ANGULAR CORRELATIONS IN 3-JET EVENTS
and
SUBJET DISTRIBUTIONS AT ZEUS

Thomas Schörner-Sadenius
Hamburg University

(for the ZEUS collaboration)

DIS 06
Tsukuba, April 19-24, 2006
**ANGULAR CORRELATIONS**

Motivation: Is it really QCD?

- QCD: accepted effective theory of strong interactions.
- But – do we really see $SU(3)_C$?
  - non-abelian $\rightarrow$ 3-gluon vertex?
  - spin-1/2 (1) quarks (gluons)?
  - Color factors?

Several tests of both the color factors and the spin structure in $e^+e^-$ and $ep$:

It seems to be QCD! Strong interaction described by $SU(3)_C$!
**ANGULAR CORRELATIONS**

Investigating the gauge structure of QCD

- In 3-jet production, several color factor combinations contribute to cross section:

\[
\sigma_{ep\rightarrow 3 \text{ jets}} = C_F^2 \cdot \sigma_A + C_F C_A \cdot \sigma_B + C_F T_F \cdot \sigma_C + T_F C_A \cdot \sigma_D
\]

- Data sample: DIS: 98-00: 81.7 pb\(^{-1}\), γp: 95-00: 127 pb\(^{-1}\);
- \(Q^2 > 125 \text{ GeV}^2\), |\(\cos\gamma_h\)| < 0.65;
  \((Q^2 < 1 \text{ GeV}^2)\), 0.2 < \(y\) < 0.85;
- At least three jets (in Breit frame) with
  - \(E_T > 14 \text{ GeV}\), \(-1 < \eta < 2.5\), \(x_\gamma^{\text{obs}} > 0.7\);
  - \(E_T > 8/5/5 \text{ GeV}\), \(-2 < \eta < 1.5\);
**ANGULAR CORRELATIONS**

Variables of interest

- $\theta_H$: the angle between the planes determined by the highest $E_T$ jet and the beam, and the two lowest $E_T$ jets.

- $\alpha_{23}$: the angle between the lowest $E_T$ jets.

- $\cos(\beta_{KSW})$: $\cos \left[ \frac{1}{2} \left( \angle[(\vec{p}_1 \times \vec{p}_3), (\vec{p}_2 \times \vec{p}_B)] + \angle[(\vec{p}_1 \times \vec{p}_B), (\vec{p}_2 \times \vec{p}_3)] \right) \right]$

- $\eta^{\text{jet}_{\text{max}}}$: the $\eta$ of the most forward jet of the 3-jet system (only measured in DIS).
ANGULAR CORRELATIONS – PHOTOPROD.
Comparisons to different theories

Calculation based on SU(3)\(_C\) shows good description of data (LO!).

Comparison to calculations based on other models (adjustment of color factors) shows sensitivity to color factors!

SU(N) in large-N limit or for \(C_F=0\) clearly disfavoured.
Calculation based on SU(3) shows good description of data (LO!).

U(1)^3 theory shows 10% differences to SU(3) – same order of stat. errors.

SU(N) in large-N limit or for C_F=0 disfavoured.
SUBJETS DISTRIBUTIONS IN DIS

Motivation: Study pattern of QCD radiation

- Tests of QCD radiation so far performed using measurements of
  - integrated / differential jet shapes $\Psi(r)$ and
  - subjet multiplicities
  and using LO MC models with parton shower models.

- At sufficiently high transverse energies $E_T$ fragmentation effects negligible
  → internal jet structure can be calculated perturbatively
  → stringent test of pQCD calculations.

- Used here: Distribution of subjets within jets. Specifically:
  Jets with two subjets at $y_{cut}=0.05$!

- Variables sensitive to subjet topology:
  - $E_{T,sub}/E_{T,jet}$
  - $\eta_{sub} - \eta_{jet}$
  - $|\phi_{sub} - \phi_{jet}|$
  - $\alpha_{sub}$

Angle (viewed from jet center) between hardest subjet and proton direction.
SUBJETS DISTRIBUTIONS IN DIS

Event and Jet Selection

- Data sample: 98-00, 81.7 pb⁻¹;
- $Q^2 > 125 \text{ GeV}^2$;
- Standard cleaning cuts;
- Longitudinally invariant $k_T$ algorithm in lab frame on calorimeter cells;
- At least one jet with
  - $E_T > 14 \text{ GeV}$ and
  - $-1 < \eta < 2.5$
- Exactly two subjets resolved in a jet at $y_{\text{cut}} = 0.05$ (small hadronisation corrections).

Analysis performed in the lab frame:

- Current NLO calculations in Breit reference frame have $\leq 3$ partons in final state; two at most can be reconstructed in one jet – jet shape at $O(\alpha_S)$.
- In lab frame, up to 3 partons can be reconstructed in one jet – $O(\alpha_S^2)$.
  $\Rightarrow$ significant test of pQCD!

- Using normalized cross-sections.
- Comparison to LO MC models and NLO QCD.
SUBJET DISTRIBUTIONS
Comparison to MC models

Data show expected behaviour:
– Symmetric behaviour of $E_T^{\text{sub}}/E_T$ by construction (two entries per event).
  Subjets tend to have similar $E_T$ values.
– No production of subjets close together in phase-space.
– The harder subjet tends to be in the backward direction.

Both models describe the data reasonably well (also double-diff. distributions).
**SUBJET DISTRIBUTIONS**

Comparison to NLO QCD

- NLO theory with up to three partons in a jet can reproduce data shapes well.
- Theory supports hypothesis of hardest subjet being in backward direction.
- Also double-differential distributions nicely described.
Slightly different shapes of quark- and gluon-induced contributions to the NLO cross section.

Data better described by quark-induced contribution which in the phase-space considered amounts to 82%.

Subjets arising from qg pairs seem to be more balanced in $E_T$ and closer together than those from qq pairs.
**SUMMARY**

- HERA offers good opportunity to test QCD dynamics and radiation pattern.

- ZEUS three-jet angular correlations
  - supply access to underlying gauge group via color factor analysis
  - provide discriminating power between SU(3)$_C$ and other theories
  - do not falsify SU(3)$_C$, although other groups also not excluded.

- ZEUS subjet distributions
  - allow study of QCD radiation pattern within jets in perturbative regime
  - are nicely described by NLO QCD calculations with up to three partons in one jet
  - are dominated by quark-induced contributions for the phase-space region in question (and provide discrimination power between gluon- und quark-induced contributions).