Measurements of Forward Jet Production at CMS

Niladri Sen
on behalf of the CMS Collaboration

DESY

19th Particles and Nuclei International Conference
Cambridge, 28th July 2011
Outline

① Introduction
   Motivation
   Experimental Setup

② Inclusive Forward Jet Spectrum
   Selection and conditions
   Systematic checks and uncertainties
   Measurement

③ Simultaneous Production of Forward and Central Jets
   Selection and conditions
   Systematic checks and uncertainties
   Measurement

④ Forward Energy Flow in Di-jet Events
   Selection and conditions
   Systematic Effects and Results

⑤ Summary
High energy collisions

- Large parton densities are important
- Large phase space for QCD emissions
- High probability for multi-parton interactions

Forward region

- High sensitivity for additional radiation and multi-parton interactions
- Large phase space region can be explored
Hadronic Forward Calorimeter at CMS

Hadronic Forward (HF)

- Coverage: $2.9 < |\eta| < 5.2$
- Steel absorber with quartz fibres
- $\Delta \eta \times \Delta \phi = 0.175 \times 0.175$
- Alternating long (165 cm) and short (starting after 22 cm) fibres: identification of electrons and photons possible
Jets

- Jets built from Calorimeter information
- Anti-$k_T$ algorithm with $R = 0.5$
- Application of jet quality criteria
- Consider jets with $p_T > 35$ GeV in $3.2 < |\eta| < 4.7$

Conditions

- Single jet trigger ($p_T > 15$ GeV) fully efficient in region of measurement
- Integrated luminosity: $3.14 \text{ pb}^{-1}$
Experimental systematic effects

- Jet Energy Scale (20–30%)
- $p_T$ resolution (for bin-by-bin corrections) (3–6%)
- Luminosity (4%)

Theoretical uncertainties

- Non-perturbative effects (Pythia and Herwig)
- Check with different PDFs
- Variation of $\mu_r$ and $\mu_f$ by a factor of 2
Corrections to hadron level utilising bin-by-bin method

- Hadron-level predictions are in good agreement with the data
- Fractional differences between forward jet spectra measured and the predictions show shape variations at high $p_T$ for CASCADE
Simultaneous production of central and forward jets

- Leading jet in central and forward region are investigated
- $p_T > 35$ GeV
- Central region: $|\eta^c| < 2.8$
- Forward region: $3.2 < |\eta^f| < 4.7$
Systematic Studies for Forward-Central Jets

**Experimental systematic effects**

- Effect of jet energy scale (25%)
- Effect of luminosity (4%)
- Variation of bin-by-bin correction factors from different MCs (5–15%)
Forward and Central Jet Cross Sections

Corrections to hadron level

- Bin-by-bin method
- Distributions re-weighted at hadron level

Results

- **PYTHIA** fails in the central region
- **HERWIG** does a better job

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Energy flow

- Measurement of $\frac{1}{N} \frac{dE}{d\eta}$
- Trigger charged particles in forward/backward region $(3.9 < \mid \eta \mid < 4.4)$

Jet Selection

- Anti-$k_T$ jets with $R = 0.5$
- $p_T > 8/20$ GeV for 900 GeV/7 TeV
- Two jets back-to-back in $\mid \eta \mid < 2.5$
Forward Energy Flow in Di-jet Events

Systematic effects

- Energy scale (10%)
- Model dependence (4%-18%)
- Overall (13%-22%)

Results

- No MPI fails
- PYTHIA encapsulates data
- HERWIG $\sqrt{s}$-dependent tunes work
### Summary

#### Inclusive forward jet cross section
- Forward calorimeter jets using the anti-$k_T$ considered; largest uncertainty is the jet energy scale
- Measurement in good agreement with theoretical predictions

#### Simultaneous production of forward and central jets
- Selection comparable; similar systematic effects
- Measurement in reasonable agreement with theoretical predictions

#### Forward energy flow in di-jet events
- Description is a challenge for event generators with multi-parton interaction models

#### Conclusion
- Interesting region of phase space; Not been fully investigated before