nPDF Measurements

New pPb dijet measurement

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HI Jet Workshop

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Dijet pseudorapidity

$$\eta_{dijet} = \frac{\eta_1 + \eta_2}{2} \propto 0.5 \log\left(\frac{x_p}{x_{Pb}}\right) + \eta_{CM}$$

CMS pPb 35 nb^{-1}

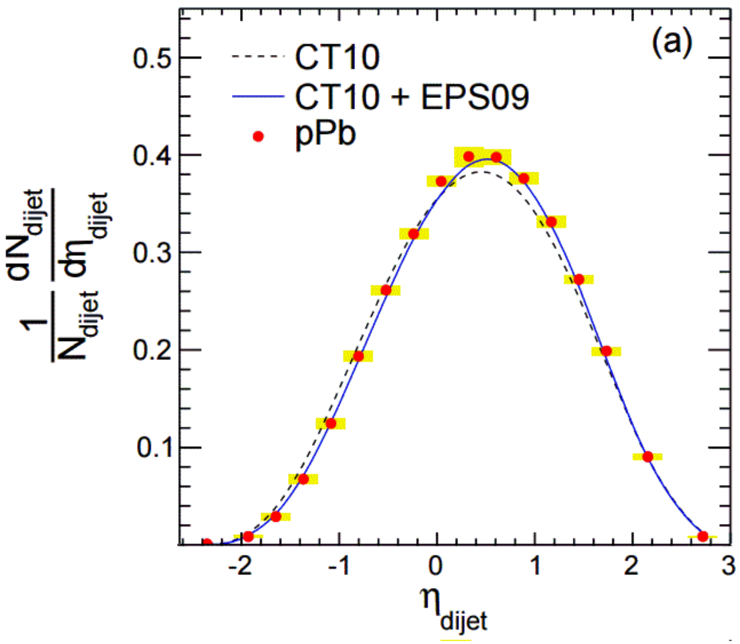
$\sqrt{s_{NN}} = 5.02$ TeV

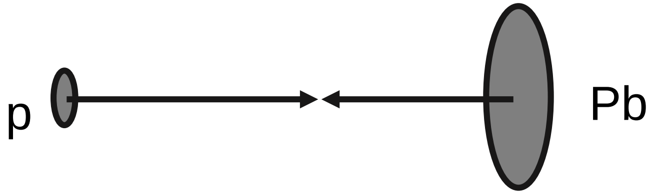
$p_{T,1} > 120$ GeV/c

$p_{T,2} > 30$ GeV/c

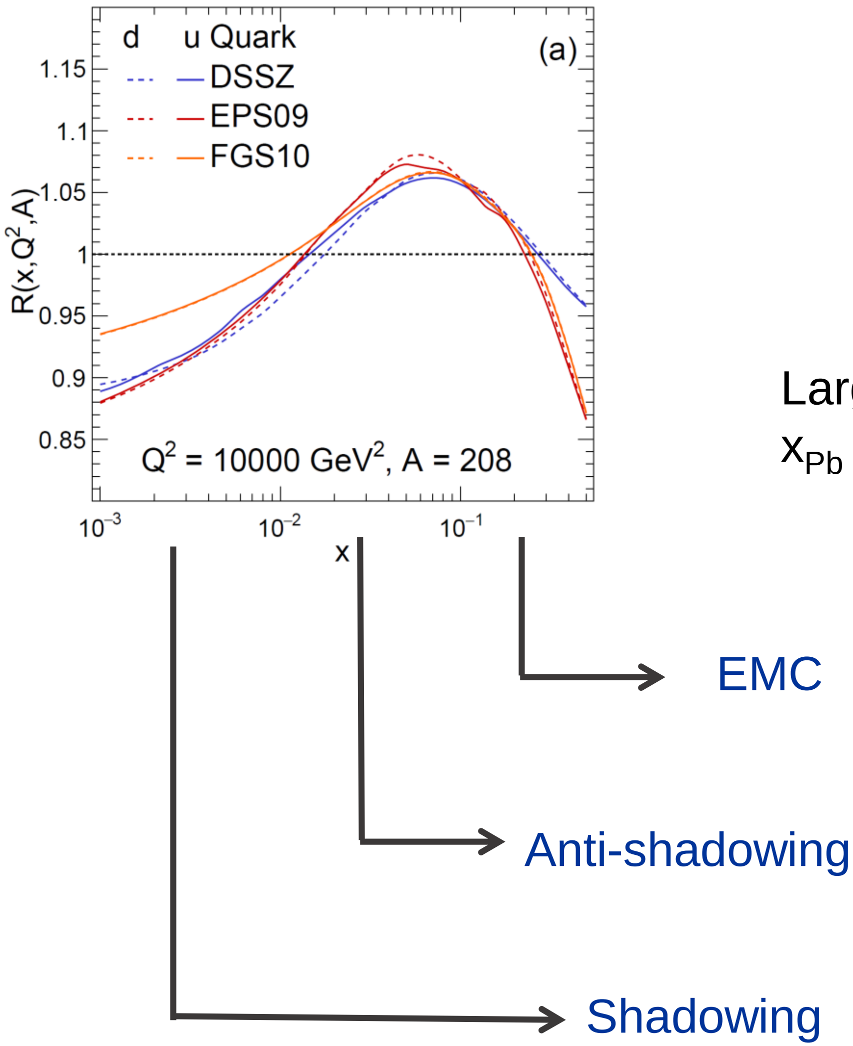
$\Delta\phi_{1,2} > 2\pi/3$

All $E_T^{4<|\eta|<5.2}$

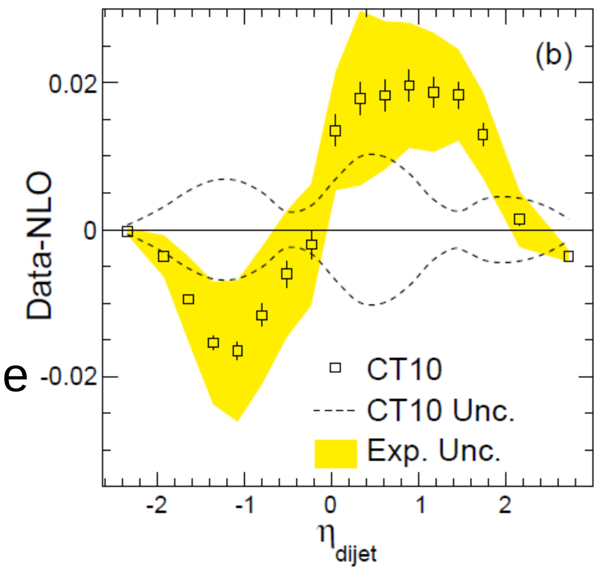




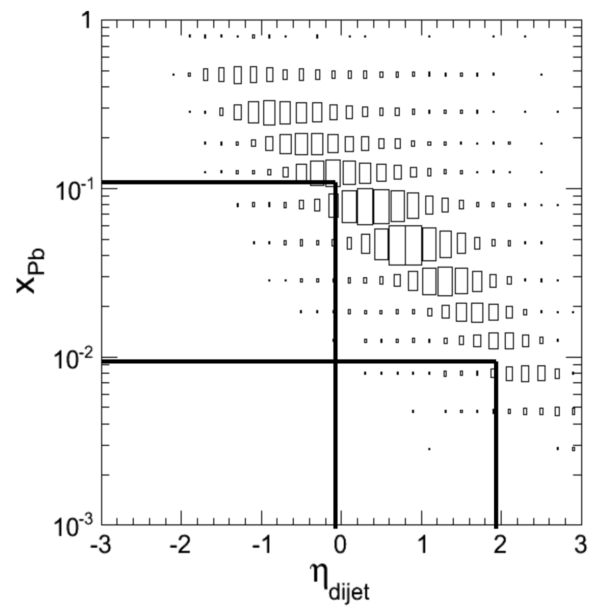
Mapping onto regions of x_{Pb}



Large x_{Pb}



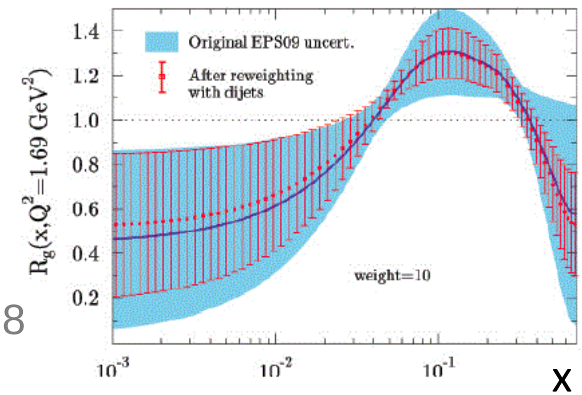
Small x_{Pb}

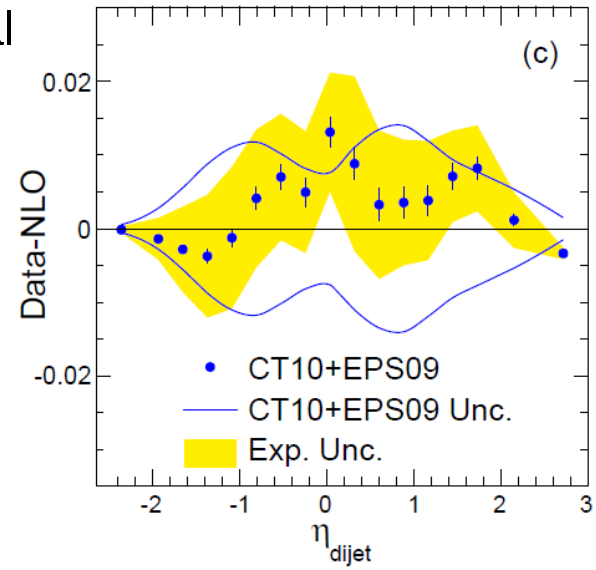


In good agreement with EPS09

After reweighting with dijet data: EPS09 central value doesn't change significantly but errors shrink

1509.02798





χ^2 1512.01528

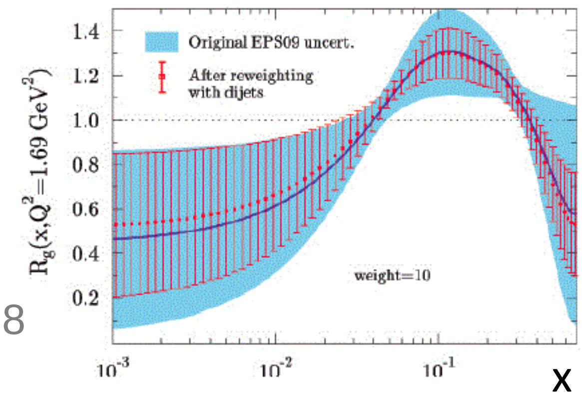
PDF + nPDF	$\text{dijets}_{\text{CMS}}$ (15)
CT10+DSSZ	94.441
CT10+EPS09	10.526
CT10 only	116.187

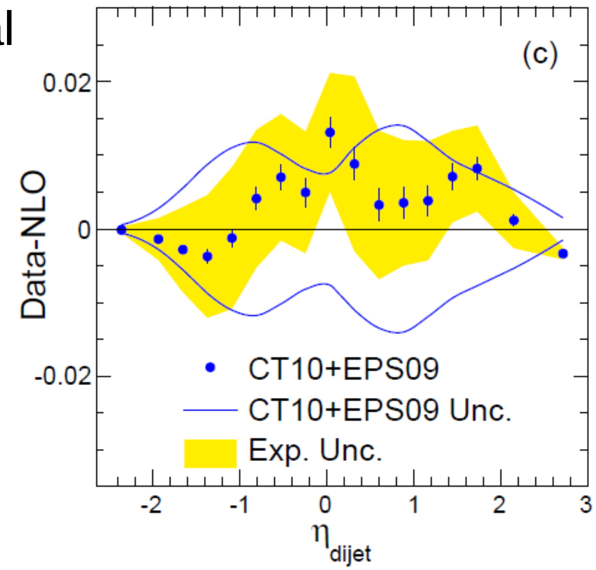
No nPDF and DSSZ nPDF cases are disfavored

Proton baseline

After reweighting with dijet data: EPS09 central value doesn't change significantly but errors shrink

1509.02798





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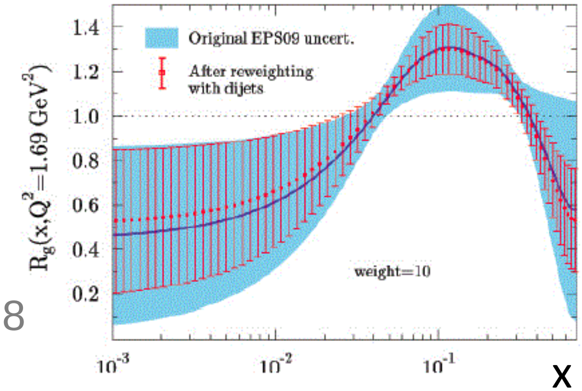

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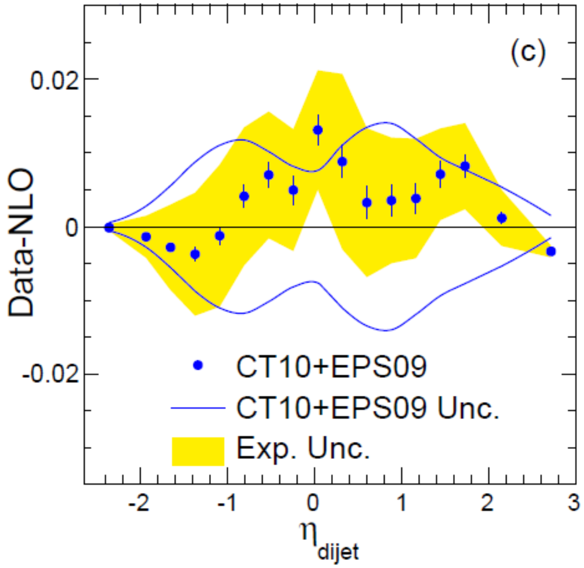

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Using a different proton PDF changes χ^2 significantly

What's new?

Measuring Q evolution with $p_T^{ave} = \frac{p_{T,1}+p_{T,2}}{2} \propto Q$

Jets:
$|\eta| < 3$
pp boosted: $-3.465 < |\eta| < 3$
R = 0.3 PF jets
No UE subtraction

Dijet selection:
$p_{T,1} > 30\ GeV$
$p_{T,2} > 20\ GeV$
$\Delta\phi > {}^{2\pi}/_{3}$
$p_T^{ave}: 25, 55, 75, 95, 115, 150, 400\ GeV$

Asymmetric p_T selection for jets was useful to search for jet quenching in pPb collisions

Balanced dijet selection reduces the contribution of three jet events making the correlation between dijet observables and x better

Most importantly

pp reference – 25.8 pb^{-1}:

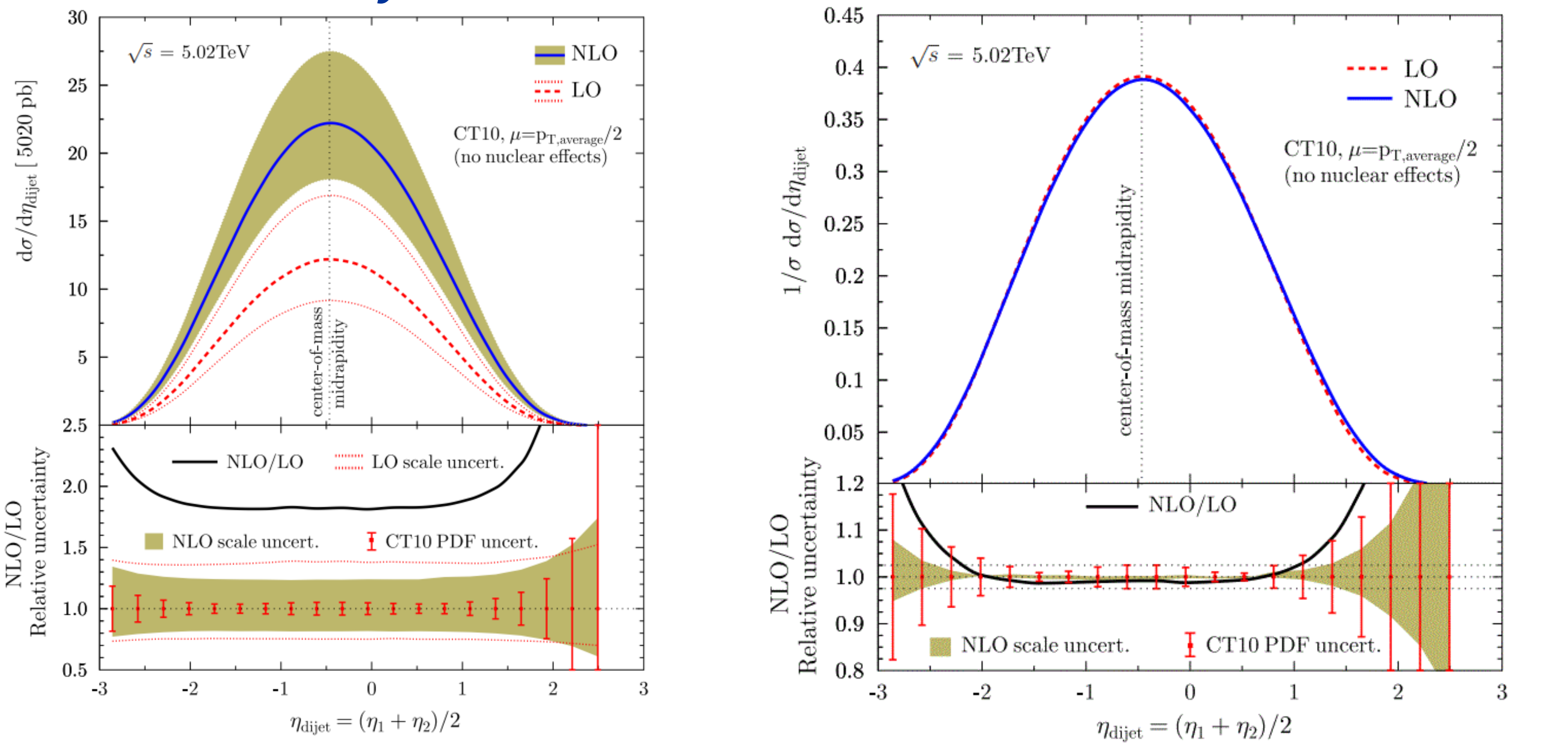
Removes misleading discrepancies between pPb and nPDF calculations which source from proton nPDF

Cancellation of uncertainties between pPb and pp improves experimental precision

Self-normalization

Scale uncertainty

1308.6733



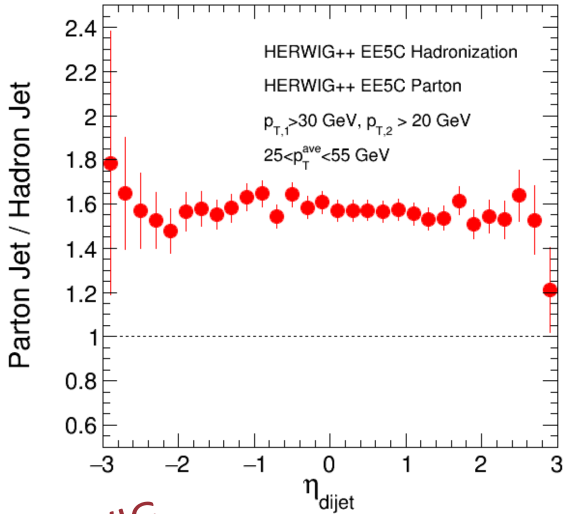
Flat off-set caused by scale uncertainty cancels after normalization of curves with respect to area underneath

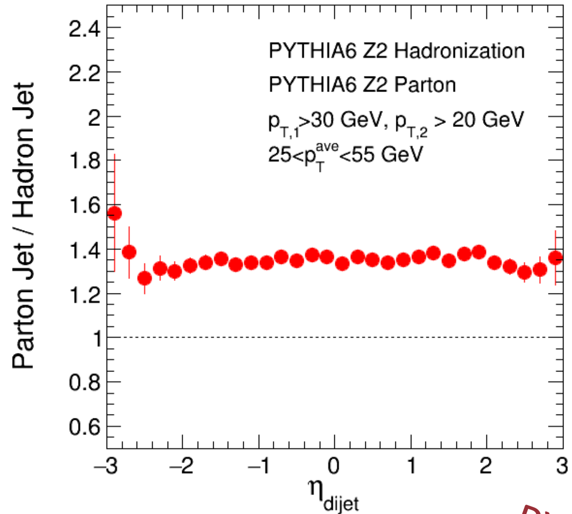
Self-normalization

HERWIG

Cross-section ratios

PYTHIA

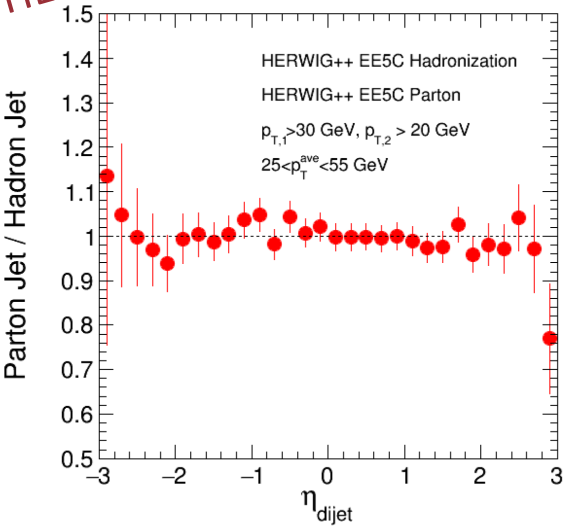


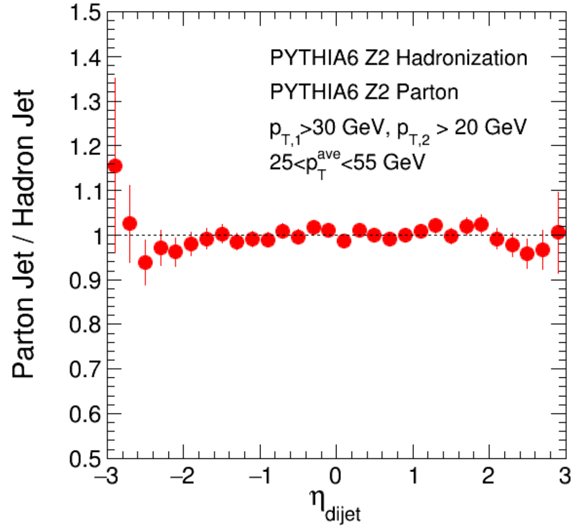


HERWIG

Area normalized ratios

PYTHIA





Hadronization uncertainty

Parton jets have higher cross section for R = 0.3 jets with same kinematic selections compared to hadron jets

Parton jets are harder fragmenting

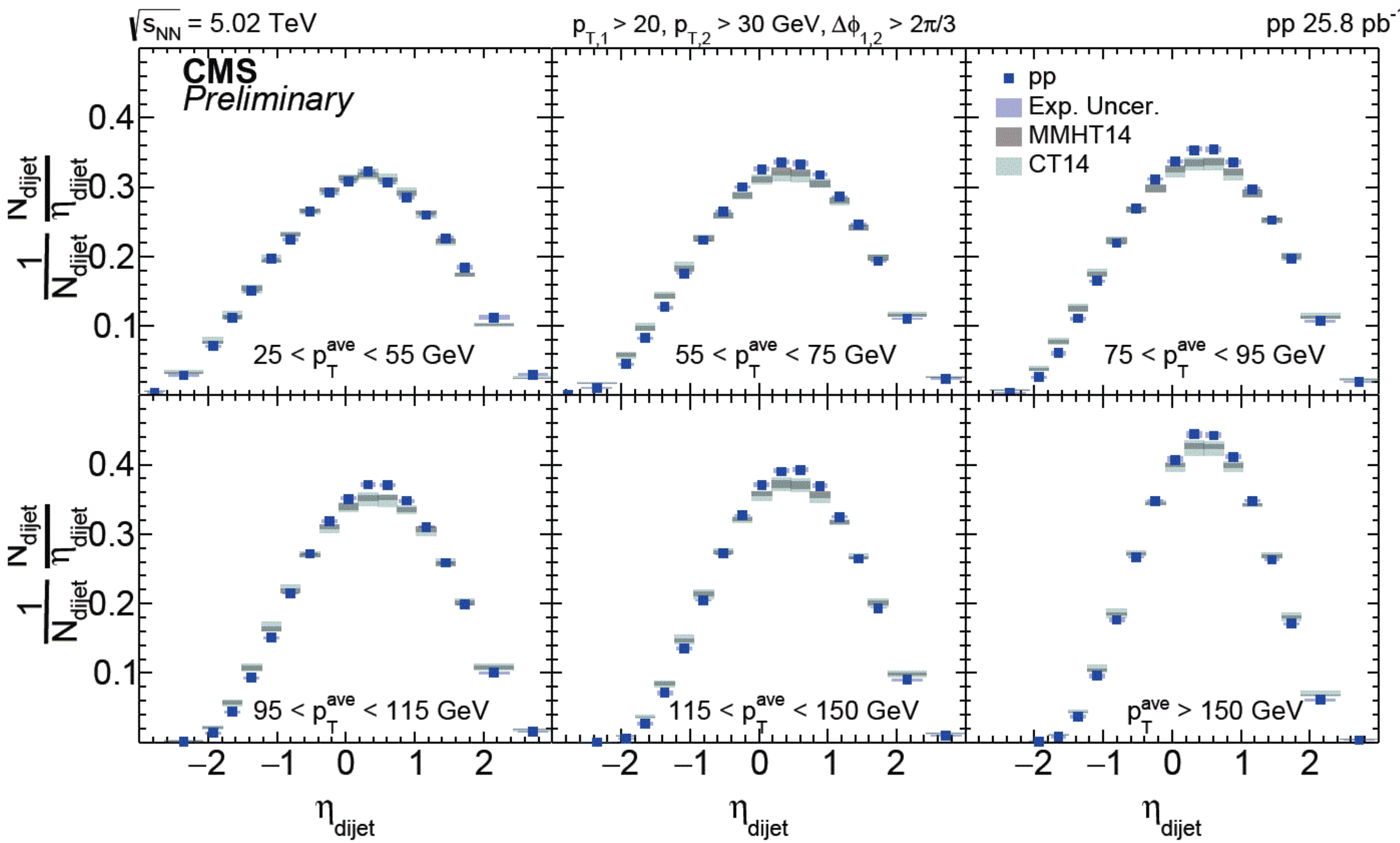
After self normalization effect of hadronization is negligible

Results

Compared to NLO calculations

..Many thanks to Nestor Armesto et. al.

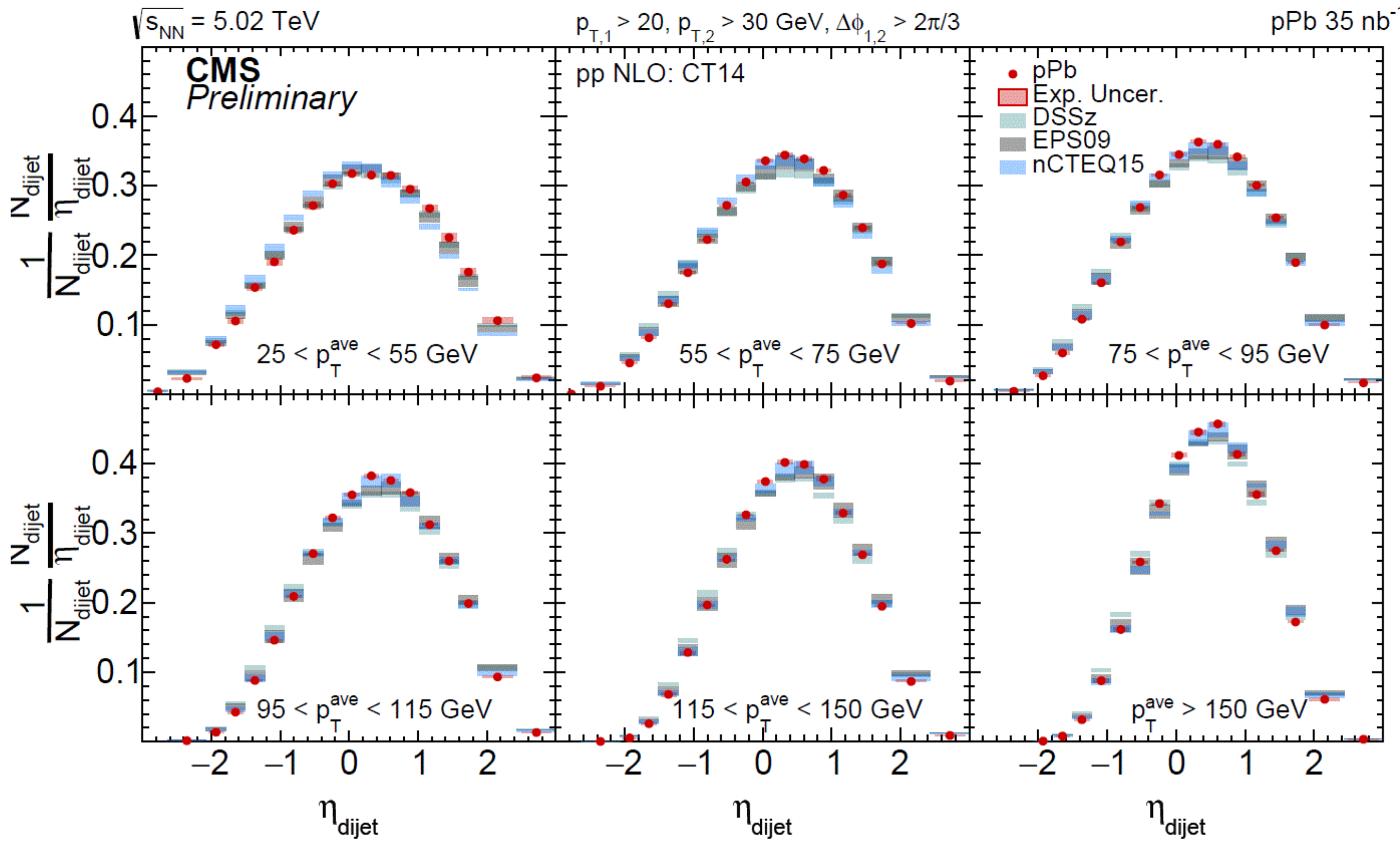
Dijet η in pp



Both NLO calculations are too wide

MMHT slightly better

Dijet η in pPb *CT*

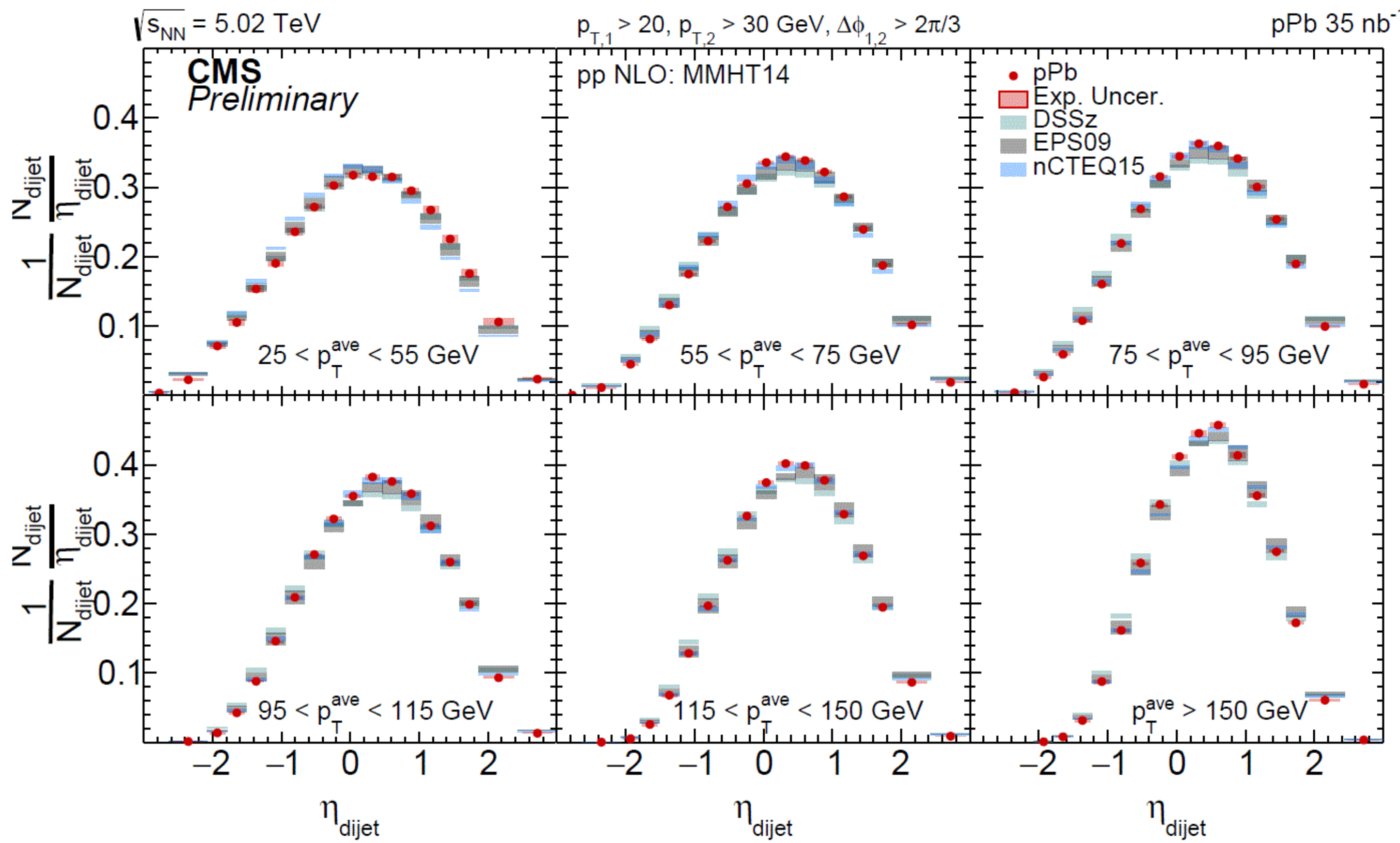


Anti-shadowing makes distributions peakier pPb closer to nPDF calculation

The pp discrepancy is hidden in this comparison

An agreement between pPb data and certain nPDF set does not necessarily indicate a better description of data

Dijet η in pPb *MMHT*

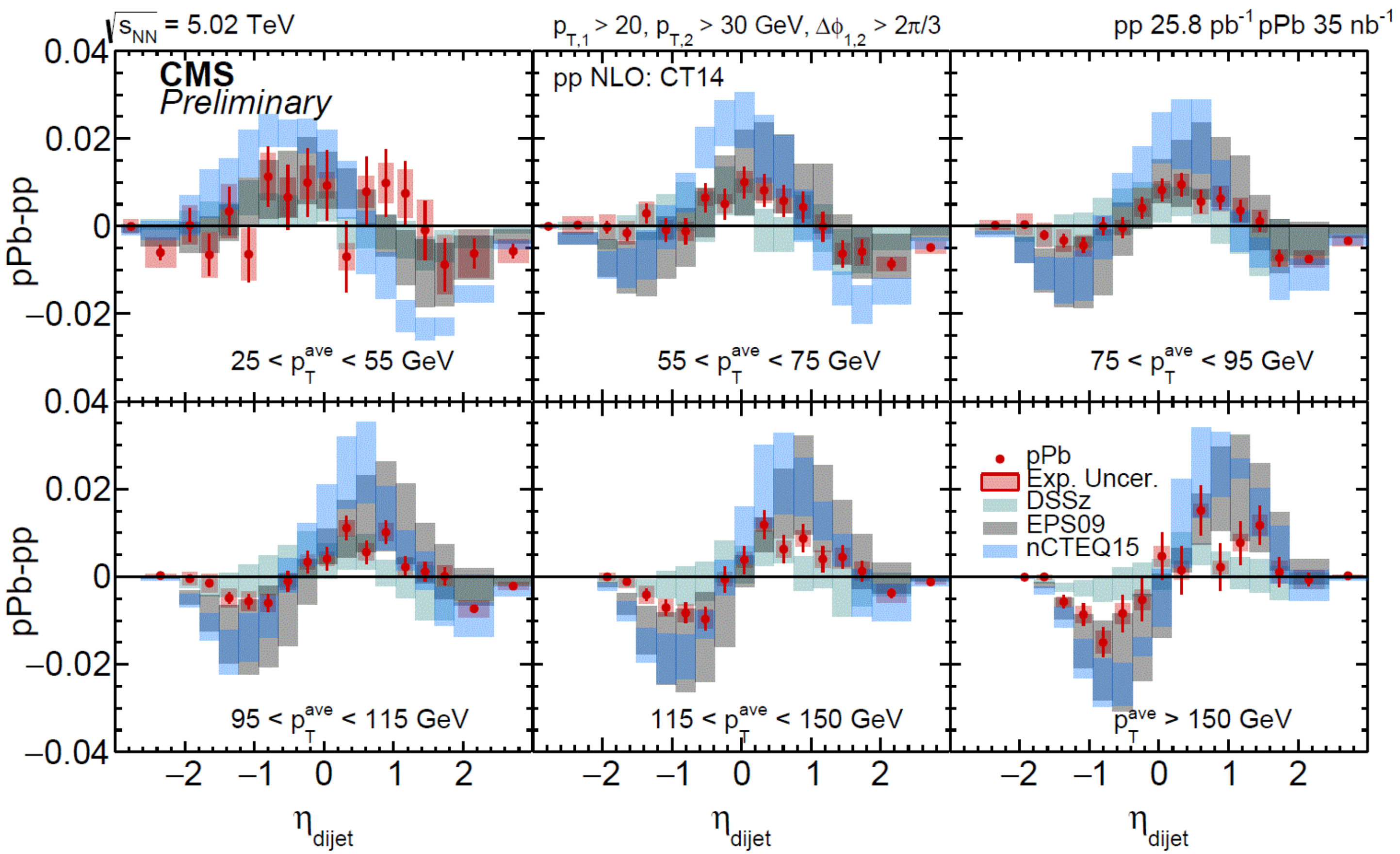


Narrower distributions in MMHT14 are also reflected in nPDF calculations which use it as a baseline

Next slides: Healthier comparison

To reduce the dependence on proton PDF take ratios and differences of pPb and pp data and compare afterwards

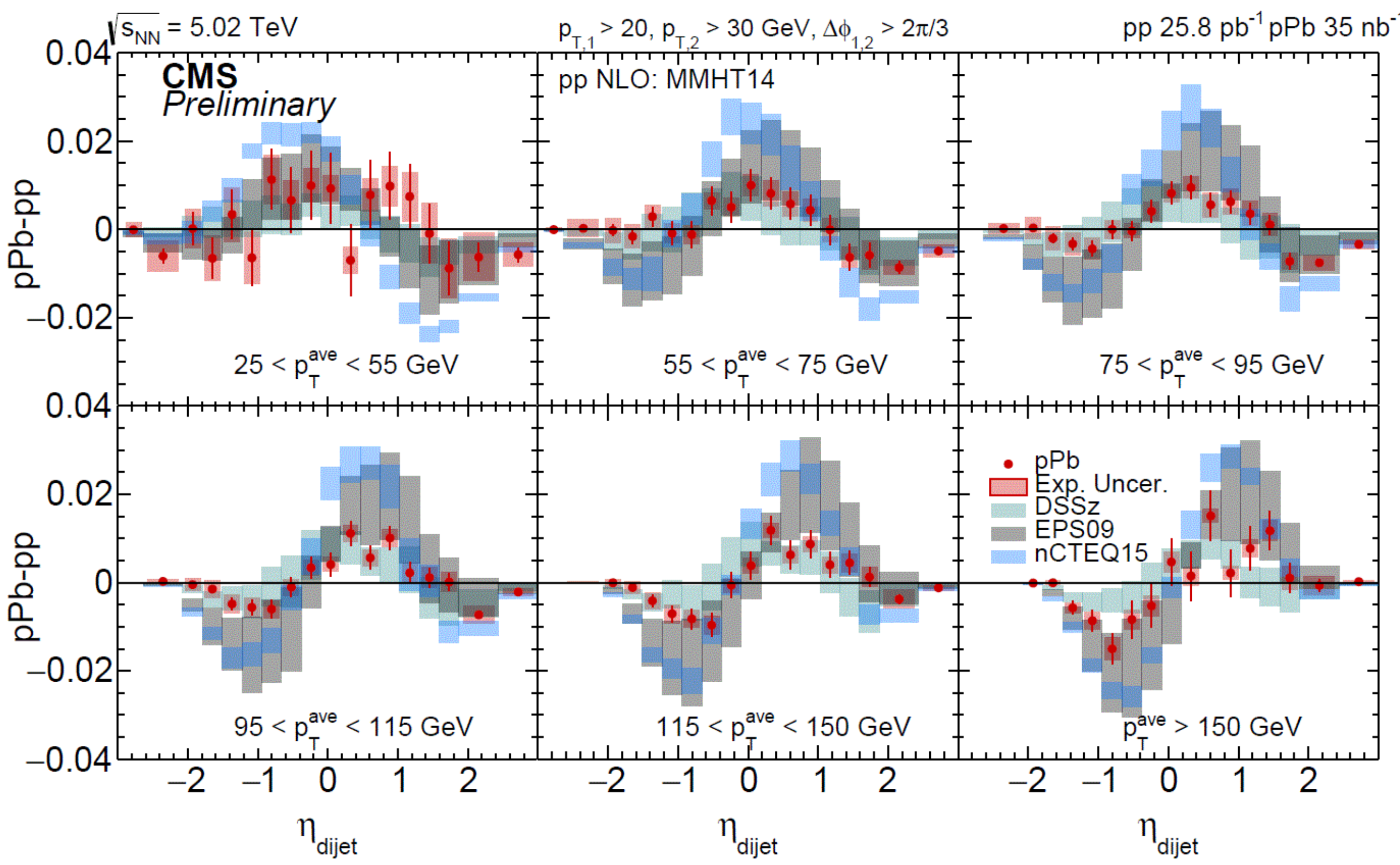
Comparison at mid-rapidity *CT*



Similar evolution of shape with p_T^{ave}

At mid-rapidity: Good agreement with EPS09 and discrepancy with DSSZ and nCTEQ

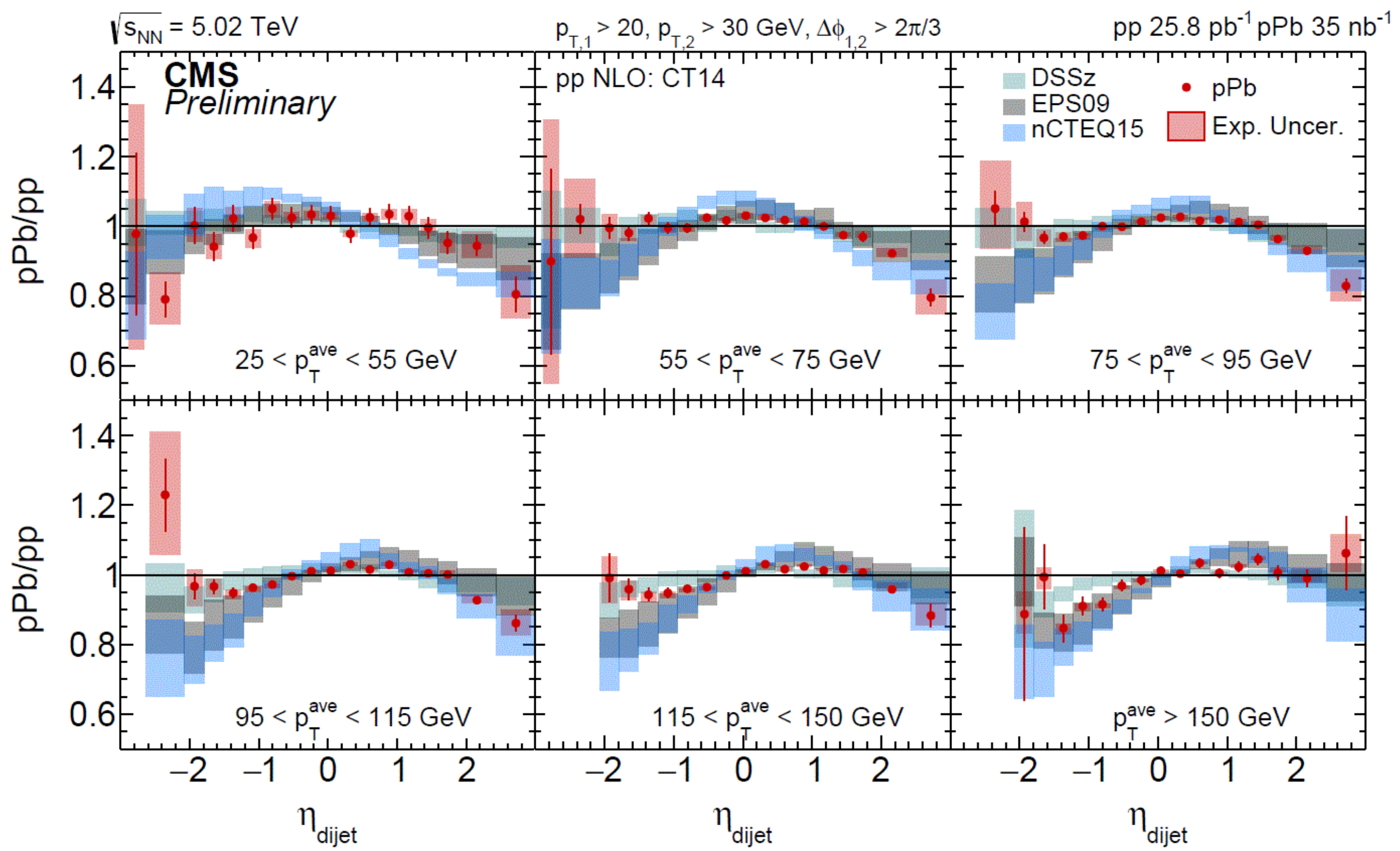
Comparison at mid-rapidity *MMHT*



Changing proton PDF still moves the results slightly

Effects in anti-shadowing and EMC regions are slightly more pronounced

Comparison for forward jets *CT*

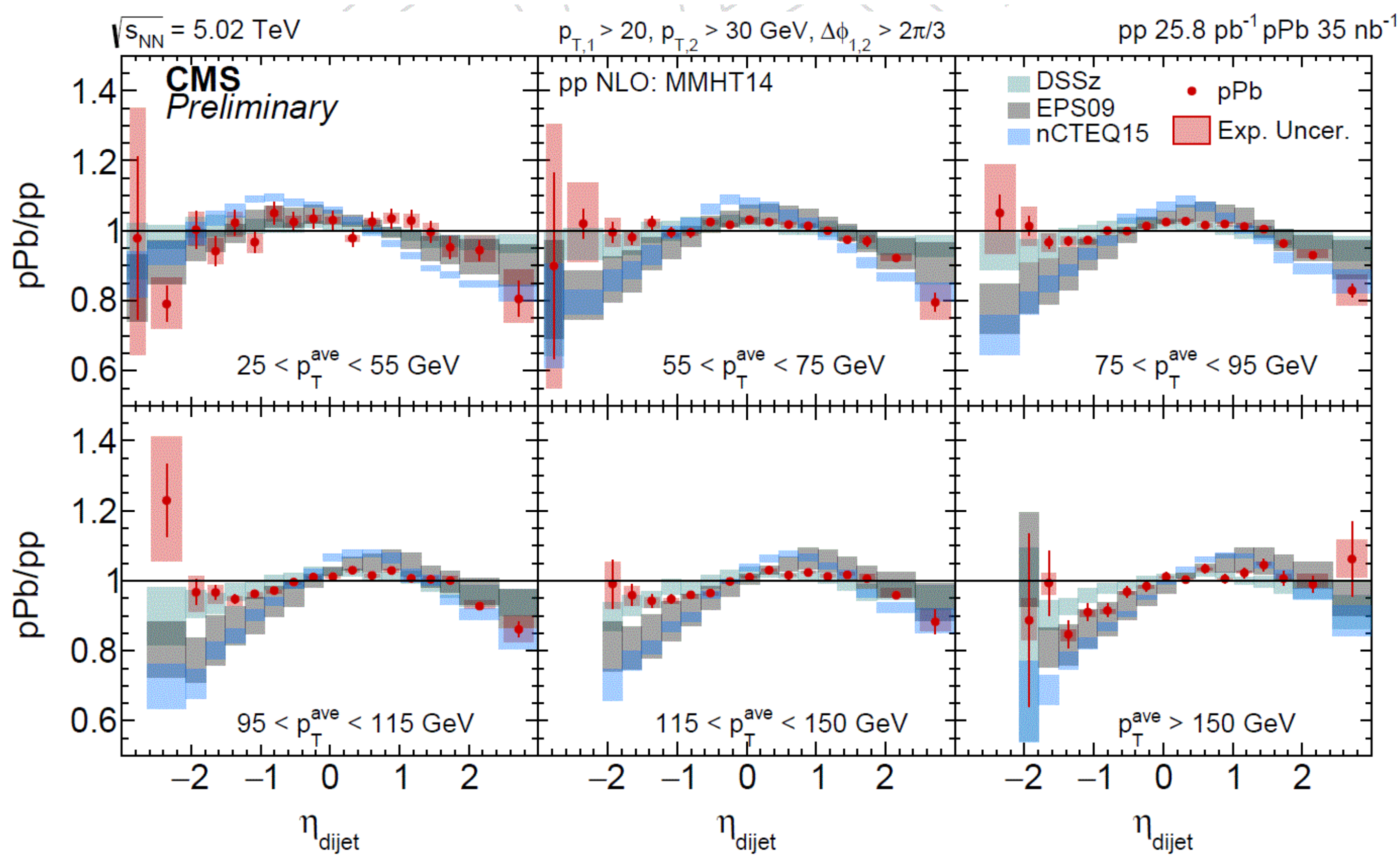


At low p_T and in the forward direction (EMC region) data starts to deviate from EPS09, agrees better with DSSZ

The systematic uncertainties and theoretical uncertainties are large in this region

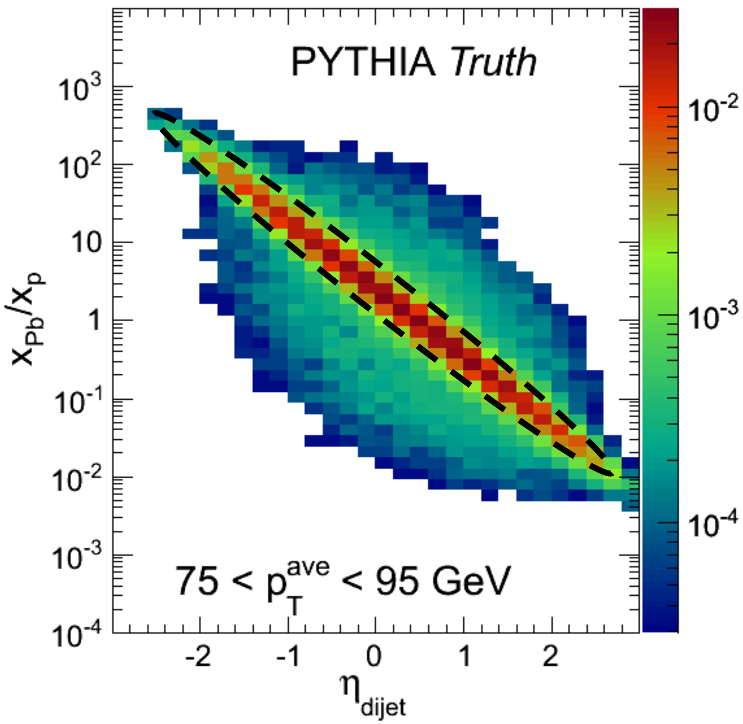
What does this say about the Q evolution?

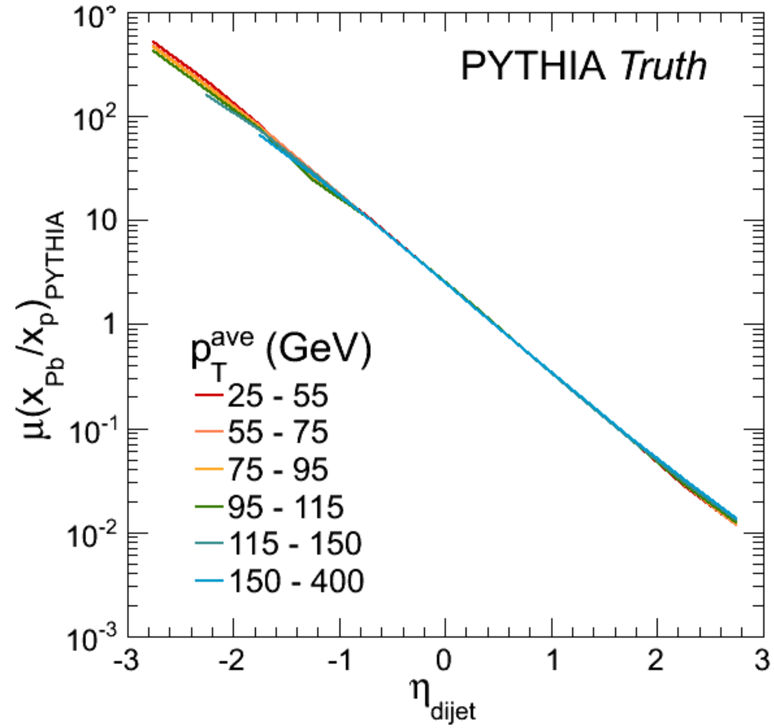
Comparison for forward jets *MMHT*



Similar conclusions discrepancy is slightly larger with MMHT14 instead of CT14 proton PDF

Q evolution of η_{dijet} - x map



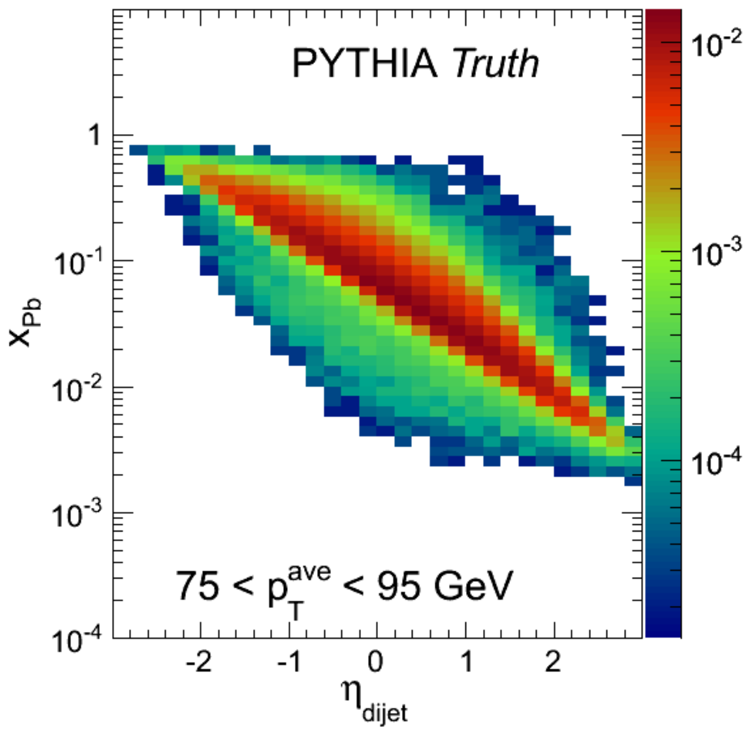


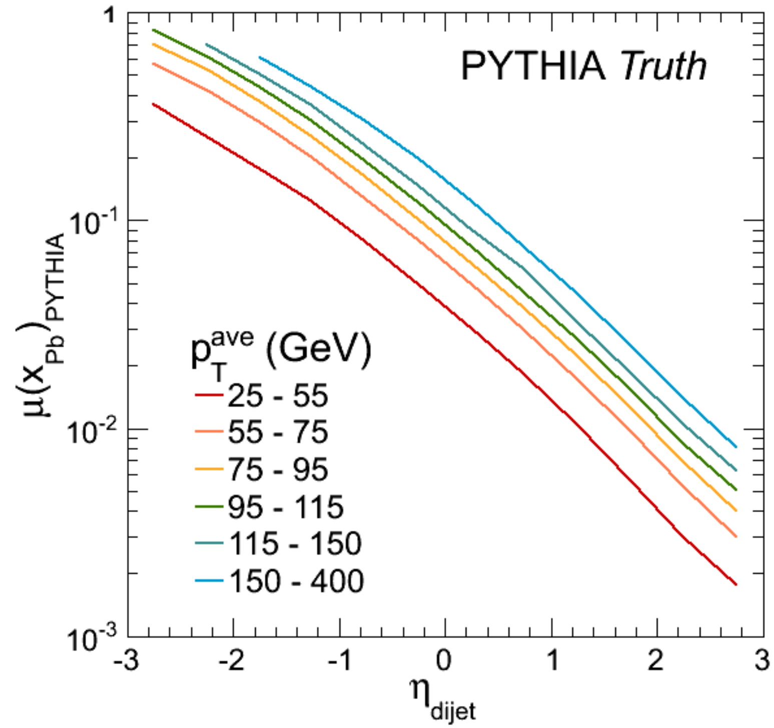
Very tight correlation between η_{dijet} and x_{Pb}/x_p.

All p_T^{ave} bins overlap with each other

Both x_{Pb} and x_p increase with Q, cancels in ratio

Q evolution of η_{dijet} - x map



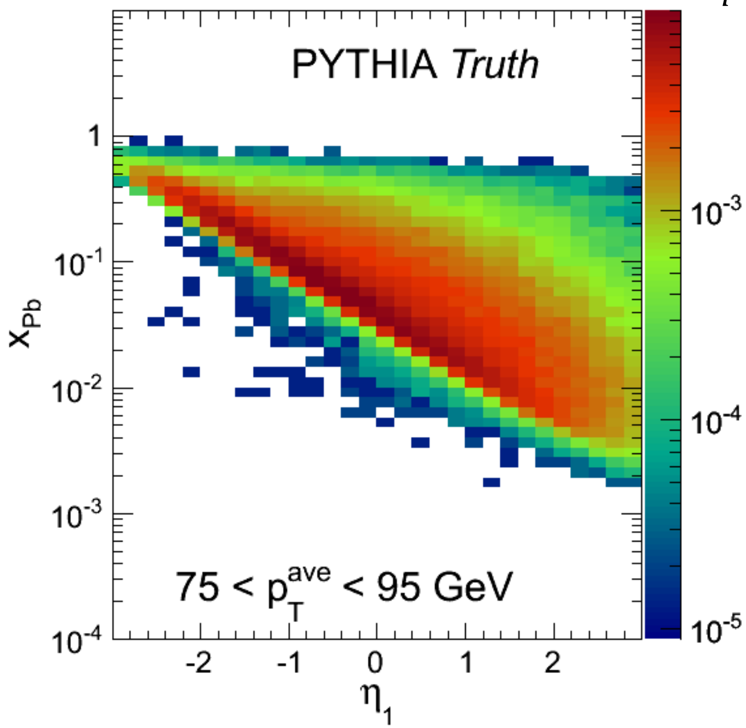


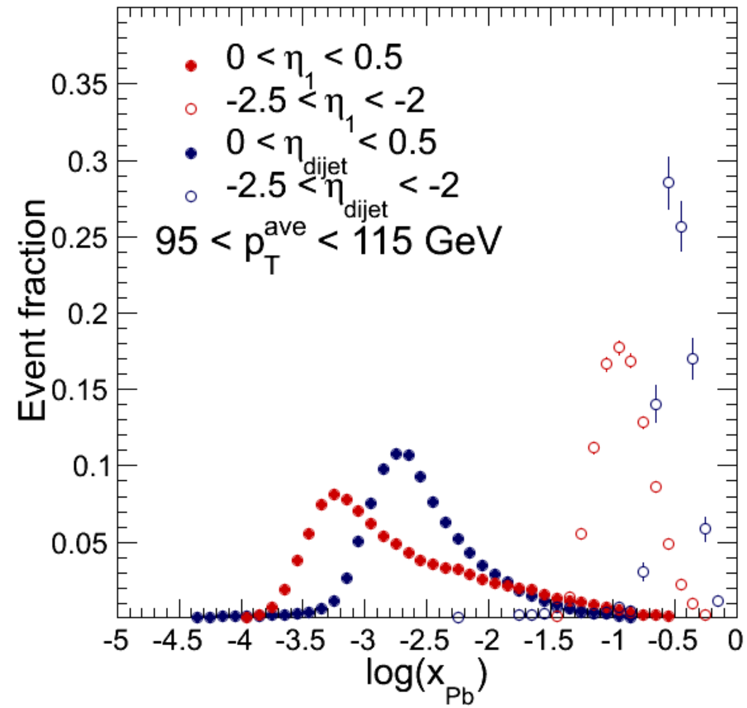
Correlation between η_{dijet} and x_{Pb} alone is smeared by x_p

Better way to get around smearing with x_p

Dijet or single jet?

Last time in this seminar we had a discussion of whether η_{dijet} becomes insensitive because of smearing by x_p





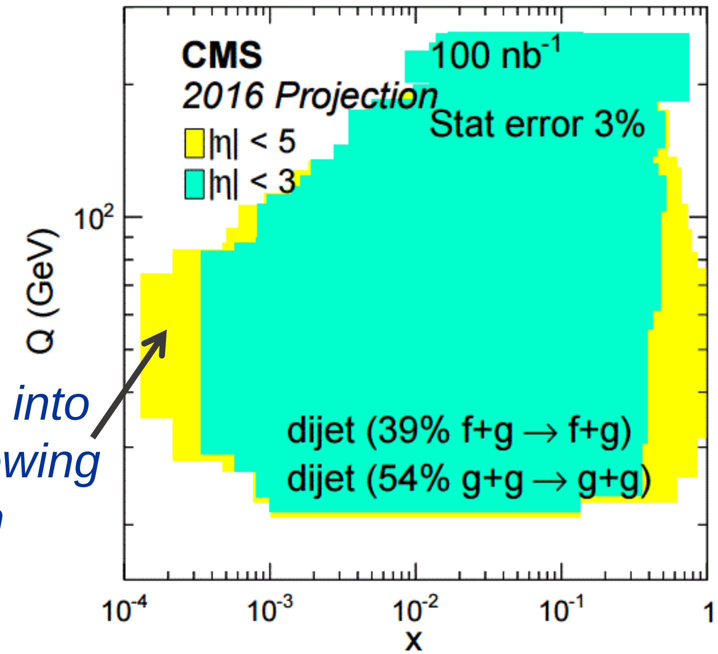
Leading jet could be a better way to reach high x_{Pb} values, but in a large phase space performs worse than dijet observables

Half of the information from hard scattering is lost

Do we have good enough experimental control at large η where leading jet becomes more favorable?

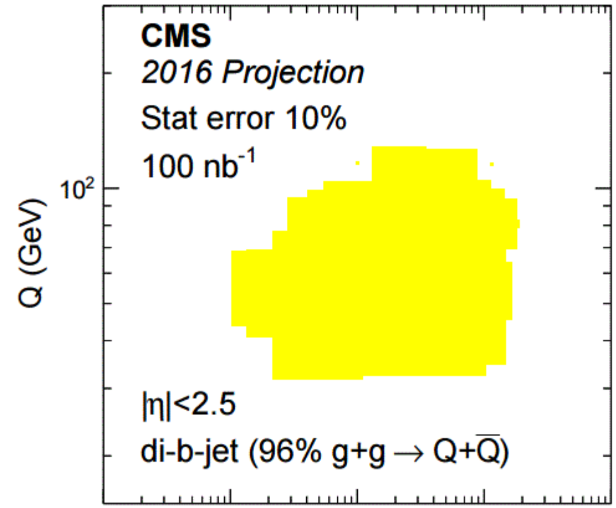
Coming 2016 pPb run *Dijets*

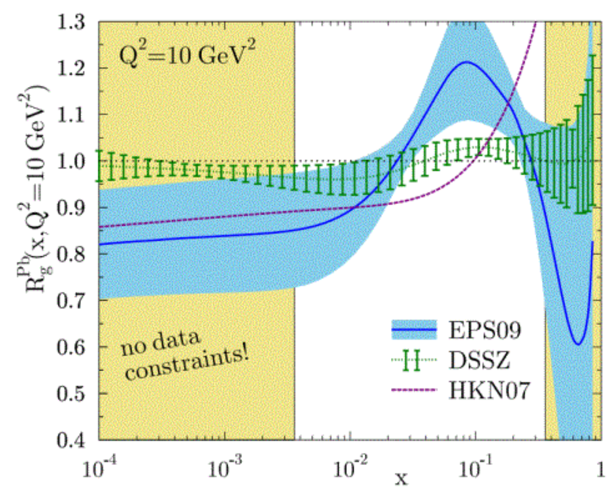
Larger statistics for dijets, but the real gain would be going into more forward regions



Going into shadowing region

Di-b-jet to probe gluon nPDF





Going from $|\eta| < 3$ to $|\eta| < 5$ is only possible by data-driven studies of jet calibration, which is based on balance of dijets in the forward region

..again not doable without large luminosity

Summary

Data from pp collisions and NLO calculations are not in good agreement

- *Comparison of pPb directly to pp is essential:* The disagreement in pp and NLO effects the comparison between pPb and NLO nPDF. Remaining small effects of proton PDF
- A better comparison can be done between pPb/pp and NLO calculations with corresponding ratio

With the inclusion of pp reference and p_T^{ave} dependence we hope that data will reduce the nPDF uncertainties

Back-up

Jet calibration

Dijet balance:

Barrel has reliable respones

Correct the η dependent response differences in data and MC

$$\mathcal{B} = \frac{p_T^{probe} - p_T^{barrel}}{p_T^{ave}}, \quad \text{where} \quad p_T^{ave} = \frac{p_T^{barrel} + p_T^{probe}}{2}.$$

$$\mathcal{R}_{\text{rel}}(\eta^{probe}, p_T^{ave}) = \frac{2 + \langle\mathcal{B}\rangle}{2 - \langle\mathcal{B}\rangle}.$$

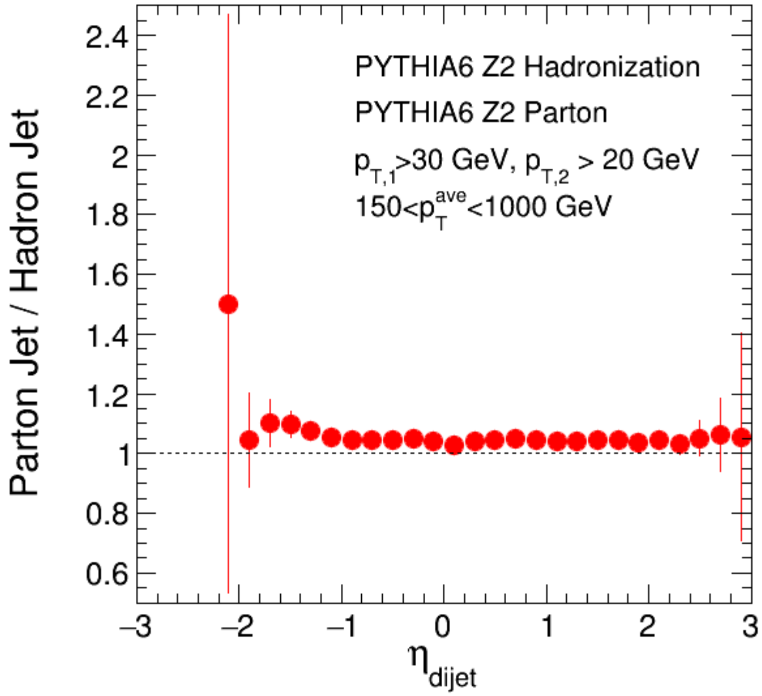
Correction on data: $(R_{rel})^{MC} / (R_{rel})^{data}$

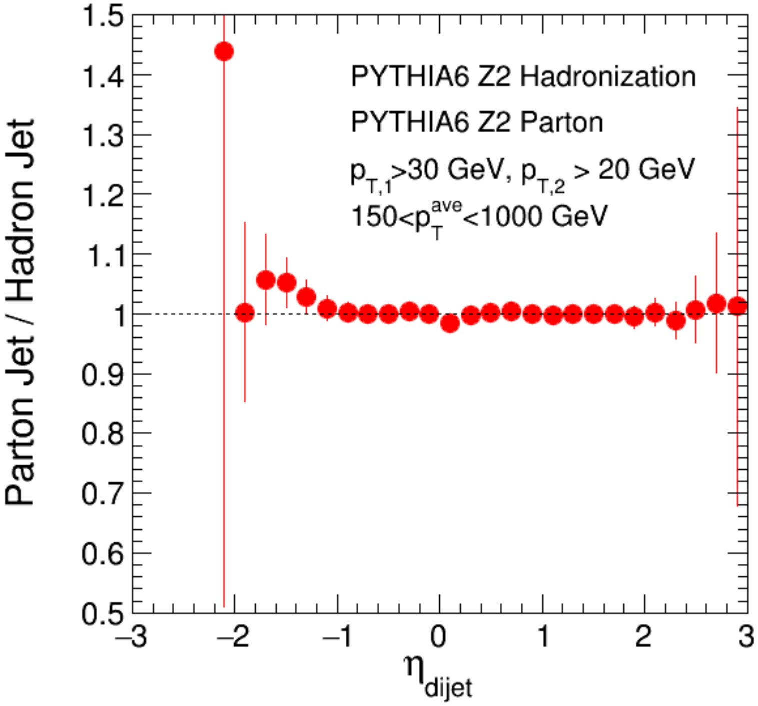
Done as a function of p_T, but usually with a constant fit

Width of B carry information about resolution

Gamma-jet balance: corrects the p_T dependence of absolute response differences between data and MC in barrel

Hadronization uncertainty





At high p_T effect of hadronization is also small for cross sections