# Jet energy correction in low pile-up data

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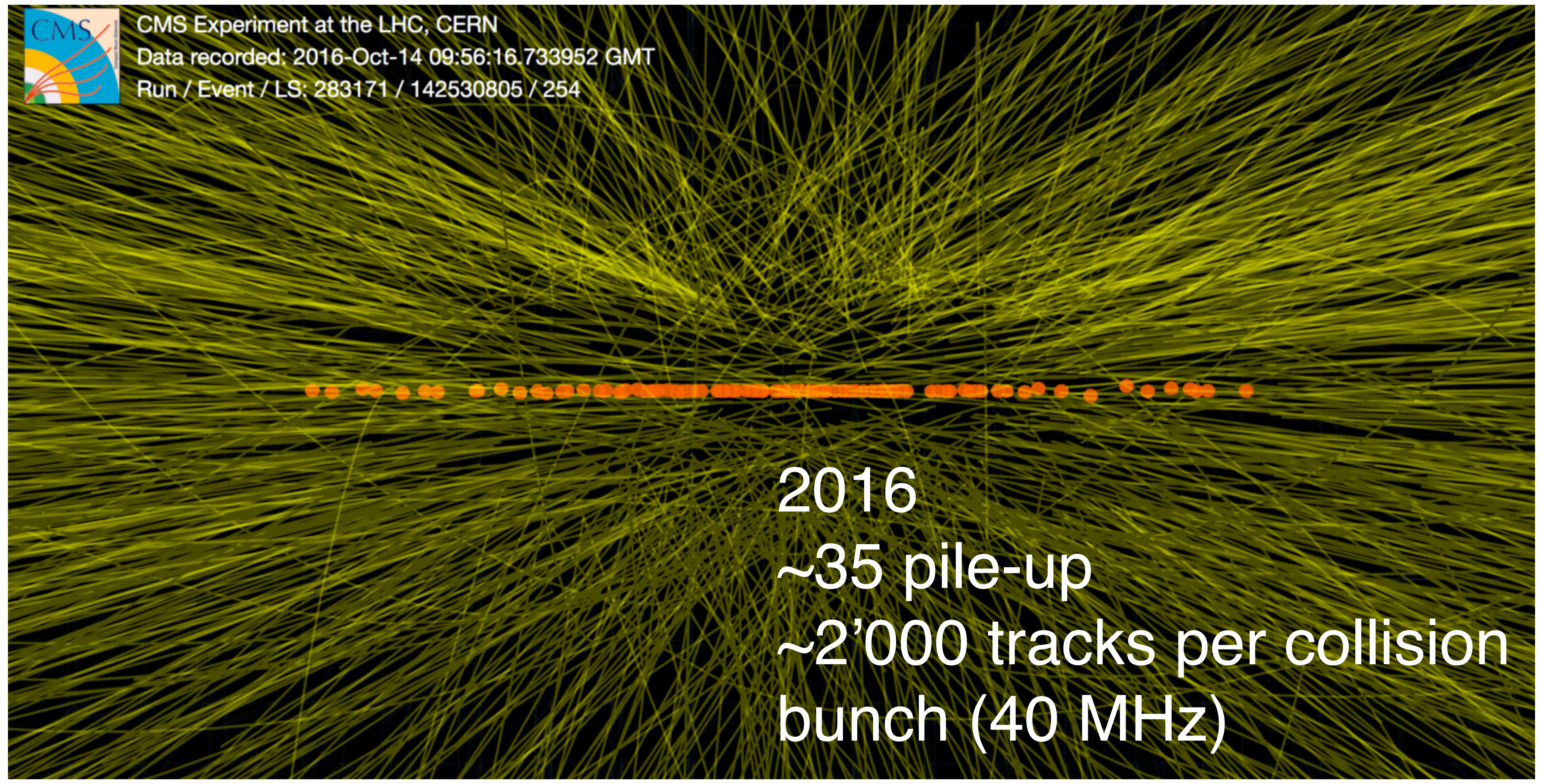
# Low pile-up Samples




Around 100 simultaneous proton–proton collisions in an event recorded by the CMS experiment

## PileUp

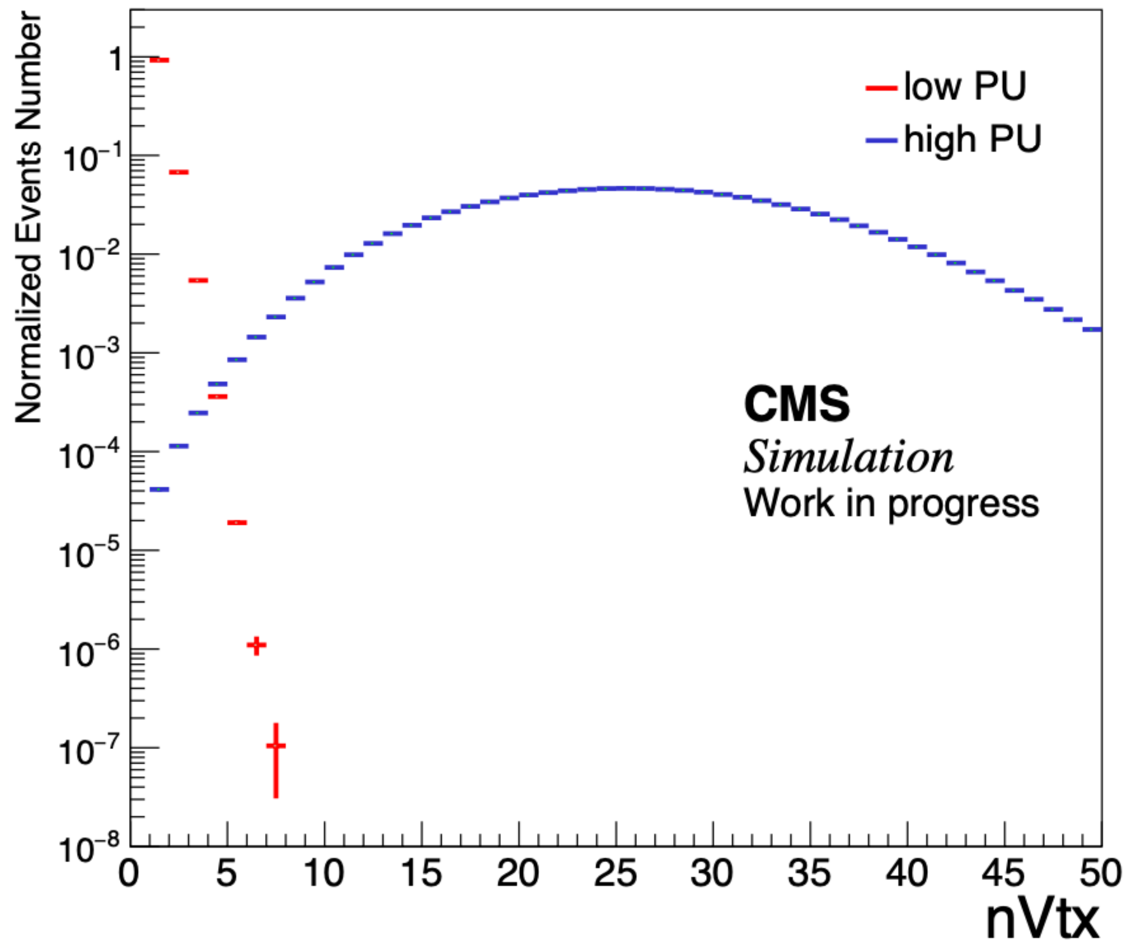
The LHC is a high-intensity particle collider with an average of about 20-60 proton-proton collisions per cluster, and we care about the hardest one.

Extra energy depositions from unrelated collisions affect **jet reconstruction, energy calibration, and resolution**.

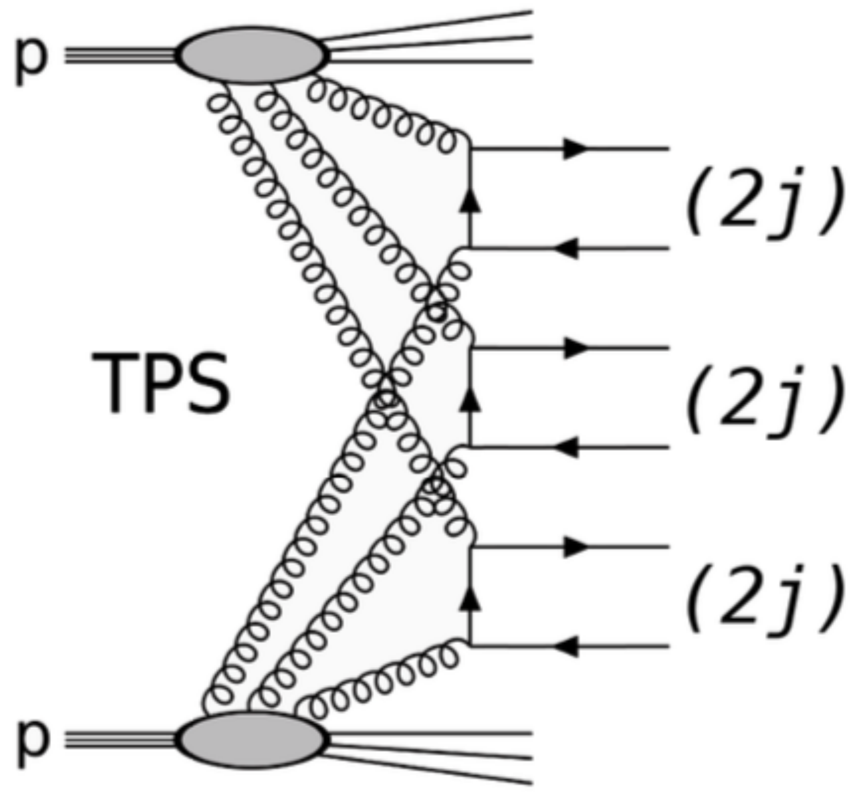
- **LowPU data in CMS**

  200 $pb^{-1}$ in 2017eraH

  2 $fb^{-1}$ expected in 2026




- LowPU analysis example:
  - Mueller-Navelet Jets
  - Measurement of W mass
  - Six-jet production from triple parton scatterings （Ongoing)



# Triple Parton Scattering in six jets events(ongoing)

- observe the TPS process in 6-jets events
- As the pT decreases, the proportion of TPS increases
- How to use lower $p_T$ real jet with dedicated JEC while reasonably handling uncertainties became crucial

$$\sigma_{\mathrm{DPS}}^{\mathrm{pp}\to X_1 X_2} = \left(\frac{m}{2}\right) \frac{\sigma_{\mathrm{SPS}}^{\mathrm{pp}\to X_1} \sigma_{\mathrm{SPS}}^{\mathrm{pp}\to X_2}}{\sigma_{\mathrm{eff}}}$$

$$\sigma_{\mathrm{TPS}}^{\mathrm{pp}\to X_1 X_2 X_3} = \left(\frac{m}{3!}\right) \frac{\sigma_{\mathrm{SPS}}^{\mathrm{pp}\to X_1} \sigma_{\mathrm{SPS}}^{\mathrm{pp}\to X_2} \sigma_{\mathrm{SPS}}^{\mathrm{pp}\to X_3}}{\sigma_{\mathrm{eff,TPS}}^2}$$

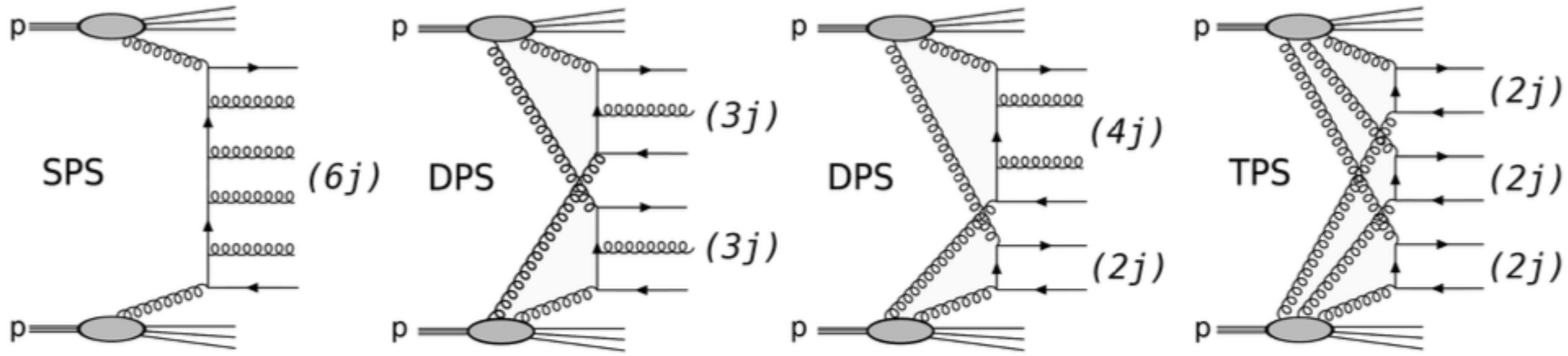
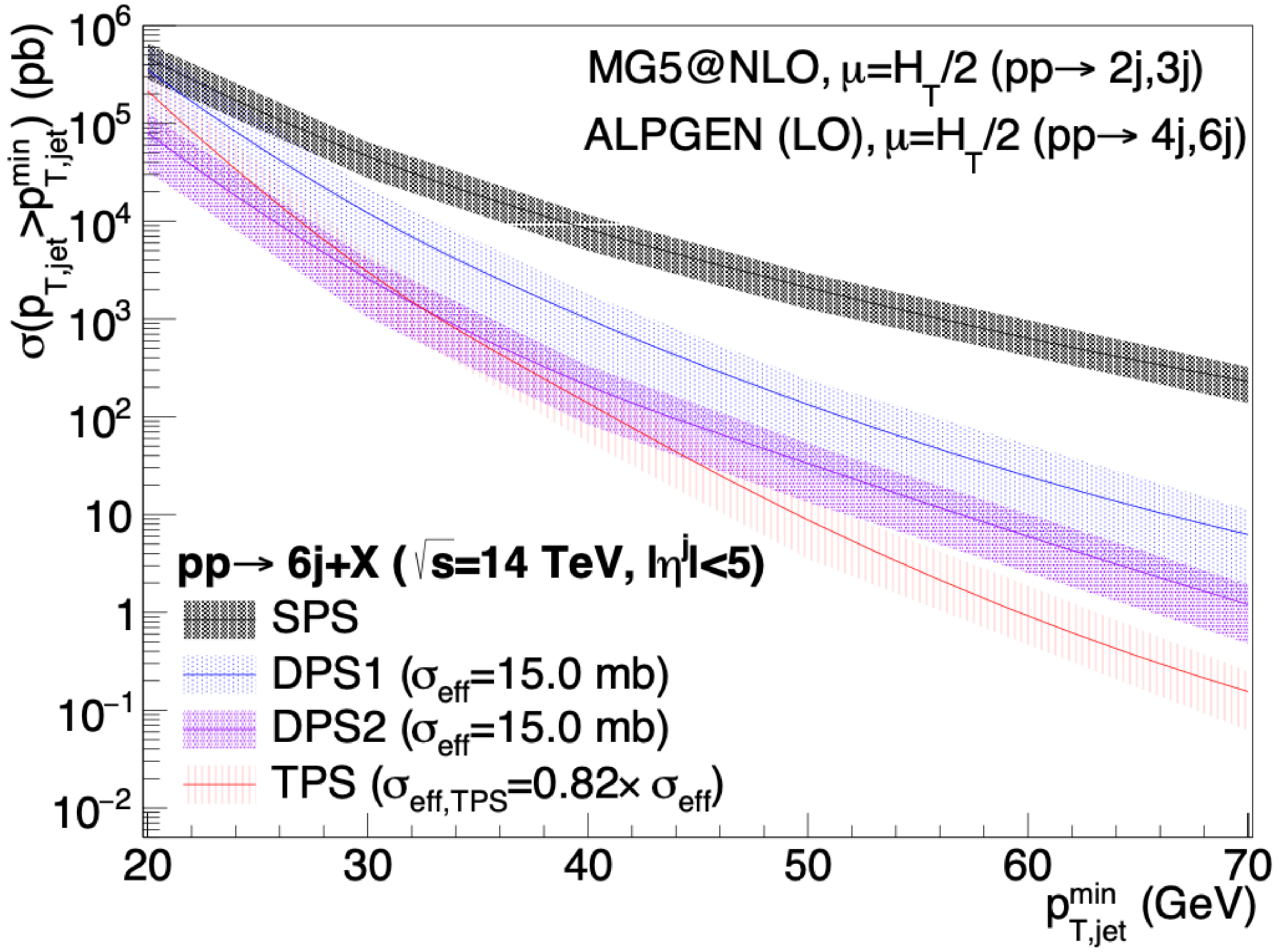
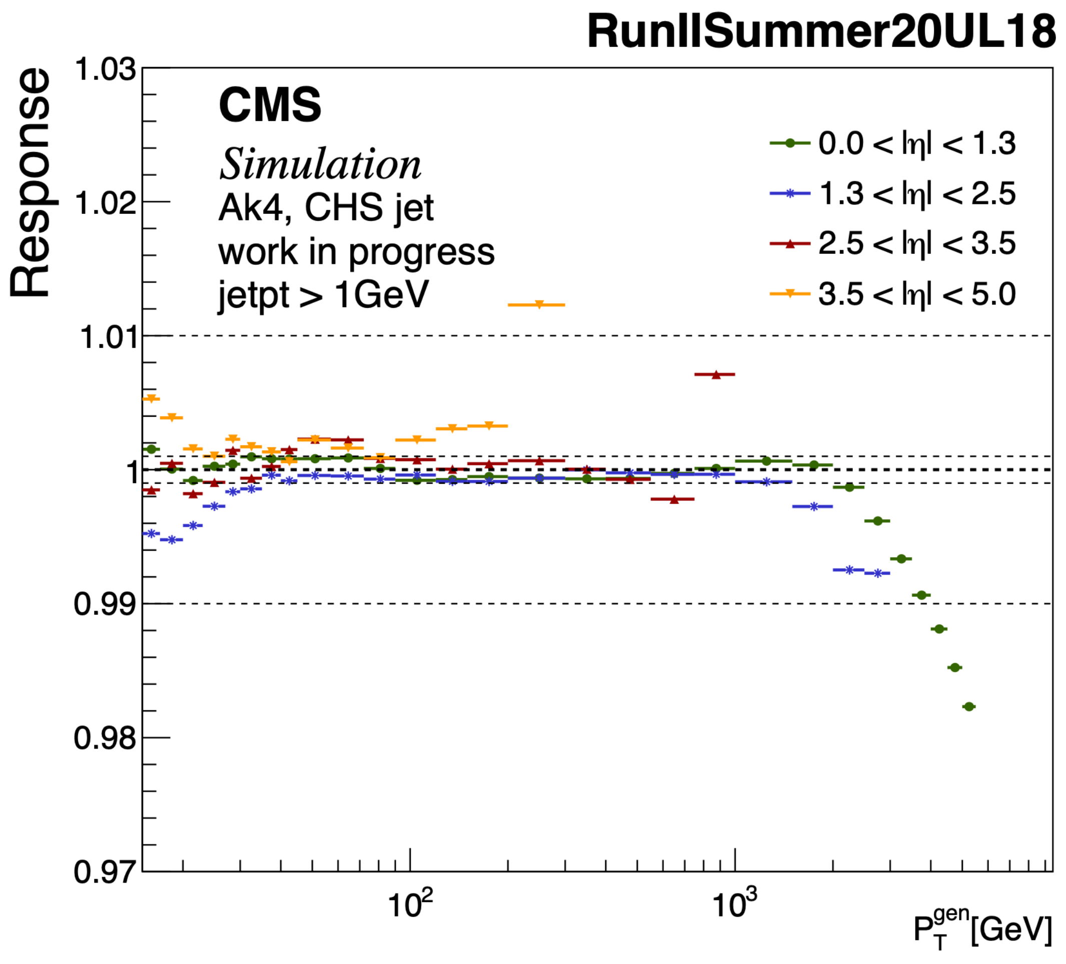


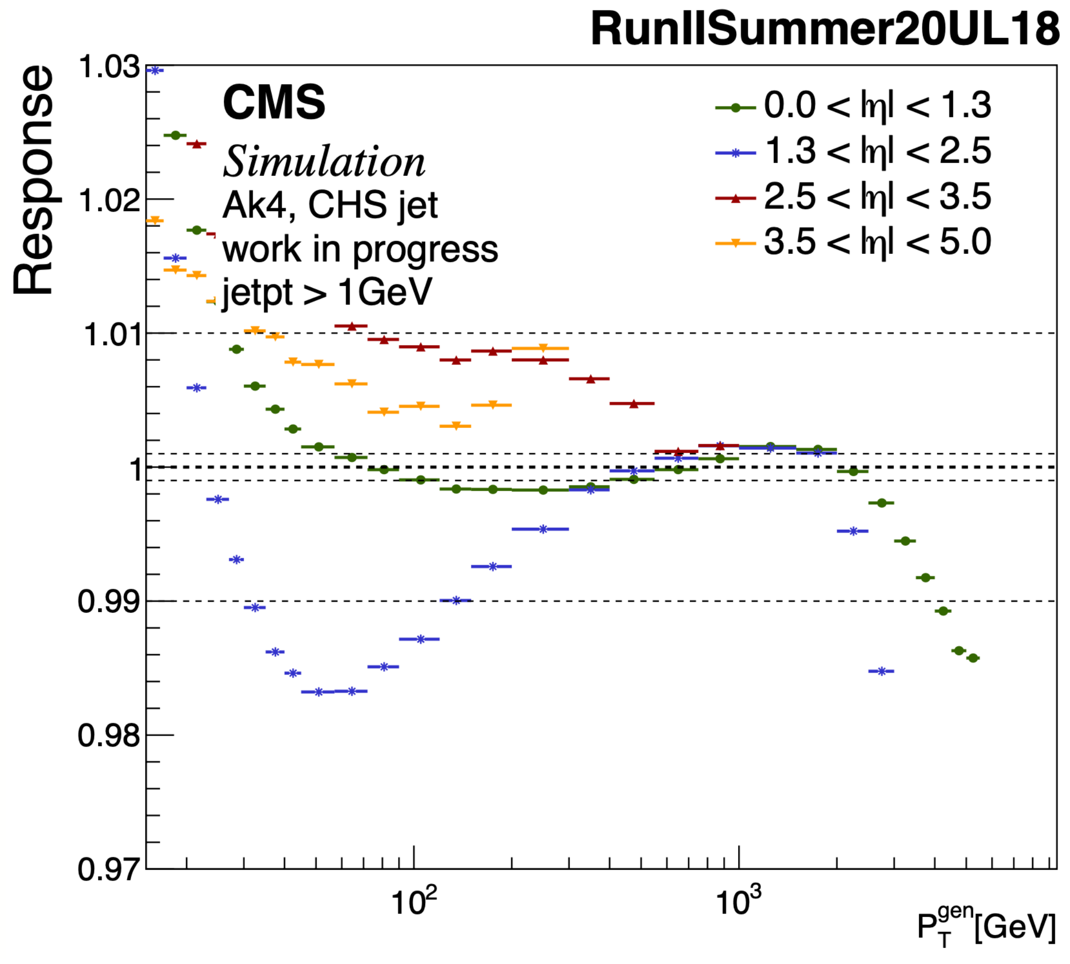

**Figure 1:** Representative diagrams for the production of 6-jets in SPS (leftmost), DPS (center, with DPS1 $(2j+4j)$) and DPS2 $(3j+3j)$, and TPS (rightmost) processes in pp collisions.



# JEC overview




Response in high-pileup sample after JEC




Response in Low-pileup sample after JEC

we need a dedicated JEC for Low-pileup

## L1-PileUp :: No Need

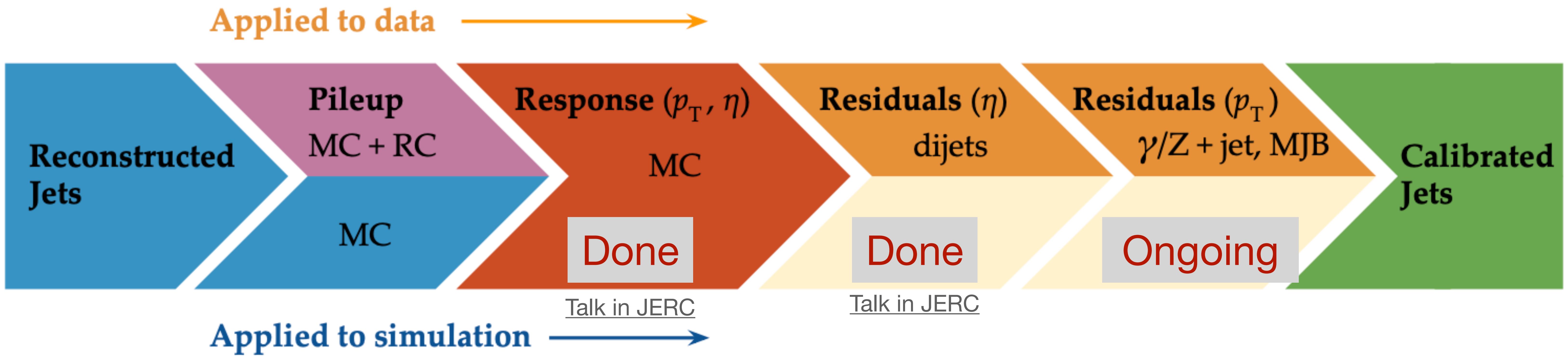
The goal of the L1 correction is to remove the energy coming from pile-up events.

## L2L3 MC-truth corrections

The simulated jet response corrections are determined on a QCD dijet sample, by comparing the reconstructed pT to the particle-level one.

## L2L3 Residuals

The L2 and L3 residuals are meant to correct for remaining small differences (of the order of %) within jet response in data and MC.



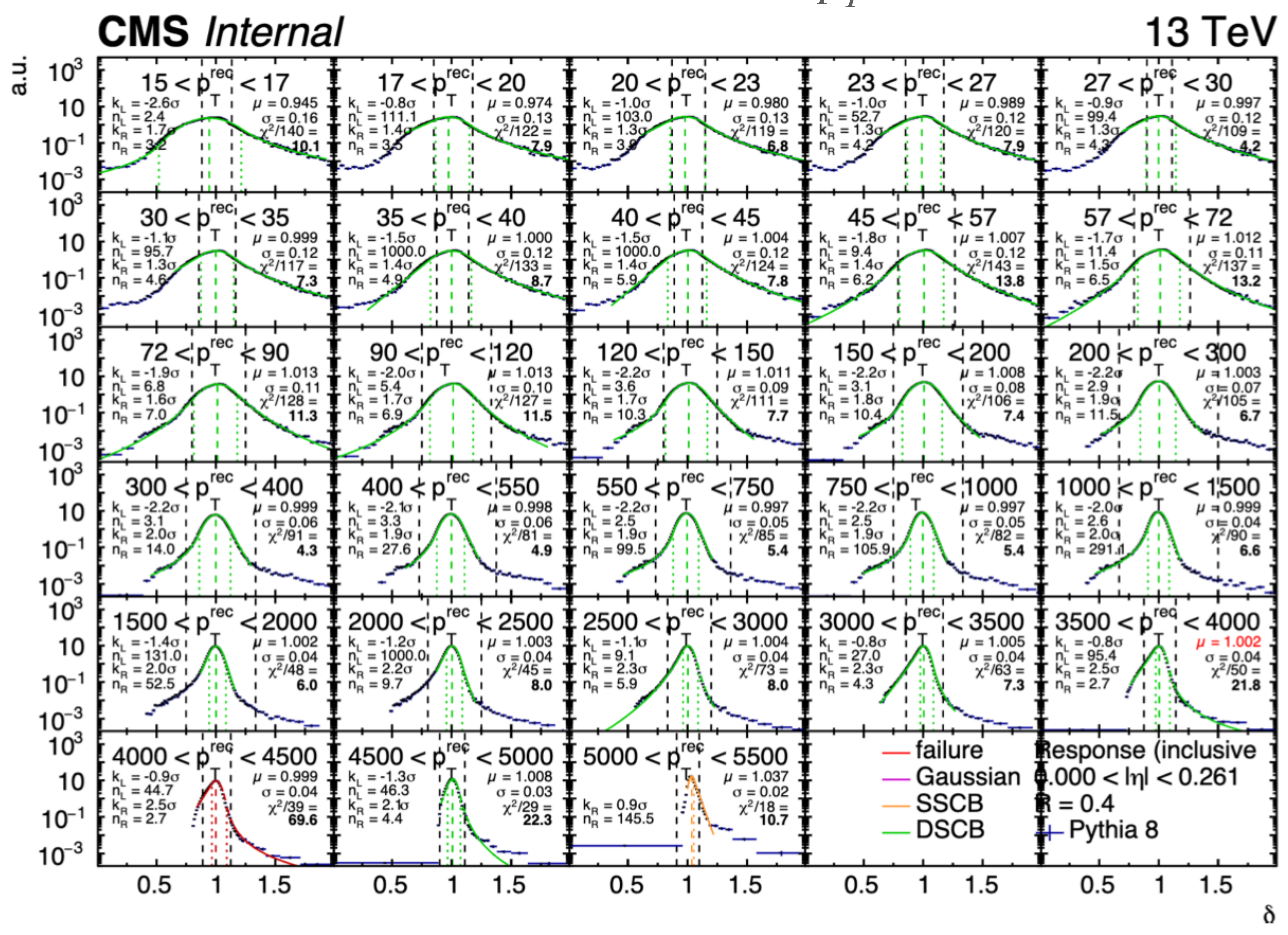

Talk in JERC

Talk in JERC

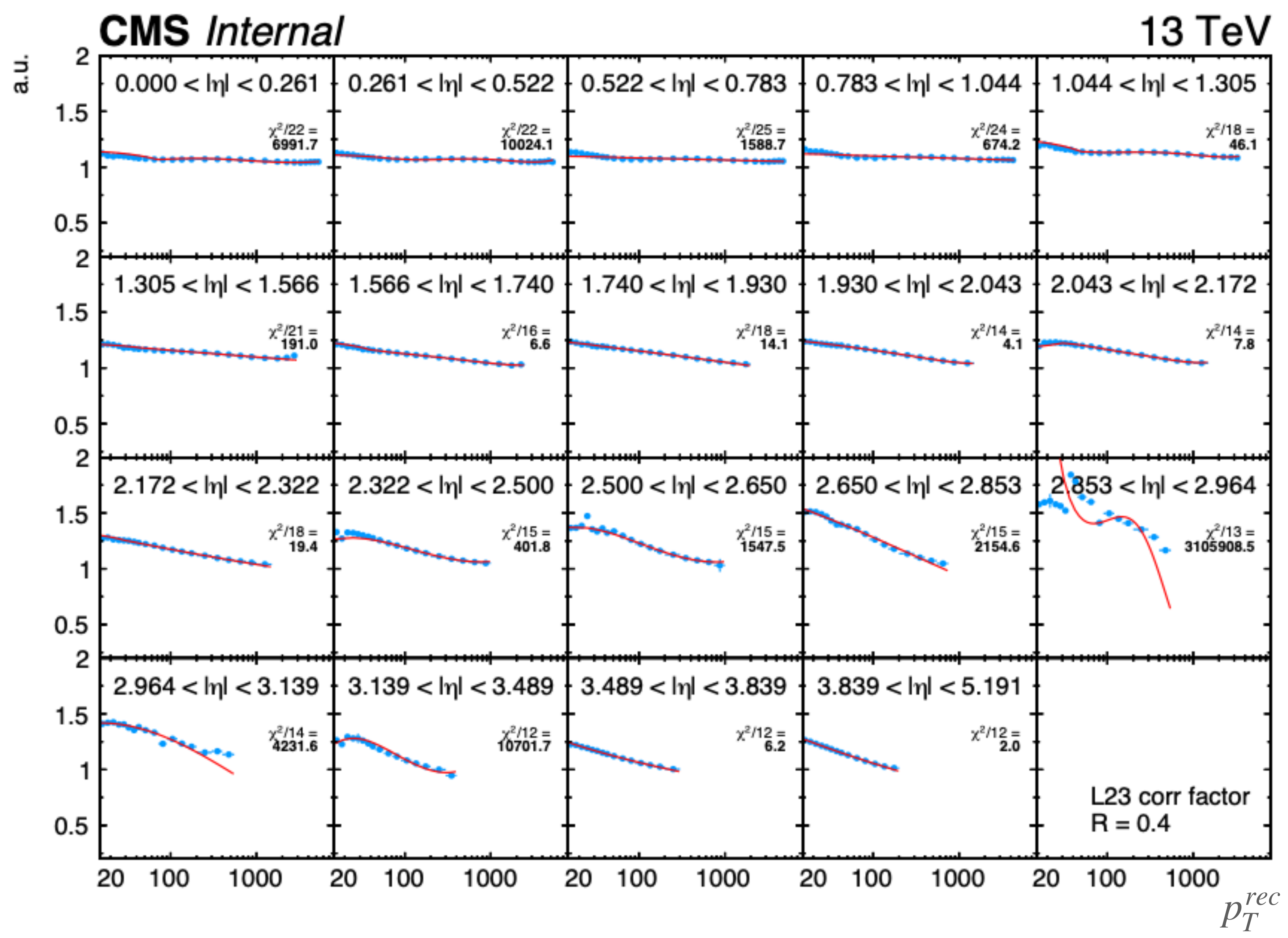
# L2L3 MC-truth corrections

Dataset:/QCD_Pt-15to7000_TuneCP5_Flat2018_13TeV_pythia8/RunIISummer19UL18MiniAODv2-EpsilonPU_106X_upgrade2018_realistic_v16_L1v1-v1/MINIAODSIM

$$\text{Response} = \frac{p_T^{rec}}{p_T^{gen}}$$




DSCB fit in $0.000 < |\eta| < 0.261$ in different pT bin




Use the polynomial function to fit the correction factor.

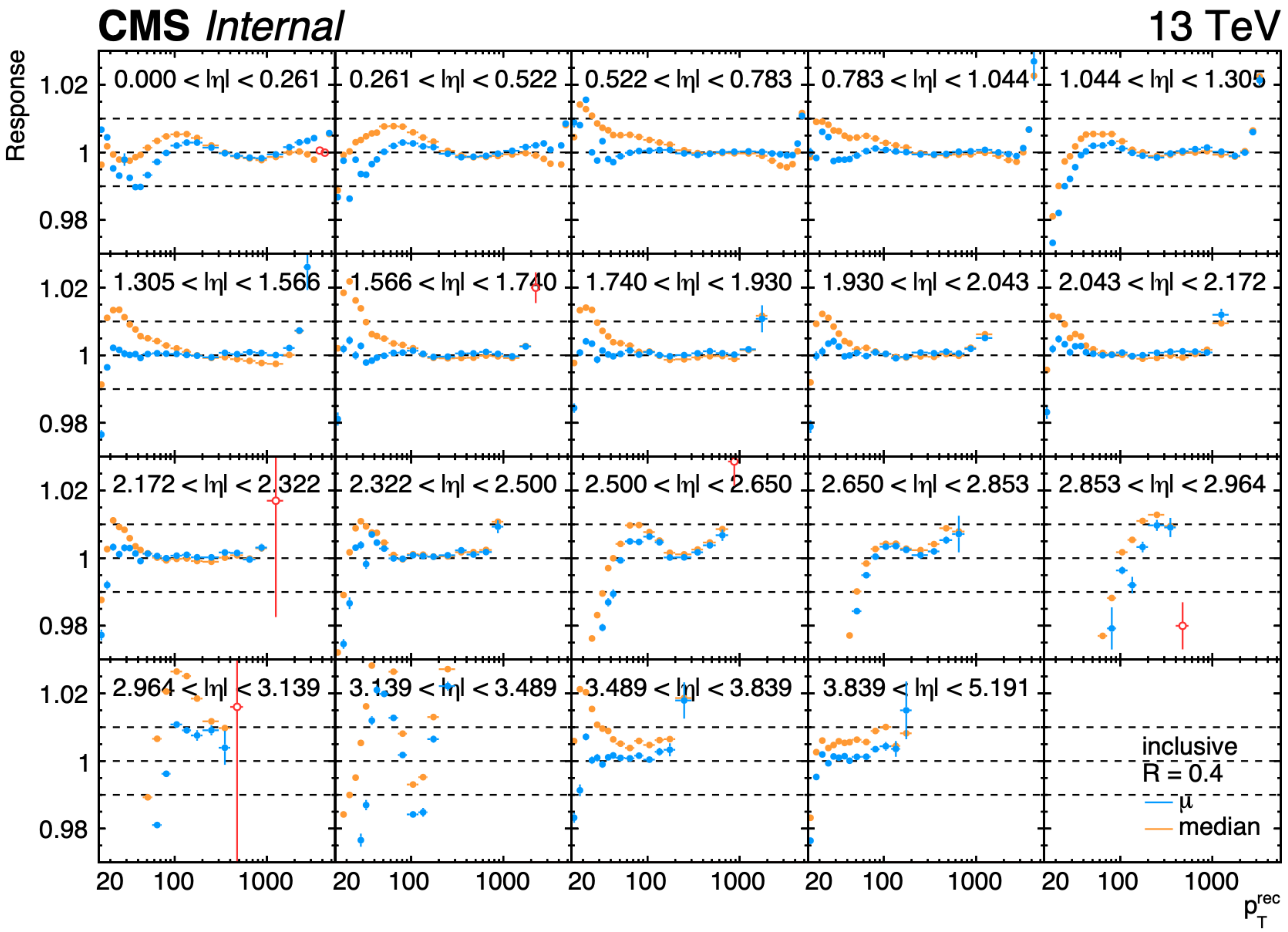
The main strategy starts with the production of the response distributions for all the determined $\eta$ and $p_T$ bins and use DSCB fit to get $\mu$ parameter.

$$C_{L2L3} = \frac{p_T^{gen}}{p_T^{rec}} = \frac{1}{\mu\ of\ DSCB\ fit\ \{Response\}}$$

# L2L3 MC-truth corrections

Dataset:/QCD_Pt-15to7000_TuneCP5_Flat2018_13TeV_pythia8/RunIISummer19UL18MiniAODv2-EpsilonPU_106X_upgrade2018_realistic_v16_L1v1-v1/MINIAODSIM

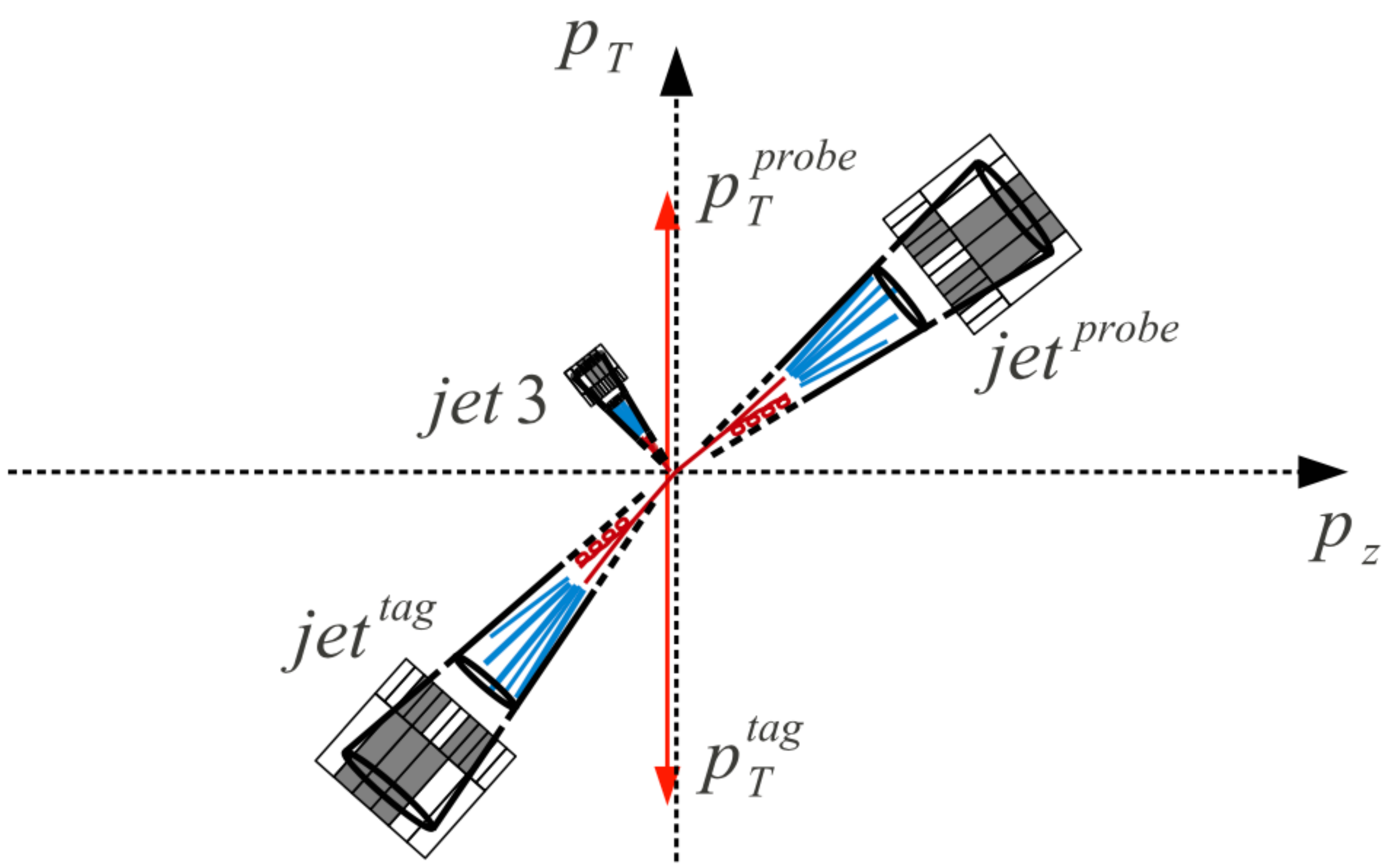
- The remaining uncorrected response is generally less than 0.5%. The correction effectiveness can be improved by increasing the statistics and enhancing the fit quality.



# L2 Residual $\eta$-dependent correction

**Motivation of L2Residual correction:**
**Efficiency disagreement between different detectors**

Residuals are derived as a function of $\eta$ and $p_T$ relative to the well-calibrated detector region with $|\eta| < 1.3$. A dijet event selection is used for the study.




- **pT balance method**

$$R_{\text{rel}}^{p_\text{T}} = \frac{1 + \langle \mathscr{A} \rangle}{1 - \langle \mathscr{A} \rangle}, \quad \mathscr{A} = \frac{p_{\text{T,probe}} - p_{\text{T},tag}}{2 p_{\text{T},ave}}.$$

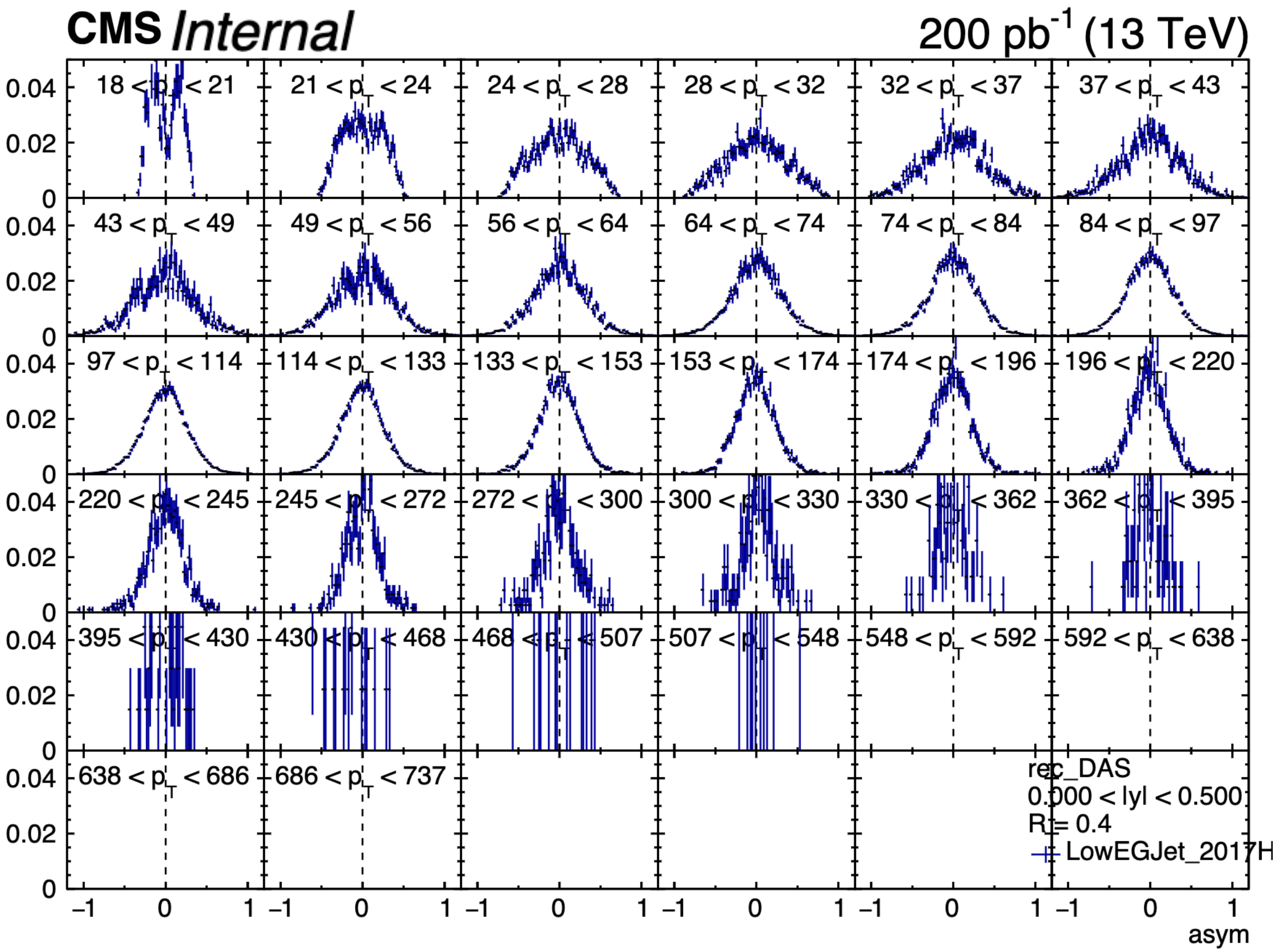
- **MPF method**

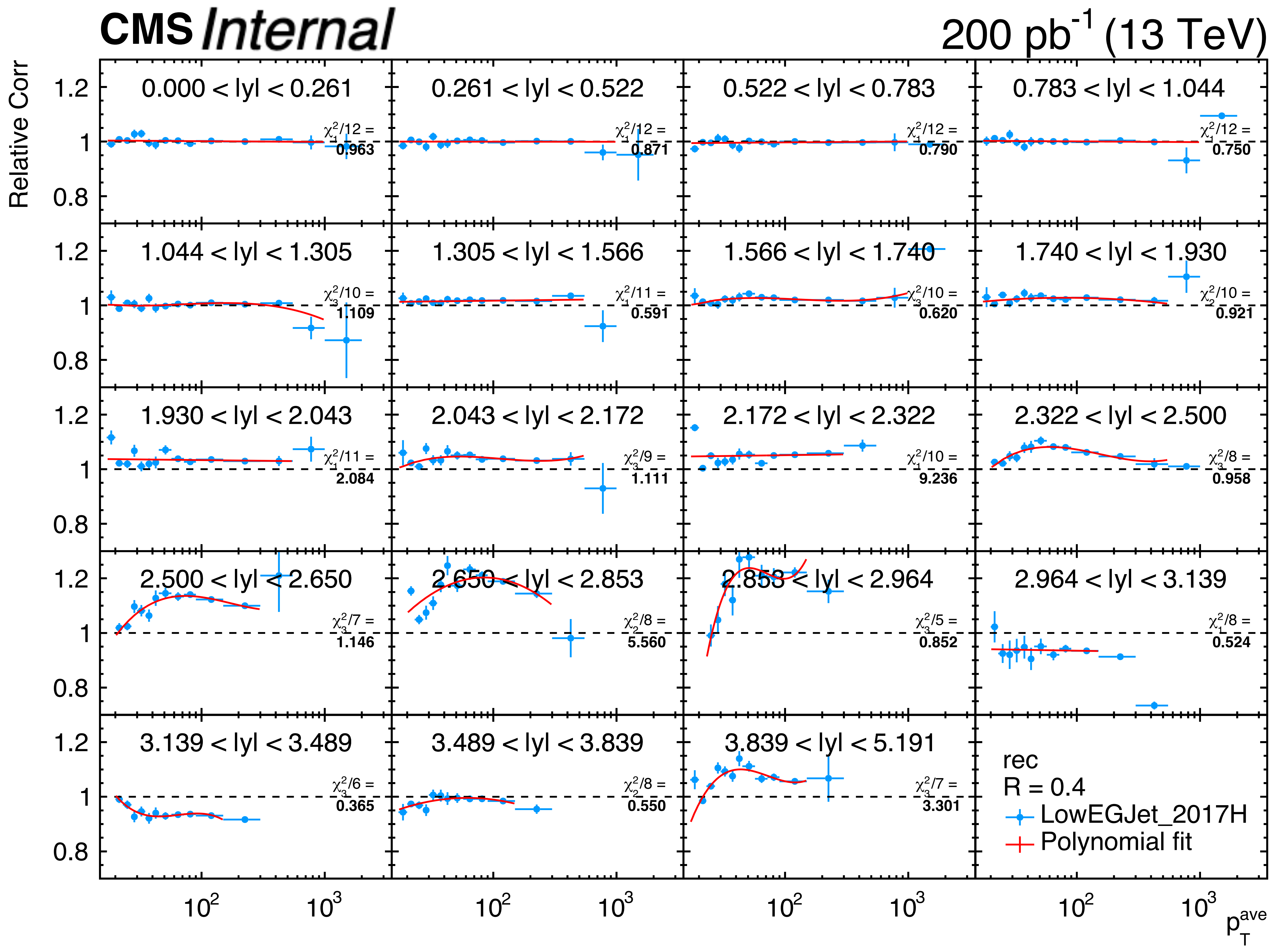
$$R_{\text{rel}}^{\text{MPF}} = \frac{1 + \langle \mathscr{B} \rangle}{1 - \langle \mathscr{B} \rangle}, \quad \mathscr{B} = \frac{\vec{p}_\text{T}^{\text{miss}} \cdot \left( \vec{p}_{\text{T,tag}} / p_{\text{T,tag}} \right)}{2 p_{\text{T,ave}}}.$$

The correction factor($\mathscr{C}$) comparing Monte Carlo predictions to data while incorporating final state radiation corrections.

$$\mathscr{C}\left(\eta^{\text{probe}}\right) = \left\langle \frac{\mathscr{R}^{\text{MC}}}{\mathscr{R}^{\text{data}}} \right\rangle_{p_T}^{\alpha<0.3} \cdot k_{FSR}, \text{ with } k_{FSR} = \frac{\left\langle \frac{R^{MC}}{R^{data}} \right\rangle_{\alpha\to 0}}{\left\langle \frac{R^{MC}}{R^{data}} \right\rangle_{\alpha<0.3}}$$

# L2Residual - pT balance method



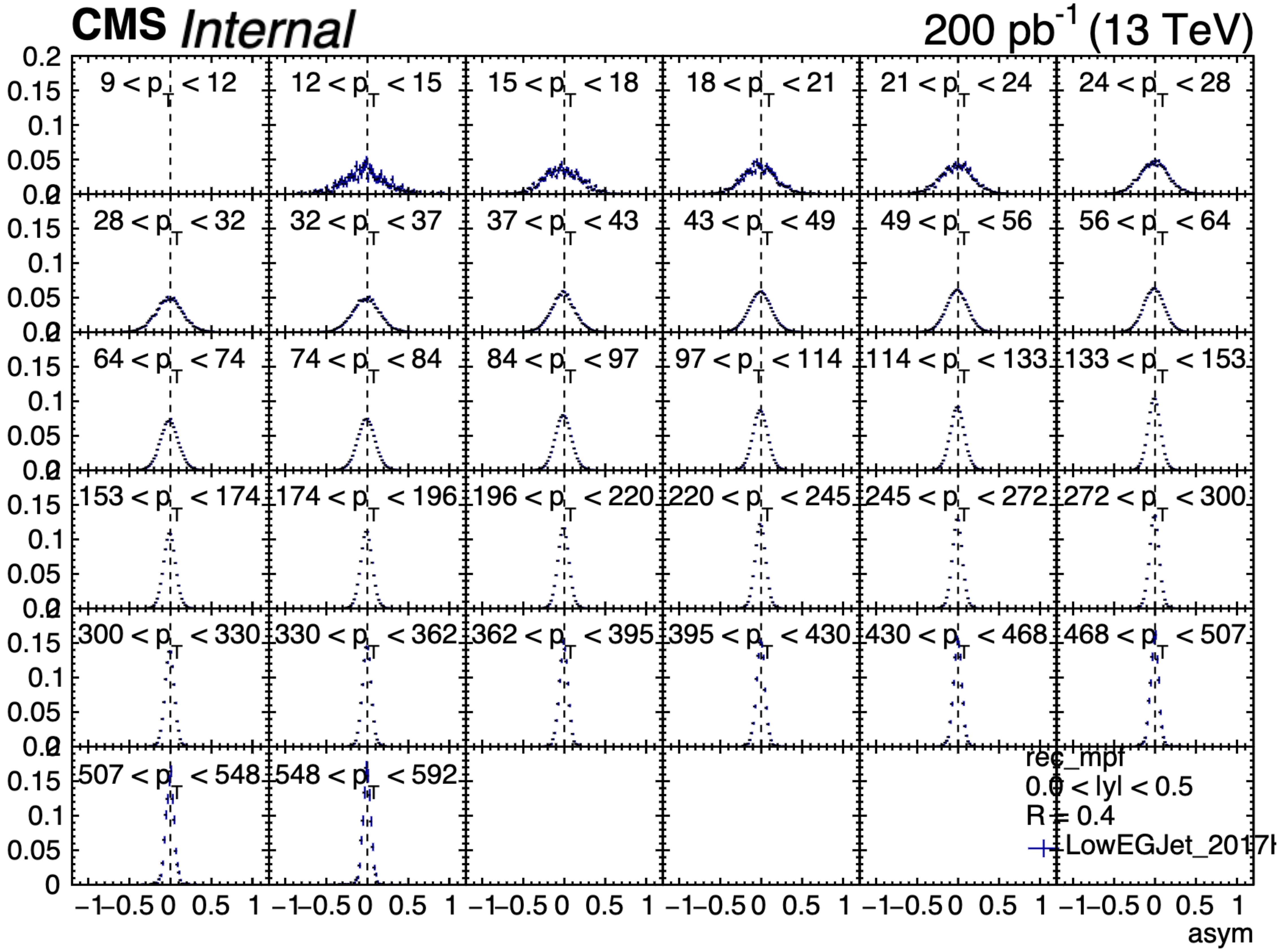



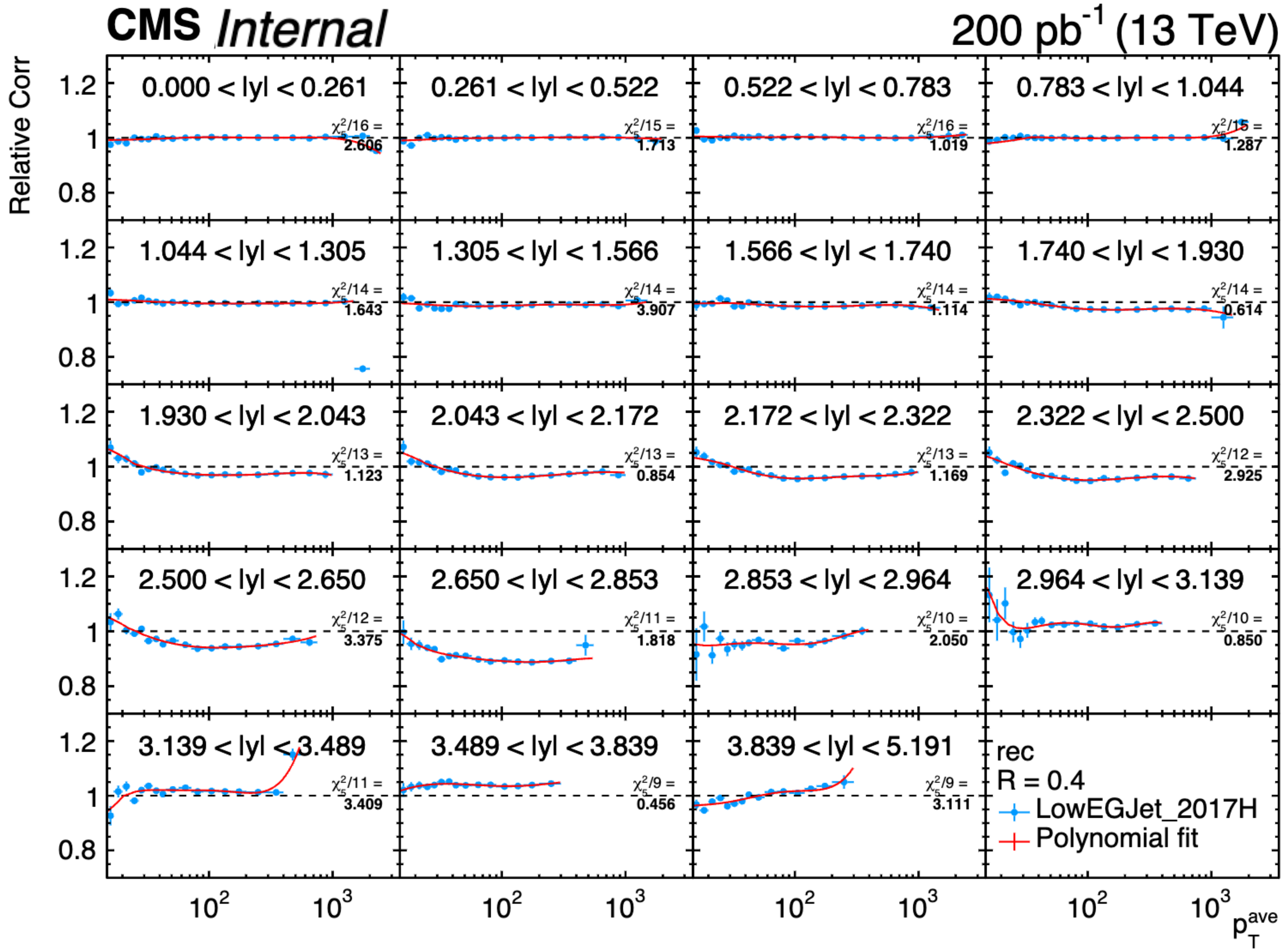

$$\mathscr{A} = \frac{p_{\mathrm{T,probe}} - p_{\mathrm{T},tag}}{2p_{\mathrm{T},ave}}$$

$$R_{\mathrm{rel}}^{p_{\mathrm{T}}} = \frac{1 + \langle \mathscr{A} \rangle}{1 - \langle \mathscr{A} \rangle}$$

$$C = < \frac{R_{MC}}{R_{DATA}} >_{\alpha<0.3}$$

# L2Residual - MPF method



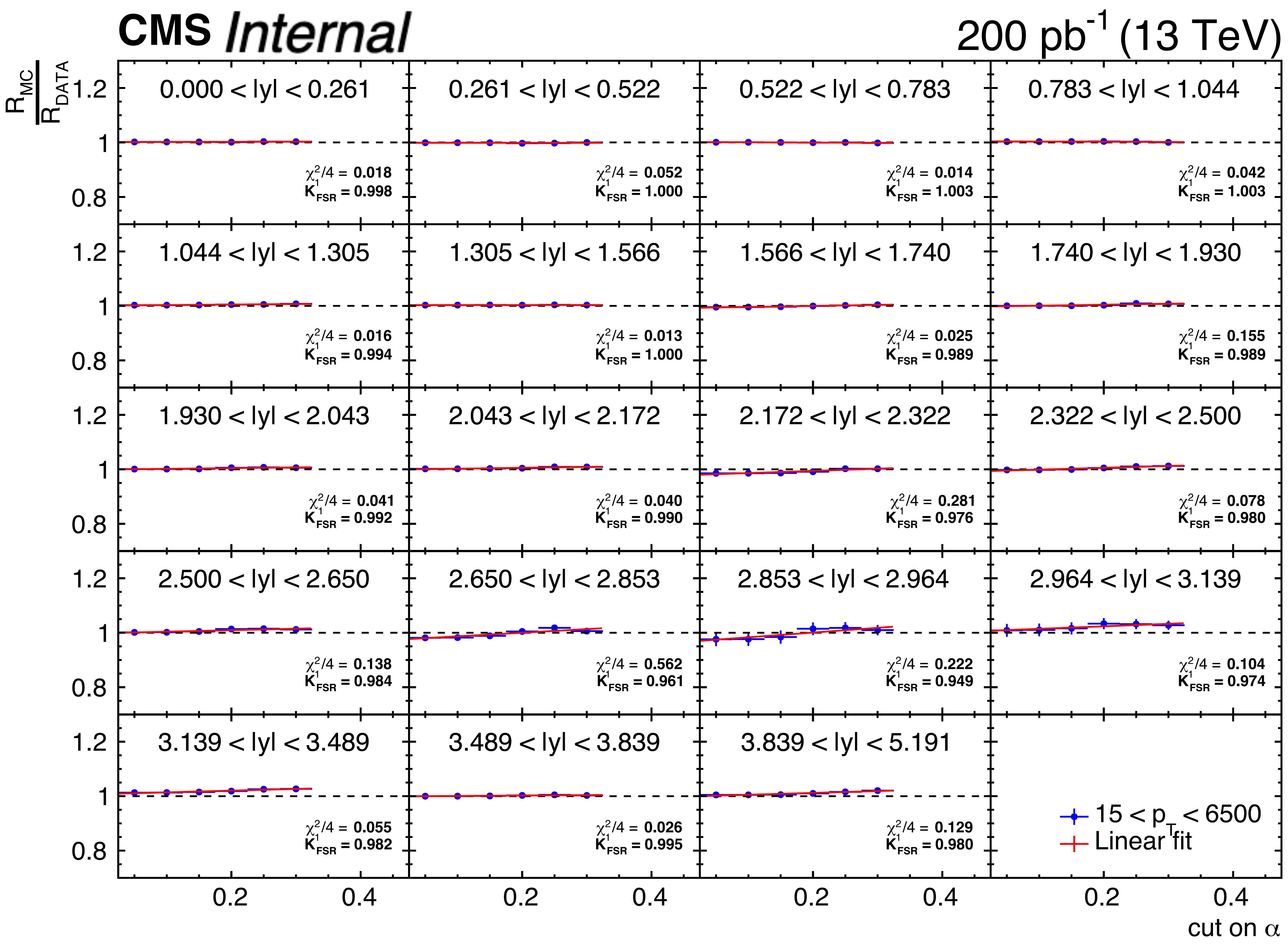




$$\mathscr{B} = \frac{\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}} \cdot \left(\vec{p}_{\mathrm{T,tag}}/p_{\mathrm{T,tag}}\right)}{2p_{\mathrm{T,ave}}}$$

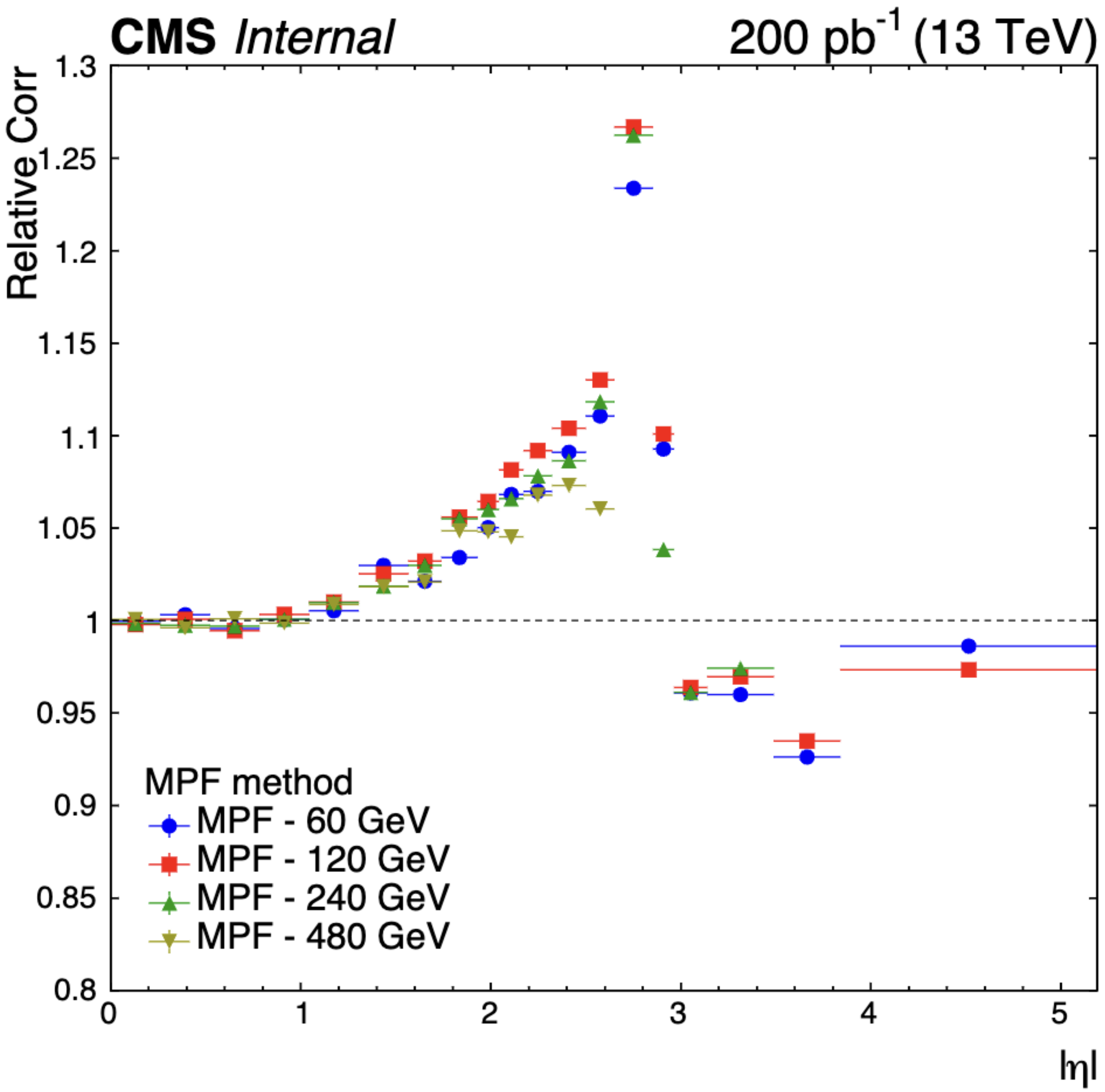
$$R_{\mathrm{rel}}^{\mathrm{MPF}} = \frac{1+\langle\mathscr{B}\rangle}{1-\langle\mathscr{B}\rangle}$$

$$C = < \frac{R_{MC}}{R_{DATA}} >_{\alpha<0.3}$$

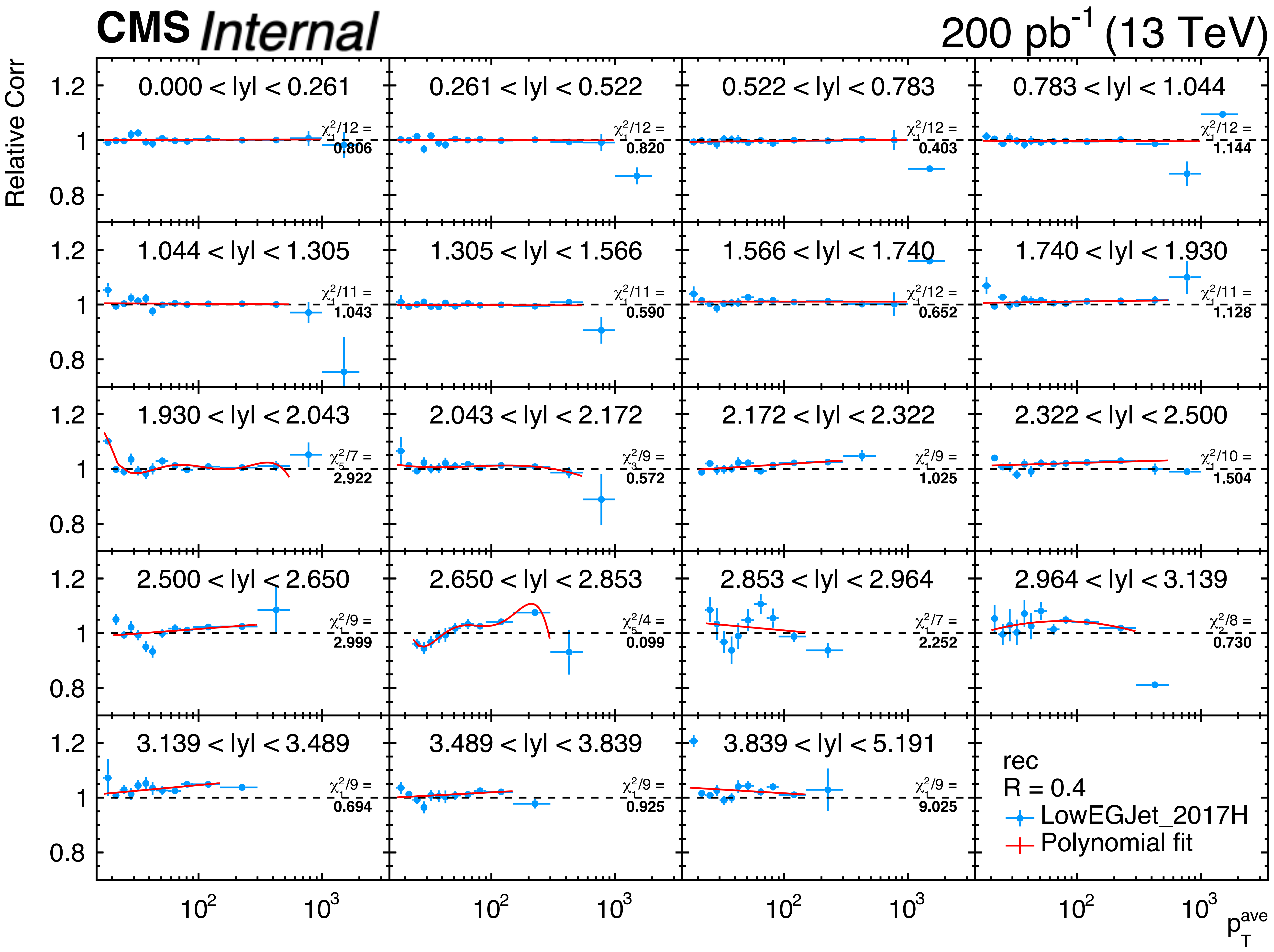
# L2Residual - $K_{fsr}$

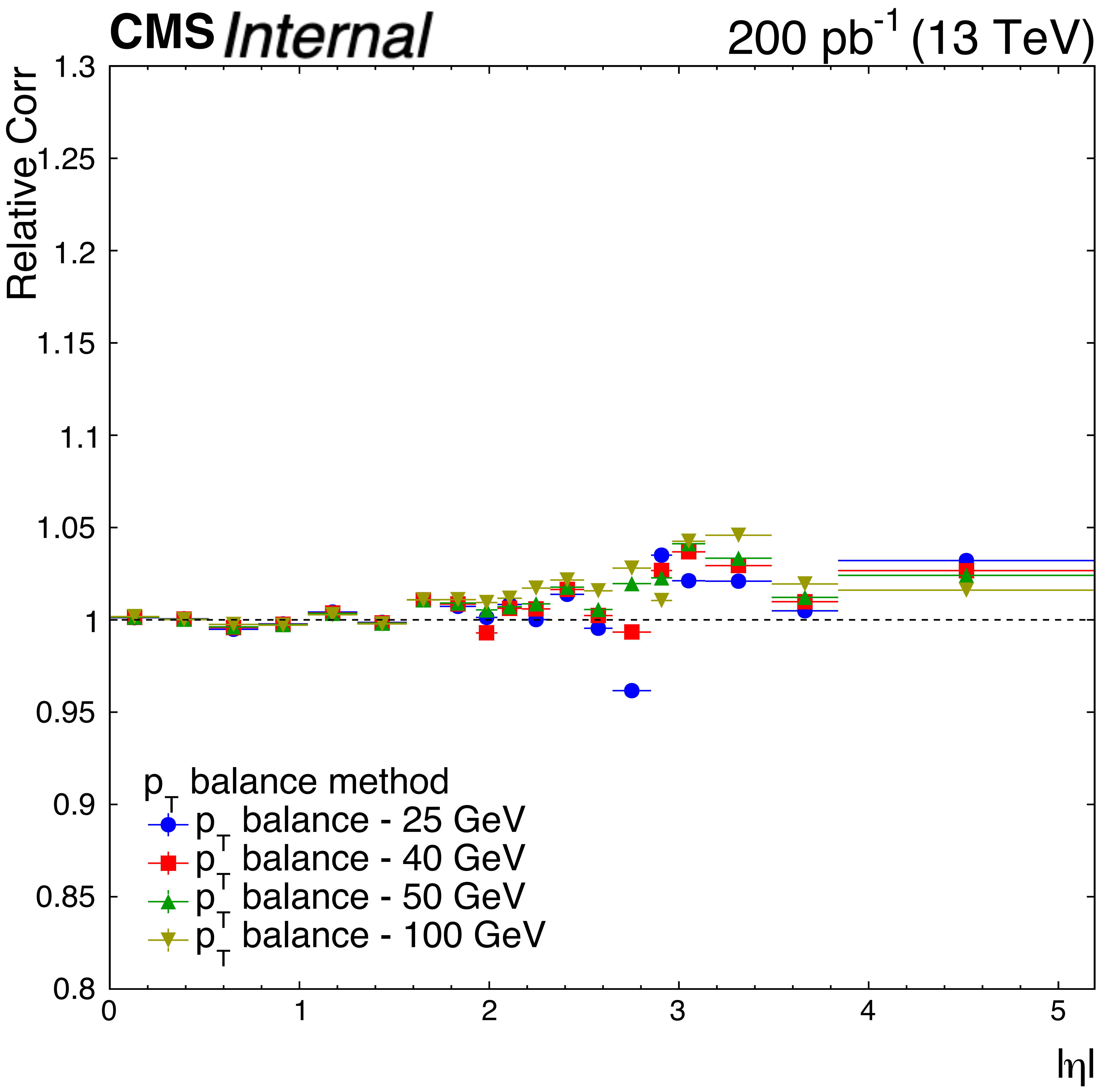



$$k_{FSR} = \frac{\left\langle \frac{R^{MC}}{R^{data}} \right\rangle_{\alpha \to 0}}{\left\langle \frac{R^{MC}}{R^{data}} \right\rangle_{\alpha < 0.3}}$$



# $K_{fsr}$ closure test



# Summary

- L2L3MC-truth and L2Residual corrections dedicated to the 17RunH lowPU sample have been derived.
- The effect of the decomposed correction is better than the original correction through closure testing, but the effect of the combined correction still needs to be evaluated.
- Next Step
  - L3Residual absolute correction
  - Resolution & Uncertainty

# Thanks for your attention!