Investigation of power corrections to event shape variables measured in deep-inelastic scattering

Addendum to Eur. Phys. J. C 14 (2000) 255

H1 Collaboration

In a recent publication [1] the H1 collaboration has presented measurements of event shape variables in deep-inelastic scattering over a large range in four-momentum transfer $Q = 7 - 100\ \mathrm{GeV}$. The energy or Q dependence of the mean values of thrust τ and τ_C, jet broadening B, C parameter and jet mass ρ was studied in the context of additive power law corrections [2] to the perturbative QCD calculations with the result that the data can, in general, be well described within this concept by two free parameters: a universal non-perturbative parameter $\overline{\alpha}_0$ and the strong coupling α_s. Meanwhile, new developments concerning event shape distributions [3] and mass effects [4] raise the questions whether (i) observed discrepancies between the NLO pQCD programs DISENT [5] and DISASTER++ [6] affect these results and (ii) how power corrections to the event shapes are influenced by hadron masses. The first point has already been addressed in [7] where it could be shown that the conclusions of [1] based on DISENT calculations remain unaltered, although the use of DISASTER++ leads to systematic shifts of $\overline{\alpha}_0$ by about -0.02 (-0.04 for the jet broadening). It should be noted right away that power corrections have been developed as soft gluon radiation and do not include effects of hadron masses. Thus, their application to event shape variables involving hadron four-momenta, like the jet mass ρ, is not unambiguous and may be problematic, whereas other variables which are calculated from particle three-momenta are not affected. Given the interest in the subject the second question is addressed in this addendum based on the data of [1], where details of the measurement and the analysis method can be found.

The event shapes are investigated in the current hemisphere of the Breit system (CH). The particular interest concerns the *Jet Mass* ρ defined as

$$\rho = \frac{(\sum_{h\in\mathrm{CH}} p_h)^2}{(2\sum_{h\in\mathrm{CH}} E_h)^2}\,, \tag{1}$$

where the sum extends over all particles h of the hadronic final state in the CH with four-momenta $p_h = \{E_h, \mathbf{p}_h\}$. The experimental data, which are based on purely calorimetric information, are unfolded for detector effects and QED radiation to a hadronic final state using Monte Carlo programs. The corrections applied to event shape variables in this procedure are derived using the hadron masses given by the event generator. This method leads to the jet mass ρ associated to massive hadrons as used previously [1]. One may assume instead the hadrons of the final state to be massless and again evaluate a jet mass, labeled ρ_0. Here, two options to derive four-momenta p_h under the assumption of massless hadrons are considered [4]: (i) the p-scheme where the modulus of the 3-momentum $|\mathbf{p}_h|$ is preserved and the energy E_h rescaled; and (ii) the E-scheme where the energy E_h is preserved and the 3-momentum $|\mathbf{p}_h|$ is rescaled. The additional corrections to the means are similar for both schemes and amount to a reduction by $\sim 15\%$ at low Q and $\sim 5\%$ at highest Q, see figure 1. The p-scheme leaves the other event shape variables unchanged.

Table 1: Results of power correction fits to the Q dependence of the mean values of the jet mass $\langle\rho\rangle$ (from [1]) and two variants of $\langle\rho_0\rangle$ calculated in the p-scheme and E-scheme. The first error contains statistics and experimental systematics, the second is an estimate of theoretical uncertainties. κ denotes the correlation coefficient between $\overline{\alpha}_0$ and $\alpha_s(M_Z)$.

$\langle F\rangle$	$\overline{\alpha}_0(\mu_I = 2\,\mathrm{GeV})$	$\alpha_s(M_Z)$	χ^2/dof	κ
$\langle\rho\rangle$	$0.597\,^{+0.009}_{-0.010}\,^{+0.050}_{-0.057}$	$0.1374\,^{+0.0024}_{-0.0032}\,^{+0.0110}_{-0.0096}$	1.1	-0.32
$\langle\rho_0\rangle$ p-scheme	$0.486\,^{+0.008}_{-0.010}\,^{+0.043}_{-0.047}$	$0.1271\,^{+0.0023}_{-0.0030}\,^{+0.0102}_{-0.0089}$	0.6	-0.31
$\langle\rho_0\rangle$ E-scheme	$0.499\,^{+0.009}_{-0.010}\,^{+0.043}_{-0.048}$	$0.1308\,^{+0.0024}_{-0.0031}\,^{+0.0105}_{-0.0091}$	0.6	-0.27

Within the concept of power corrections the mean value of an event shape variable F can be written as [2]

$$\langle F\rangle \;=\; \langle F\rangle^{\mathrm{pert}} + a_F\,\mathcal{P}\,, \tag{2}$$

where $\langle F\rangle^{\mathrm{pert}}$ is the second order perturbative QCD prediction and the last term describes the hadronisation contribution. The coefficient a_F is calculable and $\mathcal{P}$ is a universal function [8]

$$\mathcal{P} \;=\; \frac{16}{3\,\pi}\,\mathcal{M}'\,\frac{\mu_I}{Q}\left[\overline{\alpha}_0(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi}\left(\ln\frac{Q}{\mu_I} + \frac{K}{\beta_0} + 1\right)\alpha_s^2(Q)\right]. \tag{3}$$

Here $\beta_0 = 11 - 2/3\,N_f$, $K = 67/6 - \pi^2/2 - 5/9\,N_f$, $N_f = 5$ and $\mathcal{M}' \simeq 0.95$ accounts for two-loop effects. The non-perturbative parameter $\overline{\alpha}_0(\mu_I)$ can be interpreted as effective coupling below an infrared matching scale $\mu_I = 2$ GeV. The renormalisation scale is taken to be Q.

Results of fits to the Q dependence of the mean jet masses, $\langle\rho\rangle$ for massive hadrons and $\langle\rho_0\rangle$ for massless hadrons, are shown in figure 1 and summarised in table 1. The fitted values $\overline{\alpha}_0$ and $\alpha_s(M_Z)$ of both $\langle\rho_0\rangle$ analyses in the p-scheme and E-scheme are consistent with each other within the experimental uncertainties. However, one observes substantial shifts of $\delta\overline{\alpha}_0 \simeq -0.11$ and $\delta\alpha_s(M_Z) \simeq -0.010$ when comparing the $\langle\rho_0\rangle$ p-scheme analysis with the $\langle\rho\rangle$ analysis. The parameters of the new $\langle\rho_0\rangle$ analysis in the p-scheme together with the previous H1 event shape measurements [1] are displayed in the $\alpha_s - \overline{\alpha}_0$ plane of figure 2. The 'isolated' values of the jet mass $\langle\rho\rangle$ analysis are shifted towards a region of parameters common with the other measurements when applying massless hadron corrections. The jet mass analysis in the p-scheme is consistent with preliminary results of the ZEUS collaboration [9].

In summary, the treatment of hadron masses has a considerable impact on the event shape variable ρ which is calculated from particle four-momenta. Fitting power corrections to the energy dependence of the mean jet mass while assuming massless hadrons reduces the spread of the non-perturbative parameter $\overline{\alpha}_0 \simeq 0.5$ and of the strong coupling $\alpha_s(M_Z)$ and supports the concept of universal power corrections in deep-inelastic scattering.

References

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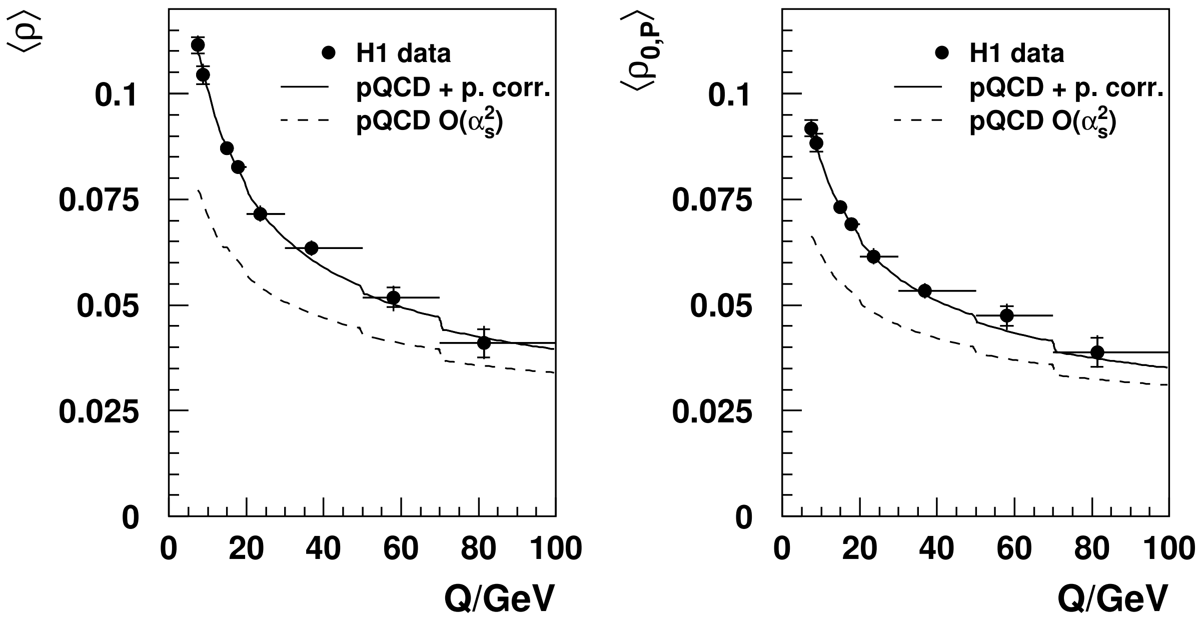

Figure 1: Mean values of ρ (left, from [1]) and ρ_0 in the p-scheme (right) as a function of Q. The error bars represent statistical and systematic uncertainties. The full line corresponds to a power correction fit with parameters $\overline{\alpha}_0$ and α_s; the dashed line shows the pQCD contribution.

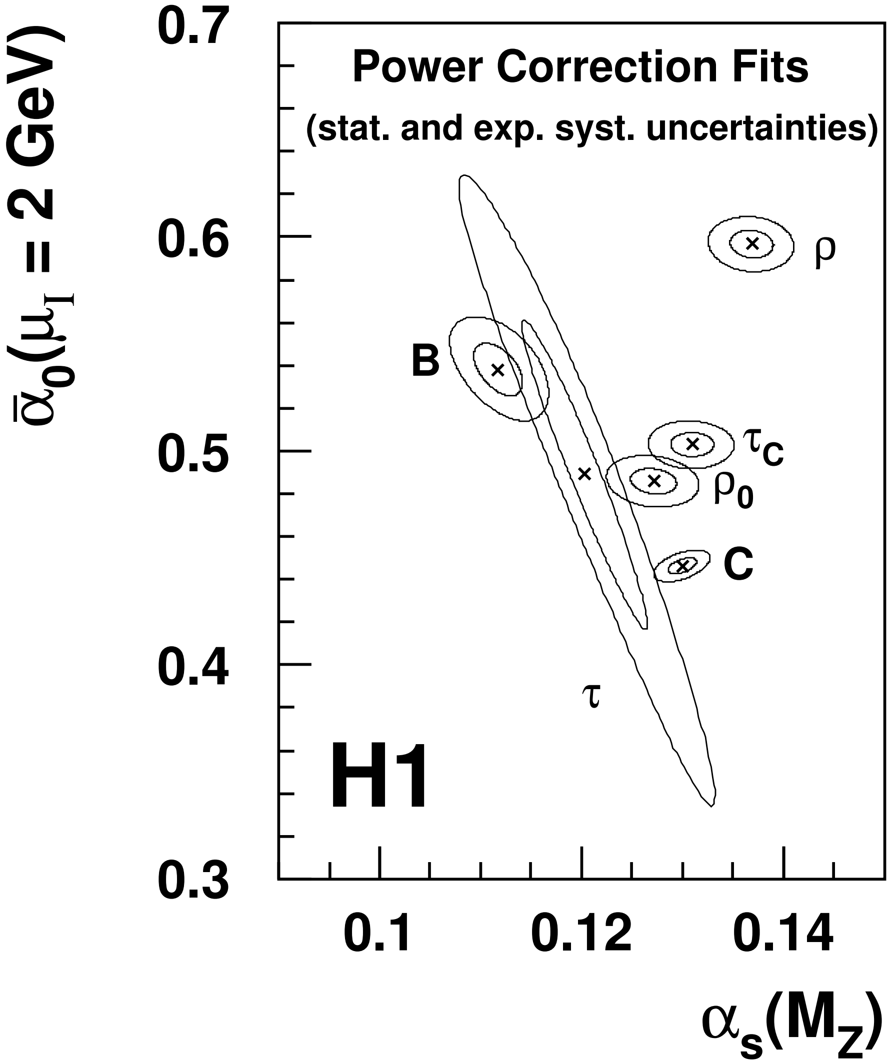

Figure 2: Results of power correction fits to the mean values of event shape variables τ, τ_C, B, C, ρ and ρ_0 (p-scheme) with contours of $\chi^2(\alpha_s, \bar{\alpha}_0) = \chi^2_{min} + 1$ and $\chi^2(\alpha_s, \bar{\alpha}_0) = \chi^2_{min} + 4$ including statistical and experimental systematic uncertainties.