Measurements of jet production properties and the strong coupling constant with the ATLAS detector

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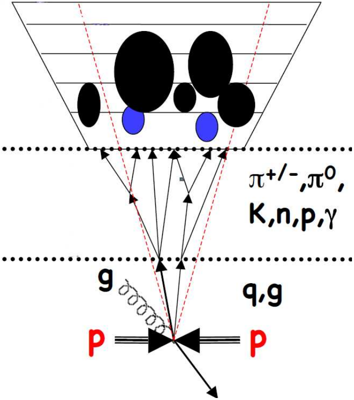
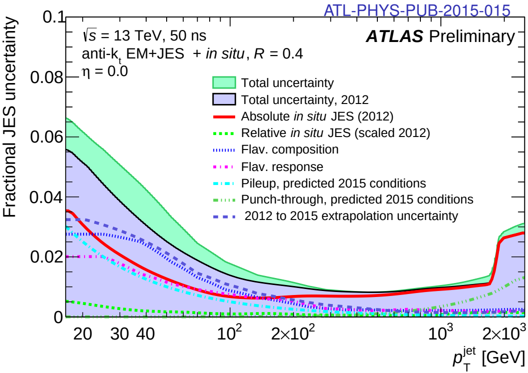
Introduction



- Jet energy scale is calibrated to about 1% (in the most precise region) in Run-1

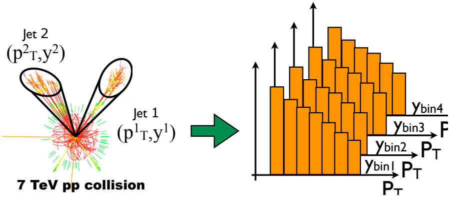
- Jet observables provide precision test of Standard Model at high scales

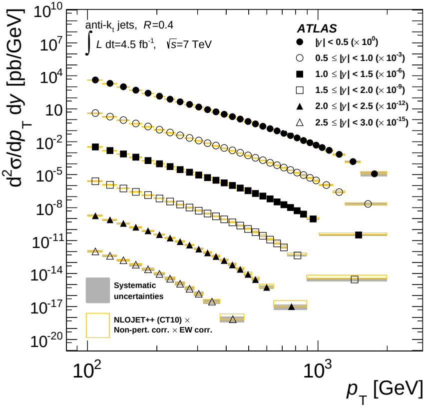


- Jet algorithm anti-k_t with two jet radii ($R = 0.4/0.6$) to get a handle on soft effect

Inclusive jet cross-section at 7 TeV

JHEP02(2015)153



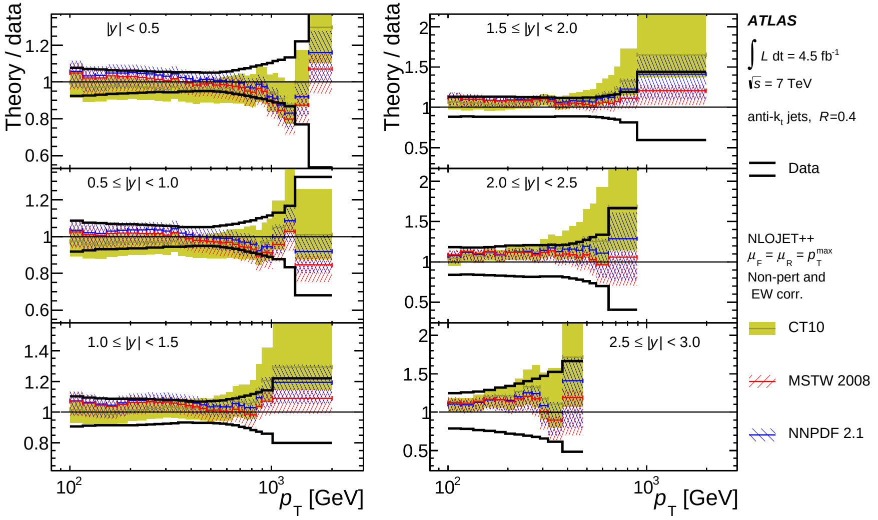


- $p_T > 100$ GeV, binned according to resolution
- $|y| < 3$, six rapidity bins, in steps of 0.5
- Theory: NLOJET++ × NPC × EW
- non-pert. correction : Pythia/Herwig with various tunes

- theory is corrected for EW effects

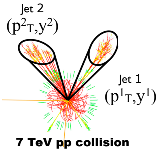
Good agreement between data and theory over 8 orders of magnitude

Inclusive jets at 7 TeV. Detailed comparison to theory



- 8–10% experimental precision allows for PDF/strong coupling determination at very high scales

Dijet mass spectra at 7 TeV



$$m_{12} = \sqrt{(p_1 + p_2)^2}$$
$$y^* = |y_1 - y_2|/2$$

- $p_T^1 > 100$ GeV, $p_T^2 > 50$ GeV, $|y^{jet}| < 3$
- $|y^*| < 3$, six rapidity separation bins, in steps of 0.5
- Theory: NLOJET++ × NPC × EW
- non-pert. correction : Pythia/Herwig with various tunes

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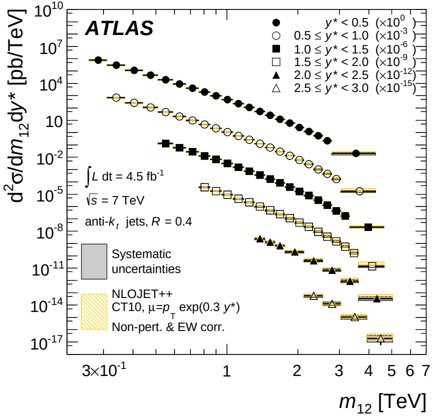
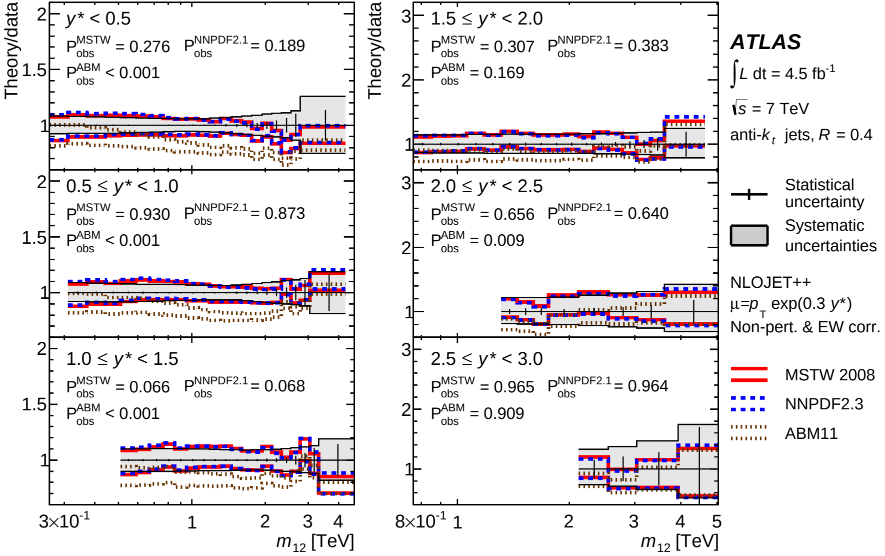


- theory is corrected for EW effects

Good agreement between data and theory over 8 orders of magnitude

Dijets. Detailed comparison to theory



- Quantitative comparison of theory/data agreement

Three-jet mass distributions at 7 TeV

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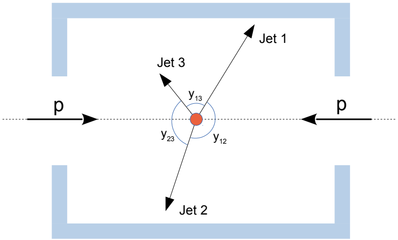
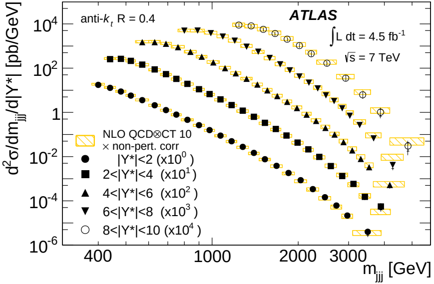


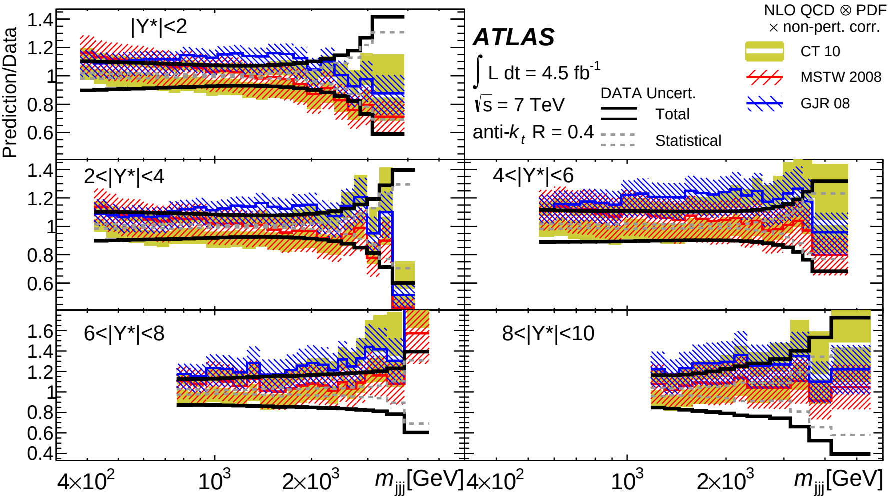


- $p_T^1 > 150$ GeV, $p_T^2 > 100$ GeV, $p_T^3 > 50$ GeV, $|y^{jet}| < 3$
- $Y^* = |y_1 - y_2| + |y_1 - y_3| + |y_2 - y_3|$
- $|Y^*| < 10$, five rapidity separation bins, in steps of 2

- Theory: NLOJET++ $\times$ NPC
- non-pert. correction : Pythia/Herwig with various tunes
- no EW correction is available

Good agreement between data and theory over 7 orders of magnitude

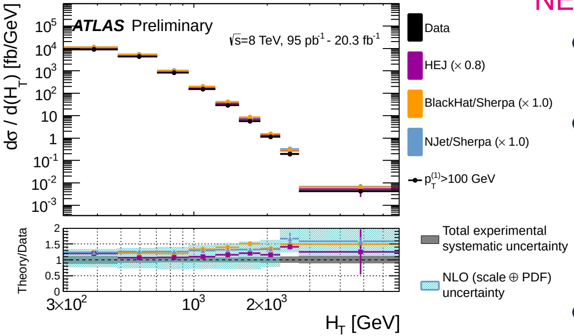
Three-jets at 7 TeV. Detailed comparison to theory

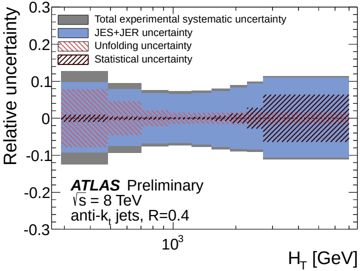


- Tests jet calculations at higher multiplicities. Provides complementary to inclusive-jet/dijet information on the PDF/α_s determination.

Four-jet cross-sections at 8 TeV

CERN-PH-EP-2015-181



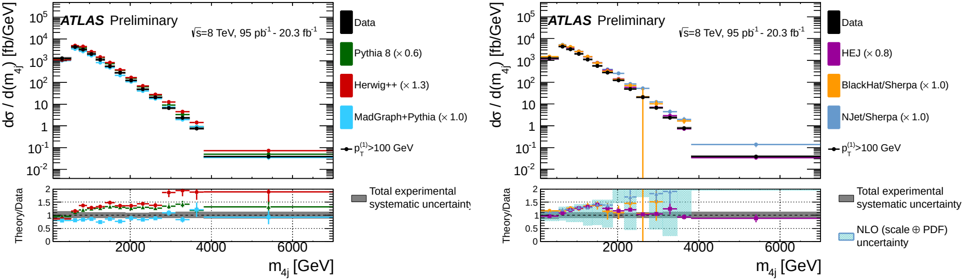


NEW for EPS

- Detailed study of four-jet topologies
- Unfolded measurements are compared to various MC generators and fixed order predictions
- These measurements test QCD predictions up to scale $H_T \sim 7$ TeV with p_T^1 reaching 3 TeV, $p_T^2 - 2.5$ TeV, $p_T^3 - 2$ TeV, $p_T^4 - 1.5$ TeV
- The total experimental uncertainty is about $8 - 12\%$

Four-jet cross-sections at 8 TeV

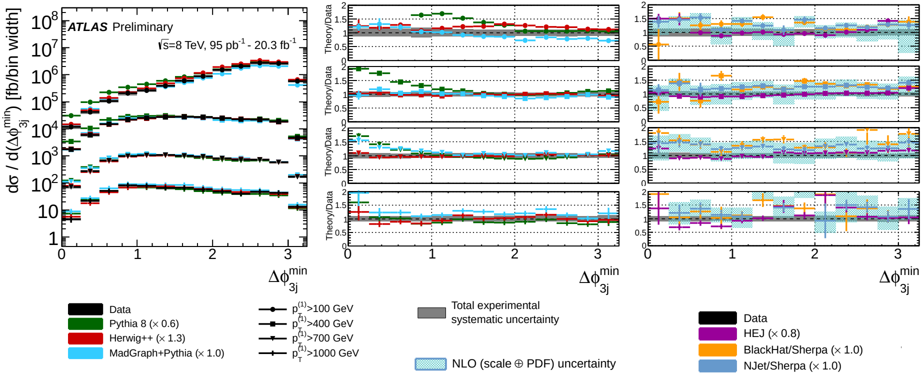
Four-jet mass spectrum probes calculations over six orders of magnitude in the cross-section in the 1–7 TeV range



- Leading order predictions : Madgraph+Pythia and Pythia 8 provide best description of data
- Fixed order calculations : agree with data up to 3 TeV and deviates at higher masses. The scale uncertainty is very large, $\sim 30\%$
- HEJ: very good agreement with data in the high mass range ($m_{4j} > 2$ TeV)

Four-jet cross-sections at 8 TeV: angular distributions

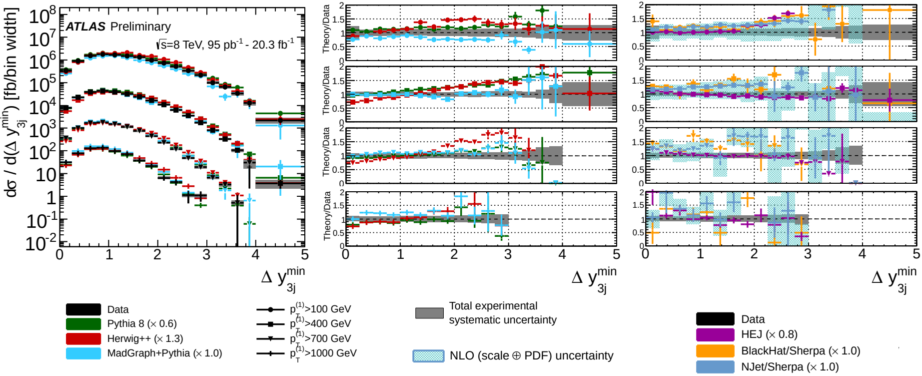
Minimal azimuthal separation between any three jets in event



- LO predictions : Herwig++ provides best description
- Fixed order: very large scale uncertainty
- HEJ : on top of data

Four-jet cross-sections at 8 TeV: angular distributions

Minimal rapidity separation between any three jets in event

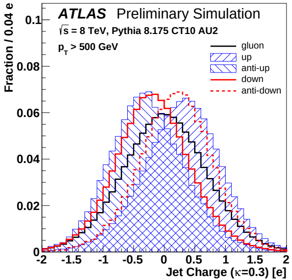


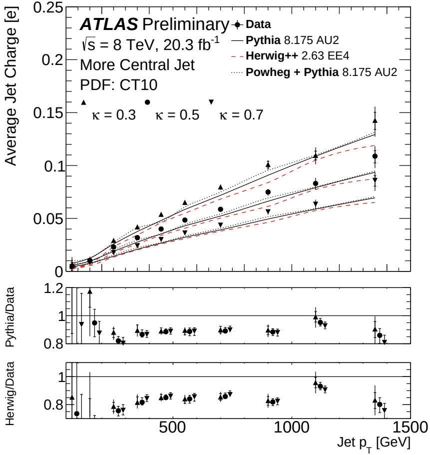
- LO predictions : Madgraph+Pythia 8 provides best description
- Fixed order: very large scale uncertainty
- HEJ : on top of data in the $p_T^{\mathrm{jet}} > 400\mathrm{GeV}$ range

Average jet charge at 8 TeV

$$Q_J = \frac{1}{\left(p_{\mathrm{T}}^{\mathrm{jet}}\right)^{\kappa}} \sum_{i \in Tracks} q_i \left(p_{\mathrm{T}}^{i}\right)^{\kappa}, \quad \kappa = 0.3; 0.5; 0.7$$

anti-k_t R=0.4 jets



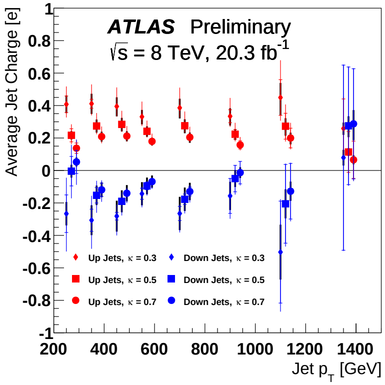


NEW for EPS

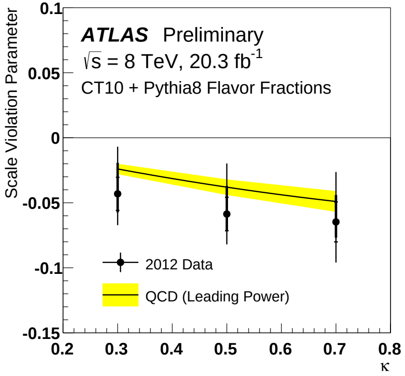
- $p_{\mathrm{T}}^{\mathrm{jet}} > 50\mathrm{GeV}; |\eta^{\mathrm{jet}}| < 2.1; p_{\mathrm{T}}^{1}/p_{\mathrm{T}}^{2} < 1.5$
- tracks for reco-jets + charged particles for particle-jets
- average jet charge increases with $p_{\mathrm{T}}^{\mathrm{jet}}$
- average jet charge in data is larger by about 10% in data than predicted by MCs
- only part of this difference can be explained by PDFs and mostly due to poor modelling of the fragmentation

ATLAS-CONF-2015-025

Average jet charge measurements at 8 TeV



← Using fractions of up/down quarks information computed in the MC, the charge of up/down quark initiated jets is extracted from data



$$\langle Q_i \rangle \approx \sum_f \alpha_{f,i} \bar{Q}_f \left(1 + c_\kappa \log p_T^i / \bar{p}_T\right)$$

$\alpha_{f,i}$ flavour fraction in the i-th p_T bin; $\bar{Q}_f$ mean charge at fixed $\bar{p}_T = 700\text{GeV}$ $\longrightarrow$

data supports prediction that $c_\kappa < 0$ and $\partial c_k / \partial \kappa < 0$

Transverse energy-energy correlation at 7 TeV

Measurements of new event shape taken from the e^+e^- annihilation and extended to hadron-hadron colliders $\frac{1}{\sigma}\frac{d\Sigma}{d\cos\phi} = \frac{1}{N\Delta\cos\phi}\sum_{1}^{N}\sum_{ij}\frac{E^A_{T_i}E^A_{T_j}}{\left(\sum_k E^A_{T_k}\right)^2}\delta\left(\cos\phi - \cos\phi_{ij}\right)$

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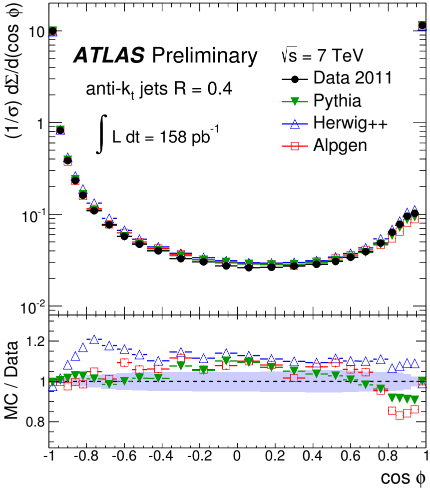
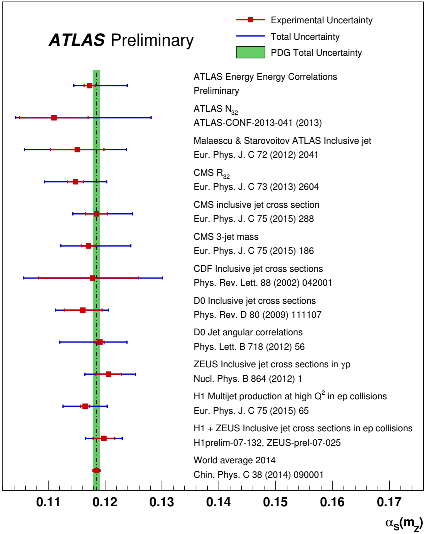


- ϕ_{ij} azimuthal angle between jets
- $p_T^1 + p_T^2 > 500$ GeV; $p_T^{all} > 50$ GeV; $|y^{jet}| < 2.5$
- total uncertainty is about 5%, dominated by the jet energy scale and pileup
- Pythia/Alpgen predictions agree reasonably well with data, Herwig++ deviates from data by up to 20%
- NLO theory agrees within scale+PDF uncertainties

Transverse energy-energy correlation: α_s

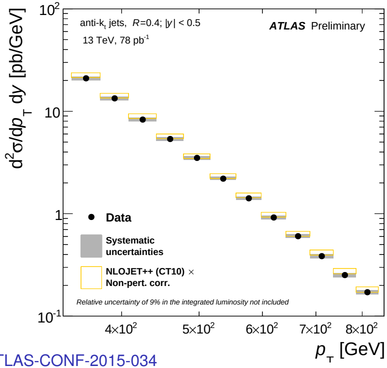


NEW for EPS

- Very good experimental precision
- Compatible with the world average
- Small sensitivity to non-perturbative effects
- Scale uncertainty in the fixed order calculations is the limiting factor for the α_s extraction

$$\alpha_s = 0.1173 \pm 0.0010(\mathrm{exp})^{+0.0063}_{-0.0020}(\mathrm{scale}) \pm 0.0017(\mathrm{PDF}) \pm 0.0002(\mathrm{NPC})$$

Inclusive jets cross-section measurement at 13 TeV



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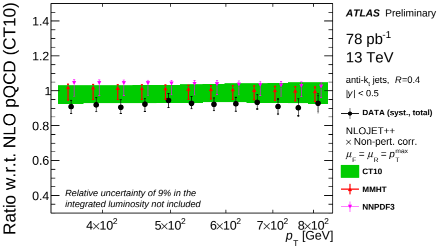


NEW energy regime

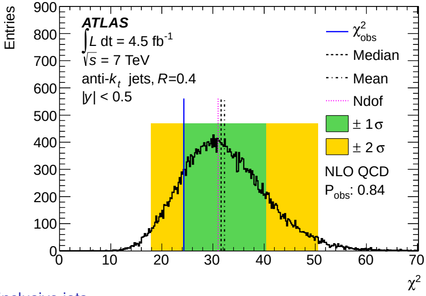
- First 78 pb^{-1} of 13 TeV data
- $346 < p_T^{jet} < 838$ GeV; $|y^{jet}| < 0.5$
- JES is based on the in situ calibration in Run-1
- Total systematic experimental uncertainty is about 5%
- Statistical uncertainty will descrease with new data
- NLO QCD is corrected for non-perturbative effects
- Very good agreement between measurements and the NLO QCD predictions

Summary

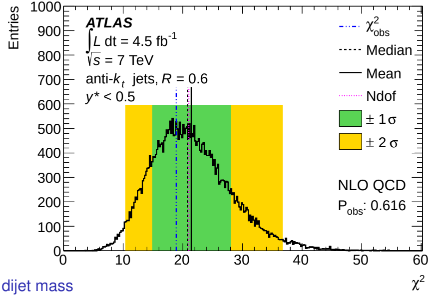
- ATLAS has performed measurements of inclusive, dijet, three-jet and four-jet cross-sections in proton-proton collisions at 7 and 8 TeV
- Average jet charge has been measured in dijet event in pp-collisions at 8 TeV
- Energy-energy correlation in pp-collisions has been measured at 7 TeV
- The strong coupling is extracted from the TEEC measurements with 0.85% experimental and $^{+5}_{-2}$% theoretical precision
- QCD calculations provide good description of the collision data, but wee do need NNLO calculations for the jet data interpretation
- !!! The measurement of the inclusive cross-sections in proton-proton collisions at 13 TeV is presented

Back-up

Quantitative comparison to theory



inclusive jets

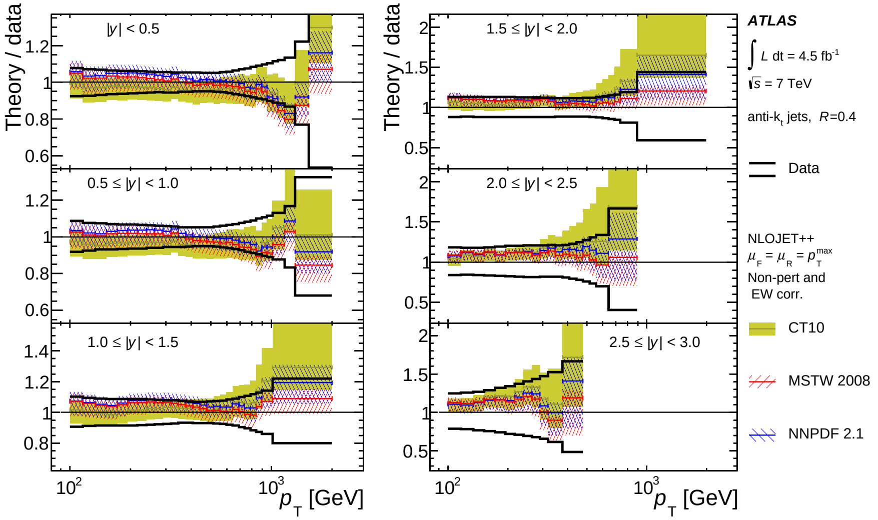


dijet mass

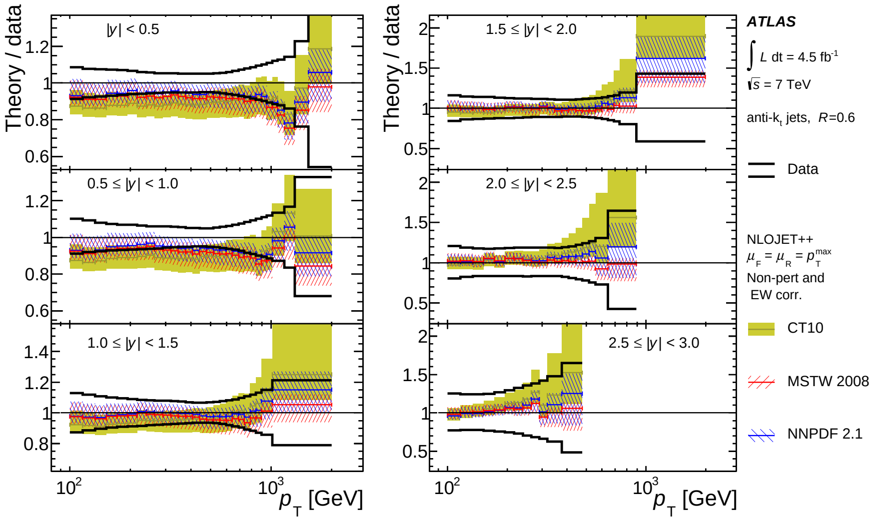
- Pseudo-experiments are generated taken into account full correlation information
- χ^2 is calculated for CT10 PDF
- Theory perfectly well describes the measurements

- Unfolded cross-sections are used for χ^2-calculations

Inclusive jets. Detailed comparison to theory (I)

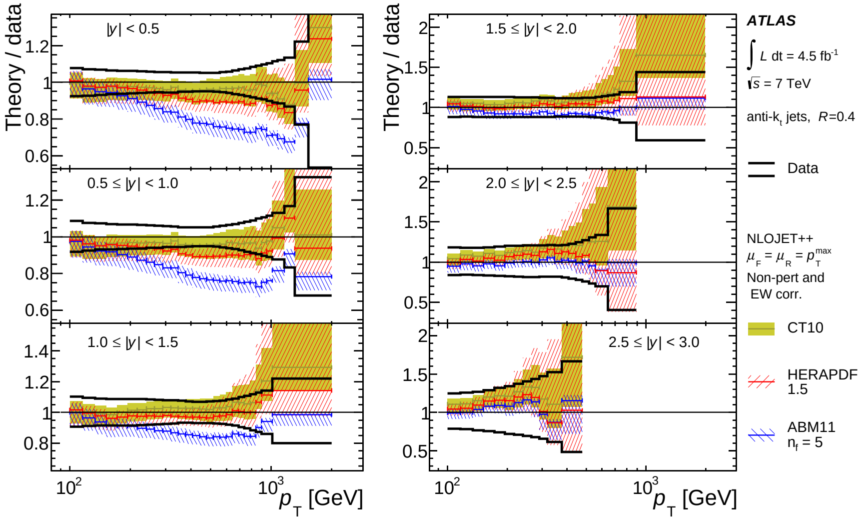


Inclusive jets. Detailed comparison to theory (II)

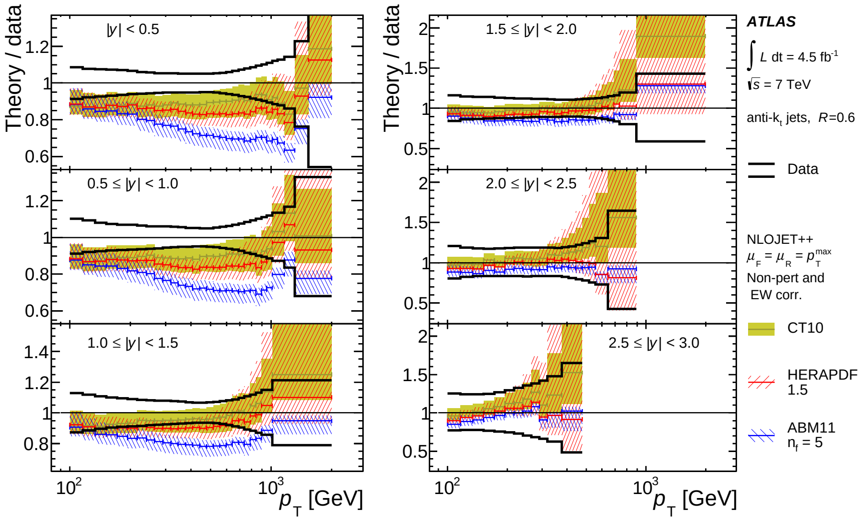


different set of PDFs

Inclusive jets. Detailed comparison to theory (III)



Inclusive jets. Detailed comparison to theory (IV)



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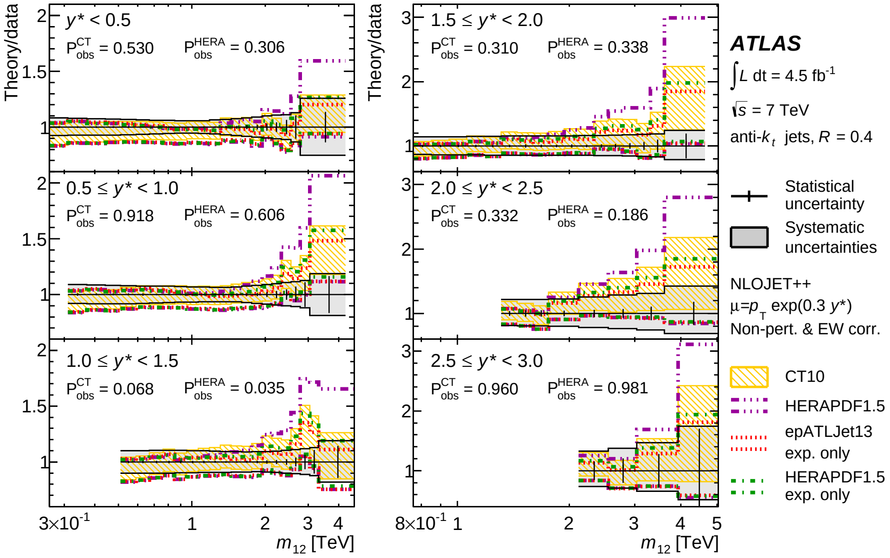
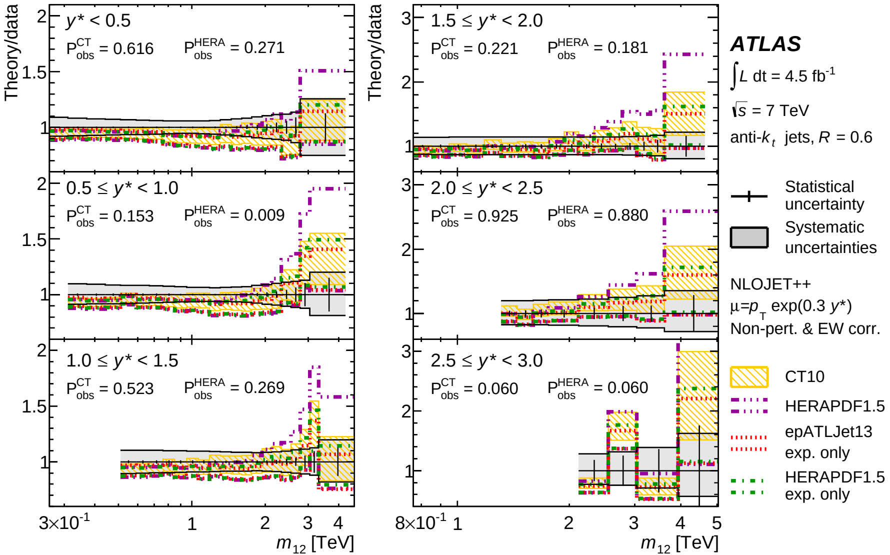
Dijets. Detailed comparison to theory (I)



Dijets. Detailed comparison to theory (II)



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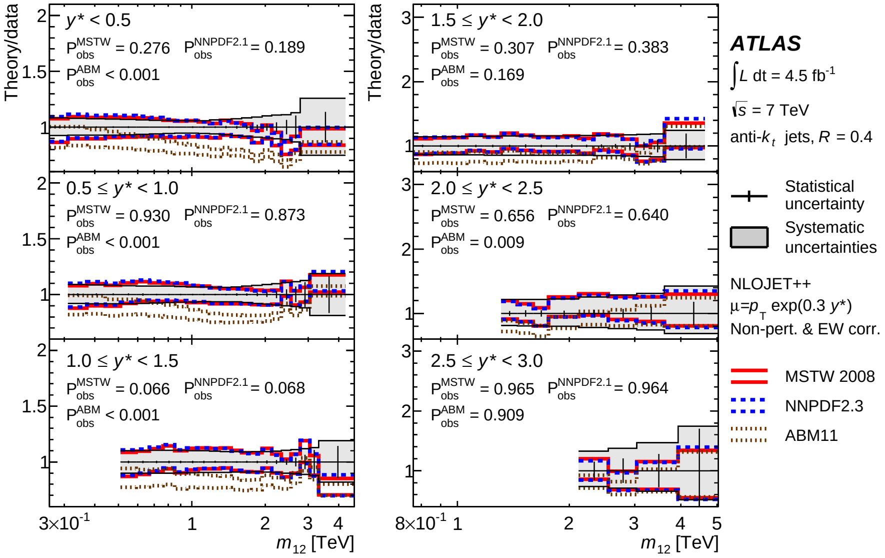
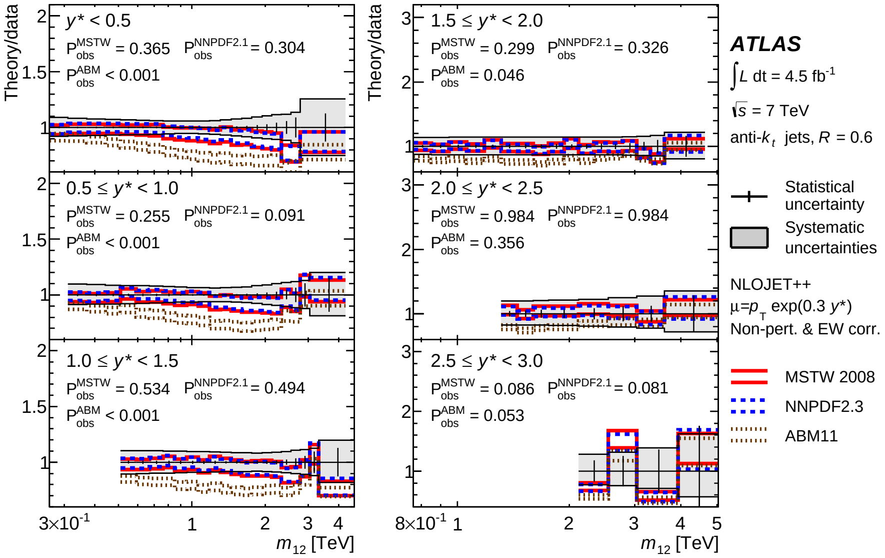


Dijets. Detailed comparison to theory (IV)



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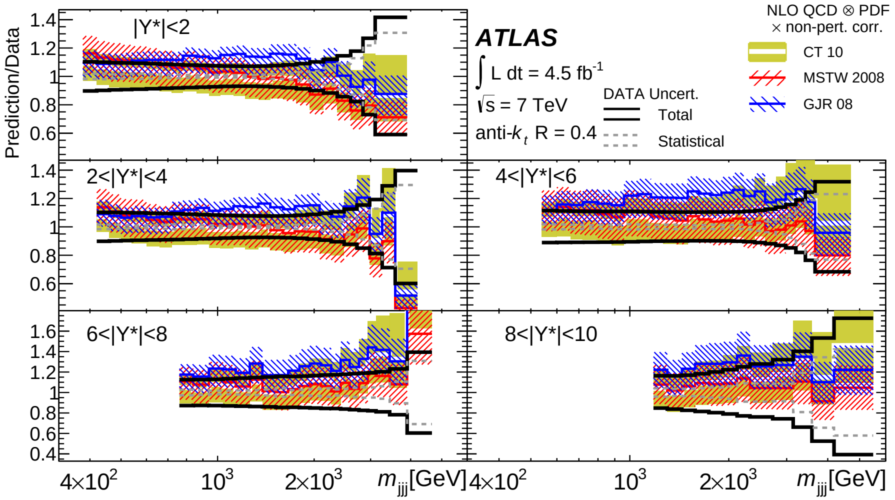
Three-jets. Detailed comparison to theory (I)



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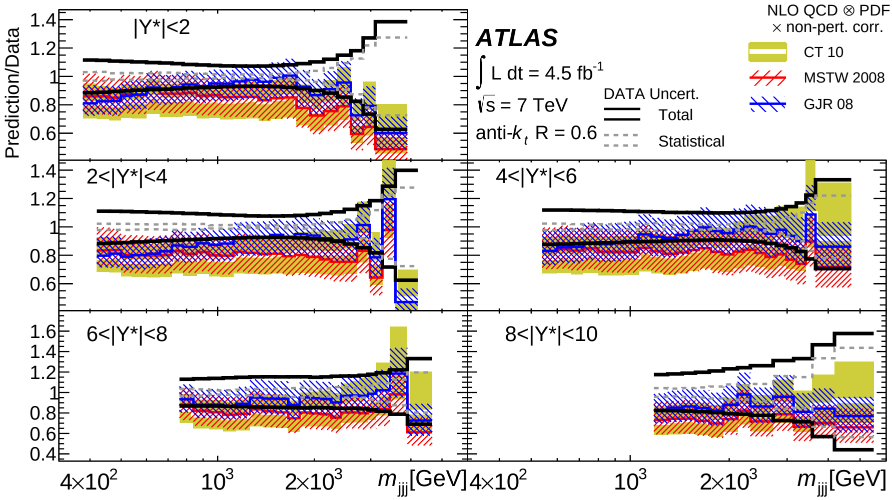
Three-jets. Detailed comparison to theory (II)



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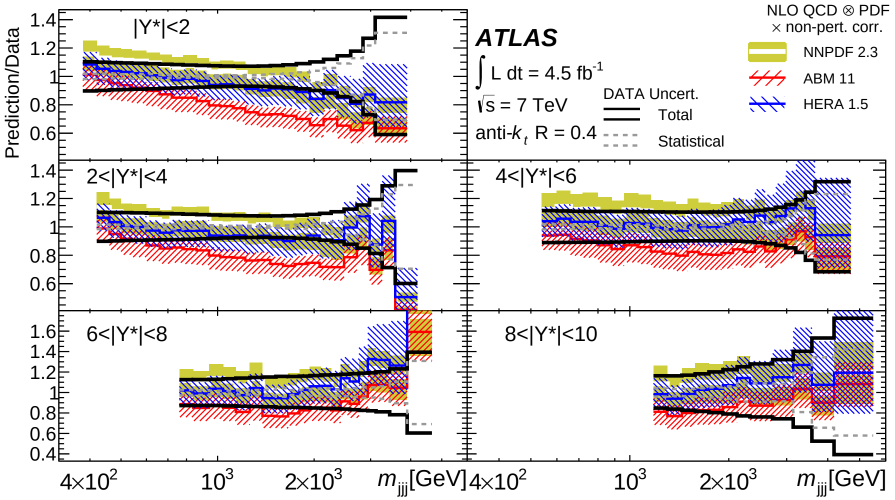
Three-jets. Detailed comparison to theory (III)



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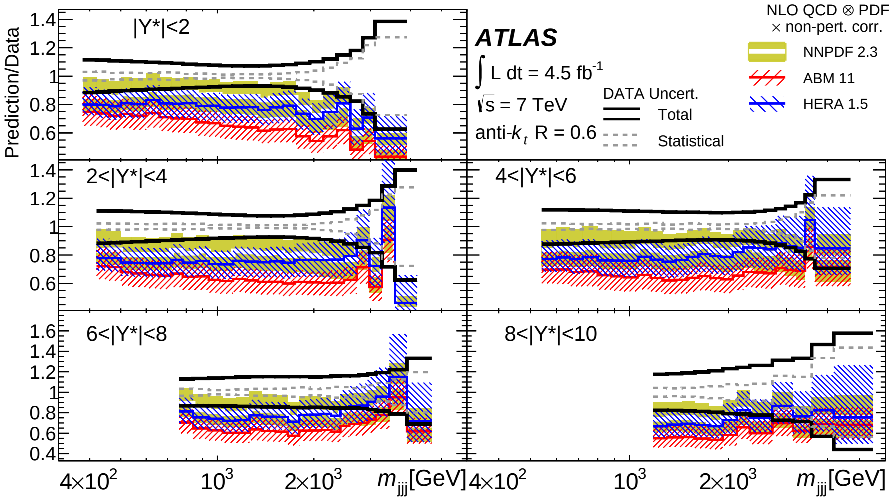
Three-jets. Detailed comparison to theory (IV)



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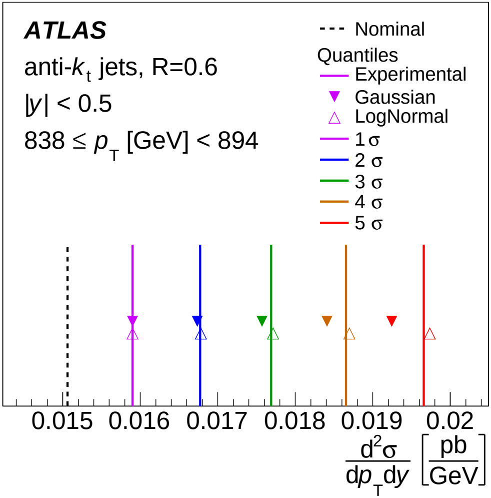
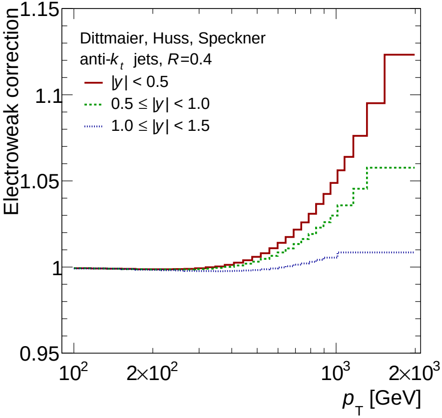
Inclusive jets. Test of gaussianity of uncertainies

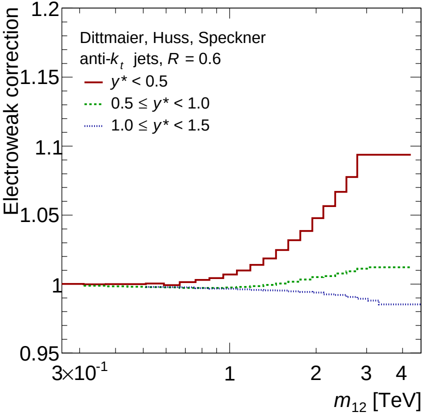


Uncertainty in the energy deposited in the EM calorimeter

Electroweak corrections



inclusive jets



dijets

- Very small impact for p_T(mass) below 600(1000) GeV
- Up to 10% effect in the high-p_T(mass) range