EVENT SHAPE STUDIES AT HERA

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(on behalf of the H1 and ZEUS collaborations)

Recent progress on the study of power corrections applied to event shape variables in deep inelastic ep scattering is discussed.

1 Introduction

Event shape variables in deep inelastic scattering allow to study QCD properties of the final state. Recent results based on high statistics data by the ZEUS[1] and H1[2] collaborations at HERA are discussed with emphasis on power law hadronisation effects.

A suitable frame of reference with optimal separation between the current jet and the proton remnant is the Breit system, where the spacelike γ/Z with momentum Q collides head-on with an incoming quark of momentum $Q/2$. The quark is back-scattered into the current hemisphere, while the proton fragments into the remnant hemisphere (QPM picture). Event shapes studied in the current region[1,2] are: thrust τ and τ_c, broadening B, C parameter and jet mass ρ and ρ_0. H1 also investigates two-jet rates, the transitions from $(2+1)$ to $(1+1)$ jets, in the whole phase space: y_{fJ} for a factorisable JADE and y_{kt} for the k_t jet algorithm. The analyses of both experiments are very similar. The kinematic range covers $Q = 7 - 140$ GeV, ZEUS distinguishes two x-bins at low $Q < 18$ GeV. The data are unfolded to the hadron level, where H1 takes the true masses and ZEUS assumes massless hadrons. This difference affects jet masses and two-jet rates.

2 Power corrections to mean values of event shapes

The mean value of an event shape variable F can be expressed as[3]

$$\langle F \rangle = \langle F \rangle^{\mathrm{pert}} + a_F \mathcal{P} \, . \qquad (1)$$

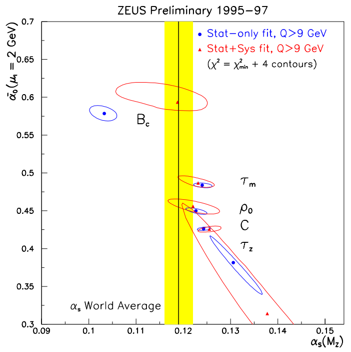

Figure 1. Correlations of $\bar{\alpha}_0$ vs $\alpha_s(M_Z)$ from power correction fits to ZEUS event shape means. Small contours include statistical errors only

The perturbative part $\langle F \rangle^{\mathrm{pert}}$ is calculated in $\mathcal{O}(\alpha_s^2)$ using DISENT[4]. The program DISASTER++[5] yields consistent but somewhat higher mean values[2], at most a few per cent for $\langle B \rangle$ at low Q. These discrepancies have no influence on the conclusions.

Hadronisation is treated within the concept of power corrections[3] with a calculable coefficient a_F and a universal function

$$\mathcal{P} = 1.61 \, \frac{\mu_I}{Q} \left[\bar{\alpha}_0(\mu_I) - \alpha_s(Q) - 1.22 \left(\ln \frac{Q}{\mu_I} + 1.45 \right) \alpha_s^2(Q) \right] . \qquad (2)$$

One expects a $1/Q$ behaviour (except for y_{kt}), which is multiplied by terms involving the strong coupling α_s and a non-perturbative effective coupling $\overline{\alpha}_0(\mu_I)$, defined at an infrared matching scale $\mu_I = 2$ GeV.

The Q dependences of the event shape means are well described by this ansatz. Results of fits to $\overline{\alpha}_0$ and $\alpha_s(M_Z)$ are shown as

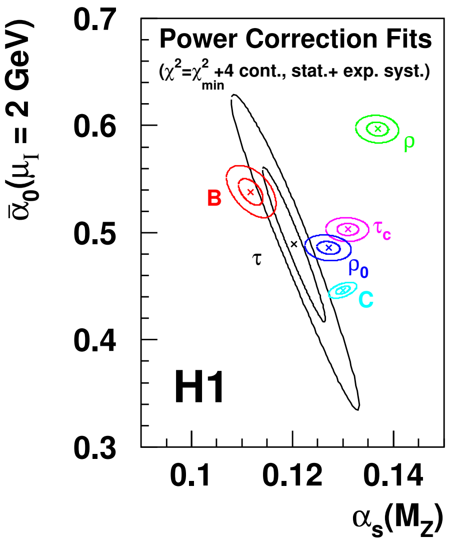

Figure 2. Correlations of $\bar{\alpha}_0$ vs $\alpha_s(M_Z)$ from power correction fits to H1 event shape means

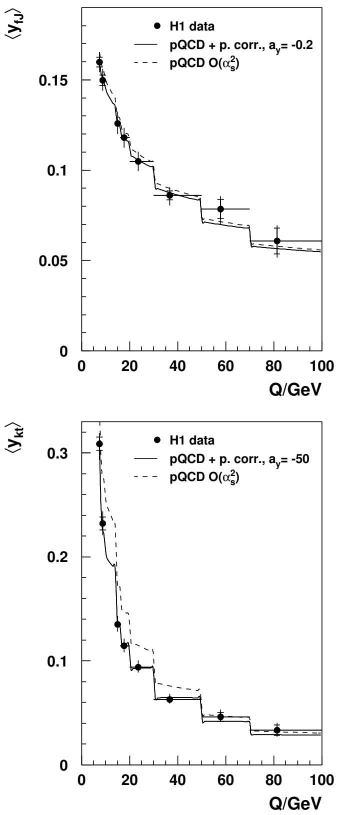

Figure 3. Mean values of two-jet rates y_{fJ} and y_{kt} vs Q of the H1 experiment

correlations in figs. 1 and 2; the renormalisation scale uncertainties (not shown) exceed the experimental errors by far. For the non-perturbative parameter one finds a universal value of $\overline{\alpha}_0 \simeq 0.5 \pm 20\%$ for most observables. ZEUS reports that fits to $\langle B \rangle$ and $\langle \tau_z \rangle$, resulting in a large spread (see fig. 1), are especially sensitive to experimental systematics and exhibit a significant x-dependence at low Q. In general, power corrections do not dependent on x; such terms may, however, arise for $\langle B \rangle$. The H1 analysis, presented in fig.2, demonstrates the strong influence of the treatment of hadrons on the jet masses ρ and ρ_0. A correction to massless hadrons, ρ_0, leads to a more consistent interpretation of power corrections. The spread of $\alpha_s(M_Z)$ is considerable for both experiments, suggesting that higher order QCD contributions are missing. This is supported by large scale uncertainties.

The energy dependence of the H1 mean two-jet rates are shown in fig. 3. They exhibit much smaller hadronisation corrections than the other variables. For the JADE algorithm $\langle y_{fJ} \rangle$ the conjectured coefficient[3] $a_{fJ} = 1$ leads to an unphysically low value of $\overline{\alpha}_0$ and is excluded by the data. Instead a small negative hadronisation contribution is preferred. In case of the k_t algorithm no firm power correction prediction exists except of a $1/Q^2$ dependence for $\langle y_{kt} \rangle$, very different from the other event shapes. Such a behaviour is supported by the H1 data, a $1/Q$ shape can be ruled out. An experimental determination of the unknown parameters, a_{kt} and $\overline{\alpha}_1$ together with α_s, suffers from large correlations[2]. In view of the existing data more theoretical work on the jet rates is needed.

3 Power corrections to spectra

Power corrections to event shape spectra lead to a shift of the pQCD prediction[6]

$$\frac{1}{\sigma_{\rm tot}} \frac{d\sigma(F)}{dF} = \frac{1}{\sigma_{\rm tot}} \frac{d\sigma^{\rm pert}(F - a_F \mathcal{P})}{dF} , \quad (3)$$

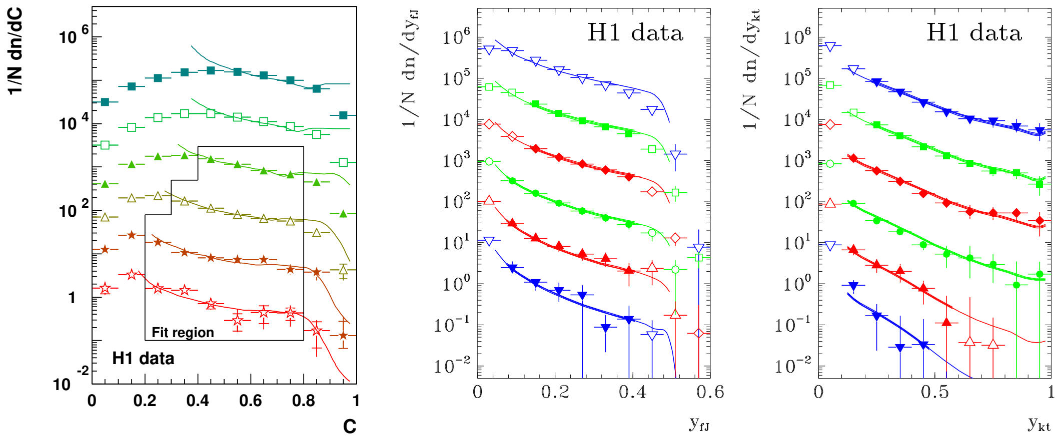

Figure 4. Fits to differential distributions of the C parameter including power corrections and the two-jet rates y_{fJ} and y_{kt} applying pQCD without hadronisation corrections. The H1 data cover a $\langle Q \rangle$ range from 15 GeV (top) to 81.3 GeV (bottom).

provided $\mu_I/Q < F < F_{max}$. The shift $a_F \mathcal{P}$ amounts to exactly the same value as for the mean values. The event shape distributions at $Q > 14$ GeV can be well described by eq. (3) within restricted regions, as shown in fig. 4. However, the fit values of $\overline{\alpha}_0$ and $\alpha_s(M_Z)$ are, in general, inconsistent (larger) to those from fits to the means. For example $(\overline{\alpha}_0,\ \alpha_s(M_Z)) = (0.45,\ 0.130)$ from $\langle C \rangle$ and $(0.62,\ 0.131)$ from $d\sigma/dC$. It is hoped that resummed QCD calculations[7] will improve the applicability of power corrections to DIS event shape spectra.

The analysis of mean values lead to small hadronisation corrections for the two-jet rates. In fact, at sufficiently high energies Q, the jet rate spectra can be reasonably well described by pQCD alone, *i.e.* neglecting power corrections or hadronisation contributions completely. This is shown in fig. 4 for $d\sigma/dy_{fJ}$ and $d\sigma/dy_{kt}$, using 0.116 and 0.118, respectively, for the strong coupling constant.

Summary

Event shape studies of deep inelastic scattering provide very useful information to get a better understanding of the interplay between perturbative and non-perturbative QCD. The basic concept of approximate universal power corrections is generally supported by the HERA experiments, yielding a common parameter $\overline{\alpha}_0 \simeq 0.5 \pm 20\%$. However, there remain several open questions. The quality of the data requires further theoretical progress concerning the jet rates and x-dependence of power corrections and resummed QCD calculations.

References

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