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Study of Event Shapes in Deep Inelastic Scattering

H1 Collaboration

Abstract

DIS $e\,p$ data are used to study event shape variables over a large range of momentum transfer Q. The Q dependence of the mean values and spectra is analysed in terms of pQCD calculations and power law corrections.

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1 Introduction

Deep inelastic $e\,p\;\rightarrow\;e\,X$ scattering data taken with the H1 detector at HERA are used to study event shape variables over a large range of momentum transfer $Q = 7 - 100$ GeV. The Breit frame provides a clean separation between current and target fragmentation. The analysis is done in the current hemisphere of the Breit frame, where the axis coincides with the γ/Z direction.

The investigated event shape variables are two variants of thrust, $\tau_z = 1 - \sum p_z \,/\, \sum p$ and $\tau_c = 1 - \max \sum \vec{p}\cdot\vec{n}_T \,/\, \sum p$, the jet broadening $B_c = \sum p_\perp \,/\, 2 \sum p$, the C parameter $C_c = 3\,(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1)$ derived from the eigenvalues λ_i of the linearized momentum tensor and two jet masses $\rho_E = M^2 \,/\, (2\sum E)^2$ and $\rho_Q = M^2/Q^2$.

The interest is whether hadronisation contributions to event shapes can be described by $\mathcal{O}(1/Q)$ power corrections [1]. The data are corrected for detector effects, details of the analysis can be found in ref. [2].

2 QCD analysis of event shape means

The Q dependence of the mean event shape variables $\langle F\rangle$ is shown in fig. 1. All variables exhibit a decrease with rising Q, the event shapes become more collimated. The data may be compared with NLO pQCD calculations $\langle F\rangle^{\rm pert} = c_1\,\alpha_s(Q) + c_2\,\alpha_s^2(Q)$ from DISENT [3]. As expected, the hadronisation contributions decrease with Q.

Non-perturbative effects are modeled with the following ansatz [1]

$$\langle F\rangle^{\rm pow} \quad = \quad a_F\,\frac{16}{3\,\pi}\frac{\mu_I}{Q}\,\left[\,\bar{\alpha}_0(\mu_I) - \alpha_s(Q) - b_0\,\alpha_s^2(Q)\,\right]\;. \tag{1}$$

The power corrections to the event shapes contain calculable coefficients a_F and a free `universal' parameter $\bar{\alpha}_0(\mu_I)$, to be interpreted as an effective strong coupling below an `infrared matching' scale μ_I defined by $\Lambda_{\rm QCD} \ll \mu_I \ll Q$. An additional factor $\ln(Q/Q_0)$ expected for the jet broadening [1] cannot be supported by the H1 data [2].

The data are well described by a fit including pQCD and power corrections, see fig. 1. The results of the fits in the $\overline{\rm MS}$ scheme are compiled in table 1. The overall errors are dominated by systematic uncertainties associated with the theory, in particular the renormalisation scale dependence. The power correction parameters $\bar{\alpha}_0$ of thrust and jet mass are of the same size and support the concept of approximate universality. The calculations for the jet broadening and the C parameter are less reliable. Choosing $a_{B_c} = 1/2$ and $a_{C_c} = 3\,\pi/2$ in eq. (1), as suggested by Salam *et al.* [4], rises the $\bar{\alpha}_0$ values by $\sim 15\%$. The large spread of the strong coupling $\alpha_s(M_Z)$ can be explained by missing higher order QCD calculations.

A simple hadronisation term of $\langle F\rangle^{\rm pow} = {\rm const}/Q$ is not able to describe the data satisfactorily. Thus the power corrections of eq. (1) seem to provide an adequate analytical form.

Recently available two-loop power corrections [5] modify the one-loop expression by a factor of $\mathcal{M} = 1.15$ common to all event shapes. Such a factor gives $\bar{\alpha}_0$ values lower by $\sim 5\%$ without significant changes of $\alpha_s(M_Z)$.

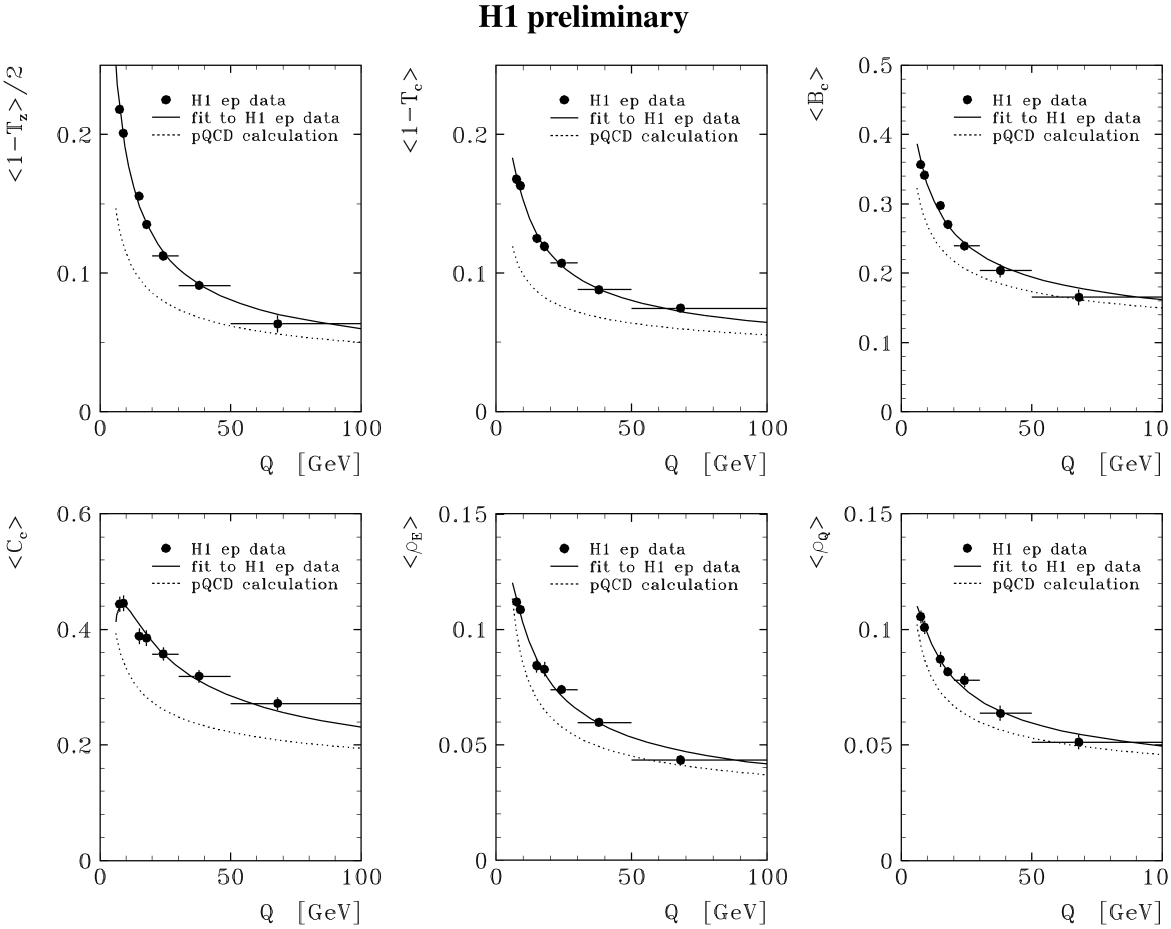

Figure 1: Mean event shape variables as a function of Q. H1 DIS $e\,p$ data (•) are compared to QCD fits including power corrections (—) and NLO pQCD calculations ($\cdot\cdot\cdot$)

$\langle F \rangle$	a_F	$\bar{\alpha}_0(\mu_I = 2\ \mathrm{GeV})$	$\alpha_s(M_Z)$	corr.	χ^2/df
$\langle \tau_z \rangle$	2	$0.492 \pm 0.010\ ^{+0.109}_{-0.051}$	$0.115 \pm 0.002\ ^{+0.007}_{-0.005}$	-0.89	$8.1/5$
$\langle \tau_c \rangle$	1	$0.481 \pm 0.005\ ^{+0.070}_{-0.036}$	$0.123 \pm 0.002\ ^{+0.007}_{-0.005}$	0.56	$5.1/5$
$\langle B_c \rangle$	2	$0.375 \pm 0.008\ ^{+0.036}_{-0.022}$	$0.116 \pm 0.002\ ^{+0.007}_{-0.004}$	-0.74	$5.3/5$
$\langle C_c \rangle$	$3\,\pi$	$0.314 \pm 0.006\ ^{+0.030}_{-0.020}$	$0.115 \pm 0.002\ ^{+0.007}_{-0.006}$	0.95	$4.5/5$
$\langle \rho_E \rangle$	$1/2$	$0.525 \pm 0.010\ ^{+0.055}_{-0.049}$	$0.137 \pm 0.003\ ^{+0.008}_{-0.007}$	-0.67	$6.1/5$
$\langle \rho_Q \rangle$	$1/2$	$0.454 \pm 0.009\ ^{+0.025}_{-0.020}$	$0.130 \pm 0.003\ ^{+0.007}_{-0.005}$	-0.46	$2.8/5$

Table 1: H1 preliminary fit results to the Q dependence of event shape means. The first error includes statistics and experimental systematics, the second error represents theoretical uncertainties

3 QCD analysis of event shape distributions

The differential event shape distributions are shown in fig. 2 for $\langle Q \rangle = 14.9 - 68\ \mathrm{GeV}$. They get more peaked towards low values of F as Q increases.

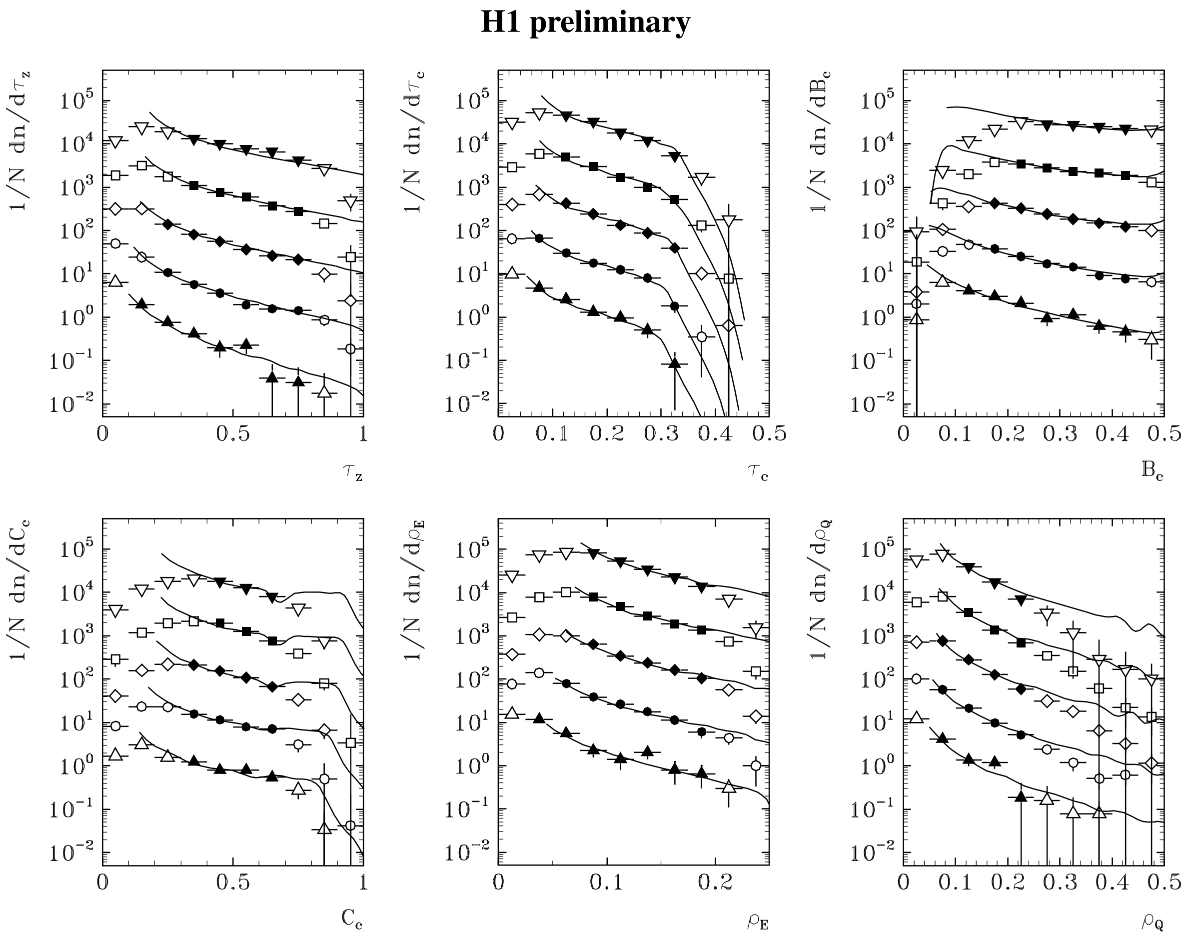

Figure 2: Differential event shape distributions of H1 DIS $e\,p$ data (full symbols indicate the data points used in the fits) are compared with fits to NLO pQCD calculations including power corrections (—). The spectra from top to bottom for $\langle Q \rangle$ values of 14.9, 17.8, 24.2, 37.9 and 68.0 GeV are multiplied by factors of 10^n $(n = 4, 0)$

Power corrections to DIS event shape spectra don't yet exist but are expected to behave similar as for thrust in e^+e^- annihilation, given in ref. [6]. The pQCD prediction is modified by a shift towards lower values of F

$$\frac{1}{\sigma_{\rm tot}}\frac{{\rm d}\sigma(F)}{{\rm d}F} \;=\; \frac{1}{\sigma_{\rm tot}}\frac{{\rm d}\sigma^{\rm pert}(F - \langle F\rangle^{\rm pow})}{{\rm d}F}\,. \tag{2}$$

This simple prediction is applicable only in the case $\mu_I/Q \ll F \ll F_{\rm max}$.

The data are fitted within a limited range of F to the pQCD spectra obtained with the DISENT [3] program and modified according to the power corrections of eq. (2). The range of observables is chosen as large as possible requiring an acceptable fit to the data. The upper bounds are kept fixed for each event shape variable independently of Q, while the lower limits increase with decreasing Q. The event shape distributions can be reasonably well described by a simple shift of the pQCD spectra over a limited range of observables, which shrinks with decreasing Q as expected, see fig. 2.

The fit values of both the power correction parameters $\bar{\alpha}_0$ and $\alpha_s(M_Z)$ are in general significantly larger than those obtained from the fits to the event shape means. Excellent agreement exists for thrust τ_z, the largest disagreement is observed for the jet masses ρ_E and ρ_Q. It should be noted that the parameters from the mean values provide a poor description of the spectra. The discrepancies may get smaller once resummed spectra become available [4].

4 Conclusion

DIS event shape data are very important to get a better understanding of perturbative and non-perturbative QCD effects. More theoretical work on power corrections is needed until one may extract a reliable, precise value of the strong coupling.

References

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