ATLAS Measurements of Jet Cross Sections

Stephanie Majewski,
Brookhaven National Laboratory

PANIC 2011
July 24-29, 2011 • Boston, MA
Jet Measurements on ATLAS

- Jet measurements based on ~40 pb⁻¹ of data collected in 2010 (√s = 7 TeV)

- Exploring the frontiers of QCD:
  - Study dynamics of interactions in a new energy regime
  - Extend to O(TeV) jet transverse momenta and forward rapidities
  - Sufficient energy available for high jet multiplicities
ATLAS Calorimeters

\eta = -\ln(\tan \theta / 2)

\[ y = \frac{1}{2} \ln \left( \frac{E + p_z}{E - p_z} \right) \]
Trigger & Event Selection

central and forward jet triggers
variety of thresholds available

Jet Quality Requirements
remove out-of-time deposits,
bad quality calorimeter pulses,
oily cells
Jet Reconstruction

3-D topological clusters
excellent noise suppression

anti-\(k_T\) algorithm
sequential recombination that is
infrared, collinear safe
\(R = 0.4, 0.6\)

arXiv:0802.1189 [hep-ex]
Jet Calibration

Jet energy scale:
jet $p_T$ corrected on avg from EM to hadronic scale ($p_T, \eta$)

Systematic Uncertainty
< 2.5 % [central, medium $p_T$]
~12.5 % [forward, low $p_T$]
Comparison to Theory

- Comparison performed at particle level
- Data corrected for detector resolutions, inefficiencies
- Theory corrected for underlying event & hadronization

- Next-to-leading order predictions: NLOJet++
- Tree-level matrix elements + parton showers: ALPGEN, Sherpa (high multiplicities); POWHEG (higher order)
- Rapidity evolution (BFKL physics + high mult): HEJ

S. Majewski
Inclusive Jet Cross-Section

Updated analysis:
- full 2010 dataset
- extension to forward region

High-E Forward Jet:
$E = 3.37 \text{ TeV}, p_T = 120 \text{ GeV}, y = -4.0$

Run Number: 167607, Event Number: 36526763
Date: 2010-10-25 05:40:24 CEST
Inclusive Jet and Dijet Cross-Sections

\[ d^2 \sigma / dp_T dy \text{ [pb/GeV]} \]

\[ d^2 \sigma / dm_{12} dy \text{ [pb/TeV]} \]

\( L dt = 37 \text{ pb}^{-1}, \sqrt{s} = 7 \text{ TeV} \)

\( \text{anti-}\k_t\text{ jets, } R = 0.6 \)

\( |y| < 0.3 \times 10^3 \)

\( 0.3 \times |y| < 0.8 \times 10^3 \)

\( 0.8 \times |y| < 1.2 \times 10^3 \)

\( 1.2 \times |y| < 2.1 \times 10^3 \)

\( 2.1 \times |y| < 2.8 \times 10^3 \)

\( 2.8 \times |y| < 3.6 \times 10^3 \)

\( 3.6 \times |y| < 4.4 \times 10^3 \)

ATLAS Preliminary

Systematic uncertainties

2.1 < |y|_\text{max} < 2.8 \times 10^3

1.2 < |y|_\text{max} < 2.1 \times 10^3

0.8 < |y|_\text{max} < 1.2 \times 10^3

0.3 < |y|_\text{max} < 0.8 \times 10^3

|y|_\text{max} < 0.3 \times 10^3

NLO pQCD (CTEQ 6.6) \times \text{Non-pert. corr.}

ATLAS Preliminary

\( \sqrt{s} = 7 \text{ TeV}, \int L dt = 37 \text{ pb}^{-1} \)
Inclusive Jet Cross-Section

NLO pQCD (CTEQ 6.6 PDF)

ATLAS-CONF-2011-047
Inclusive Jet Cross-Section

NLO pQCD (MSTW 2008 PDF)

Powheg + Pythia
Powheg + Herwig

S. Majewski

ATLAS-CONF-2011-047
High-\(p_T\) Dijet Event:
jet 1 (\(p_T,y\)) = 1.5 TeV, -0.58
jet 2 (\(p_T,y\)) = 1.0 TeV, 0.44
\(m_{jj} = 2.8\) TeV, MET = 310 GeV
Dijet Cross-Section

NLO pQCD (MSTW 2008 PDF)

- Powheg + Pythia
- Powheg + Herwig

ATLAS-CONF-2011-047
Dijet Angular Decorrelations

- Observables such as $\Delta \phi$, $\Delta y$ probe corners of phase space (that may not be well-described by event generators)

- Azimuthal Decorrelations ($\Delta \phi$):
  - sensitive to multiple jet production and ISR
  - events with $\Delta \phi << \pi$ impact searches for new physics (e.g. SUSY)

- Dijet Production with a Jet Veto ($\Delta y$):
  - BFKL dynamics, wide-angle soft gluon radiation, color-singlet exchange
  - jet veto used in vector-boson-fusion Higgs searches
Dijet Azimuthal Decorrelations

$\Delta \phi_{\text{dijet}}$

**ATLAS $\sqrt{s}=7$ TeV**
- anti-$k_t$ jets $R=0.6$
- $p_T^{\text{max}}>110$ GeV
- Leading two jets: $|y|<0.8$
- Data $\int L dt = 36$ pb$^{-1}$

**ATLAS $\sqrt{s}=7$ TeV**
- anti-$k_t$ jets $R=0.6$
- $p_T^{\text{max}}>110$ GeV
- Leading two jets: $|y|<0.8$
- Data $\int L dt = 36$ pb$^{-1}$

**Number of Events**
- $\geq 2$ jets
- $\geq 3$ jets
- $\geq 4$ jets
- $\geq 5$ jets
- PYTHIA

**$1/\sigma d\sigma/d\Delta \phi$ [radians$^{-1}$]**
- $\Delta \phi$ in radians

**Phys. Rev. Lett. 106, 172002**

S. Majewski
Dijet Azimuthal Decorrelations

NLO pQCD

Monte Carlo Generators

Phys. Rev. Lett. 106, 172002

S. Majewski
Dijets with Jet Veto

$Q_0 = 20 \text{ GeV}$
(jet veto scale)

Gap fraction:

$\frac{\text{#events w/ no jets (> } Q_0 \text{) in gap}}{\text{#events}}$

S. Majewski

arXiv:1107.1641, submitted to JHEP
Dijets with Jet Veto

$\varphi$  \hspace{1cm} $p_T$  \hspace{1cm} $\Delta y$  \hspace{1cm} $y$

$Q_0 = 20$ GeV  
(jet veto scale)

Gap fraction:
#events w/ no jets (> $Q_0$) in gap  
#events

arXiv:1107.1641, submitted to JHEP
Multijet Event:
6 jets with $p_T > 60$ GeV, $|y| < 2.8$

arXiv:1107.2092, submitted to EPJC
Multijet Cross-Sections

\# events w/ ≥ 3 jets

\# events w/ ≥ 2 jets

**NLO pQCD**

\[ p_T^{(1)} > 80 \text{ GeV}, \]
\[ p_T^{(n-1)} > 60 \text{ GeV} \]

\[ R=0.6, \int L \, dt=2.4 \text{ pb}^{-1} \]

Data (\( s=7 \text{ TeV} \)) + syst.

NLO + non. pert. + syst

**Monte Carlo Generators**

arXiv:1107.2092, submitted to EPJC
Summary

- Exciting jet results from ATLAS; just a snapshot was shown today
- NLO pQCD calculations performing quite well, along with high-multiplicity ME+PS generators (Alpgen, Sherpa)
- Comparisons also made to promising new generators (Powheg, HEJ)
  - Perturbative QCD tested over an unprecedented kinematic range