Jet Energy Calibration with Z+Jets events

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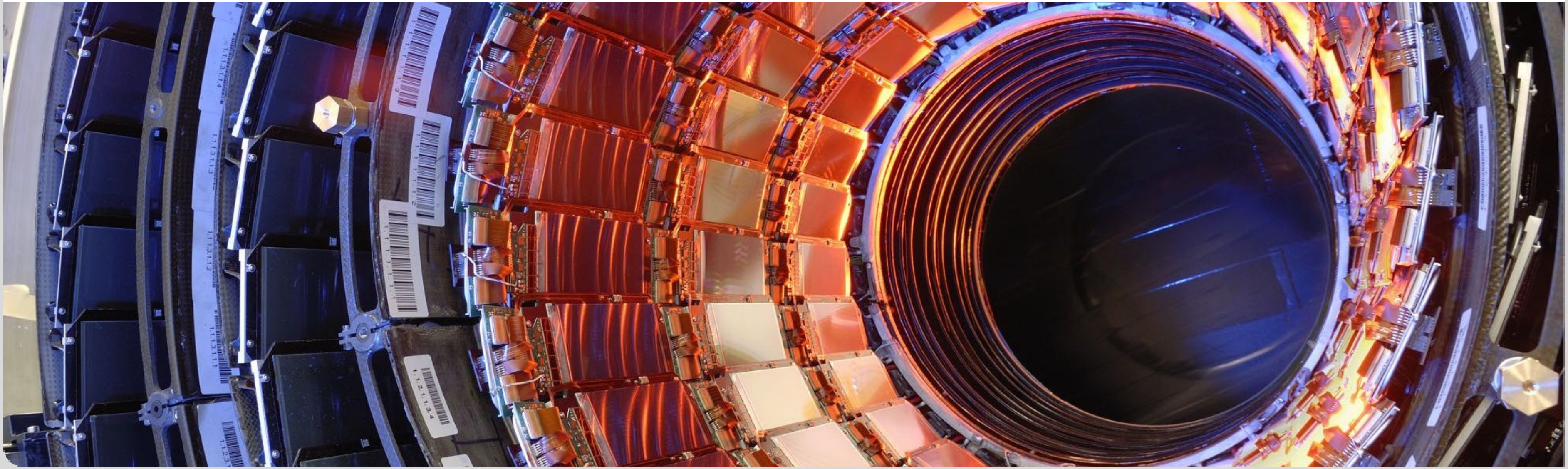


Big Picture: Jets in the CMS Experiment

- jet in CMS detector
  - use of particle flow candidates to cluster jets
- challenges in jet measurement:
  - **pileup** increases measured jet energy

    ➔ need of mitigation methods
  - constituents of jets mis-associated by **clustering algorithms** affect jet energy measurement
  - **Monte Carlo** simulations must be validated using data-driven methods

➔ need to calibrate jets!

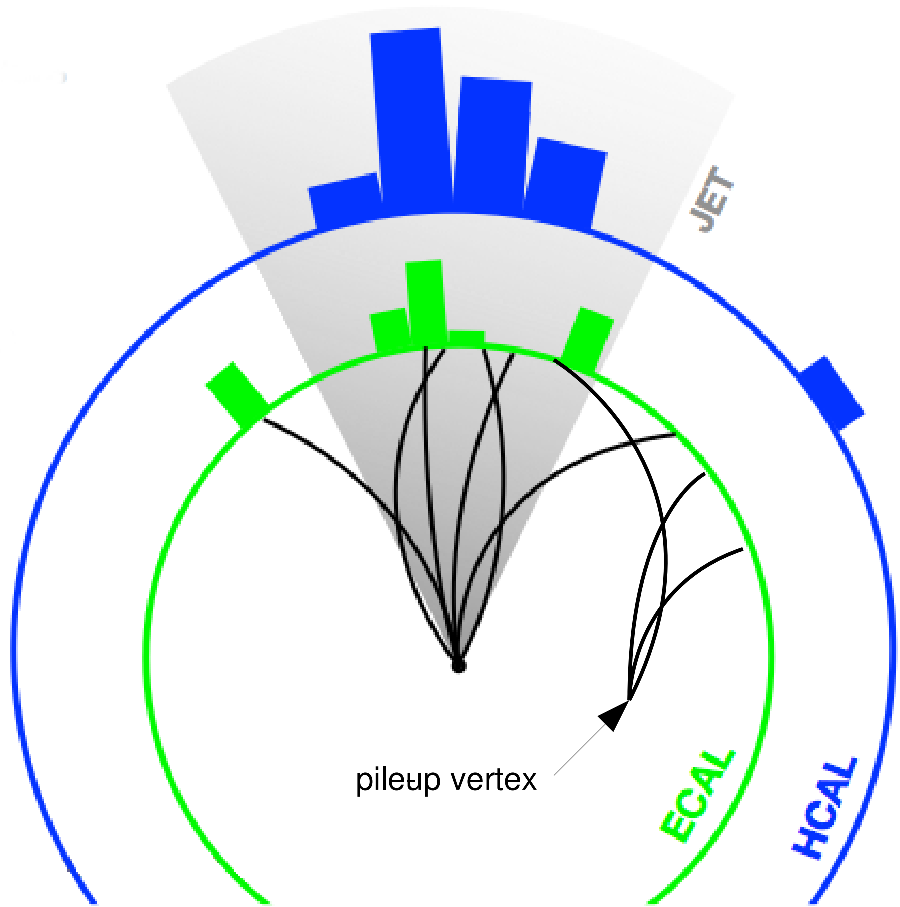
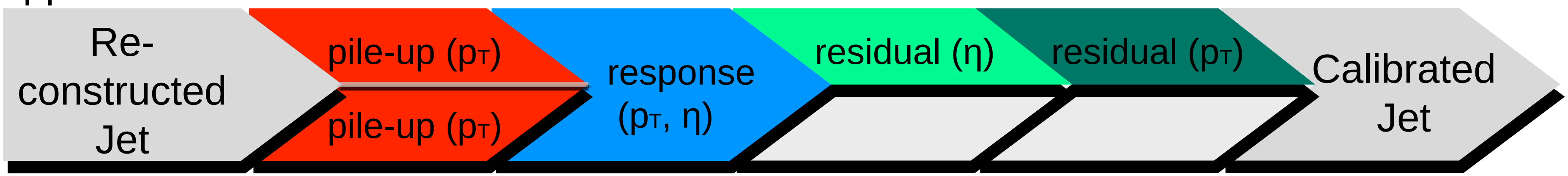


Image: http://moriond.in2p3.fr/QCD/2011/ThursdayMorning/Pandolfi.pdf

Stages of Jet Energy Corrections

applied to data →

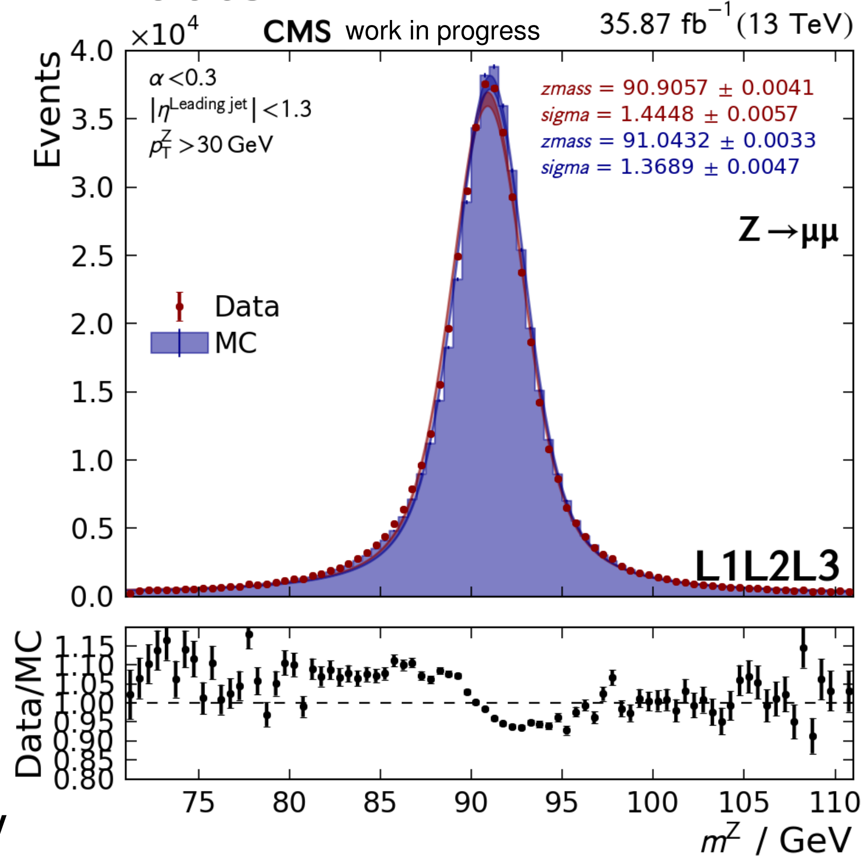


applied to MC →

- apply corrections in multiple stages:
  - from **MC** simulation:
    comparisons of response simulated to detector level to inputs at generator level
    - **pileup correction**
    - **detector effects, non-linear calorimeter response**
  - from **data**: balancing methods
    - **relative residual correction**:
      comparison of a jet in central or forward regions to a jet in central region
    - **absolute residual correction**:
      comparison of a jet in central region to reference object (photon or Z-boson)

Absolute Residual Correction: Z + Jets

- muon kinematic range:
  - $p_T^{\mu} > 20$ GeV
  - $|\eta^{\mu}| > 2.3$
- electron kinematic range:
  - $p_T^{\mu} > 25$ GeV
  - $|\eta^{\mu}| > 2.4$
- Z boson selection:
  - kinematic range: $p_T^Z > 30$ GeV
  - mass window: $|m_{\ell\ell} - m_Z^{PDG}| < 20$ GeV
  - back-to-back: $|\Delta\Phi(Z,\text{leading Jet}) - \pi| < 0.34$



→ quasi background-free, very clear signal

→ jet energy calibration with precise reconstructed Z boson mass and p_T

Absolute Residual Correction: Z+ Jets

- **p_T-balance method**:

$$R_{\mathrm{jet},p_\mathrm{T}} = \frac{p_\mathrm{T,jet}}{p_\mathrm{T,ref}}$$

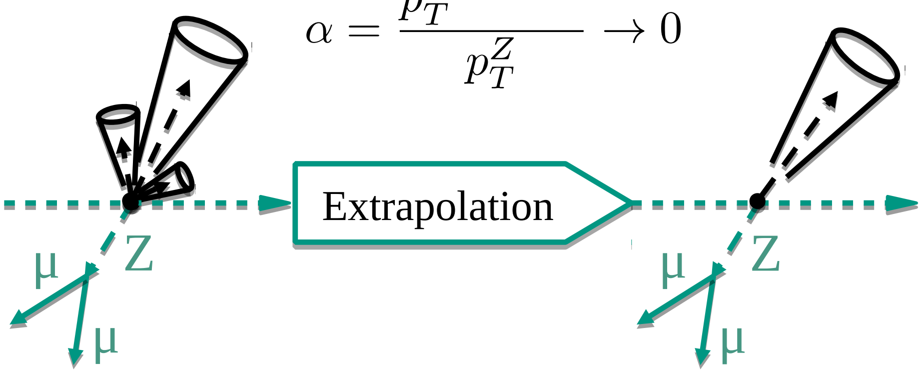
  - advantage:

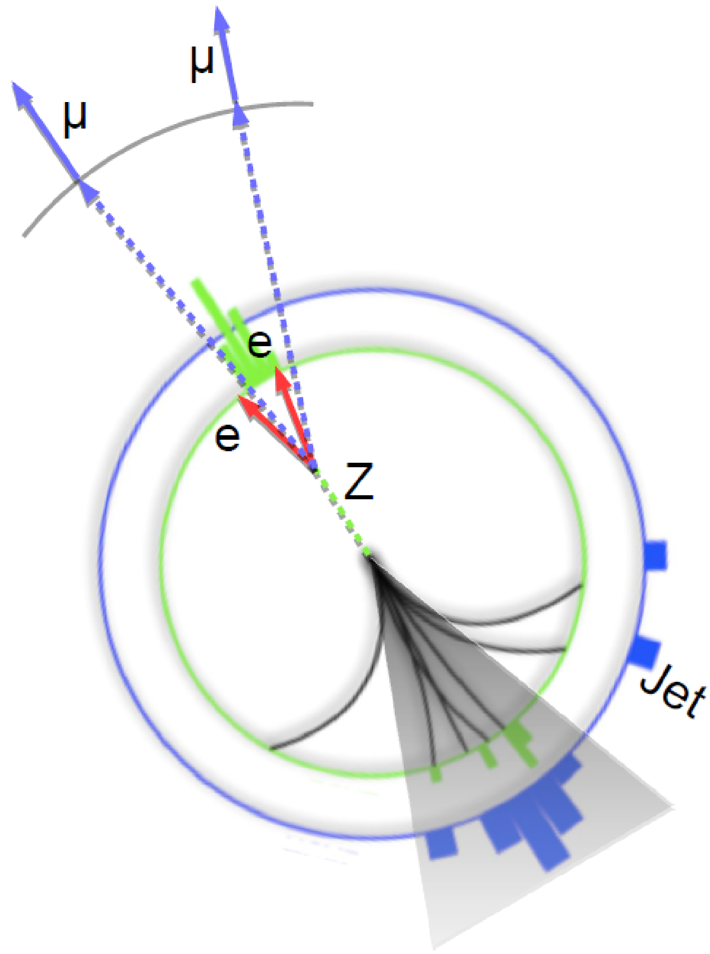
    only reconstruction of reference object is limiting factor
  - disadvantage:

    highly dependent on additional jets

    ➔ extrapolation necessary!

$$\alpha = \frac{p_T^{\mathrm{second\ jet}}}{p_T^Z} \to 0$$



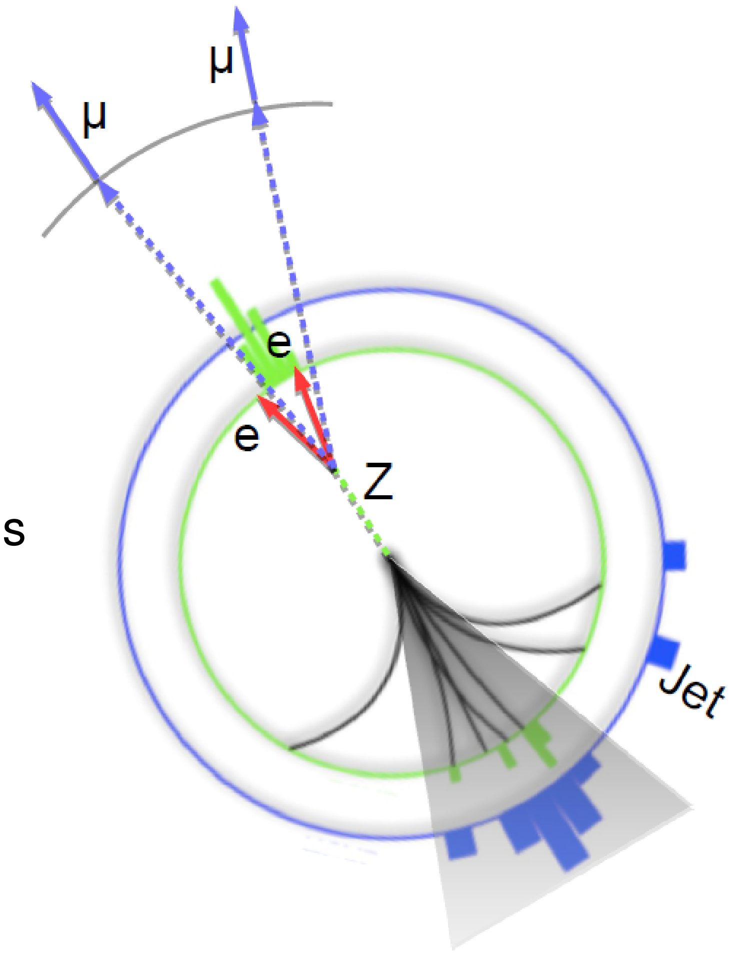


Absolute Residual Correction: Z+ Jets

- **MPF method**:
  (Missing E_T Projection Fraction)

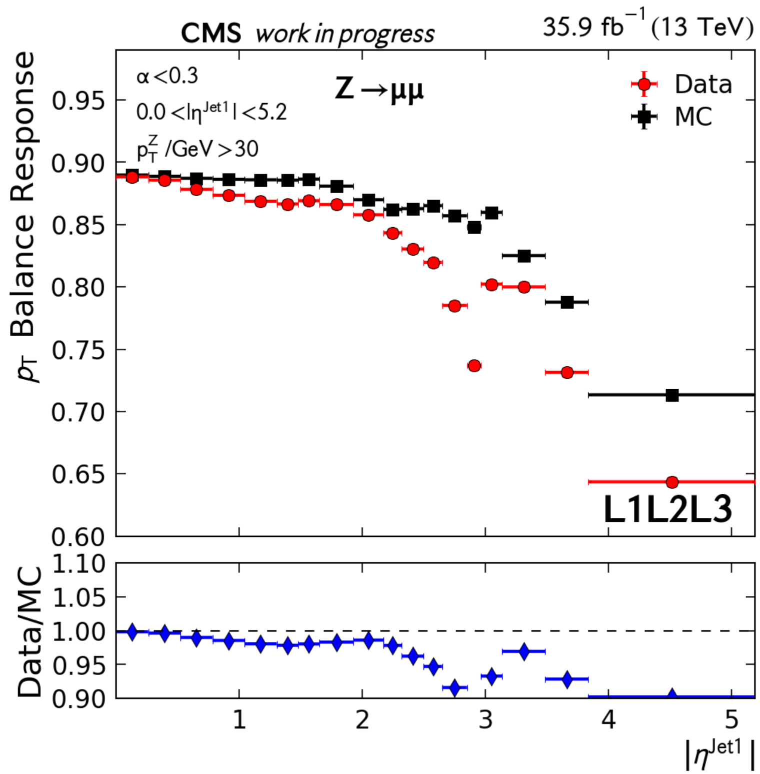
$$R_{\text{jet,MPF}} = 1 + \frac{\vec{\not{p}}_T \cdot \vec{p}_{T,\text{ref}}}{(p_{T,\text{ref}})^2}$$

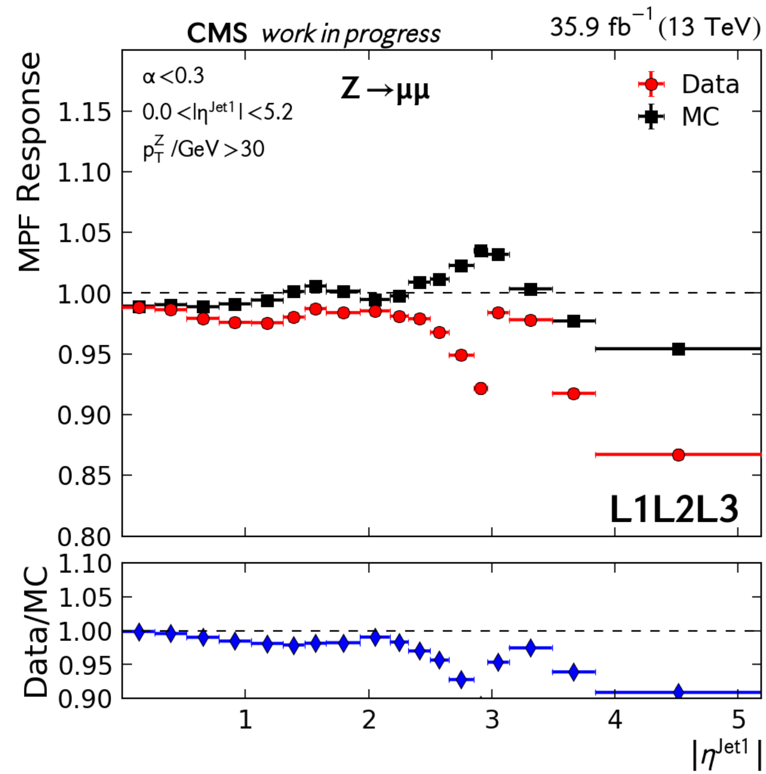
  - advantage:
    takes into account all detector subsystems
    ➔ less sensitive to additional jets
  - disadvantage:
    requires already well-calibrated detector



Balance Response: η^{Jet1} dependent

- data well described by MC within %-level
  ➔ residual corrections to reach even better agreement

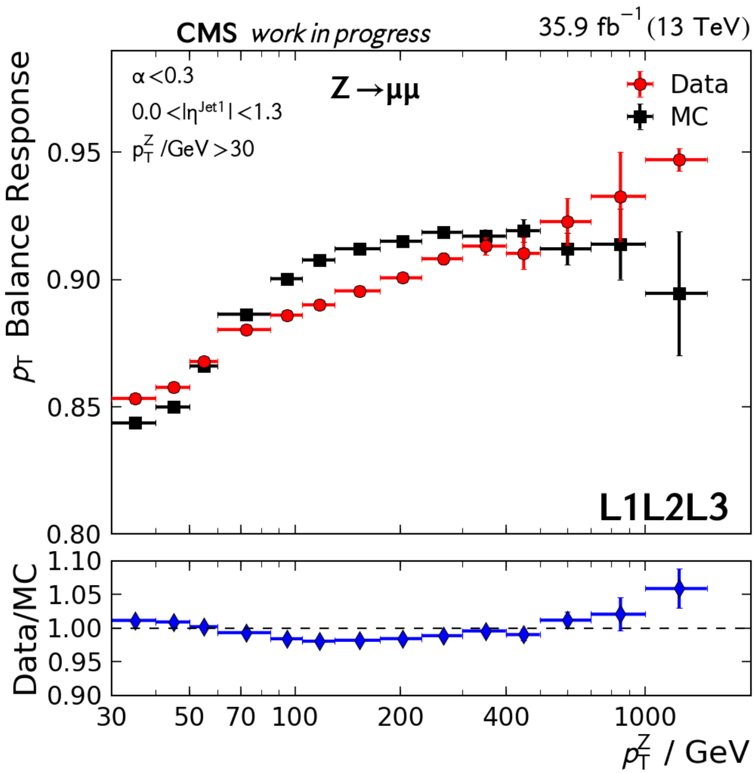


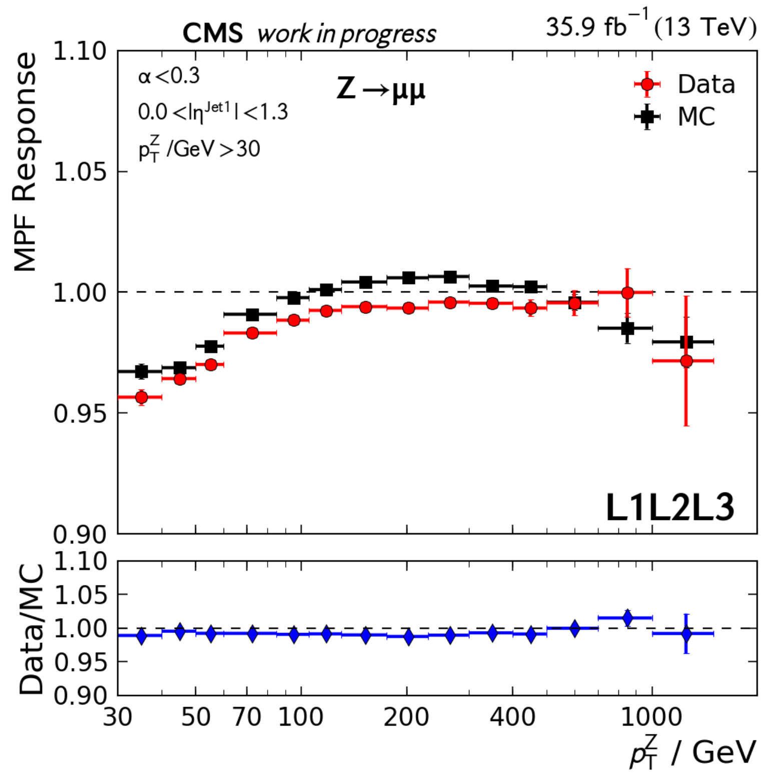


- **p_T-balance**:
  - low response in forward region
  - sub-leading jets ignored
- **MPF**:
  - response close to one
  - requires correct E_T values

Balance Response: p_T dependent

- data well described by MC within %-level
  ➔ residual corrections to reach even better agreement





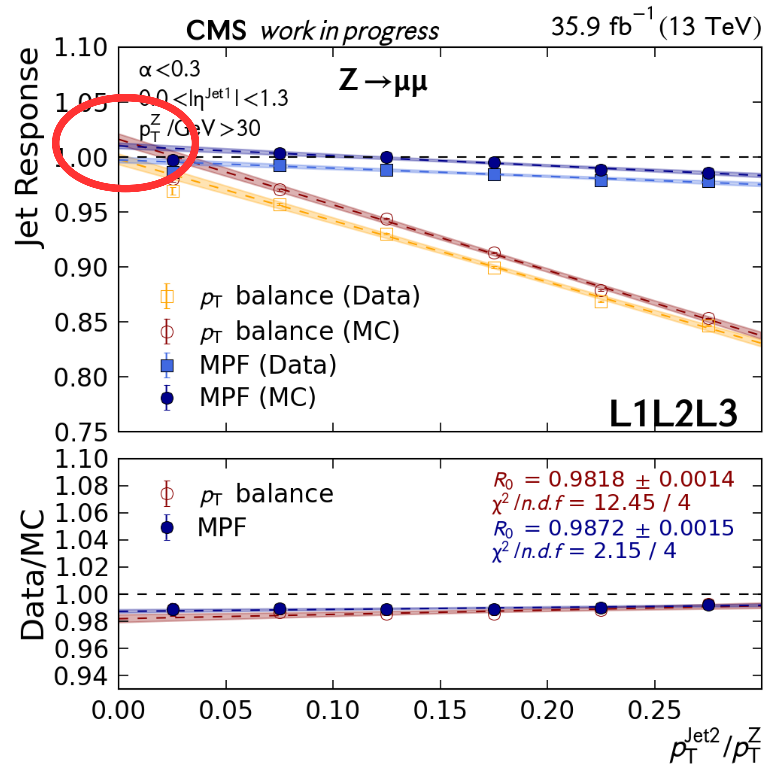
- **p_T-balance**:
  - increased response at higher p_T
- **MPF**:
  - remains stable over broad of p_T

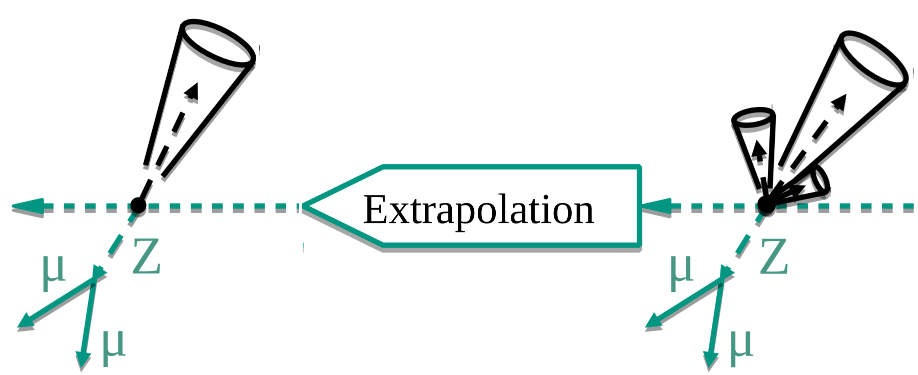
Account for extra jets: MC

- subleading jets taken into account via

$$\alpha = \frac{p_T^{\text{second jet}}}{p_T^Z} \to 0$$

- extrapolation of α → 0 corresponds to topology: Z + 1 Jet
- both balancing methods agree within this limit
- residual differences are accounted for in jet energy scale uncertainty



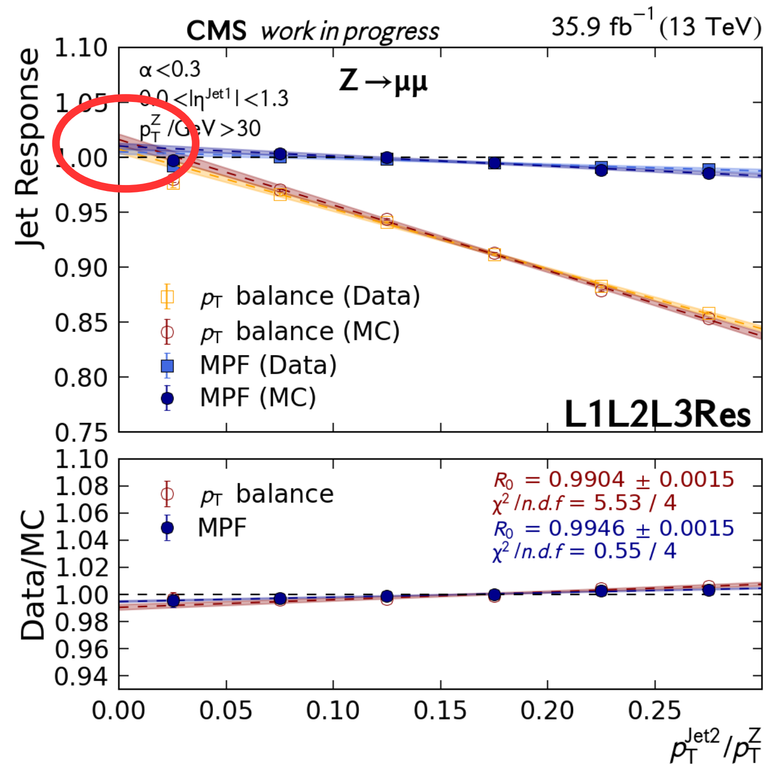


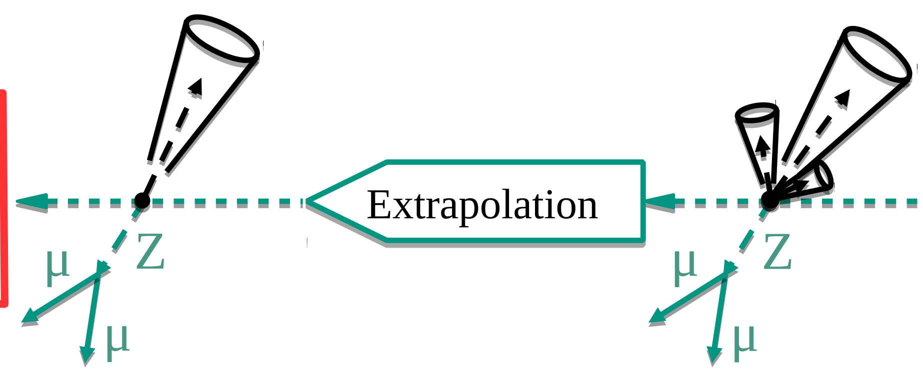
Account for extra jets: MC + Data

- subleading jets taken into account via

$$\alpha = \frac{p_T^{\text{second jet}}}{p_T^Z} \rightarrow 0$$

- extrapolation of $\alpha \rightarrow 0$ corresponds to topology: Z + 1 Jet
- both balancing methods agree within this limit
- residual differences lead to correction factors and jet energy uncertainty
- applying residual corrections leads to better agreement between MC and data

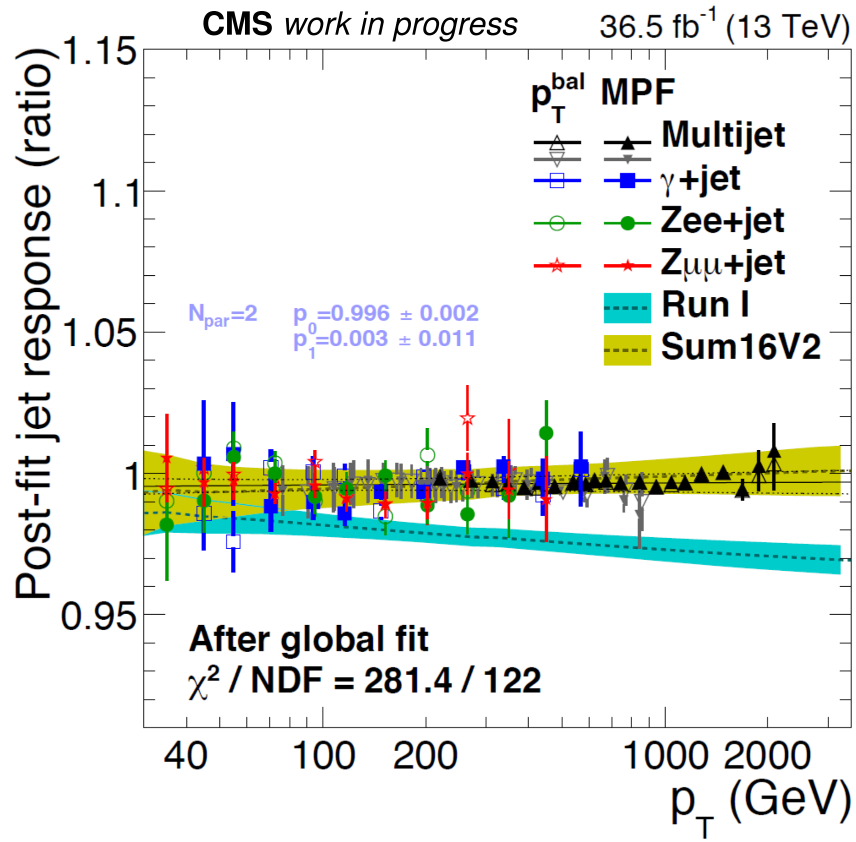




Absolute Residual Corrections: Global Fit

- combination of all possible channels to reach highest accuracy in a wide pT range used by physics analyses
  - $Z\rightarrow\mu\mu$+Jets: muon sub-detector
  - $Z\rightarrow ee$+Jets: ECAL sub-detector
  - γ+Jets: higher p_T range
  - Multijet: very high p_T jets
- latest estimation for 2016 data:

  JES unc. < 1% (for ~300 GeV)
- final calibration of 2016 data is ongoing
- estimation for 2017 data in progress



Summary & Outlook

- absolute residual corrections are a fundamental part of high precision analysis!
- global fit proves to be the best combination method for calibration channels
- jet Energy Calibration for 2016 data in final steps
- 2017: JEC even more challenging:
  - changed detector conditions especially in forward η regions due to high radiation exposure
  - higher luminosity: increased pileup
  - huge amount of data: computing resources reach their limits!

Thank you for your attention!