Future Studies of Jet Production and Properties in ATLAS

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on behalf of ATLAS collaboration

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Outline

Introduction

Future Studies of Jet
- Measurement of Coupling Constant Radiation in Dijet System
- Contribution of Gluon Splitting
- Jet Substructure
- Multijet Observables

Summary
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Summary
ATLAS Inner Detector and Calorimeters

Inner Detector
- Pixel detectors, semiconductor tracker (SCT), transition radiation tracker
  - 87M readout channels, coverage up to $|\eta| < 2.5$
  - Immersed in 2T solenoidal magnetic field

Calorimeters
- EM barrel/endcap (LAr-Pb)
  - $|\eta| < 1.475$ and $1.375 < |\eta| < 3.2$
- HAD barrel (Fe-scintillator tiles)
  - $|\eta| < 1.7$
- HAD endcap (Cu-LAr)
  - $1.5 < |\eta| < 3.2$
- EM/HAD forward (Cu-W-LAr)
  - $3.1 < |\eta| < 4.9$
Jet Reconstruction and Calibration

- Jets are reconstructed using anti-$k_T$ jet algorithm with $R = 0.4$ or $R = 0.6$.
- The input objects are 3-D topological clusters, build from calorimeter cells,
  1. Start with a seed cell, which has the highest energy deposit amongst its neighbours and $|E| > 4\sigma_{\text{noise}}$
  2. Include neighbouring cells with $|E| > 2\sigma_{\text{noise}}$
  3. Include last layer of cells with $|E| > 0\sigma_{\text{noise}}$

Calorimeter jet response needs to be corrected for:
- Non-compensating calorimeters
- Inactive material
- Out-of-cone effects

MC-based $\eta$, $p_T$ dependent calibration.
Eta Inter-calibration with Dijet Balance

- Use central region of calorimeter as the reference region and get the relative response of the probe jet in other region

\[
\frac{1}{c} = \frac{p_T^{\text{probe}}}{p_T^{\text{ref}}}, \quad p_T^{\text{avg}} = \frac{p_T^{\text{probe}} + p_T^{\text{ref}}}{2}
\]
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Measurement of Coupling Constant

- Ratio of inclusive 3-jet and 2-jet cross section is of order $\mathcal{O}(\alpha_s)$

$$R_{3/2}(p_T^{\text{max}}) = \frac{d\sigma_{3\text{jet}}/dp_T^{\text{max}}}{d\sigma_{2\text{jet}}/dp_T^{\text{max}}}$$

- Ratio of cross-sections with different cone size
Measurement of Coupling Constant  

Multijet measurements in ATLAS (ATLAS-CONF-2011-043)
Radiation in Dijet System

ATLAS results

- Jet veto vs azimuthal decorrelation. Number and distribution of soft jets. Event-wide variables
  - The fraction of dijet events that do not have an additional jet with a transverse momentum $p_T$ greater than a given veto scale $Q_0$ in the rapidity region bounded by the dijet system

![Graph showing number of events vs $\Delta \phi$]

[Yield vs $p_T$ distribution]

[arXiv:1102.2696]

[ATLAS-CONF-2011-038] average $p_T$
Radiation in Dijet System

- **Gaps between jets in hadronic collisions.**
  

- Implemented parton-level next leading logarithmic (NLL) BFKL calculation into HERWIG

\[
R = \frac{\text{NLL BFKL}}{\text{Jet Herwig}} \times \frac{\text{LO QCD}}{\text{NLO QCD}}
\]

[E_T : second leading jet E_T]
Radiation in Dijet System

- Azimuthal decorrelation of Mueller-Navelet jets at the Tevatron and the LHC

- Mueller-Navelet jets: two jets with a large interval in rapidity and with similar $p_T$
Contribution of Gluon Splitting

- $b\bar{b}$ azimuthal correlations. CDF. Phys. Rev. D 71, 092001 (2005)
- The leading-order (LO) process: back-to-back
- Flavor excitation and gluon splitting processes are providing very different opening angle distributions from the LO process
- $b\bar{b}$ azimuthal correlations gives additional insight into the effective contributions from higher-order QCD processes to $b$ quark production
**Contribution of Gluon Splitting**

CDF results

**Electron data:**
- Fraction with $\Delta \phi < 90^\circ$: $29.8 \pm 1.3$ (stat.) $\pm 2.9$ (syst)%
- Trigger B: $p_T > 14$ GeV/c, $|\eta| < 1$
- Other B: $p_T > 7.5$ GeV/c, $|\eta| < 1$

**Muon data:**
- Fraction with $\Delta \phi < 90^\circ$: $26.4 \pm 1.7$ (stat.) $\pm 3.7$ (syst)%
- Trigger B: $p_T > 14$ GeV/c, $|\eta| < 0.6$
- Other B: $p_T > 7.5$ GeV/c, $|\eta| < 1$
Contribution of Gluon Splitting

CDF results

flavour creation

flavour excitation & gluon splitting

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Contributions of Gluon Splitting

- Measurement of b-jet shapes at CDF. 
- Gluon splitting: two b-quark in one jet → fat jet.
- Flavour creation: one b-quark in one jet.
- The shapes of b-jets are sensitive to the relative fraction of gluon splitting and flavour creation.

- To check whether the fraction of b-jet from gluon splitting is well described by Monte Carlo.
Contribution of Gluon Splitting

\[ \psi(r/R) = \left\langle \frac{p_T(0 \rightarrow r)}{p_T(0 \rightarrow R)} \right\rangle \]

where \( p_T(0 \rightarrow r) \) is the scalar sum of the transverse momenta of all objects inside a sub-cone of radius \( r \) around the jet axis. The integrated shapes are by definition normalized such that \( \psi(r/R = 1) = 1 \).
b-jets Cross Section in ATLAS

- First ATLAS inclusive and dijet cross section for b-jets
- Jets are reconstructed using anti-$k_T$ with $R = 0.4$. Contains secondary vertices
- Selection : $|y| < 2.1$  Inclusive jet $p_T$ : all jets $p_T > 20$ GeV  Dijet : both jets $p_T > 40$ GeV

- Correct the data to physics b-jet using bin-by-bin unfolding method
Jet Substructure

- **Jet Substructure as a New Higgs-Search Channel at the Large Hadron Collider.** J. Butterworth, A. Davison, M. Rubin and G. Salam. Phys.Rev.Lett. 100, 242001

Fast-moving low mass SM higgs decays to $b\bar{b}$

\[ H \rightarrow b\bar{b} \]

- Has the potential to transform the high-$p_T$ WH, ZH ($H \rightarrow b\bar{b}$) channel into one of the best channels for discovery of a low mass Standard Model Higgs
Multijet Observables

Multijet measurements in ATLAS (ATLAS-CONF-2011-043)

\[ H_T = \sum \rho_T \]

\[ |\Delta \phi_{12}| \rightarrow \Delta \phi \text{ between leading and next leading jet} \]
Multijet Observables

- **Phenomenology of event shapes at hadron colliders.**
  A. Banfi, G. Salam, G. Zanderighi. JHEP 1006:038, 2010

- First NLO+NLL predictions
- There are lots of observables which can be measured.
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Summary
Several jet measurements are there in ATLAS using 2010 data.

Still can do lots of measurement and searches in the next step:
- Measure running coupling constant
- Radiation in dijet system
- B-jet measurements
- Jet substructure and higgs search
- Different observables for event shape
backup
Underlying Event (LHC Environment)

All particles from single particle collision except those from the process of hard interactions

The transverse regions are most sensitive to the underlying event, since they are generally perpendicular to the axis of hardest scattering and hence have the lowest level of activity from this source.
Jet Response

Jet response at EM scale

$E = 30$ GeV
$E = 60$ GeV
$E = 110$ GeV
$E = 400$ GeV
$E = 2000$ GeV

$R_{t, \text{anti-k}}$ = 0.6, EM+JES

$\eta_{\text{det}}$