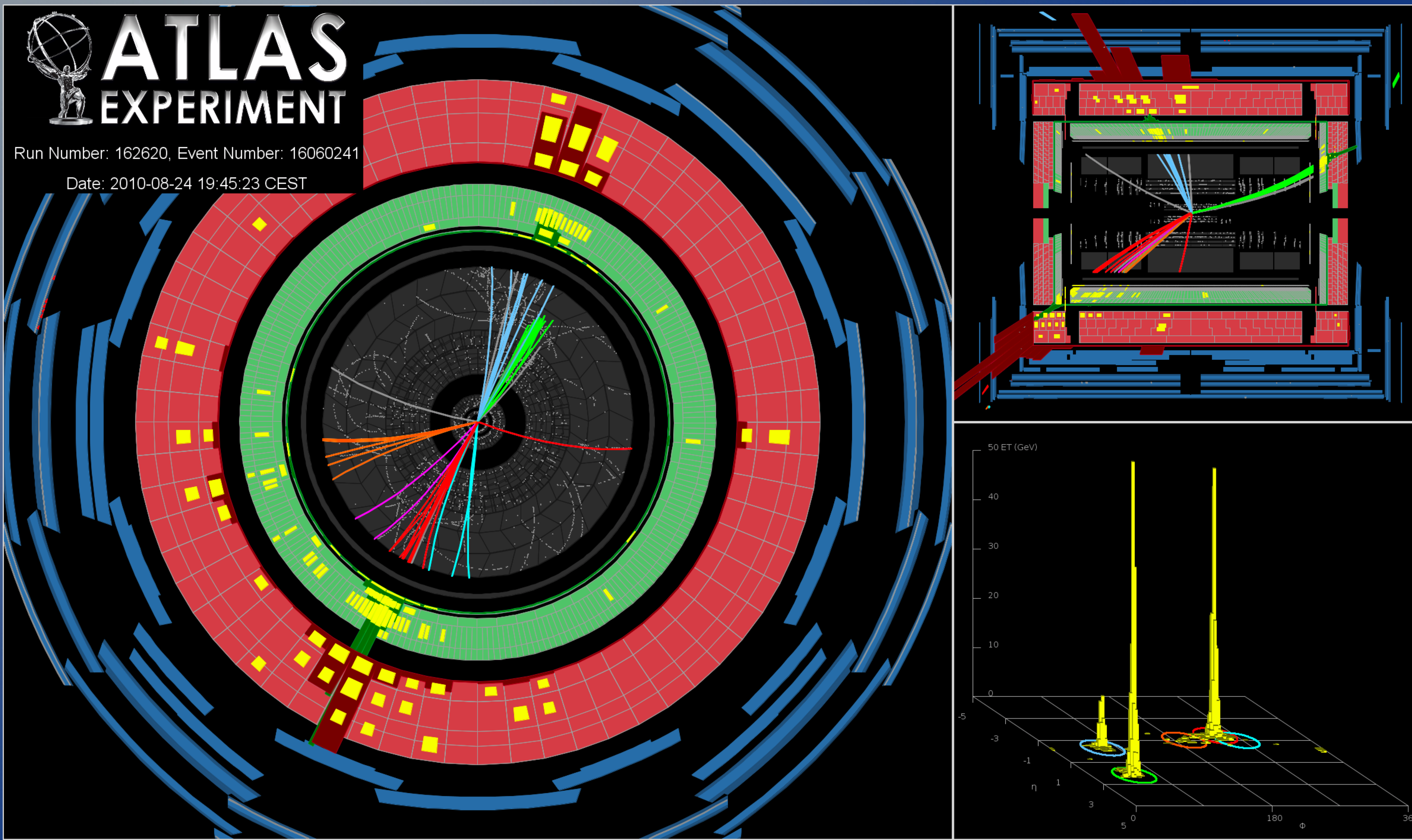
Jet cross-section and jet veto measurements in ATLAS

Mario Campanelli/ UCL



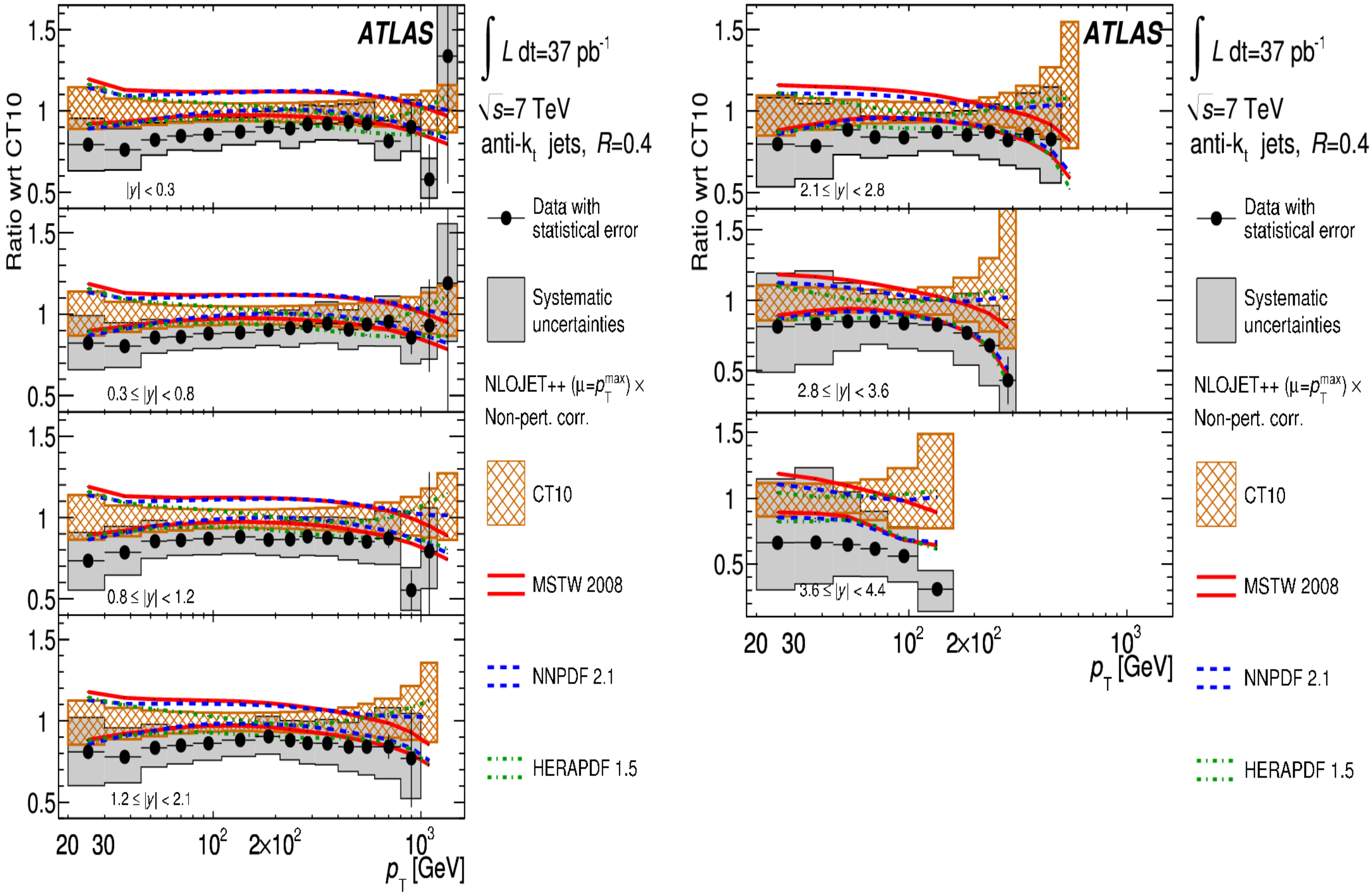
Why measuring inclusive and dijet cross-section

- One of the most common processes at the LHC
- Theory known to NLO up to 3 jets, much more for gluon-only final states
- Fundamental ingredient of PDF fits
- New physics can show up in peaks in dijet mass, or deviations in the pt spectrum

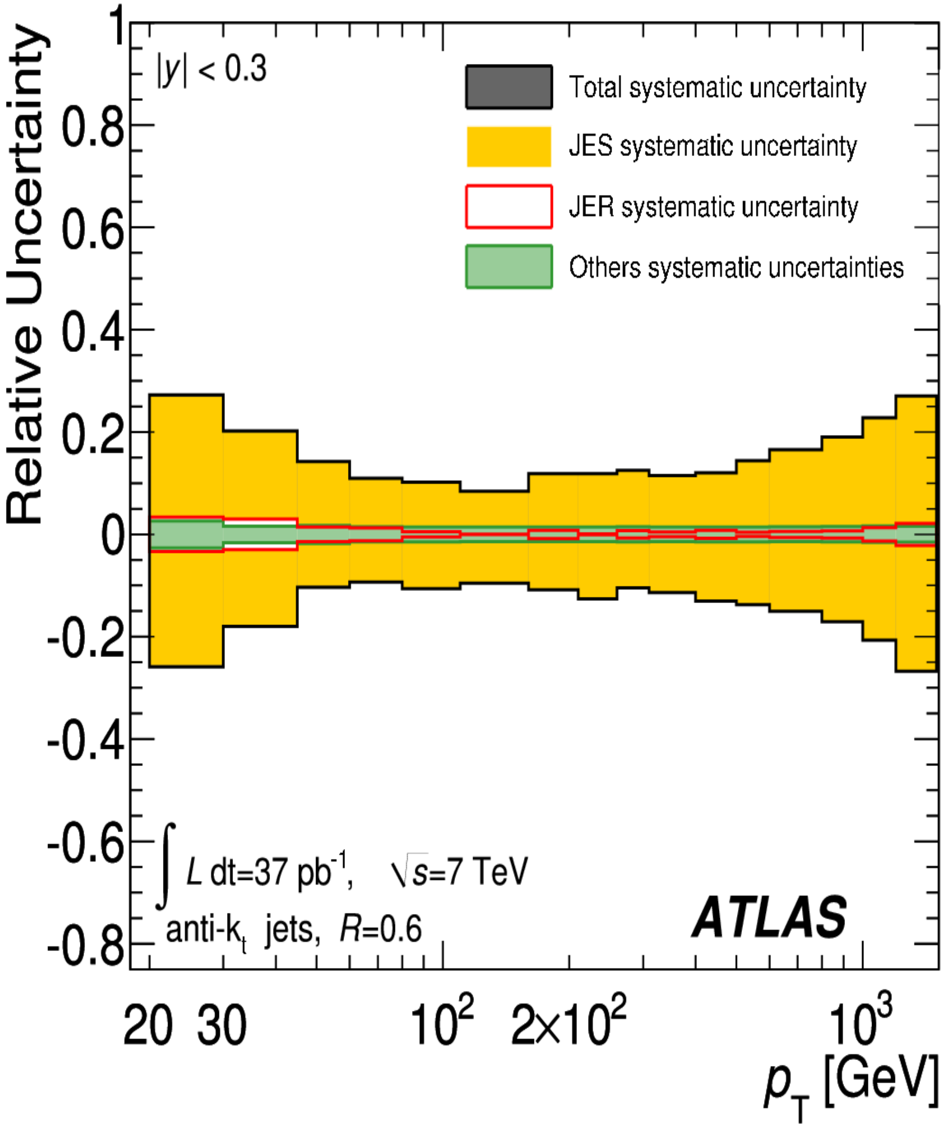
→ important to have quantitative statements on agreement between data and theory

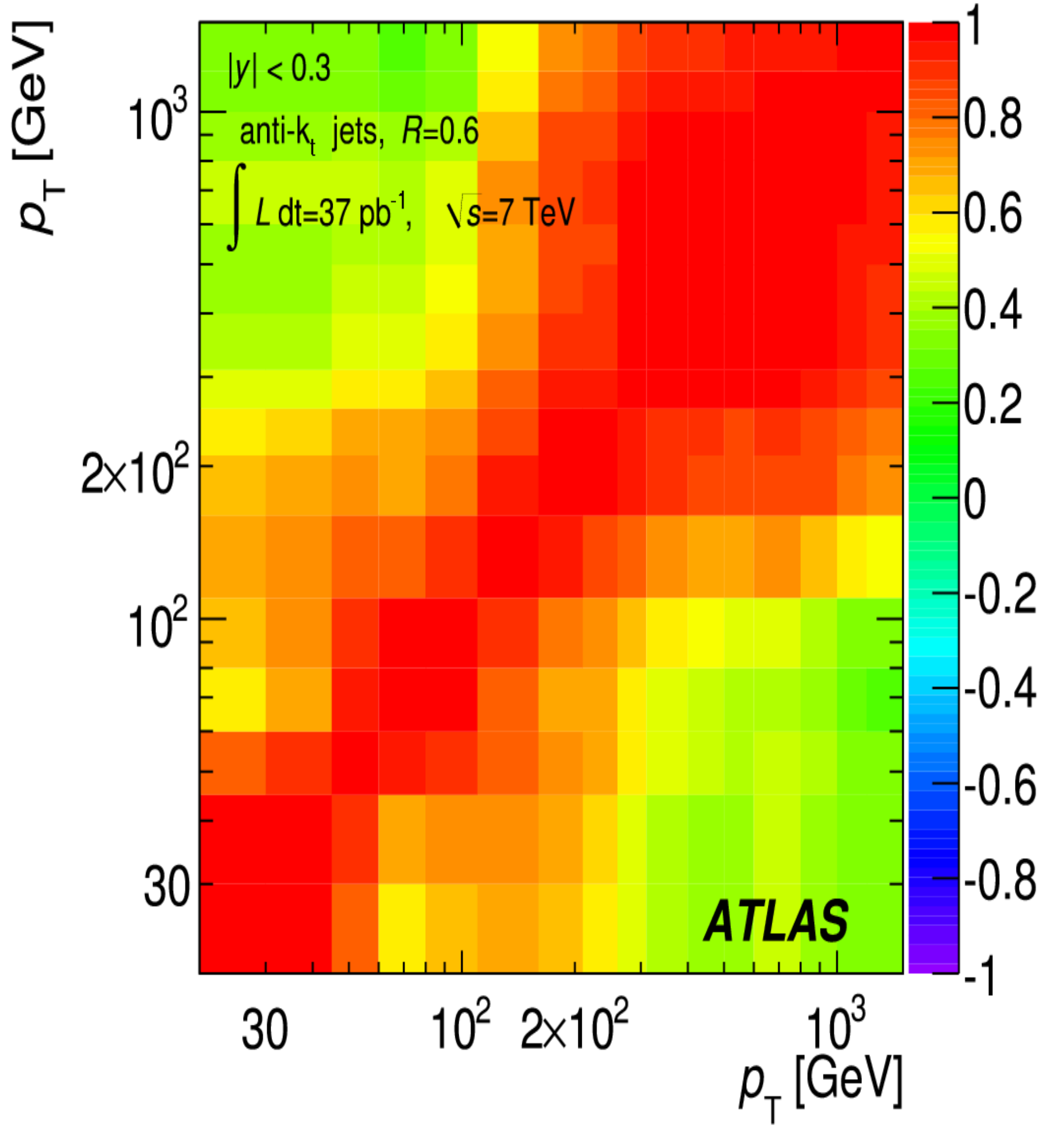
Experimental results much more useful when they include quantitative comparisons with theoretical models

ATLAS 2010 inclusive jets PRD86 (2012) 014022



But systematics large and dominant, with large correlations. Can't estimate agreement looking at plots





A more sophisticated approach is needed

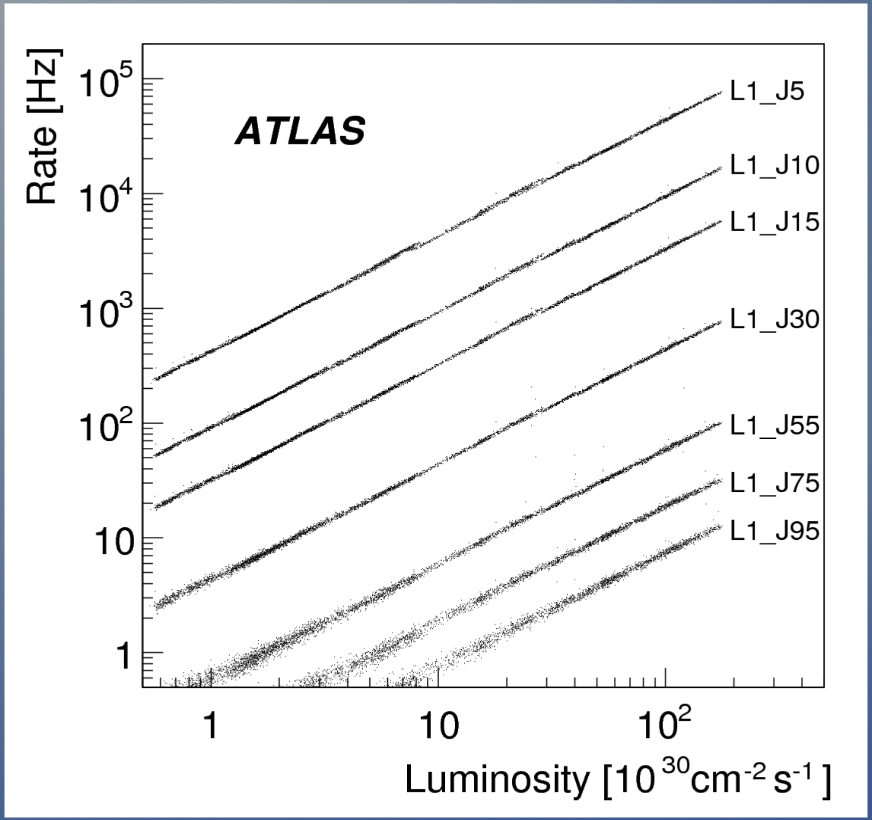
The 2011 dijet ATLAS measurement JHEP05 (2014) 059

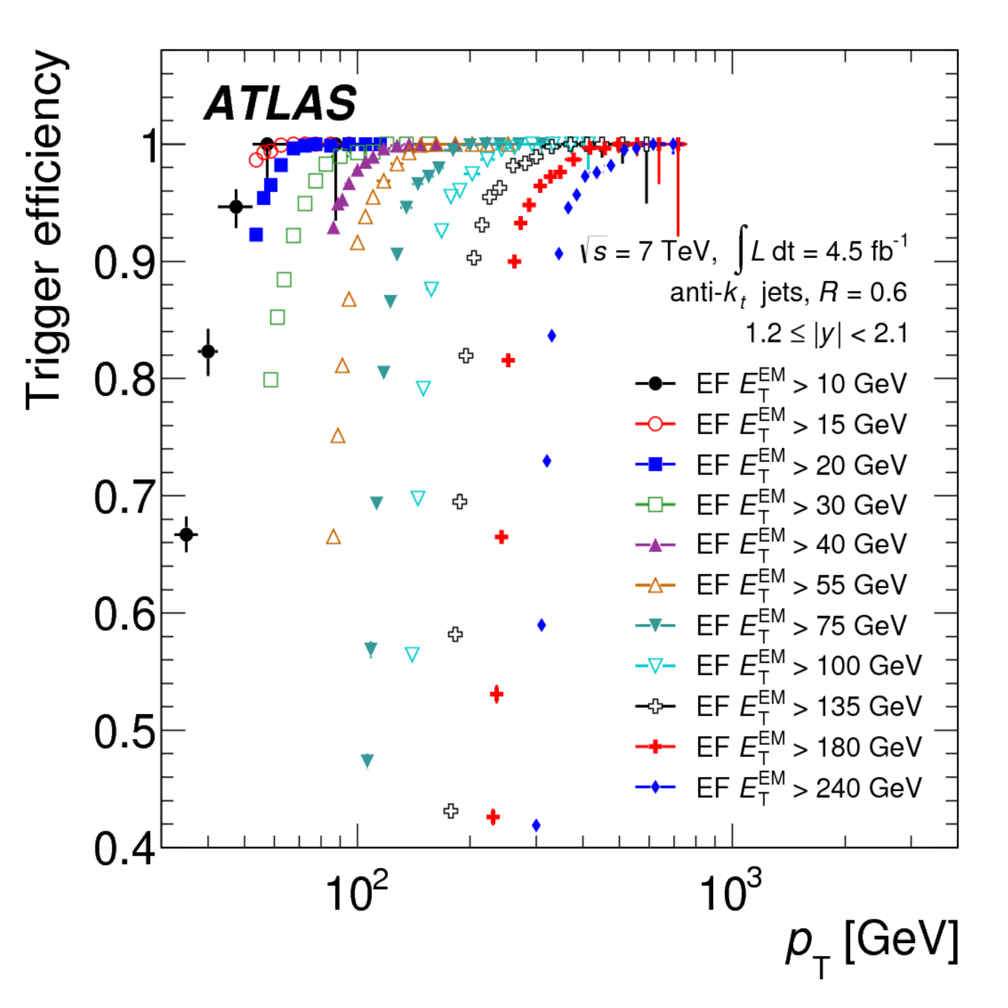
As for the 2010 measurement, provide all information needed for a quantitative estimation of agreement between data and various theory models

Quantify the agreement using a frequentist technique

Set limits on new physics using UNFOLDED distributions, allowing any new theory to be properly compared to these data

Triggering on jets





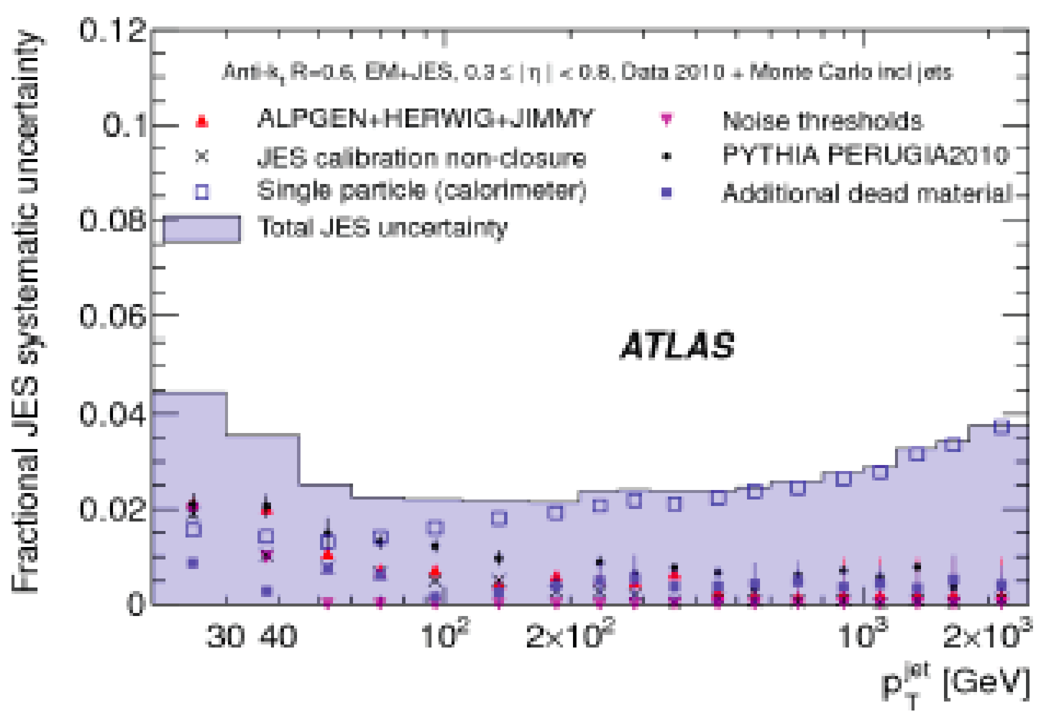
Jet production is the most common process at the LHC, and can be measured over several orders of magnitude.
NLO QCD can be tested over a wide range, and sensitivity to PDF's (derived before LHC data) can be strong

Jet reconstruction in ATLAS

3-dimensional topological clusters in the calorimeter are locally calibrated and combined with the anti-kt algorithm (R = 0.4,0.6). Calibration constants for 2011 derived using in-situ methods (arXiv:1406.0076)

Tracking only used to establish systematics from double ratio, and to count vertices for pileup correction

Eur. Phys. J. C, 73 3 (2013) 2304



Systematic uncertainties from detector and modeling, validated in situ with γ-jet and dijets

Theory comparison

NLO accuracy available:

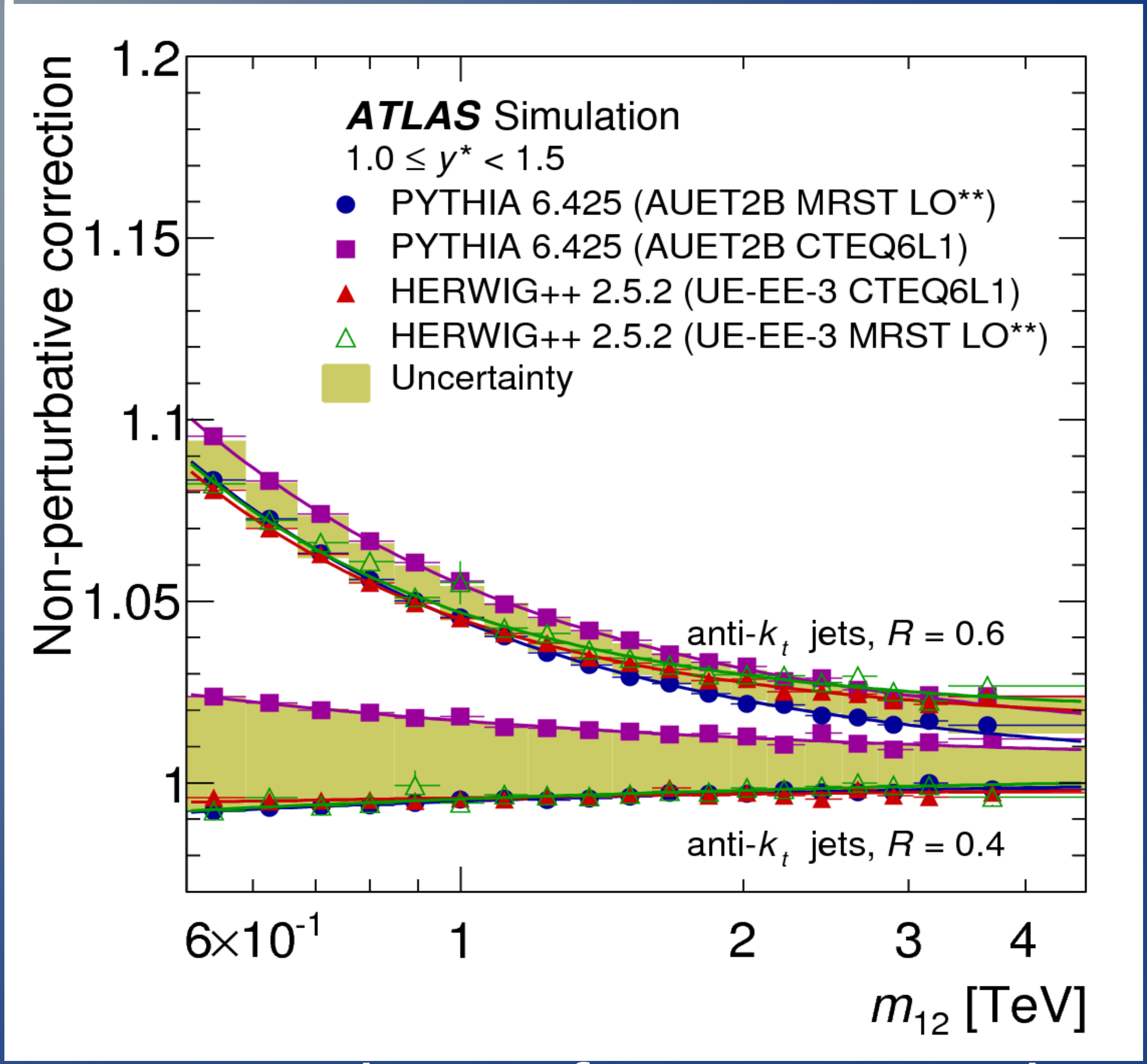
- At parton level, using NLOJet++
- With parton shower matching, using POWHEG

Both are compared to data, but new physics models and several PDF sets are only generated in the NLOJet++ framework

EW corrections included, (Dittmeier et al. JHEP 11 (2012) 095)

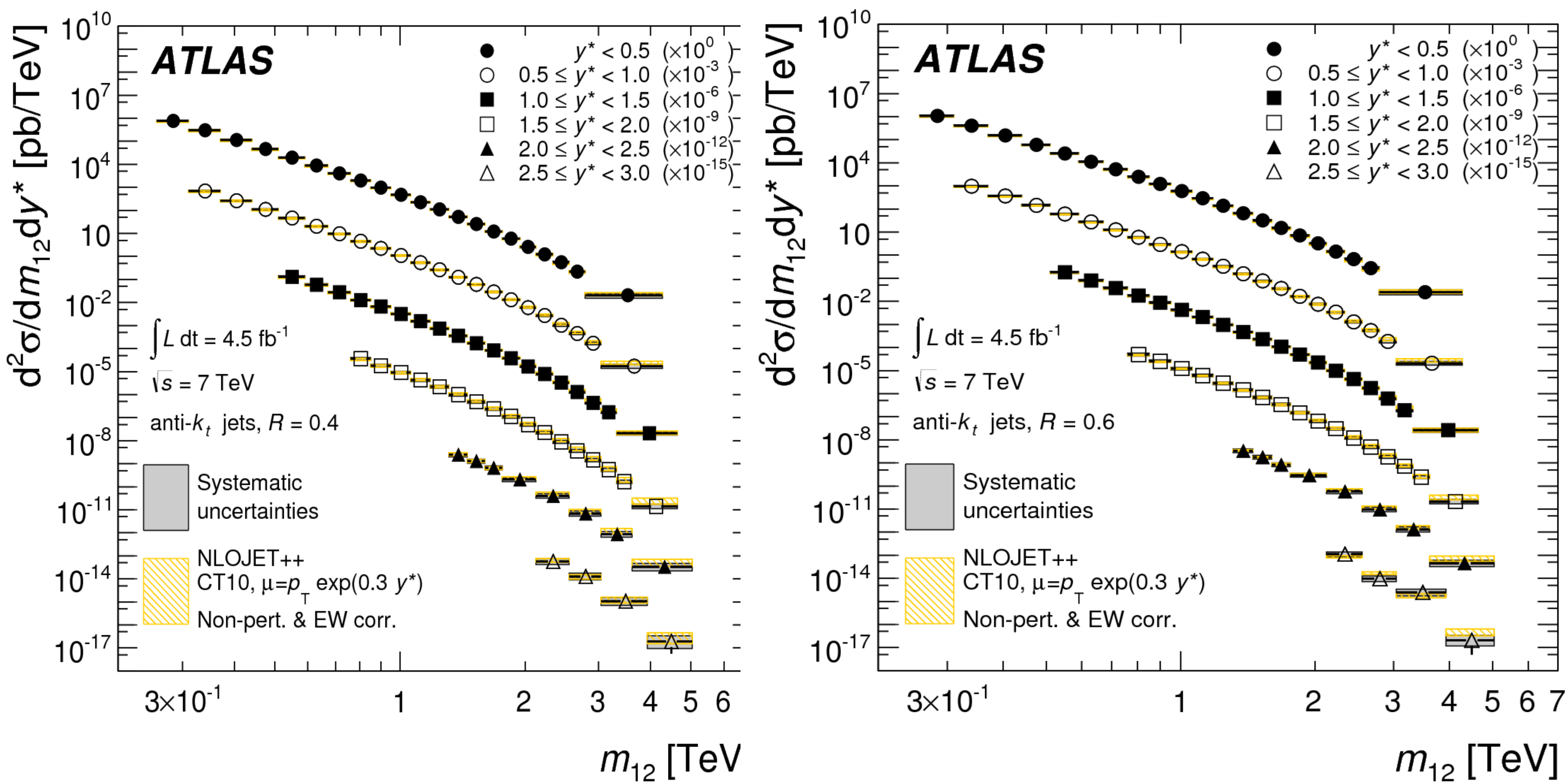
Non-perturbative corrections used to convert particle level from parton level. Differences between models used as systematics

Non-perturbative effects corrections



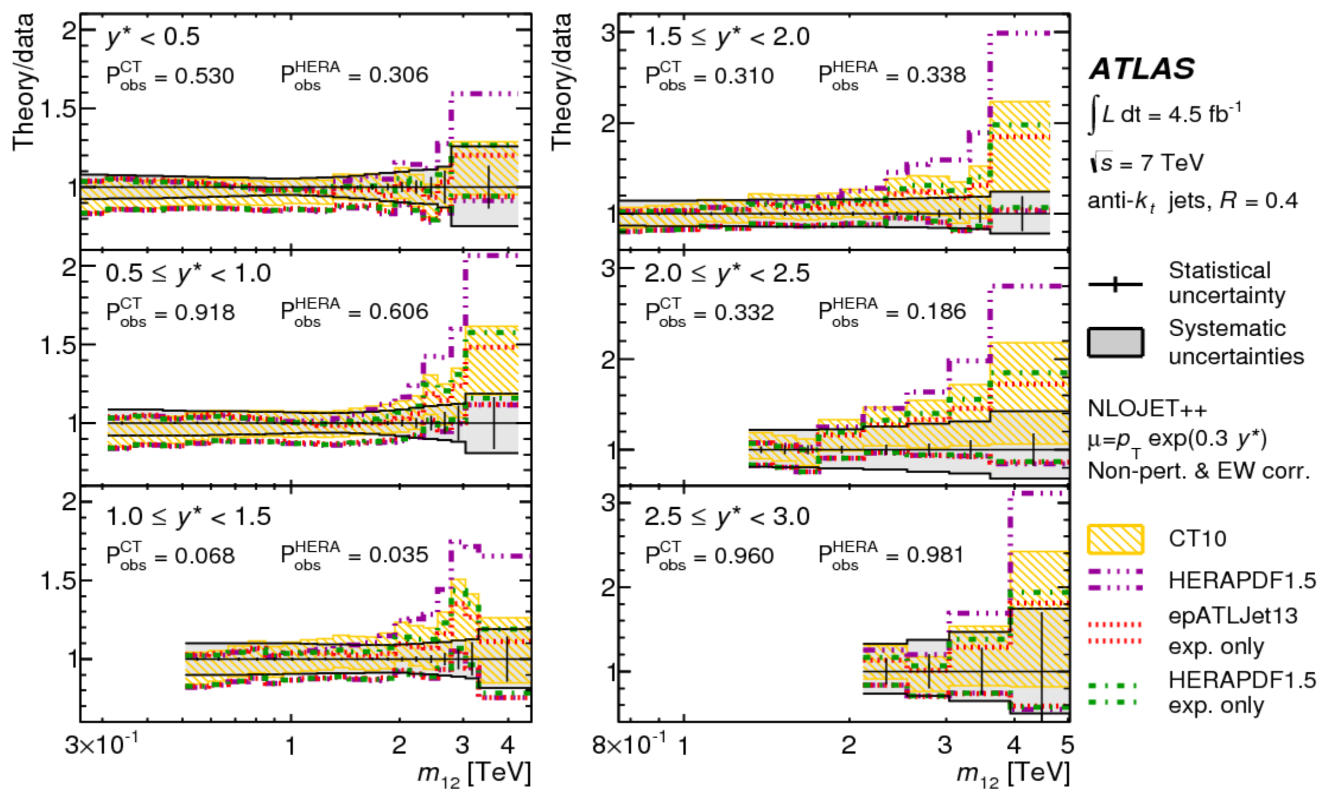
Underlying event and out-of-cone corrections very different between the two jet sizes, so interesting to measure both

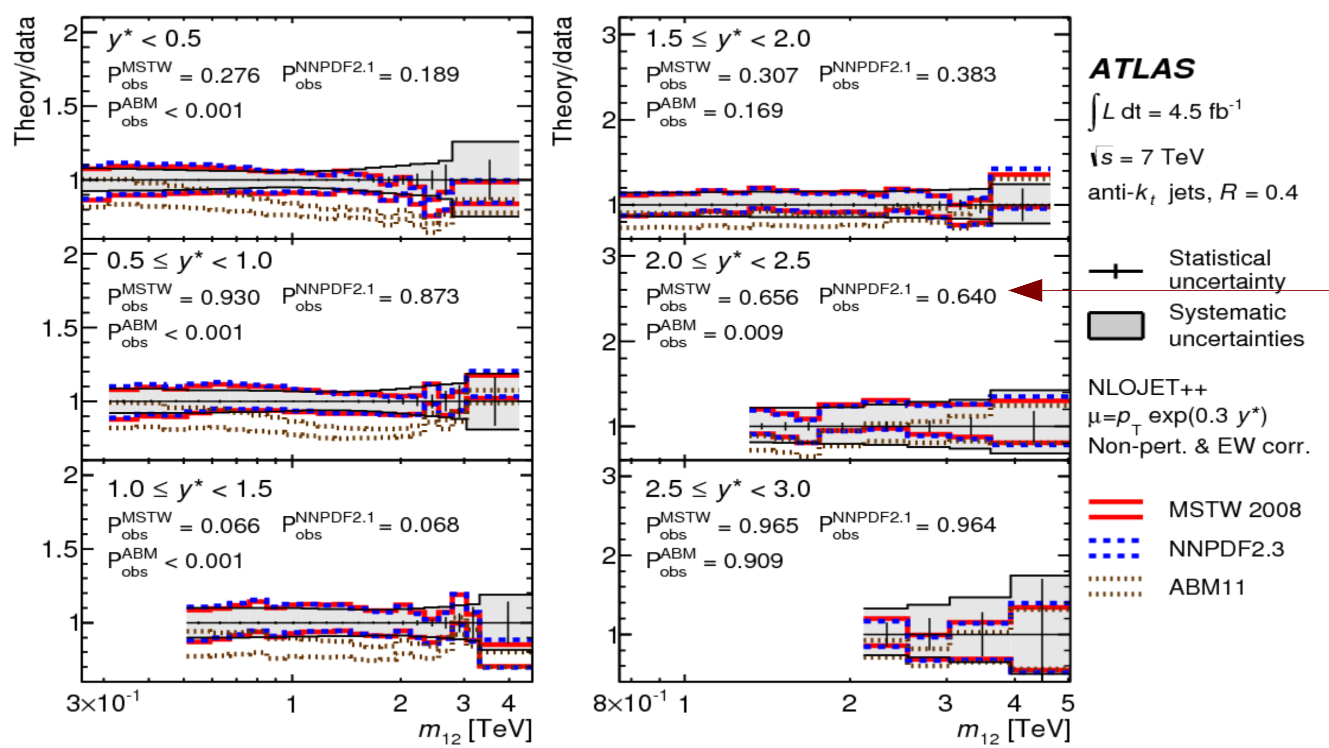
Cross-section results



Measurement spanning several orders of magnitude

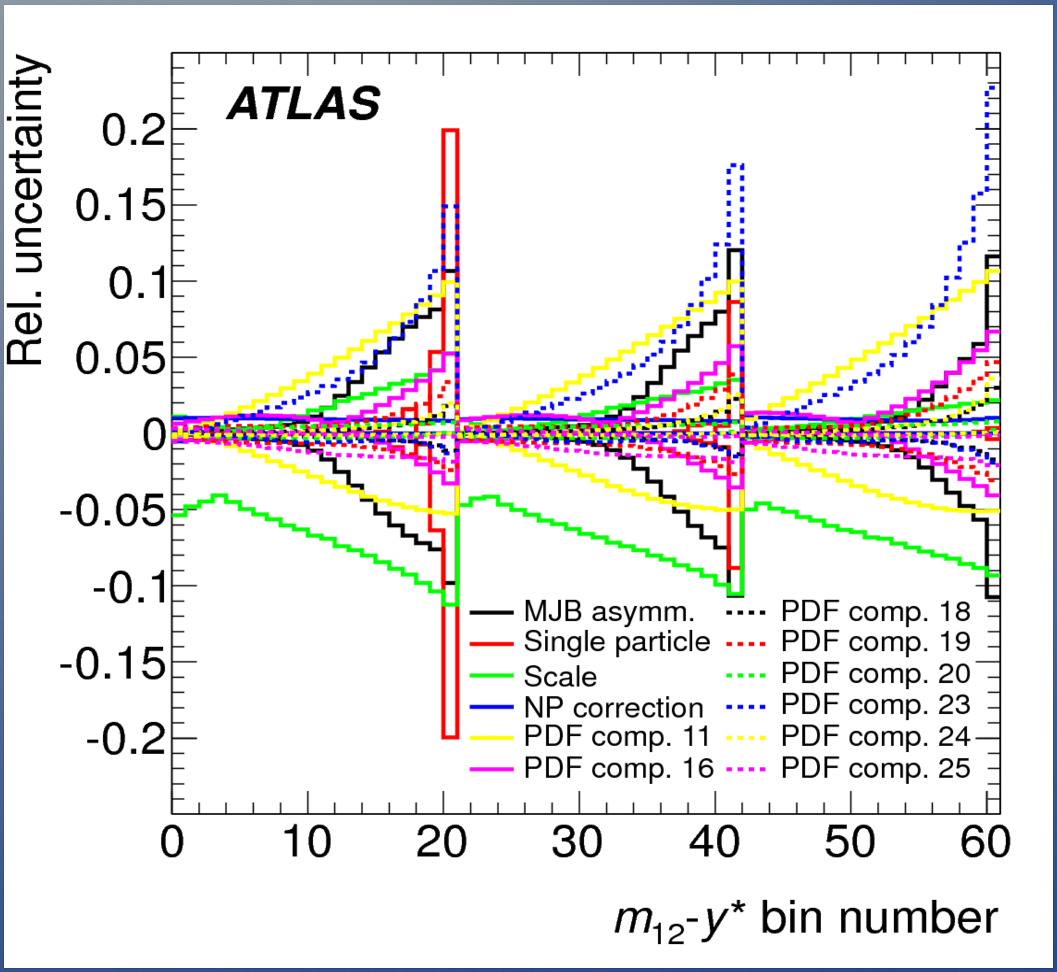
Atlas 2011dijets: comparisons with PDF's

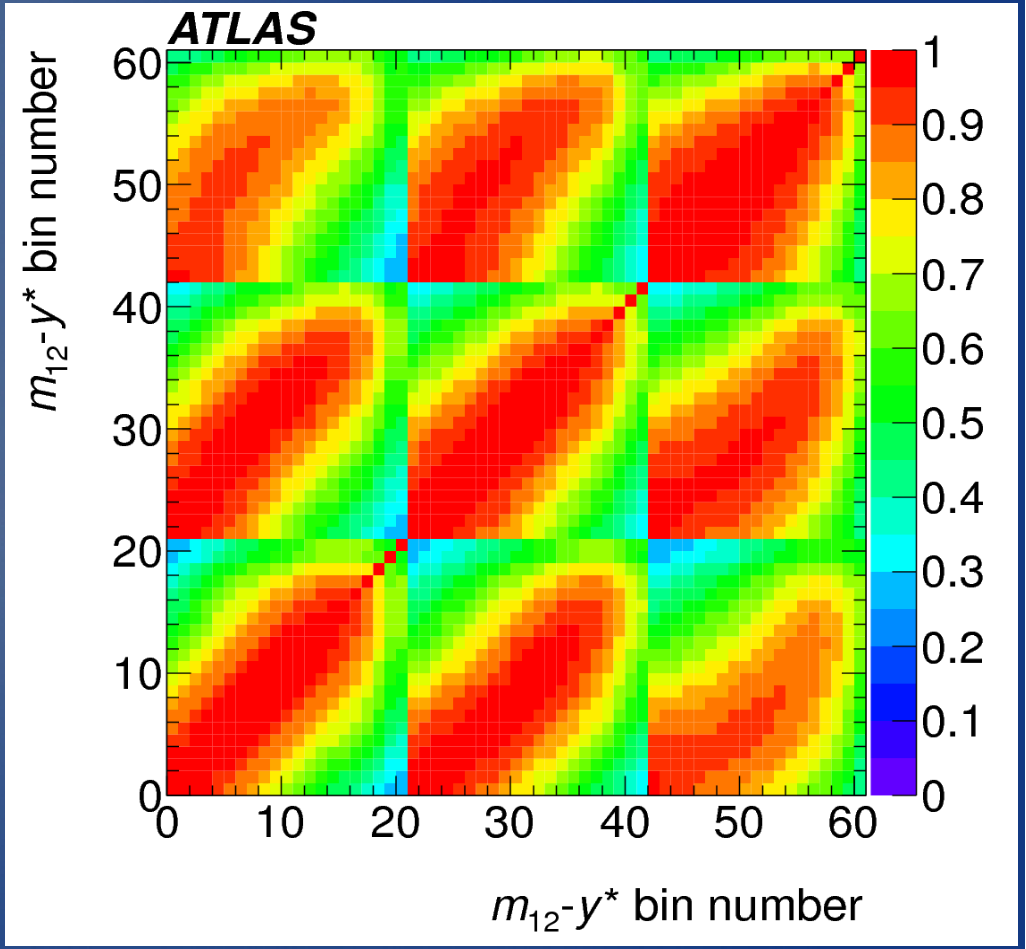




P-values in reasonable ranges, apart from ABM11

Systematic uncertainties and correlations



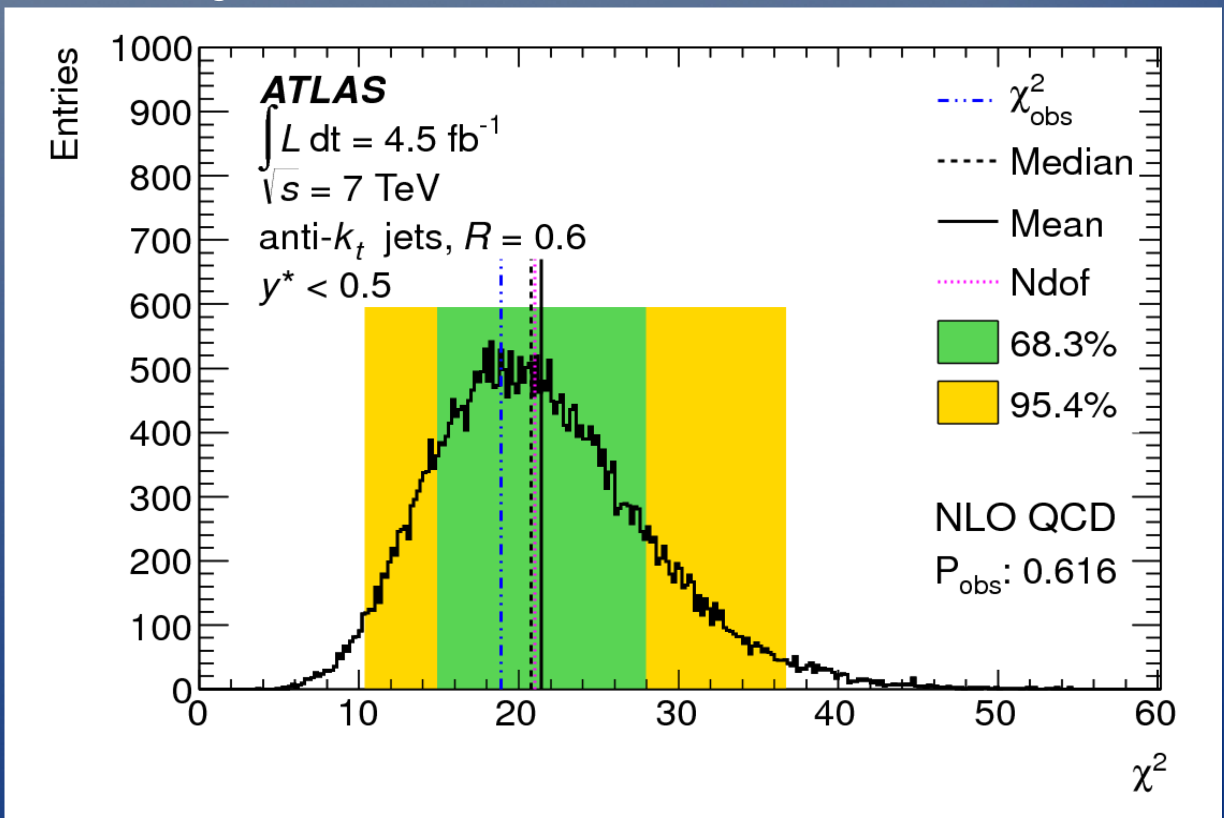


The 2d space m12-y* has been linearised to obtain 1- or 2-dimensional distributions

Statistical interpretation

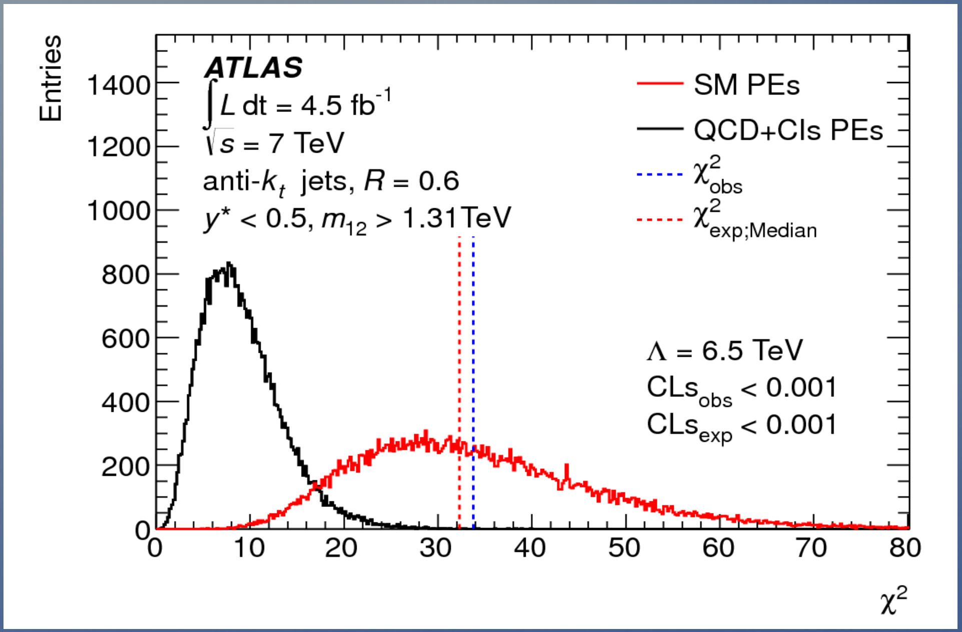
Using a frequentist approach: pseudo-experiments are generated by varying the theory prediction according to its uncertainties and correlations

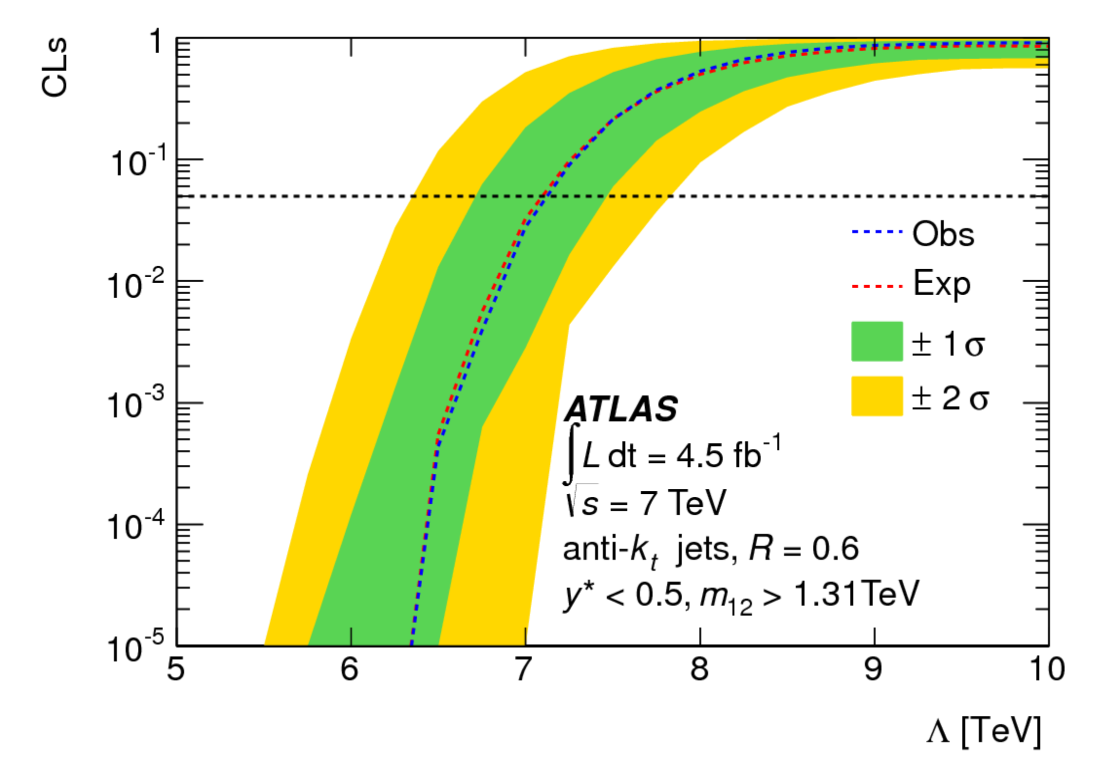
The X^2 distribution of the toys is compared to the one observed on data to assess compatibility with various theory models



PDF set	y^* ranges	mass range (full/high)	P_{obs} $R = 0.4$	P_{obs} $R = 0.6$
CT10	$y^* < 0.5$	high	0.742	0.785
	$y^* < 1.5$	high	0.080	0.066
	$y^* < 1.5$	full	0.324	0.168
HERAPDF1.5	$y^* < 0.5$	high	0.688	0.504
	$y^* < 1.5$	high	0.025	0.007
	$y^* < 1.5$	full	0.137	0.025
MSTW 2008	$y^* < 0.5$	high	0.328	0.533
	$y^* < 1.5$	high	0.167	0.183
	$y^* < 1.5$	full	0.470	0.352
NNPDF2.1	$y^* < 0.5$	high	0.405	0.568
	$y^* < 1.5$	high	0.151	0.125
	$y^* < 1.5$	full	0.431	0.242
ABM11	$y^* < 0.5$	high	0.024	$< 10^{-3}$
	$y^* < 1.5$	high	$< 10^{-3}$	$< 10^{-3}$
	$y^* < 1.5$	full	$< 10^{-3}$	$< 10^{-3}$

Setting new physics limits based on unfolded distributions



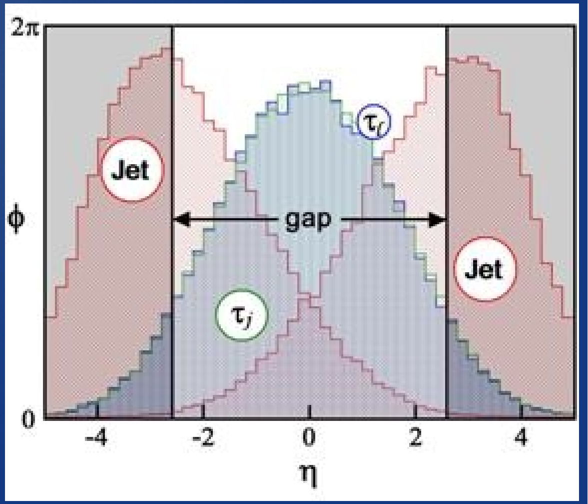


Contact interactions are taken as an example NP signal since no peak is present and can mimic different PDF's. A full analysis including all systematic sources allowed to set limits compatible with a dedicated search

Why jet veto

Colored quarks and gluons from LHC collisions emit a large number of jets, roughly equally spaced in rapidity. Probability for finding a region without jets (rapidity gap) goes as exp(-$\Delta\eta$)

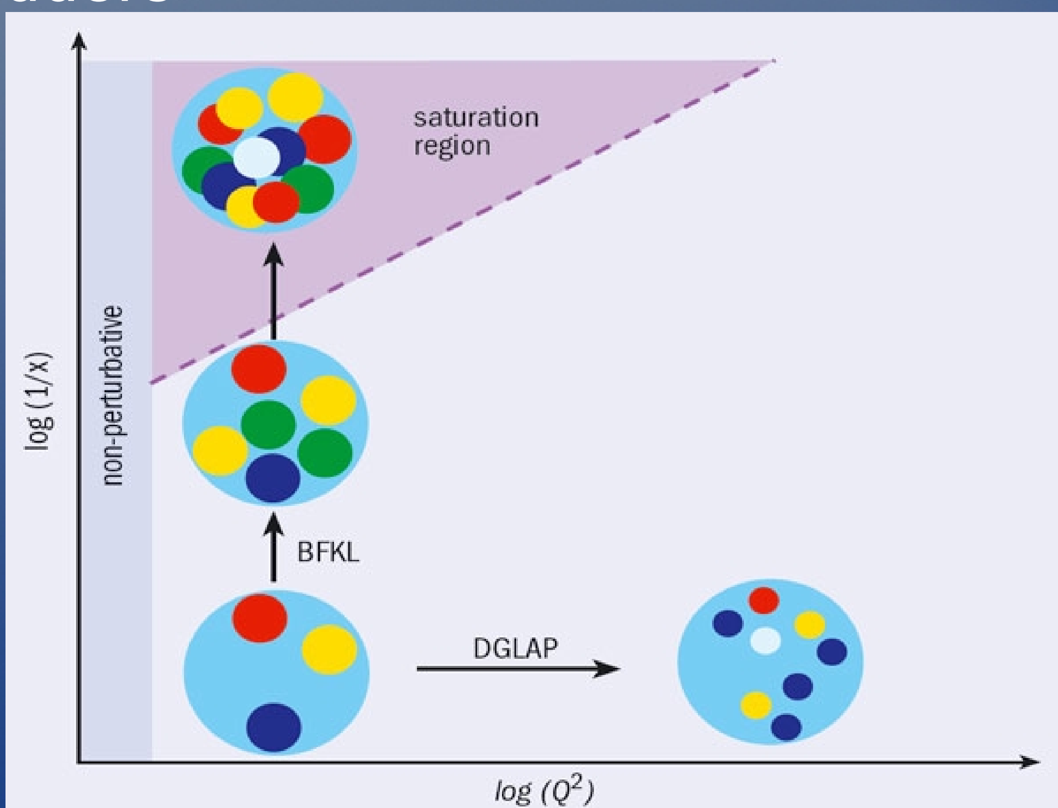
Processes involving exchange of colour-singlet objects have a constant probability for rapidity-gap production, so veto on additional jet production is used as a signature for color singlet production (ex. Higgs VBF)

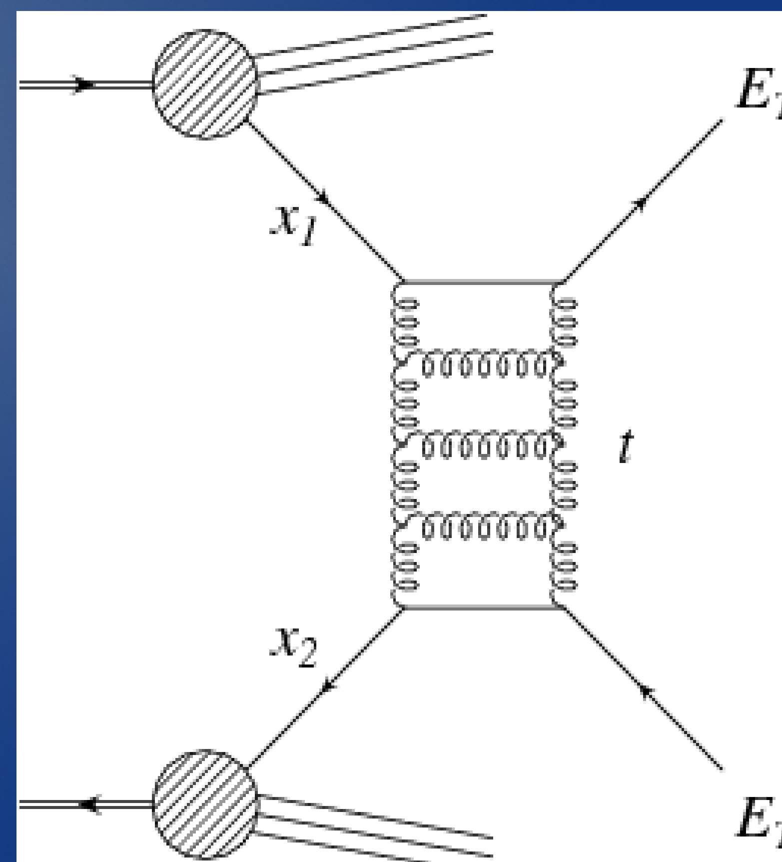


QCD evolution

Connection between various scales in QCD (for instance, between PDFs and the high-momentum scattering) is performed via evolution differential equations, the most famous being DGLAP, whose solution is expanded in terms of powers of $\alpha_s \ln Q^2$.

An alternative approach is the BFKL equation, whose solutions expand in terms of log(1/x), more suitable for low-x physics, when different scales are present and leading to color-singlet "gluon ladders"

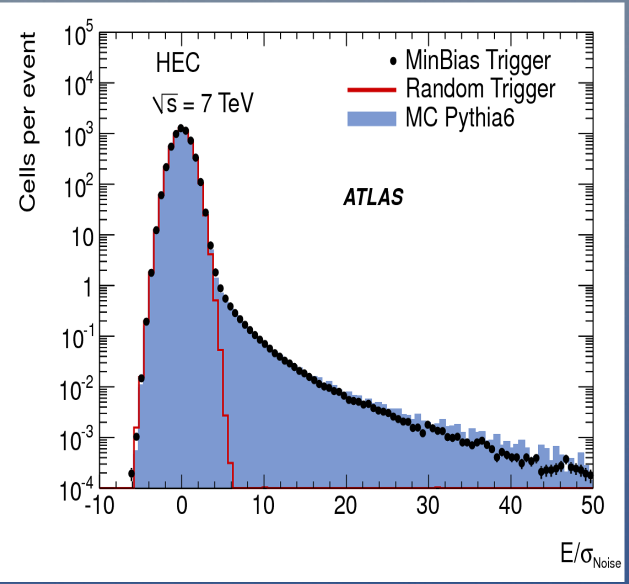




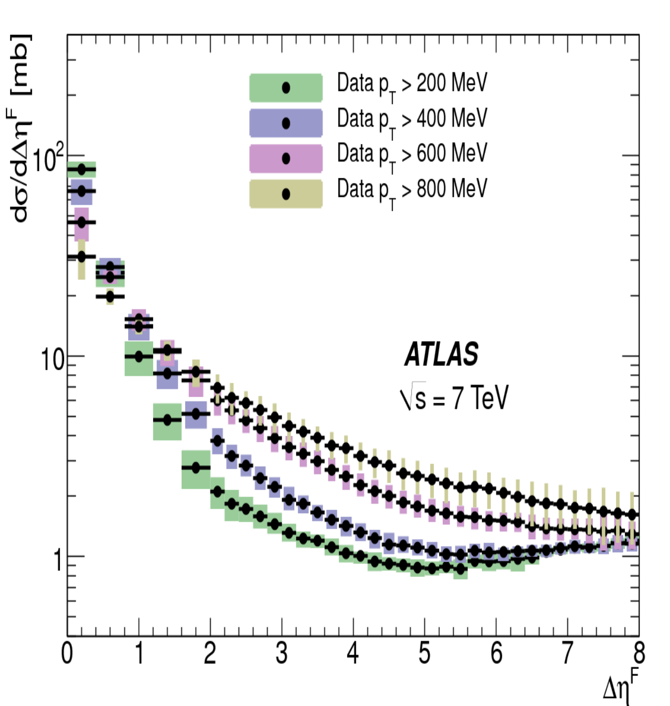
Clean rapidity gaps at the LHC

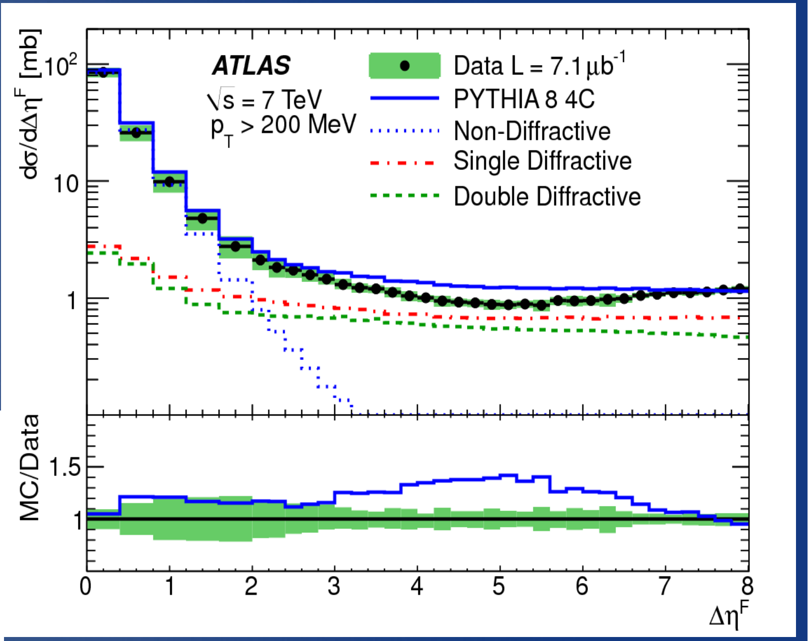
The LHC environment is harsh for the search of clean rapidity gaps, due to pileup and calorimeter noise.

Atlas performed a measurement on March 2010 data, with 7/pb at average number of interactions/bunch-crossing μ=0.005 (Eur. Phys. J. C72 (2012) 1926)



Careful study of calorimeter noise





Gap size as signature of diffraction

Measurement as a function of total energy in gap, and comparison/tuning of different models

From gaps to jet veto

For high-pt physics under pileup conditions, it is impossible to ask for clean gaps.
Color-singlet signatures searched vetoing on jets above threshold Q_0 of order 20 GeV.

Two approaches to define “boundary jets”:

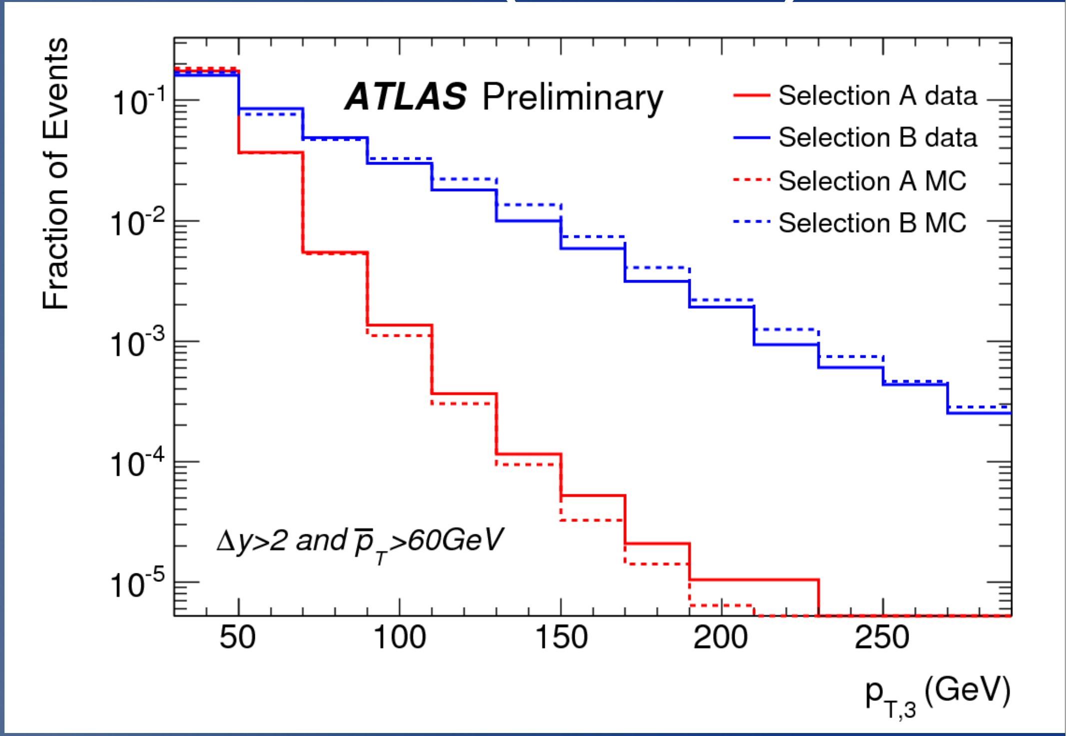
- The two leading jets in the event (probes high-Q^2 – DGLAP-like approach)
- The most forward and backward jets above a given threshold. Mueller-Navelet jets, gives larger gaps, should probe more BFKL-like dymanics

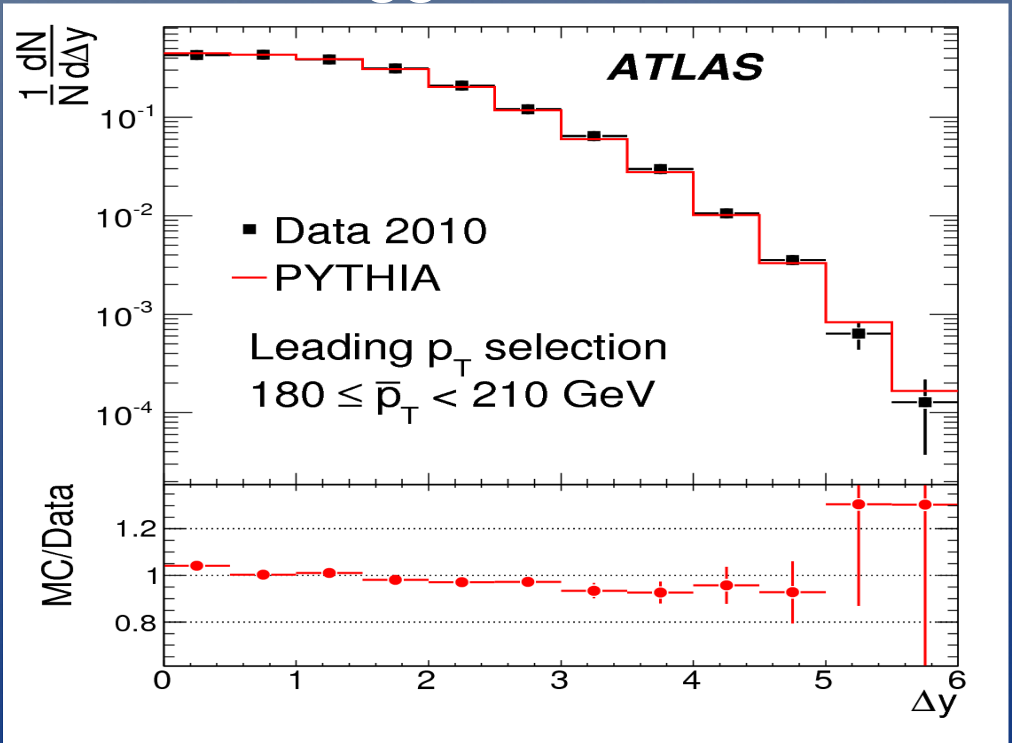
Testing ground for theory and experimental techniques
Measure gap fraction (fraction of events without veto jet) as a function of *Δy* and $\overline{P_t}$ (average pt of two leading jets)

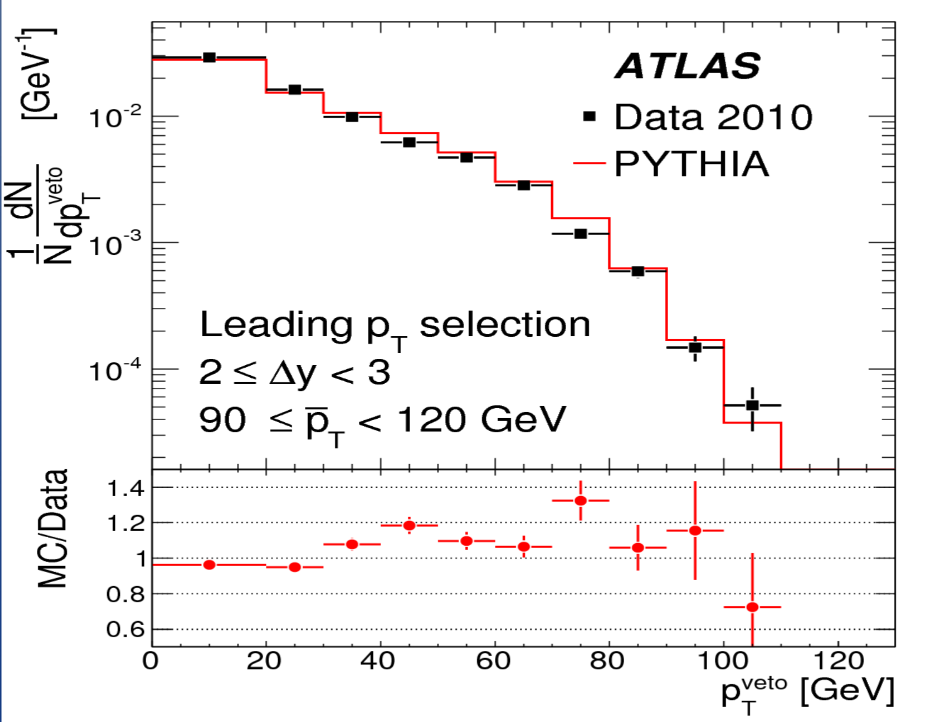
ATLAS dijet veto JHEP 1109 (2011) 053

In f/b selection, the veto jet can also be the leading jet in the event, and is on average much harder than for leading pT selection; also *Δη* is larger.

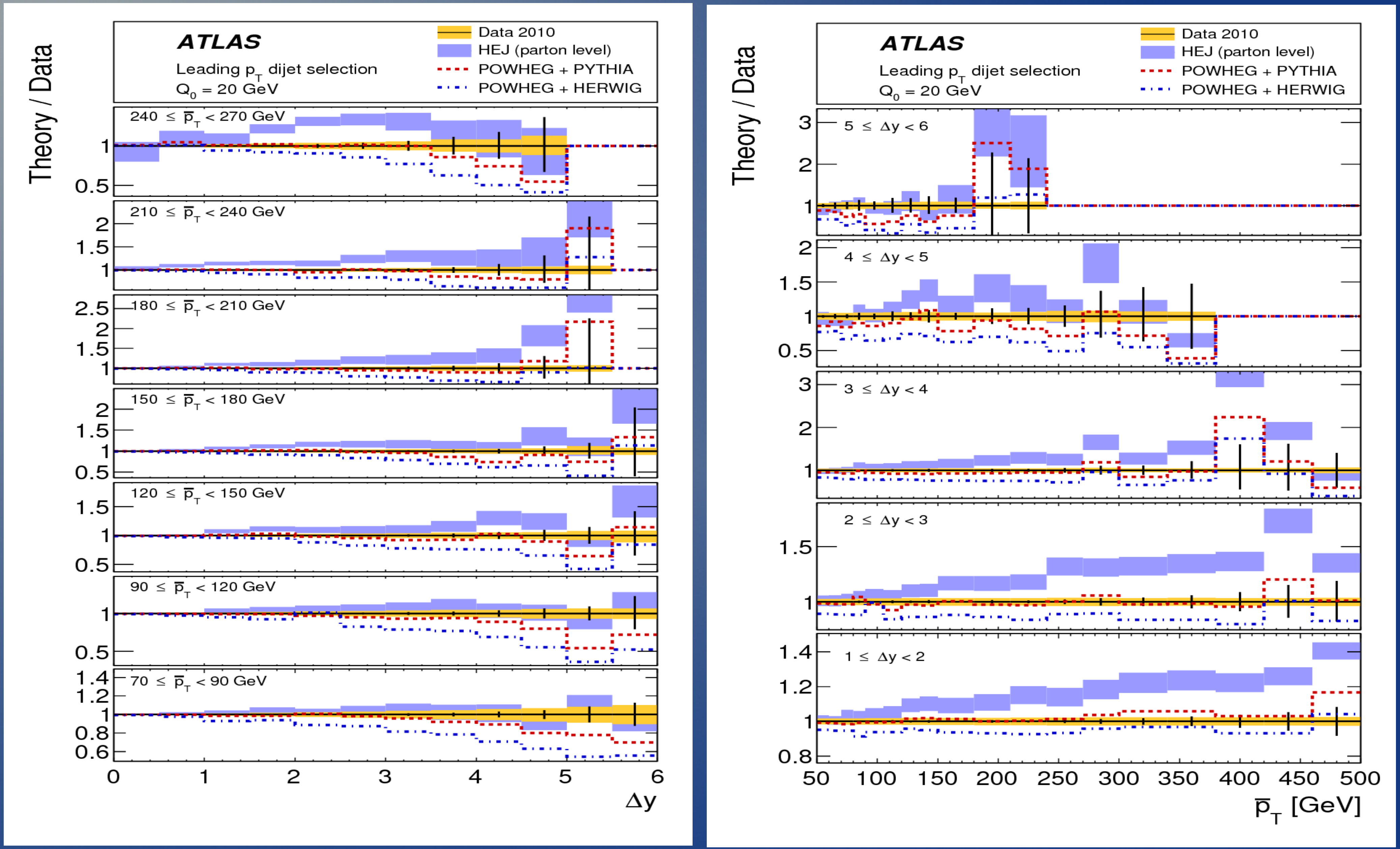
Average pT of two jets above 60 GeV, to be selected by inclusive trigger







Comparisons with Powheg/HEJ



Best agreement with Powheg + Pythia, apart from the low-Pt high rapidity difference region

Motivations for a new analysis

Combine jet veto and azimuthal de-correlation since looking at same physics

Use an optimised 2-jet trigger technique to reach large Δy (up to 8) on 2010 data (no pileup), and add 2011 data to extend the high-pt region up to 1.5 TeV

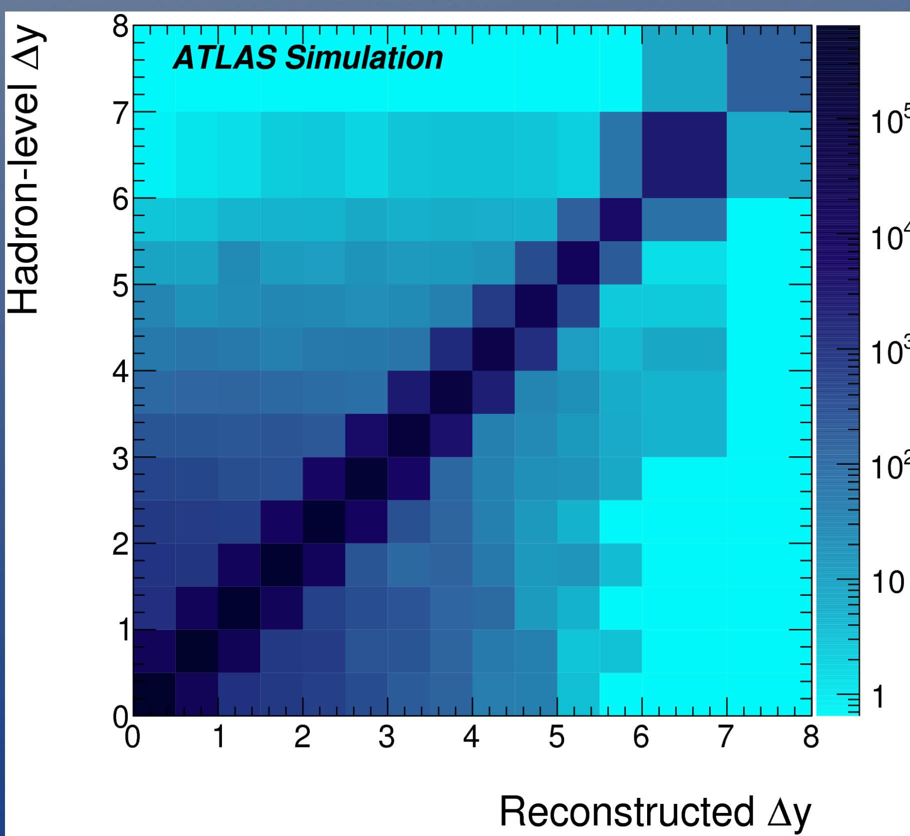
Observables:

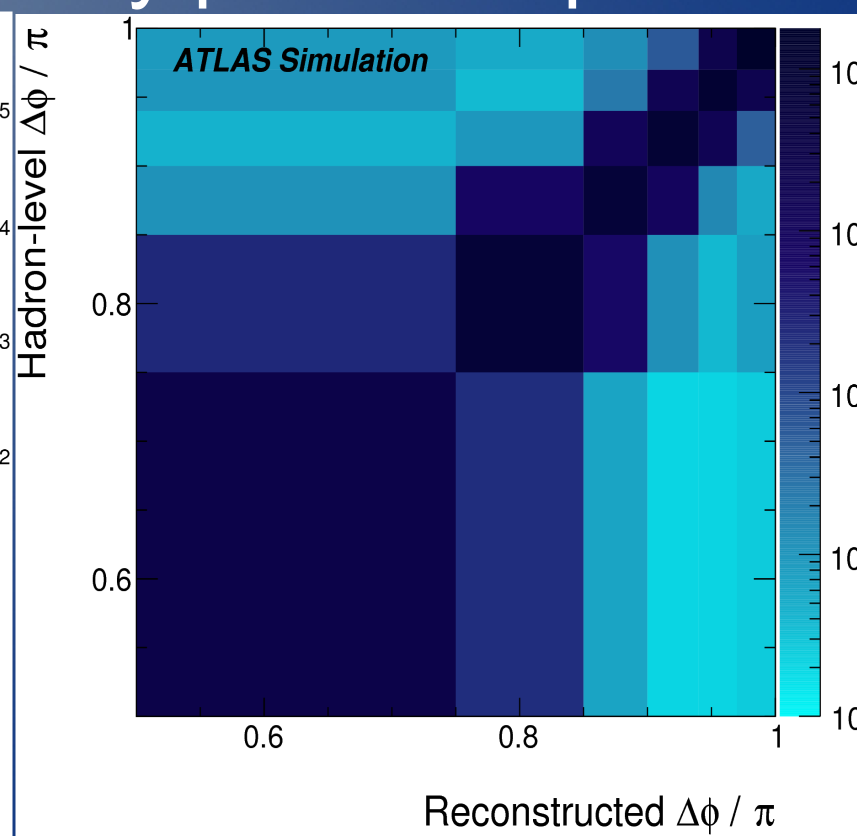
- Gap fraction vs Δy for Q0 = 20 GeV
- Gap fraction vs pT for Q0 = 30 GeV
- Gap fraction vs Q0 for slices of y
- <Njets> vs ***Δy and pT***
- Cross section vs ***$\Delta\varphi$, Δy***
- ***<cos $\Delta\varphi$>, <cos 2$\Delta\varphi$> vs Δy, pT***

Trigger strategy and unfolding

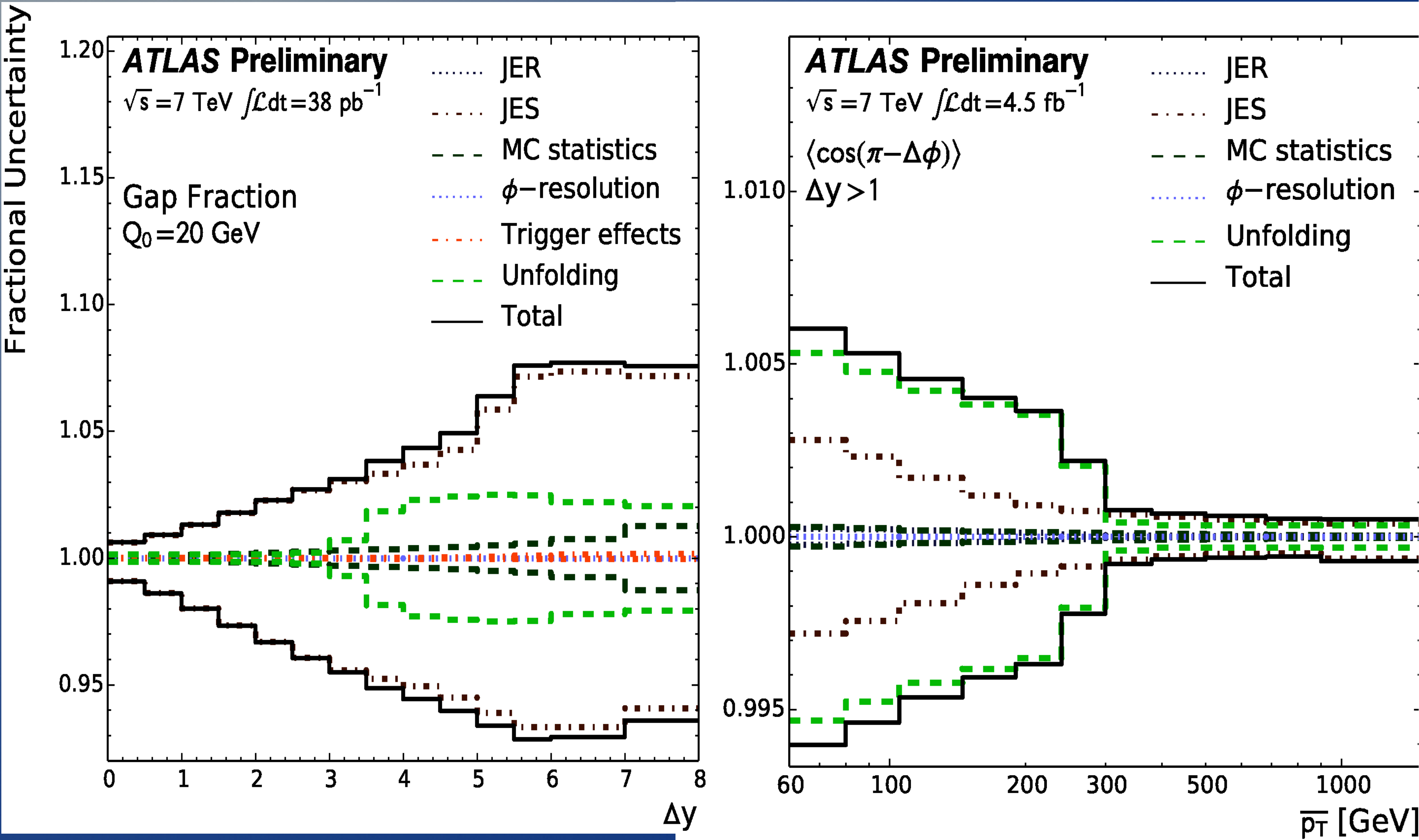
Events are divided into several categories according to pt and eta of leading two jets. They are searched in the dataset with the lowest trigger prescale for the combination.

2-iteration Bayesian unfolding performed in 6D, with statistical errors estimated by pseudoexperiments

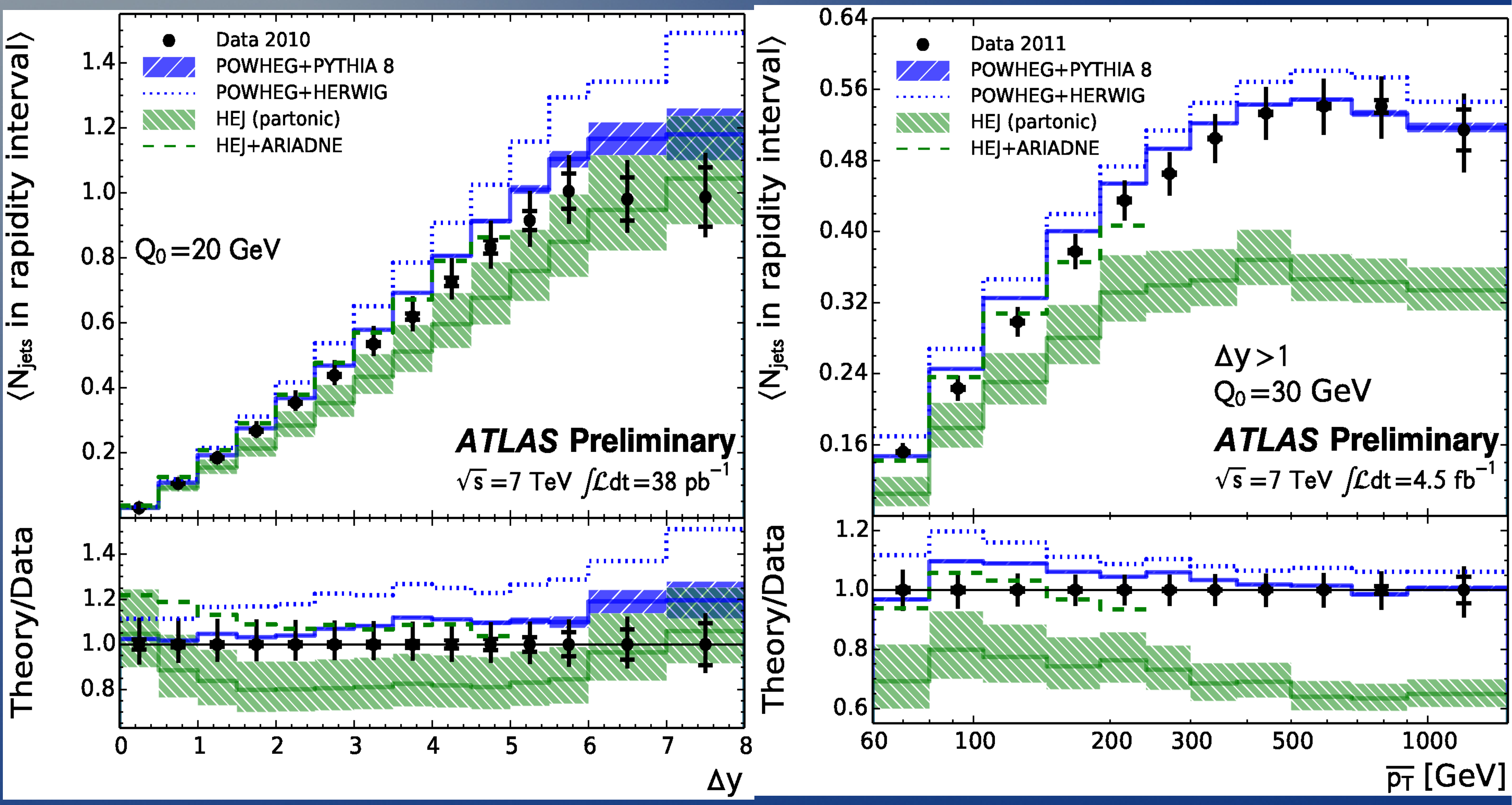




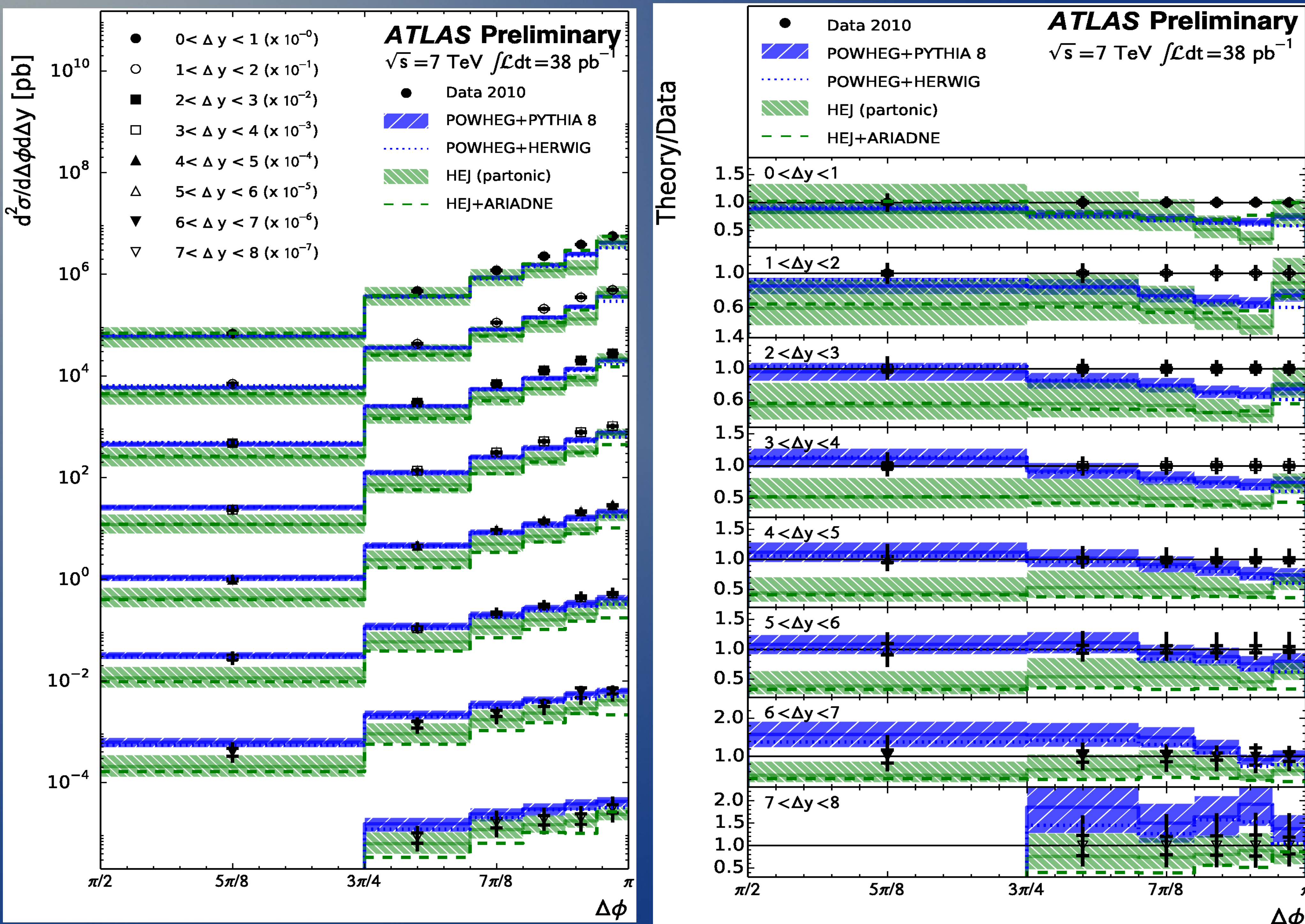
Systematic uncertainties



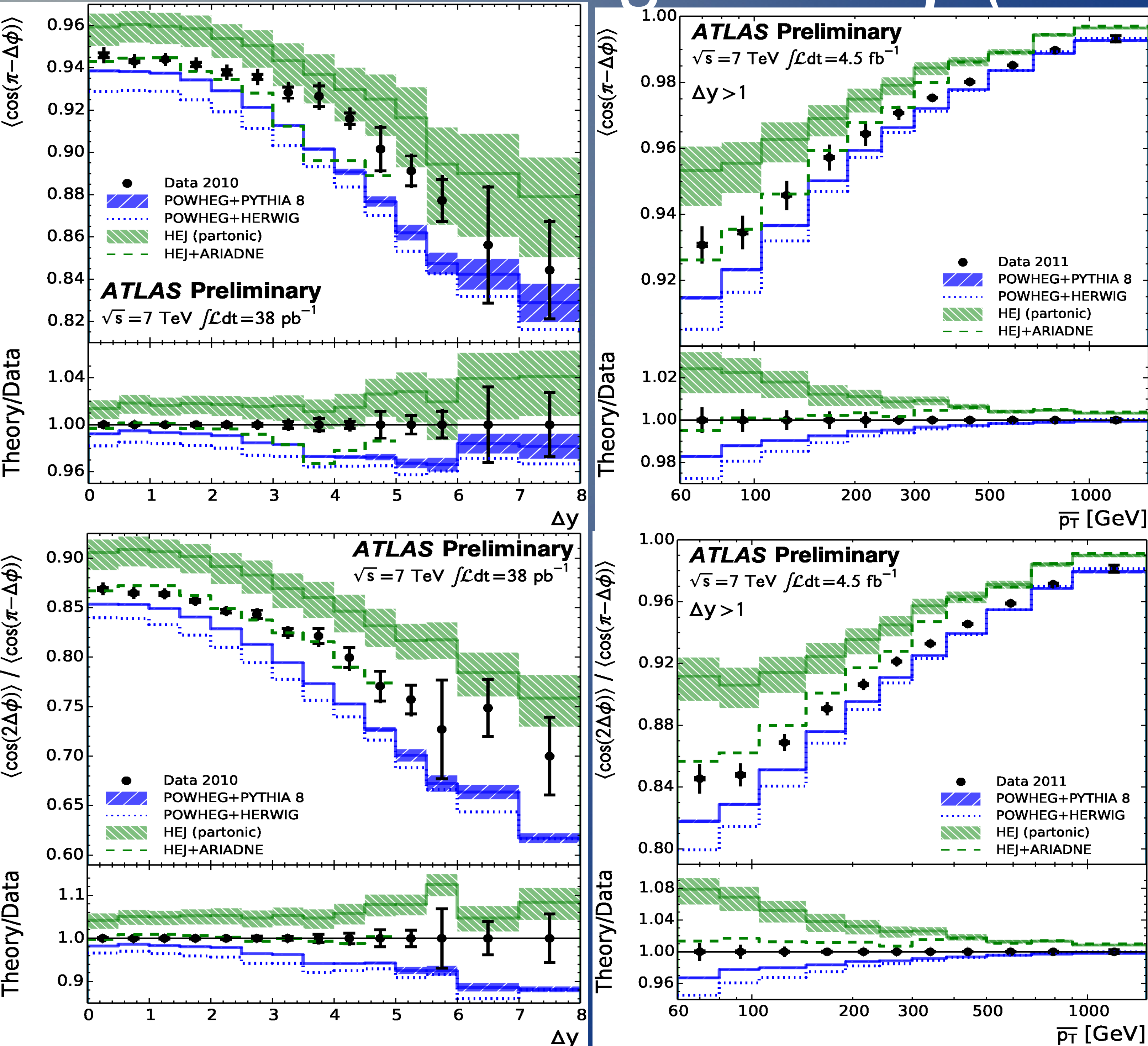
Number of jets in rapidity intervals



Azimuthal de-correlation

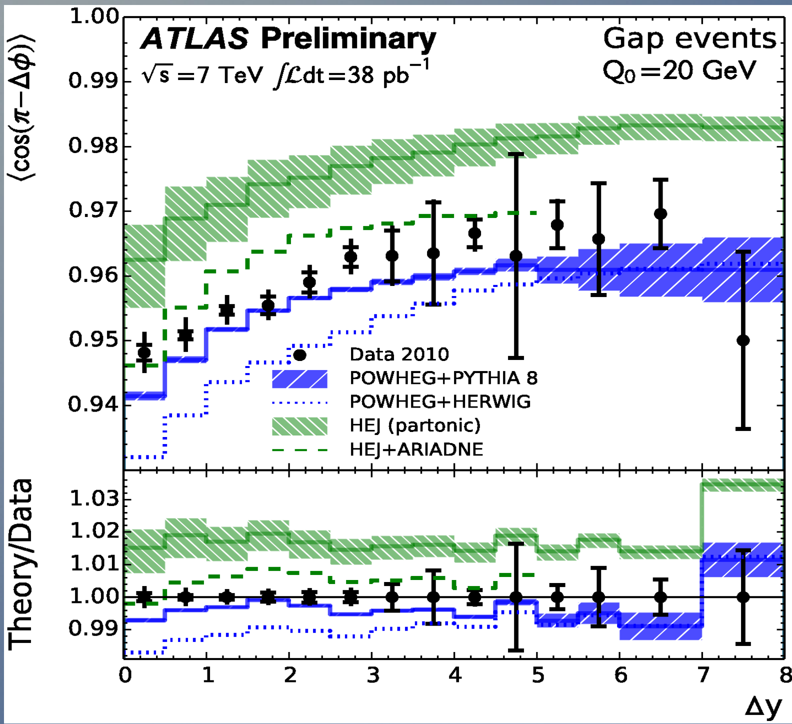


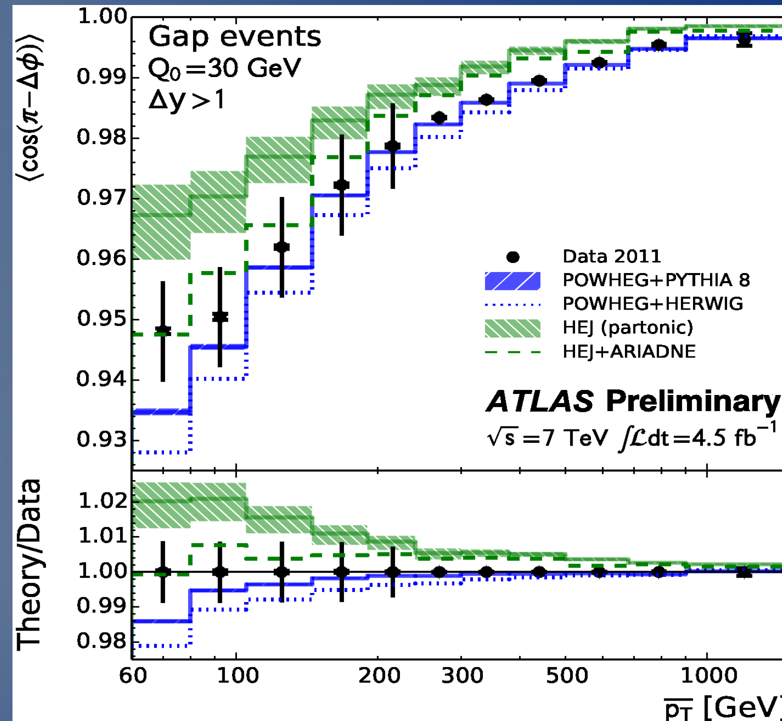
Azimuthal angle vs Δφ (all events)

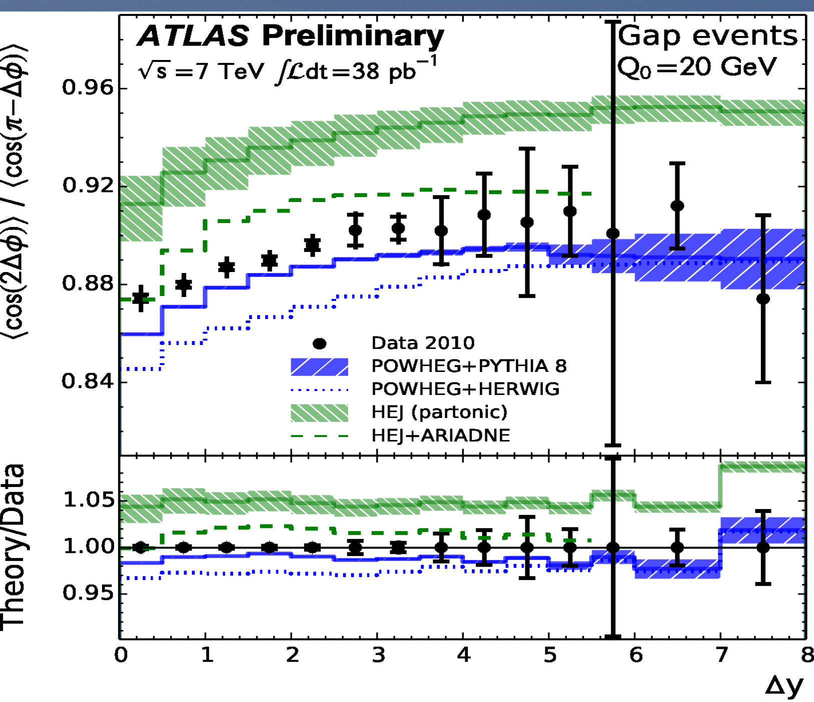


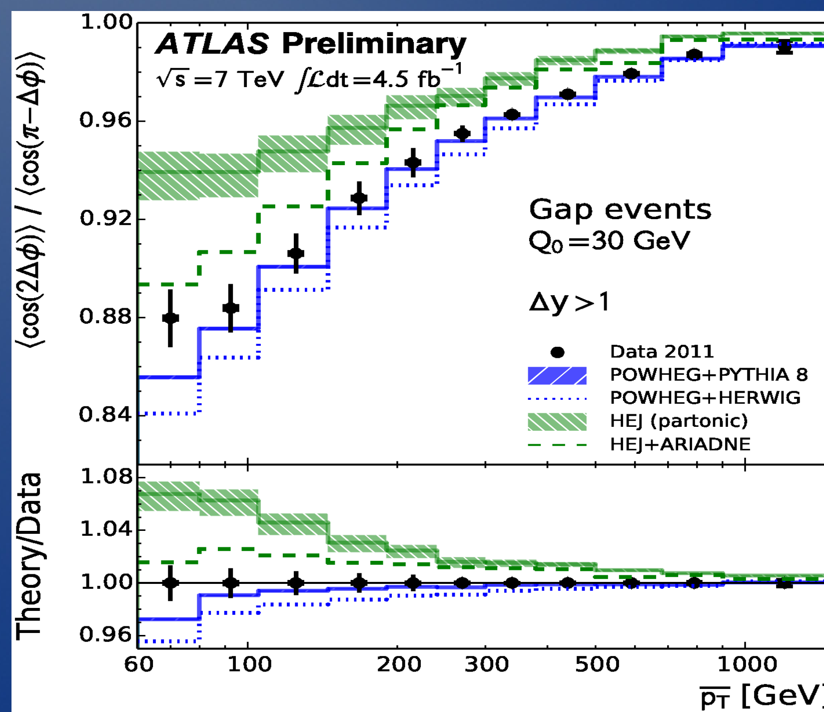
Hadronisation effects (ARIADNE) seem to improve the HEJ prediction quite considerably

Azimuthal angle vs $\Delta\phi$ (*gap events*)









Conclusions

The new dijet measurement from ATLAS brings quantitative estimates of agreement with theory to a new level, and all the information is present to derive limits on unfolded distributions.
Limits on contact interactions are derived as an example

Gap fraction and azimutal de-correlation have been combined into a single measurement, that extends the kinematic reach and challenges even further the current QCD models