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Measurement of the Inclusive DIS Cross Section at Low Q^2 and High x using Events with Initial State Radiation

H1 Collaboration

Abstract

The inclusive DIS cross section is measured at low Q^2 and relatively large x using events with initial state photon radiation from the incoming electron. In this analysis the radiated photon is not explicitly detected. Instead its energy is inferred from a longitudinal momentum imbalance, such that the energy of the interacting electron and the event kinematics can be reconstructed. The neutral current cross section is thus measured for $0.35 \leq Q^2 \leq 0.85\ \mathrm{GeV}^2$ and $10^{-4} \lesssim x \lesssim 5 \cdot 10^{-3}$.

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Brief Analysis Details

These results represent an extension to our previous measurements [1] of inclusive DIS cross sections at $Q^2 \lesssim 1$ GeV^2, obtained using a dedicated sample corresponding to around $600\ \mathrm{nb}^{-1}$ for which the ep interaction region was shifted by $70\ \mathrm{cm}$ in the outgoing proton direction. The shifted vertex extends the detector acceptance to smaller electron scattering angles and hence to lower Q^2 values. In the new analysis, an extension to larger x values at low Q^2 is achieved by making use of events with initial state photon radiation (ISR) from the incoming electron. The photon radiation results in a reduced effective incoming electron energy, such that the ep centre of mass energy is reduced and larger values of x are accessed at fixed Q^2 than is the case for non-radiative events.

In contrast to earlier ISR analyses [2], this analysis does not require the observation of the radiated photon. Instead, its presence is inferred from energy and longitudinal momentum conservation. Assuming that the photon is radiated collinear with the electron beam, the energy E_γ of the radiated photon is then given by $2E_\gamma = 2E_e^0 - (E - p_z)_{e'} - (E - p_z)_h$, where $E_e^0 = 27.6$ GeV is the electron beam energy, $(E - p_z)_{e'}$ is the measured difference between the energy and the longitudinal momentum of the scattered electron and $(E - p_z)_h$ is the same quantity for the full hadronic final state. The reduced incoming electron beam energy E_e is then given by $E_e = E_e^0 - E_\gamma$. The reconstruction of y and Q^2 proceeds using the 'Σ method', which relies on $\Sigma = (E - p_z)_h$. The reconstruction of x is then performed in a manner that is independent of the electron beam energy E_e^0. The kinematics are resonstructed using

$$y_\Sigma = \frac{\Sigma}{\Sigma + E_{e'}(1 - \cos\theta_e)} \qquad Q^2_\Sigma = \frac{E^2_{e'} \sin^2\theta_e}{1 - y_\Sigma} \qquad x_R = \frac{Q^2_\Sigma}{2\Sigma E_p}$$

where θ_e is the electron scattering angle. The remaining details of the analysis procedure closely follow those reported in [1].

Control distributions corresponding to the measured ISR-dominated phase space are shown in figure 1. There is good agreement between the observed uncorrected data distributions and the expectation based on a DJANGO simulation of inclusive DIS together with a PHOJET simulation of the photoproduction background.

Figure 2 shows the resulting measurements, expressed in the form of the reduced cross section,

$$\begin{aligned} \sigma_r &= \frac{Q^4 x}{2\pi\alpha^2 Y_+} \frac{\mathrm{d}\sigma}{\mathrm{d}x\mathrm{d}Q^2} \\ &= F_2(x, Q^2) - \frac{y^2}{Y_+} \cdot F_L(x, Q^2) , \end{aligned}$$

where $Y_\pm = 1 \pm (1 - y)^2$. The data points have total uncertainties of around 10% and cover the region $0.35 \leq Q^2 \leq 0.85$ GeV^2 and $10^-4 \lesssim x \lesssim 5 \cdot 10^{-3}$. They are compared with the extrapolated predictions of a fit for F_2 based on a self-similar structure to the proton (FRACTAL FIT F_2) [3], to which an F_L term has also been added, based on a dipole model [4].They are also compared with the results from a parameterisation (ALLM97 F_2) [5] of inclusive and exclusive DIS and photoproduction data. All predictions are in good agreement with the data.

The extension in kinematic phase space achieved using the new method is illustrated in figure 3, where the present data are compared with the results from the non-radiative shifted vertex analysis [1]. Figure 4 shows the overall status of DIS measurements in the low Q^2 region, including in addition data from the ZEUS beampipe tracker [6], from a further H1 measurement at low Q^2 and large x using QED-Compton events [7] and from NMC [8]. The new data are compatible with the previous measurements.

The new data allow improved extractions of the parameter λ, which describes the growth of F_2 at low x according to $F_2 = c(Q^2) \cdot x^{-\lambda(Q^2)}$. Figure 5 shows the results for λ obtained by fitting the current data at fixed Q^2 values, together with the previous shifted vertex measurements [1]. Also shown are H1 results from larger Q^2 values [9] and ZEUS results [6]. The new measurements confirm the change in behaviour of λ from a logarithmic dependence on Q^2 at large Q^2 to a weaker dependence compatible with reaching a constant consistent with the soft pomeron intercept as $Q^2 \to 0$. The change takes place on distance scales of the order of 0.3 fm and can be interpreted as being related to a transition from partonic to hadronic degrees of freedom.

References

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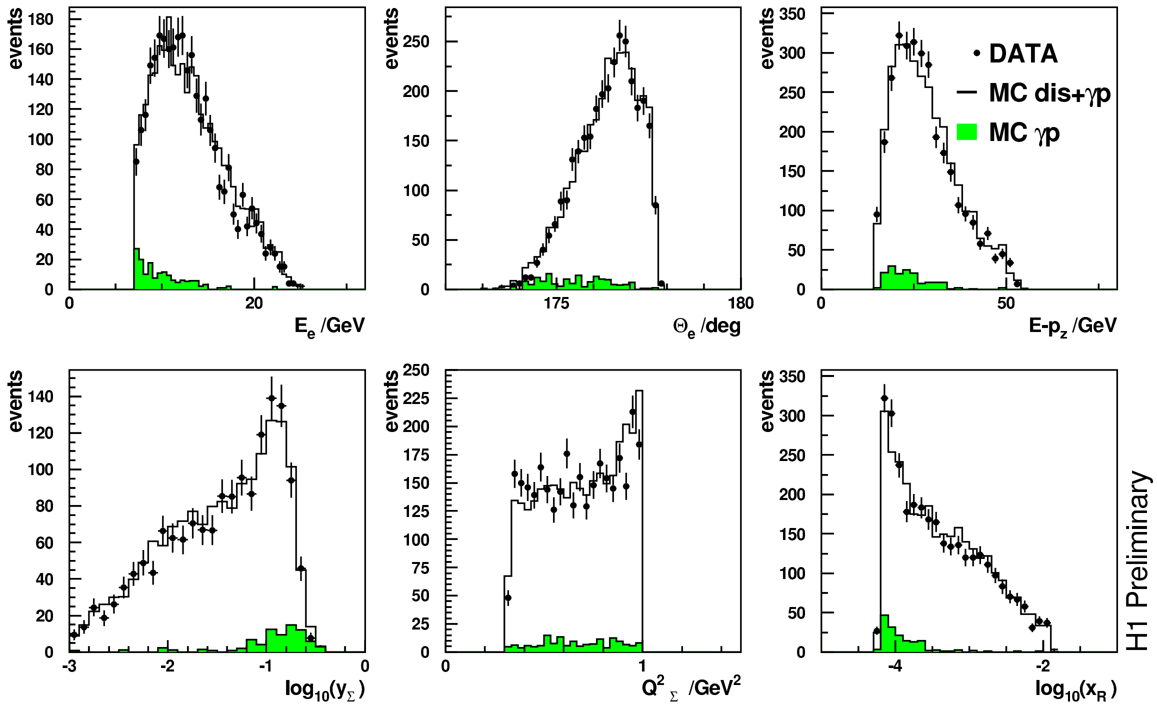

Figure 1: Control distributions for the ISR-dominated event selection. The uncorrected data distributions are compared with the sum of the DIS expectation (DJANGO Monte Carlo model) and the expected photoproduction background (PHOJET Monte Carlo model). The comparisons are shown for the effective incoming electron energy E_e, the electron scattering angle θ_e, the sum of the electron and hadron $E - p_z$ and the reconstructed y, Q^2 and x as used in the measurement.

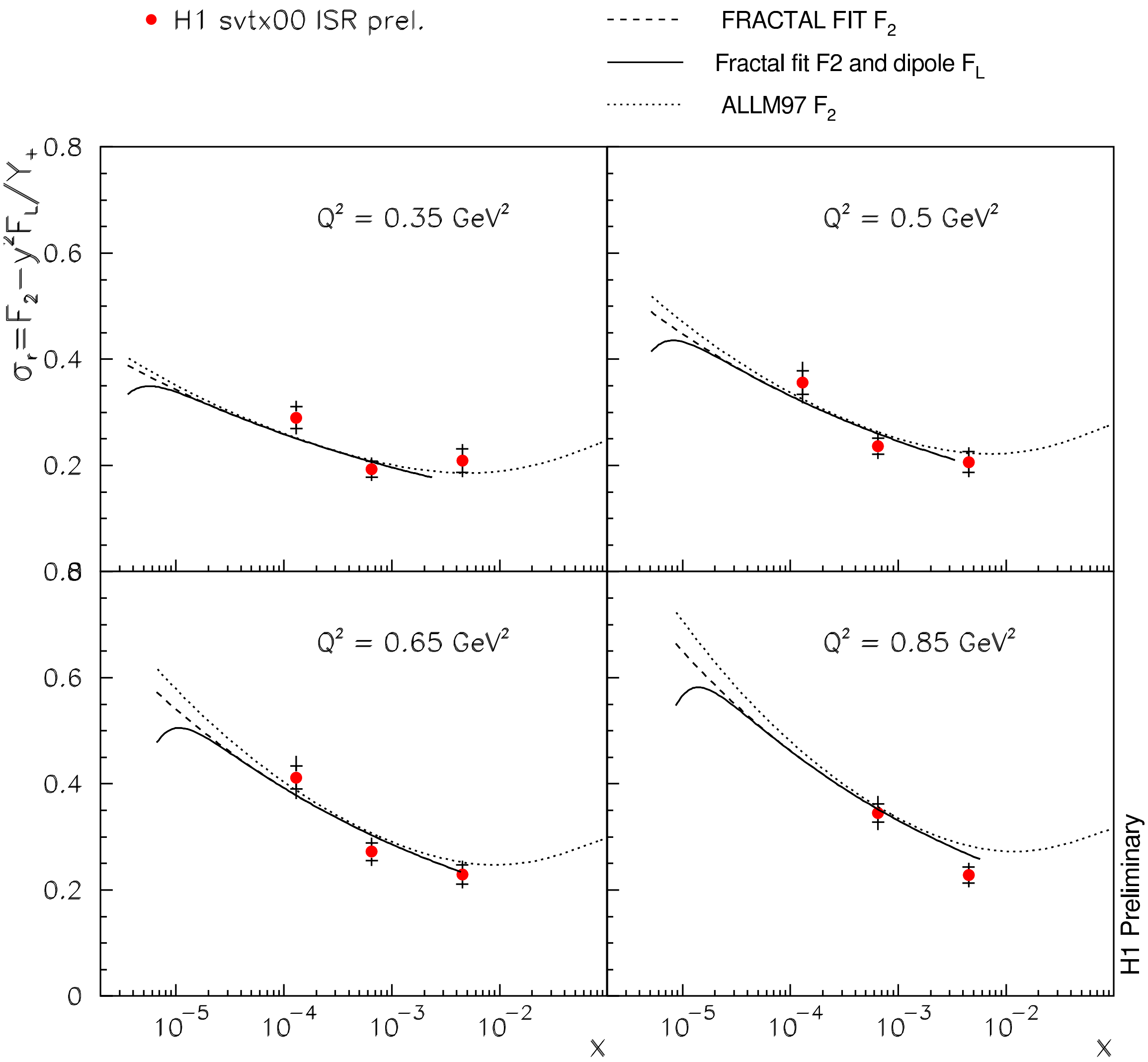

Figure 2: Measured reduced cross section from the shifted vertex ISR analysis, compared with the extrapolated predictions of a 'fractal' fit based on self-similar proton structure, with the sum of the fractal fit result for F_2 and a F_L contribution from a dipole model and with the ALLM97 parameterisation.

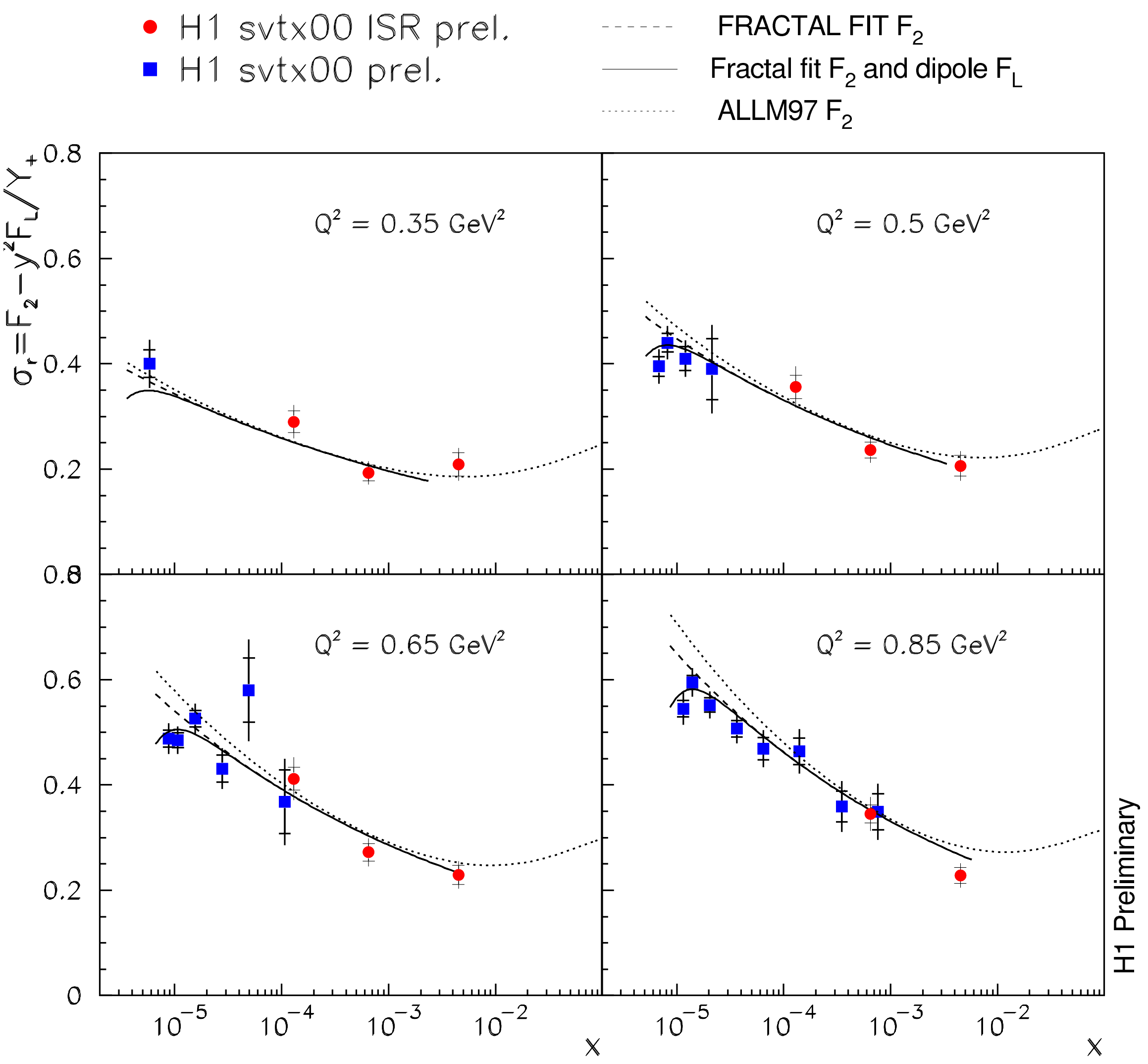

Figure 3: Measured reduced cross section from both ISR and non-radiative measurements using shifted vertex data.

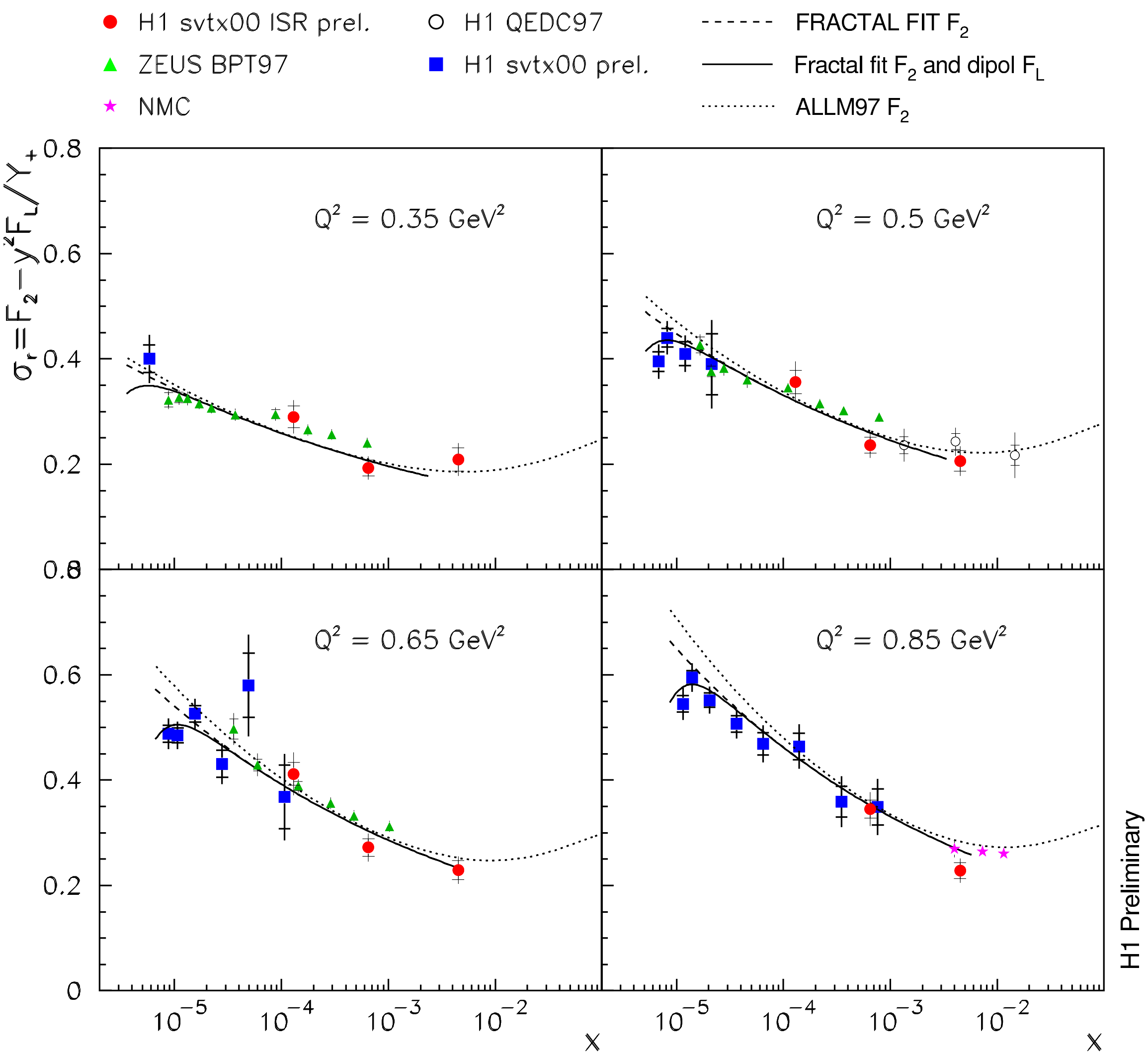

Figure 4: Compilation of reduced cross section measurements with $Q^2 < 1$ GeV^2 from H1, ZEUS and NMC.

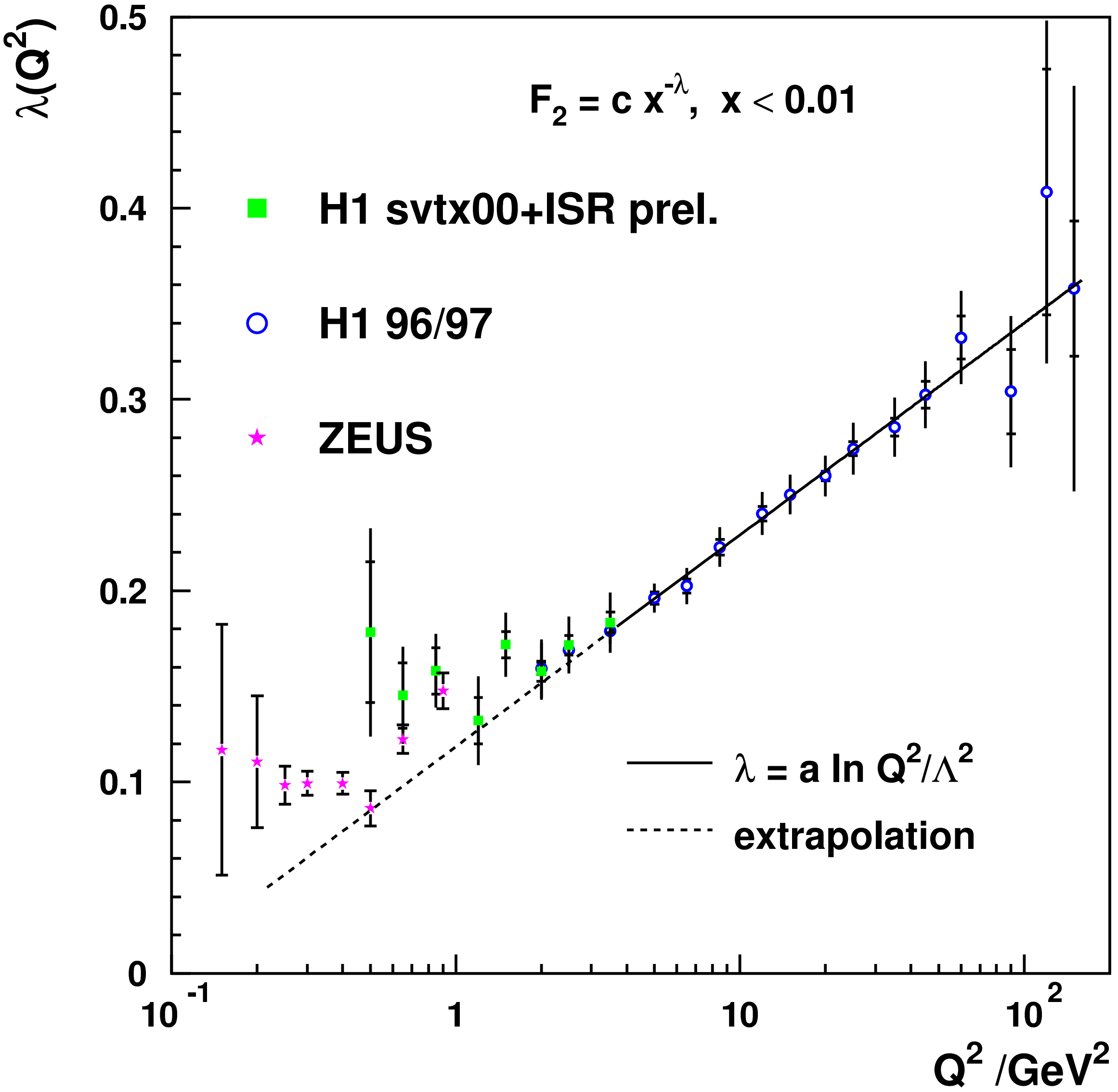

Figure 5: Compilation of selected HERA results on the parameter λ, obtained from fits of the form $F_2 = c(Q^2) \cdot x^{-\lambda(Q^2)}$ to low x data.