version of July 9, 2001

Submitted to

International Europhysics Conference on High Energy Physics, July 12, 2001, Budapest

EPS 2001:	Abstract:	**833**
	Parallel Session	**1,2**
	Plenary Session	**1,2**

XX International Symposium on Lepton and Photon Interactions, July 23, 2001, Rome

LP 2001:	Abstract:	**494**
	Plenary Session	**S08**

www-h1.desy.de/h1/www/publications/conf/conf_list.html

A Measurement of the Rise of $F_2(x, Q^2)$ Towards Low x

H1 Collaboration

Abstract

A measurement of the derivative $(\partial \ln F_2/\partial \ln x)_{Q^2} \equiv -\lambda(x, Q^2)$ of the proton structure function F_2 is presented in the low x domain of deeply inelastic positron–proton scattering. For $0.01 \geq x \geq 5 \cdot 10^{-5}$ and $Q^2 \geq 1.5\,\mathrm{GeV}^2$, $\lambda(x, Q^2)$ is found to be independent of x and to rise linearly with $\ln Q^2$.

The inclusive cross section for deeply inelastic lepton-proton scattering is governed by the proton structure function $F_2(x,Q^2)$. Because of the large centre-of-mass energy squared, $s \simeq 10^5$ GeV^2, the ep collider HERA has accessed the region of low Bjorken x, $x > Q^2/s > 10^{-5}$ for four-momentum transfers squared $Q^2 > 1$ GeV^2, and F_2 was observed to rise towards low x [1].

Perturbative Quantum Chromodynamics (QCD) provides a rigorous and successful theoretical description of the Q^2 dependence of $F_2(x,Q^2)$. Although the x dependence of F_2 is not predicted in QCD, in the limit of small x the evolution equations [2] can be approximately solved in the double asymptotic limit to leading order [3] and F_2 can be represented as

$$F_2(x,Q^2) \sim x^{-\lambda(x,Q^2)}. \tag{1}$$

Below the deeply inelastic region, for $Q^2 < 1$ GeV^2, Regge theory [4] predicts that λ approaches a value given by the Pomeron intercept, $\lambda = \alpha_{\mathbb{P}}(0) - 1 \simeq 0.08$, independently of x and Q^2 [5].

Very recently the H1 Collaboration has presented [6] a new measurement of $F_2(x,Q^2)$ in the kinematic range $3 \cdot 10^{-5} \leq x \leq 0.2$ and $1.5 \leq Q^2 \leq 150$ GeV^2 based on data taken in the years 1996/97 with a positron beam energy $E_e = 27.6$ GeV and a proton beam energy $E_p = 820$ GeV. The high accuracy of these data allows for the first time the function λ to be measured as a two-dimensional function of x and Q^2 from the derivative

$$-\left(\frac{\partial \ln F_2(x,Q^2)}{\partial \ln x}\right)_{Q^2} = \lambda(x,Q^2). \tag{2}$$

Use of this quantity for investigating the behaviour of F_2 at low x has been advocated e.g. in [7]. The derivative is extracted in the full kinematic range using F_2 data points for adjacent x bins at fixed Q^2 taking into account the full error correlations and correcting for finite bin size. As can be seen in Figure 1, in this low x region $\lambda(x,Q^2)$ becomes independent of x for $x \leq 0.01$ to within the experimental accuracy. Thus there is no experimental evidence that the steepness of the rise of F_2 with decreasing x is tempered throughout the measured deeply inelastic kinematic range.

In perturbative QCD the observed behaviour of $(\partial \ln F_2/\partial \ln x)_{Q^2}$ is very well described, see Figure 1. At low x, for $Q^2 > 3$ GeV^2, this behaviour is driven solely by the gluon field, since quark contributions to the scaling violations of F_2 are negligible [6]. At larger x the transition to the valence-quark region causes a strong dependence of λ on x as is indicated by the QCD curves in Figure 1.

Figure 2 displays the measured derivative as a function of Q^2 for different x values. It is well described by the NLO QCD calculation. The derivative is observed to rise approximately logarithmically with Q^2. For $x \leq 0.01$ its behaviour can be well described by a universal function $\lambda(Q^2)$.

The function $\lambda(Q^2)$ is determined from a fit of $F_2(x, Q^2) = c(Q^2) \cdot x^{-\lambda(Q^2)}$, restricted to the region $x \leq 0.01$ where λ is now explicitly assumed to be independent of x. This fit yields values $c(Q^2) \simeq 0.18$, approximately independent of Q^2. The result for $\lambda(Q^2)$ is illustrated in Figure 3. It is more accurate than data hitherto published by the H1 Collaboration [8] and by the ZEUS Collaboration [9]. As can be seen, $\lambda(Q^2)$ rises approximately linearly with $\ln Q^2$. The dependence can be represented as $\lambda(Q^2) = a \cdot \ln Q^2/\Lambda^2$, see Figure 3. The coefficients are $a = 0.0481 \pm 0.0013(\mathrm{stat}) \pm 0.0037(\mathrm{syst})$ and $\Lambda = 292 \pm 20(\mathrm{stat}) \pm 51(\mathrm{syst})$ MeV, obtained for $Q^2 \geq 3.5$ GeV^2 with a χ^2 per degree of freedom of 1.0 using statistical errors only. When extrapolating $\lambda(Q^2)$ into the lower Q^2 region it takes the value of 0.08 at $Q^2 = 0.45$ GeV^2.

To summarise, the derivative $-(\partial \ln F_2/\partial \ln x)_{Q^2} = \lambda$ is observed to be independent of x for $x \leq 0.01$. This implies that the rise of F_2 towards low x, $\partial F_2/\partial x$, is continuous and proportional to F_2/x throughout the covered deeply inelastic domain. At low x, $\lambda(Q^2)$ rises linearly with $\ln Q^2$.

Acknowledgements We are very grateful to the HERA machine group whose outstanding efforts made this experiment possible. We acknowledge the support of the DESY technical staff. We appreciate the substantial effort of the engineers and technicians who constructed and maintain the detector. We thank the funding agencies for financial support of this experiment. We wish to thank the DESY directorate for the support and hospitality extended to the non-DESY members of the collaboration.

References

[1] I. Abt *et al.* [H1 Collaboration], Nucl. Phys. B **407** (1993) 515.
M. Derrick *et al.* [ZEUS Collaboration], Phys. Lett. B **316** (1993) 412.

[2] Y. L. Dokshitzer, Sov. Phys. JETP **46** (1977) 641 [Zh. Eksp. Teor. Fiz. **73** (1977) 1216]. V. N. Gribov and L. N. Lipatov, Yad. Fiz. **15** (1972) 1218 [Sov. J. Nucl. Phys. **15** (1972) 675]. V. N. Gribov and L. N. Lipatov, Yad. Fiz. **15** (1972) 781 [Sov. J. Nucl. Phys. **15** (1972) 438]. G. Altarelli and G. Parisi, Nucl. Phys. B **126** (1977) 298.

[3] A. De Rujula, S. L. Glashow, H. D. Politzer, S. B. Treiman, F. Wilczek and A. Zee, Phys. Rev. D **10** (1974) 1649;
R. D. Ball and S. Forte, Phys. Lett. B **335** (1994) 77 [hep-ph/9405320].

[4] T. Regge, Nuov. Cim. **14** (1959) 951, Nuov. Cim. **18** (1960) 947;
G. Chew, S. Frautschi and S. Mandelstam, Phys. Rev. **126** (1962) 1202.

[5] A. Donnachie and P. V. Landshoff, Z. Phys. C **61** (1994) 139 [hep-ph/9305319].

[6] C. Adloff *et al.* [H1 Collaboration], hep-ex/0012053.

[7] H. Navelet, R. Peschanski and S. Wallon, Mod. Phys. Lett. A **9** (1994) 3393 [hep-ph/9402352].

[8] S. Aid *et al.* [H1 Collaboration], Nucl. Phys. B **470** (1996) 3 [hep-ex/9603004].
C. Adloff *et al.* [H1 Collaboration], Nucl. Phys. B **497** (1997) 3 [hep-ex/9703012].

[9] J. Breitweg *et al.* [ZEUS Collaboration], Eur. Phys. J. C **7** (1999) 609 [hep-ex/9809005].

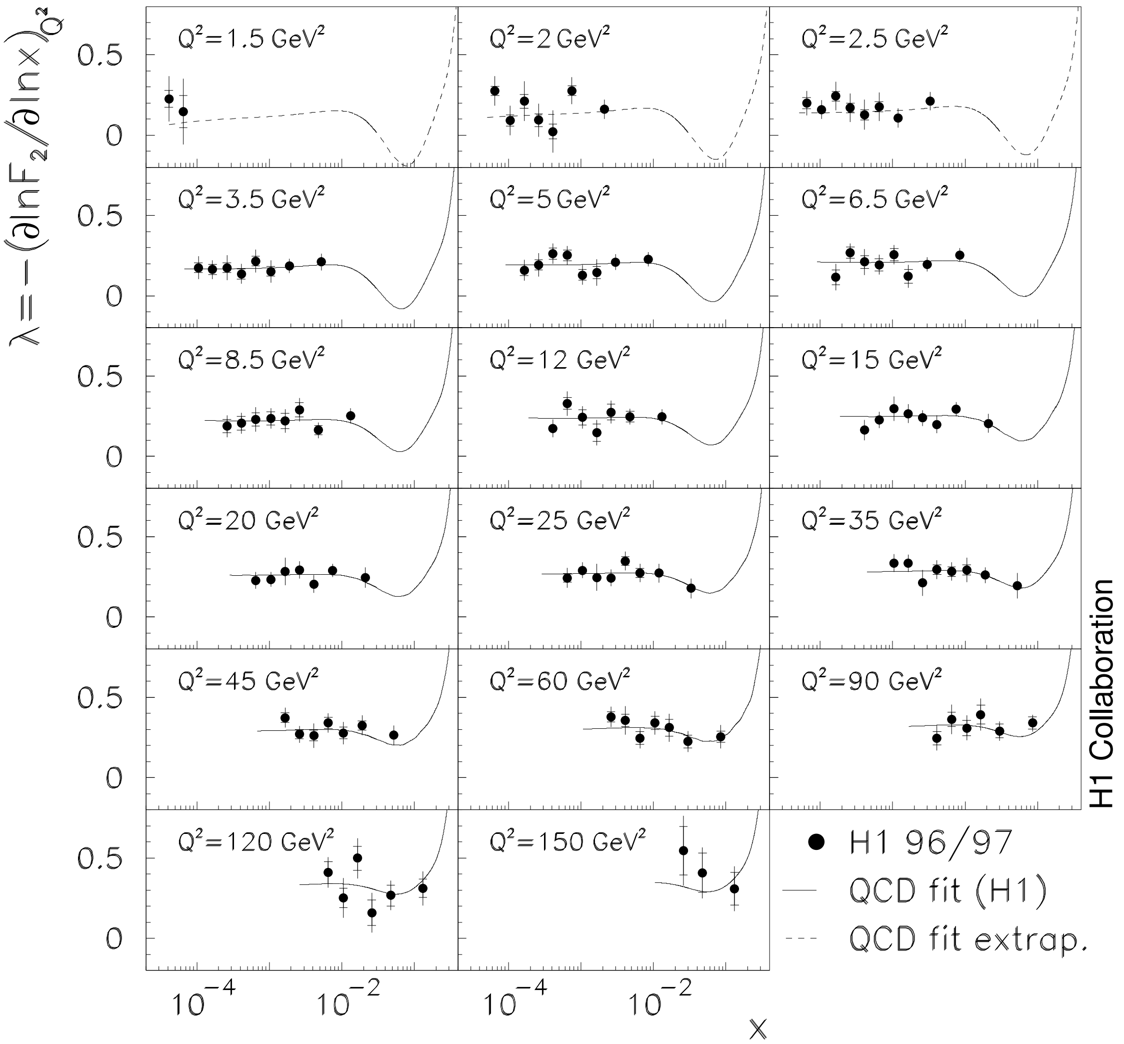

Figure 1: Measurement of the function $\lambda(x, Q^2)$: the inner error bars represent the statistical experimental uncertainty, while the full error bars include the systematic uncertainty added in quadrature; the solid curves denote the NLO QCD fit to the H1 cross section data described in [6]; the dashed curves represent the extrapolation of the QCD fit below $Q^2 = 3.5$ GeV^2.

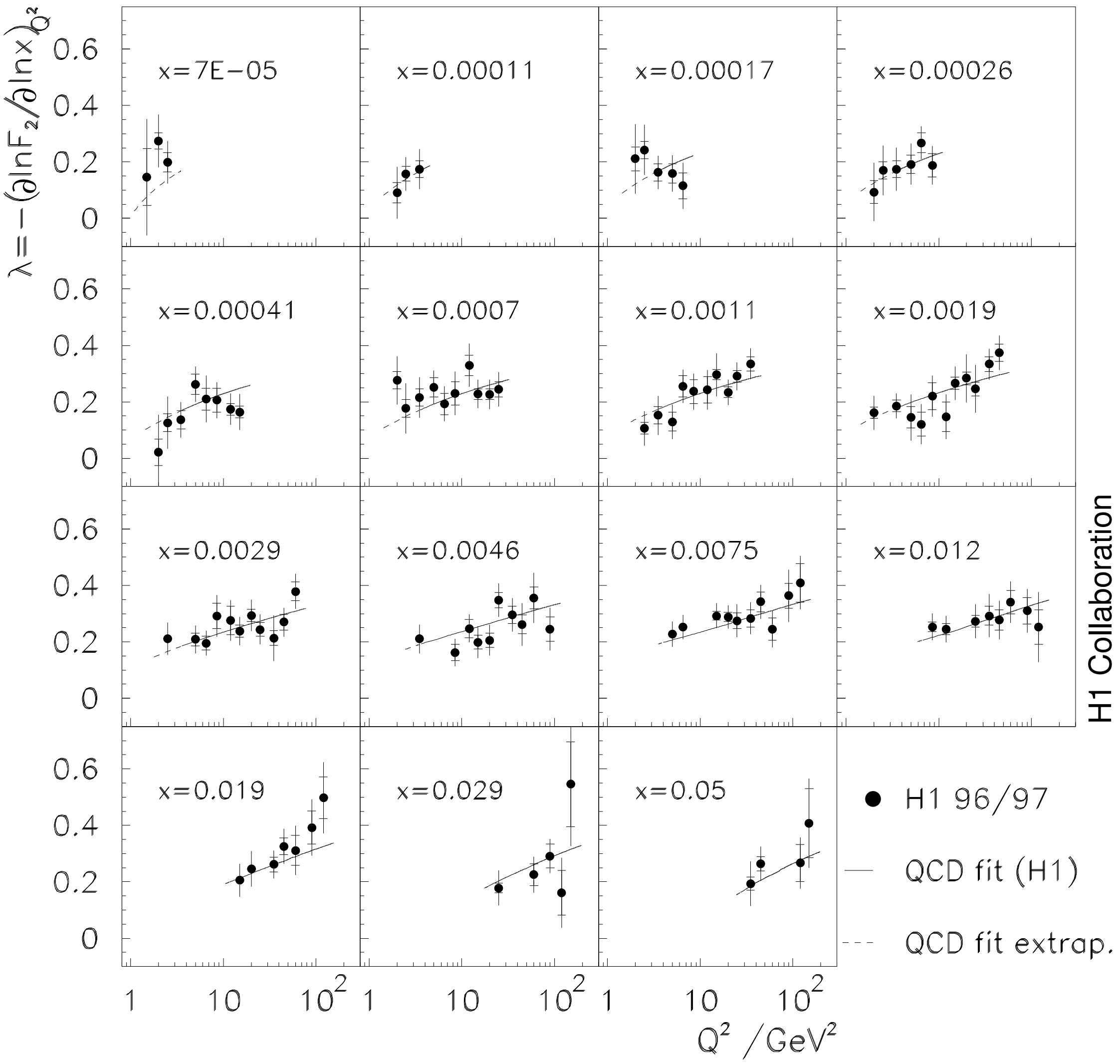

Figure 2: Measurement of the function $\lambda(x, Q^2)$: the inner error bars represent the statistical experimental uncertainty, while the full error bars include the systematic uncertainty added in quadrature; the solid curves denote the NLO QCD fit to the H1 cross section data described in [6]; the minimum Q^2 value of cross section data included in this fit is $Q^2 = 3.5$ GeV^2.

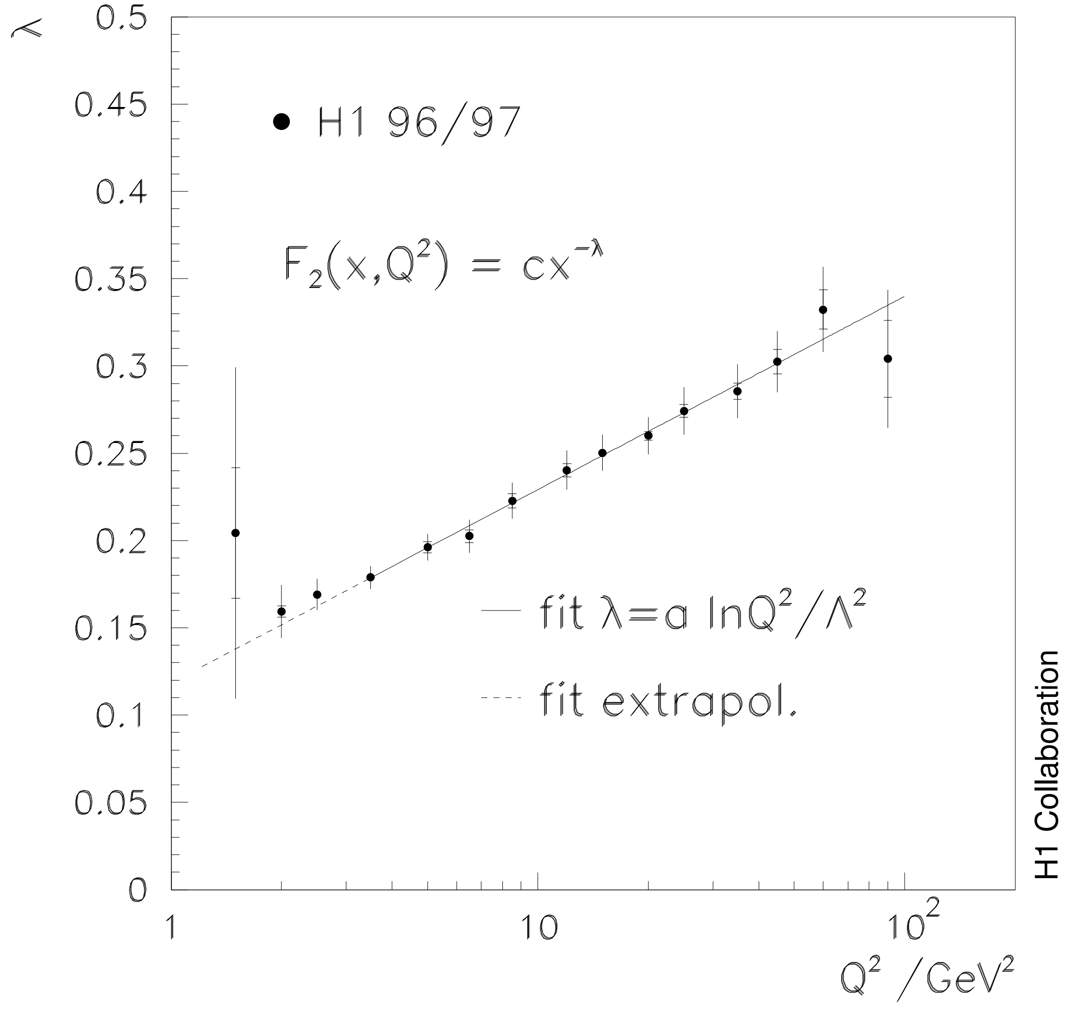

Figure 3: Determination of the exponent $\lambda(Q^2)$ from a fit $F_2 = cx^{-\lambda}$ to the H1 data [6] for $x \leq 0.01$; the inner error bars illustrate the statistical uncertainties, the full error bars represent the statistical and the systematic uncertainties added in quadrature. The solid line is a fit $\lambda = a \ln Q^2/\Lambda^2$, see text, using data for $Q^2 \geq 3.5$ GeV^2