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Measurements of the Proton Structure Function F_2 at Low Q^2 at HERA

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Two new measurements of the proton structure function $F_2(x,Q^2)$ at low virtualities of the exchanged photon Q^2 are the focus of this report. They are based on radiative events collected by the H1 detector at HERA allowing to gain overlap with data from fixed target experiments by extending the accessible range of Bjorken x towards large values. Covering the transition region of $Q^2 \approx 1\,\mathrm{GeV}^2$ between deep inelastic scattering and quasi-real photoproduction, the results can be used to study the x dependence of $F_2(x,Q^2)$ in the non-perturbative regime.

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1. Introduction

Since the advent of the HERA accelerator, colliding electrons or positrons[1] with protons, the accessible kinematic phase space in deep inelastic lepton nucleon scattering (DIS) has been considerably extended in terms of Q^2, the negative squared four-momentum transfer carried by the exchanged electroweak gauge boson, and x, the fraction of the proton's longitudinal momentum carried by the struck quark. In the low Q^2 regime considered in this report the inclusive scattering cross section can be expressed in terms of two independent proton structure functions $F_2(x,Q^2)$ and $F_L(x,Q^2)$ in the form

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\mathrm{d}Q^2} = \frac{2\pi\alpha^2}{Q^4 x}Y^+\left(F_2(x,Q^2) - \frac{y^2}{Y^+}F_L(x,Q^2)\right) \equiv \frac{2\pi\alpha^2}{Q^4 x}Y^+\sigma_r,$$

with Y^+ being defined as $Y^+ = 1+(1-y)^2$ and σ_r denoting the so-called reduced cross section. The inelasticity y is related to x and Q^2 via $y \approx Q^2/(sx)$, s being the squared centre of mass energy.

The HERA experiments H1 and ZEUS have shown that the Q^2 evolution of the proton structure function $F_2(x,Q^2)$ is well described by perturbative Quantum Chromodynamics (pQCD) throughout a wide range in x and Q^2. However, at $Q^2 \approx 1\,\mathrm{GeV}^2$ the transition to soft hadronic physics takes place, the strong coupling constant becomes large and pQCD is no longer applicable. Only phenomenological models are able to describe the data in this domain.

With the scattered electron being detected in the main detector standard DIS events can be reconstructed for $Q^2 > 2\,\mathrm{GeV}^2$. To cover the transition region special experimental techniques have to be employed. One possibility is to use dedicated detectors mounted close to the beam pipe far outside the main detector to reconstruct the outgoing electron under small scattering angles, thus accessing very low values of Q^2 [1]. Smaller scattering angles are also reached during special running periods of the HERA collider in which the interaction region is shifted by 70 cm in the direction of the incoming proton. Preliminary results based on a shifted vertex run in the year 2000 have recently been presented by the H1 Collaboration covering the phase space $0.35 < Q^2 < 3.5\,\mathrm{GeV}^2$ and $7\cdot 10^{-6} < x < 2\cdot 10^{-3}$ [2].

In the following an extension of this measurement towards larger x is presented making use of so called initial state radiation (ISR) events in which a hard photon is emitted collinear with the incoming electron [3]. Inelastic QED Compton (QEDC) events form a further class of radiative processes that allow to explore the region of large x which only fixed target experiments reached so far. A new analysis based on these events is also discussed below [4].

2. QEDC Analysis

A first measurement of F_2 in inelastic QEDC scattering has recently been performed by the H1 Collaboration using data from the 1997 standard running period [4]. For QEDC events the photon emission from the electron line leads to an experimental configuration in which the outgoing electron and the radiated photon are approximately back-to-back in the azimuthal plane. While the electron and the radiated photon can still be detected at sizeable scattering angles in the main detector their transverse momenta nearly balance each other leading to a small transverse momentum of the exchanged photon which corresponds to a low virtuality Q^2.

[1] In the following the expression "electron" is used to refer to both electrons and positrons.

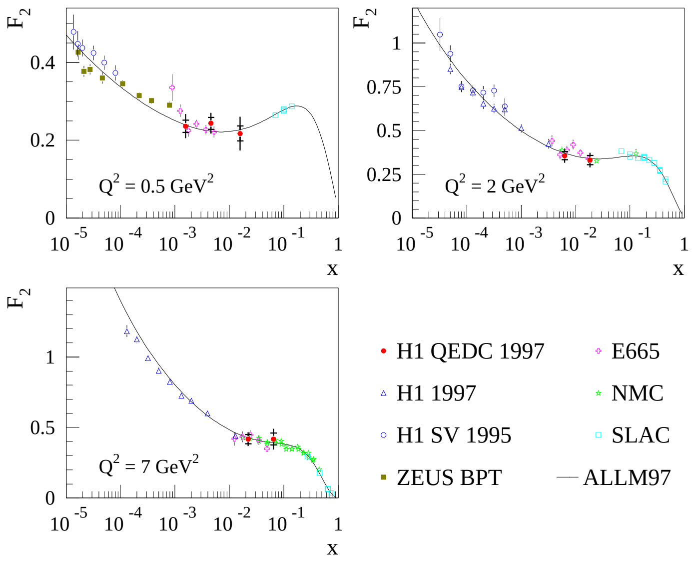

Figure 1: F_2 measurement from QEDC events by H1 (closed circles), compared with other results obtained at HERA and fixed target experiments. The solid line represents the ALLM97 parametrisation.

The signature of the radiated photon can be faked by a neutral particle of the hadronic final state (typically a π^0). Hence standard DIS events dominate the QEDC signal at low x where the hadronic final state mainly occupies the same region of the detector as the scattered electron and the radiated photon. The new measurement therefore concentrates on medium to large values of x. An accurate reconstruction of the hadronic final state at large x requires a good simulation of hadronisation processes at low Q^2 and low invariant masses. This was achieved down to the resonance region using the SOPHIA Monte Carlo program [5].

Figure 1 shows the F_2 values determined from QEDC events as a function of x for different Q^2 bins. They are compared to data from other H1 measurements, the ZEUS Beam Pipe Tracker (BPT) [1] and different fixed target experiments. The new analysis extends the kinematic range of the non-radiative HERA measurements at low Q^2 towards larger values of x previously only covered by fixed target experiments. The QEDC analysis and the fixed target measurements are found to be in good agreement. The data are well described by the ALLM97 parametrisation [6].

3. ISR Analysis

Due to the photon radiation an ISR event can be interpreted as a usual *ep* scattering event at a lower electron beam energy, resulting in a lower centre of mass energy such that larger values of x are reached at fixed Q^2 compared to non-radiative events. In contrast to previous measurements the new preliminary analysis of the H1 Collaboration [3], based on data taken in 2000 with a shifted vertex, does not require the detection of the radiated photon. Instead, its presence is inferred from energy and longitudinal momentum conservation which is also exploited to determine the photon energy, assuming a collinear radiation with the electron beam. Apart from an increased acceptance this has the advantage that overlap events of photoproduction/DIS and Bethe-Heitler events are absent which are the dominant background contribution if the photon is tagged. The Backward Silicon Tracker which is used to reconstruct the scattered electron provides an efficient reduction of the background arising from neutral particles in photoproduction events.

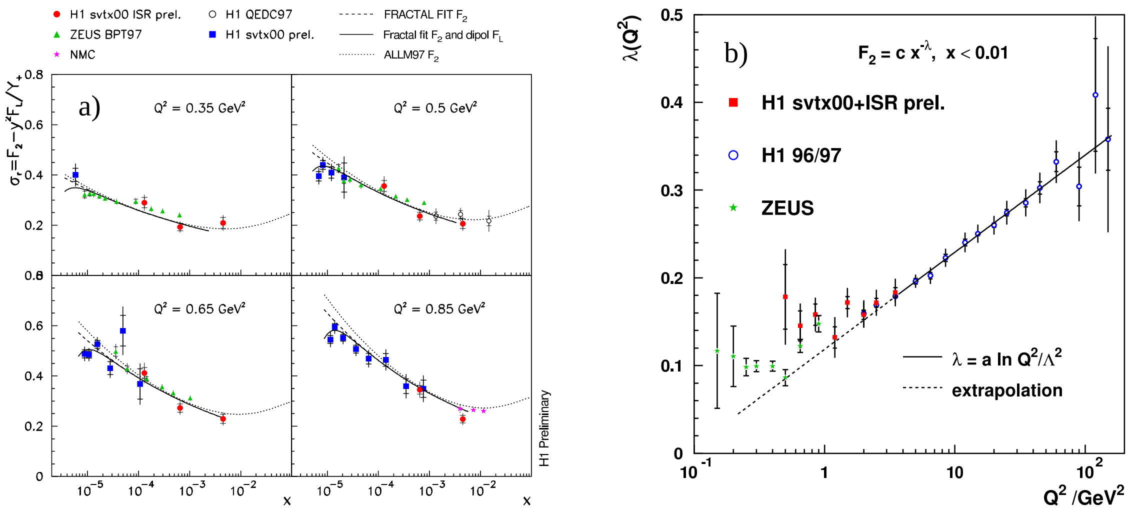

Figure 2: a) Reduced cross-section as measured by H1, ZEUS and NMC. The lines represent various phenomenological fits. b) Selected HERA results on the parameter λ, obtained from fits of the form $F_2(x,Q^2) = c(Q^2) \cdot x^{-\lambda(Q^2)}$ to low x data.

The preliminary ISR analysis [3] complements the accessible phase space of the non-radiative shifted vertex analysis [2] at large x for $0.35 < Q^2 < 0.85\,\mathrm{GeV}^2$ as can be seen from the reduced cross section σ_r depicted in figure 2a. The new data are consistent with results from QEDC events [4], the ZEUS Beam Pipe Tracker [1] and fixed target data. In addition the predictions of the extrapolated Fractal Fit [7] assuming a self-similar structure of the proton at low x and the ALLM97 parametrisation [6] are displayed. Data and predictions are in good agreement.

Previous measurements have shown that the structure function F_2 can be parametrised by $F_2(x,Q^2) = c(Q^2) \cdot x^{-\lambda(Q^2)}$ for $x < 0.01$. The parameter λ quantifies the rise of F_2 towards low x at fixed Q^2 and has been recently extracted from fits of the given form [2]. The ISR analysis allows for an improved extraction of λ from H1 data via a combined fit with the F_2 values extracted in the non-radiative shifted vertex analysis. The result is shown in figure 2b. The new measurement confirms the change from a logarithmic dependence of λ on Q^2 to a weaker dependence tending to the value of 0.08 as $Q^2 \to 0$ known to describe total hadron-hadron and photoproduction cross-sections. The change takes place at a distance scale of around $0.03\,\mathrm{fm}$ and can be interpreted as being related to a transition from partonic to hadronic degrees of freedom.

References

[1] J. Breitweg *et al.* (ZEUS Collaboration), Phys. Lett. B **487** (2000) 53 [`arXiv:hep-ex/0005018`].

[2] H1 Collaboration, Contributed paper to EPS 2003, Aachen, Abstract **082**.

[3] H1 Collaboration, Contributed paper to EPS 2005, Lisbon, Abstract **623**, PoS(HEP2005)623.

[4] A. Aktas *et al.* (H1 Collaboration), Phys. Lett. B **598** (2004) 159 [`arXiv:hep-ex/0406029`].

[5] A. Mücke *et al.*, Comput. Phys. Commun. **124** (2000) 290 [`arXiv:astro-ph/9903478`].

[6] H. Abramowicz and A. Levy, `arXiv:hep-ph/9712415`.

[7] T. Laštovička, Eur. Phys. J. C **24** (2002) 529 [`arXiv:hep-ph/0203260`].