Measurement of single and multi-jet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with ATLAS

Paolo Francavilla
Universitá di Pisa
School of Graduate Studies “G. Galilei”
On behalf of the ATLAS Collaboration

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Jets in the LHC era

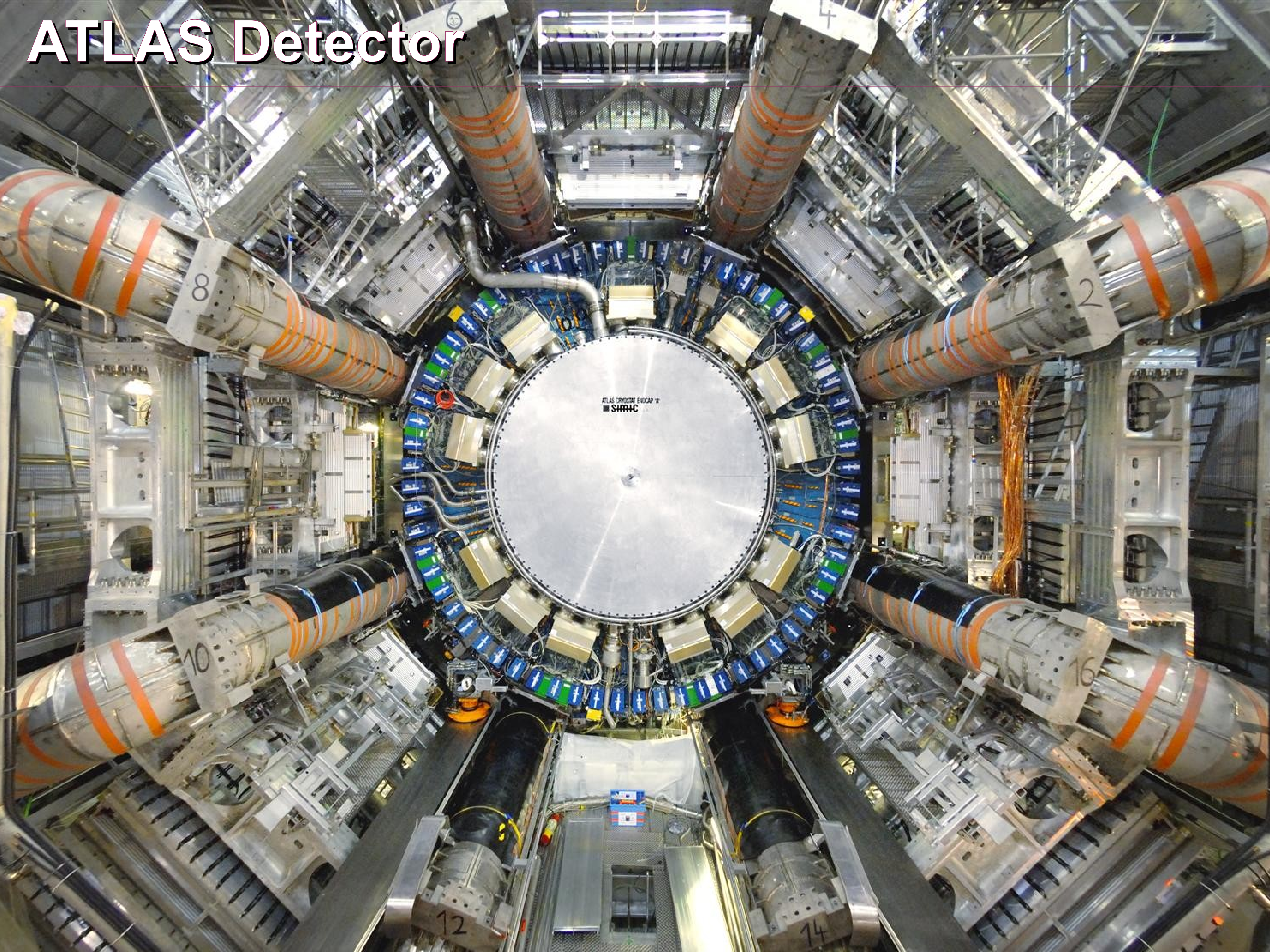
At the Large Hadron Collider (LHC), jet production is the dominant high transverse-momentum (p_T) process.

It gives the first glimpse of physics at the TeV scale.

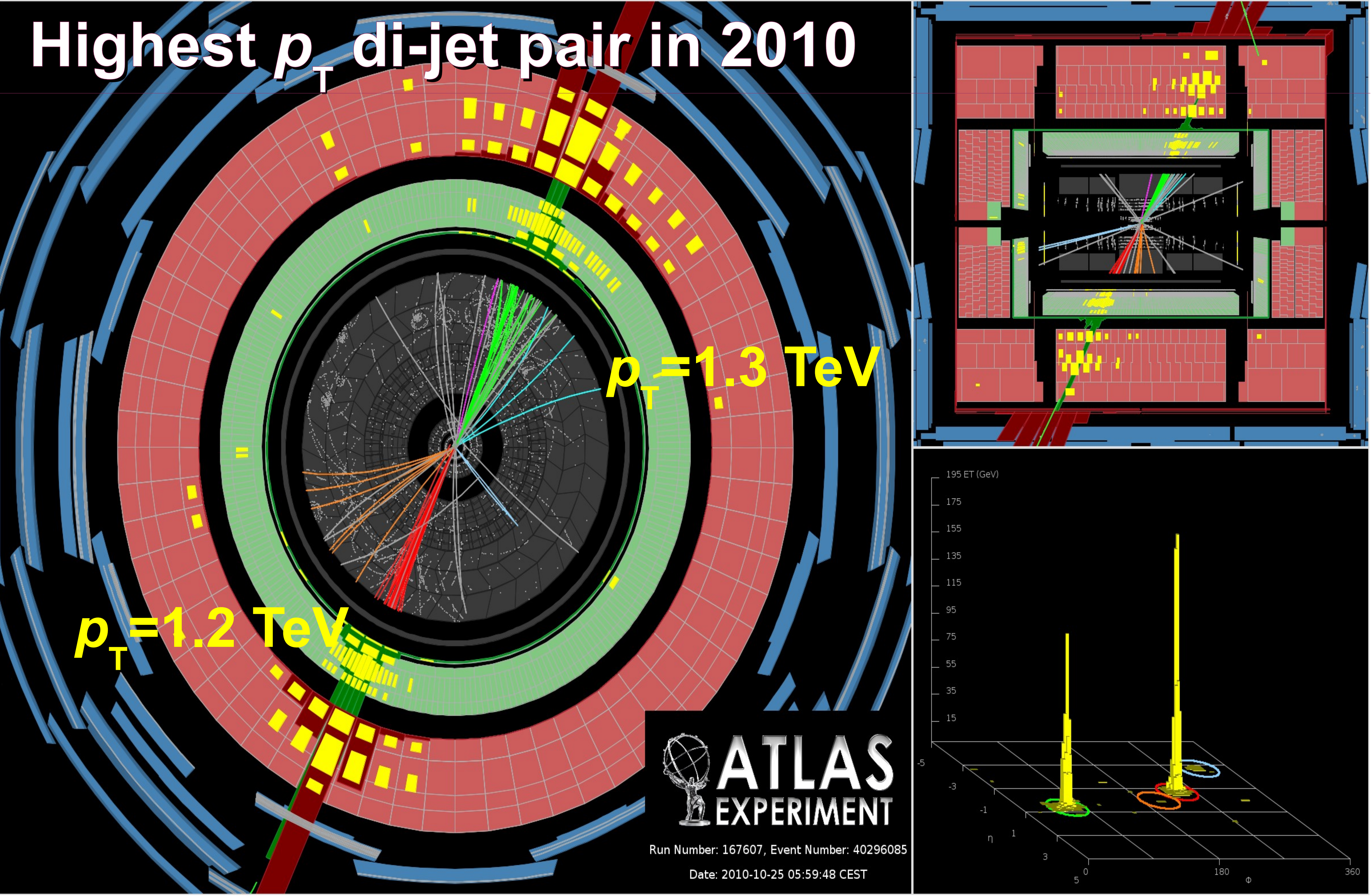
Jet cross sections and properties are key observables in high-energy particle physics.
Measured in $\mathbf{e^+e^-}$, **ep** , $\mathbf{p\bar{p}}$, and **pp** colliders,
and in $\boldsymbol{\gamma}$**p** and $\boldsymbol{\gamma\gamma}$ collisions.

•Measurements of the strong coupling constant.
•Information about the structure of the proton.
•Tools for understanding the strong interaction.
•Tools for searching for physics beyond the Standard Model.

ATLAS Detector



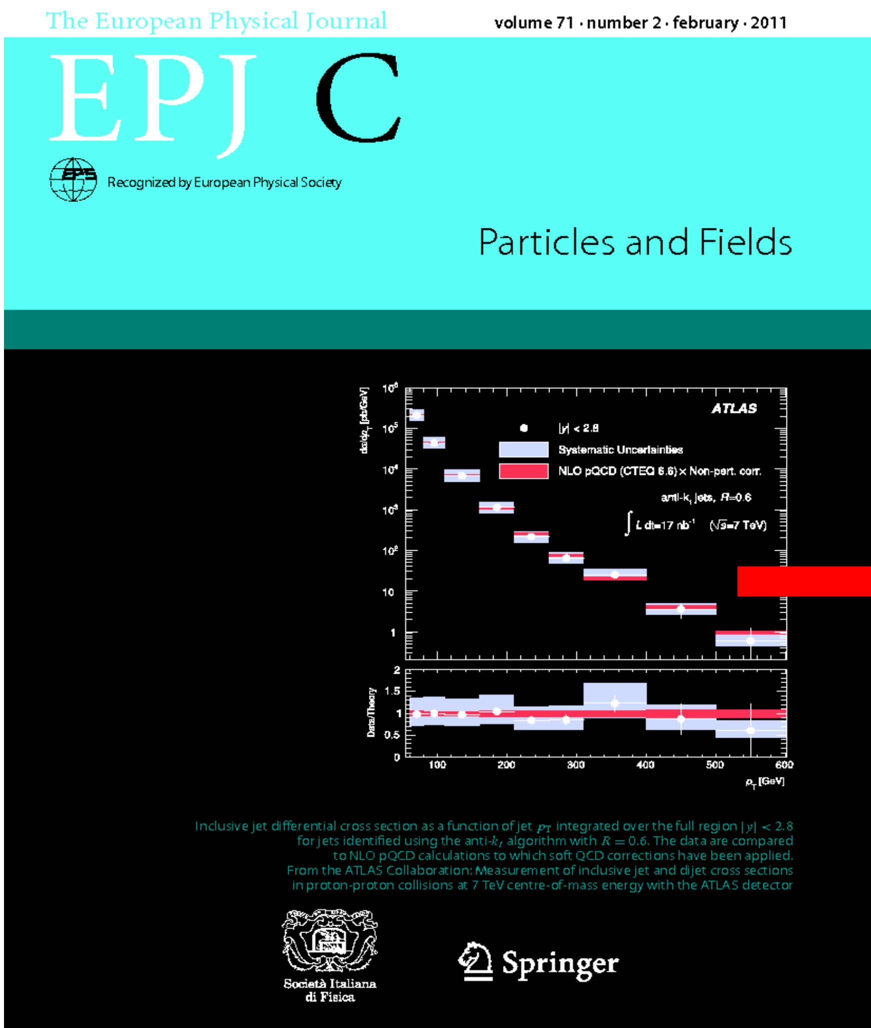
Highest p_T di-jet pair in 2010

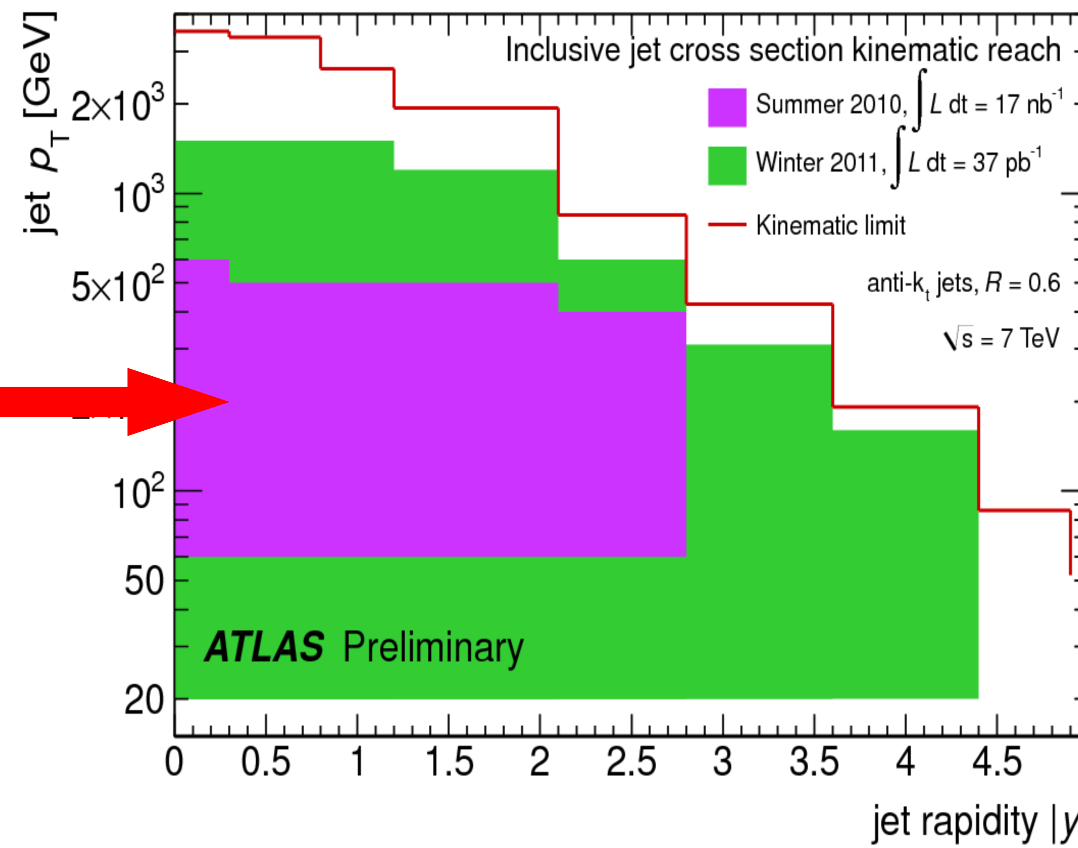


Dataset

Measurement of the jet cross sections at √s= 7 TeV
Probing perturbative QCD over 10 order of Magnitude

NEW KINEMATIC REGIME
Uncharted ground!!
Full 2010 dataset: 37 pb^{-1}





Theoretical Prediction

Fixed (next-to-leading) order calculations

→ NLOjet++, POWHEG

Parton showers

→In Q^2 , p_T^2 or angle (Herwig, Pythia, Sherpa)

Matched to tree-level ME

→High multiplicities (Alpgen, Sherpa)

→Higher order (POWHEG)

Also other large logarithms can be implemented

→HEJ fully re-summed, inspired by BFKL evolution

Make comparisons at the particle level

– Physically well-defined

– Requires application of soft corrections (Underlying event, hadronization) to the NLO

Z. Nagy, Phys. Rev. D68 (2003) 094002

S. Alioli et al arXiv:1012.3380 [hep-ph], arXiv:1002.2581[hep-ph]

M. Bahr et al. Eur. Phys. J. C58 (2008) 639–707.

G. Corcella et al., JHEP 01 (2001) 010

T. Sjostrand, S. Mrenna, P. Skands, JHEP 05 (2006) 026.

T. Gleisberg et al., J. High Energy Phys. 02 007 (2009).

M. L. Mangano et al., JHEP 07 (2003) 001.

J. R. Andersen and J. M. Smillie, arXiv:1007.4449 [hep-ph], arXiv:1101.5394 [hep-ph].

Data unfolding and systematics

Measurement corrected back to particle level by **bin-by-bin single correction.**

Systematics uncertainties on:

→Jet energy scale (dominant uncertainty)

→Jet energy resolution

} see C. Doglioni's talk

→Jet angular resolution, recon. efficiency, modeling of spectral shape in MC

Cross Section: Inclusive single and di-jet

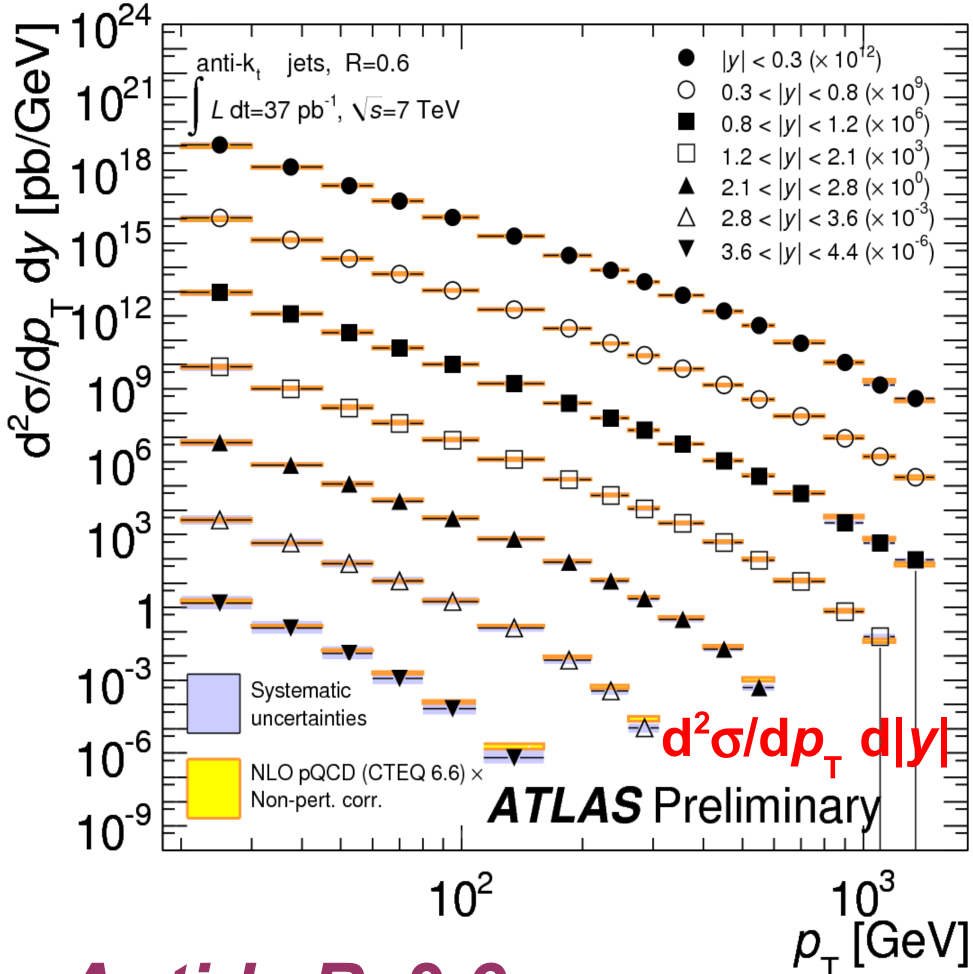
$p_T > 20$ GeV

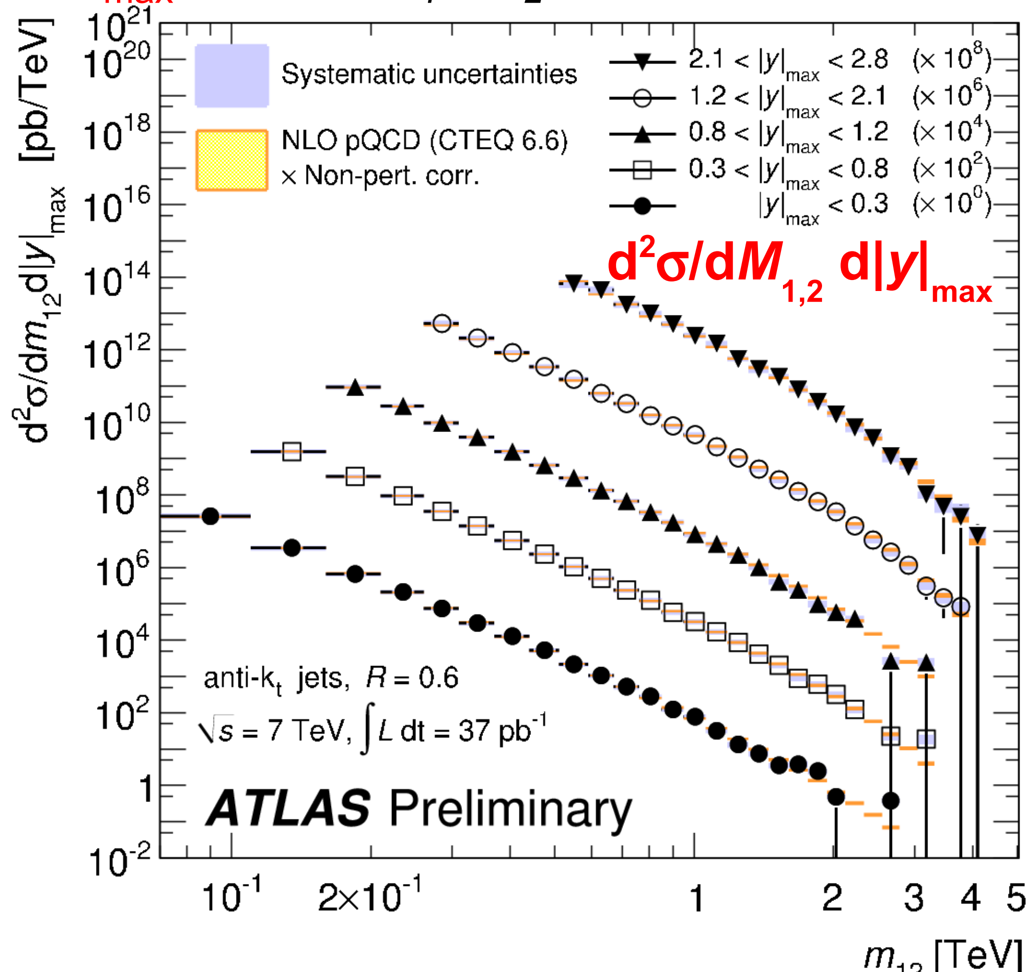
$|y| < 4.4$

$M_{1,2}$ *invariant mass leading 2 jets*

$p_{T,1} > 30$ GeV, $p_{T,2} > 20$ GeV

$|y|_{max} = \max(|y_1|,|y_2|) < 2.8$



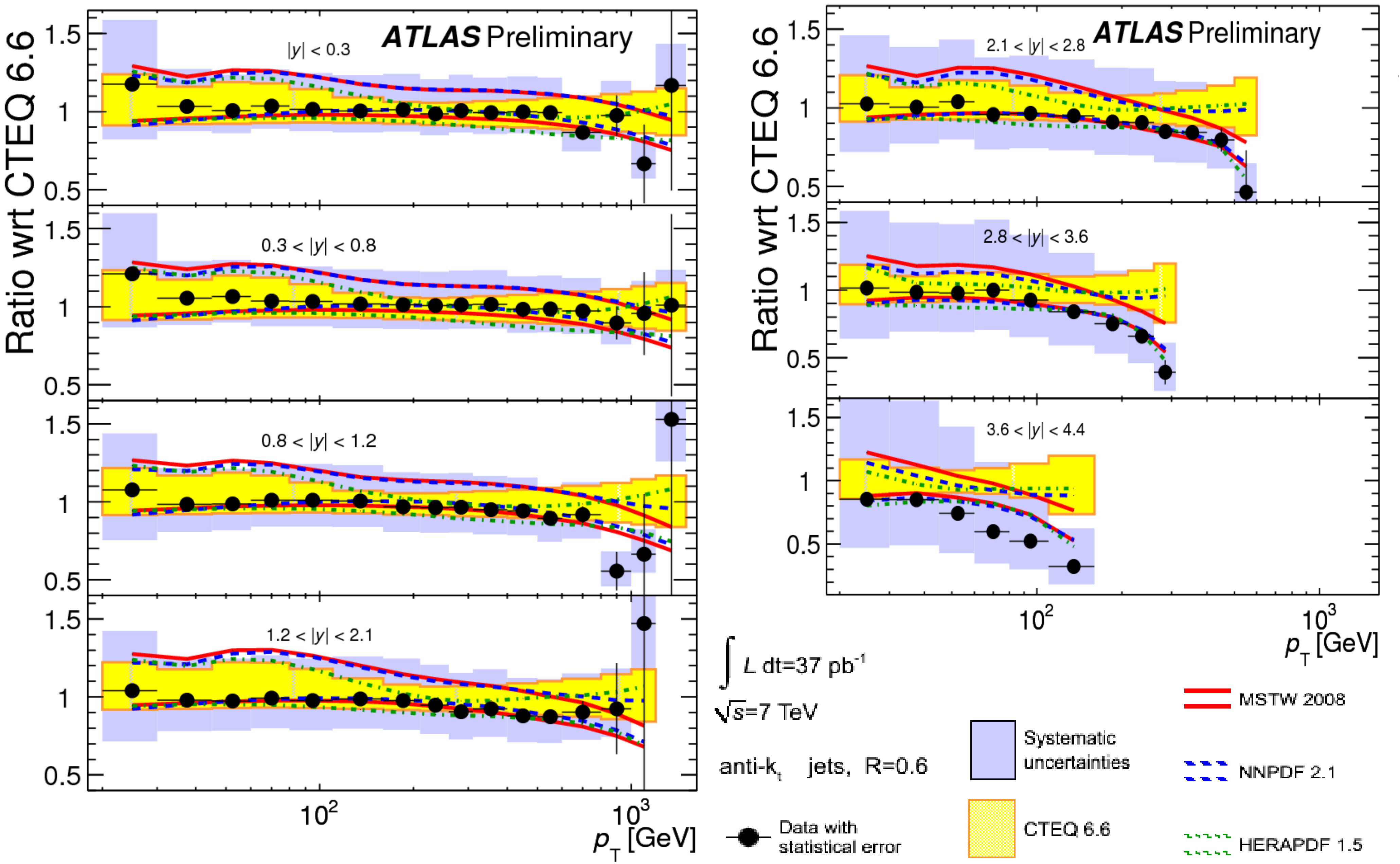


Anti-k_t R=0.6

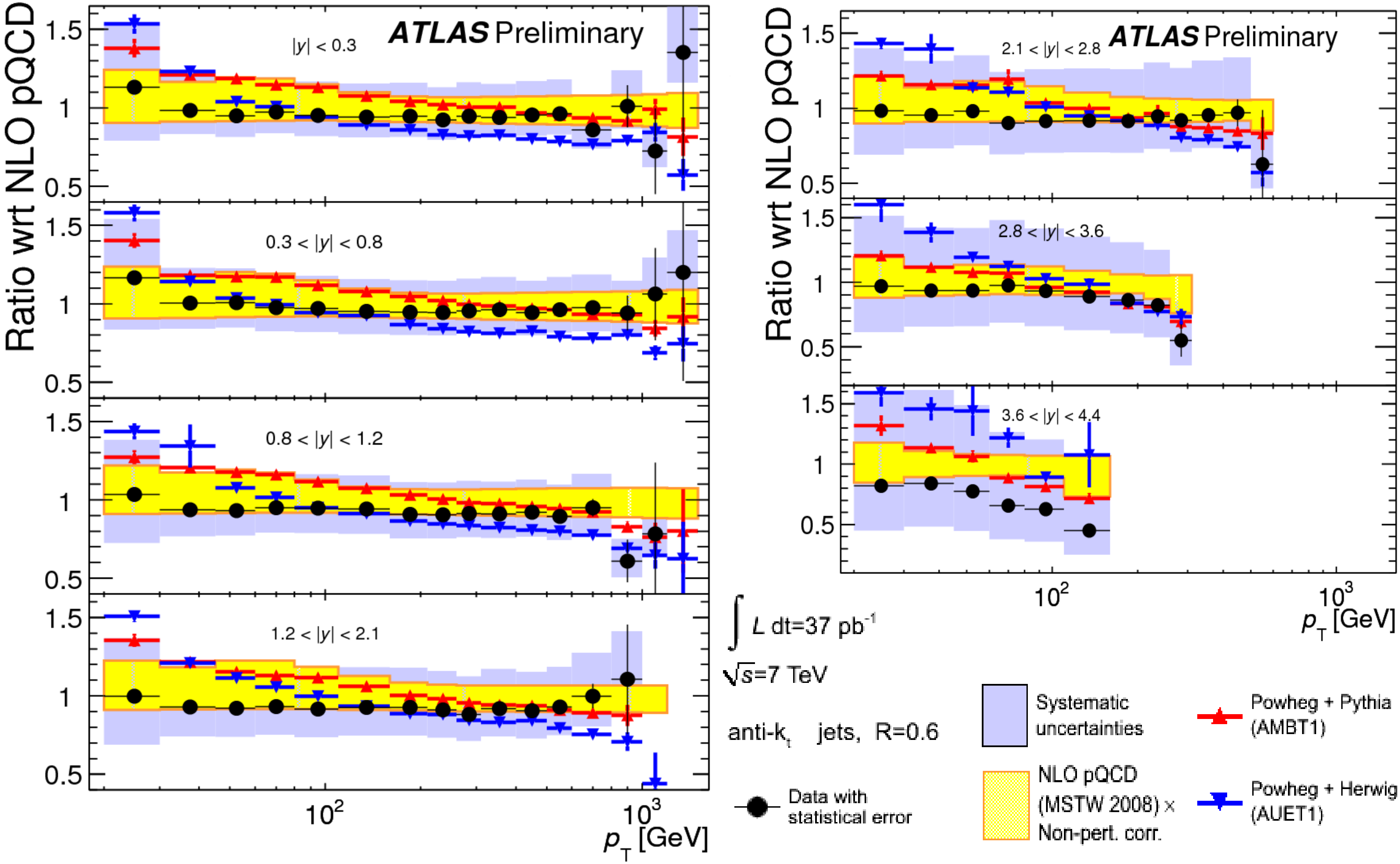
(R=0.4 in **ATLAS-CONF-2011-047**)

M. Cacciari, G. P. Salam and G. Soyez, JHEP 0804 (2008) 063

Inclusive jet: Ratios with NLO theory R=0.6



Inclusive jet: Ratios with Powheg *R*=0.6



Di-jet systems

Di-jet azimuthal decorrelation: arXiv:1102.2696

Transverse momentum: p_T>100 GeV Rapidity: $|y|$ < 2.8

$\Delta\varphi$ Leading 2 jets in p_T , with $|y_1|<0.8$, $|y_2|<0.8$

Di-jet production with a veto: arXiv:1107.1641

Transverse momentum: p_T > 20 GeV Rapidity: $|y|$ < 4.4

Jet selection criteria:

1) Leading 2 jets in p_T 2) Most forward and most backward

Gap veto:

if a jet with $p_T>Q_0$=20 GeV in the rapidity gap inside the di-jet syste

$\Delta y= |y_1-y_2|$ $\bar{p}_T=(p_{T,1}+p_{T,2})/2$ > 50 GeV

Gap fraction=(# events passing the Gap veto)/(all events)

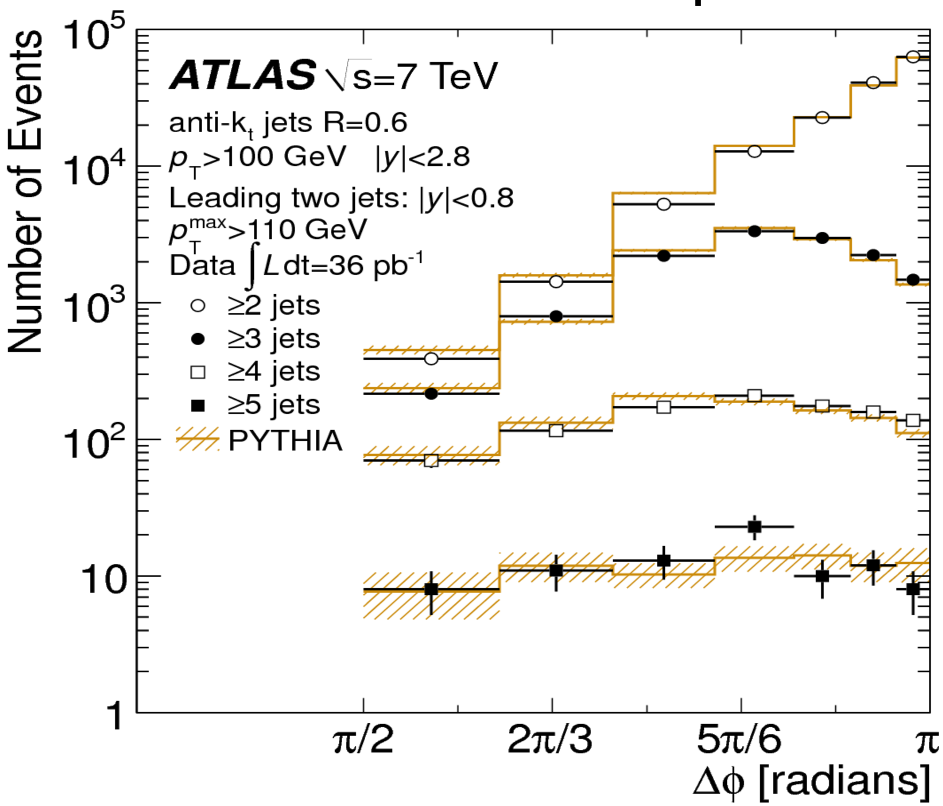
Jet algorithm: anti-k_T jets R=0.6

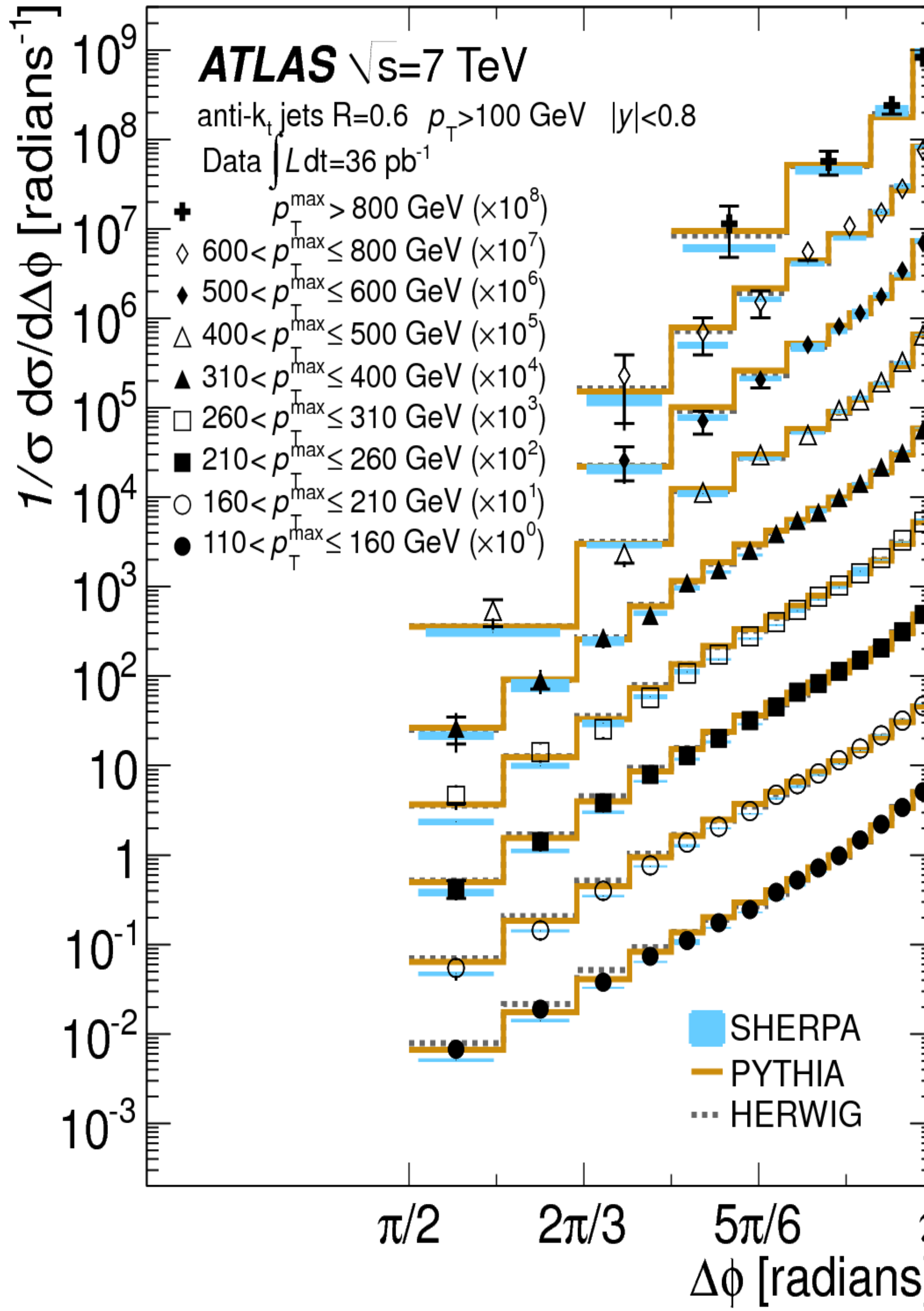
Integrated luminosity: 37 pb^{-1}

Di-jet azimuthal decorrelation

Indirect way to test extra radiation in the di-jet system

MC predictions (and NLO) generally describe the measured spectra.





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Di-jet + veto

POWHEG + PYTHIA

generally agrees with data

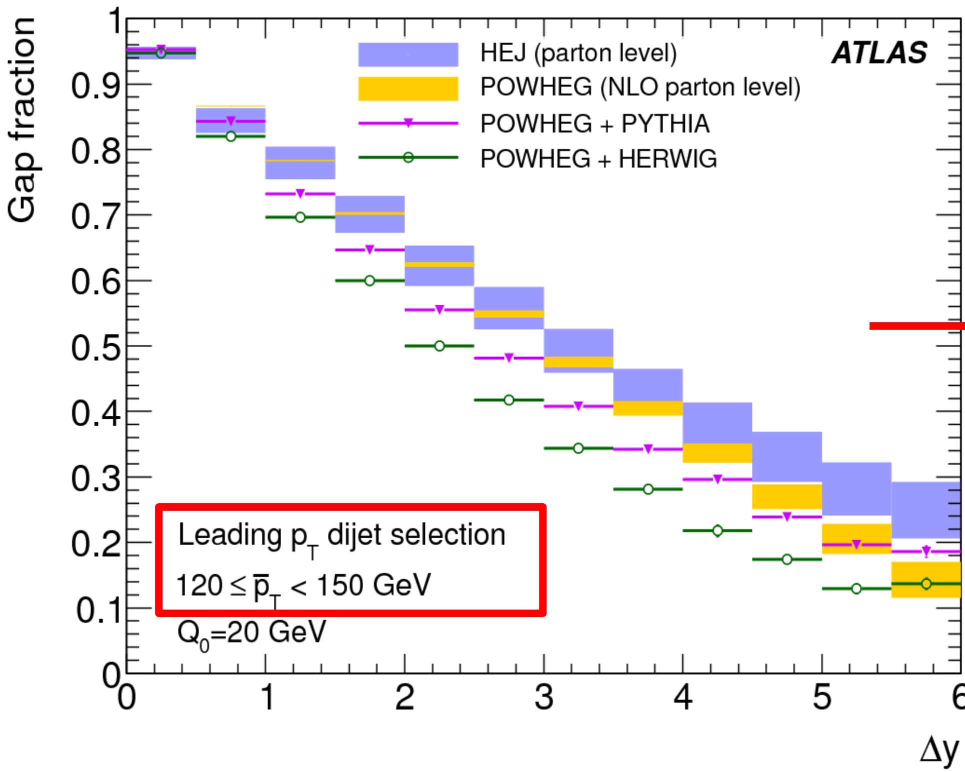
HEJ

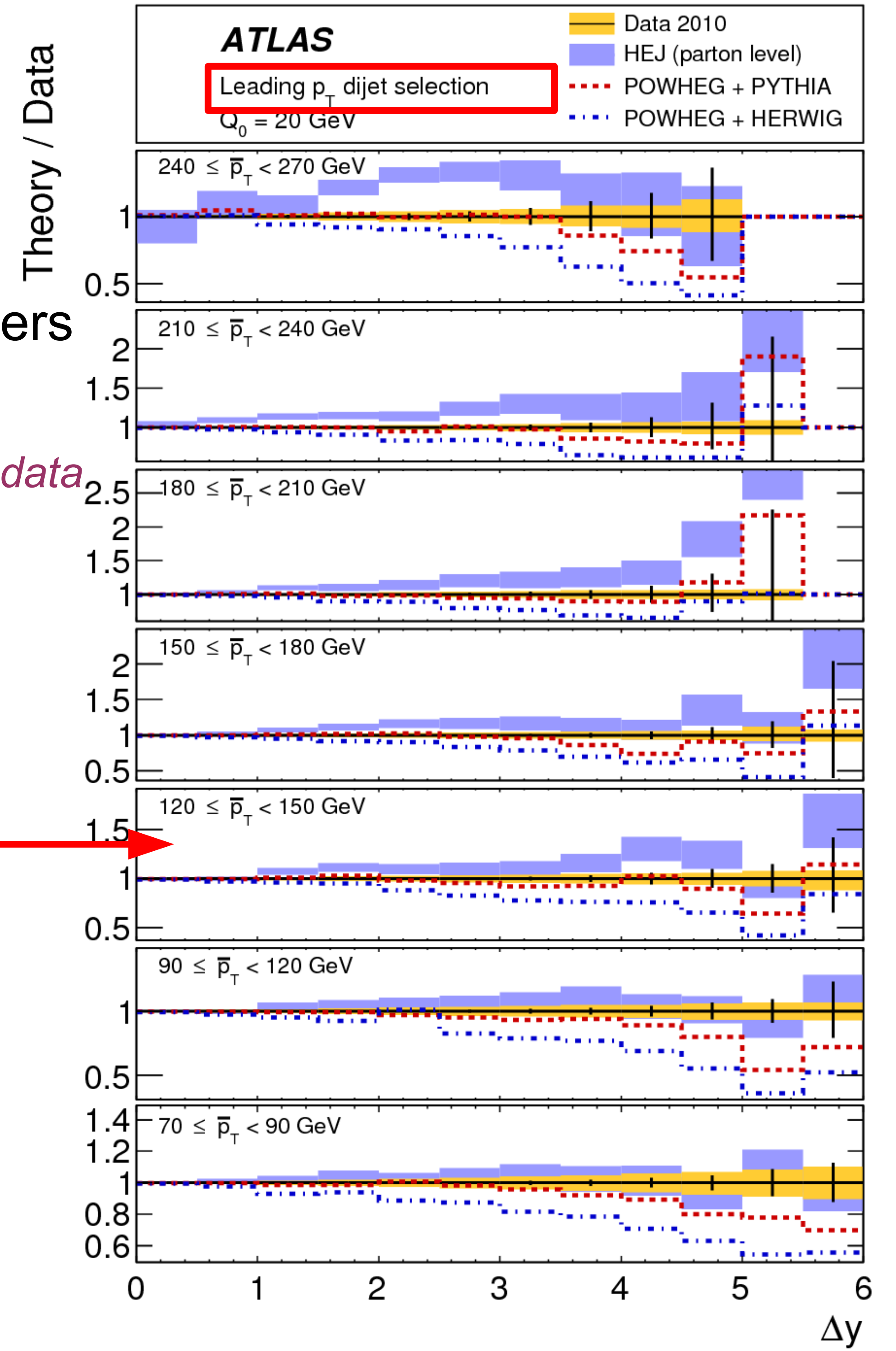
agrees better in some places than others

These results triggered a quick theory reaction:

R.M. Duran Delgado at al, arXiv:1107.2084

"The message is clear: the accuracy of the ATLAS data already demands better theoretical calculations"





Multi-jets cross sections

arXiv:1107.2092

A first step toward the measurement of complex QCD final states

- Important as a measurement in itself
- Fundamental to start the controls for the QCD background for searches.

Transverse momentum: $p_T > 60$ GeV Rapidity: $|y| < 2.8$

Leading jet: $p_{T1} > 80$ GeV.

Multi-Jet cross section:

- Jet multiplicity
- p_T spectrum for the 1st, 2nd, 3rd, 4th jet (ordered in p_T)
- $H_T = \Sigma \boldsymbol{p}_T$ distribution for different multiplicity
- Ratio $\mathbf{R}^{32}(H_T^{(2)}) = d\sigma^{N\geq 3} / dH_T^{(2)} \,/\, d\sigma^{N\geq 2} / dH_T^{(2)}$

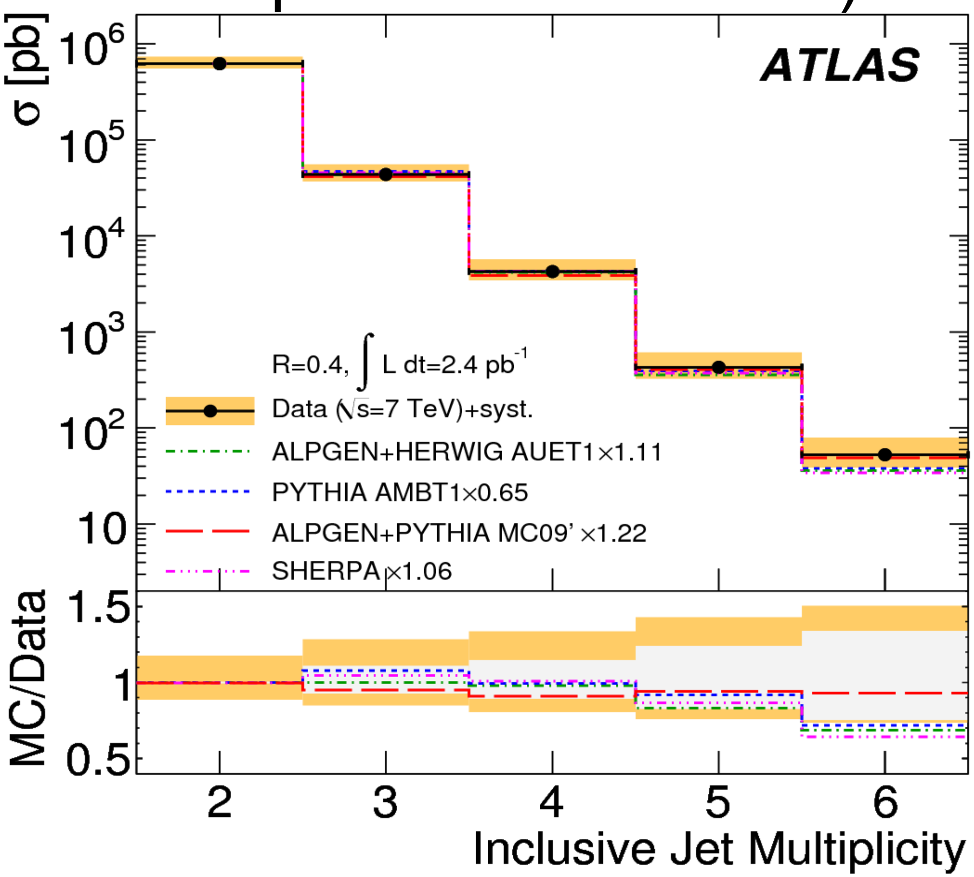
Jet Algorithm: anti-k_T jets with R=0.4 (and R=0.6 for testing NLO)

Integrated Luminosity: 2.43 pb^{-1}

Multi-jets cross sections

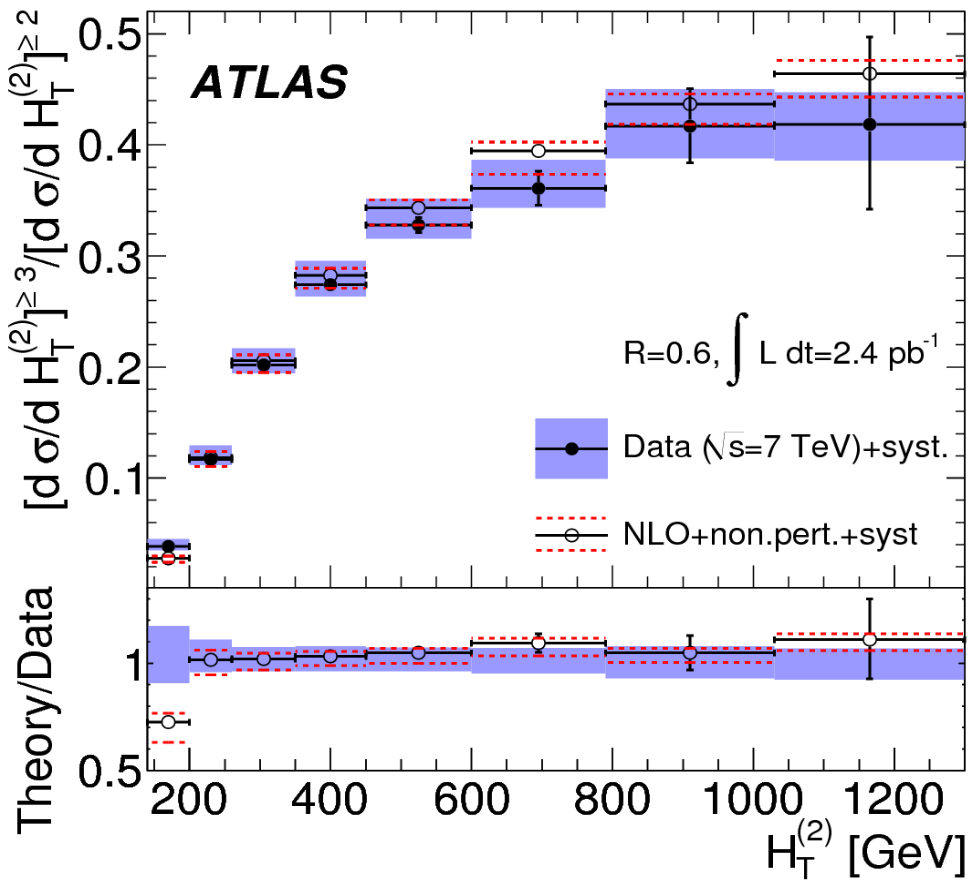
Alpgen describes better the data.
Pythia has a factor 0.65

(In gray the relative sys. error with respect to the first bin)



$H_T^{(2)} = \Sigma p_T$ of two leading jets

Inclusive variable to describe the events.
The ratio reduces the systematics



Conclusions

Exciting period for the QCD analysis at LHC

A rich program of QCD measurements begun
with the LHC collisions.

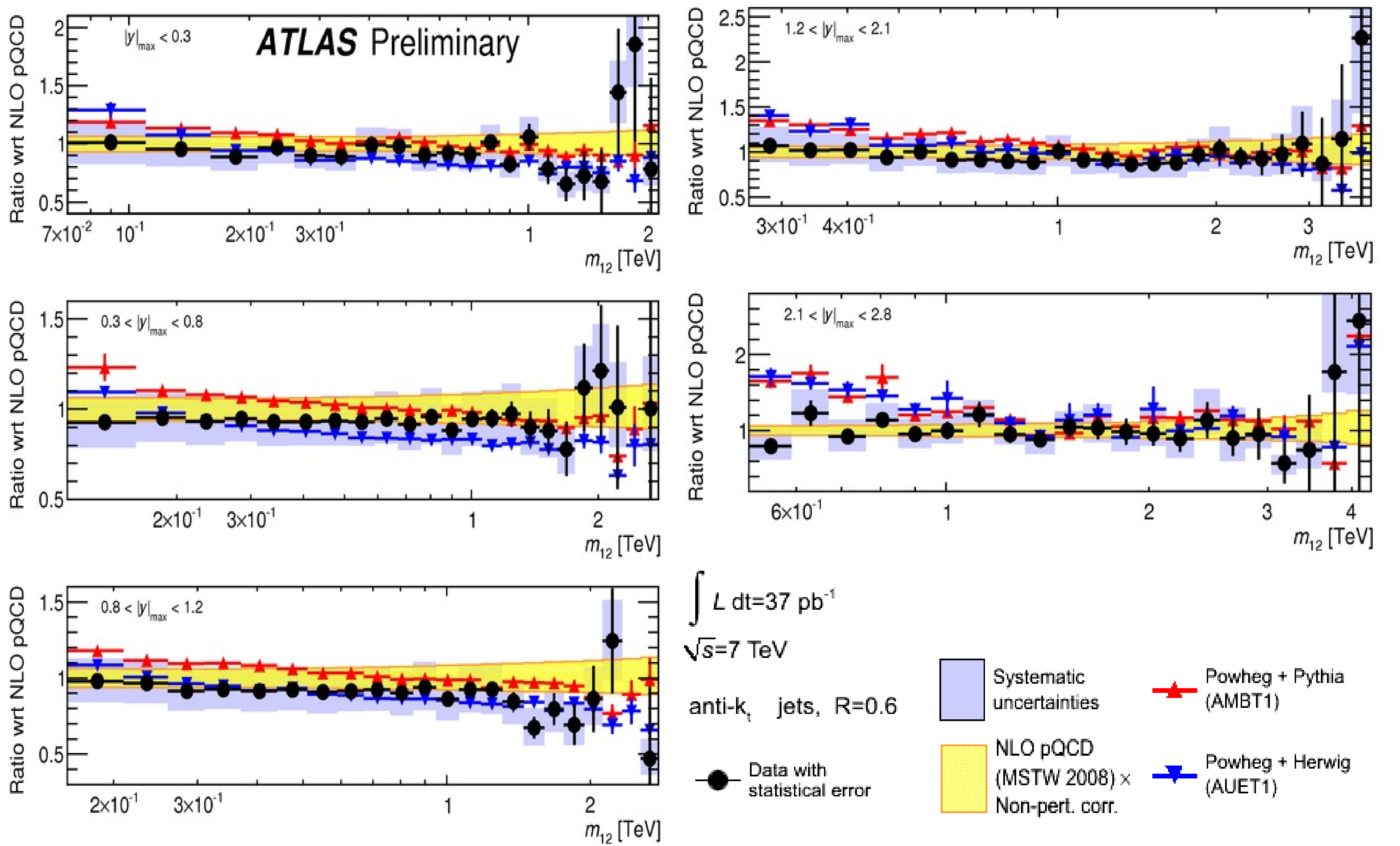
ATLAS is performing very well, triggering on and
measuring jets over a huge range

Most of the analysis have been improved in the last months:
By a deeper understanding of the detector (smaller systematic)
By increasing the statistics

Ready to digest the 1st fb^{-1} of data recorded in 2011

BACKUP

Di-jet cross section compared with Powheg



Cross Section: Inclusive single and di-jet

ATLAS-CONF-2011-047

Inclusive single jet cross sections:

$$d^2\sigma/dp_T \, d|y|$$

Transverse momentum: $p_T > 20$ GeV   Rapidity: $|y| < 4.4$

Di-jet cross-sections:

$$d^2\sigma/dM_{1,2} \, d|y|_{max}$$

$M_{1,2}$ is invariant mass of first two leading jets with $p_{T,1} > 30$ GeV and $p_{T,2} > 20$ GeV

$|y|_{max} = \max(|y_1|,|y_2|)$ with y_1 and y_2 rapidity of two leading jets $|y|_{max} < 2.8$

Jet algorithm: anti-k_T jets with R=0.4 and R=0.6

M. Cacciari, G. P. Salam and G. Soyez, JHEP 0804 (2008) 063

Integrated luminosity: 37 pb^{-1}