

THREE-JET ANGULAR CORRELATIONS AND SUBJET DISTRIBUTIONS AT ZEUS

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Besides structure function measurements and jet physics, there is a lively collection of more specific QCD analyses at HERA. In this contribution we present three-jet angular correlations and subjet distributions measured in ep collisions with the ZEUS detector. The angular correlations provide sensitivity to the color factors of the underlying gauge group and thus facilitate tests of basic properties of the strong interaction. The subjet distributions allow tests of the QCD radiation pattern within a jet in the perturbative regime.

1. Three-Jet Angular Correlations

QCD is widely accepted as the theory of the strong interaction. Nevertheless, it is worthwhile to test basic properties of QCD. In two new analyses¹ ZEUS investigated the color factors of QCD which define the relative strengths of the various QCD vertices.

In three-jet production, various combinations of color factors contribute to the cross-section which, in leading order, symbolically can be written as: $\sigma_{3jet} = C_F^2 \cdot \sigma_A + C_F C_A \cdot \sigma_B + C_F T_F \cdot \sigma_C + T_F C_A \cdot \sigma_D$. Here, C_F , C_A and T_F are the color factors of the $q \rightarrow qg$, the $g \rightarrow gg$ and the $g \rightarrow q\bar{q}$ vertices, respectively. The σ_i denote the contributions to the cross-section for the color factor combination in question. Special note should be given to the contributions containing the color factor C_A since the three-gluon vertex is a very specific feature of non-abelian gauge theories such as QCD.

In DIS, the analysis of the three-jet correlations is restricted to 81.7 pb^{-1} from the years 1998-2000 with $Q^2 > 125 \text{ GeV}^2$. Three jets with transverse energies (in the Breit frame) of at least 8, 5 and 5 GeV had to be recon-

*Talk given on behalf of the ZEUS collaboration at DIS06, Tsukuba, Japan, April 2006.

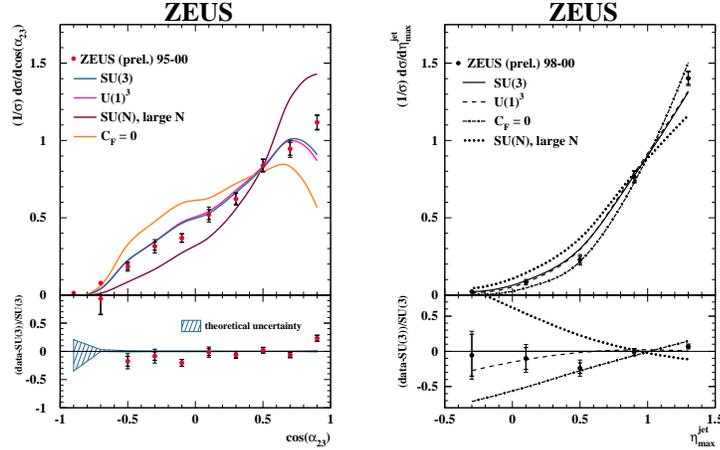


Figure 1. Left: normalised cross-section $d\sigma/d\cos\alpha_{23}$ for the photoproduction analysis. Right: normalised cross-section $d\sigma/d\eta_{max}^{jet}$ for the DIS analysis.

constructed using the longitudinally invariant k_T cluster algorithm; the jets had to be in the pseudorapidity interval $-2 < \eta_{Breit} < 1.5$.

In photoproduction, 127 pb^{-1} from 1995–2000 were analysed; the three jets were all required to have at least 14 GeV transverse energy and to be well contained in the detector acceptance, $-1 < \eta_{lab} < 2.5$. In addition, the photoproduction analysis was restricted to a data sample enriched in direct photon-parton interactions using the quantity x_γ^{obs} , $x_\gamma^{obs} > 0.7$.

Normalised cross-sections were measured and compared to both leading-order MC models and to fixed-order QCD calculations for a number of observables. Examples are Θ_H , the angle between the plane determined by the highest transverse energy jet and the beam and the plane determined by the two lowest transverse energy jets, or the cosine of the angle between the two lowest transverse energy jets, $\cos\alpha_{23}$. In DIS, also the pseudorapidity of the most forward jet in the Breit frame, η_{max}^{jet} , was measured. In both the DIS and the photoproduction analysis the fixed-order calculations were only at leading order; they nevertheless provided access to the color factors and thus allowed to change the gauge group underlying the calculations.

Figure 1 (left) shows the normalised three-jet cross-section as a function of the observable $\cos\alpha_{23}$ for the photoproduction analysis. The data are compared to a fixed-order calculation with four different settings of the color factors, one of which corresponds to the QCD gauge group SU(3). Also shown is an abelian gauge group, U(1)³, which is similar to QCD

except for the triple-gluon vertex. As can be seen, the two other, rather extreme choices of color factors are excluded by the data, but there is little discrimination power between SU(3) and the abelian model. The same statement holds also for the other observables under study.

On the right hand side of figure 1, the normalised cross-section as function of η_{max}^{jet} is shown for the DIS analysis. The data are compared to the same four different color factor choices, and again the SU(N) and $C_F = 0$ models can clearly be excluded whereas there is little discrimination between QCD and the abelian model. New angular correlations need to be designed that enhance the contribution from the triple-gluon vertex to discriminate between SU(3) and U(1)³.

2. Subjet Distributions

At high transverse energies, when jet fragmentation effects become negligible, jet structure can be described perturbatively. The lowest non-trivial (LO) contribution to the jet structure is given by $\mathcal{O}(\alpha_S)$ pQCD calculations in the laboratory frame with one or two partons in one jet. Next-to-leading order (NLO) calculations in this frame are feasible since it is possible to have up to three partons in one jet. In a new measurement² the internal structure of jets is analysed in terms of subjets. Subjets within a given jet identified by the k_T cluster algorithm are identified by re-applying the algorithm to all particles of a jet and clustering until for all particle pairs i, j the quantity $d_{ij} = \min(E_{T,i}, E_{T,j}) \cdot (\Delta\phi_{ij}^2 + \Delta\eta_{ij}^2)$ is greater than $d_{cut} = y_{cut} \cdot E_T^2$. $E_{T,i}$ is the transverse energy of particle i , and $\Delta\phi_{ij}$ ($\Delta\eta_{ij}$) is the difference in azimuthal angle (pseudorapidity) of particles i and j .

Subjet cross-sections are measured in 81.7 pb⁻¹ of ZEUS data collected in 1998-2000. The kinematic range of the analysis is restricted to $Q^2 > 125$ GeV². Jets were reconstructed in the laboratory frame using the k_T cluster algorithm. Subjets were then reconstructed in jets with transverse energies of at least 14 GeV in the pseudorapidity range $-1 < \eta_{lab} < 2.5$. The final sample consisted of jets with exactly two subjets $y_{cut} = 0.05$.

Subjet cross-sections were measured as functions of the difference in transverse energy between the subjet and the jet, of the difference in azimuthal angle or in pseudorapidity, and of the angle between the highest transverse energy subjet and the beam line in the pseudorapidity-azimuth plane, α^{sbj} . The measured distributions were compared to leading order MC models, resulting in a good description of the data, and to fixed-order QCD calculations with up to three partons in one jet.

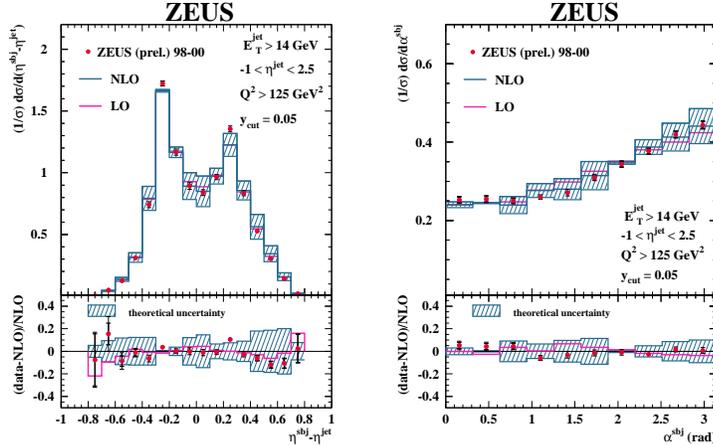


Figure 2. Left: normalised subject cross-section as function of the pseudorapidity difference $\eta^{sbj} - \eta^{jet}$. Right: normalised subject cross-section as function of α^{sbj} .

Figure 2 (left) shows the normalised subject cross-section as a function of the difference in pseudorapidity between subject and jet. The data are well described by both LO and NLO calculations and show that the highest-energy subject tends towards the rear direction. The same behaviour is observed for α^{sbj} which is shown on the right hand side of figure 2. Also this distribution is well described by the QCD calculations.

3. Conclusion

An investigation of the color factors of the strong interaction in three-jet correlations in photoproduction and DIS can exclude some exotic candidates for the gauge structure of the theory of the strong interaction. However, QCD/SU(3) and an abelian model of type U(1)³ cannot be separated with the angular correlations studied.

Studies of subject cross-sections in DIS show that the pattern of parton radiation within jets in the perturbative regime can be described by fixed-order QCD calculations with up to three partons in a jet.

References

1. ZEUS Coll., contributed papers N-379, N-383 to the HEP2005 Internat. Europhysics Conference on High Energy Physics, 21-27 July 2005, Lisbon, Portugal.
2. ZEUS Coll., contributed paper N-384 to the HEP2005 Internat. Europhysics Conference on High Energy Physics, 21-27 July 2005, Lisbon, Portugal.