Measurements of Jet Production in pp Collisions with the ATLAS Detector
XX International Workshop on Deep Inelastic Scattering and Related Subjects

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on behalf of the ATLAS Collaboration
Jet Measurements at ATLAS

- At the LHC, jet production is the dominant high $p_T$ process
- Provides precise information on the structure of the proton and allows direct tests of QCD predictions at leading and next-to-leading order
- Current results on jets at rapidities up to 4.4, and 20 GeV < $p_T$ < 1.5 TeV
- Dijet mass measurements up to 5 TeV
- Multi-jet measurements are critical for understanding backgrounds in searches for new physics
- Track jet measurements allow comparisons to simulations at very low $p_T$ (4 GeV)

- “Measurement of inclusive jet and dijet production in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector”
- “Measurement of high mass dijet production in pp collisions at sqrt(s)=7 TeV using the ATLAS detector”
- “Measurement of multi-jet cross sections in proton-proton collisions at a 7 TeV center-of-mass energy”
- “Properties of jets measured from tracks in proton-proton collisions at center-of-mass energy sqrt(s) = 7 TeV with the ATLAS detector”
Inclusive and Di-jet Measurements

- Using 2010 data set (37 pb\(^{-1}\)) for inclusive and 2011 data set (4.8 fb\(^{-1}\)) for di-jet results
- Using anti-\(k_T\) jet-finding algorithm
- PYTHIA with MRST LO* PDF used to simulate and correct for detector effects
- Measurements compared to
  - fixed-order predictions from NLOJET++ corrected for non-perturbative effects with PYTHIA
  - NLO matrix element and parton shower predictions from POWHEG and PYTHIA or HERWIG
- See talk by B. Malaescu for more details (Thursday morning)

- Calorimeter trigger thresholds for jets in each \(p_T\) bin chosen to maintain efficiency of > 99% with as low as possible prescale
- Minimum-bias trigger used for jets with 20 GeV < \(p_T\) < 60 GeV
• Jet energy scale is the dominant source of uncertainty
• Uncertainty in jet energy resolution becomes more important in forward detectors
Inclusive Jet Cross Section

- Inclusive jet double-differential cross section compared to NLO pQCD using NLOJET++
- Probe $7 \times 10^{-5} < \chi < 0.9$ (parton momentum fraction)
- Agreement over 10 orders of magnitude in the cross section
Di-Jet Cross Section

- Dijet Cross Section versus Mass, binned in $y^*$
- $y^* = |y_1 - y_2| / 2$, rapidity in the two-parton center-of-mass frame of two leading jets in $p_T$

- $P_{T,1} > 100$ GeV
- $P_{T,2} > 50$ GeV
Multi-jet Measurements

• Using 2010 data (2.4 pb⁻¹)

• Two types of comparisons to theory
  1) Shape comparison done with different leading-order simulations for use in new particle searches
  2) Comparison to NLO pQCD - NLOJET++ with MSTW 2008 PDF, corrected for non-perturbative effects with PYTHIA

• $p_{T,\text{leading}} > 80$ GeV
• Count jets with $p_T > 60$ GeV

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Unfolding and Uncertainties

- Bin-by-bin unfolding using ALPGEN+HERWIG/JIMMY simulation
- Uncertainties from
  - comparisons to PYTHIA
  - Variations of jet resolution within measured uncertainty
  - Jet energy scale including flavor composition, nearby jets, and pileup
Uncertainties from Flavor Composition and Nearby Jets

- The fractions of light-quark and gluon jets in multi-jet samples determined in data using template fits to the distribution of jet widths and the number of tracks in jets

- Presence of nearby jets alters jet energy scale
  - Has been studied by comparing momenta of tracks and calorimeter deposits associated to jets
Jet Multiplicity

- Jet cross section compared to LO simulations
- Ratio of n-jet to (n-1)-jet cross section
- Monte Carlo simulations are normalized to the measured two-jet cross section
Jet $p_T$ Spectra

- Jet $p_T$ spectra in reasonable agreement with data
  - Large spread in predictions from different simulations
- Monte Carlo simulations are normalized to the measured two-jet cross section
Comparisons to NLO pQCD Simulations

- Three-to-two-jet cross section ratio as a function of leading jet $p_T$
- Direct comparison to NLO pQCD corrected for non-perturbative effects
- Good agreement except in lowest $p_T$ bin, diminished with higher jet $p_T$ cut
Jets from Charged Particles

- Anti-$k_T$ jets reconstructed from all charged particles with $p_T > 300$ MeV

- Events are selected using a minimum bias trigger allowing study of jets at very low $p_T$

- Five quantities measured for charged particle jets:
  
  \[
  \frac{d^2 \sigma_{\text{jet}}}{dp_{T,\text{jet}} dy_{\text{jet}}}; \quad \frac{1}{N_{\text{jet}}} \frac{dN_{\text{jet}}}{dN_{\text{ch}}}; \quad \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dz}; \quad \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dp_T^{\text{rel}}}; \quad \rho_{\text{ch}}(r)
  \]
Charged Particle Multiplicity

- Measurements made for $|y_{\text{jet}}| < 1.9$
- No tune describes all of the kinematic distributions well
- Most models underestimate the contribution of the underlying event
Conclusions

• ATLAS has measured jet, dijet, and multijet differential cross sections
• First ATLAS results on jet cross sections using 2011 data presented
• Jet energy scale uncertainties of a few percent allow precision measurements extending into new kinematic regimes
• Jets reconstructed from charged particles allow measurements of very low-$p_T$ jets