Dijet production with a jet veto

Latest results on multi-jets production, and beyond-DGLAP (BFKL, saturation) studies with jets

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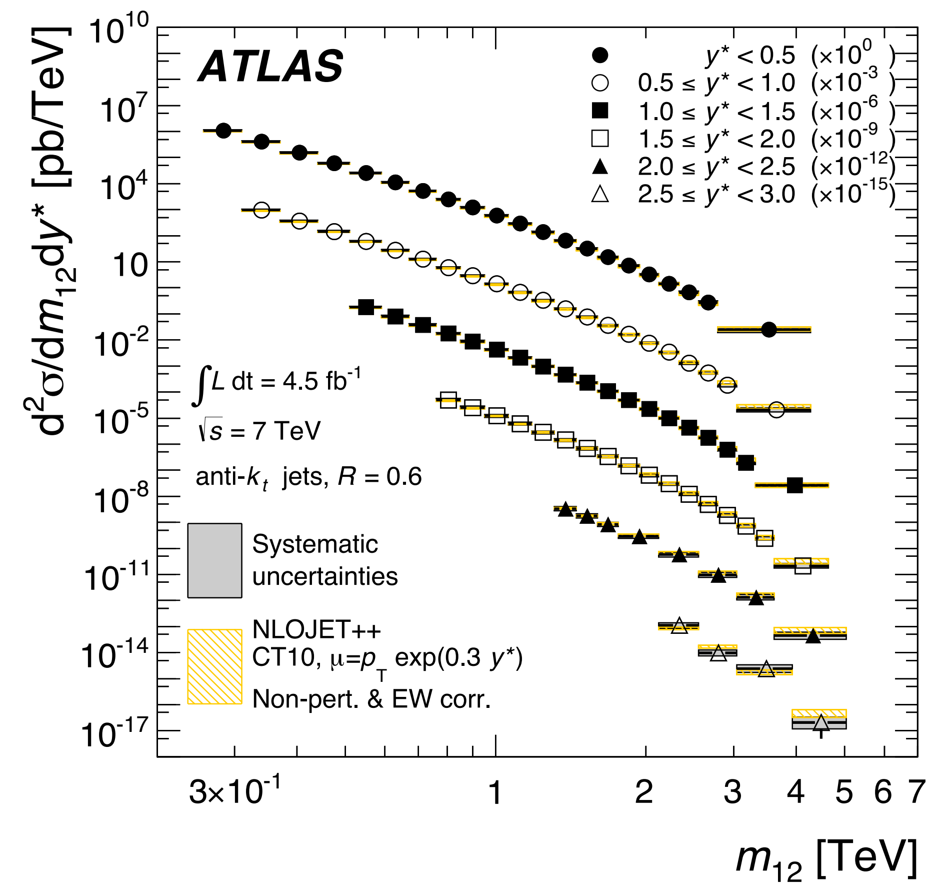
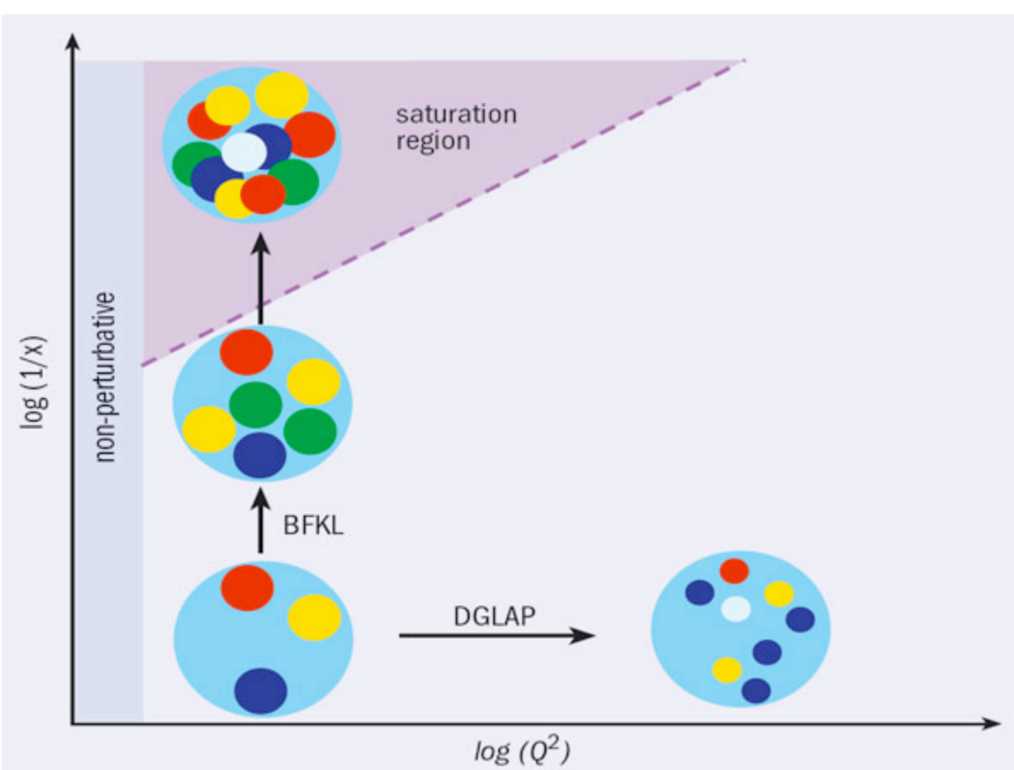
Introduction

Next-to-leading-order (NLO) perturbative QCD succeeds to describe the LHC TeV data.

- e.g. Dijet production cross sections
  - m_{jj} measured up to 5 TeV
  - well described by the predictions.



However, higher-order corrections may get important in some region of phase-space.



Approaches to higher-order calculations:

- **BFKL** approach:
  resummation in terms of **ln(1/x)**
- **DGLAP** approach:
  resummation in terms of **ln(Q^2)**

Dijet production with a jet veto

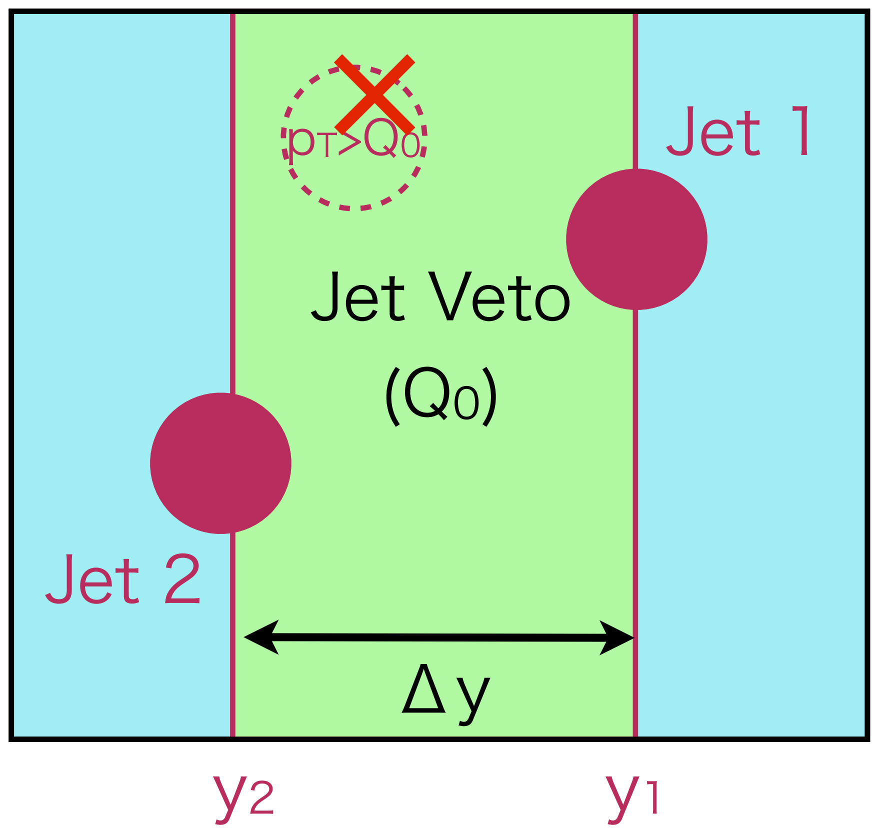
Resummation of higher-order terms has large contribution in dijet topologies with:

- Large rapidity separation between two jets.
- A veto on additional jet activity (Gap Events)

Δy: Gap separation

Q_0 : Jet veto scale

$p_T^{avg}=(p_T^1+p_T^2)/2$



Large Δy

➜ BFKL dynamics

$p_T^{avg} >> Q_0$

➜ wide-angle soft gluon radiation

With both limits

➜ t-channel colour singlet exchange.

Measured observables

The following observables are measured.

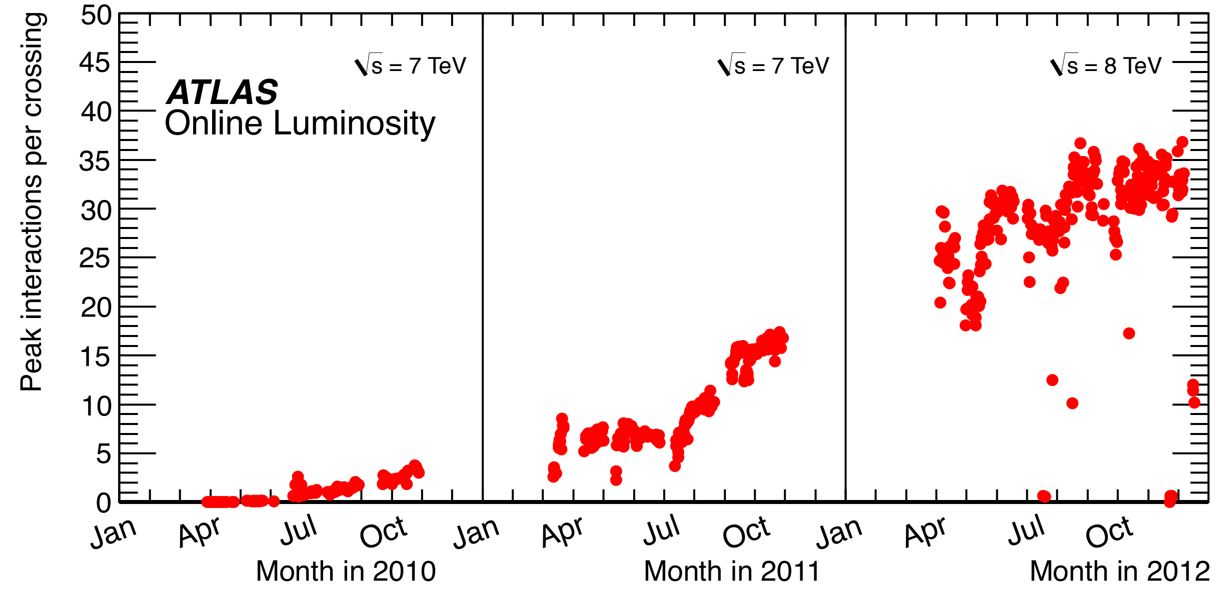
- **Gap Fraction**: $f(Q_0)=\sigma_{jj}(Q_0)/\sigma_{jj}$, Q_0 is the veto scale.
- Mean number of jets in the rapidity interval: **$\langle N_{\text{Jets in rapidity interval}} \rangle$**
- Azimuthal decorrelations in terms of angular moments: $\langle\cos(n(\pi-\Delta\phi))\rangle$
  ref. arXiv:0702158, arXiv:1106.6172
  - 1st moment: **$\langle\cos(\pi-\Delta\phi)\rangle$**
  - 2nd moment: **$\langle\cos(2\Delta\phi)\rangle$**
- **Double differential cross sections** as a function of $\Delta\phi$ and Δy

Measured for **inclusive events** and **gap events.**

Measurements are unfolded and compared to

- POWHEG predictions : DGLAP approach
- HEJ predictions: BFKL approach

Data analysis



2010 and 2011 data are used to complement different phase-space.

2011 data have more "pileup", i.e. simultaneous pp interactions in the same bunch crossing.

2010 data: 38 pb^{-1}

→ Explore **larger Δy**

Jets: p_T>20 GeV, |y|<4.4

Veto scale: Q_0=20 GeV

Events with only 1 primary vertex

2011 data: 4.8 fb^{-1}

→ Explore **higher p_T**

Jets: p_T>30 GeV, |y|<2.4

Veto scale: Q_0=30 GeV

$\Delta y > 1$

Jets should have >75% of its momentum coming from the vertex

anti-k_t jets, R=0.6

Dijet selection leading jet p_T>60 GeV, subleading jet p_T>50 GeV

Unfolding

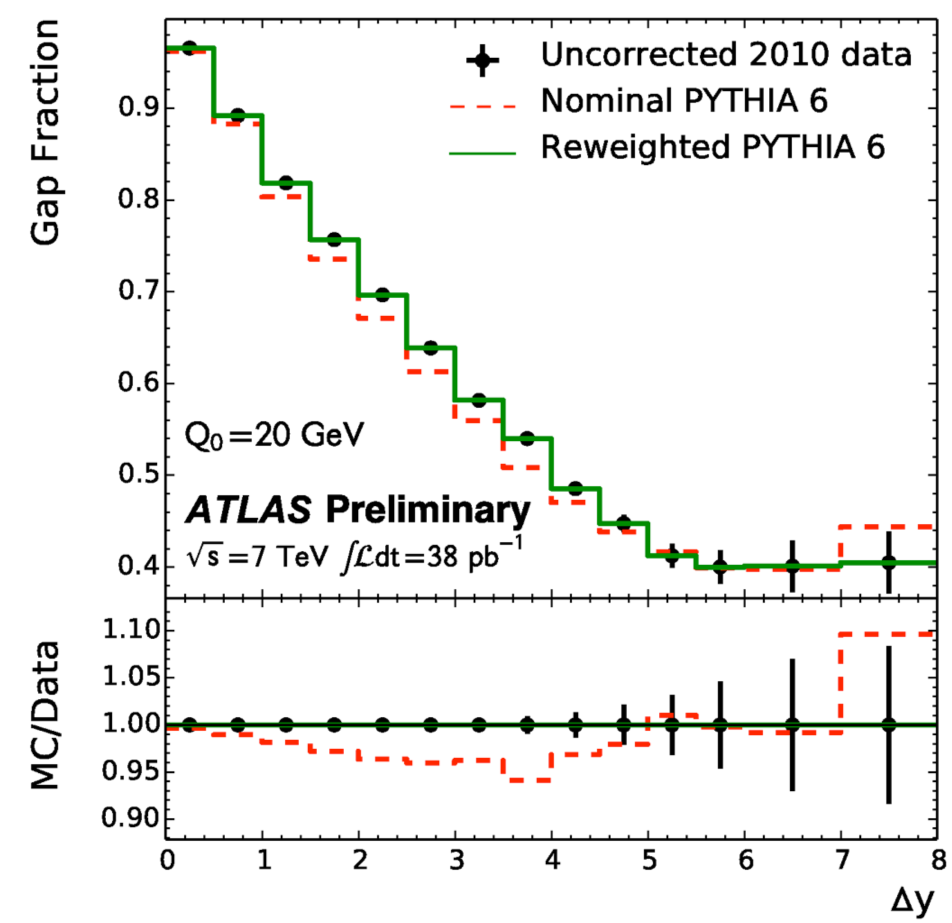
Detector effects are corrected by Bayesian unfolding.

- PYTHIA 6.4
- Each distribution is unfolded in 4 or 6 dimensions.
  (2 or 3 variables x gap/non-gap)

Check of model-dependence:

- PYTHIA is reweighted to reproduce the data distribution.
- Reweighted PYTHIA is unfolded by the nominal PYTHIA

→ Bias is considered as uncertainty.

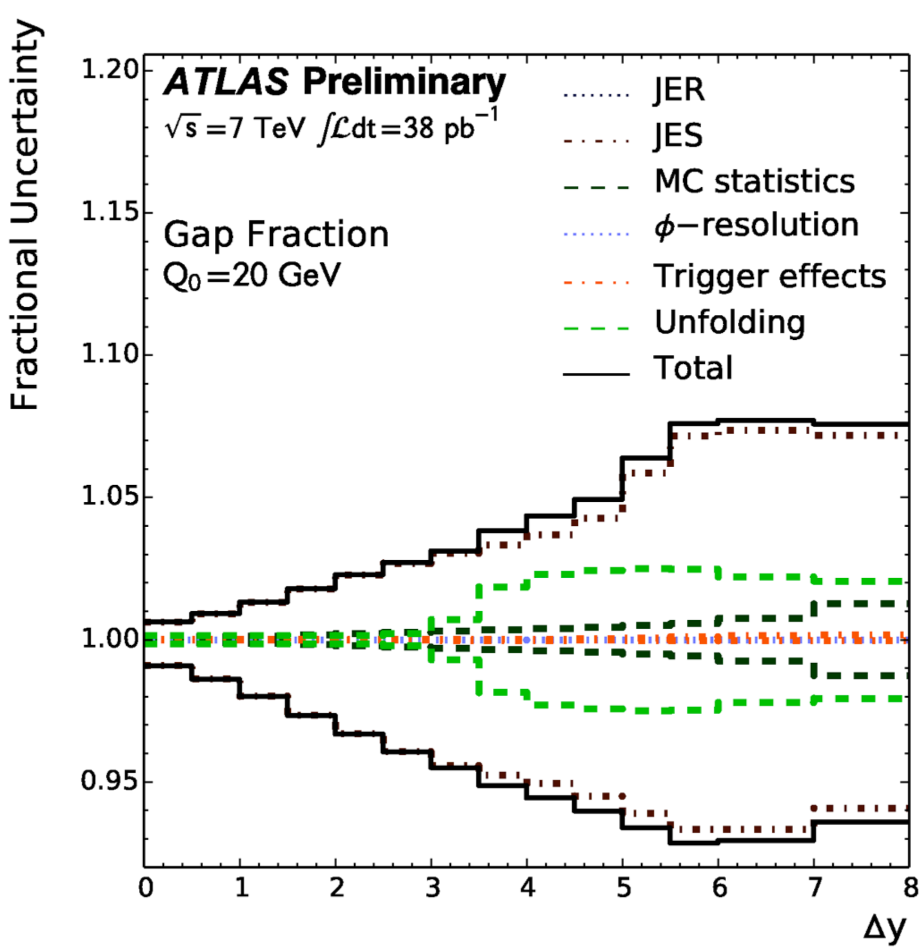


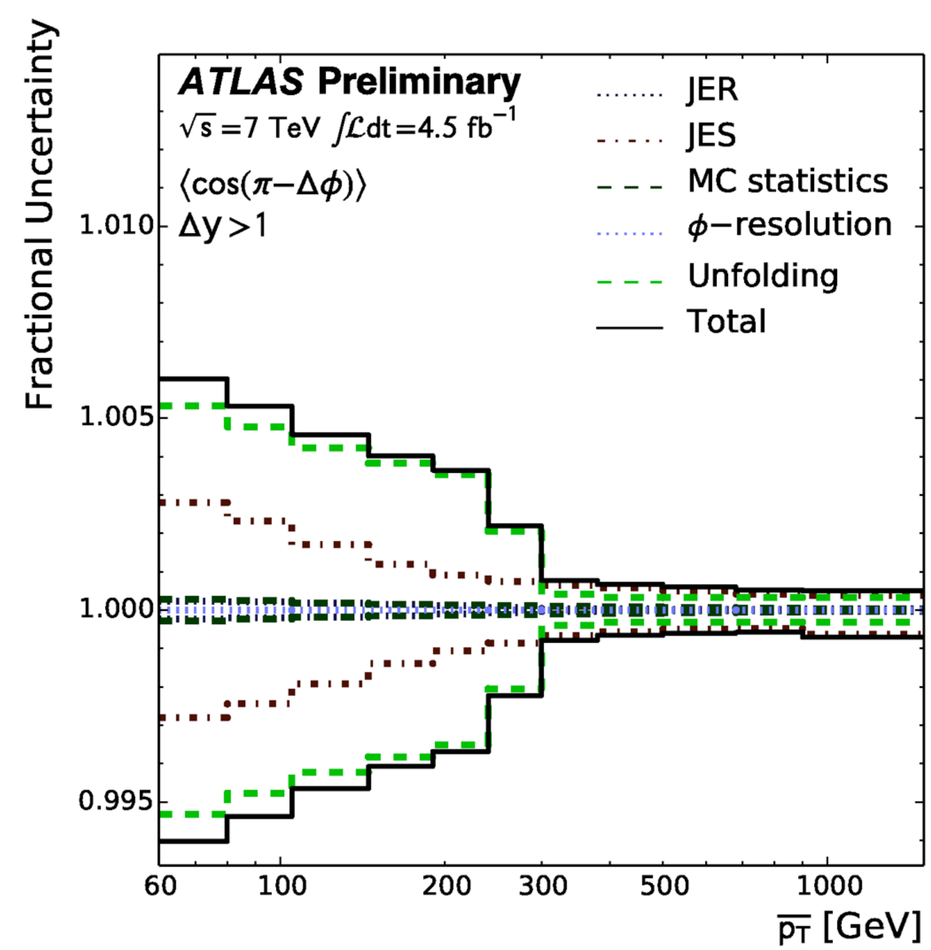
Systematic uncertainties

The following sources are considered

- Jet energy scale (JES)
- Jet energy resolution (JER)
- Jet ϕ resolution
- Trigger effects
- Unfolding
- Luminosity (only for cross sections)

→ JES is the dominant uncertainty.





Theoretical predictions

HEJ predictions

Leading-log (LL) calculation of the perturbative terms

→ BFKL approach

- HEJ (purely partonic)
- HEJ+ARIADNE
  - Parton shower with hadronisation by PYTHIA
  - Soft and collinear radiations are included.

POWHEG predictions

Next-to-leading order dijet matrix elements

→ DGLAP approach

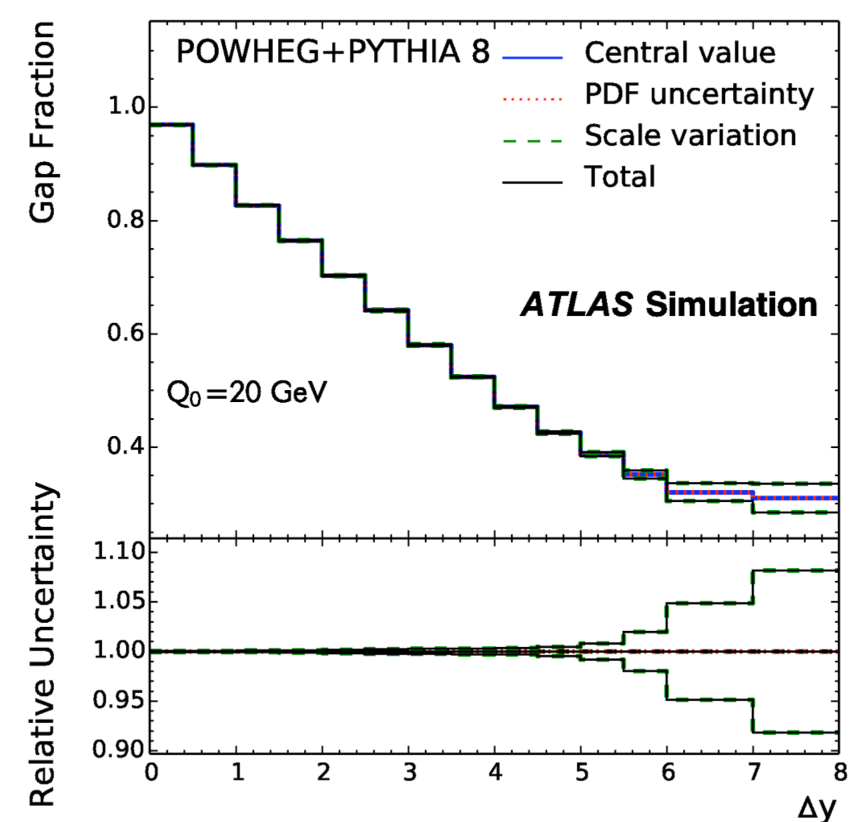
Interfaced to leading-order MCs.

- POWHEG+PYTHIA8
- POWHEG+HERWIG6.5

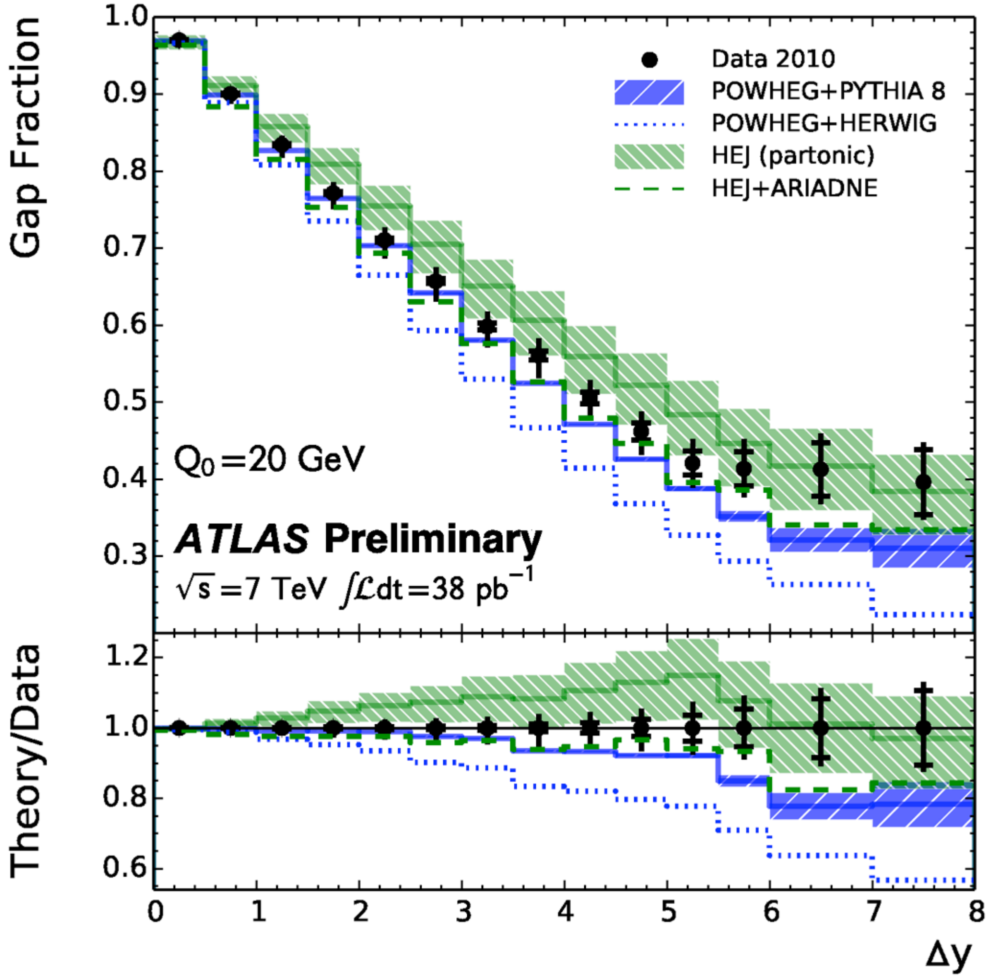
CT10 PDF sets, $\mu_R = \mu_F = p_T^{\text{leading parton}}$ are used.

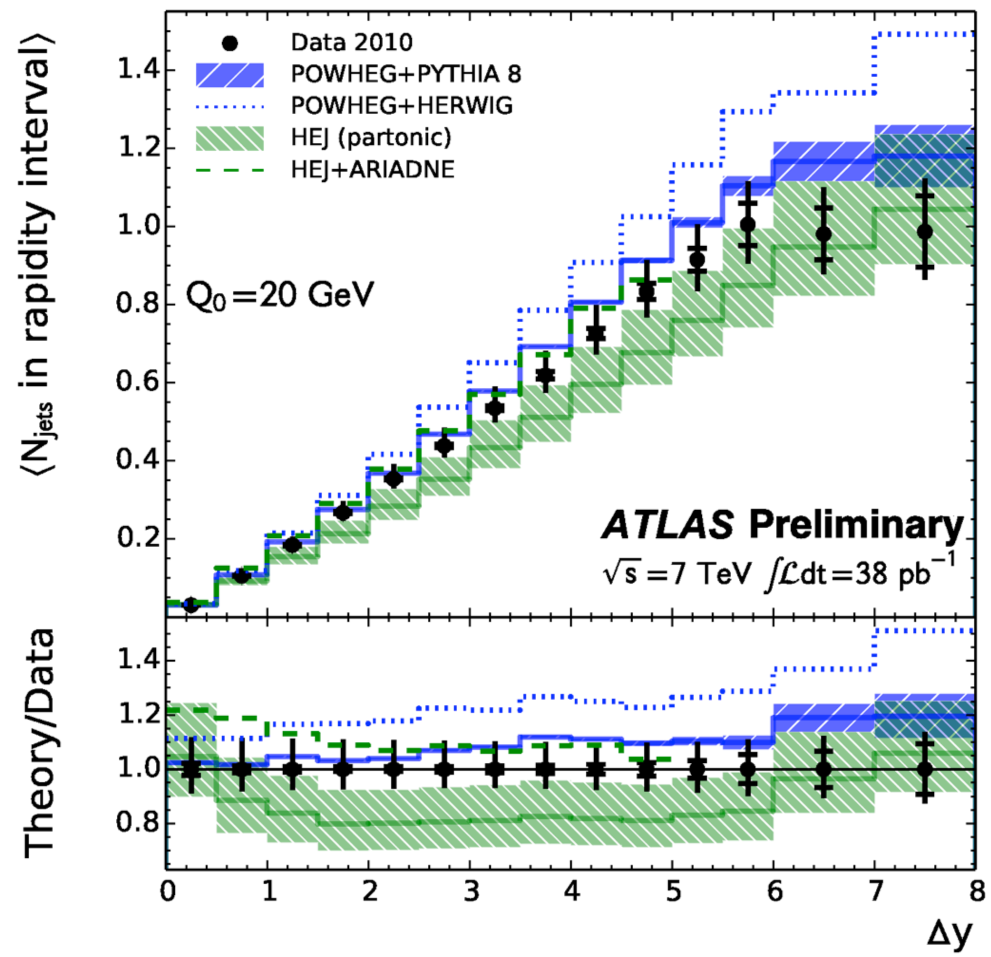
Uncertainties:

- PDF uncertainties
- Scale variations by x2 and x0.5.



Gap fraction / N_{Jets} vs Δy

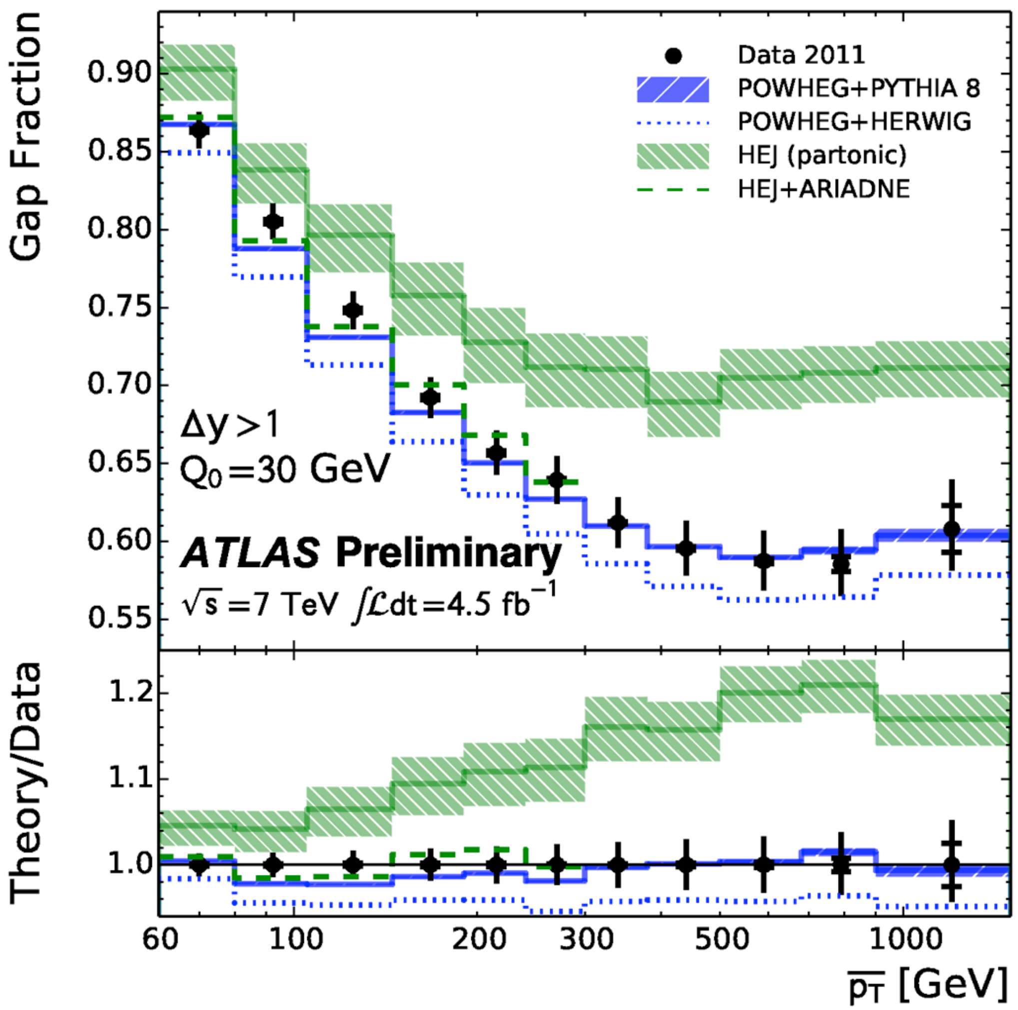


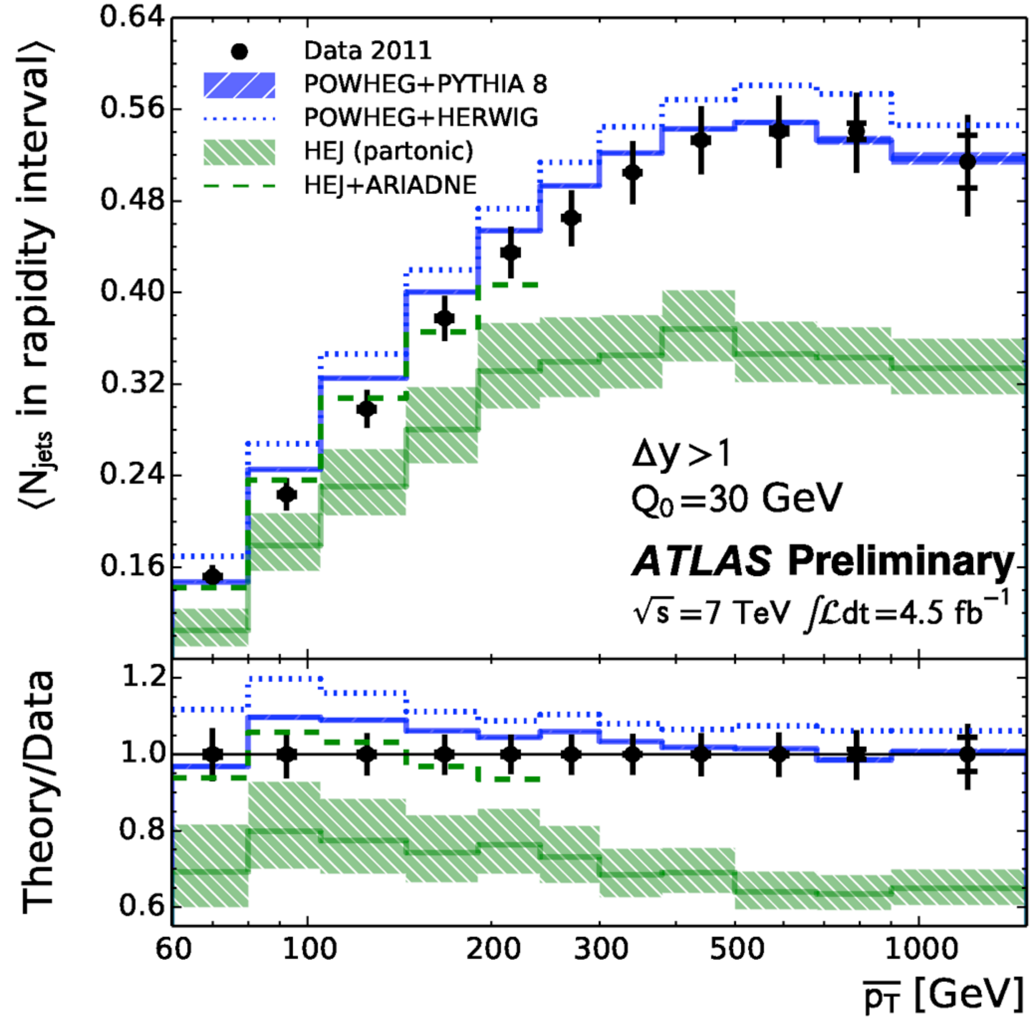


- Exponentially suppressed gap fraction for larger Δy due to exchange of colour in t-channel.
- Deviation from exponential behaviour at highest Δy.
  - Steeply falling parton distributions reduces additional jet activity.
  - Colour singlet exchange.

- POWHEG predictions underestimate Gap fractions at high Δy.
- Partonic HEJ overestimate Gap fraction.
- Addition of ARIADNE improves the description.

Gap fraction / N_{Jets} vs p_T^{avg}

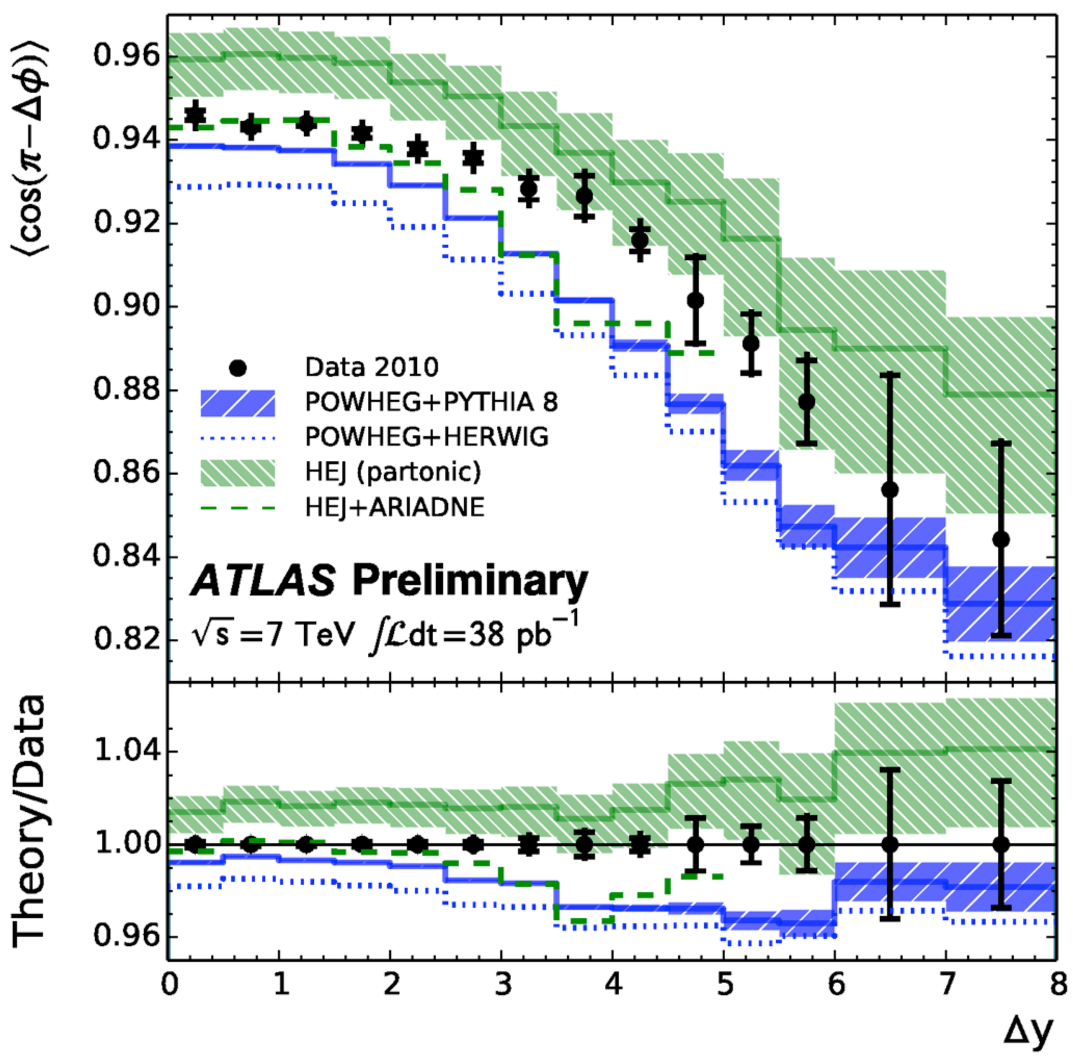


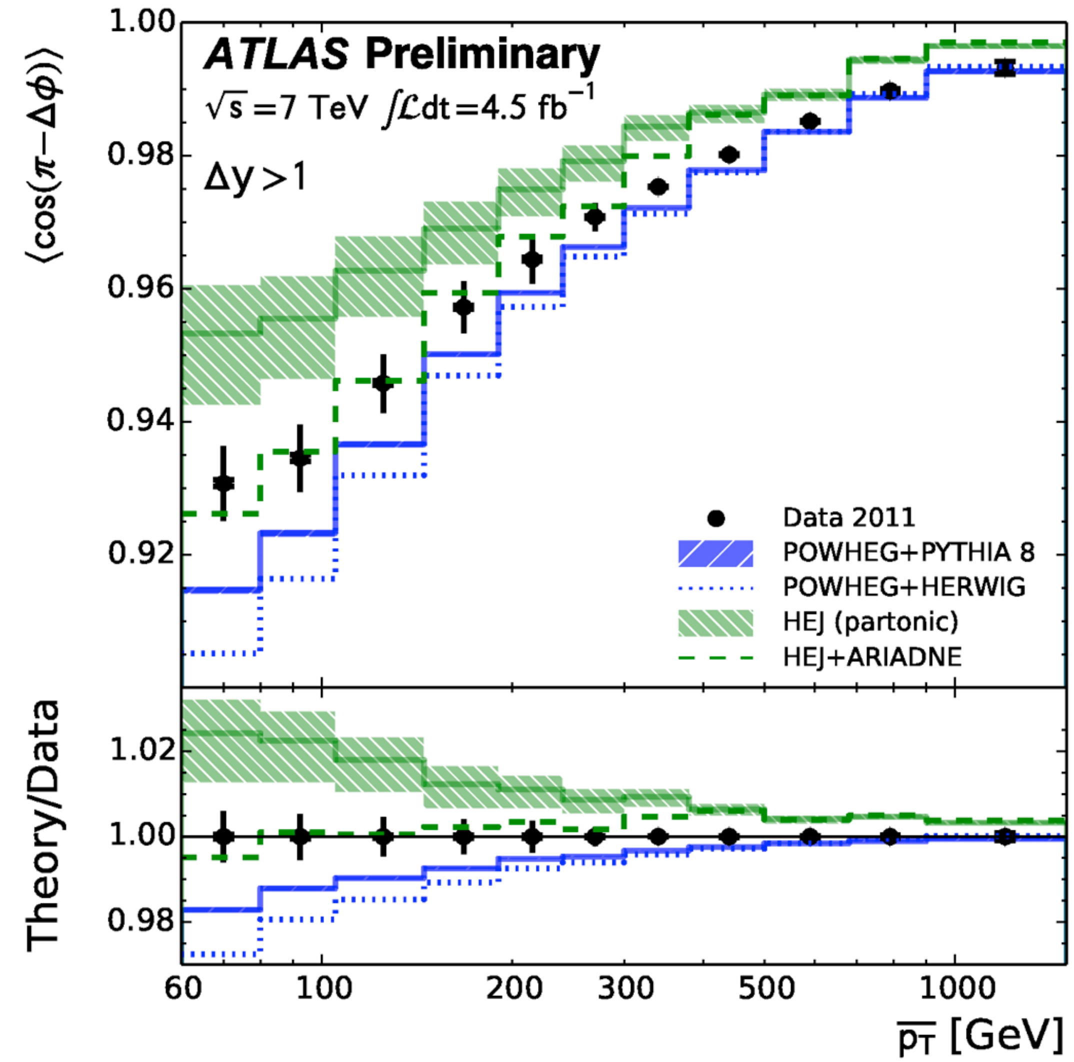


- Exponentially suppressed gap fraction for larger p_T^{avg}, following naive expectation due to exchange of colour in t-channel.
- Deviation from exponential behaviour at highest p_T^{avg}
  - Steeply falling parton distributions reduces additional jet activity.

- POWHEG+PYTHIA and HEJ+ARIADNE provide good description.
- POWHEG+HERWIG gives too many jets.
- Poor description by HEJ at large $\ln(p_T^{avg}/Q_0)$.

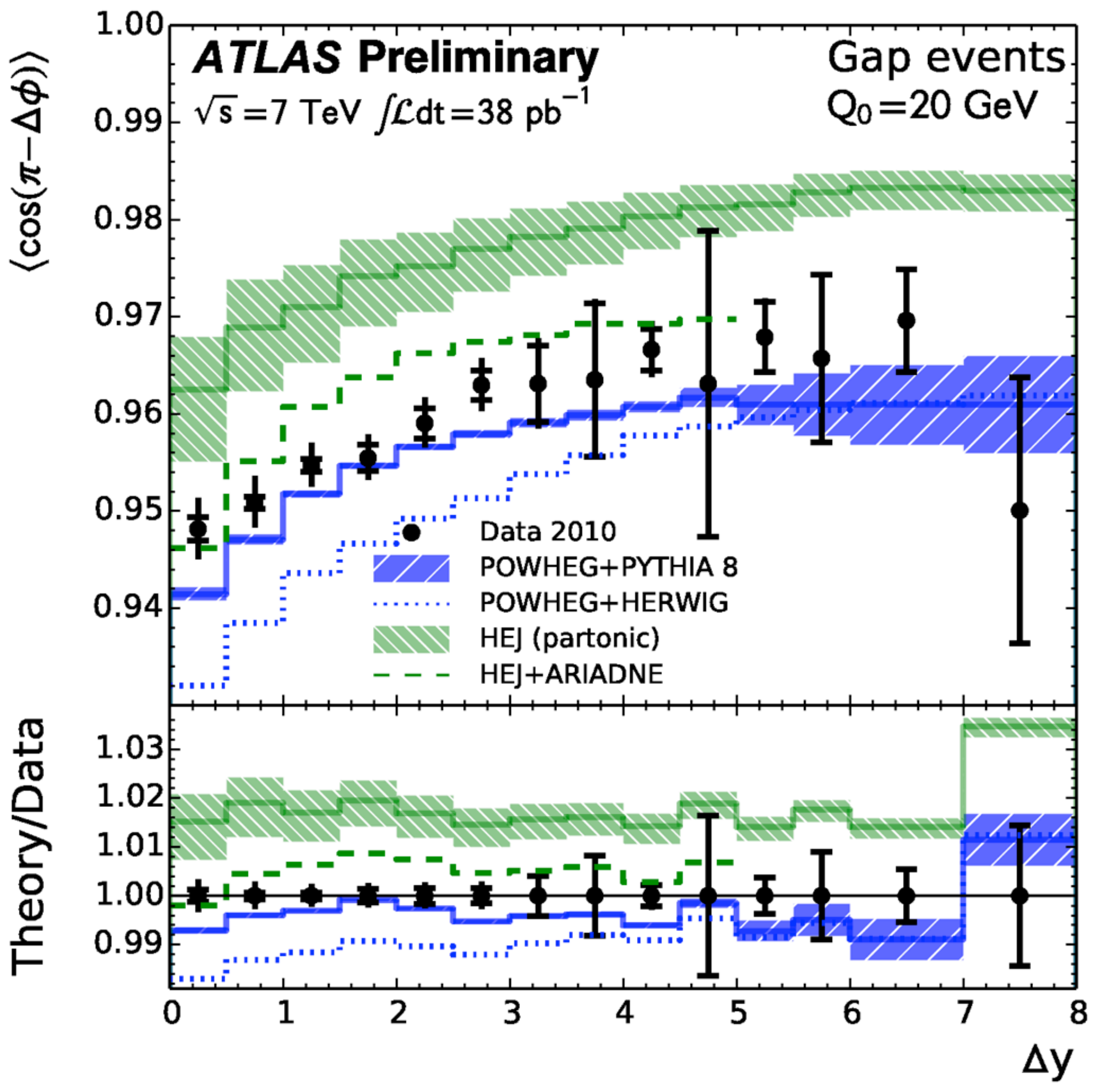
1st angular moment (Inclusive)

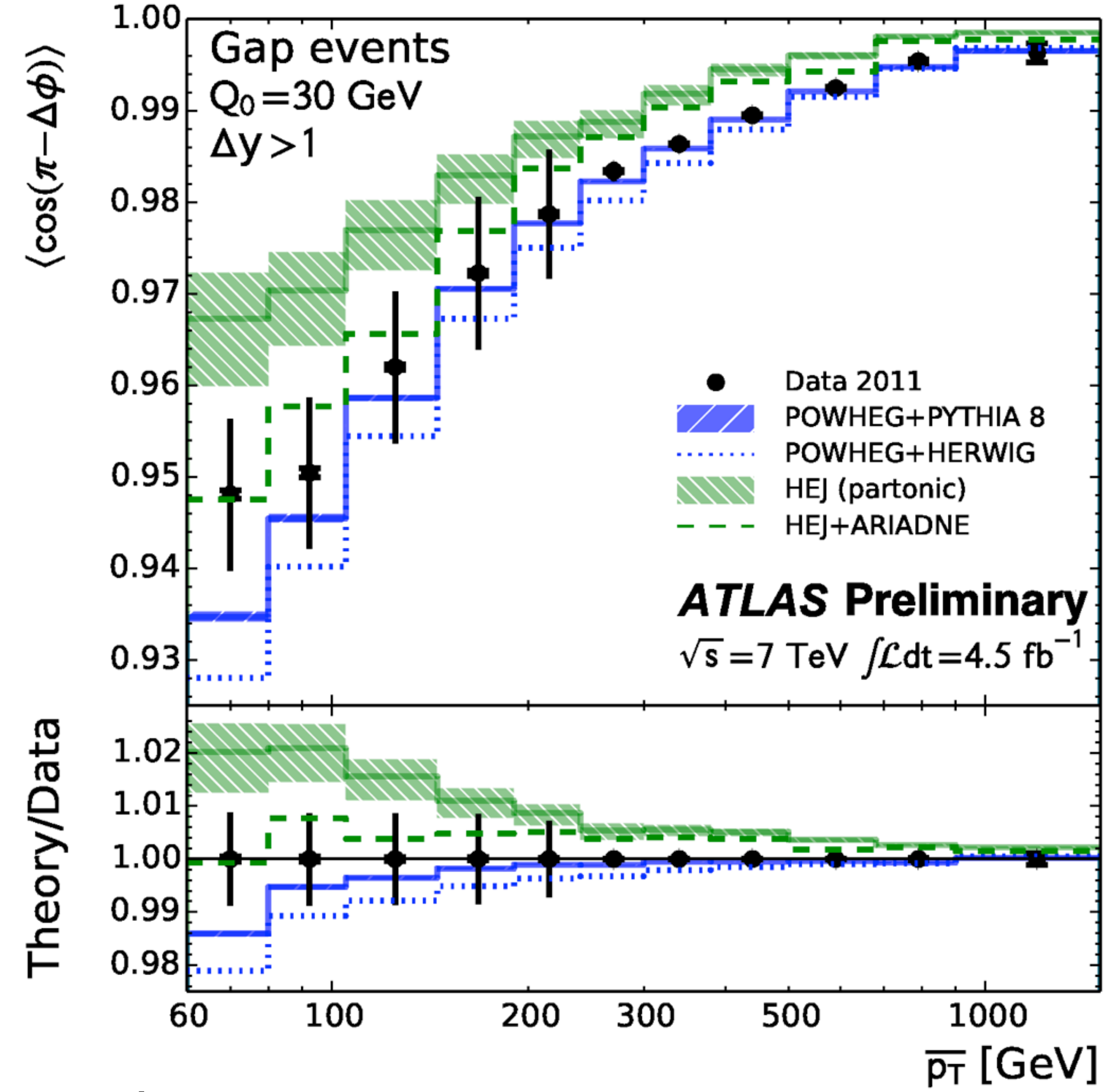




- Larger angular correlation ↔ Larger angular moment
- POWHEG predictions underestimate the data.
- partonic HEJ overestimates the data.
- Larger differences at high Δy and low p_T^{avg}.

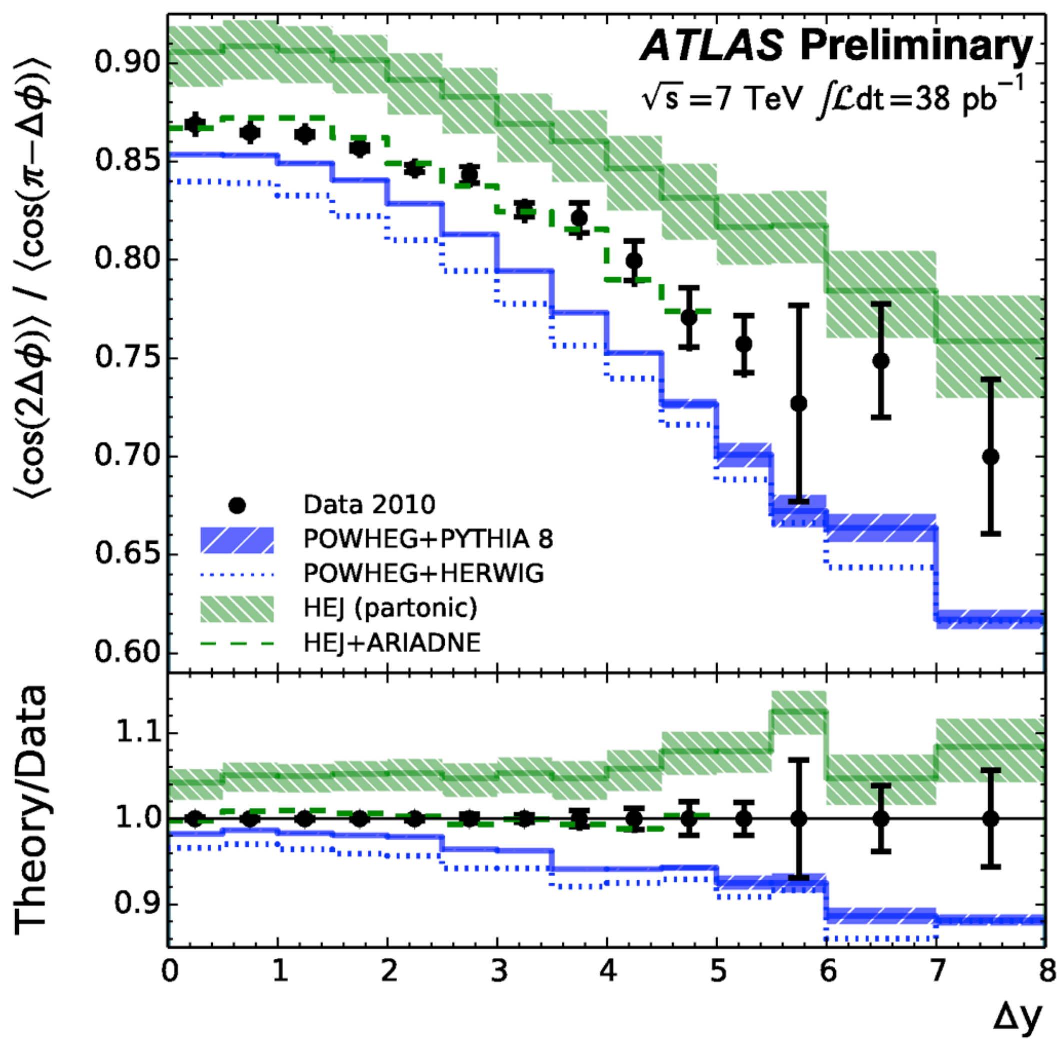
1st angular moment (Gap events)

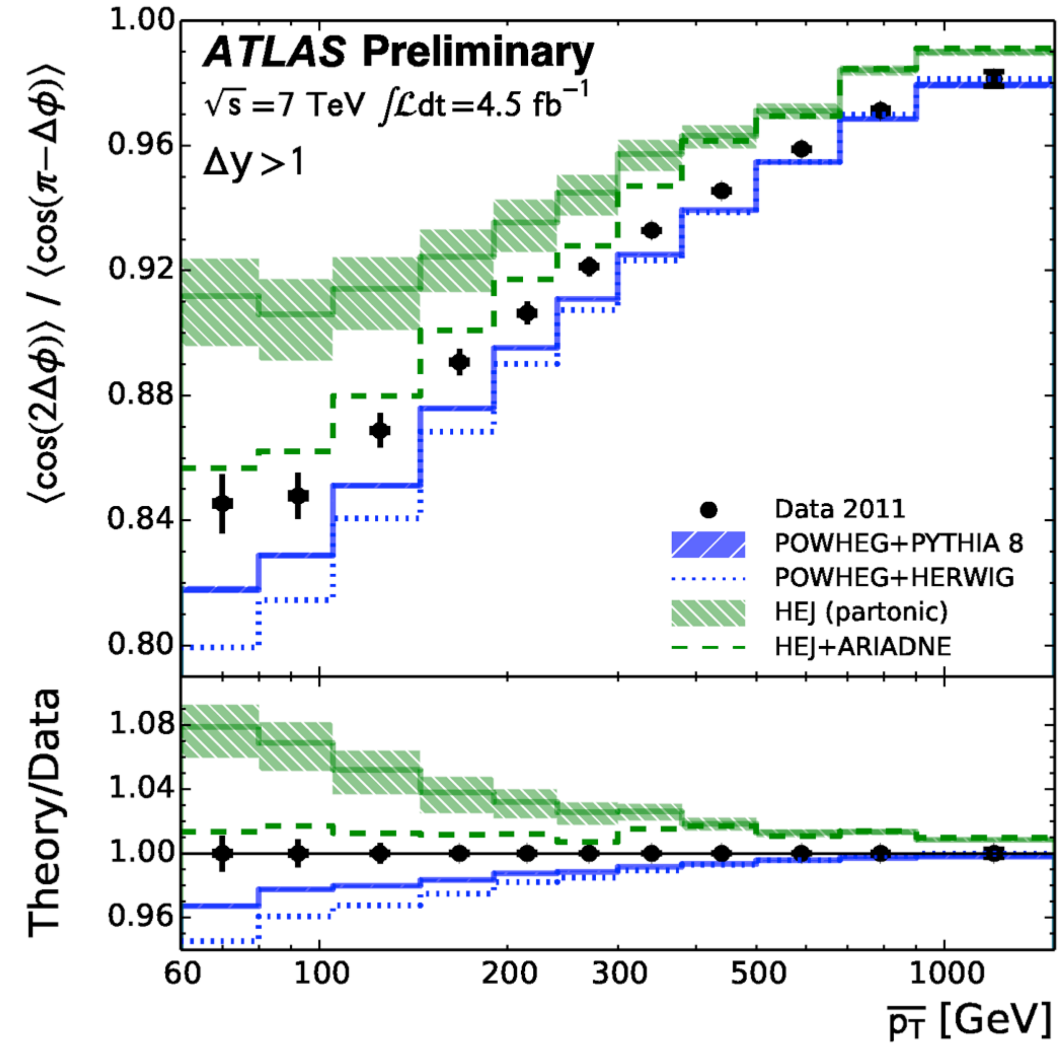




- Different Δy dependence for Gap events
- Partonic HEJ overestimates the data.
- ARIADNE parton shower makes HEJ prediction give better description, but the agreement is worse than in the inclusive case.
- POWHEG+PYTHIA gives reasonable description, especially at high p_T^{avg}.

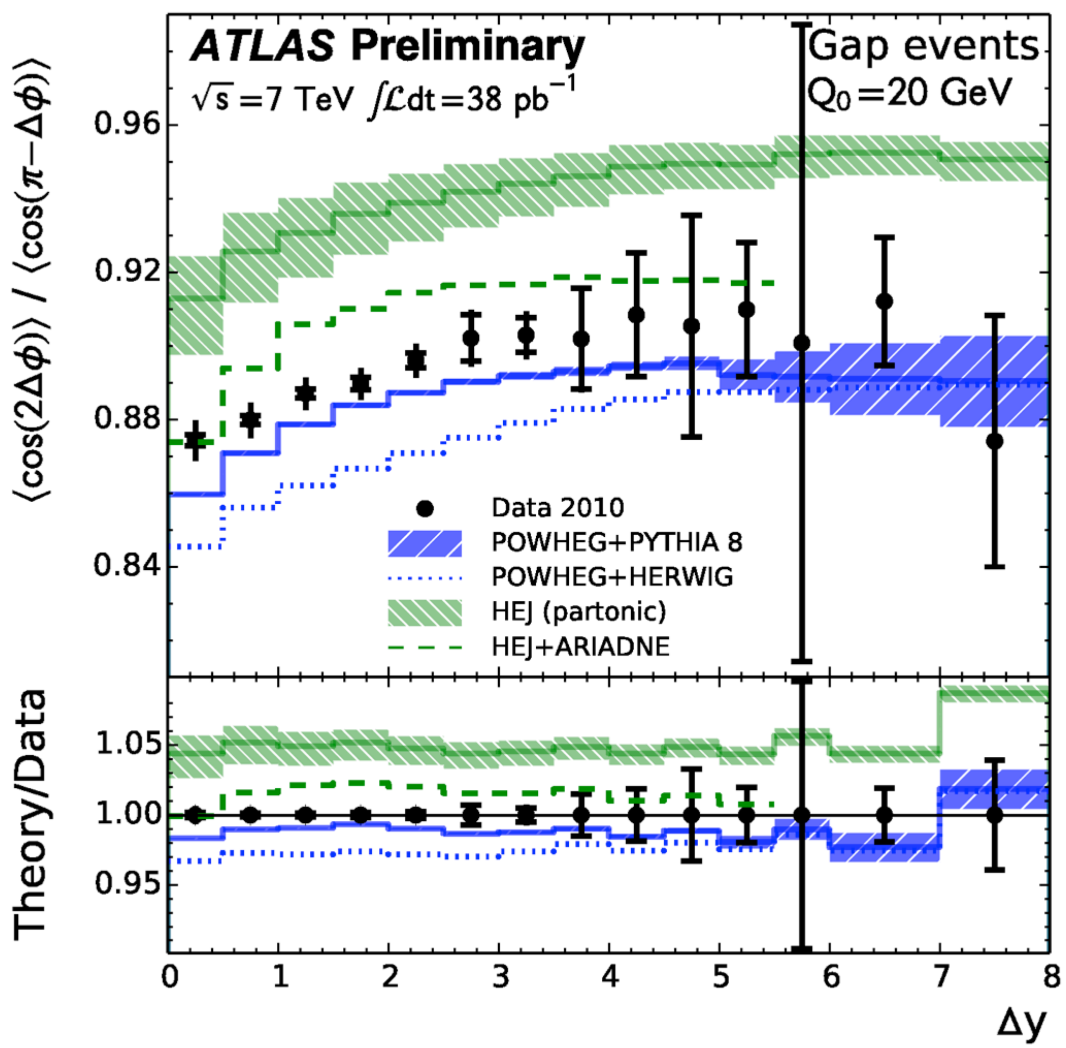
2nd/1st moments (Inclusive)

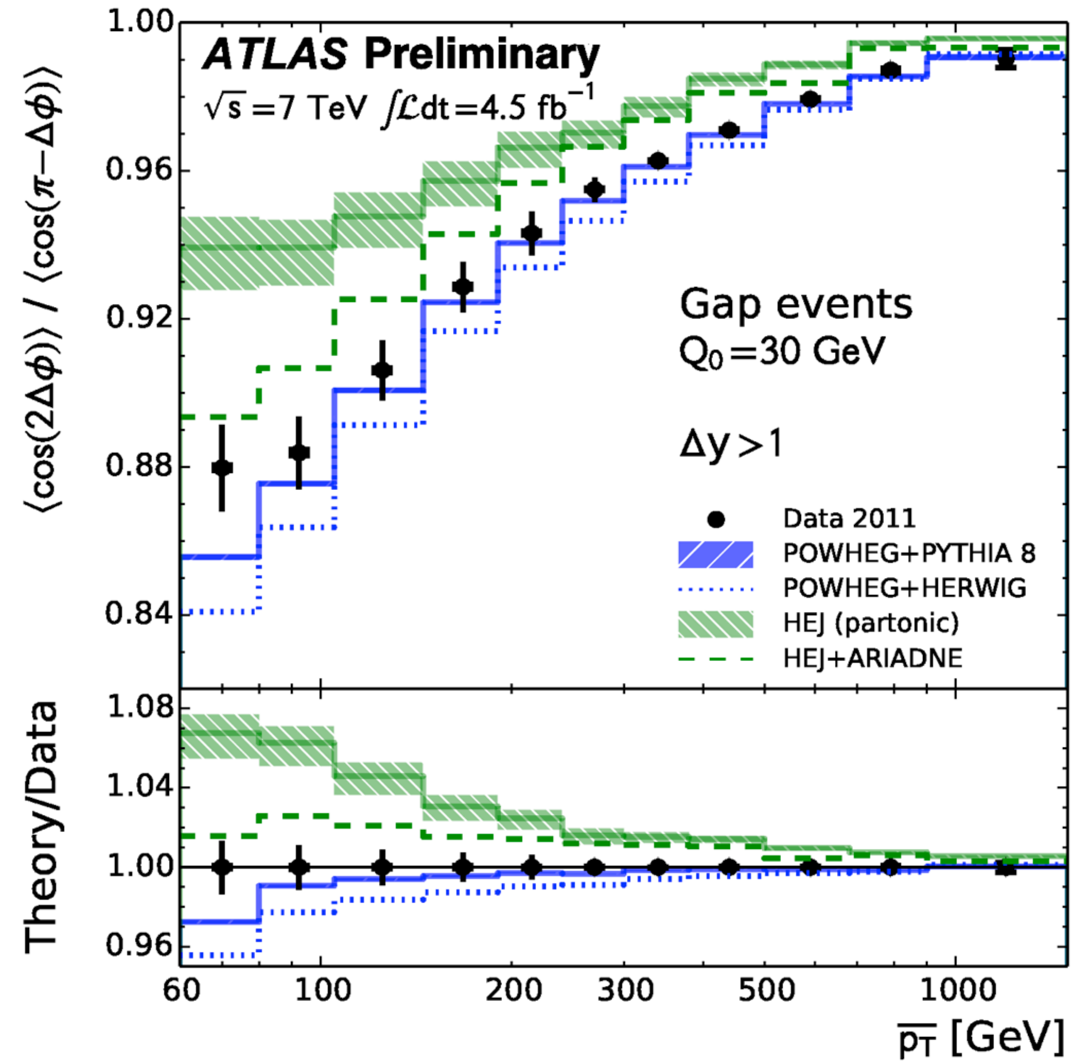




- 2nd moments, <cos(2Δϕ)>, falls more rapidly than the 1st, as the dijet deviates from a back-to-back topology.
- More discrimination power for BFKL-like and DGLAP-like predictions than 1st moment only.
- Best description is given by HEJ+ARIADNE.

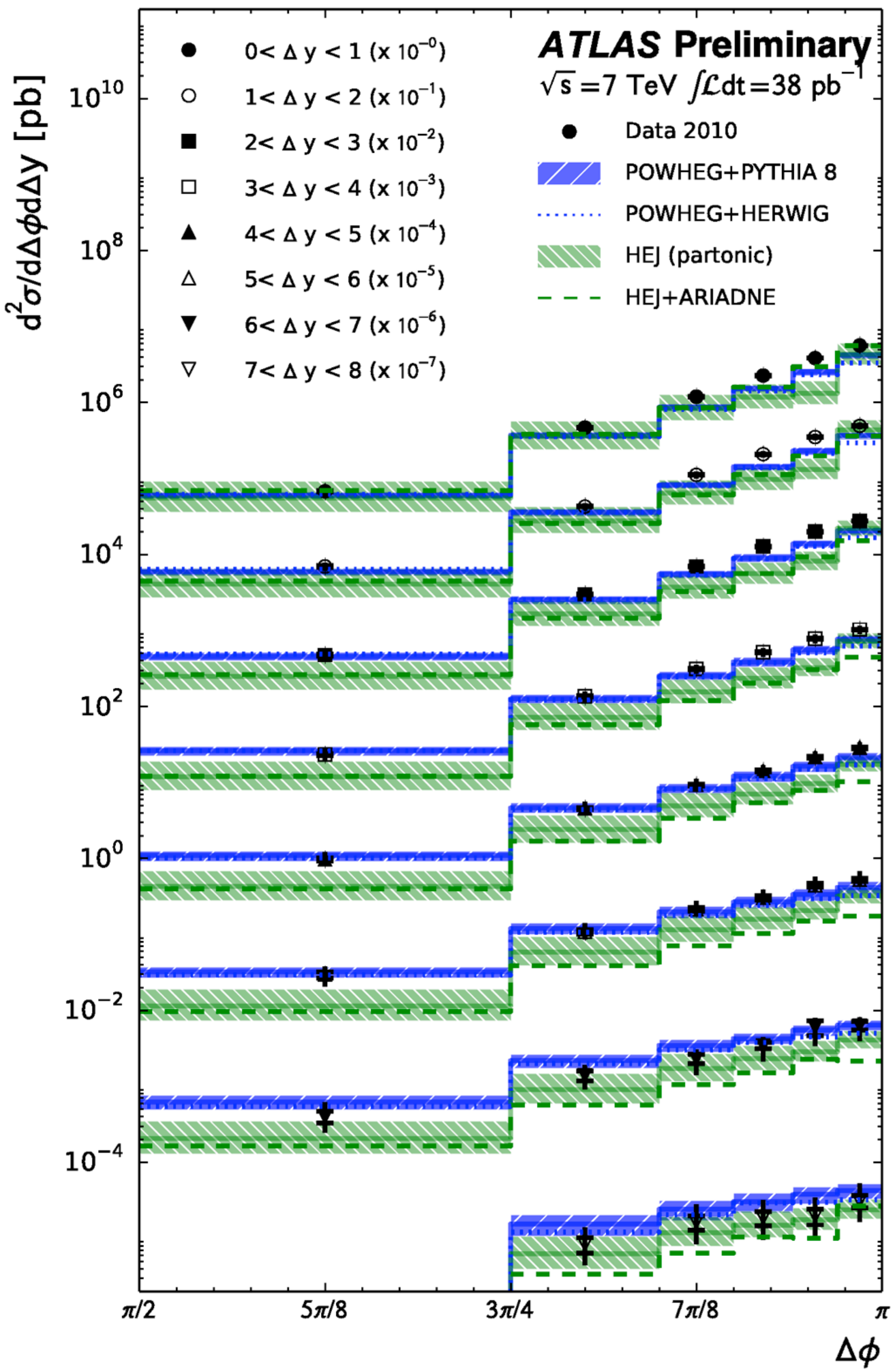
2nd/1st moments (Gap events)

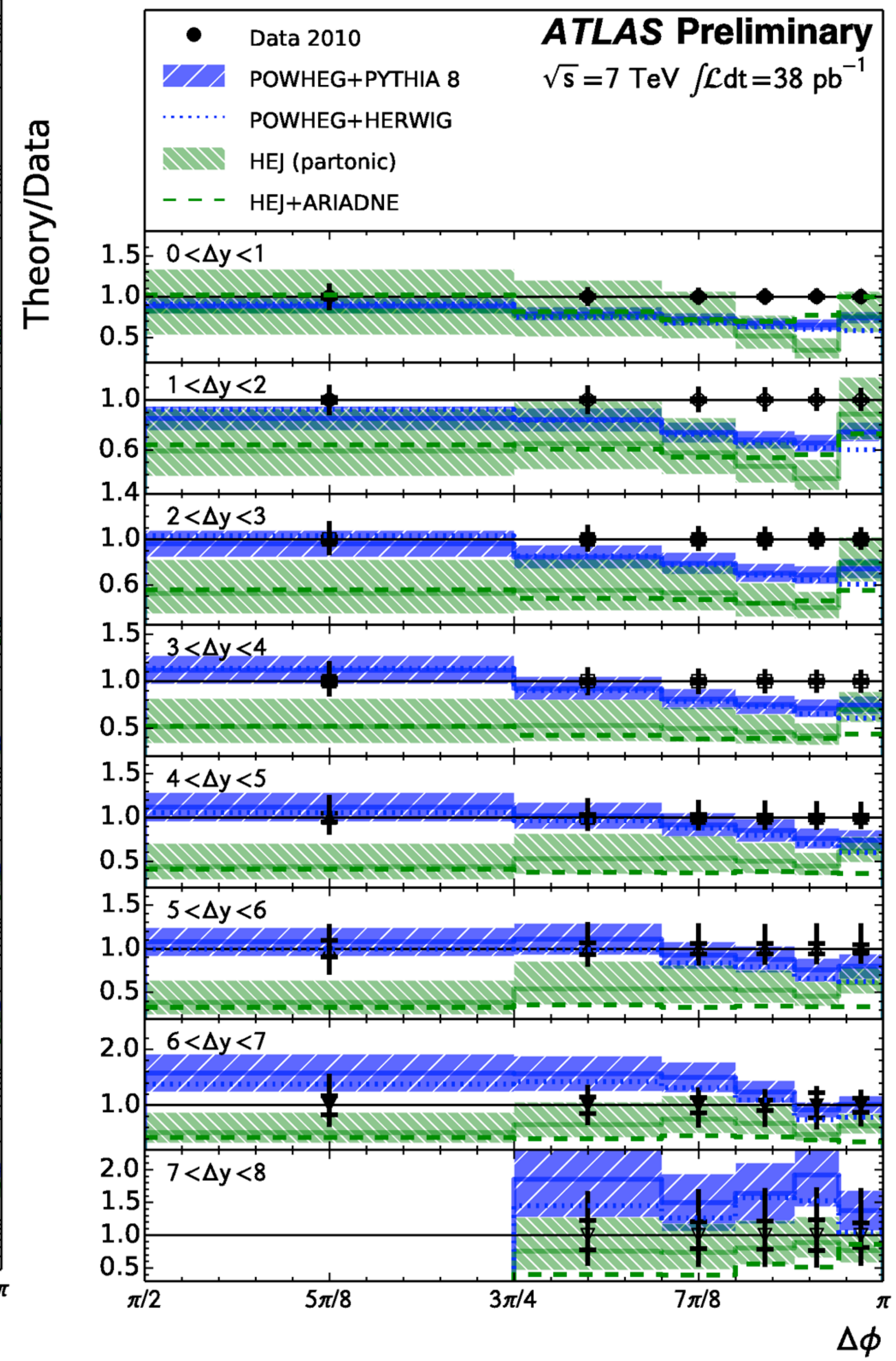




- HEJ+ARIADNE also deviates from the data.
- POWHEG+PYTHIA gives the best description, especially at high p_T^{avg}.

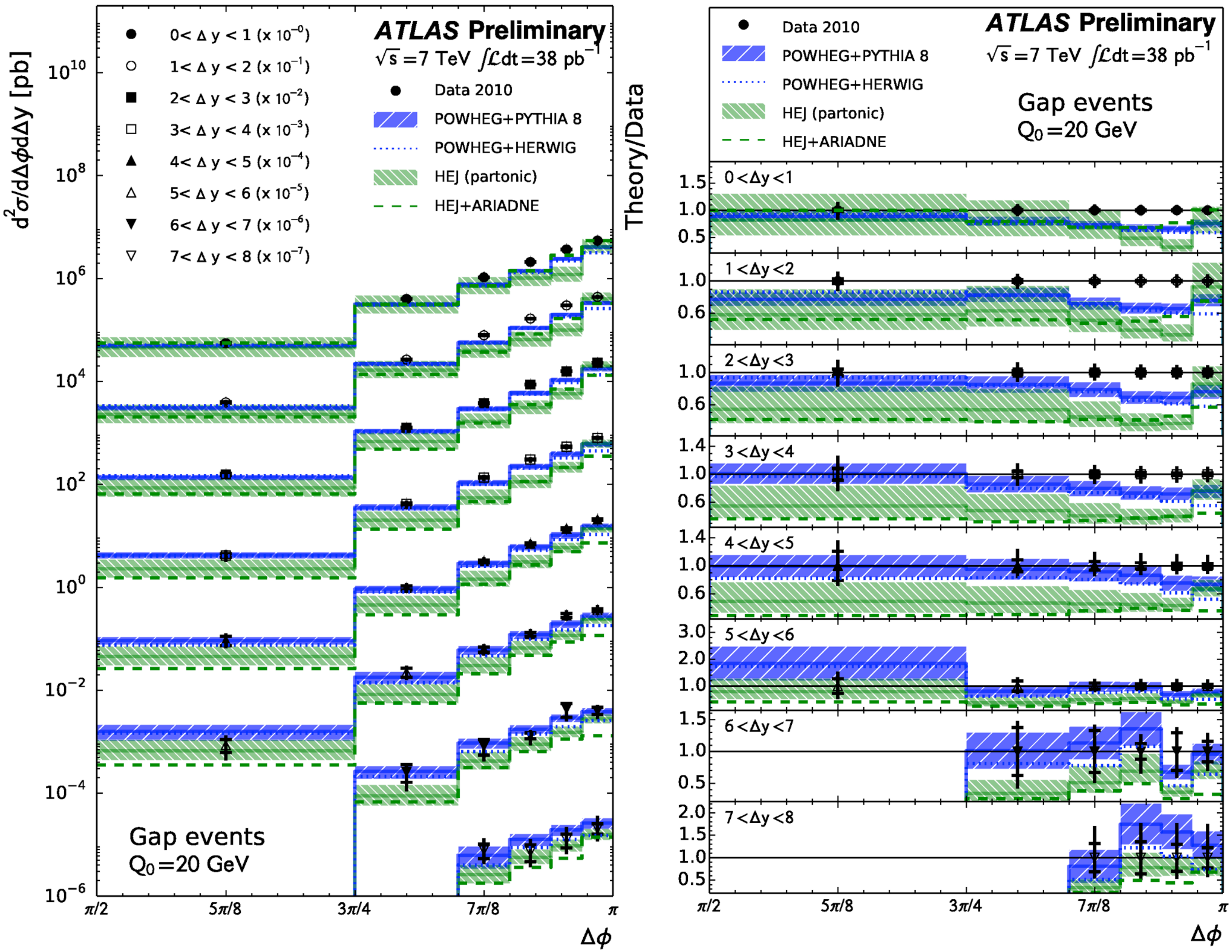
Cross-section (Inclusive)





- POWHEG predictions are consistent with data, except for high $\Delta\phi$ in the low Δy bins.
- HEJ predictions underestimate the data.

Cross-section (Gap events)



- Similar tendency as in inclusive events.

Summary

- Gap fraction and azimuthal decorrelation are measured as functions of Δy and p_T^{avg}, with $\Delta y<8$ and $p_T^{avg}<1.5$ TeV, at $\sqrt{s}=7$ TeV.
- Theoretical predictions are compared to the measured data.
  HEJ (BFKL approach) vs POWHEG (DGLAP approach):
    - POWHEG+PYTHIA gives reasonable descriptions except for azimuthal variables at large Δy or small p_T^{avg}/Q_0.
    - POWHEG+HERWIG predicts too many jets.
    - Partonic HEJ gives a poor description of data.
    - HEJ+ARIADNE gives reasonable descriptions.

  None of them can describe the whole phase-space measured simultaneously.
  → Improved theoretical prediction is needed.
- $\langle\cos(2\Delta\phi)\rangle/\langle\cos(\pi-\Delta\phi)\rangle$ gives best discrimination of DGLAP approach and BFKL approach.
- Measurement can be a crucial input for parton shower modelling and for discussions on BFKL effects or colour-singlet exchange.

Backup

Gap fraction vs Q_0