

Inclusive Properties of Hadronic Final States at HERA

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Abstract. Recent results from the H1 and ZEUS collaborations using the hadronic final state in high Q^2 Deep-Inelastic Scattering to investigate QCD are presented. Measurements of azimuthal asymmetries, event shapes and the charged particle scaled momentum spectra are compared with next-to-leading order perturbative QCD predictions and with Monte Carlo models.

1. Azimuthal Asymmetries

The distribution of the azimuthal angle of charged and neutral hadrons relative to the lepton plane in the hadronic centre-of-mass (HCM) frame has been studied for neutral current DIS using an integrated luminosity of 45 pb^{-1} taken with the ZEUS detector [1]. The kinematic range is $100 < Q^2 < 8000 \text{ GeV}^2$, $0.2 < y < 0.8$ and $0.01 < x < 0.1$ where Q^2 is the virtuality of the exchanged boson, y is the inelasticity and x is the Bjorken variable. The analysis exploits the energy-flow method and uses energy-flow objects with a minimum transverse momentum in the laboratory frame of $p_T > 0.15 \text{ GeV}$ and with polar angle $\theta > 8^\circ$.

The dependence of the moments of the azimuthal distributions on pseudo-rapidity are presented in figure 1. Although the predictions from next-to-leading-order QCD describe the data better than the Monte Carlo models incorporating leading-logarithm parton showers, they still fail to describe the magnitude of the asymmetries. This suggests that higher-order calculations may be necessary to describe these data.

2. Event Shapes

Deep-inelastic ep scattering data taken with the H1 detector at HERA and corresponding to an integrated luminosity of 106 pb^{-1} are used to study the differential distributions of event shape variables [2]. Measurements are made in the Breit frame of reference using hadronic energy flow and include thrust, jet broadening, jet mass and the C-parameter. The four-momentum transfer Q is taken to be the relevant energy scale and ranges between 14 GeV and 200 GeV. The event shape distributions are compared with perturbative QCD predictions, which include resummed contributions and analytical power law corrections, the latter accounting for non-perturbative hadronisation effects.

The data clearly exhibit the running of the strong coupling $\alpha_s(Q)$ (figure 2) and are consistent with a universal power correction parameter α_0 for all event shape variables (figure 3). A combined QCD fit using all event shape variables yields $\alpha_s(m_Z) = 0.1198 \pm 0.0013_{-0.0043}^{+0.0056}$ and $\alpha_0 = 0.476 \pm 0.008_{-0.059}^{+0.018}$.

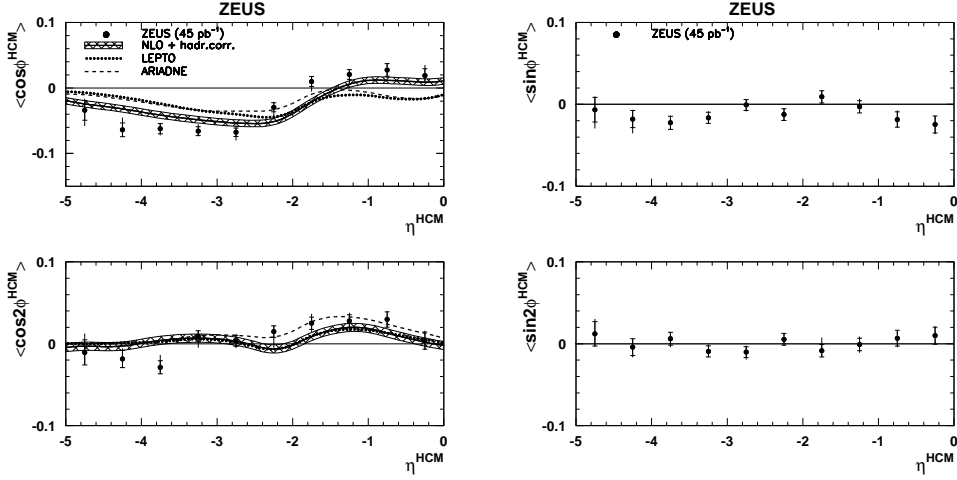


Figure 1. The azimuthal asymmetries as a function of hadron pseudorapidity. The inner error bars are statistical uncertainties, the outer are statistical and systematic uncertainties added in quadrature. The NLO QCD predictions of DISENT (solid line), with its associated uncertainty (shaded band), corrected for hadronisation and hadron losses, the predictions of Lepto 6.5.1 (dotted line), and the predictions of Ariadne 4.12 (dashed line) are also shown.

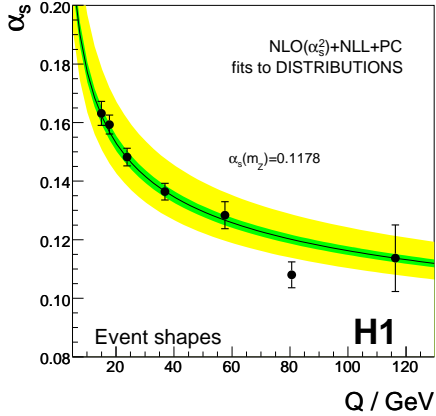


Figure 2. The strong coupling as a function of the scale Q from an average of the results obtained by fitting the differential event shape distributions. The fit curve is shown as the full line. The inner (outer) shaded band represents the uncertainty from experimental (theoretical) errors.

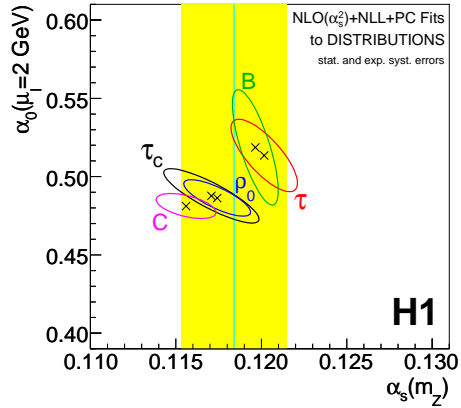


Figure 3. Fit results to the differential distributions of event shape variables in the (α_s, α_0) plane. The 1σ contours include statistical and experimental systematic uncertainties. The vertical line and its uncertainty (shaded band) is the world average of α_s [3].

3. Charged Particle Scaled Momentum Spectra

The normalised distribution of the scaled momentum, x_p , of charged final state hadrons in the current region of the Breit frame has been measured in DIS at high Q^2 by both H1 [4]

and ZEUS [5]. The analyses cover the range of photon virtuality $100 < Q^2 < 40,000 \text{ GeV}^2$. Compared with previous results presented by HERA experiments, these analyses have a significantly higher statistical precision and extend the phase space to higher Q^2 and to the full range of x_p . The four-momentum transfer Q is taken to be the relevant energy scale and is taken to be equivalent to E^* in e^+e^- .

The results are compared with e^+e^- annihilation data in figure 4 and broadly support the concept of quark fragmentation universality in ep collisions and e^+e^- annihilation. The results, when compared with NLO QCD calculations, show that all three parameterisations of the fragmentation functions used fail to describe the scaling violations seen in the data (figure 5).

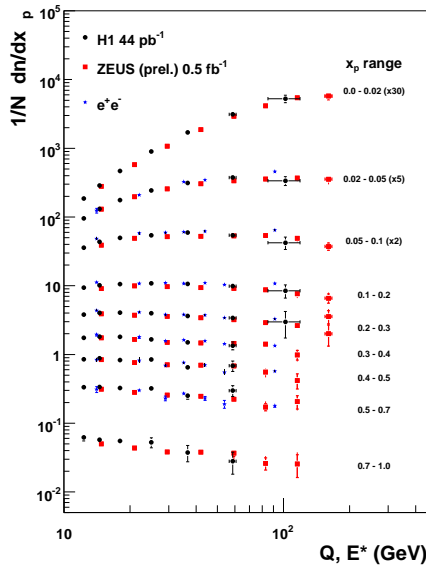


Figure 4. The measured normalised distributions of the scaled momentum $1/Ndn/dx_p$ as a function of Q for the different x_p intervals compared with the e^+e^- annihilation data.

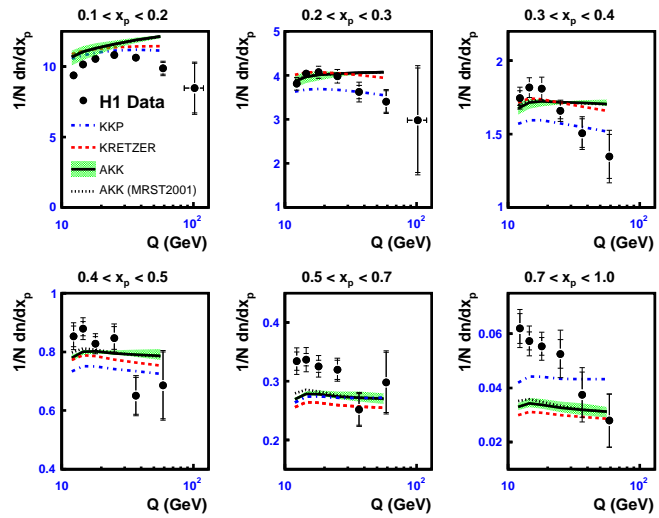


Figure 5. The measured normalised distributions of the scaled momentum $1/Ndn/dx_p$ as a function of Q for the different x_p intervals compared with infra red safe NLO QCD prediction.

4. Conclusion

The description of the hadronic final state in DIS is influenced by pQCD in several ways that can be calculated through exact matrix elements or leading-logarithm parton showers. While the event shape variables were well described by such calculations, the description of the azimuthal asymmetries and scaled momentum spectra were noticeably worse.

References

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