Karlsruher Institut für Technologie

Bundesministerium für Bildung und Forschung

Analysis of Z(→μμ)+Jet Events and Jet Energy Calibration in CMS

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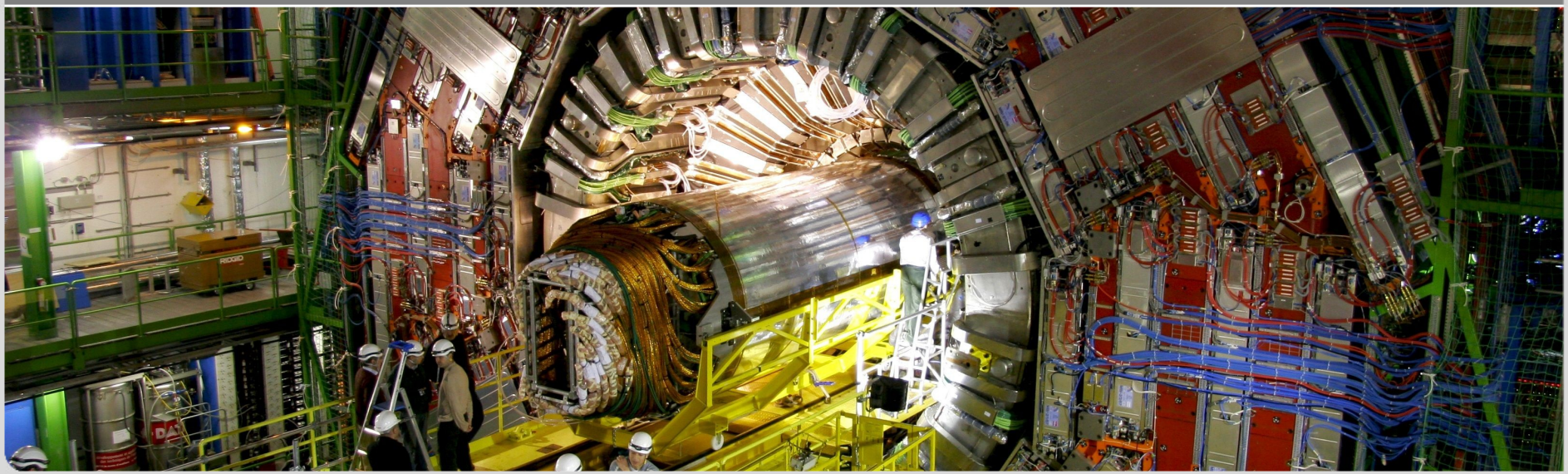


Introduction & Motivation

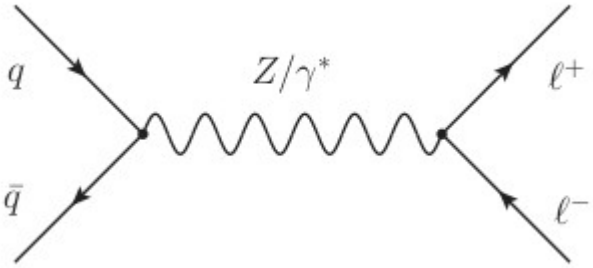
1. Analysis of Z(→μμ)+Jet Events
   An interesting topology and well suited for calibration purposes

2. Jet Energy Calibration in CMS
   A well-described *jet energy scale* is important for many analyses

3. Deriving Absolute Residual Corrections with Z(→μμ)+Jet Events
   Combining both of the above

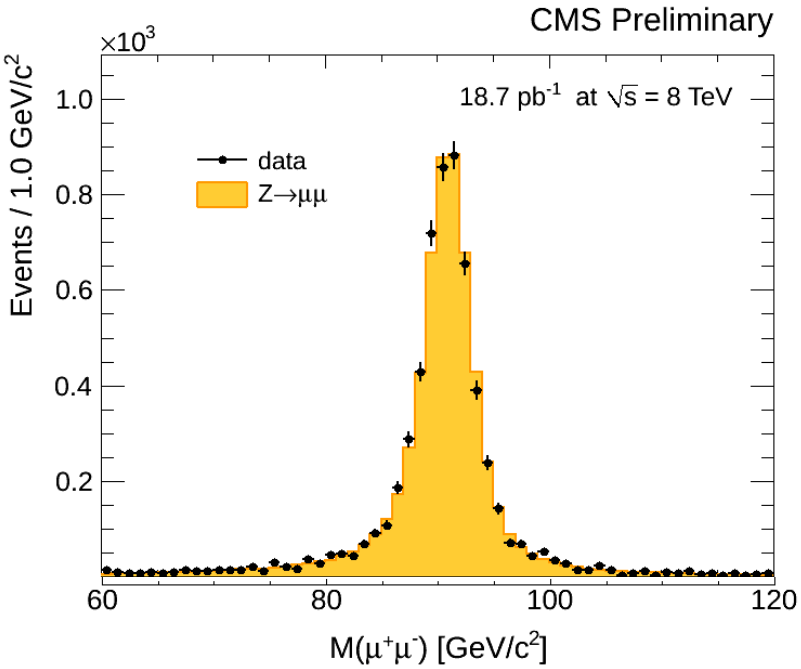
Topology of Z(→μμ) Events

- Drell-Yan process: quark-antiquark annihilation produces a virtual photon / Z decaying in two leptons



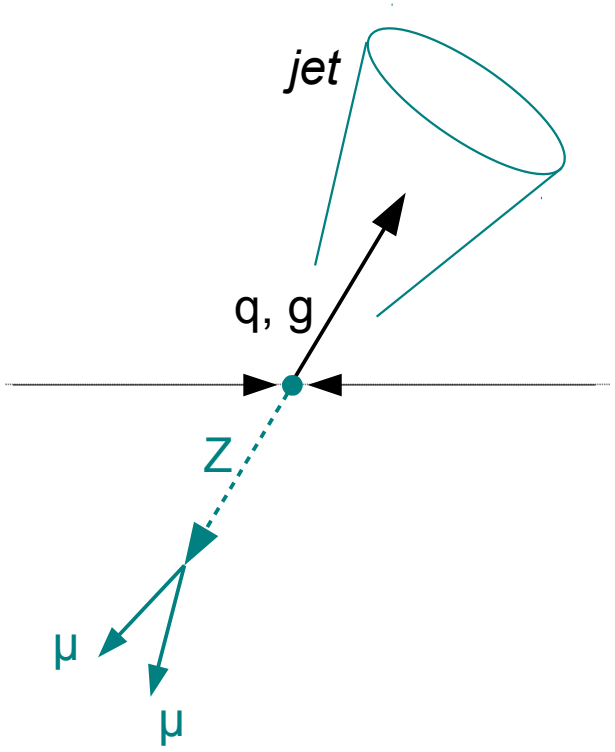
- Clear signature of the outgoing leptons

- The design of the CMS detector allows especially precise muon measurement

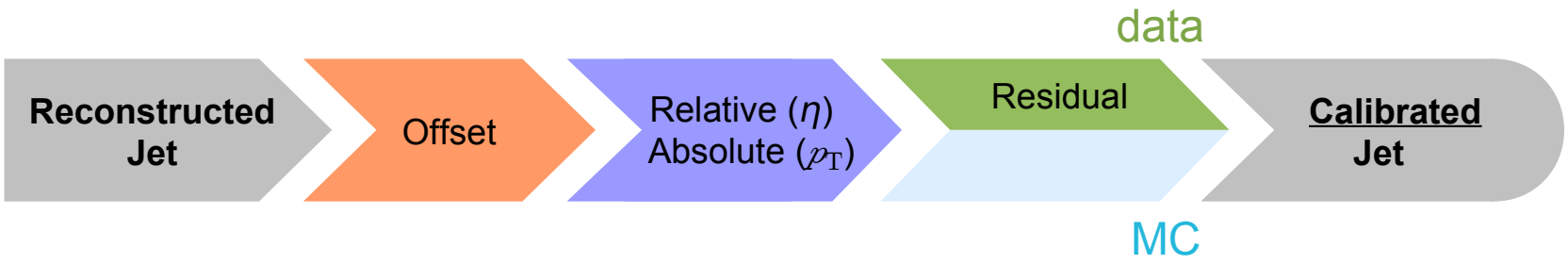


Topology of Z(→μμ)+Jet Events

- An additional outgoing parton, balanced to the Z/photon, hadronizes into a particle jet
- The jet response is the ratio between the measured and the 'true' jet energy
- The initial transverse momentum p_T of the colliding partons is zero on average, its conservation can be used for calibration



Jet Energy Calibration in CMS



Factorized jet energy correction approach:

1) Remove *pile-up effects* and *detector noise*

→ derived from data/MC and scaled to MC-Truth

2) Correct for *different* η / p_T *regions*

→ derived from MC-Truth

3) Correct for *residual data/MC difference* (applied on data only)

→ relative: derived from dijet balancing

→ absolute: derived from Z/photon+jet balancing

Increased Pile-up in 2012

- ~70% increase in number of primary vertices (compared to 2011) due to higher luminosity

- Two complementary methods to deal with pile-up:

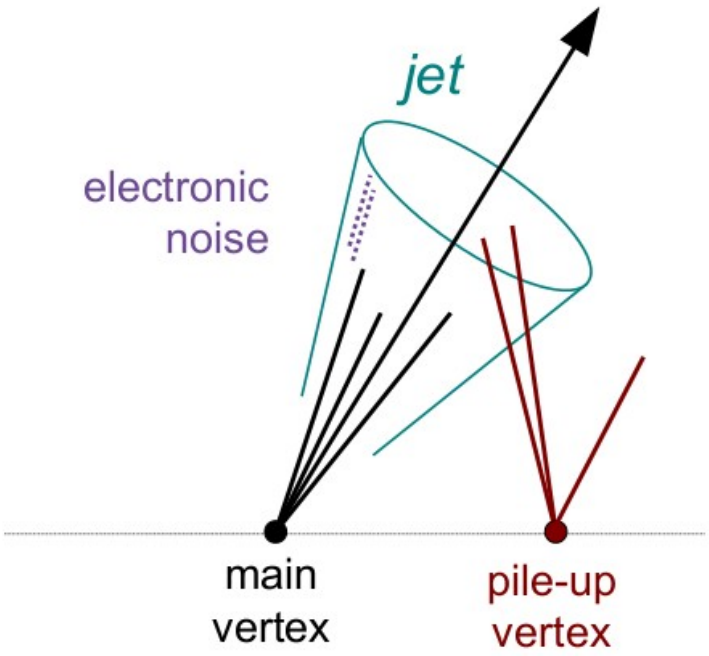
  - Charged Hadron Subtraction (CHS)

    Charged hadrons stemming from pile-up-vertices are *ignored by the jet algorithm*

  - Pile-up jet energy correction

    Two key quantities for calculation:

    - *jet area* A_j (determined from the y-ϕ extent of artificially added, infinitely soft 'dust' particles clustered in the jet)
    - p_T*-density* ρ (defined on an event-by-event basis as the median of the $p_{T,j} / A_j$ distribution for k_T(R=0.6)-jets)



Event Selection

- An average event contains: ~50 Jets, ~12 reconstructed primary vertices, lots of low-p_T pile-up jets and detector noise

- How to obtain a 'clean' Z(→μμ)+jet sample?

  - Kinematic cuts on the muons and the reconstructed Z
  - Kinematic cuts on the leading jet
  - Topological cuts
    - Second jet cut $p_T^{\text{Second Jet}} / p_T^{Z} < 0.2$
    - Back-to-back cut $| \Delta\varphi (Z, \text{Leading Jet}) - \pi | < 0.34$

→ Only events are selected where the Z is balanced by exactly one jet!

Absolute Residual Correction

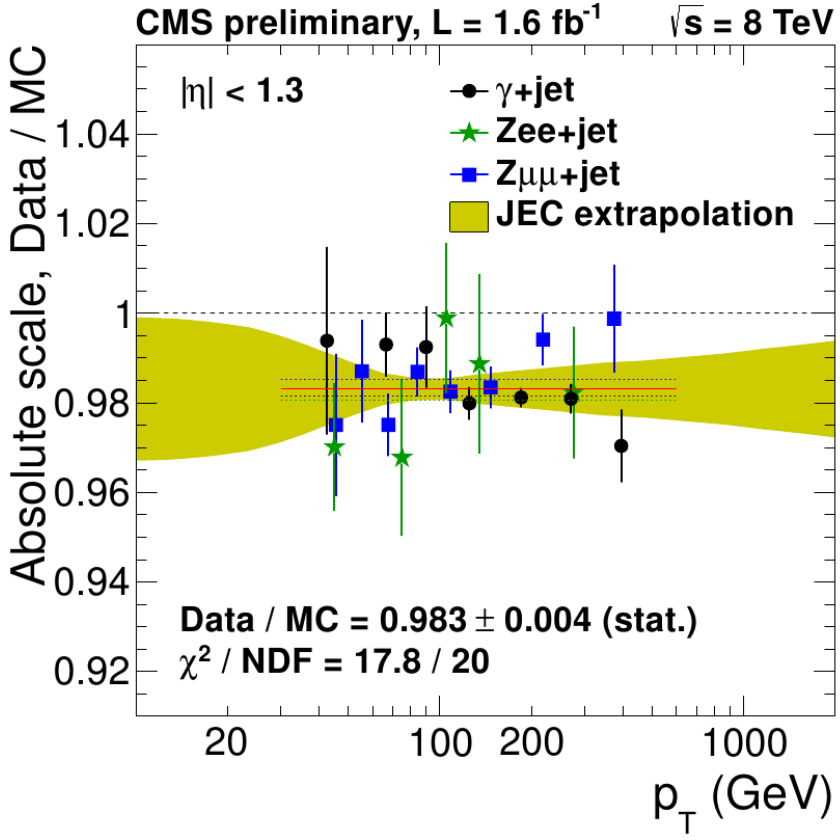
- Combination of the jet response derived from
  - Z(→μμ)+jet
  - Z(→ee)+jet
  - photon+jet

- Average data/MC ratio:

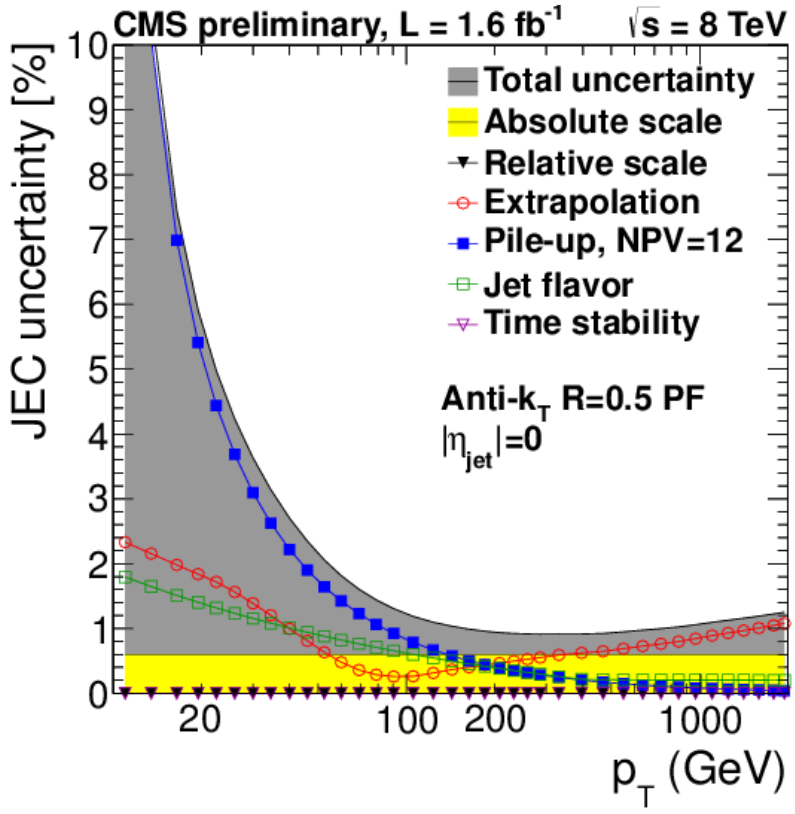
  r = 0.983 +- 0.004

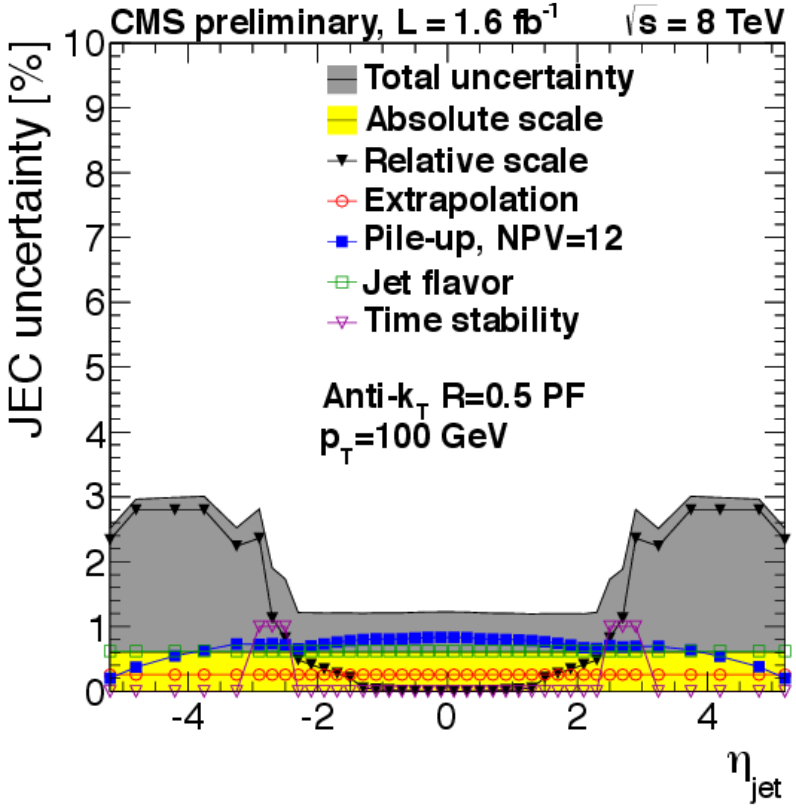
  → Final correction factor on data:

  c = 1.017



Combined Uncertainties





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

Conclusion

- Z(→μμ)+jet topology is well understood
- CMS successfully uses factorized jet energy corrections
  - Advanced MC-Truth-based techniques and robust data-driven methods are combined
- Jet energy uncertainty as small as 1% in the central detector region
- Further improvements down to the per mill level possible

Approach and methods: JINST 6 (2011) P11002

Recent results: DP 2012/012

Backup Slides

Two Methods to Measure the Jet Response

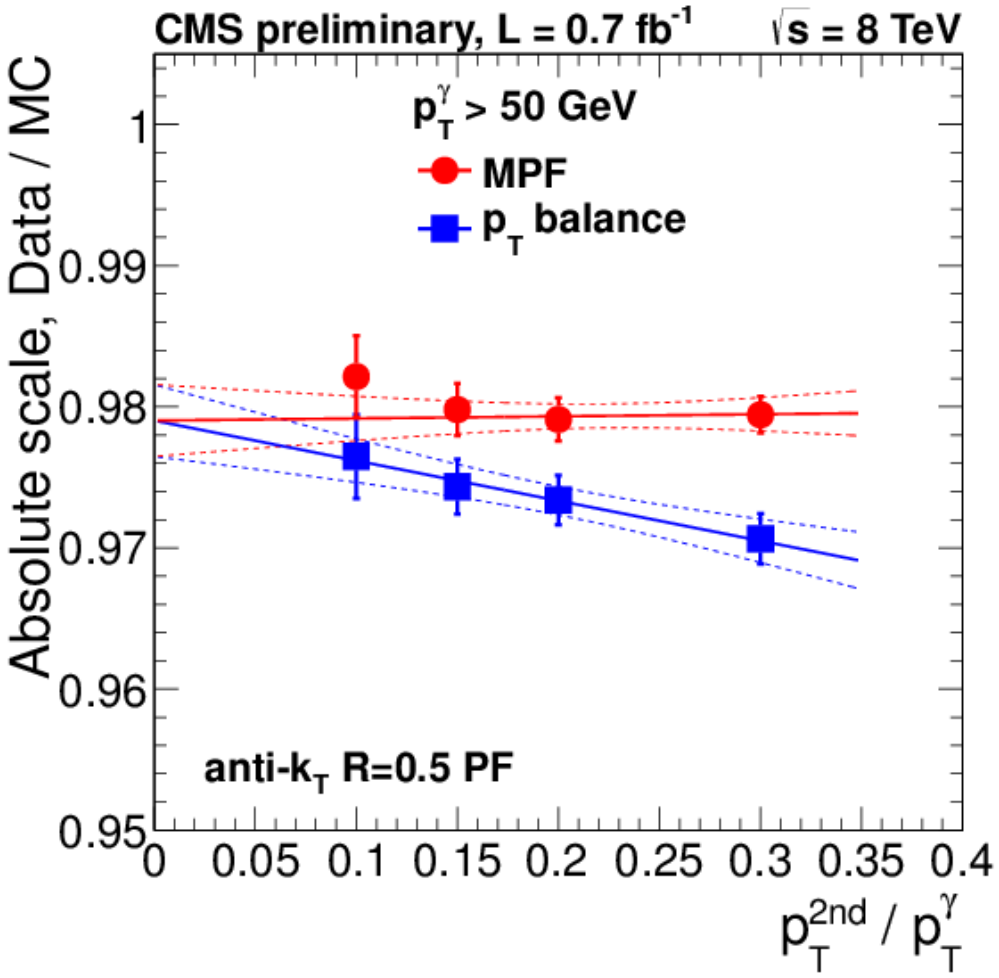
p_T balance

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

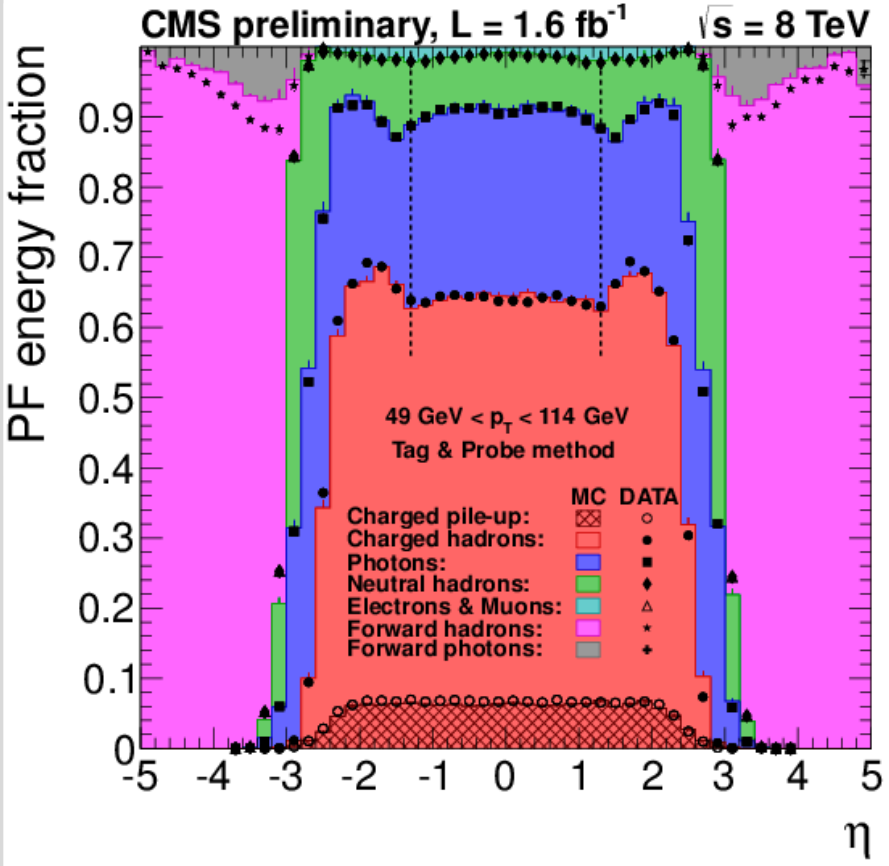
MPF

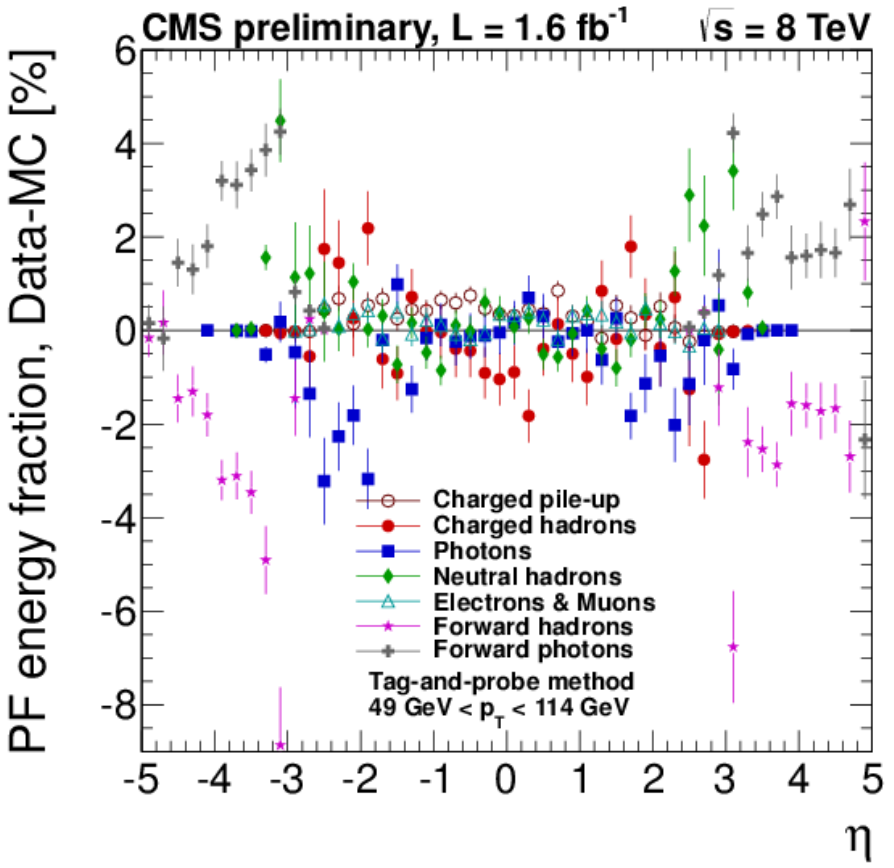
(Missing E_T Projection Method)

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

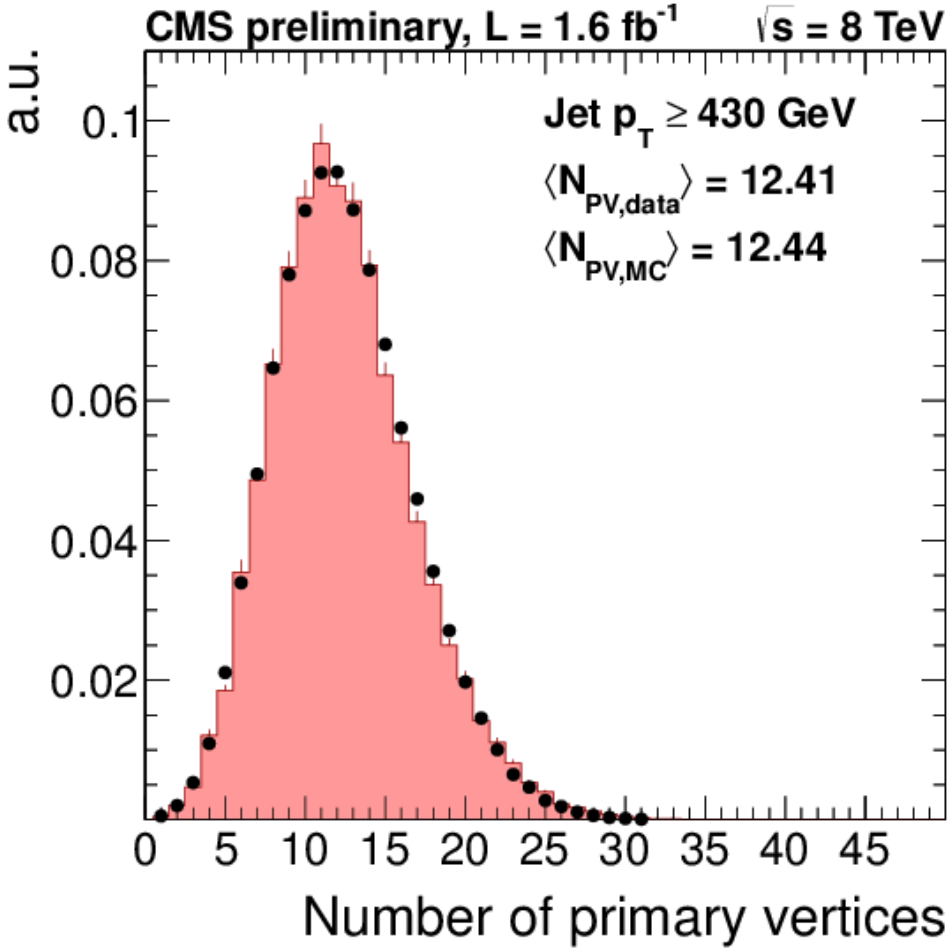


Jet Composition



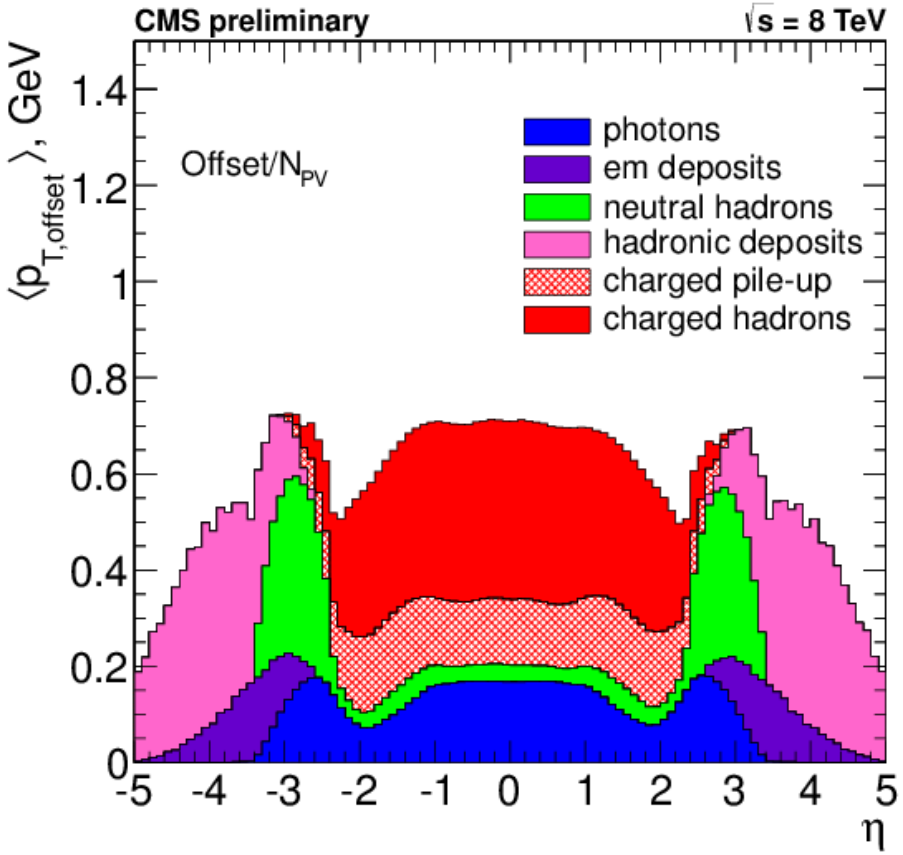


Pileup-Reweighting



Pile-up and Offset Correction

Pileup composition



Correction