Precision Measurement of the Inclusive Deep Inelastic *ep* Scattering Cross Section at low Q^2

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Abstract

A preliminary precise measurement of the deep inelastic ep scattering cross section is reported for momentum transfers squared $2 \leq Q^2 \leq 120$ GeV^2 and for Bjorken-x values $3 \cdot 10^{-5} < x < 0.1$ using data collected in 1997 by the HERA experiment H1. An analysis of the cross section data combined with fixed target experiments shows NLO QCD to be in very good agreement with the new data. A new method has been developed to access the longitudinal structure function F_L down to low values of $Q^2 \simeq 3$ GeV^2.

1. Definitions

The inclusive deep inelastic scattering (DIS) cross section for $Q^2 << M_Z^2$ is dominated by one photon exchange and defined as

$$\frac{Q^4 x}{2\pi\alpha^2 Y_+} \cdot \frac{d^2\sigma}{dxdQ^2} = \sigma_r = F_2(x,Q^2) - \frac{y^2}{Y_+} \cdot F_L(x,Q^2) \quad (1)$$

with $Y_+ = 1 + (1-y)^2$. The so-called reduced cross section σ_r is decomposed into two proton structure functions $F_2(x,Q^2)$ and $F_L(x,Q^2)$ which are related by $0 \leq F_L \leq F_2$. The contribution of F_L is thus suppressed in most of the kinematic range explored by the H1 experiment except for the high y region.

2. H1 Detector

The H1 detector [1] is a nearly hermetic apparatus with a solenoidal magnetic field of 1.15 T built to investigate high-energy ep interactions at HERA. Due to the redundant measurement of the final state various reconstruction methods can be employed in specific kinematic regions.

For polar angles $\theta_e > 153^o$ the energy of the scattered positron E_e' is measured in the backward electromagnetic lead-fibre scintillator calorimeter (SPACAL [2]). Here θ is defined with respect to the proton beam direction. Identification of the scattered positron and the polar angle measurement is performed using a backward drift chamber (BDC) and a backward silicon strip detector (BST [3]) situated in front of the SPACAL.

The hadronic final state is reconstructed with the Liquid Argon (LAr) calorimeter, the tracking detectors and the SPACAL. The interaction vertex is determined with the central drift chambers mainly using the hadronic final state particles. The luminosity has been determined to within 1.5% using elastic bremsstrahlung [4].

3. Event Selection and Data Analysis

The data are triggered using the local energy sums in the SPACAL calorimeter. The threshold energy is set to 5 GeV apart from a special "high y" trigger with 2 GeV threshold energy operating on a special fiducial volume and requiring a valid vertex trigger signature in the central proportional chambers. The efficiency of all trigger elements was found to be larger than 96% with an accuracy of 0.5-1%.

The scattered positron was identified as the cluster with maximum transverse momentum p_t for large $Q^2 > 10$ GeV^2 and as the cluster with the maximum energy deposition for low $Q^2 < 10$ GeV^2. The systematic error for positron identification was estimated to be $1-2\%$.

The distributions of selected events were compared with simulations of deep inelastic scattering, photoproduction and Compton scattering. The simulated Monte Carlo events were subject to the same reconstruction and analysis chain as the real data.

The cross section is determined by converting the measured number of events, after background subtraction, in a bin averaged cross section using acceptance calculations from the Monte Carlo sample. Due to the imposed requirement on energy-momentum conservation ($E - p_z > 35$ GeV) the radiative corrections are small.

The measurement of the DIS cross section at high y requires the scattered positron of a few GeV of energy to be identified and the large background from photoproduction processes to be removed. Since the main part of the background electromagnetic energy deposits is due to $\pi_0 \to \gamma\gamma$ decays, the low energy background is removed to a large extent by requiring a track in the BDC or BST pointing to the cluster reconstructed in the SPACAL.

4. QCD Analysis

A NLO QCD fit to the cross section data including BCDMS [5] and NMC [6] results was performed in the $\overline{MS}$ renormalization scheme using the DGLAP evolution equations for three light flavours with the charm contribution added according to the NLO calculation of the photon-gluon fusion process [7]. The input distributions of $q = g, u_v, d_v$ and S at the starting scale Q_o^2 were parametrized as:

$$xq(x) = A_q x^{B_q}(1-x)^{C_q}(1 + D_q x + E_q\sqrt{x}) \quad (2)$$

where $S = \bar{u} = \bar{d} = 2\bar{s}$ defines the sea distributions. The momentum sum rule and the quark counting rules were applied.

In Figure 1 the QCD fit is compared with the cross section data obtained in this measurement. The data are seen to be very well described by the fit to the cross section (solid line). The χ^2 is 1495 for 1095 data points using the uncorrelated errors of the measurements only.

At high y the cross section departs from the behaviour of F_2 (dashed line in Figure 1). This departure is due to the longitudinal structure function differing significantly from zero.

5. F_L Determination

The determination of the structure function F_L was based on assumptions about the structure function F_2 using two independent methods. The first one, introduced previously [8], uses the extrapolation of F_2 fitted at $y < 0.35$ to the high y region and subtraction of F_2 from σ_r.

The second method is based on the cross section derivative defined as:

$$\frac{\partial \sigma_r}{\partial \log y} = \frac{\partial F_2}{\partial \log y} - F_L \cdot 2y^2 \cdot \frac{2-y}{Y_+^2} - \frac{\partial F_L}{\partial \log y} \cdot \frac{y^2}{Y_+}. \quad (3)$$

This derivative is a linear function of $\log y$ (see [9]) for low y. For each Q^2 bin a straight line fit to the cross section derivative for $y < 0.2$ was performed and extrapolated to high y. F_L was then calculated according to Eq.3. assuming that $\partial F_2/\partial \log y$ is a linear function of $\log y$ up to high y.

The results of both methods obtained from the same data are consistent within the errors. F_L comes out to be large consistent with QCD expectations based on a large gluon distribution.

References

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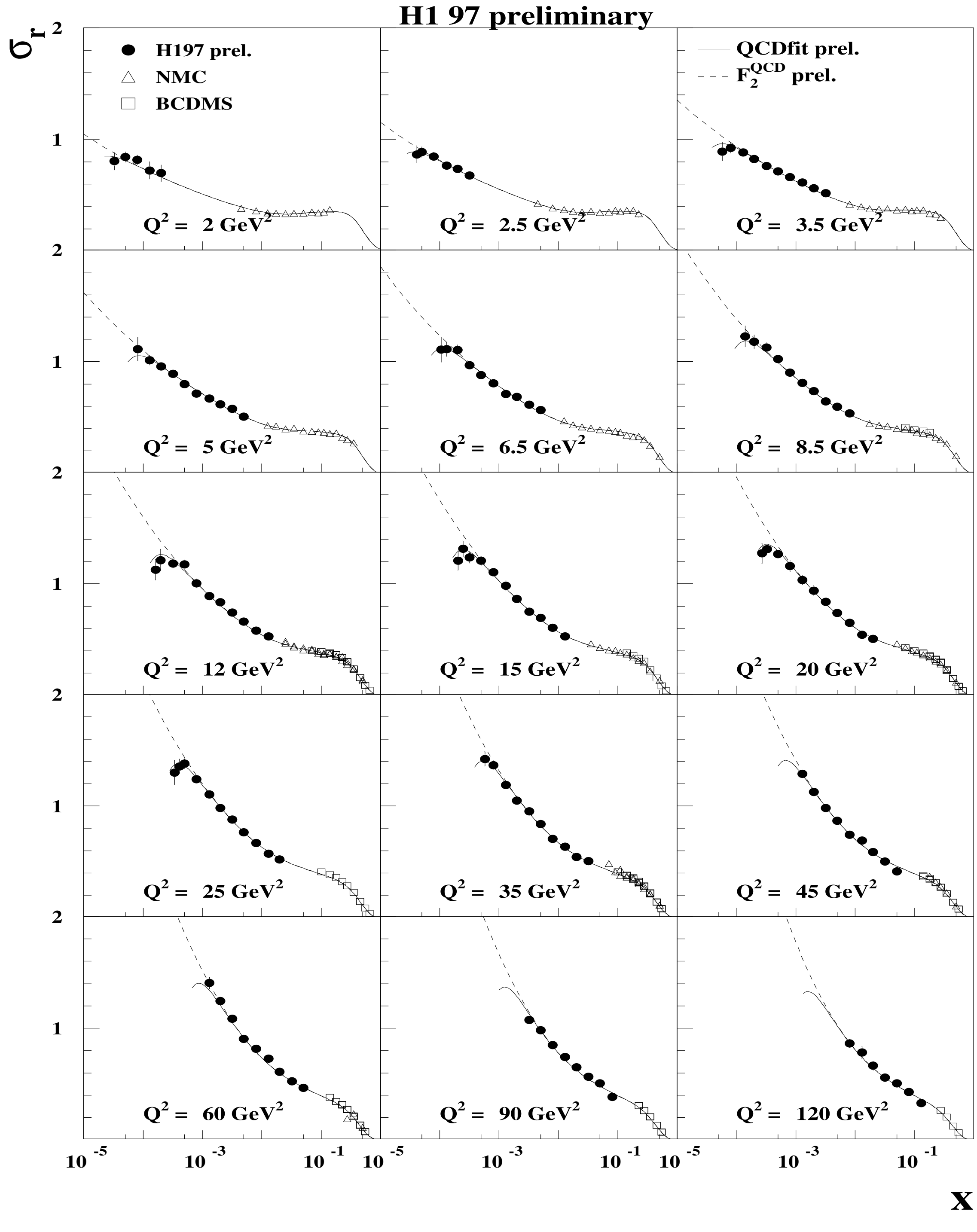

Figure 1. Measurement of the reduced DIS scattering cross section, eq.1, closed points. Triangles (squares) represent data by the NMC (BCDMS) muon proton experiments. The fit is a NLO QCD fit to the H1, the NMC and BCDMS proton and deuteron cross section data as described in the text. The dashed curve is the F_2 structure function determined with this fit. At lowest x, corresponding to large $y \geq 0.5$, departures of the cross section from the rise of F_2 towards low x occur which are mostly due to F_L differing from zero.