PHENOMENOLOGY OF THE PROTON STRUCTURE FUNCTION F_2 AT LOW Q^2

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Phenomenological studies of the proton structure function F_2, measured in e^+p scattering using the ZEUS detector at HERA, are presented. Particular emphasis is placed on the transition from hadronic type behavior at $Q^2 \approx 0$ GeV^2 to the deep inelastic scattering regime ($Q^2 \gg 1$ GeV^2). The derivatives $d\ln(F_2)/d\ln(1/x)$ for fixed Q^2 and $dF_2/d\log_{10}(Q^2)$ for fixed x are shown and compared with the results for the total diffractive cross section and for vector meson production.

1 Introduction

Analyses of the data of the proton structure function F_2 [1] have shown that the data for $Q^2 > 1$ GeV^2 were well-described by perturbative QCD (pQCD). For $Q^2 < 1$ GeV^2, the data were successfully described by a non-perturbative approach based on the generalized vector dominance model and Regge theory. In this phenomenological analysis we present new results on $d\ln(F_2)/d\ln(1/x)$ and $dF_2/d\log_{10}(Q^2)$. The recently published ZEUS BPT 1997 [2] and ZEUS 96/97 [3] data sets were used, which have significantly reduced uncertainties of the measurements and extend the kinematic region compared to the previous ZEUS measurements [4,5]. ZEUS shifted vertex data [6] and data from various fixed-target experiments were also used. The results on $d\ln(F_2)/d\ln(1/x)$ are compared with the results for the total diffractive cross section and for vector meson production.

2 Analysis

Bin-centering corrections were applied to the data. The data were shifted to the chosen x and Q^2 value for the $dF_2/d\log_{10}(Q^2)$ and $d\ln(F_2)/d\ln(1/x)$ analyses, respectively. The data were scaled by the ratio of a parametrization of F_2 of the original and shifted (x,Q^2) values. For $Q^2 > 1$ GeV^2, ALLM97 [7] was used, otherwise the ZEUS REGGE 97 [2] parametrization. The statistical and systematic uncertainties were scaled by the same ratio. For both analyses, the shifted data were fitted by a χ^2-minimization using MINUIT [8]. The errors of the fitted parameters were obtained using the MINOS package in MINUIT.

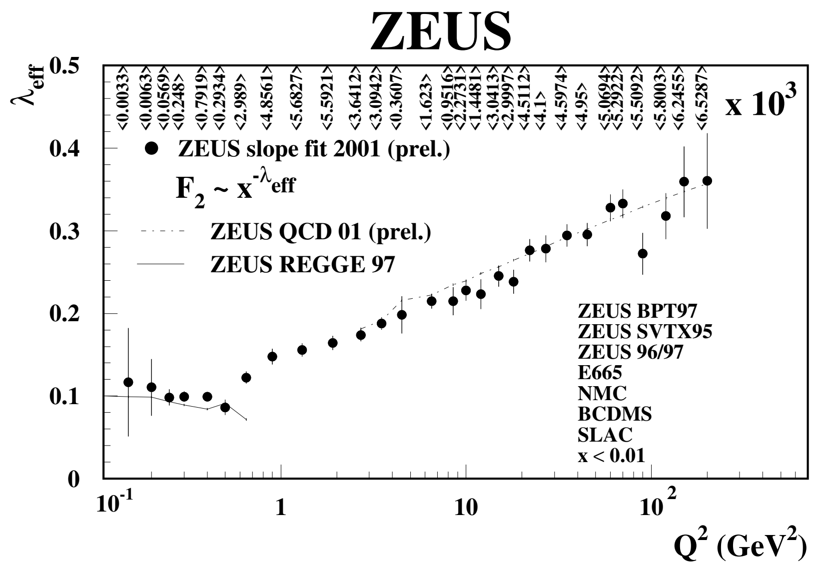

Figure 1. $\lambda_{\rm eff}$ as a function of Q^2. The estimate for the ZEUS REGGE97 and ZEUS QCD 01 parametrizations are also shown. The values at the top of the figure give the average x values multiplied by 10^3 in the bins.

The statistical and systematic uncertainties of the data points were added in quadrature. The results changed by less than 5% for most points if only the statistical errors were used.

2.1 dln(F_2)/dln(1/x)

The proton structure function F_2 was fitted to the functional form $F_2(x, Q^2) = C(Q^2) \cdot x^{-\lambda_{\rm eff}}$ in bins of Q^2 for $x < 0.01$. The results are shown in figure 1. The results agree with the ZEUS QCD 01 parametrization down to $Q^2 = 2.5$ GeV^2. For $Q^2 < 0.6$ GeV^2, $\lambda_{\rm eff}$ is consistent with a constant value of ≈ 0.1 as expected from the assumption of a single soft Pomeron according to Regge Theory. Using the relation between F_2 and $\sigma_{\rm tot}$, figure 2 shows the results for the total diffractive cross section [9,10,11] and vector meson production at HERA [12]. The slope of the total diffractive cross section is compatible with being constant. Below $Q^2 = 1$ GeV^2, the result is consistent with the naive expectation that the slope should be twice as big as for the total cross section due to 2-gluon-exchange. For vector mesons of mass M produced at a γp

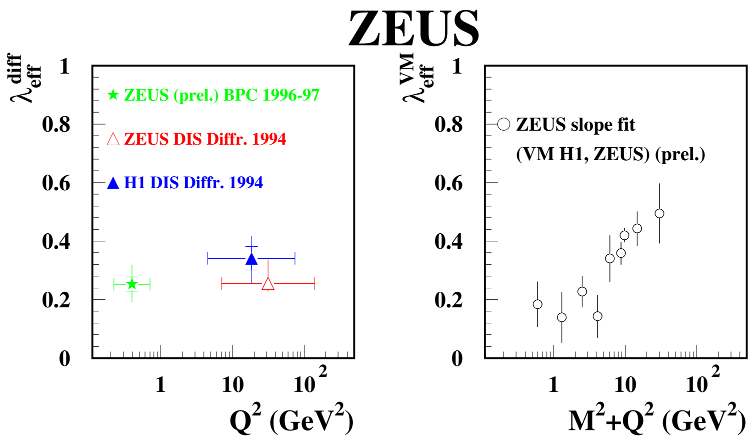

Figure 2. $\lambda_{\rm eff}$ as a function of Q^2 for the total diffractive cross section (left) and $M^2 + Q^2$ for vector meson production at HERA (right).

center-of-mass energy W, x_{VM} was defined as $x_{VM} = \frac{Q^2+M^2}{W^2}$. It was found that $\lambda_{\rm eff}^{VM}$ for different M follows a single curve with (M^2+Q^2) instead of Q^2. For $(M^2+Q^2) > 7\,\mathrm{GeV}^2$, the results are compatible with the naive expectation that the slope should be twice as big as for the total cross section, also due to 2-gluon-exchange.

2.2 $dF_2/d\log_{10}(Q^2)$

The proton structure function F_2 was fitted to the functional form $F_2(x, Q^2) = A(x) + B(x) \cdot \log_{10}(Q^2) + C(x) \cdot \log_{10}(Q^2)^2$ in bins of x. The slope $dF_2/d\log_{10}Q^2 = B(x)+2\cdot C(x)\cdot\log_{10}(Q^2)$ is shown in figure 3. The errors were calculated from the uncertainty of B(x) and C(x). The slope $dF_2/d\log_{10}(Q^2)$ is changing as a function of Q^2, or x for fixed W. Naively, it is expected that at LO $dF_2/d\log_{10}(Q^2) \sim xg \sim x^{-\lambda}$ in the region where DGLAP is applicable (Q^2 large) and that $dF_2/d\log_{10}(Q^2) \sim Q^2\sigma_0$ in the low Q^2 region. This is approximately true as shown in figure 3. At low Q^2 (left plot) and high x (right plot) the data are approximately independent of W.

3 Conclusion

The phenomenology of the proton structure function F_2 has been studied using the derivatives $d\ln(F_2)/d\ln(1/x)=\lambda_{\rm eff}$ for fixed Q^2 and $dF_2/d\log_{10}(Q^2)$

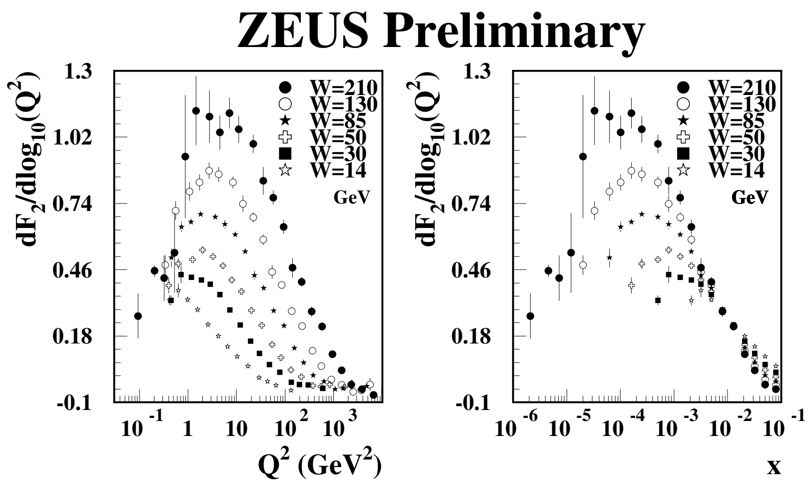

Figure 3. $dF_2/d\log_{10}(Q^2)$ as a function of Q^2 and x in bins of W.

for fixed x. The ZEUS BPT 1997 and ZEUS 96/97 data have increased the kinematic range covered and reduced the uncertainties. $\lambda_{\rm eff}$ agrees with the prediction from the ZEUS QCD fit within its range of applicability down to $Q^2 \approx 2.5$ GeV^2 and is consistent with a Regge prediction for $Q^2 < 0.6$ GeV^2. $\lambda_{\rm eff}^{\rm diff}$ is compatible with being constant, while $\lambda_{\rm eff}^{\rm VM}$ rises linearly with $(M^2 + Q^2)$ for $(M^2 + Q^2) > 7$ GeV^2.

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