenges:
  - Advanced pileup mitigation techniques
    - Pileup treatment on particle, jet and event level
  - Flavour tagging
  - Jet substructure & grooming
  - Multijet balancing

Conclusion

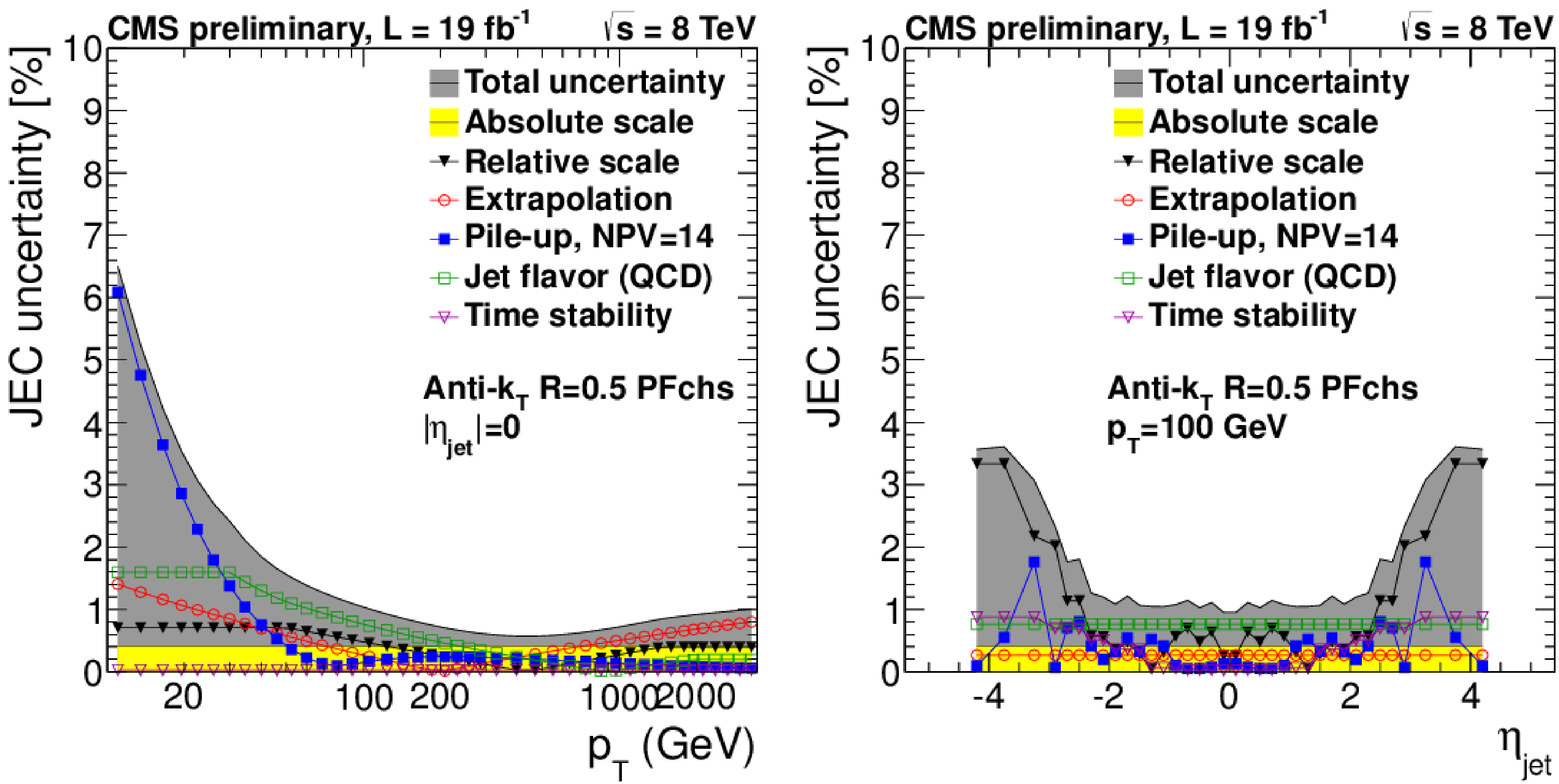
- **Jet energy uncertainty as small as 0.55%** (central detector region)
- Robust data-based techniques and advantages of simulation studies are combined for calibration
- Exploring new approaches to tackle the challenges of $\sqrt{s}$=13 TeV
- Significant german contribution: Dijet residuals from Uni Hamburg, $Z\rightarrow\mu\mu$+jet residuals from KIT
- Paper with recent results in preparation: CMS-JME-13-004

Backup Slides

Event Selection: Cuts

- Muon
  - Muon η — $\eta^{\mu} < 2.3$
  - Muon p_T — $p_T^{\mu} > 20$ GeV
- Z
  - Z p_T — $p_T^{Z} > 30$ GeV
  - Z mass window — $|\, m_{\mu\mu} - m_Z \,| < 20$ GeV
- Jet
  - Leading jet p_T — $p_T^{Jet} > 12$ GeV
  - Leading jet η — $\eta^{Jet} < 1.3$
- Z+Jet
  - Second jet cut — $p_T^{Jet2} / p_T^{Z} < 0.2$
  - Back-to-back cut — $|\, \Delta\varphi\,(Z, Jet) - \pi \,| < 0.34$

Combined Uncertainties



- Very small uncertainties for |eta|<2.4, p_T^{Jet} > 100 GeV
- High pile-up uncertainties for low-p_T jets