Measurement of the Inclusive ep Scattering Cross Section at low Q^2 and x at HERA

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Measurements of the inclusive ep scattering cross section in the region of low four-momentum transfer squared, $0.2\,\mathrm{GeV}^2 < Q^2 < 12\,\mathrm{GeV}^2$, and low Bjorken x, $4\times10^{-6} < x < 0.02$ are presented. The results are based on two data sets collected in dedicated runs by the H1 Collaboration at beam energies of 27.6 GeV and 920 GeV for positrons and protons. These new measurements extend the kinematic phase space to lower values of Q^2 by using non tagged radiative ep scattering events. The combination of these new measurements with data previously published by H1 is presented.

1 Introduction

The kinematics of inclusive deep inelastic scattering (DIS) are usually described by the variables Q^2, the negative four-momentum transfer squared, and x, the fraction of the proton's longitudinal momentum carried by the struck quark. The reduced cross section for electron-proton scattering in the one-photon approximation, which is valid in the region of this measurement, is given by the expression:

$$\sigma_r = F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2) \qquad Y_+ = 1+(1-y)^2 \tag{1}$$

where y is the inelasticity, given by $y = Q^2/sx$, and s is the centre of mass energy of the ep collision.

The proton structure function F_2 is the dominant contribution to the inclusive cross section, while F_L contributes only at high values of y. The experiments at the HERA ep collider have shown that the Q^2 evolution of the proton structure F_2 is well described by pQCD over a wide range in x and Q^2 [2, 3]. However, at low $Q^2 < 2\,\mathrm{GeV}^2$, the transition to photoproduction takes place and the data can be only described by phenomenological models. This note presents new cross section measurements of the H1 collaboration in the transition region. A combination of the new measurements with previous H1 data with comparable accuracy is also presented.

2 Cross Section Measurements

Two dedicated runs taken in the years 1999 (MB'99) and 2000 (SVX'00) by the H1 experiment, were used to measure the cross section in the transition region. The MB'99 data sample covers a kinematic phase space from $0.5 \leq Q^2 \leq 12\,\mathrm{GeV}^2$ while the SVX'00 data sample covers the lowest values $0.2 \leq Q^2 \leq 3.5\,\mathrm{GeV}^2$. The trigger configuration of the MB'99 data taking allows to measure the cross section towards high $y = 0.75$, into the region of high sensitivity to F_L. During the SVX'00 data sample, the interaction point of the ep collision was shifted in the proton beam direction, such that larger positron scattering angles could be measured and hence lower values of Q^2 were accessed. In addition, the measurement at even lower values of Q^2 was possible by using initial state radiative (ISR) events. In this analyses the detection of the radiated photon was not required. The energy of the incoming electron is reconstructed from energy and longitudinal momentum conservation, assuming that the photon is radiated collinearly with the electron beam. Using the reduced incoming electron energy, the kinematic variables are reconstructed with the so called Σ method.

In Fig. 1 the cross section measurements are shown for the MB'99 and SVX'00 data samples. A good agreement between the two data sets is observed in the overlap region $0.5 \leq Q^2 \leq 3.5\,\mathrm{GeV}^2$.

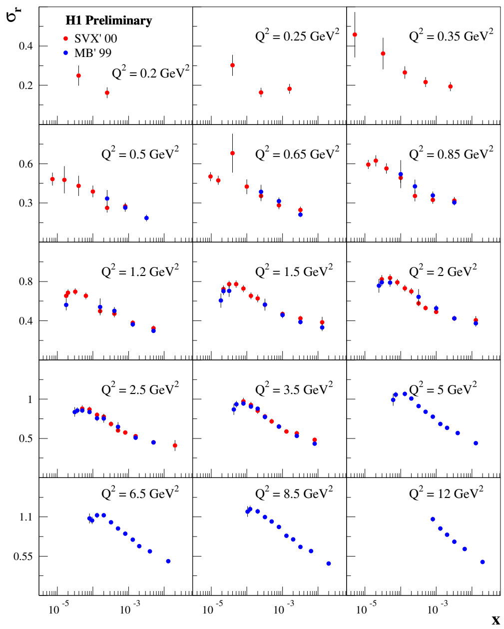

Figure 1: Reduced inclusive *ep* scattering cross sections as measured with the MB'99 and SVX'00 data samples

The total error of the measurement contains two types of error sources. One error source affects the measurement bin by bin (uncorrelated), while the another source affects the measurement as a whole (correlated). Examples of correlated sources are the uncertainty on the measurement of the energy, angular position of the scattered electron, while uncertainties on efficiencies are examples of uncorrelated sources. The dominant uncertainties of the MB'99 and SVX'00 cross section measurements are the vertex efficiency (2%) and the uncertainty on the luminosity measurement (3%), respectively. The total error of the measurement for the MB'99 sample varies from 10% at low values of Q^2 to 2% for the bulk region $Q^2 > 2\,\mathrm{GeV}^2$. The SVX'00 sample has comparable precision for values of $Q^2 > 2\,\mathrm{GeV}^2$, but is of limited precision for the lowest values of Q^2.

The MB'99 and SVX'00 measurements are the final H1 DIS cross section measurements in the low Q^2 transition region. These measurements have a comparable precision with the previously published H1 data collected in 1997 (MB'97) [2]. For obtaining a coherent result of minimum uncertainty, the data is combined using the procedure described below. The agreement between the MB'99, SVX'00 and the published MB'97 measurement is good, after a global 3.4% correction of the MB'97 data sample. This correction did result from a detailed luminosity reanalysis of the MB'97 data taking.

3 Combination of Data Sets

The combination of the three data samples is performed using a minimization procedure [4]. The correlated and uncorrelated errors of the different cross section measurements are taken carefully into account.

Let M_i be a set of cross section measurements, the combined cross section measurement M^{comb} can be obtained by minimazing the χ^2 function:

$$\chi^2(M_i^{comb}, \alpha_j) = \sum_i \frac{\left[M_i^{comb} - \left(M_i + \sum_j \frac{\partial M_i}{\partial \alpha_j}\alpha_j\right)\right]^2}{\sigma_i^2} + \sum_j \frac{\alpha_j^2}{\sigma_{\alpha_j}^2} \quad (2)$$

where σ_i are the statistical and uncorrelated systematic uncertainties of the measurement. The sensitivity of the measurement to the correlated uncertainties α_j are taken by the term $\partial M_i/\partial\alpha_j$ into account.

The χ^2 function of Eq. 2 has by construction a minimum $\chi^2 = 0$ for $M_i^{comb} = M_i$ and $\alpha_j = 0$. The total uncertainty for M_i^{comb} determined from the formal minimisation of Eq. 2 is equal to the sum in quadrature of the statistical and systematic uncertainties.

The combination of the MB'99, SVX'00 and MB'97 cross section measurements is performed using the prescription of Eq. 2. The published H1 data [2] were taken with a different proton beam energy, $E_p = 820\,\mathrm{GeV}$. Thus a centre of mass energy correction is applied to the published cross section. The correction becomes sizable only for the highest y analysis bins which for the published data is at $y = 0.75$. The combination of the three data sets is shown in Fig. 2. The total error of the combined cross section measurement has a precision varying with Q^2 and x, for the central values of Q^2 and x is about 2% but larger towards the edges of the covered phase space. The behaviour of the cross section data, which extend from photoproduction to the DIS region, can be analysed within phenomenological models. As an example, the data in Fig. 2 is compared to the fractal model [5], in which F_2 is parameterised exploiting self similarity features of proton structure at low x. F_L is expressed via F_2 and the cross section ratio $R = F_L/(F_2 - F_L)$. A good fit is obtained with $R \simeq 0.5$ in the whole Q^2 range covered which corresponds to $F_2 \simeq 3F_L$.

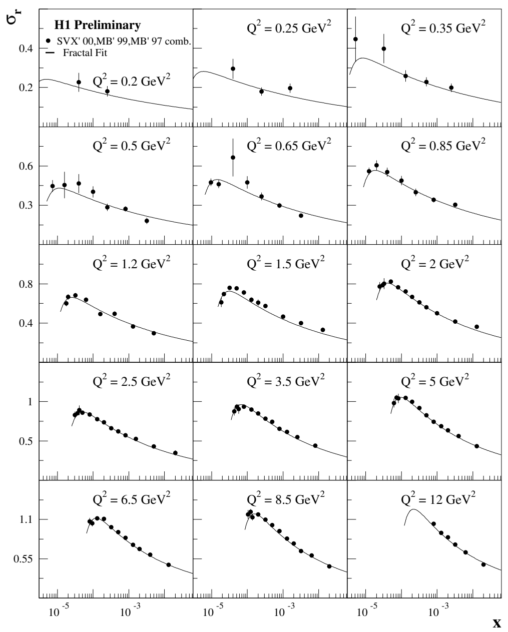

Figure 2: Reduced inclusive ep scattering cross section measurement obtained by combining the MB'99, SVX'00 and the published MB'97 cross sections (see text).

4 λ Extraction

The rise of the structure function F_2 at low values of x can be described by a power law in x, $F_2 \sim x^{-\lambda}$. The coefficient λ increases approximately linearly as a function of $\ln Q^2$ for $Q^2 > 2\,\mathrm{GeV}^2$. The rise of F_2 above $1\,\mathrm{GeV}^2$ increases with $\ln Q^2$. This parametrisation can be used at low x to fit the reduced cross section σ_r, allowing the extraction of λ and F_L simultaneously. Assuming that F_L is constant for a given Q^2, the reduced cross section from Eq. 1 can be written as:

$$\sigma_r(x, Q^2) = c(Q^2) x^{-\lambda(Q^2)} - \frac{y^2}{Y_+} F_L(Q^2) \qquad (3)$$

The global normalisation $c(Q^2)$, the power law exponent $\lambda(Q^2)$ and F_L are three parameters which are obtained by fitting the reduced cross section. The result of these fits are shown in Fig. 3.

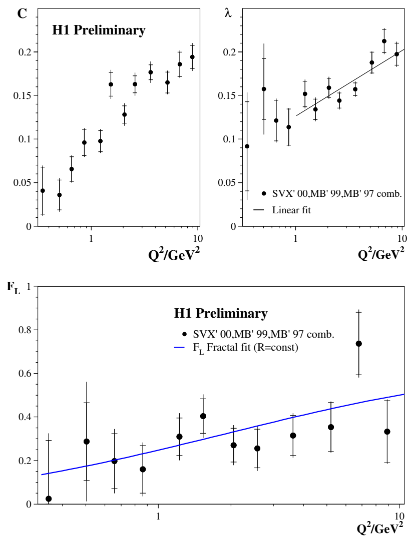

Figure 3: Coefficients c, λ and F_L defined in Eq. 3 determined from a fit to the H1 preliminary data (Fig. 2) as a function of Q^2.

5 Summary

New inclusive cross section measurements of ep collision in the Q^2 transition region from photoproduction to DIS are presented. The data from dedicated runs in 1999 and 2000 are combined here with previously measured data, leading to a coherent result for the low Q^2 cross section data measured by H1 in the HERA-I data taking period. The systematic uncertainty for a large part of the phase space is about 2%.

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