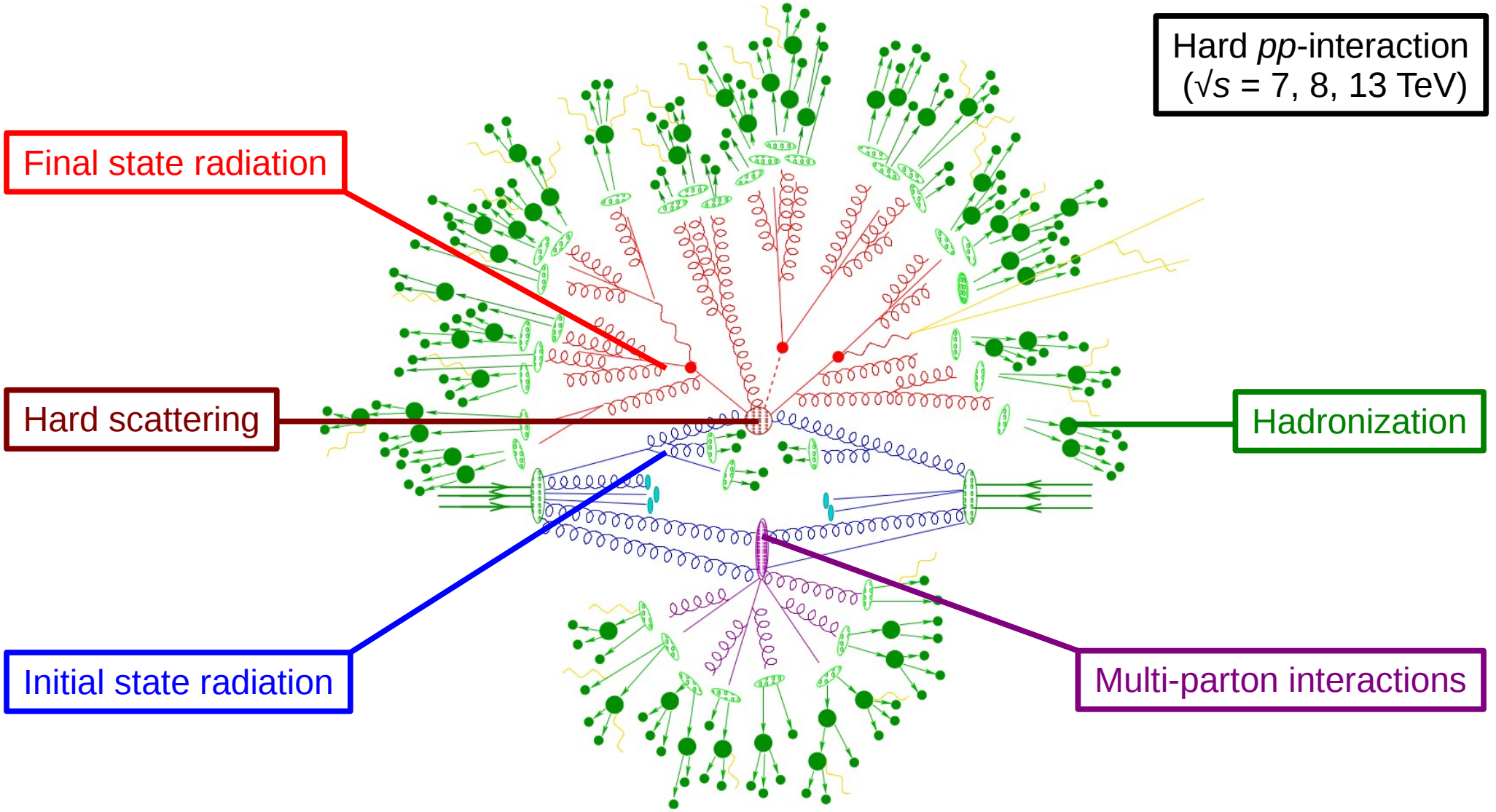
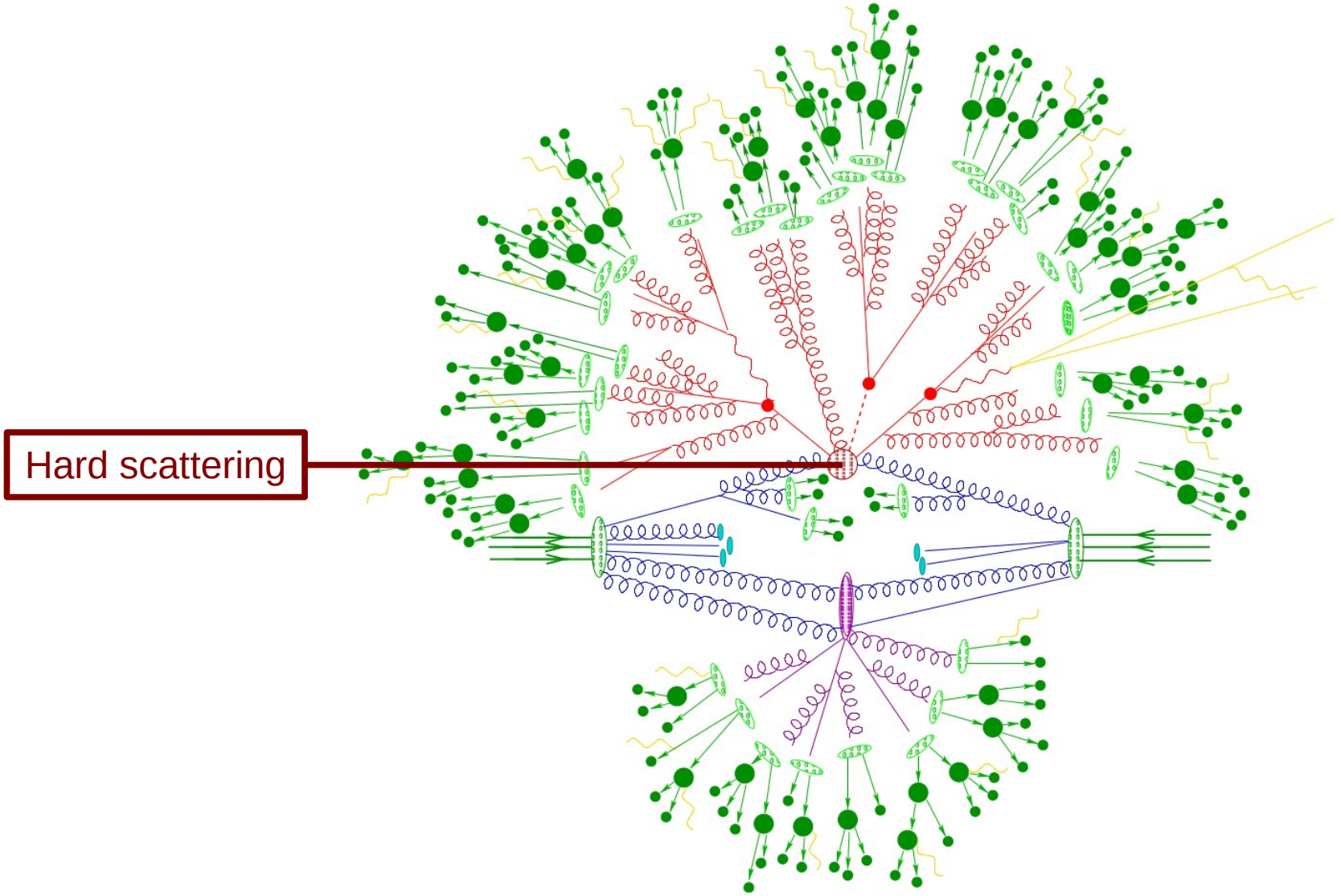
Recent QCD results from ATLAS

Vojtěch Pleskot, Institut für Physik, JGU Mainz
On behalf of the ATLAS collaboration
Lake Louise Winter Institute 2016

Introduction

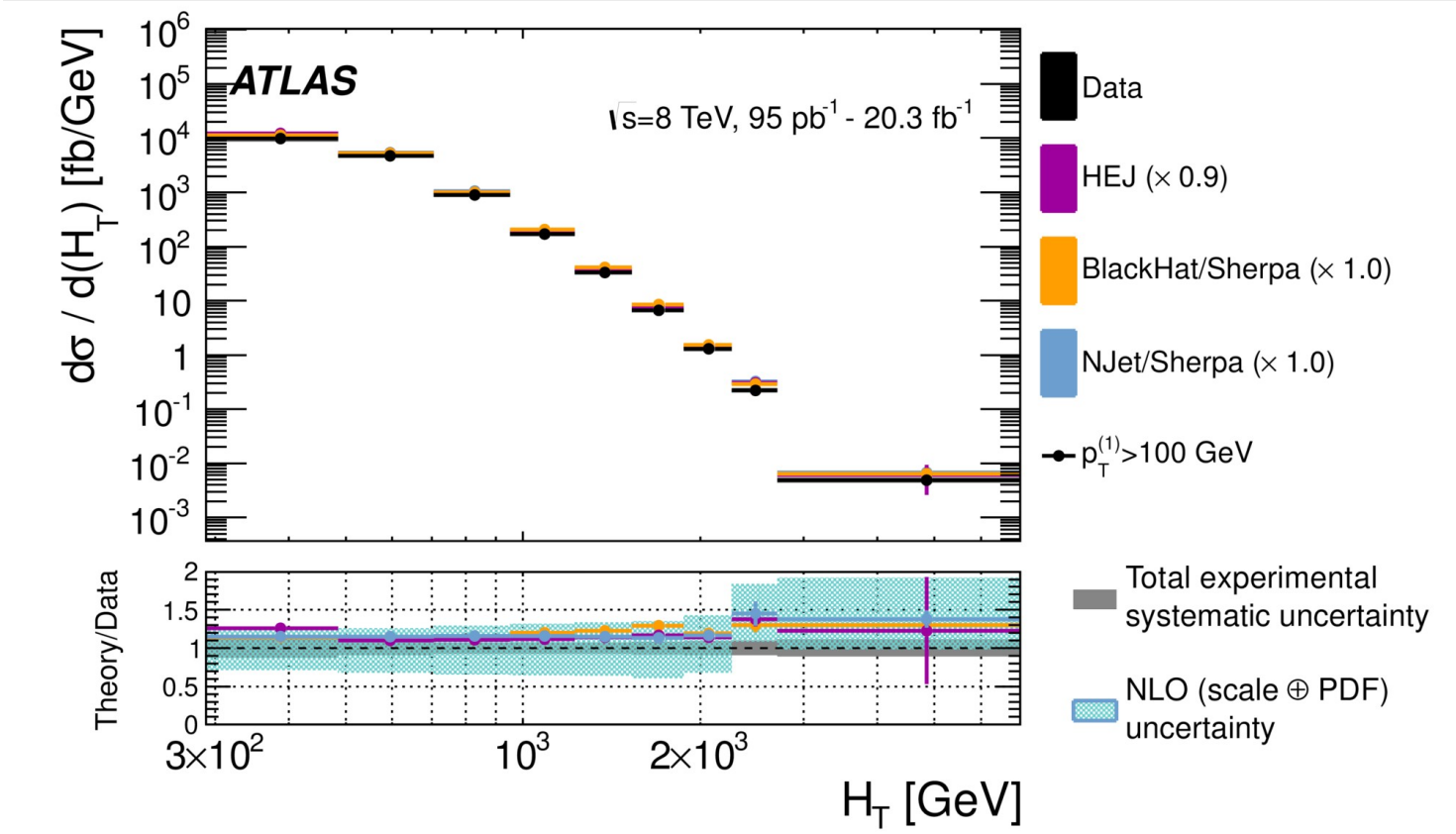


High-p_T jets



Four-jet cross-section @ 8 TeV

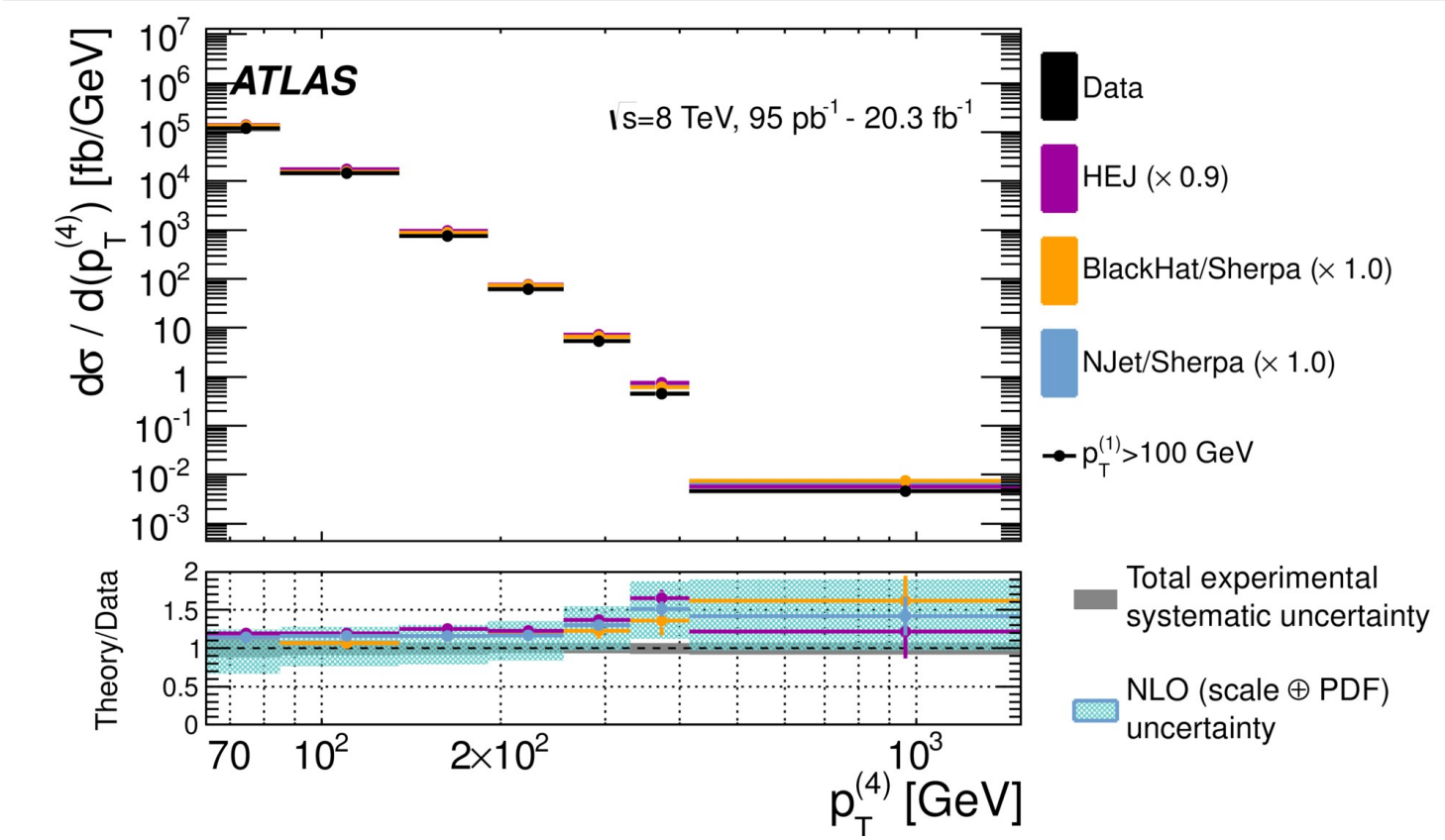
JHEP12 (2015) 105



- Sherpa and HEJ in agreement with data

Four-jet cross-section @ 8 TeV

JHEP12 (2015) 105



- Some deviation of theory?
  - Mostly covered by uncertainties

Transverse energy-energy correlations

Phys. Lett. B 750 (2015) 427-447

- Energy-weighted angular distribution of jets

$$\alpha_s(m_Z) = 0.1173$$

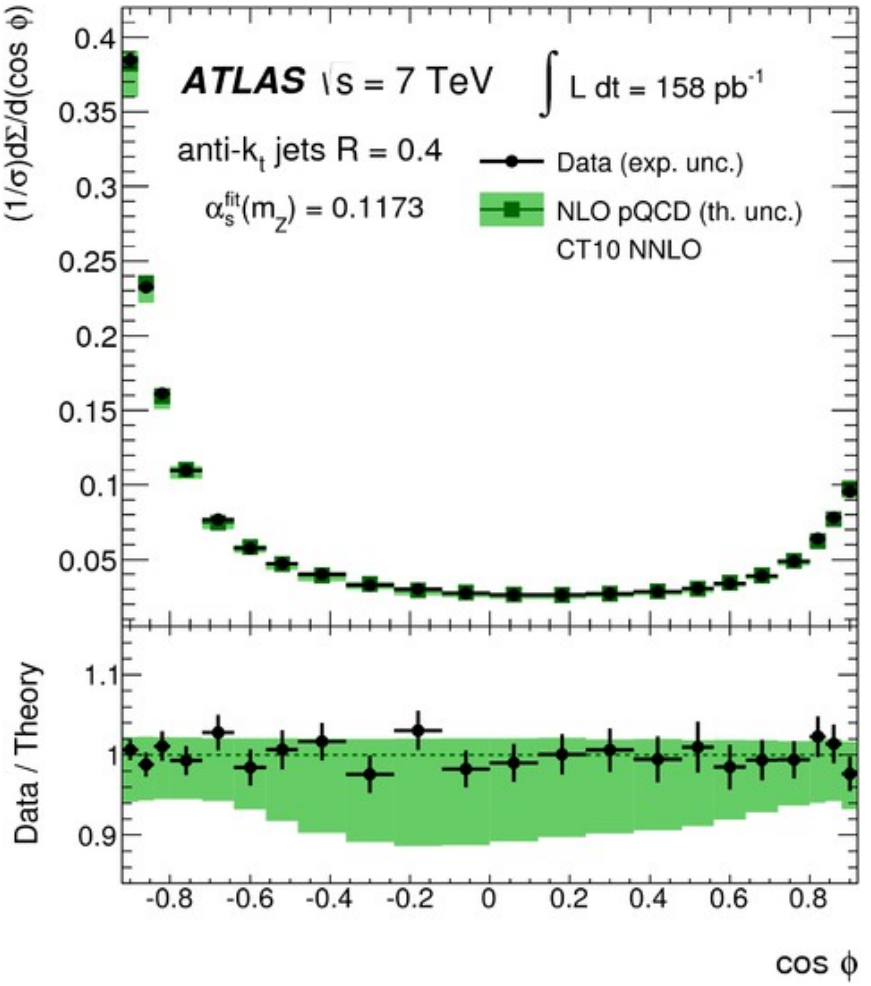
$$\pm\ 0.0010\ (\text{exp.})$$

$$^{+0.0063}_{-0.0020}\ (\text{scale})$$

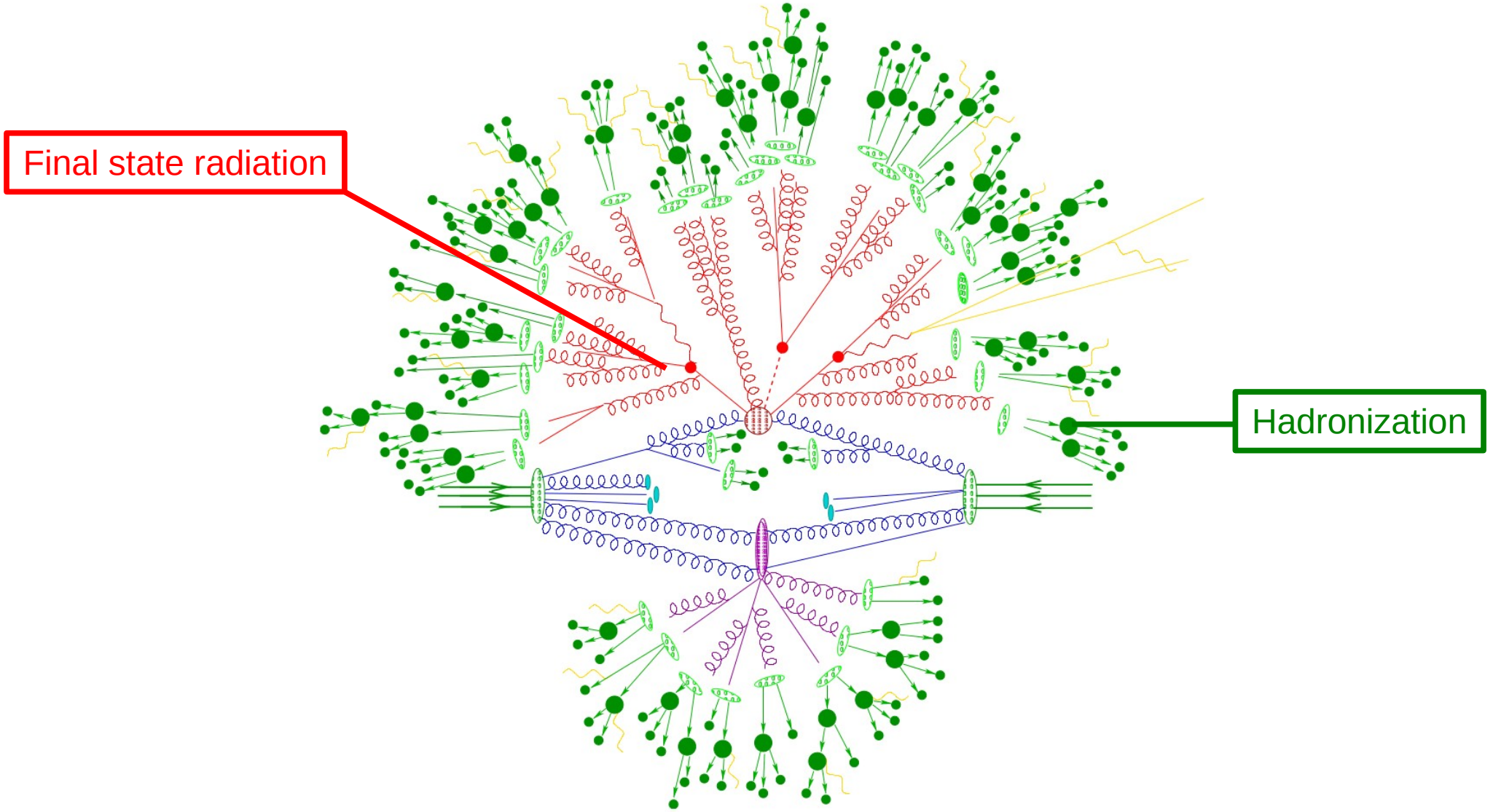
$$\pm\ 0.0017\ (\text{PDF})$$

$$\pm\ 0.0002\ (\text{NPC})$$

- NNLO pQCD prediction needed

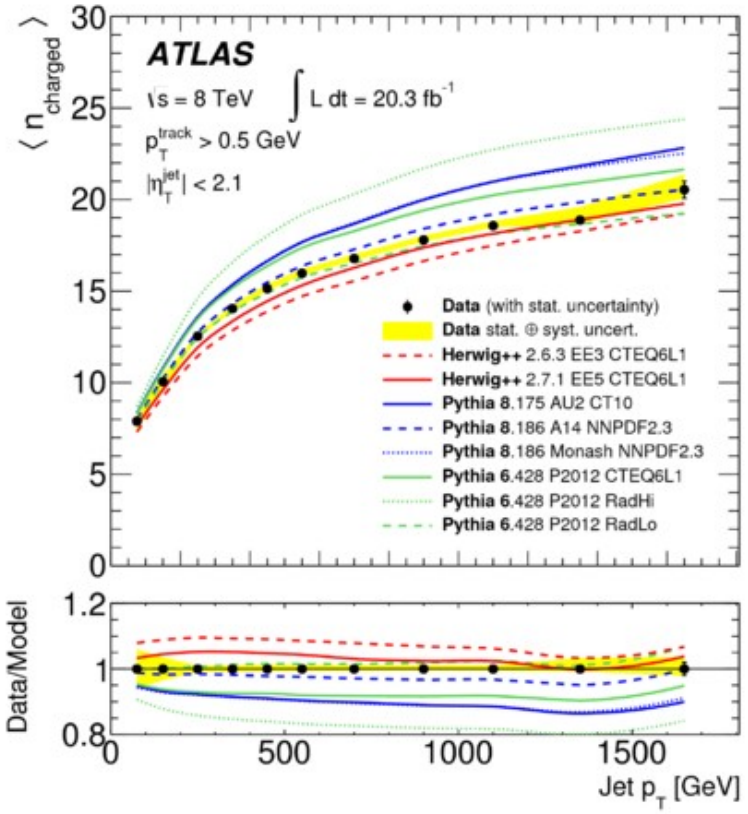


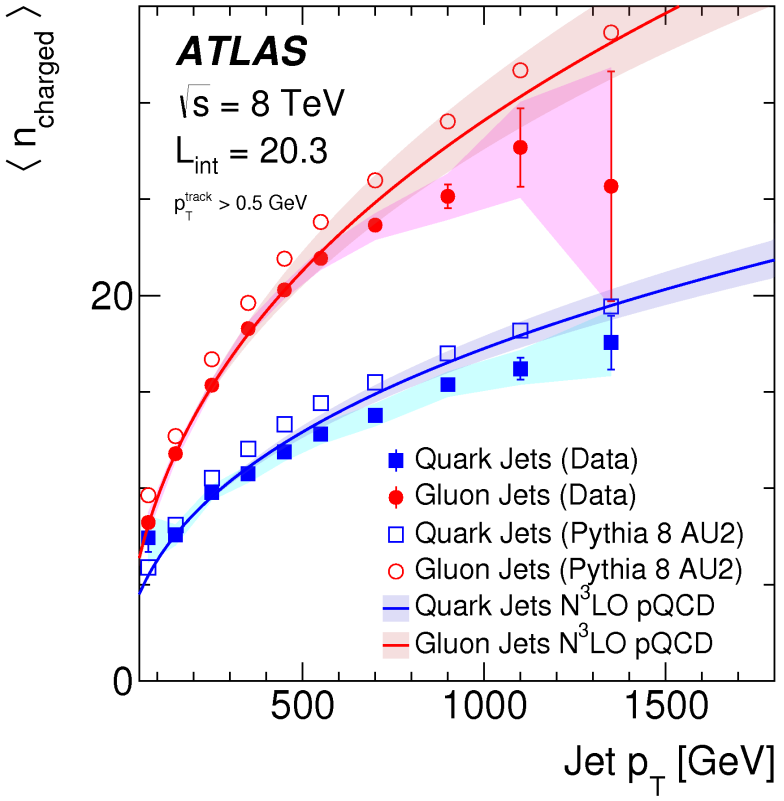
Jet structure



Number of charged particles in jets

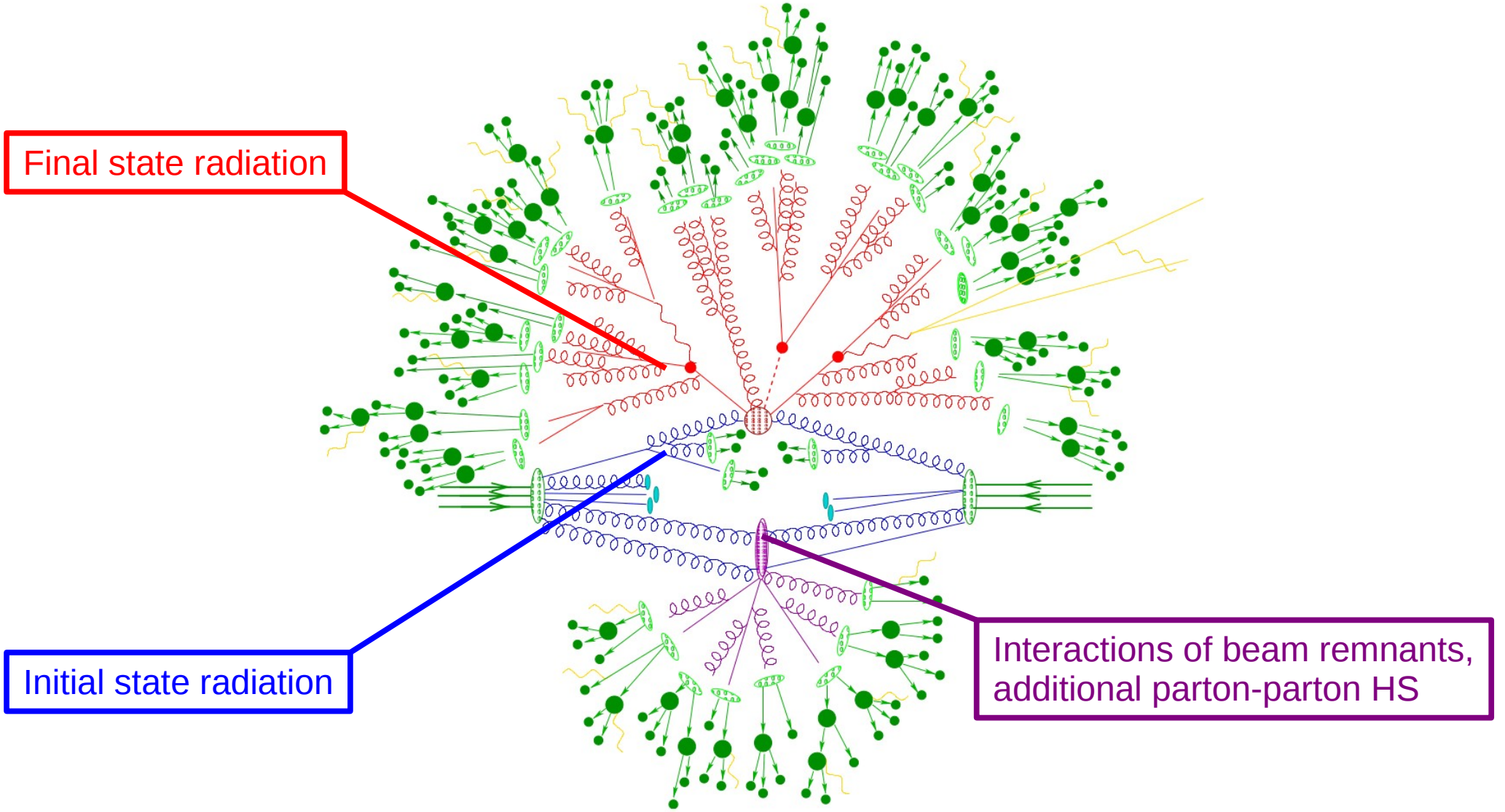
arXiv:1602.00988





- Data between Pythia and Herwig++
- $\langle n_{charged} \rangle$ higher for gluon jets
  - Increases faster with jet p_T

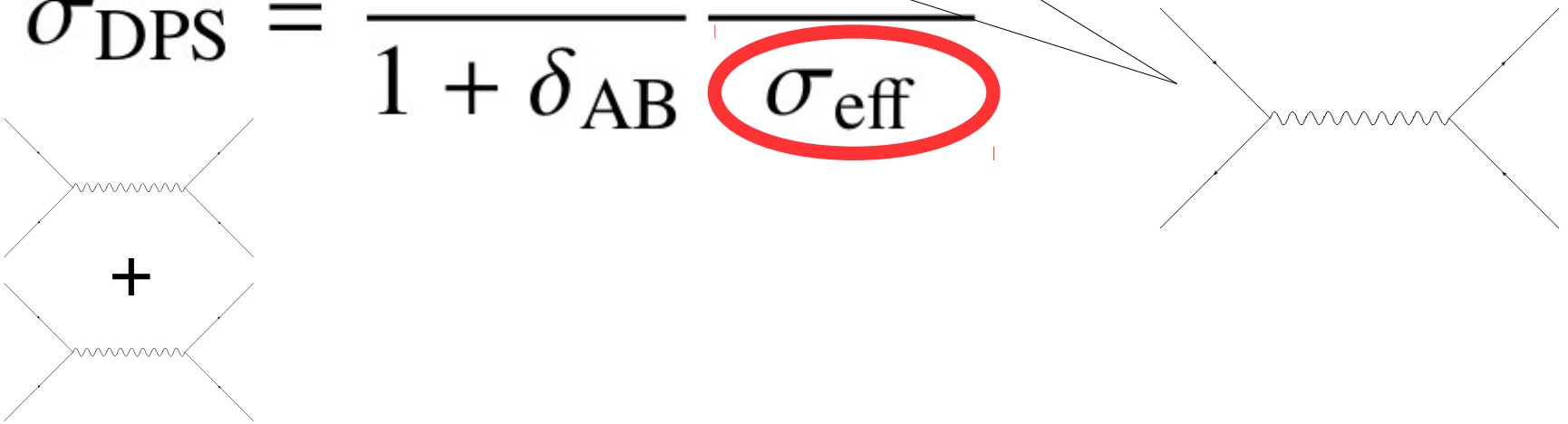
Underlying event studies



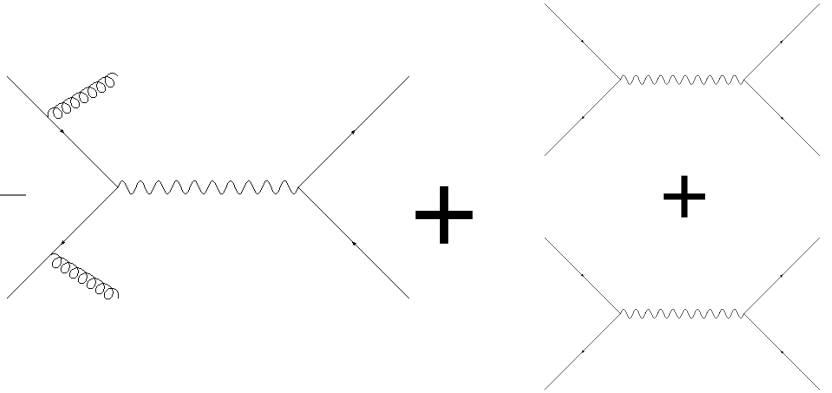
DPI in four-jet events @ 7 TeV

ATLAS-CONF-2015-058

$$\sigma_{\mathrm{DPS}} = \frac{1}{1+\delta_{\mathrm{AB}}} \frac{\sigma_{2\mathrm{j}}^{\mathrm{A}} \sigma_{2\mathrm{j}}^{\mathrm{B}}}{\sigma_{\mathrm{eff}}}$$



$$\sigma_{\mathrm{DPS}} = f_{\mathrm{DPS}} \cdot \sigma_{4\mathrm{j}}$$



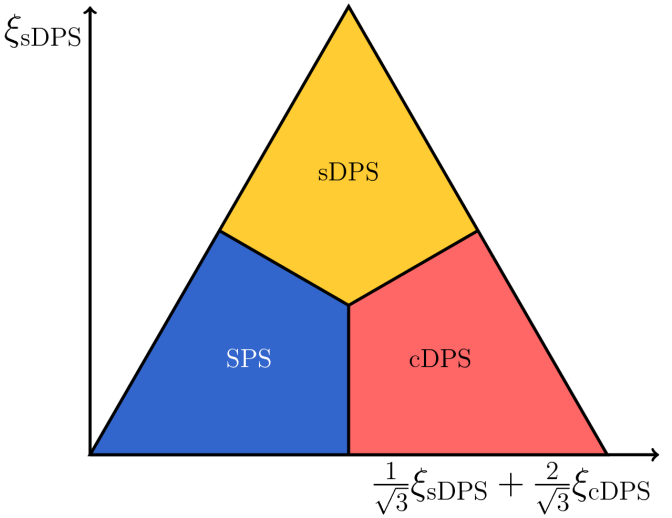
DPI in four-jet events @ 7 TeV

ATLAS-CONF-2015-058

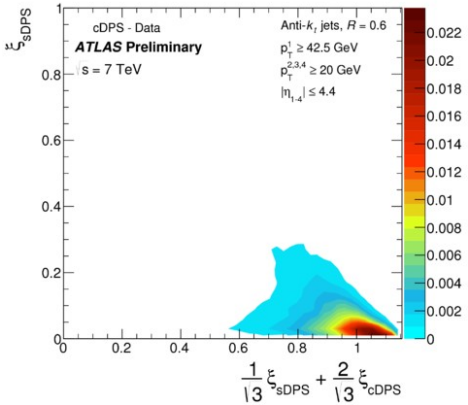
$$\Delta_{ij}^{p_T} = \frac{\left|\vec{p}_T^{\,i} + \vec{p}_T^{\,j}\right|}{p_T^i + p_T^j}; \quad \Delta\phi_{ij} = \left|\phi_i - \phi_j\right|; \quad \Delta y_{ij} = \left|y_i - y_j\right|;$$

$$|\phi_{1+2} - \phi_{3+4}|; \qquad |\phi_{1+3} - \phi_{2+4}|; \qquad |\phi_{1+4} - \phi_{2+3}|;$$

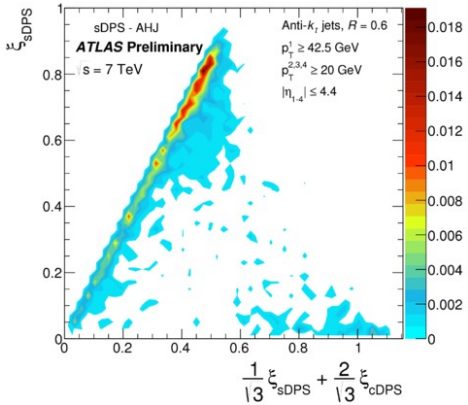
Neural network



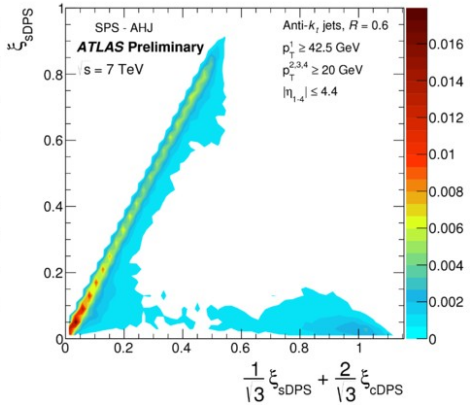
cDPS



sDPS



SPS



$$f_{\mathrm{DPS}} = 0.084$$

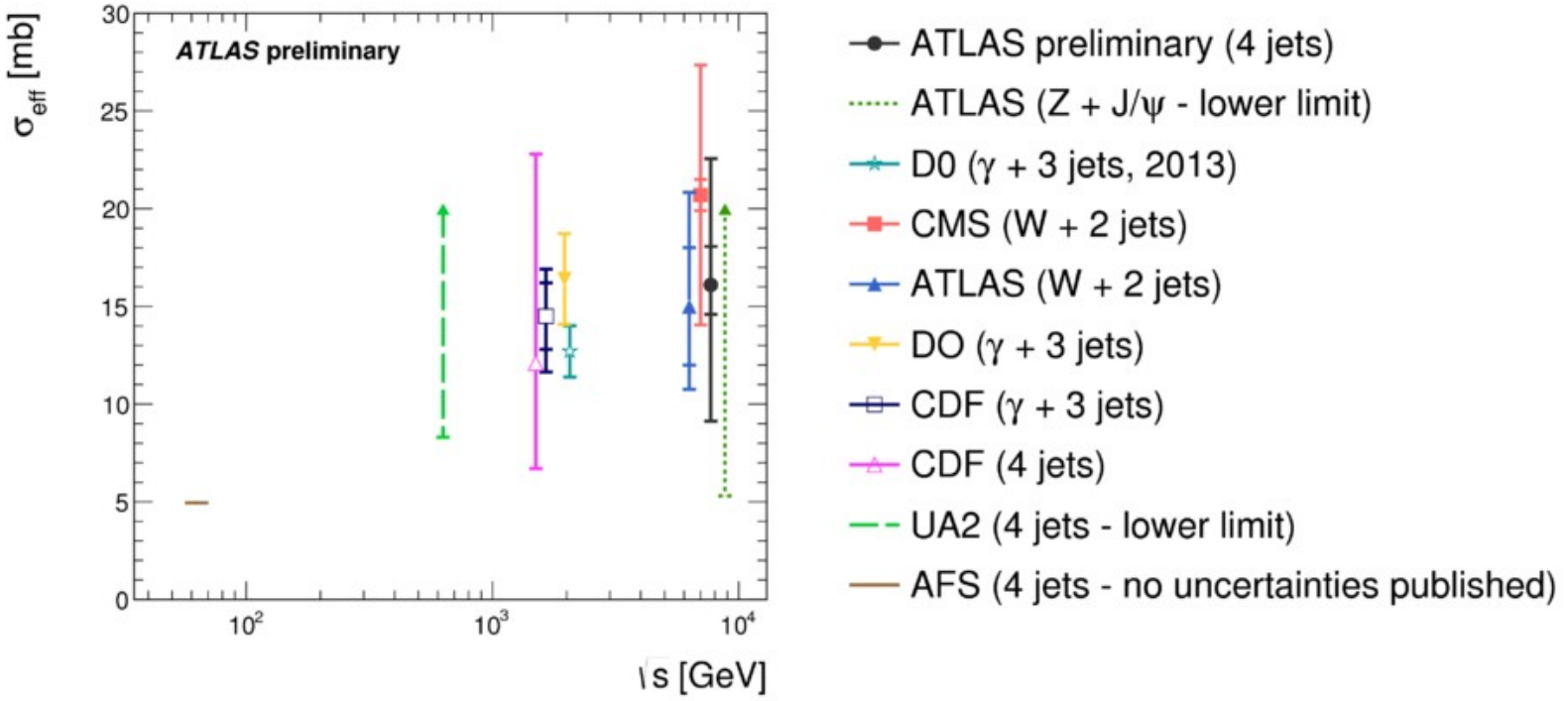
$$^{+0.054}_{-0.036}\ (\mathrm{syst.})$$

$$^{+0.009}_{-0.012}\ (\mathrm{stat.})$$

DPI in four-jet events @ 7 TeV

ATLAS-CONF-2015-058

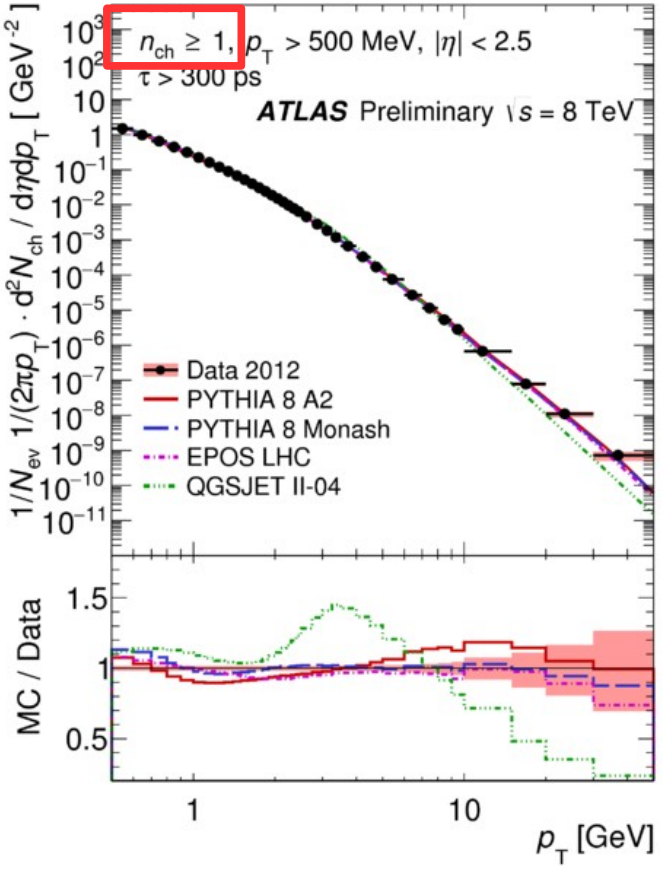
$$\sigma_{\text{eff}} = 16.1\ ^{+2.0}_{-1.5}\ (\text{stat.})\ ^{+6.1}_{-6.8}\ (\text{syst.})\ \text{mb}$$

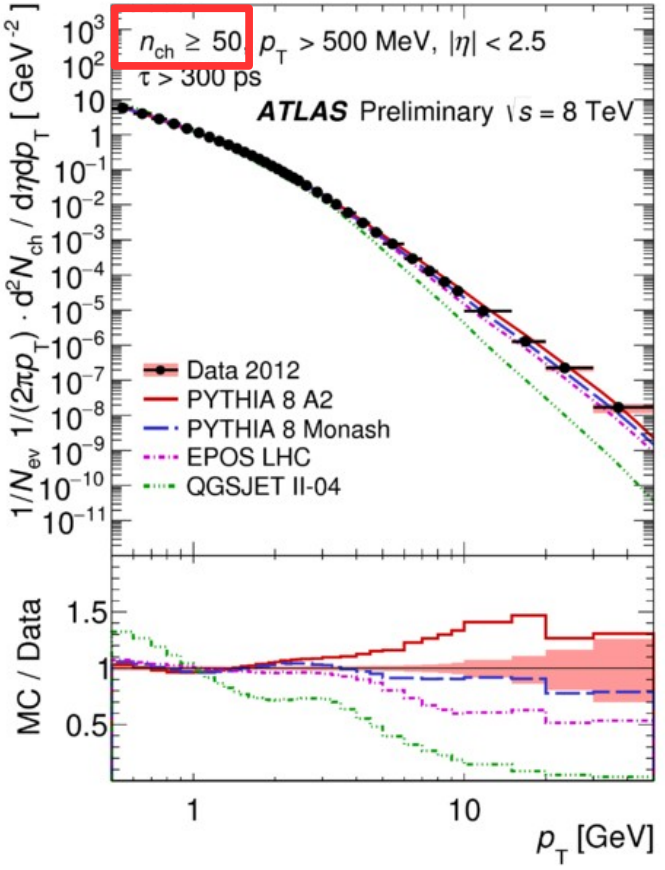


- Compatible with other measurements
- Large uncertainties

Minimum bias charged particle distributions @ 8 TeV

ATLAS-STDM-2014-19

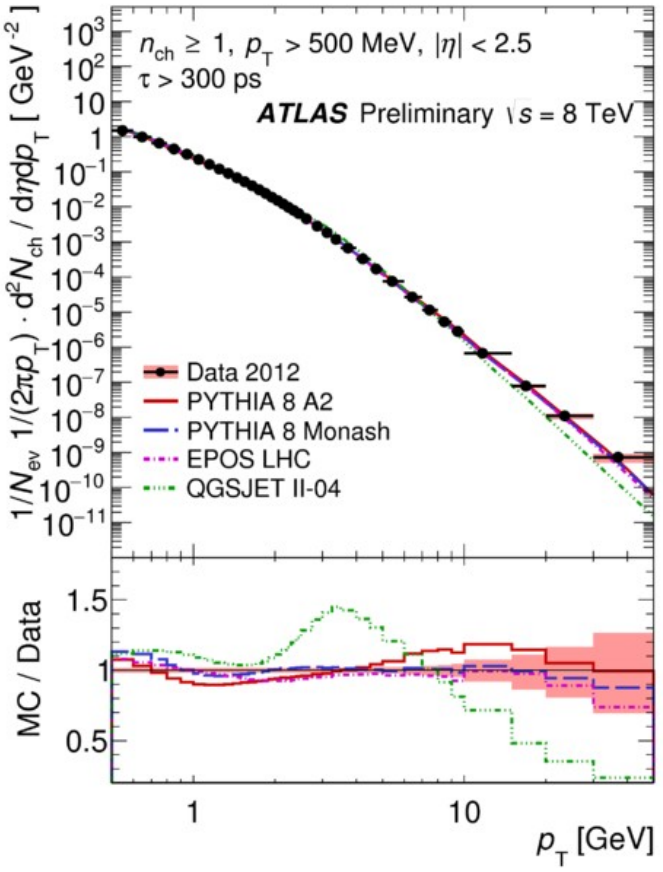


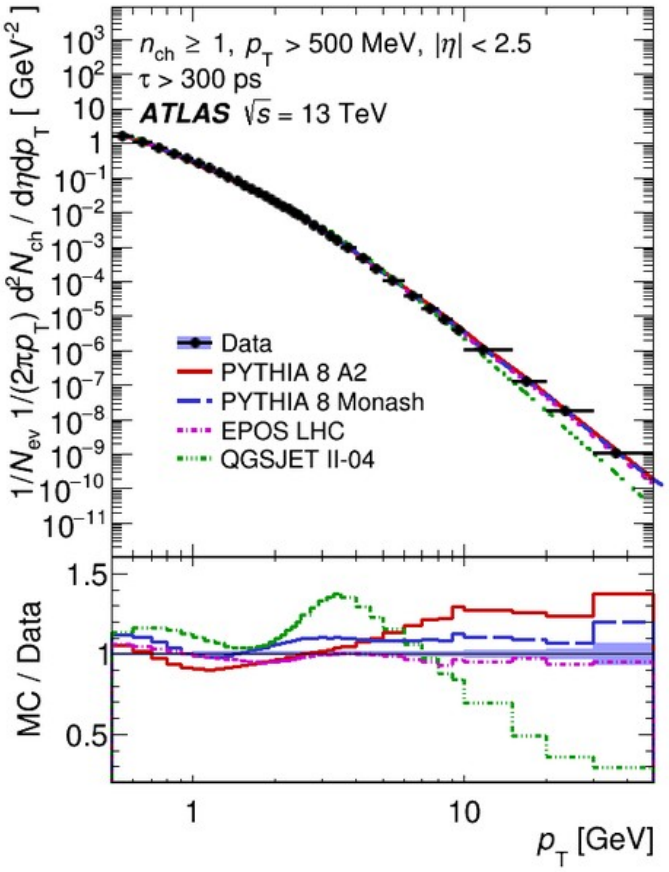


- EPOS and Pythia+Monash: the best description
  - Still space for improvement!

Minimum bias charged particle distributions @ 8, 13 TeV

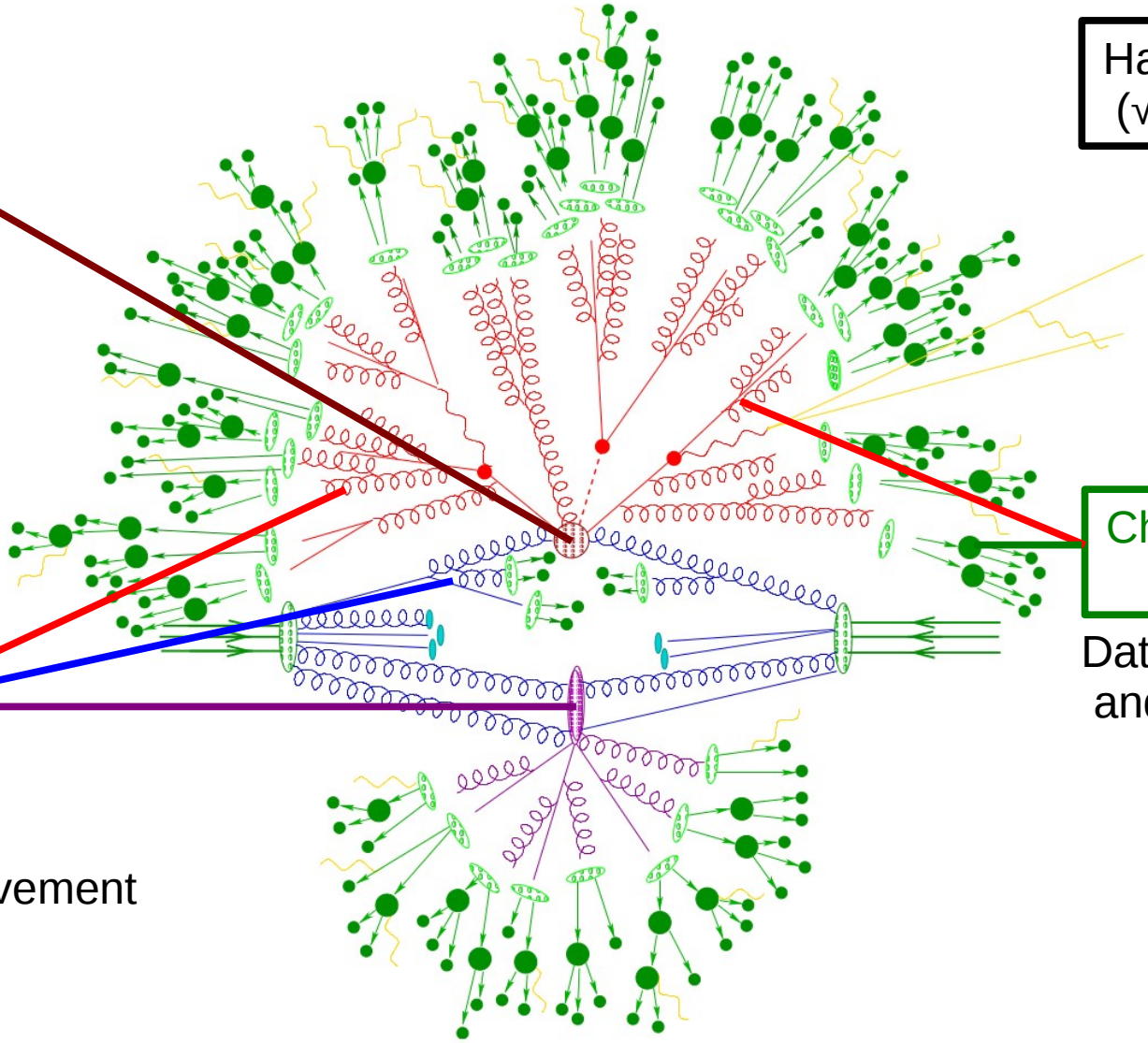
ATLAS-STDM-2014-19, arXiv:1602.01633





- 13 TeV: Valentina's Maria Cairo poster!

Conclusion:
Models describe data well! ...but



Hard *pp*-interaction
($\sqrt{s}$ = 7, 8, 13 TeV)

Four-jet
cross-section

Constraining power
for some variables

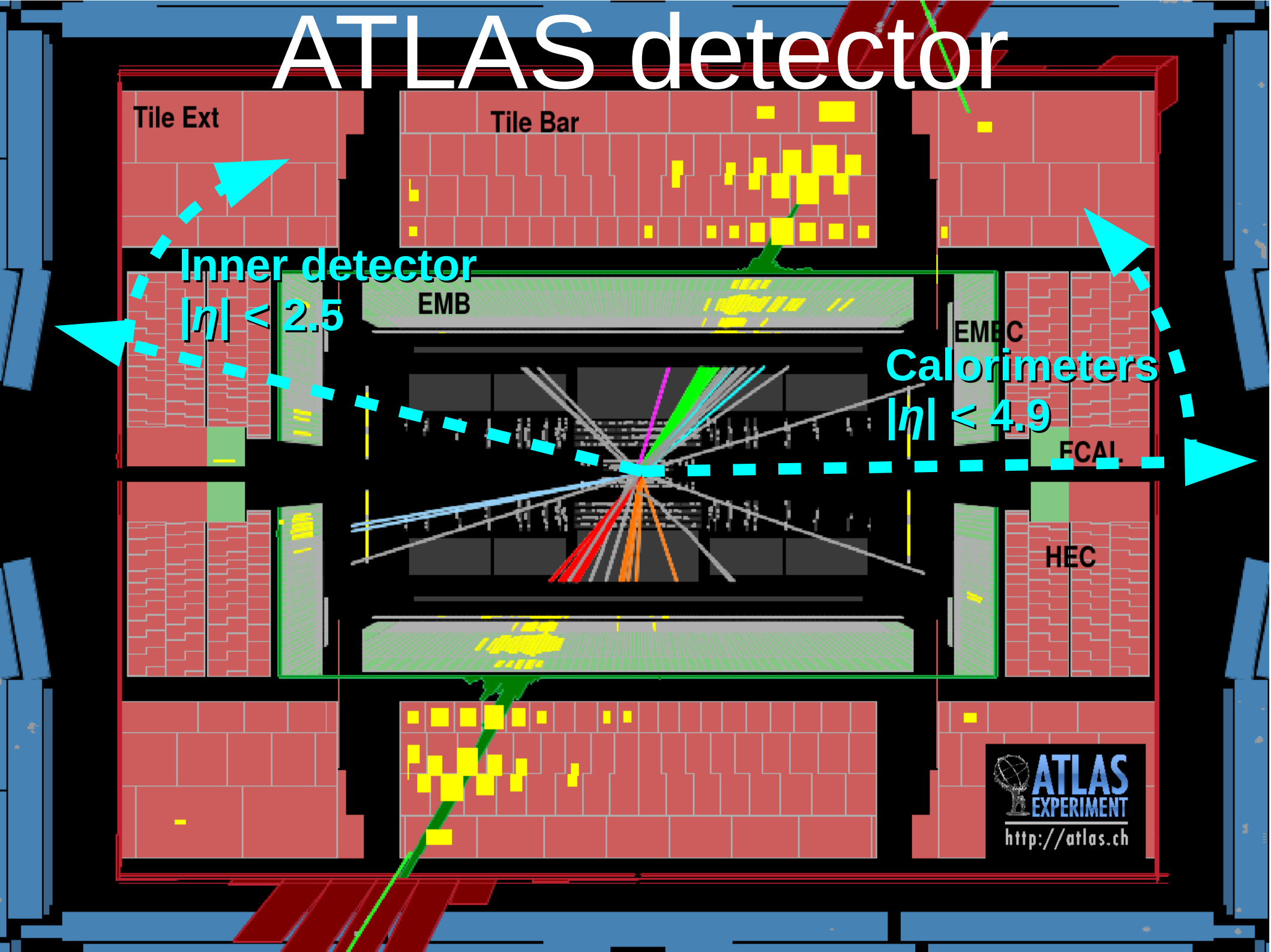
Charged particles
in jets

Data between Pythia
and Herwig++

Underlying
event
studies

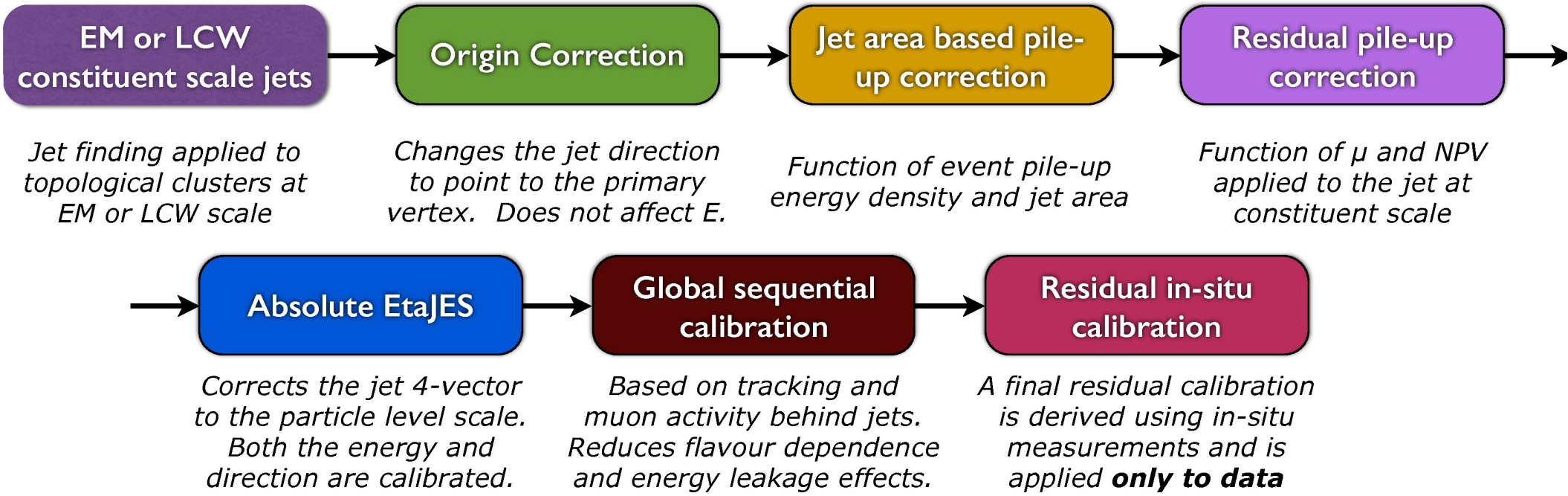
Still space for improvement

Back-up


ATLAS detector
Tile Ext
Tile Bar
Inner detector
|η| < 2.5
EMB
EMEC
Calorimeters
|η| < 4.9
FCAL
HEC
ATLAS
EXPERIMENT
http://atlas.ch

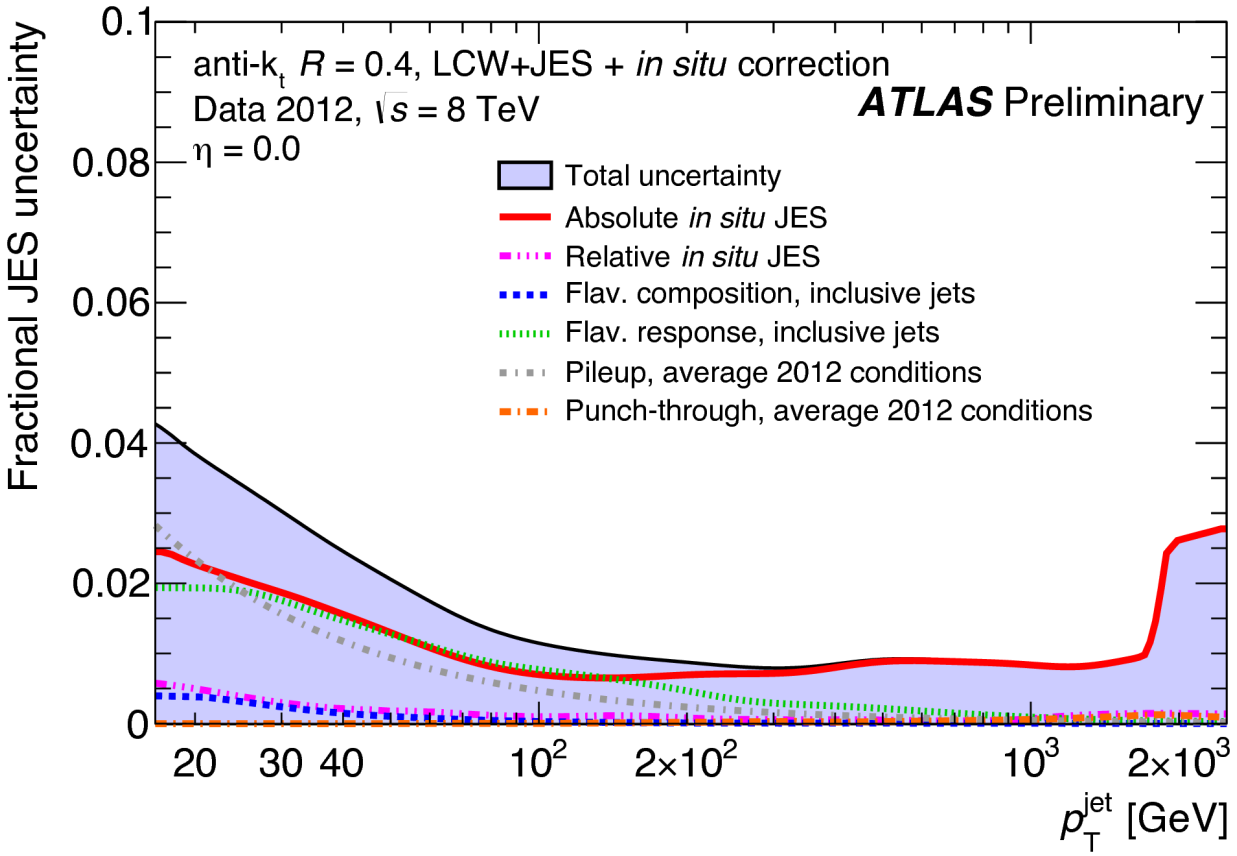
Jet reconstruction with ATLAS (2012)

- Calorimeter cells → Topoclusters → Anti-k_t jets
- Calibration:



Jet reconstruction with ATLAS

Eur. Phys. J. C (2015) 75:17



- JES uncertainty of ~1% in 0.1 – 1.5 TeV!
  - Measured in-situ

Transverse energy-energy correlations

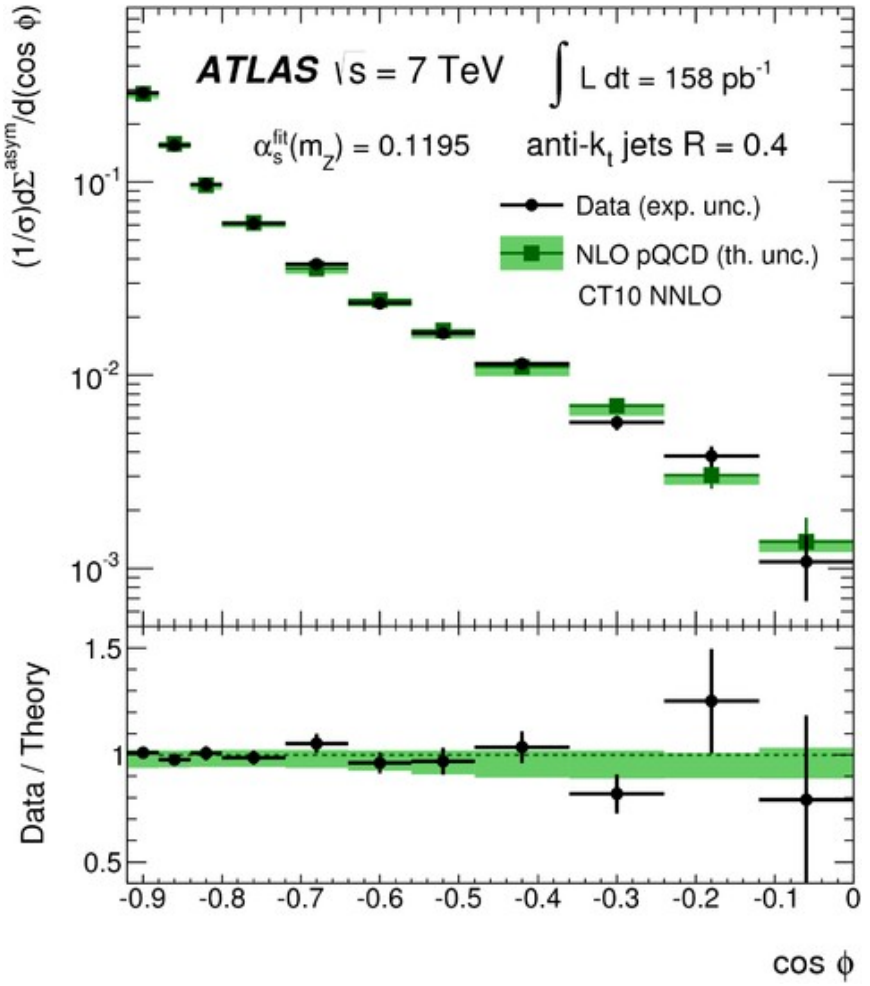
Phys. Lett. B 750 (2015) 427-447

- TEEC:

$$\frac{1}{\sigma}\frac{\mathrm{d}\Sigma}{\mathrm{d}(\cos\phi)} = \frac{1}{\sigma}\sum_{ij}\int \frac{\mathrm{d}\sigma}{\mathrm{d}x_{\mathrm{T}i}\mathrm{d}x_{\mathrm{T}j}\mathrm{d}(\cos\phi)} x_{\mathrm{T}i}x_{\mathrm{T}j}\mathrm{d}x_{\mathrm{T}i}\mathrm{d}x_{\mathrm{T}j}$$

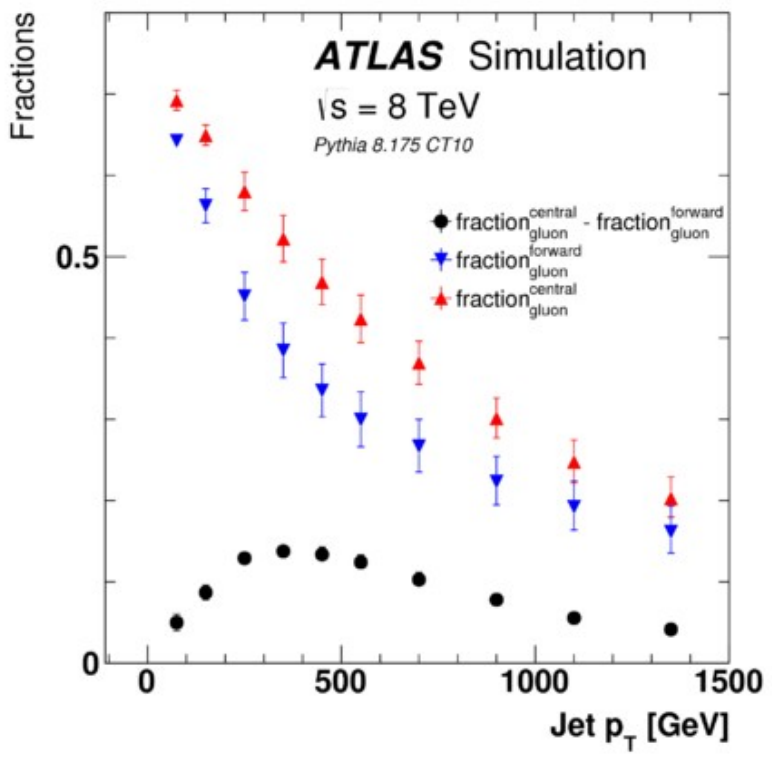
- Asymmetry of TEEC:

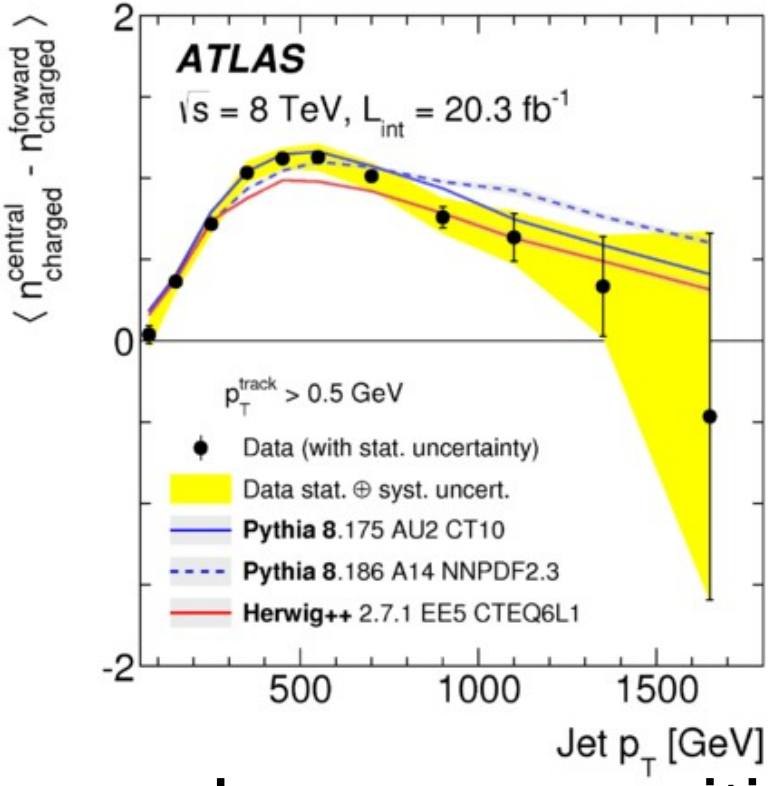
$$\frac{1}{\sigma}\frac{\mathrm{d}\Sigma^{\mathrm{asym}}}{\mathrm{d}(\cos\phi)} \equiv \frac{1}{\sigma}\frac{\mathrm{d}\Sigma}{\mathrm{d}(\cos\phi)}\bigg|_{\phi} - \frac{1}{\sigma}\frac{\mathrm{d}\Sigma}{\mathrm{d}(\cos\phi)}\bigg|_{\pi-\phi}$$



Number of charged tracks in jets

arXiv:1602.00988





- Exploit difference in $\langle n_{charged} \rangle$ and q-g composition of more central and more forward jets

$$\langle n^f_{\text{charged}} \rangle = f^f_q \langle n^q_{\text{charged}} \rangle + f^f_g \langle n^g_{\text{charged}} \rangle$$

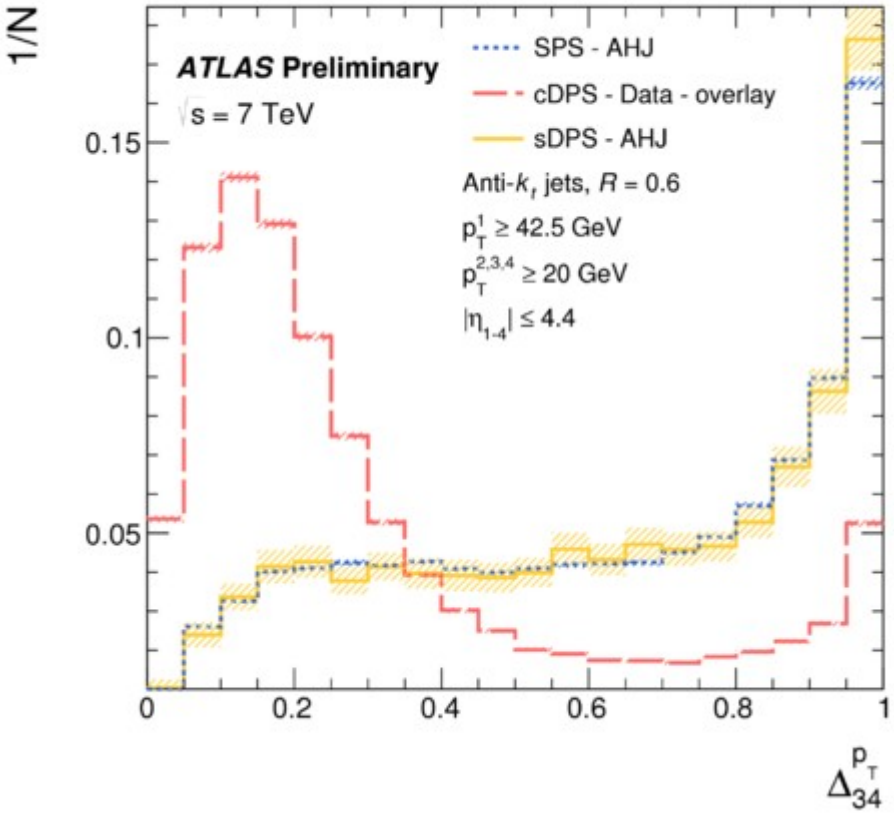
$$\langle n^c_{\text{charged}} \rangle = f^c_q \langle n^q_{\text{charged}} \rangle + f^c_g \langle n^g_{\text{charged}} \rangle.$$

DPI in four-jet events @ 7 TeV

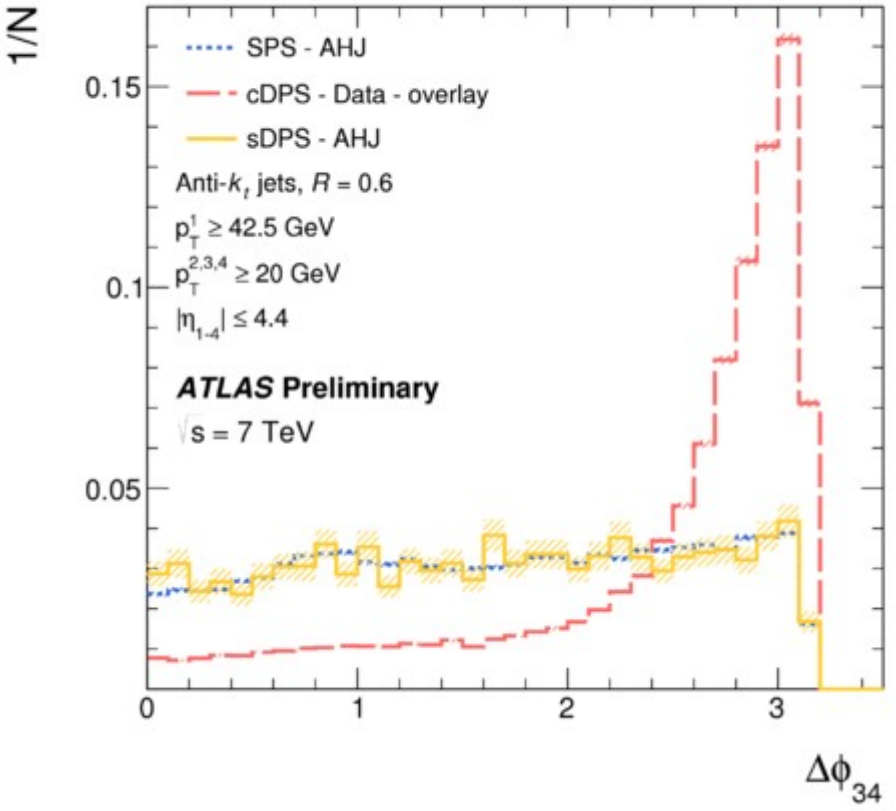
ATLAS-CONF-2015-058

- Discriminating variables

$$\Delta_{ij}^{p_{\mathrm{T}}} = \frac{\left|\vec{p}_{\mathrm{T}}^{\,i} + \vec{p}_{\mathrm{T}}^{\,j}\right|}{p_{\mathrm{T}}^{i} + p_{\mathrm{T}}^{j}}$$

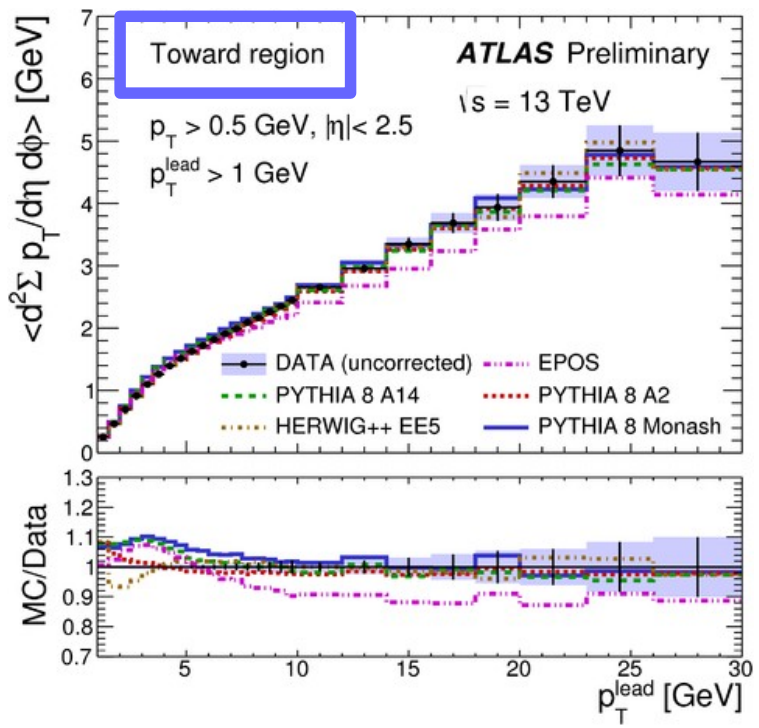


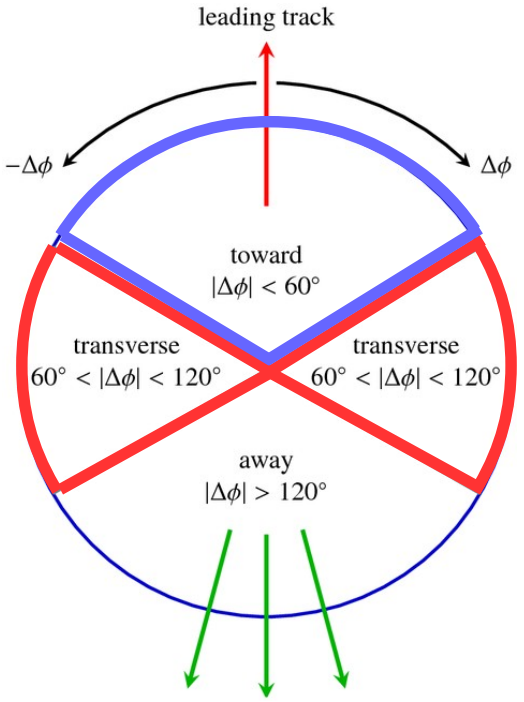
$$\Delta\phi_{ij} = \left|\phi_i - \phi_j\right|$$

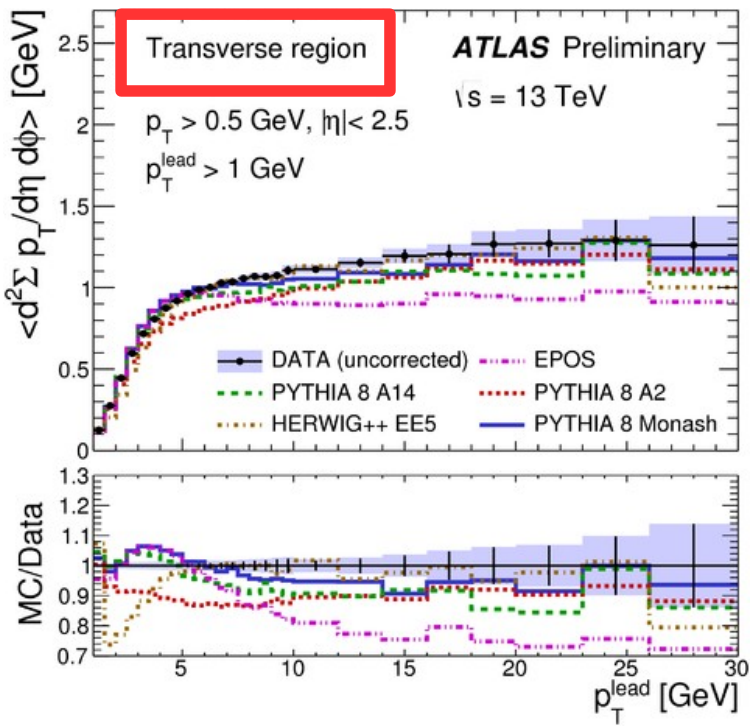


Leading Track UE @ 13 TeV

ATL-PHYS-PUB-2015-019



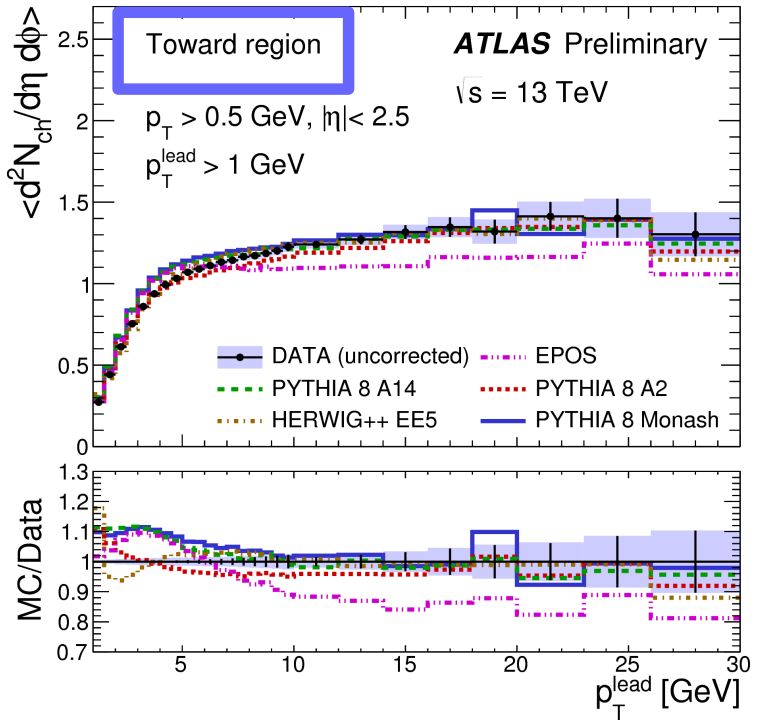


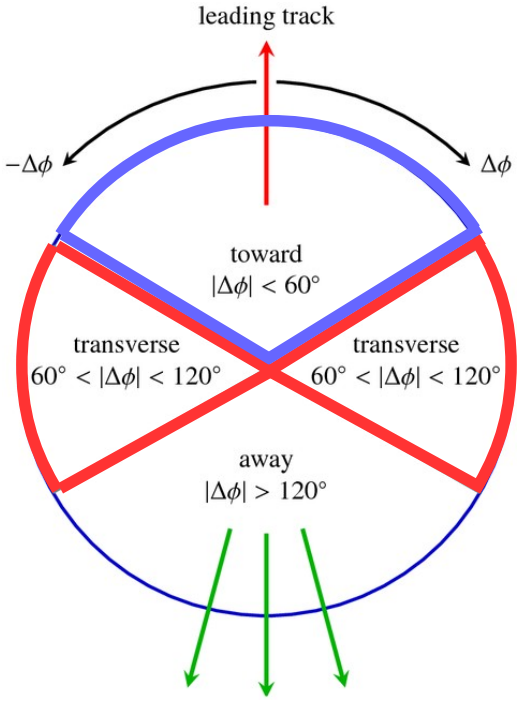


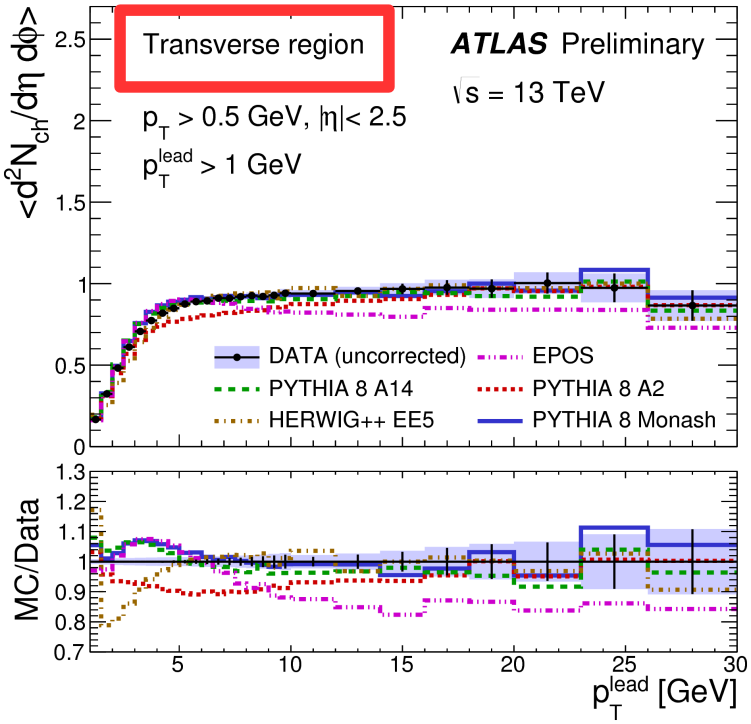
- Detector-level distributions, 170 μb^{-1}
- Plateau in transverse region described by UE tunes

Leading Track UE @ 13 TeV

ATL-PHYS-PUB-2015-019



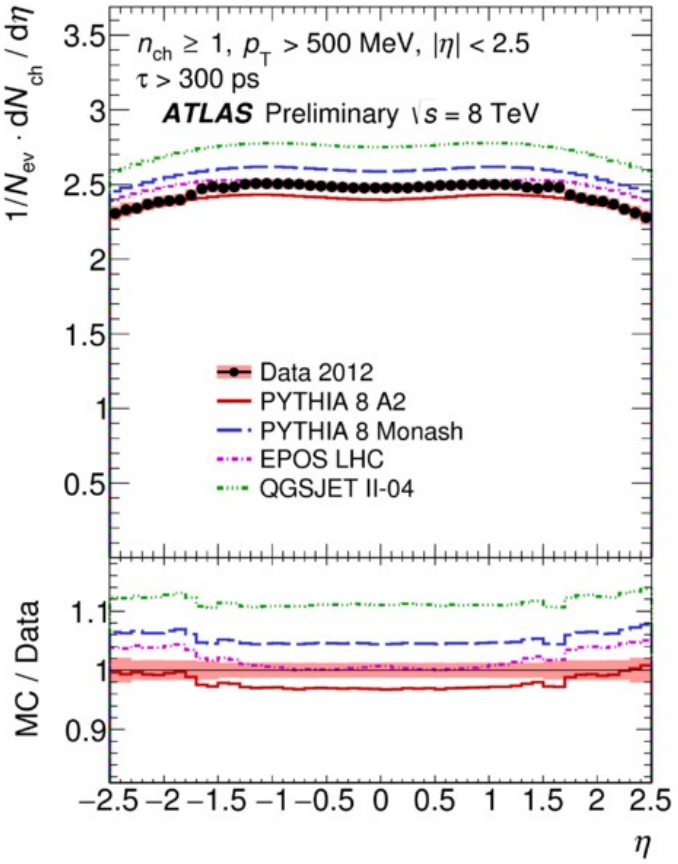


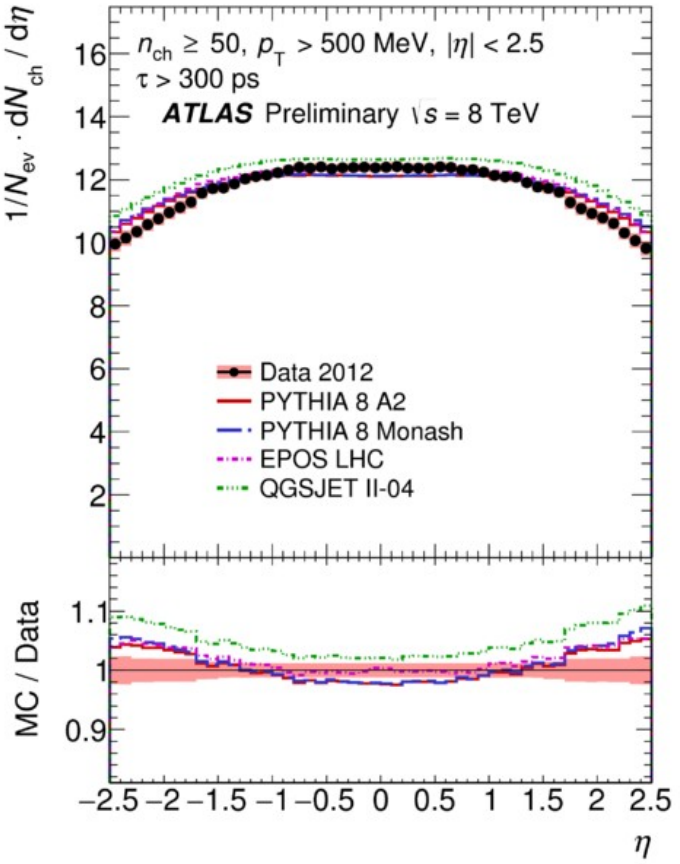


- Detector-level distributions, 170 μb^{-1}
- Plateau in transverse region described by UE tunes

Minimum bias charged particle distributions @ 8 TeV

ATLAS-STDM-2014-19

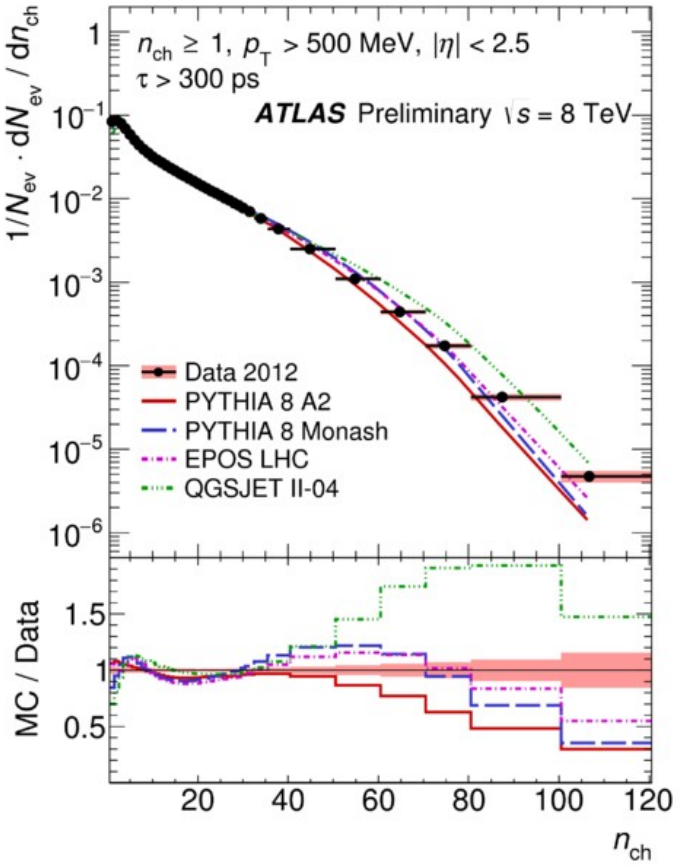


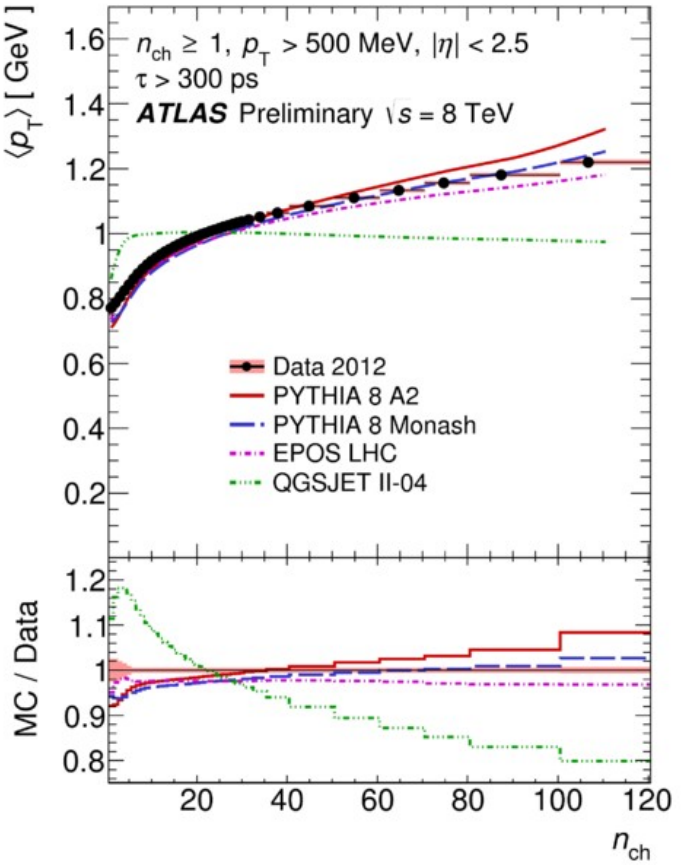


- EPOS and A2: the best description
  - Still space for improvement!

Minimum bias charged particle distributions @ 8 TeV

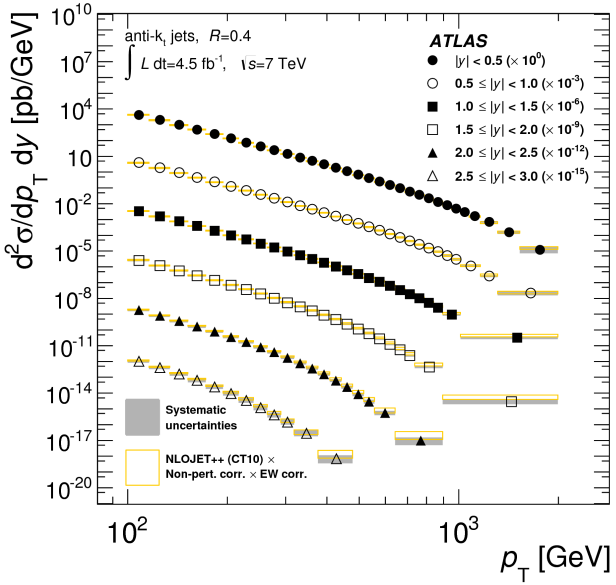
ATLAS-STDM-2014-19



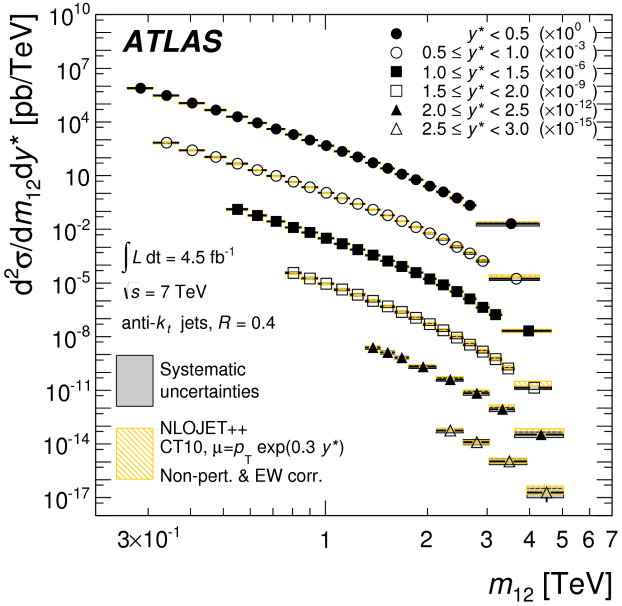


- EPOS and Monash: best agreement
  - Still space for improvement!

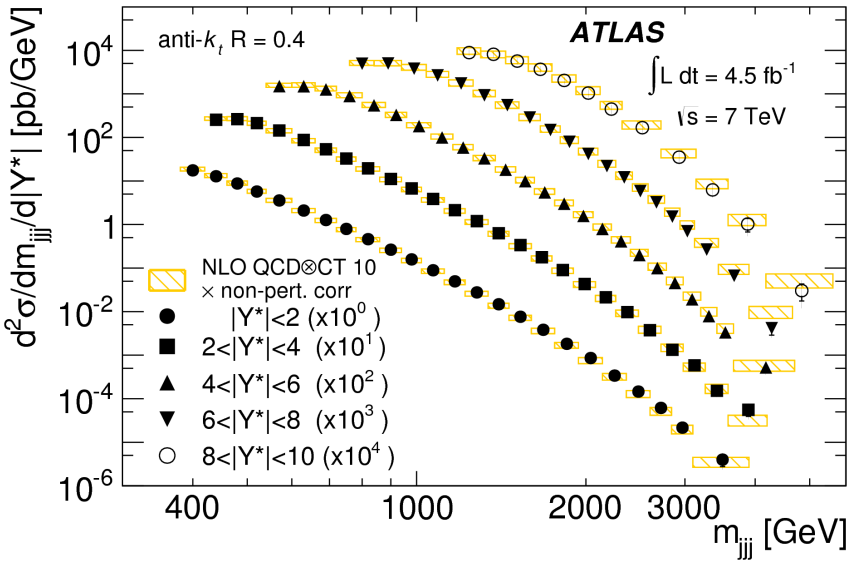
Inclusive-, di- and three-jet cross-sections @ 7 TeV



JHEP02 (2015) 153



JHEP05 (2014) 059



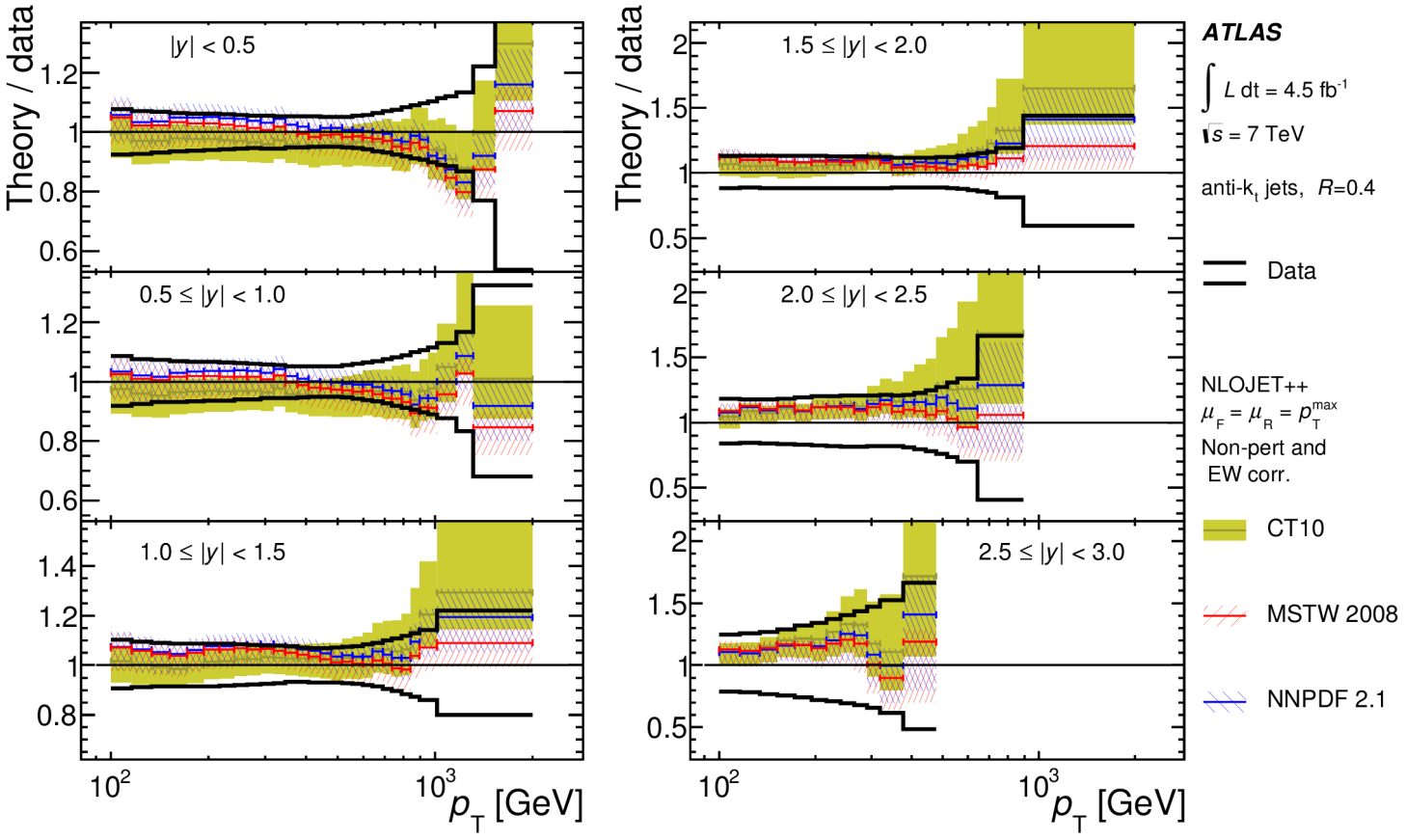
Eur. Phys. J. C (2015) 75

- Good agreement between data and NLO pQCD
- Correlation of stat. and syst. unc. determined

Inclusive jet cross-section @ 7 TeV

JHEP02 (2015) 153

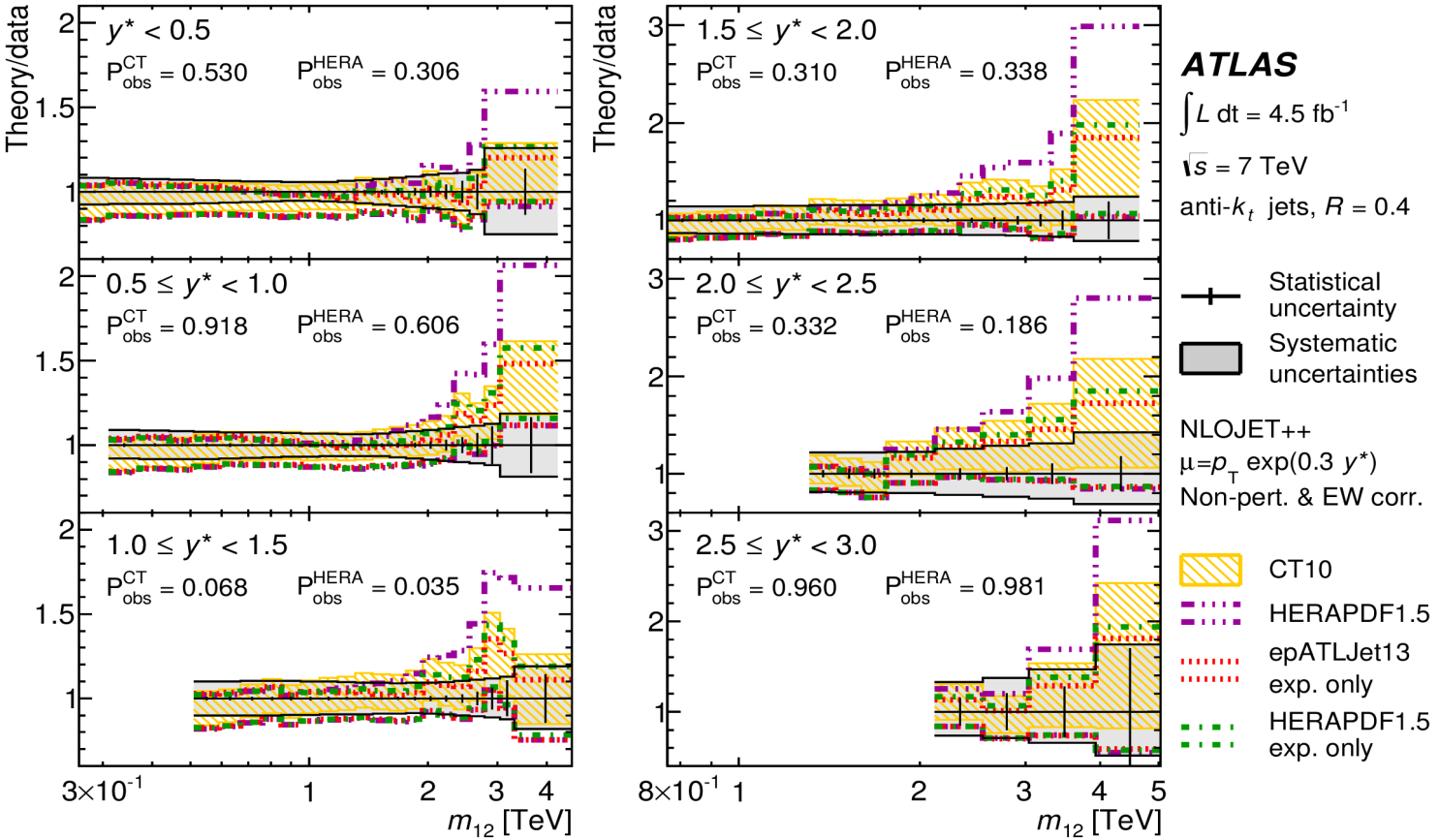
- R = 0.4 jets



Dijet cross-section @ 7 TeV

JHEP05 (2014) 059

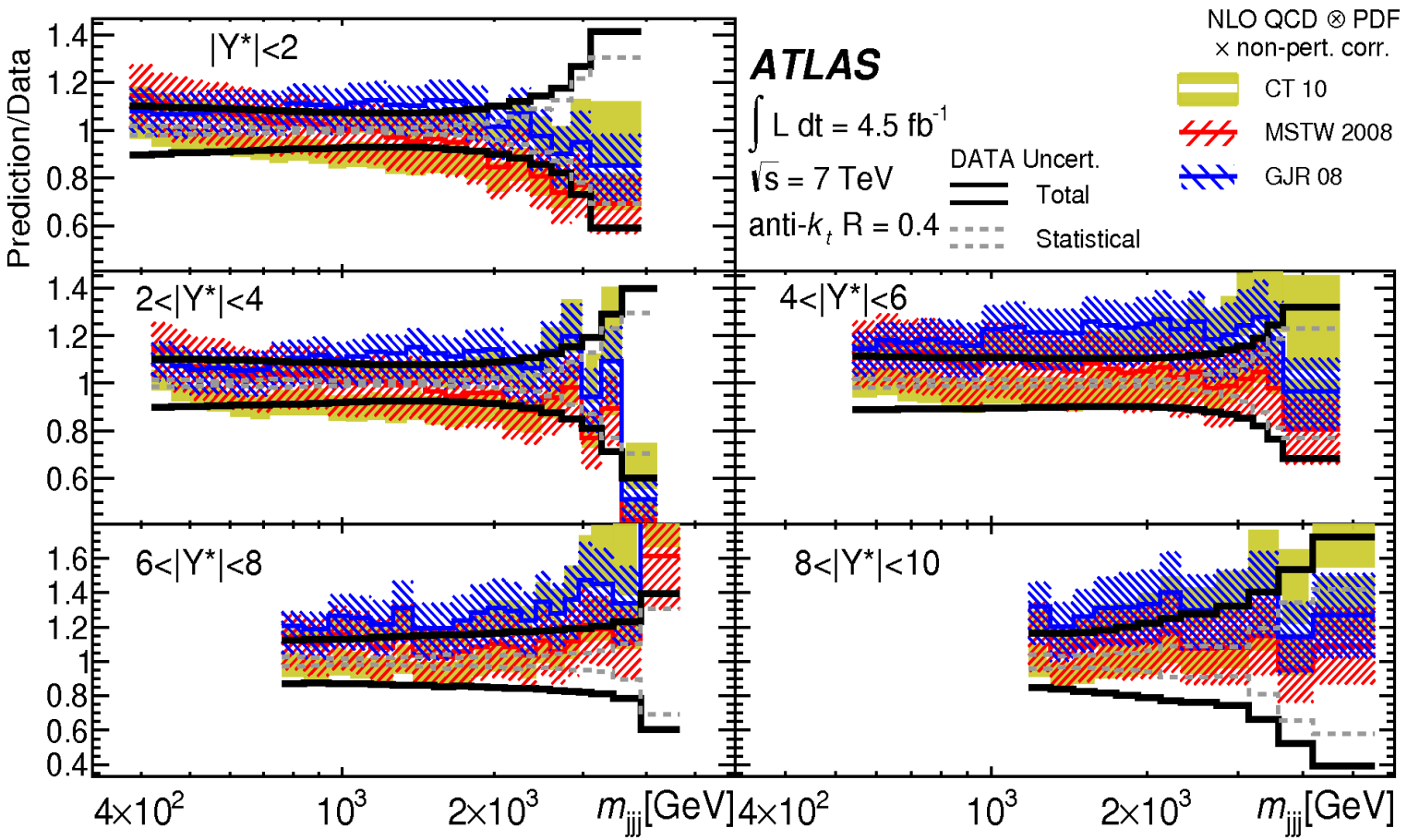
- R = 0.4 jets



Three-jet cross-section @ 7 TeV

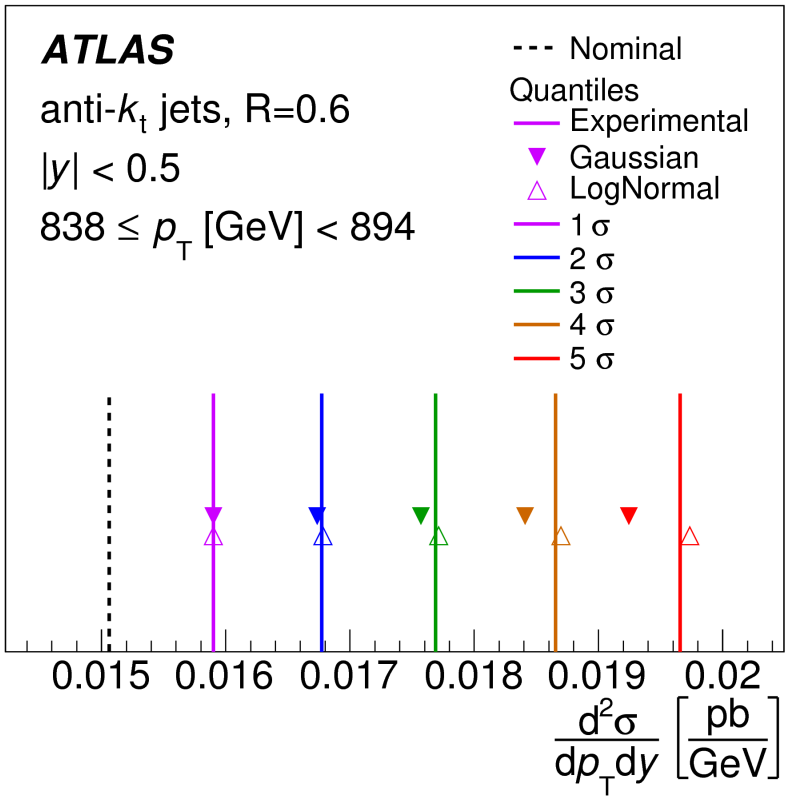
Eur. Phys. J. C (2015) 75

- R = 0.4 jets



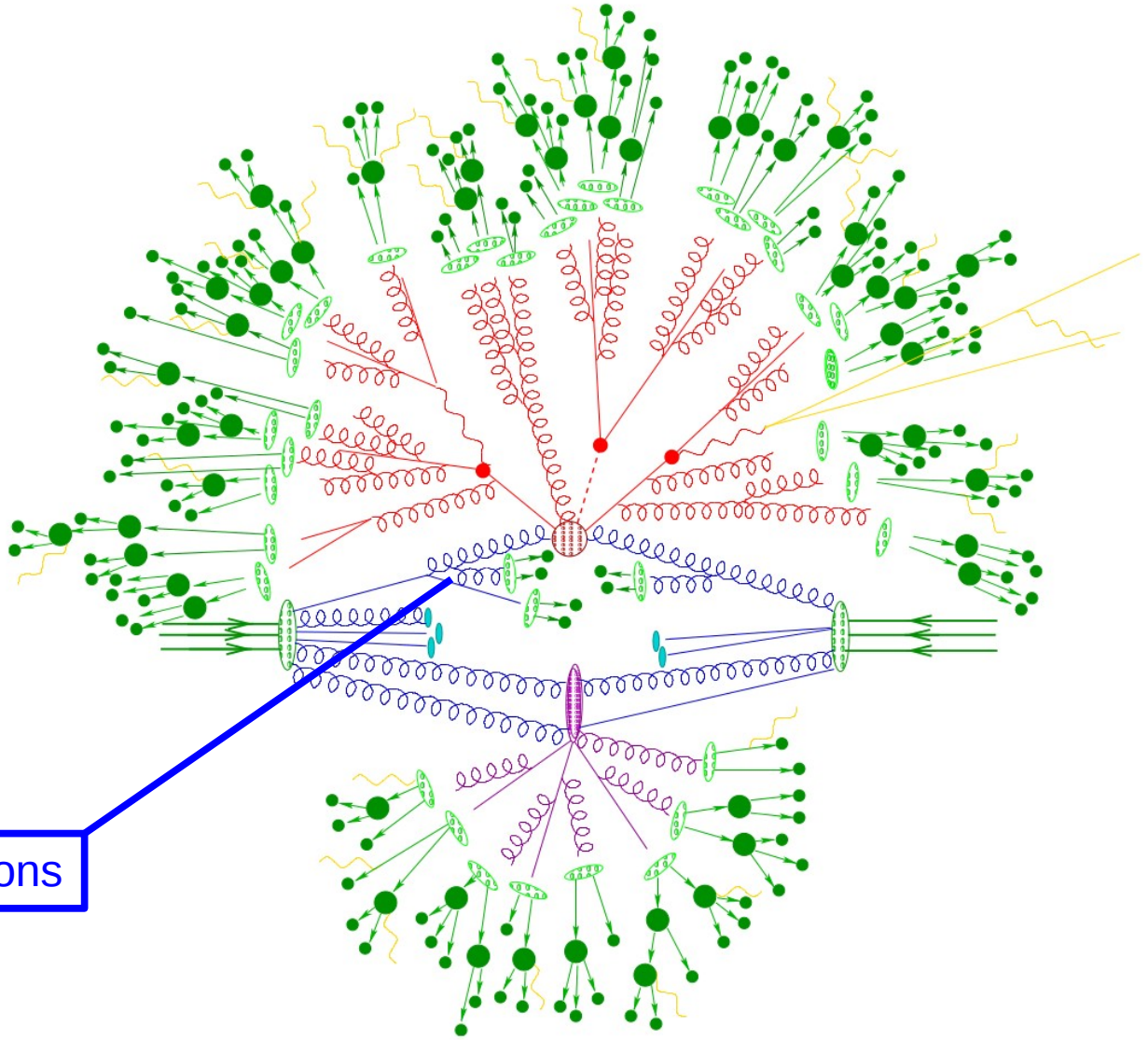
Shape of systematic uncertainty

Inclusive jet cross-section @ 7 TeV, JHEP02 (2015) 153



- Large systematic uncertainties are non-gaussian

Parton distribution functions



Quantitative comparison data-theory

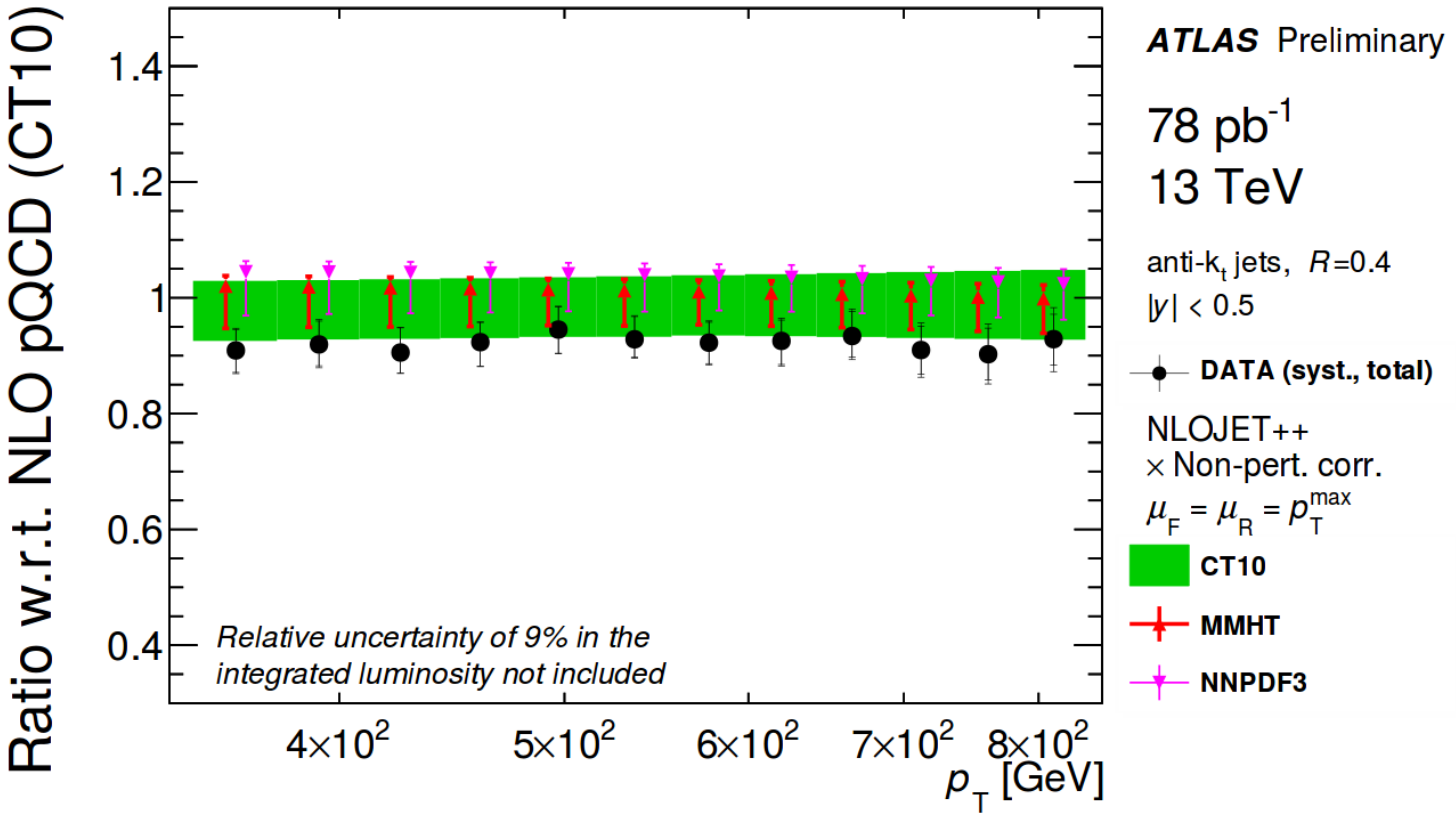
Inclusive jet cross-section @ 7 TeV, JHEP02 (2015) 153

y ranges		P_{obs}				
	NLO PDF set:	CT10	MSTW2008	NNPDF2.1	HERAPDF1.5	ABM11
$\lvert y\rvert < 0.5$		81%	60%	70%	58%	<0.1%
$0.5 \leq \lvert y\rvert < 1.0$		90%	92%	88%	50%	<0.1%
$1.0 \leq \lvert y\rvert < 1.5$		87%	87%	84%	92%	3.5%
$1.5 \leq \lvert y\rvert < 2.0$		91%	88%	90%	72%	60%
$2.0 \leq \lvert y\rvert < 2.5$		89%	82%	85%	25%	54%
$2.5 \leq \lvert y\rvert < 3.0$		95%	92%	96%	83%	87%

- Anti-k_t, R = 0.4 jets
- ABM11 excluded: p-value < 0.1%

Qualitative comparison data-theory

Inclusive jet cross-section @ 13 TeV, ATLAS-CONF-2015-034



- Agreement for CT10, NNPDF3.0, MMHT