Results on Event Shapes in DIS

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Abstract. The event shape variables thrust, jet broadening and jet mass, defined in the current hemisphere of the Breit frame, are studied for the first time in deep-inelastic ep scattering using data of the H1 experiment at HERA in a range of momentum transfer Q from $7\,GeV$ to $100\,GeV$. Applying power corrections to account for hadronisation effects the Q dependence of the event shape means corrected for detector deficiencies is fit to second order pQCD calculations. The determined fit parameters $\overline{\alpha_0}$ and $\alpha_s(M_Z^2)$ are compatible with a $1/Q$ behaviour of all investigated shape variables.

INTRODUCTION

Event shapes, studied extensively in e^+e^- experiments [1], have proven to be useful tools to extract information on the strong coupling constant α_s and on the rather large hadronisation corrections $\propto 1/E$. As suggested already in [2] a close correspondence can be established between one hemisphere of an e^+e^- event and the current hemisphere H_C of the Breit frame in ep DIS. In this case the relevant hemisphere energies E are respectively $\sqrt{s_{e^+e^-}}/2$ and $Q_{DIS}/2$. It is a great advantage of ep DIS experiments that the energy dependence can be investigated over a large range within the same experiment.

The kinematic phase space of H1 data used in this analysis extends over $7\,GeV < Q < 100\,GeV$ in momentum transfer Q and $0.05 < y < 0.8$ in the inelasticity variable y. Diffractive events were excluded from the DIS sample. For a more detailed description see [3].

EVENT SHAPE VARIABLES

The infrared safe event shape variables considered here are two versions of thrust, T_C and T_Z, the jet broadening B_C and the jet mass ρ_C:

$$T_C = \max \frac{\sum_h |\mathbf{p_h} \cdot \mathbf{n_T}|}{\sum_h |\mathbf{p_h}|} \qquad (\mathbf{n_T} \equiv \text{thrust axis}) \qquad (1)$$

$$T_Z = \frac{\sum_h |\mathbf{p_h} \cdot \mathbf{n}|}{\sum_h |\mathbf{p_h}|} = \frac{\sum_h |p_{zh}|}{\sum_h |\mathbf{p_h}|} \qquad (\mathbf{n} \equiv \text{boson axis}) \tag{2}$$

$$B_C = \frac{\sum_h |\mathbf{p_h} \times \mathbf{n}|}{2\sum_h |\mathbf{p_h}|} = \frac{\sum_h |p_{\perp h}|}{2\sum_h |\mathbf{p_h}|} \qquad (\mathbf{n} \equiv \text{boson axis}) \tag{3}$$

$$\rho_C = \frac{\left(\sum_h \mathbf{p_h}\right)^2}{Q^2} . \tag{4}$$

In these definitions the summation index h extends always over all objects in H_C, which may be either partons in the pQCD calculations or calorimetric clusters in the detector. The selection of objects contributing to the sums therefore depends on the given boson axis $\mathbf{n} = (0, 0, -1)$.

T_C is defined in analogy to e^+e^- experiments where an event axis first has to be found. Here, however, the necessary maximizing procedure can be applied to one hemisphere only, which results in measuring, on an event by event basis, a mixture of longitudinal and transversal event properties with respect to the boson axis $\mathbf{n}$. Following a proposal by Webber [4] T_Z as well as B_C and ρ_C are evaluated using the boson direction as event axis. For experimental reasons T_Z and B_C are normalized to the total momentum in H_C instead of the expected energy $Q/2$. In addition T_C and T_Z are more comparable when so defined. In [5] it is shown, that this modified normalization does not spoil the assumed power corrections.

QCD CALCULATIONS AND POWER CORRECTIONS

According to [5,6] the Q or energy dependence of any event shape mean $\langle F \rangle$ can be written as sum of a perturbative part $\langle F \rangle^{pert}$ and a power suppressed contribution $\langle F \rangle^{pow}$.

The perturbative part may be obtained to $\mathcal{O}(\alpha_s^2)$ via

$$\langle F \rangle^{pert} = \frac{1}{\sigma_{tot}} \int_0^{F_{\max}} F \frac{d\sigma}{dF} dF , \tag{5}$$

where σ_{tot} needs to be known only up to $\mathcal{O}(\alpha_s)$. Currently, the two programs MEPJET [7] and DISENT [8] are available for this task. Due to the integration method applied in MEPJET, however, a lower cut in F such that $0 < F_{cut} < F \leq F_{max}$ has to be imposed. Hence DISENT is used for the analysis. In the overlapping phase space, i.e. for F not too small, the results from both programs are in agreement on a level of precision of $\sim 3-5$ % as can be seen e.g. in the differential distributions (not normalized) for four different Q bins of $1 - T_Z$ in figure 1.

At the same time it is interesting to compare the NLO calculations directly with experimental data as done in figure 2 for the same four Q bins of the

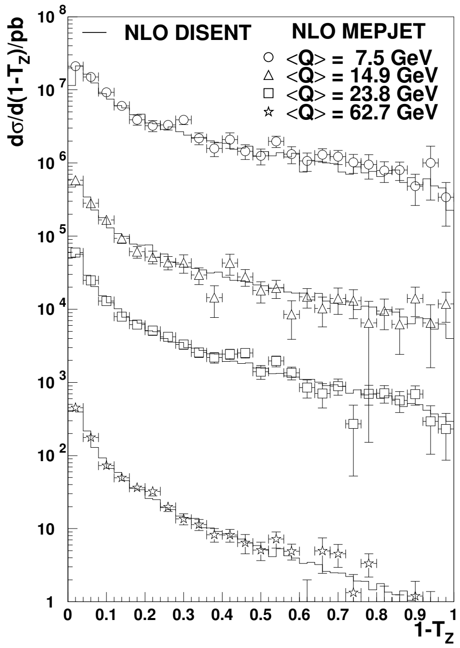

FIGURE 1. Differential distributions of $1-T_Z$ for 4 out of 7 investigated Q bins. NLO pQCD calculations of MEPJET (hollow symbols) and DISENT are compared. The spectra are multiplied by factors of 10^n , $n = 0 \ldots 3$.

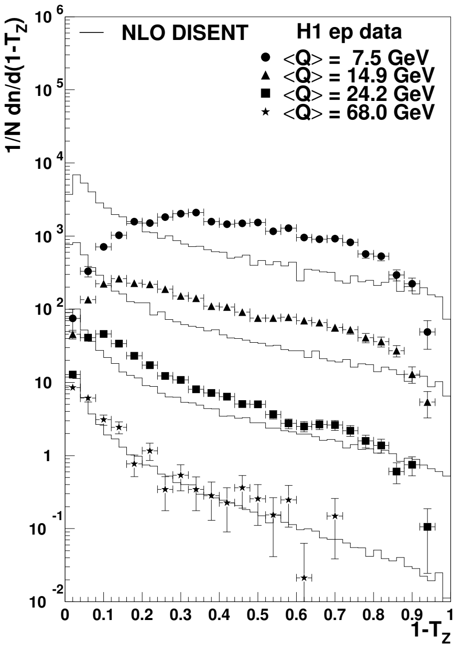

FIGURE 2. Normalized differential distributions of $1-T_Z$ for 4 out of 7 investigated Q bins. H1 ep DIS data (full symbols, stat. errors only) are compared with NLO pQCD calculations of DISENT. The spectra are multiplied by factors of 10^n , $n = 0 \ldots 3$.

normalized differential distributions in $1-T_Z$, including the ones with lowest and highest examined $\langle Q \rangle$ values. In the low Q region the shape of the distribution is obviously not described by the perturbative approximation, but as Q increases the discrepancy diminishes until the NLO prediction agrees well with the data at $\langle Q \rangle \approx 70\, GeV$.

The power suppressed contribution is written as [5,6]

$$\langle F \rangle^{pow} = a_F \, \frac{16}{3\,\pi} \, \frac{\mu_I}{Q} \, \ln^p \frac{Q}{\mu_I} \left[\overline{\alpha_0}(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\,\pi} \left(\ln \frac{Q}{\mu_I} + \frac{K}{\beta_0} + 1 \right) \alpha_s^2(Q) \right] \tag{6}$$

with $\beta_0 = 11 - 2/3 N_f$, $K = 67/6 - \pi^2/2 - 5/9 N_f$ and $N_f = 5$ flavours. a_F and p are shape dependent coefficients deduced in [5] and listed in table 1. Note however, that the original value of $p = 1$ for B_C could not be used here. The infrared matching scale $\mu_I = 2\, GeV$ divides the Q range into two parts, an upper one, where pQCD is applicable and α_s represents the coupling strength, and a lower one with an effective mean coupling $\overline{\alpha_0}$. The coupling parameters are determined simultaneously by a fit to the data.

FIT RESULTS

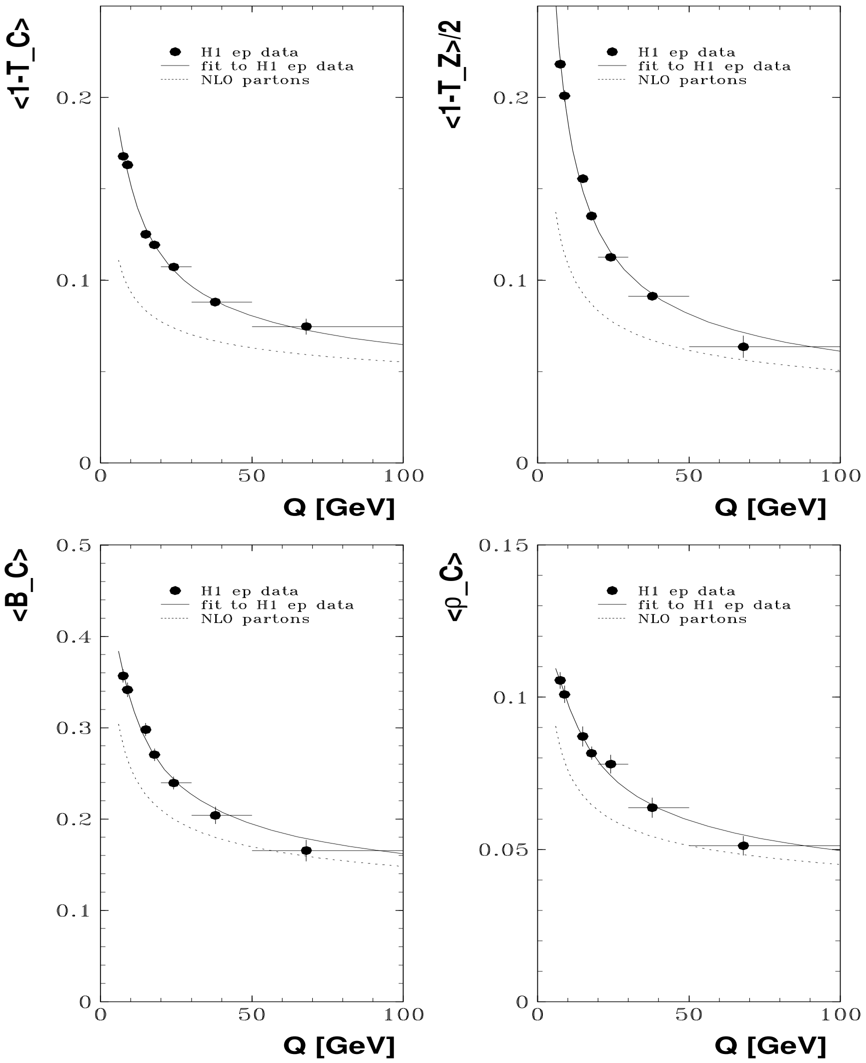

FIGURE 3. Event shape means as a function of Q for $\langle 1 - T_C \rangle$, $\langle 1 - T_Z \rangle /2$, $\langle B_C \rangle$ and $\langle \rho_C \rangle$. H1 ep DIS data (full symbols, errors include statistics and systematics) are compared with QCD fits (full lines) and NLO pQCD calculations of DISENT (dotted lines).

Figure 3 shows the fit results for the Q dependence of the means of all four investigated event shape variables together with the corresponding pQCD calculations and H1 data points. Within the given statistical and systematic errors the data are nicely described by the fits and exhibit a clear $1/Q$ behaviour. $1/Q^2$ terms are not needed.

Note that for $1-T_Z$ an additional factor of $1/2$ is introduced here to account for the different ranges available in $1 - T$, which are $0 \leq 1 - T_C \leq 0.5$ and

$0 \leq 1 - T_Z \leq 1$ respectively. At high Q where the collimation of hadron production is maximal, the dependences of both thrust variables are similar. In the low Q region with more isotropic events, however, the thrust axis $\mathbf{n_T}$ more often does not lie near the direction of the boson axis $\mathbf{n}$ resulting in a less steep rise of $1 - T_C$ for $Q \to 0$.

The final results for the fit parameters $\overline{\alpha_0}$ and $\alpha_s(M_Z^2)$ in the $\overline{\mathrm{MS}}$ scheme as well as the corresponding χ^2/ndf values are compiled in table 1. Except for B_C the general outcome is within errors in good agreement with the assumed $1/Q$ power correction behaviour and compatible values for $\overline{\alpha_0}$ and $\alpha_s(M_Z^2)$ are determined. The errors are dominated by theoretical uncertainties with the largest contribution stemming from a variation of the renormalization scale.

Concerning B_C it must be emphasized that with $p = 1$ a good fit was not possible even with the scale μ_I in the logarithmic factor of eq. 6 replaced by an additional free parameter Q_0. This may be the reason for the somewhat lower result for $\overline{\alpha_0}$ in this case.

A more complete discussion and error evaluation may be found in [3].

TABLE 1. Results on $\overline{\alpha_0}$ and $\alpha_s(M_Z^2)$ from fits to the Q dependence of the event shape means (first error experimental, second error theoretical uncertainties). The a_F and p values as used in the fits are listed in columns 2 and 3.

Observable	a_F	p	$\overline{\alpha_0}\,(\mu_I = 2\,GeV)$	$\alpha_s(M_Z^2)$	χ^2/ndf
$\langle 1 - T_C \rangle$	1	0	$0.497 \pm 0.005\ ^{+0.070}_{-0.036}$	$0.123 \pm 0.002\ ^{+0.007}_{-0.005}$	5.0/5
$\langle 1 - T_Z \rangle / 2$	1	0	$0.507 \pm 0.008\ ^{+0.109}_{-0.051}$	$0.115 \pm 0.002\ ^{+0.007}_{-0.005}$	8.5/5
$\langle B_C \rangle$	2	0[a]	$0.408 \pm 0.006\ ^{+0.036}_{-0.022}$	$0.119 \pm 0.003\ ^{+0.007}_{-0.004}$	5.3/5
$\langle \rho_C \rangle$	1/2	0	$0.519 \pm 0.009\ ^{+0.025}_{-0.020}$	$0.130 \pm 0.003\ ^{+0.007}_{-0.005}$	3.1/5

[a] Originally a value of $p = 1$ was proposed for this variable!

SUMMARY AND CONCLUSIONS

A first analysis of event shapes in ep DIS has been presented taking advantage of the large range in the relevant energy variable Q accessible in one experiment. After computing the $\mathcal{O}(\alpha_s^2)$ pQCD predictions for the event shape means with DISENT it is possible to attribute the remaining difference with respect to the data to power suppressed contributions modelled after the form of eq. 6. In case of B_C, however, the additional logarithmic factor due to $p = 1$ is not supported by the data and $p = 0$ was used instead. The fitted values of the other three event shapes for $\overline{\alpha_0}$ and $\alpha_s(M_Z^2)$ are within errors dominated by theoretical uncertainties consistent with each other and compatible with a universal value of ≈ 0.5 for $\overline{\alpha_0}$. Future investigations of other event shapes or differential event shape spectra may give additional insights into the connection between hadronisation and power corrections.

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