Measurement of Forward Jets and Dijets with a Jet Veto

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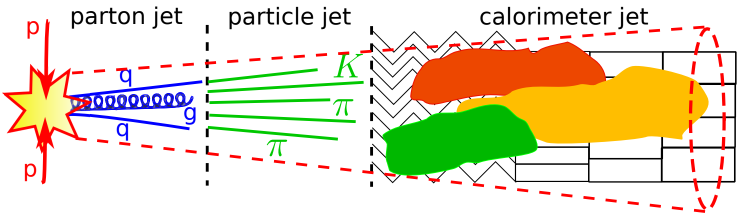
ATLAS EXPERIMENT

FSP 101 ATLAS

Outline

- $\rightarrow$ Motivation
- $\rightarrow$ ATLAS Detector
- $\rightarrow$ Forward Jet Performance
- $\rightarrow$ Forward Jet Cross-Section Measurement
- $\rightarrow$ Dijet Production with Jet Veto
- $\rightarrow$ Conclusion



- Jet production in p-p: PDF · matrix element · parton shower · hadronization · underlying event
- PDF - probe gluon PDF's at low-x
- QCD dynamics - probe description by standard event generators:
  - BFKL-like dynamics (becomes important for large rapidity intervals)
  - Effects of wide-angle soft-gluon radiation
  - Colour singlet exchange (becomes important for widely separated jet + high mean p_T of dijet system)
- Forward jet measurement required

MC Simulation and Theory Prediction

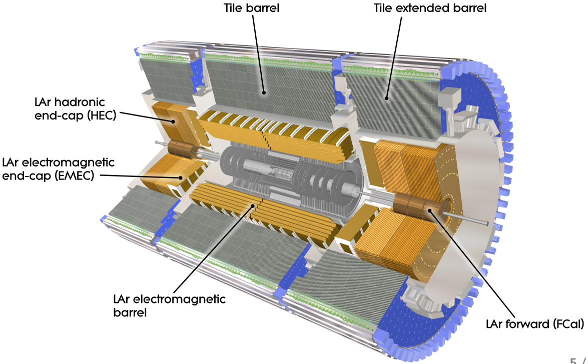
- Event generators for systematic uncertainties and detector effect corrections (LO):
  - PYTHIA 6
  - HERWIG++
  - ALPGEN
- NLOJET++ (NLO):
  - Hadronisation and underlying event (non-perturbative corrections) obtained using e.g. PYTHIA
- POWHEG (NLO)
  - NLO dijet calculation passed through PYTHIA/HERWIG for showering, hadronisation, and underlying event
- HEJ[1] (all-order):
  - Parton level only
  - Provides an all-order description of wide angle emissions

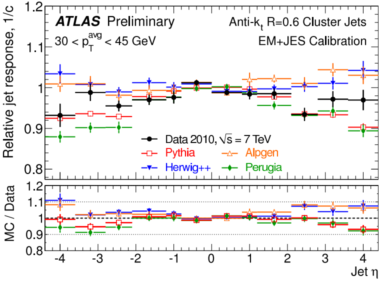
[1] arXiv:1007.4449v1

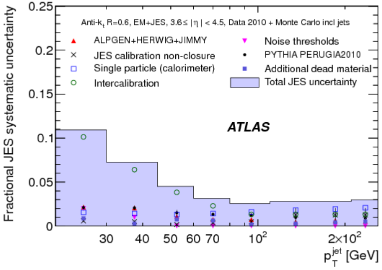
ATLAS Detector

- In 2010 the LHC provided proton-proton collisions with a center-of-mass energy of $\sqrt{s} = 7\text{TeV}$
- Approximately 45 pb^{-1} have been recorded by ATLAS
- Relevant sub-systems: tracking system, electromagnetic, and hadronic calorimeter
- Total coverage of the ATLAS calorimeters is $|\eta| < 4.9$
  - Tracking detector: $|\eta| < 2.5$
  - Forward calorimeter (FCal): $3.1 < |\eta| < 4.9$

- FCal measures electromagnetic and hadronic energy
- Designed to operate in high rate environments







- Forward jet energy scale (JES) uncertainty via dijet p_T balance[2]
- Discrepancies from different physics model predictions
- JES uncertainty increases at low p_T jets
- In central part of the detector $< 2.5\%$ for $60 < p_T < 800$GeV
- Reduction of JES uncertainties - work in progress

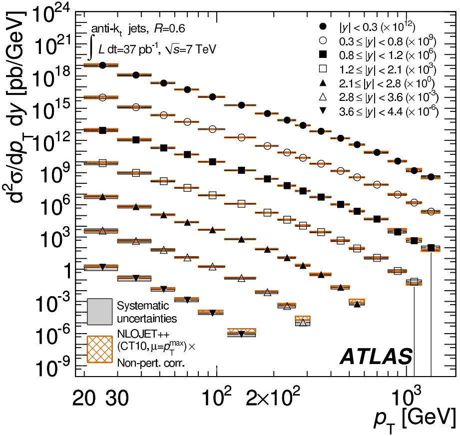
[2] arXiv:1112.6426, submitted to EPJC

Inclusive Jet Measurement: Event Selection

- Measurement performed using 2010 collision data with 37pb^{-1}
- Jets reconstructed at electromagnetic scale, calibrated with MC derived corrections.
- Jet finding algorithm: Anti-Kt with $R = 0.4$ and $R = 0.6$

- Different triggers used: central, forward, ...
- Jets are required to have $p_T > 20\text{GeV}$ and $|y| < 4.4$
- Several jet quality criteria

- Jet energy scale uncertainty determined using measurements and MC, e.g. for jets with $p_T \approx 20\text{GeV} \approx 5\%$ in central region and up to $\approx 13\%$ in the forward region.

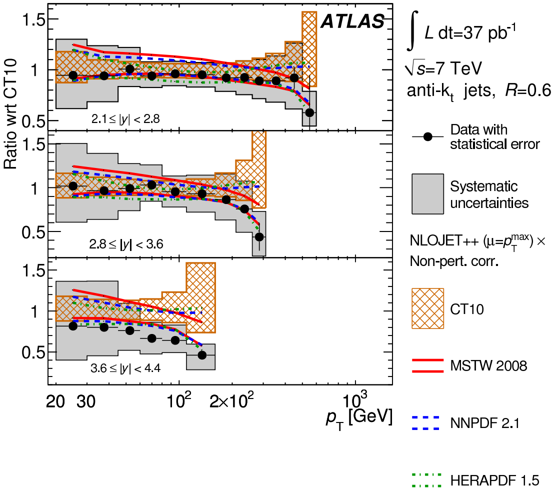


- Jet double-differential cross section in forward region measured[3]
- Cross-section spectra corrected for detector effects
- Careful treatment of systematic uncertainties
- Good description of data over many orders of magnitude

[3] arXiv:1112.6297v2

- Ratios of inclusive jet double-differential cross-section to the theoretical prediction

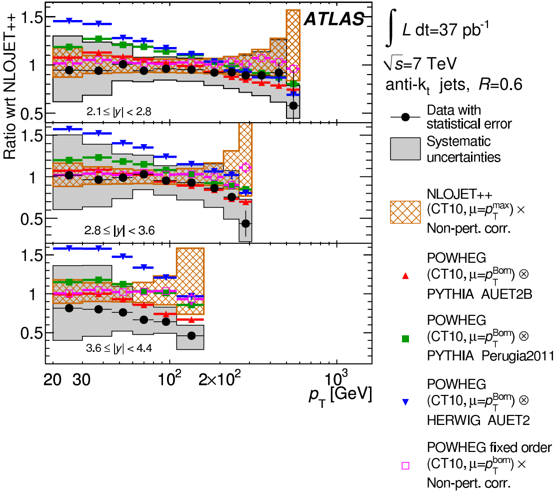
- Normalized to NLOJET++(+non-pert. corr., CT10 PDF) prediction
- Non-pert. corr. derived from PYTHIA (AUET2B tune)
- MSTW, NNPDF, and HERAPDF give a slightly better description than CT10
- Systematic uncertainties large due to JES (in forward region at low p_T)



Inclusive Jet Measurement: Generators

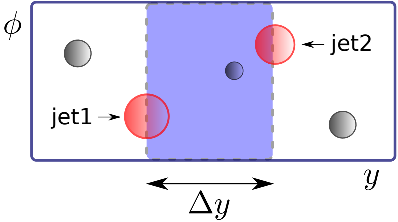
- Ratios of data & POWHEG to the NLOJET++ predictions corrected for non-perturbative effects

- CT10 PDF set used for predictions
- POWHEG passed through PYTHIA/HERWIG for showering, hadronisation, and underlying event (AUET2B/AUET2)
- POWHEG+PYTHIA gives the best description



Dijet Production with Jet Veto

- The aim of this analysis is to study effects of QCD radiation and compare to predictions
- Measurement of additional hadronic activity in high p_T dijet events in the rapidity interval Δy between the two leading jets



- Two variables to quantify the amount of additional radiation in rapidity interval Δy:
  - Gap fraction - fraction of events that do not have an additional jet with $p_T > Q_0$
  - Mean number of jets with $p_T > Q_0$
- $Q_0 =$ veto scale is chosen to be 20GeV

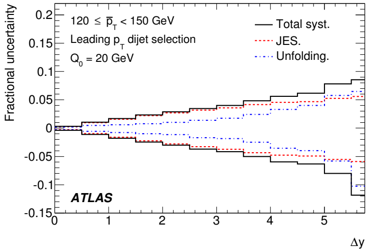
10.1007/JHEP09(2011)053

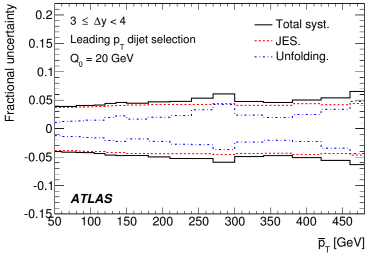
Event Selection and Tunes

- Measured data and jet reconstruction same as for inclusive jet cross-section measurement

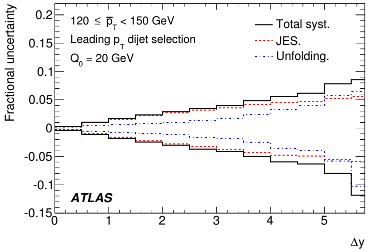
- Number of jets required to be ≥ 2
- Trigger: $\bar{p}_T$ (mean p_T of dijet system) regions defined, where the chosen trigger for each region was at least 99% efficient
- Jets are required to have $p_T > 20\text{GeV}$ and $|y| < 4.4$
- $\bar{p}_T$ of the jets define the dijet system $> 50\text{GeV}$
- Veto jet $p_T > Q_0$, where $Q_0 = 20\text{GeV}$
- Pile-up suppression: only events with exactly one reconstructed primary vertex

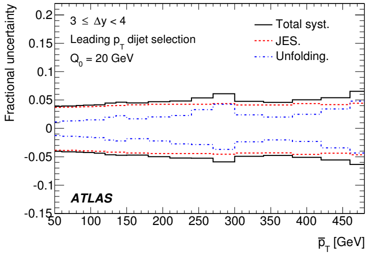
- PYTHIA 6 (MRST LO* PDF + AMBT1 tune)
- HERWIG++ (MRST LO* PDF + LHC-UE7-1 tune)
- ALPGEN (CTEQ6L1 PDF + AUET1 tune)
- POWHEG (MSTW 2008 NLO PDF + AMBT1/AUET1)
- HEJ (MSTW 2008 NLO PDF)





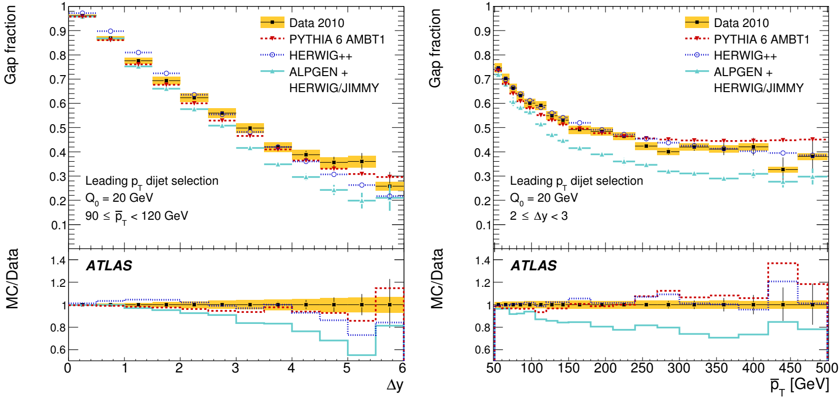
- Experimental uncertainty dominated by ...
  - Jet energy scale uncertainty
  - Correction for detector effects (unfolding)
  - Other uncertainties found to be negligible
- For example: in gap fraction few % up to 9%





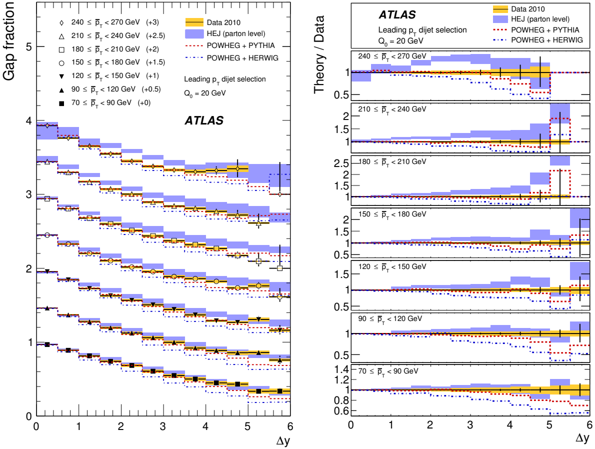
- Overall uncertainty in HEJ dominated by scale choice and are larger than non-perturbative corrections (estimated using PYTHIA)
  - Typically 5% for the gap fraction and 8% for the mean number of jets
- Difference between POWHEG+PYTHIA and POWHEG+HERWIG larger than intrinsic uncertainty in POWHEG NLO calculation

Gap Fraction: PYTHIA, HERWIG, ...



- PYTHIA: best description as a function of Δy (slightly underestimates at $\Delta y \approx 3$); good description as function of $\bar{p}_T$
- HERWIG: overestimates for low Δy, underestimates for large Δy; good description as function of $\bar{p}_T$
- ALPGEN: largest deviation from data

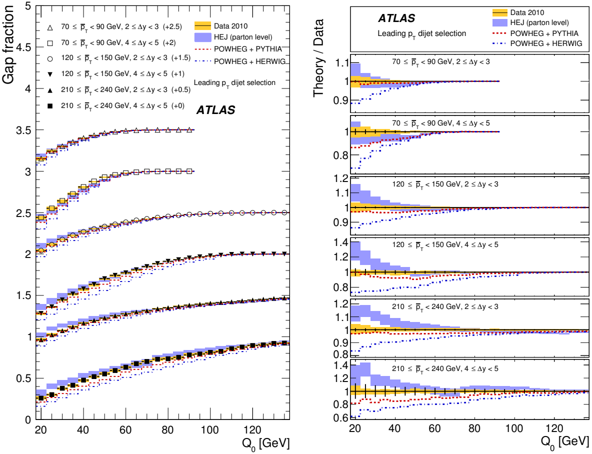
- POWHEG+HERWIG:
  - Tends to produce too much activity
- HEJ:
  - Describes data at low $\bar{p}_T$ as function of Δy
  - Predicts too many gap events at large $\bar{p}_T$ (expected for $\bar{p}_T >> Q_0$)



- POWHEG+PYTHIA:
  - Provides best description, considering the full phase-space
  - Deviates from data for large Δy (expected, contributions to full QCD important at large Δy)

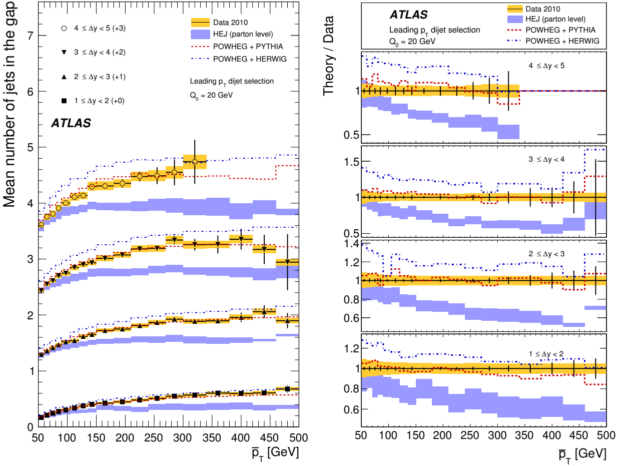
Gap Fraction: Dependence on Veto Scale Q_0

- Q_0 dependence of cross-section useful in studying colour structure of event



- HEJ: Description becomes better for $Q_0 \to \bar{p}_T$
- POWHEG+PYTHIA and POWHEG+HERWIG: Large differences
  For large $\bar{p}_T$ and Δy none of theoretical predictions describe data well - important for colour singlet exchange.

Mean Number of Jets in Rapidity Interval



- HEJ: Deviates from data (as for gap fraction)
- POWHEG+PYTHIA: Best description
- POWHEG+HERWIG: Worse for low $\bar{p}_T$, not observed in the gap fraction distributions

Conclusion

- Need forward jets to probe perturbative QCD calculations, PDF's, and to constrain phenomenological models
- Nearly 4π coverage of the ATLAS high granularity calorimeter system allows precise measurement of forward jets

- Inclusive jet cross-section measurement in forward region
  - Comparison between data and predictions for different PDF sets and NLO+parton shower
  - Sensitive to PDF's and physics models
- Dijet Production with Jet Veto
  - Activity in the rapidity interval between boundary jets
  - Best overall description by POWHEG+PYTHIA
- Approx. 120x more data at $\sqrt{s} = 7$TeV and 150x more data at $\sqrt{s} = 8$TeV already collected
- Challenges:
  - High pile-up environment
  - Reduction of jet energy scale uncertainty