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MEASUREMENT OF EVENT SHAPES IN DEEP INELASTIC SCATTERING AT HERA

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Event shape variables have been measured in the current region of the Breit frame for neutral current deep inelastic scattering using an integrated luminosity of 83pb^{-1} collected with the ZEUS detector at HERA. The kinematic range used was $80 < Q^2 < 20480$ GeV^2 and $0.0024 < x < 0.6$, where Q^2 is the virtuality of the exchanged boson and x is the Bjorken variable. The Q-dependence of the means and distributions of the shape variables are compared with a model based on fixed order plus NLL perturbative calculations and the Dokshitzer-Webber non-perturbative corrections ('power corrections').

1 Introduction

Event shape variables study aspects of the topology of an event's hadronic final state. Event shape studies have been made by several e^+e^- [1][2][3] and ep [4][5] experiments. However, there are two significant barriers to the study of QCD using these variables. Firstly, they are subject to large hadronisation corrections which must be applied. Secondly, the perturbative series do not strongly converge at low values of the shape variables [6]. Hadronisation can be described by a power correction of the type proposed by Dokshitzer and Webber [7]. In order to deal with the lack of convergence at low shape values, it is necessary either to consider an observable which is not strongly affected by that region, such as a mean event shape, or to include higher order terms in the calculation.

The ZEUS Collaboration has previously published results on mean event shapes, which suggested that higher order corrections were necessary. Here, mean event shape variables are revisited with a larger sample of data. In addition, the first ZEUS fits to differential event shape data are presented. Finally, NLL resummed calculations, matched to NLO, are examined.

2 Event Shape Variables

The variables considered here are: thrust, measured with respect to both the thrust and the photon axes, T_T and T_γ respectively; jet broadening, similarly measured with respect to both thrust and photon axes, B_T and B_γ; the normalised invariant jet mass, M^2, and the C parameter. These are defined in equations 1 to 4. The sum is taken over all particles in the current region of the Breit frame. The p-scheme is used throughout.

$$T_T = \frac{\sum_i |\vec{p_i}.\vec{n}|}{\sum_i |\vec{p_i}|} \tag{1}$$

$$B_T = \frac{\sum_i |\vec{p_i} \times \vec{n}|}{\sum_i |\vec{p_i}|} \tag{2}$$

For T_T and B_T, $\vec{n}$ is varied to maximise the thrust. For T_γ and B_γ, $\vec{n}$ is replaced with the virtual photon axis.

$$M^2 = \frac{\left(\sum_i E_i\right)^2 - \left|\sum_i \vec{p_i}\right|^2}{\left(2\sum_i E_i\right)^2} \tag{3}$$

$$C = \frac{3\sum_{ij} |\vec{p_i}||\vec{p_j}| \sin^2(\theta_{ij})}{2(\sum_i |\vec{p_i}|)^2} \tag{4}$$

where θ_{ij} is the angle between two final state particles, i and j.

3 Event Selection and Analysis

The analysis is based on an inclusive sample of neutral current DIS events collected at HERA in the 1998-2000 running period, corresponding to an integrated luminosity of 83pb^{-1}. The kinematic region used was 80 GeV^2 $< Q^2 <$ 20480 GeV^2 and $0.0024 < x < 0.6$ [5].

Hadronic energy-flow objects, combining tracking information with calorimetry, were used to determine the six event shapes. Bin-by-bin correction factors were calculated using a Monte Carlo sample of neutral current DIS events, generated using DJANGOH [8] with the Colour Dipole Model, as implemented in ARIADNE [9]. Systematic errors were estimated by changing the event selections and replacing ARIADNE by HERWIG [10].

Both the mean values of the event shapes and the differential distibutions have been fitted to NLO fixed order QCD predictions and power corrections. In addition, the distibutions have been fitted to NLO + NLL plus power corrections. The fitted parameters were $\alpha_s(M_Z)$, the strong coupling constant, and $\overline{\alpha}_0(\mu_I = 2$ GeV),the non-perturbative parameter introduced by the power correction. Statistical and experimental systematic errors are included in the fits using the Hessian method [11].

The means were fitted using a sample of 10^8 events generated with DISASTER++ [12] and the CTEQ4M [13] structure function set. To fit the differential distributions, 2×10^9 DISASTER++ events were generated using the DISPATCH [14] program with MRS99 [15] structure functions. The power correction and matched resummation were calculated using the DISRESUM [14] package. The

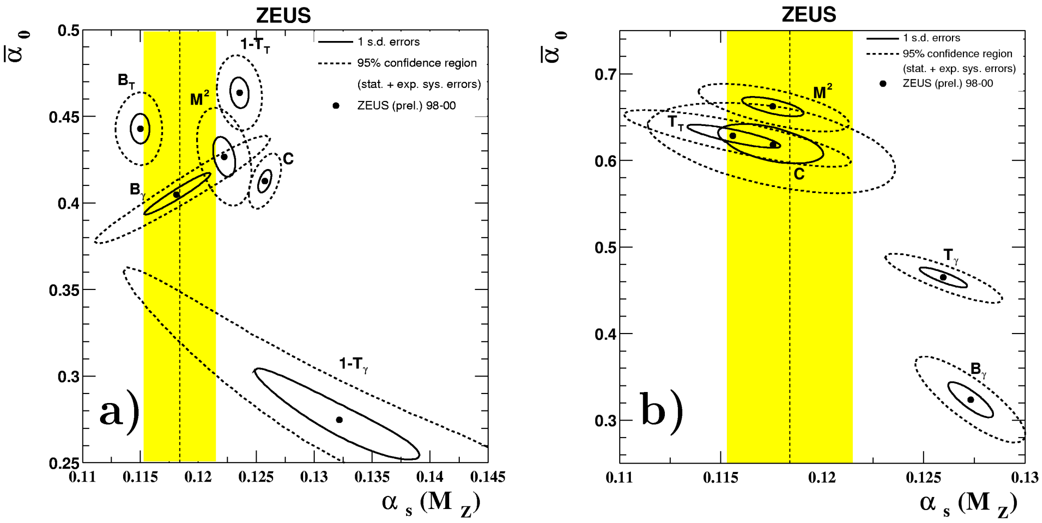

Figure 1. a) NLO + Power Correction fits to mean event shape variables. b) NLO + Power Correction fits to the central ranges of the differential event shape distributions. In both cases, the vertical line and shaded area indicate the world average value of $\alpha_s(M_Z)$ [17].

modified M_2 matching scheme [16] was used as it minimised the dispersion in the fitted α_s and $\overline{\alpha}_0$ values between the variables.

4 Results

The NLO + Power Correction model has been fitted to the mean values of the shape variables. The extracted parameters are shown in figure 1a. For all variables except $1 - T_\gamma$, the $\overline{\alpha}_0$ is consistently fitted as 0.45 within 10%. That determined from $1 - T_\gamma$ is significantly lower. α_s is consistent between all variables with the exception of B_T, which fits to an α_s about 5% lower. This discrepancy cannot be explained by experimental systematic errors since these have the same sign for all variables. The dispersion of fitted α_s and $\overline{\alpha}_0$ values can be taken to indicate the importance of higher order terms that are omitted from the NLO + PC calculations.

A similar set of fits have been made to the differential distributions of the event shape variables. The fitted α_s and $\overline{\alpha}_0$ values resulting from a fit to NLO + PC are shown in figure 1b. The lack of consistency between the fitted values is a clear demonstration of the inadequacy of NLO + PC as a description of the data.

The results of the NLO + NLL + PC model fitted to the differential distributions are shown in figure 2. The model describes well the differential distributions and, when extended into the region where resummation effects dominate, gives α_s values that are consistent with the world average. With the exception of C, the $\overline{\alpha}_0$ values are consistent with those found for the means.

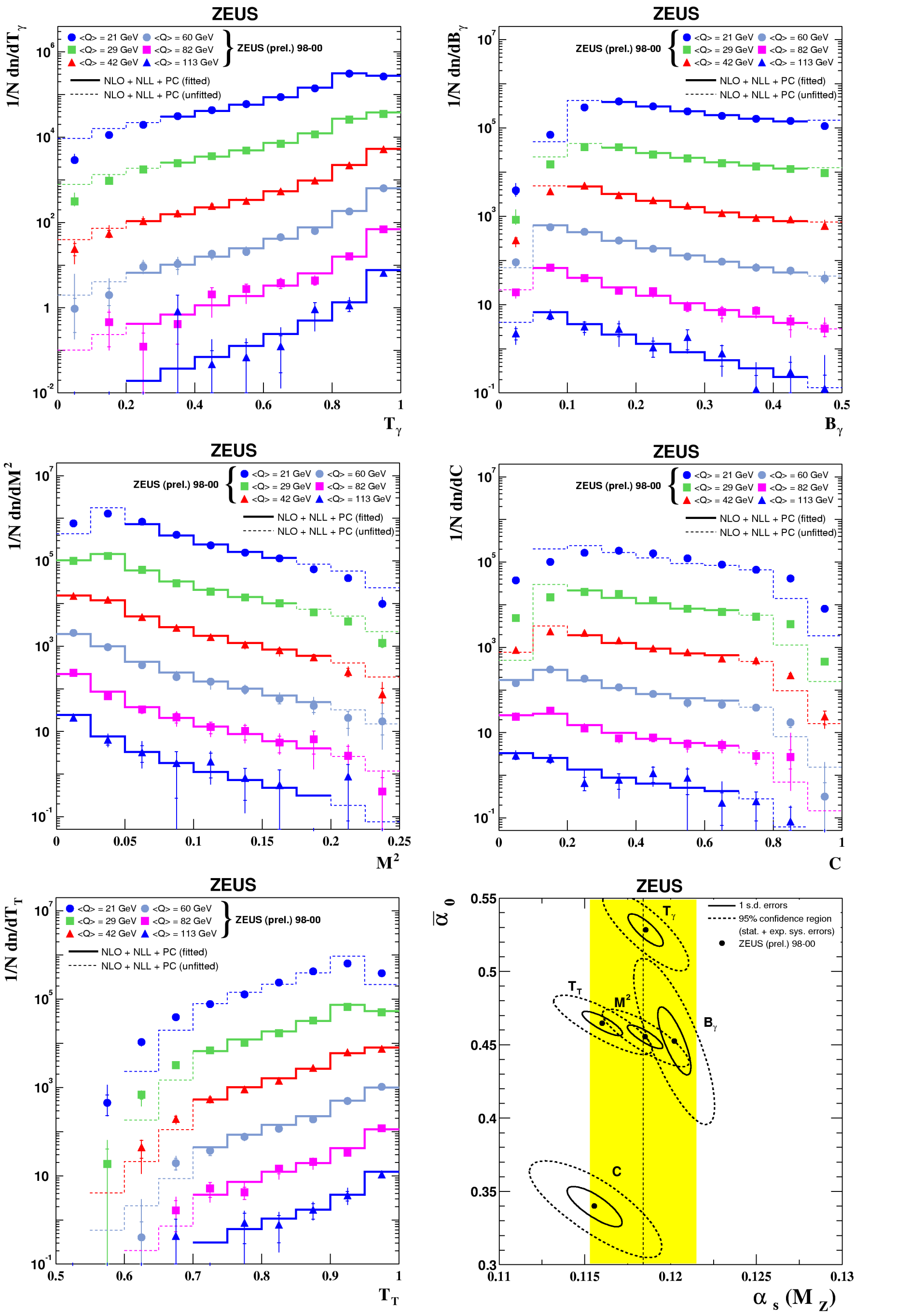

Figure 2. Event shape distributions, fitted with NLL resummed calculations, matched to NLO + Power Corrections, and the extracted parameter values. The vertical line and shaded area on the $(\alpha_s, \overline{\alpha}_0)$ plot indicates the world average value of $\alpha_s(M_Z)$[17].

5 Conclusions

Existing ZEUS event shape data [5] have been complemented by a new measurement of the means, using a larger data sample, and by the first measurements of differential distributions. It is found that the NLO + Power Correction model can describe neither mean nor differential data with consistent extracted parameters. When matched NLL resummations are added to the model, good fits to the differential distributions are obtained that yield $\alpha_s(M_Z)$ values that are consistent with the world average.

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