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Deep-Inelastic Inclusive ep Scattering at Low x and a Measurement of α_s

H1 Collaboration

Abstract

A precise measurement at HERA of the inclusive deep-inelastic e^+p scattering cross section is reported for four-momentum transfers squared $1.5 \leq Q^2 \leq 150$ GeV^2 and Bjorken-x values $3 \cdot 10^{-5} \leq x \leq 0.2$ using new instrumentation in the backward region of the H1 detector. In most of this kinematic range the cross section σ is determined to good approximation by the proton structure function $F_2(x, Q^2)$. At intermediate Q^2 and large x, the data confirms the measurements of previous fixed target muon-proton scattering experiments. At smallest x, the longitudinal structure function $F_L(x, Q^2)$ is determined. The behaviour of the measured cross section and of the derivatives, $\partial\sigma/\partial \ln y$ and $\partial F_2/\partial \ln Q^2$, is in accord with perturbative Quantum Chromodynamics. In a DGLAP QCD fit to H1 ep and BCDMS μp inclusive cross section data, the gluon momentum distribution xg and the strong interaction coupling constant α_s are determined simultaneously. A value of $\alpha_s(M_Z^2) = 0.1150 \pm 0.0017\ (exp)\ ^{+\,0.0011}_{-\,0.0012}\ (model)$ is obtained in next-to-leading order QCD with an extra theoretical error of about ± 0.005 due to renormalisation scale uncertainties.

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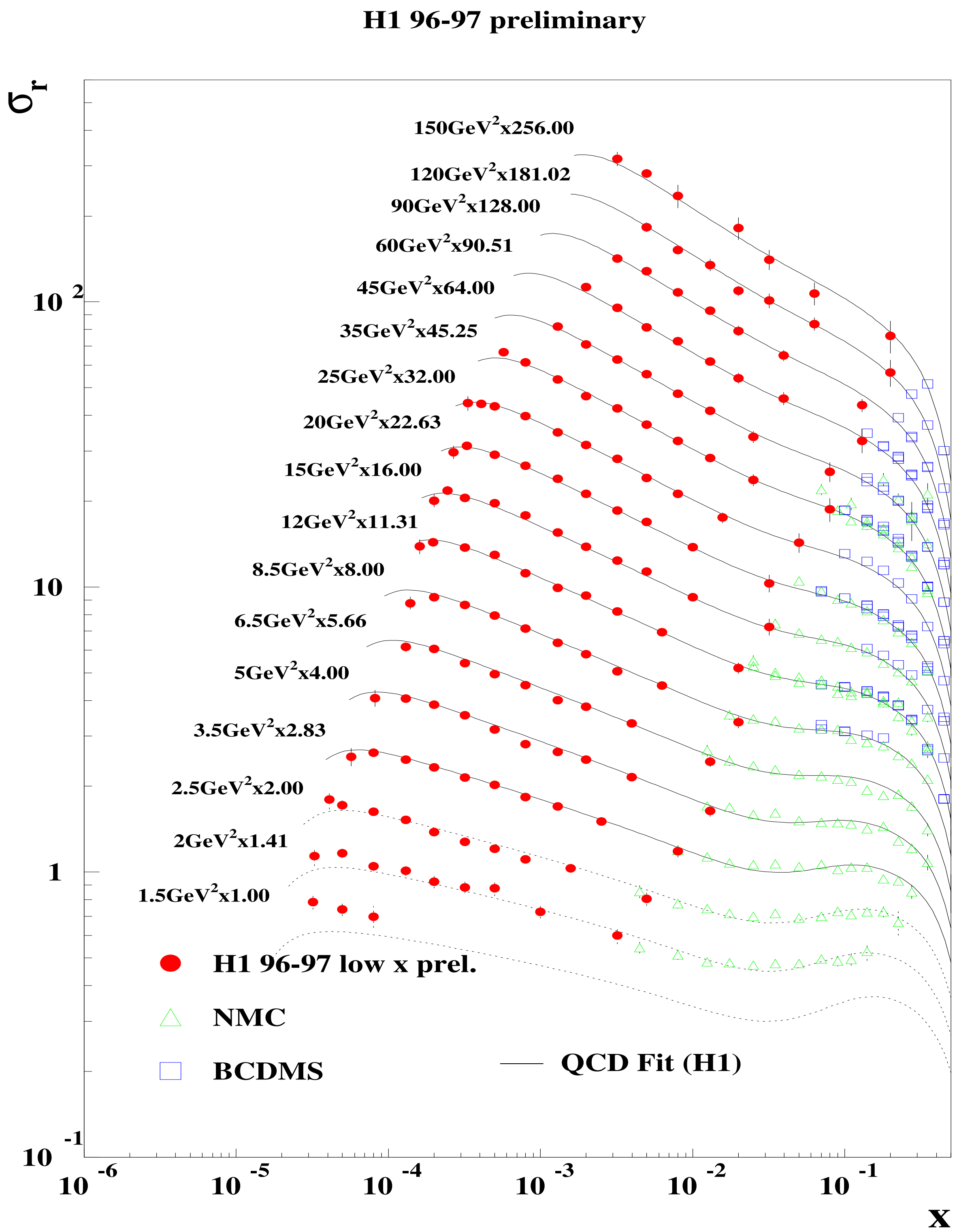

Figure 1: *Measurement of the reduced DIS scattering cross-section, closed points. Triangles (squares) represent data by the NMC (BCDMS) muon proton experiments. The solid curves illustrate the cross-section obtained in a NLO DGLAP QCD fit to only the H1 data at low x and high Q^2, with $Q^2_{min} = 3.5$ GeV^2. The dashed curves show the extrapolation of this fit towards lower Q^2.*

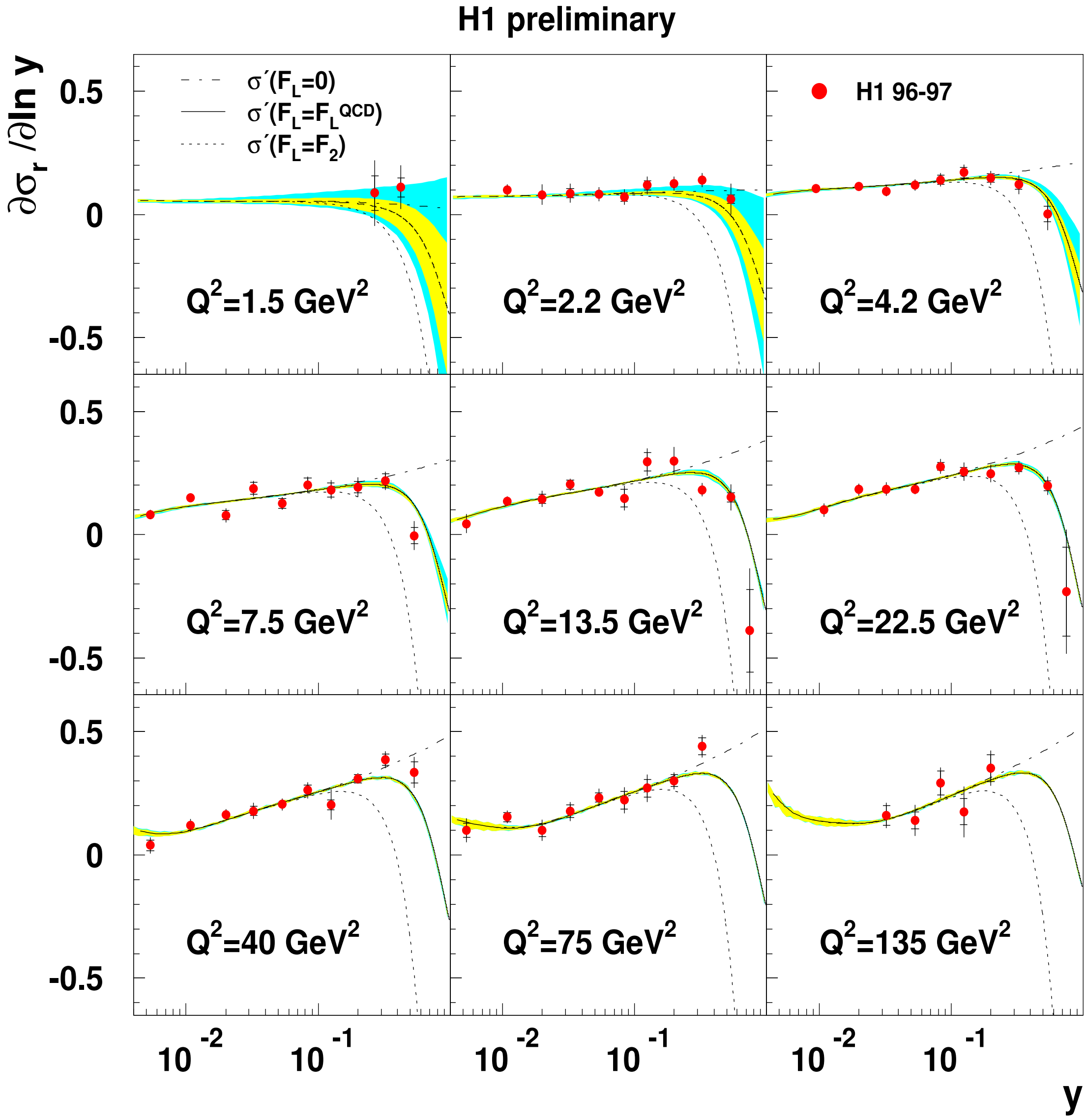

Figure 2: *Measurement of the derivative $\partial\sigma_r/\partial \log y$. The inner error bar is the statistical error and the total error bar denotes the statistical and systematic errors added in quadrature. The curves represent the QCD fit (solid curve) replacing the F_L fit result by $F_L = 0$ (dashed-dotted curve) or by $F_L = F_2$ (dotted curve). The inner error band is the experimental uncertainty of the fit result, and the outer band represents the additional uncertainty due to the fit assumptions. The fit results for $Q^2 < 3.5$ GeV^2 are due to backward extrapolation.*

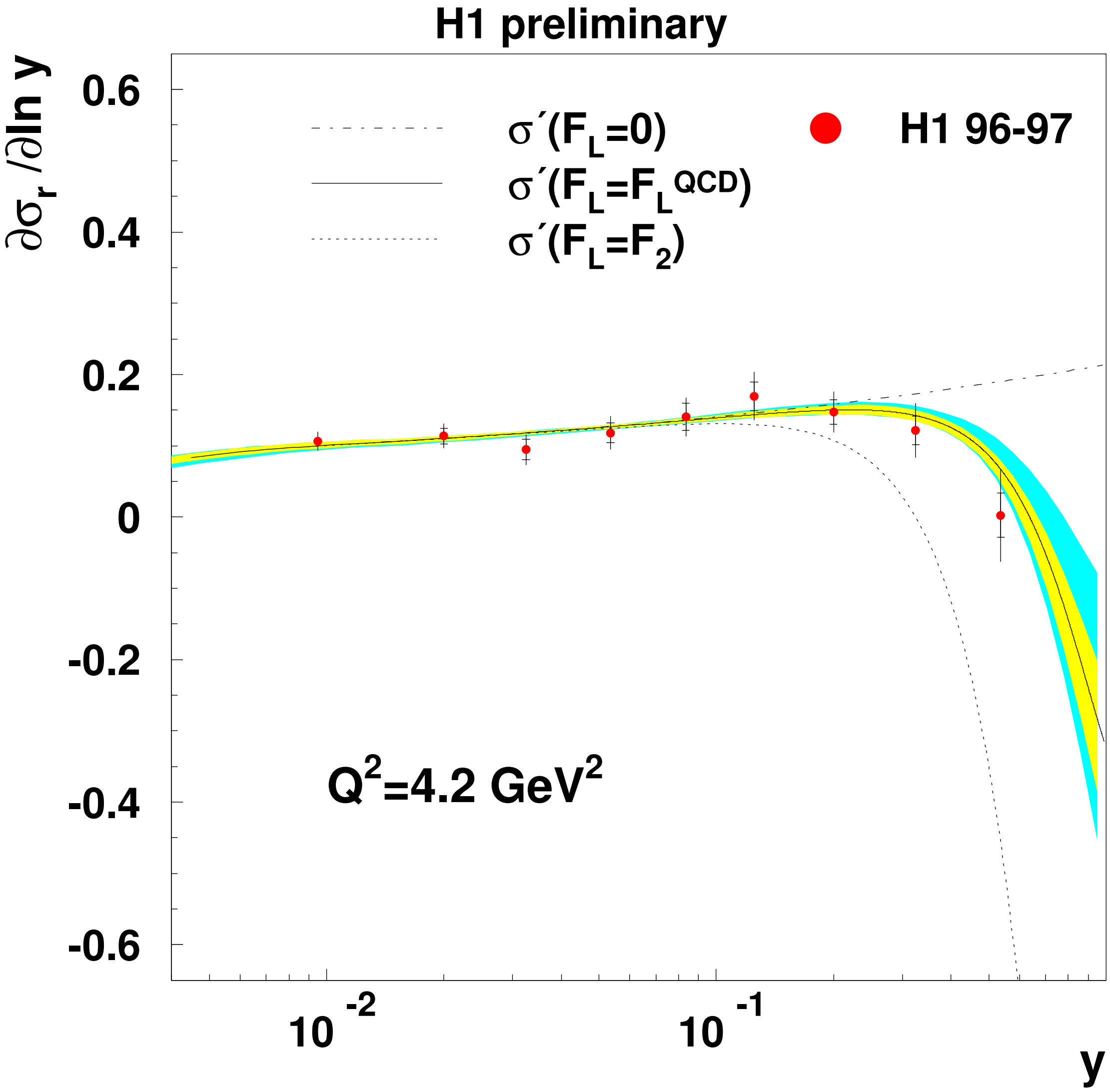

Figure 3: zoom into Fig.2

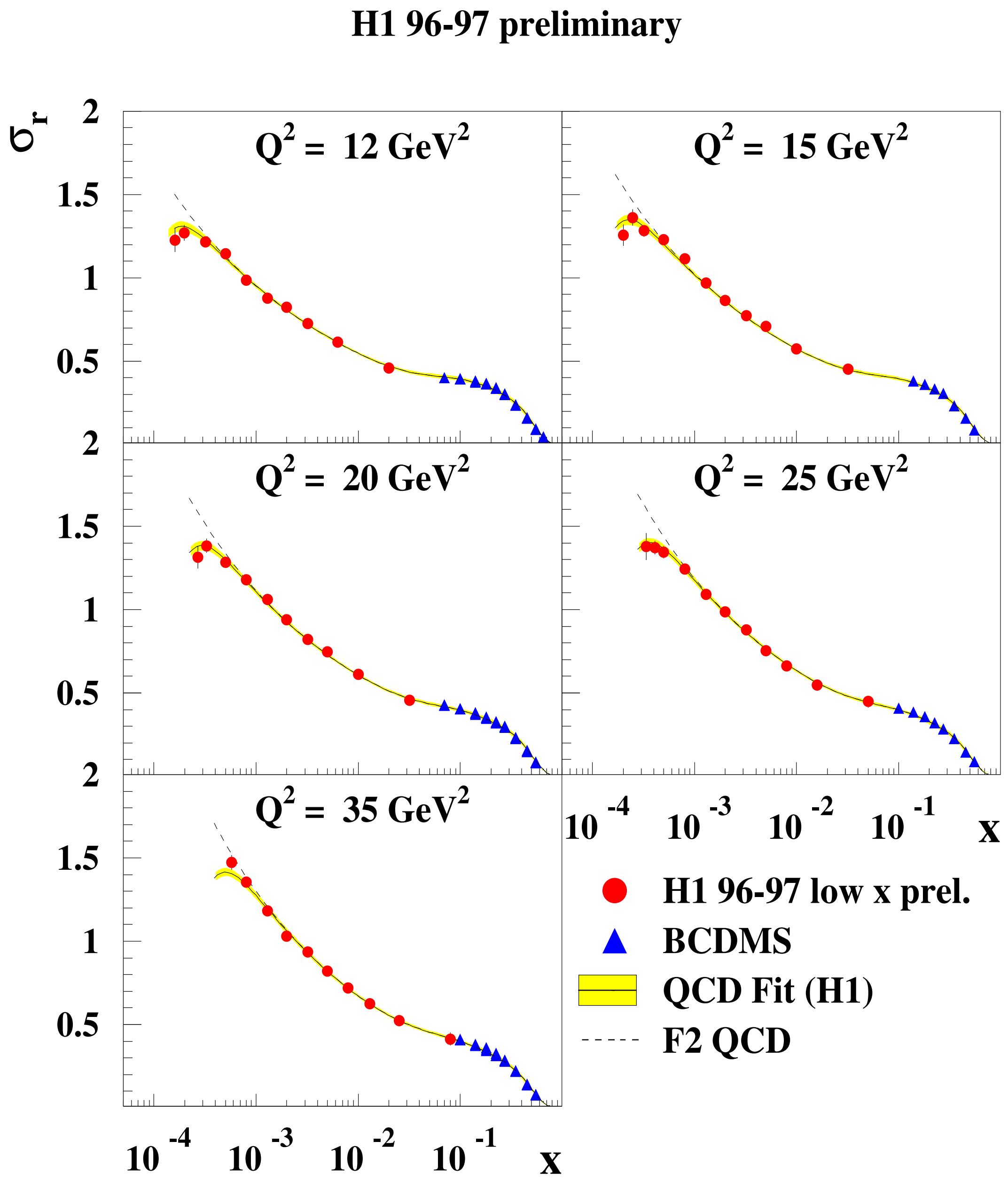

Figure 4: *Measurement of the reduced DIS scattering cross-section, closed points. Triangles represent data by the BCDMS muon-proton experiment. The curves represent a NLO QCD fit to the H1 data alone, requiring $y < 0.35$ and $Q^2 \geq 3.5$ GeV^2. The dashed curves are the F_2 structure function values determined with this fit. The error bands represent the small experimental and model uncertainty of the QCD 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 attributed to F_L.*

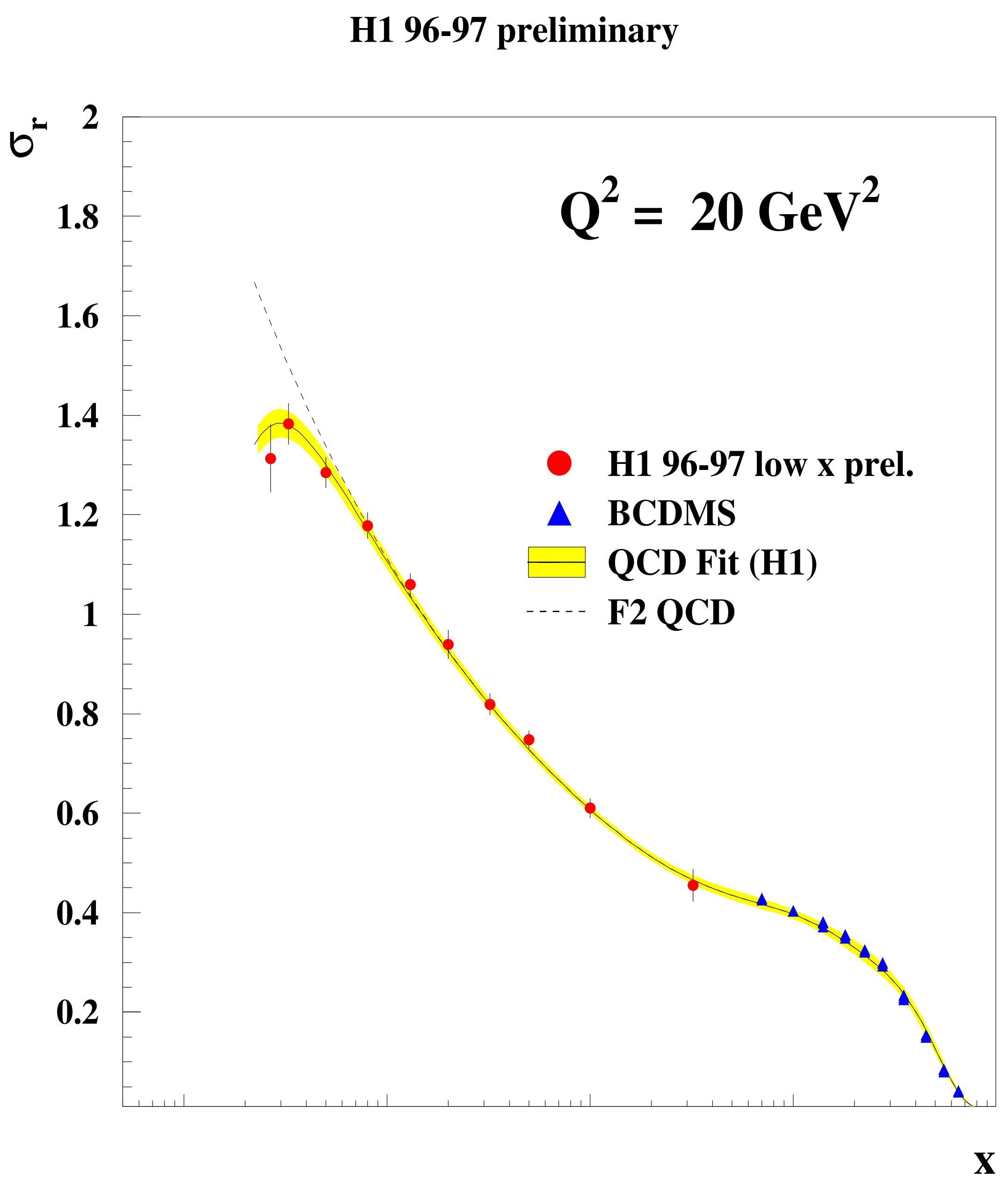

Figure 5: *Zoom into Fig. 4*

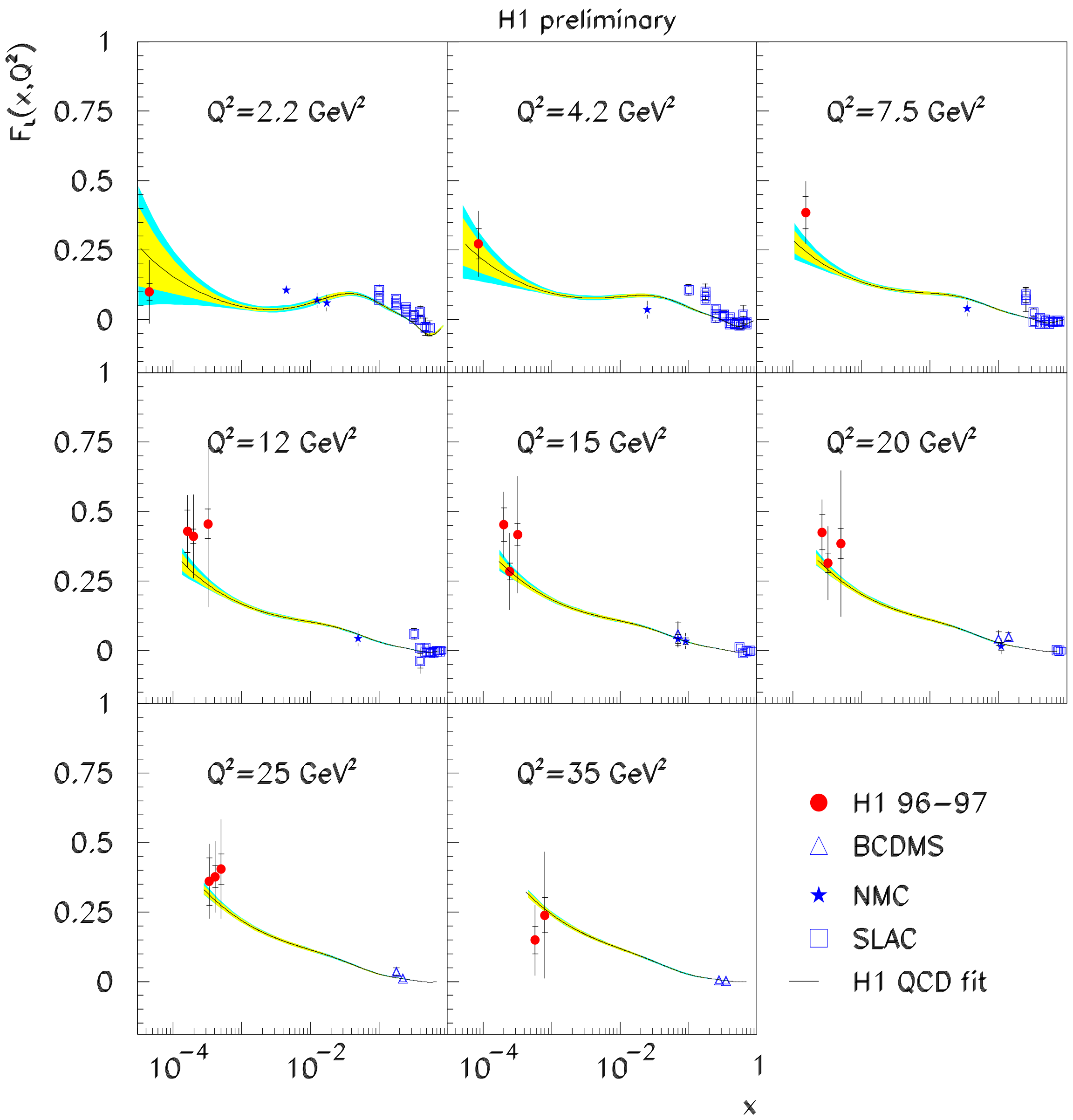

Figure 6: *Data on the longitudinal structure function $F_L(x, Q^2)$ as obtained by this experiment, at low x, and by charged lepton-nucleon fixed target experiments at larger x. The data at $Q^2 < 10$ GeV^2 are obtained with the derivative method while the points for larger Q^2 are due to the extrapolation method. The error on the data points is the total uncertainty of the determination of F_L representing the statistical, the systematic and the model errors added in quadrature. The inner error bars denote the statistical measurement accuracy. The error bands are due to the experimental (inner) and model (outer) uncertainty of the calculation of F_L using the NLO QCD fit to the H1 data for $y < 0.35$ and $Q^2 \geq 3.5$.*

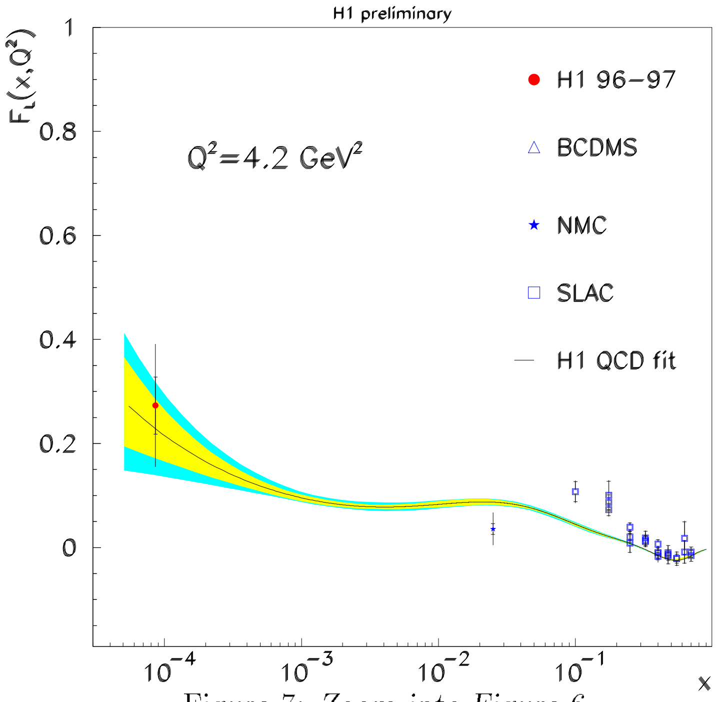

Figure 7: *Zoom into Figure 6*

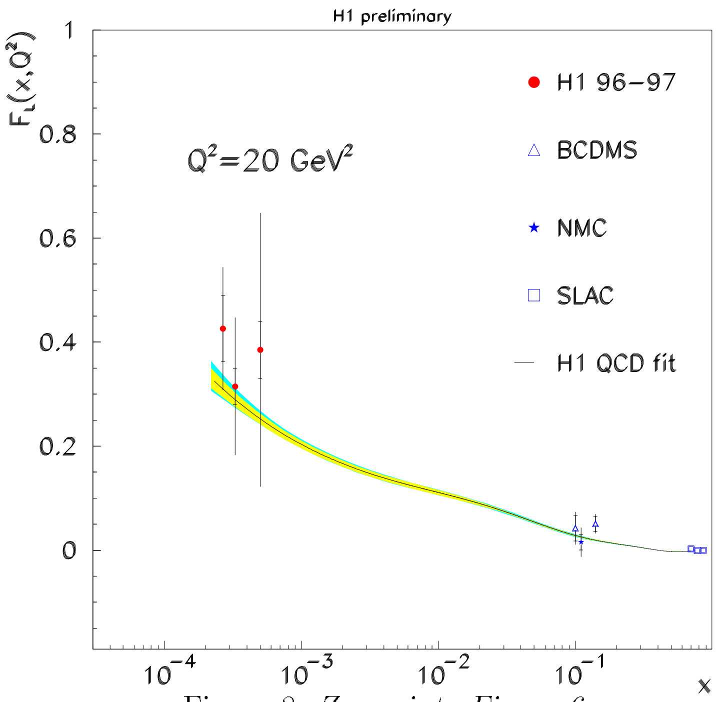

Figure 8: *Zoom into Figure 6*

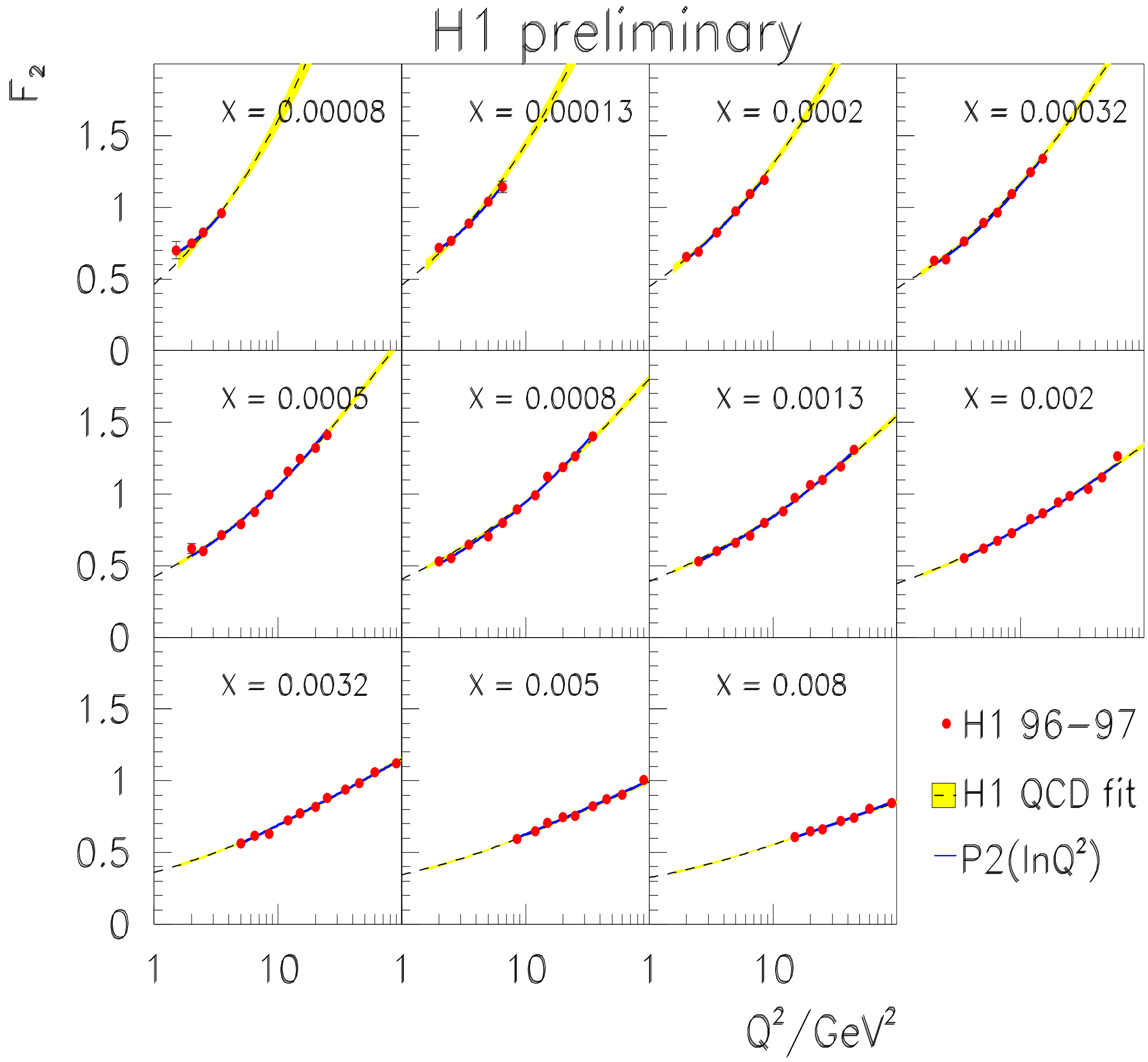

Figure 9: *Measured F_2 structure function data as function of Q^2. The solid lines represent fits to $F_2(x, Q^2)$ in the x bins according to $F_2 = a + b\ln Q^2 + c(\ln Q^2)^2$. The dashed lines result in the NLO QCD fit to the H1 data. The error bands are due to the model uncertainty in the QCD fit which includes data for $Q^2 \geq 3.5$ GeV^2.*

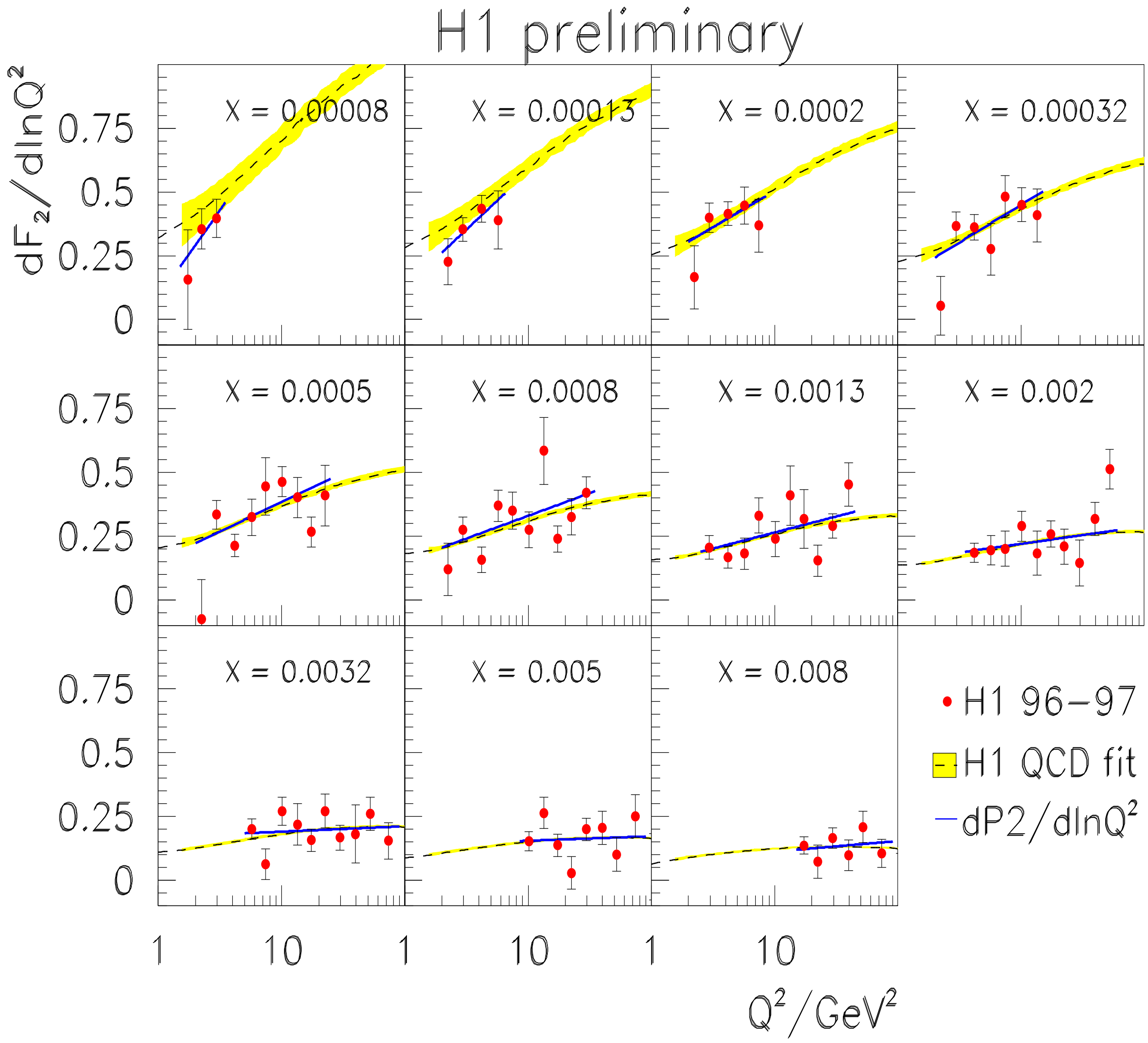

Figure 10: *Derivative $\partial F_2/\partial \log Q^2$ taken at fixed x as functions of Q^2. The error bars represent the quadratic sum of statistical and systematic errors. The straight solid lines are given by the function $b + 2c \ln Q^2$ determined in fits to $F_2(x, Q^2)$ at fixed x. The dashed lines represent the derivatives of the structure function F_2 in the QCD fit to the H1 data. The error bands are due to the model uncertainty in the QCD fit which includes data for $Q^2 \geq 3.5$ GeV^2.*

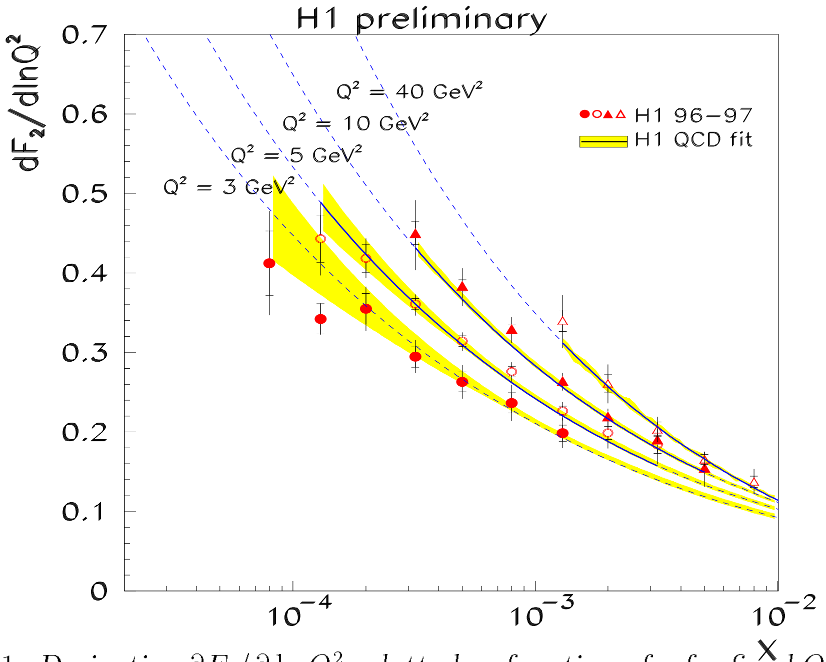

Figure 11: *Derivative $\partial F_2/\partial \ln Q^2$, plotted as function of x for fixed Q^2, for the H1 data (points) and the QCD fit (curves) to the H1 data, for $Q^2 \geq 3.5$ GeV^2. The dashed curves are extrapolations to outside the data region considered in the fit. The error bands represent the model uncertainty of the QCD analysis.*

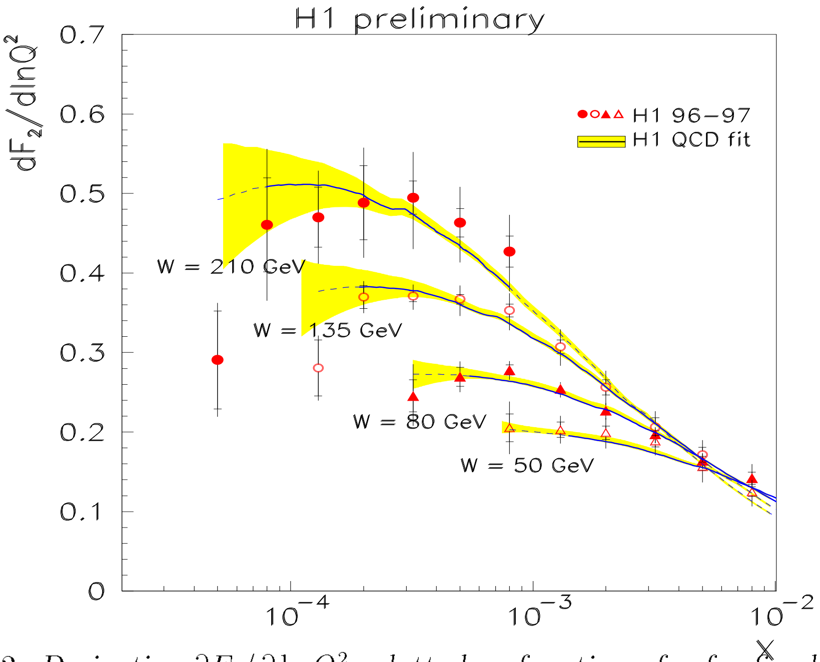

Figure 12: *Derivative $\partial F_2/\partial \ln Q^2$, plotted as function of x for fixed $W \simeq \sqrt{Q^2/x}$, for the H1 data (points) and the QCD fit (curves) to the H1 data, for $Q^2 \geq 3.5$ GeV^2. The dashed curves are extrapolations to outside the data region considered in the fit. The error bands represent the model uncertainty of the QCD analysis.*

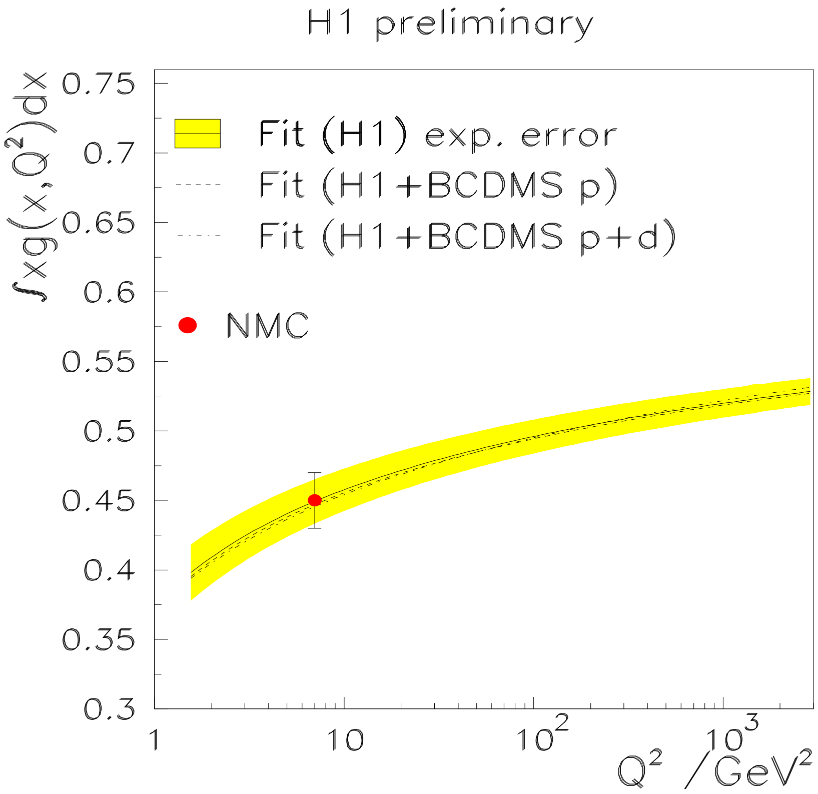

Figure 13: *Momentum fraction of the gluon as function of* $\ln Q^2$ *as obtained in different NLO DGLAP fits. Solid curve: fit to H1 data alone; dashed curve: fit to H1 and BCDMS proton data; dotted curve: fit to H1* ep *and BCDMS* μp *and* μd *data. The shaded error band represents the experimental uncertainty in the analysis of the H1 data alone. The solid point marks the result of a QCD analysis to NMC data [1].*

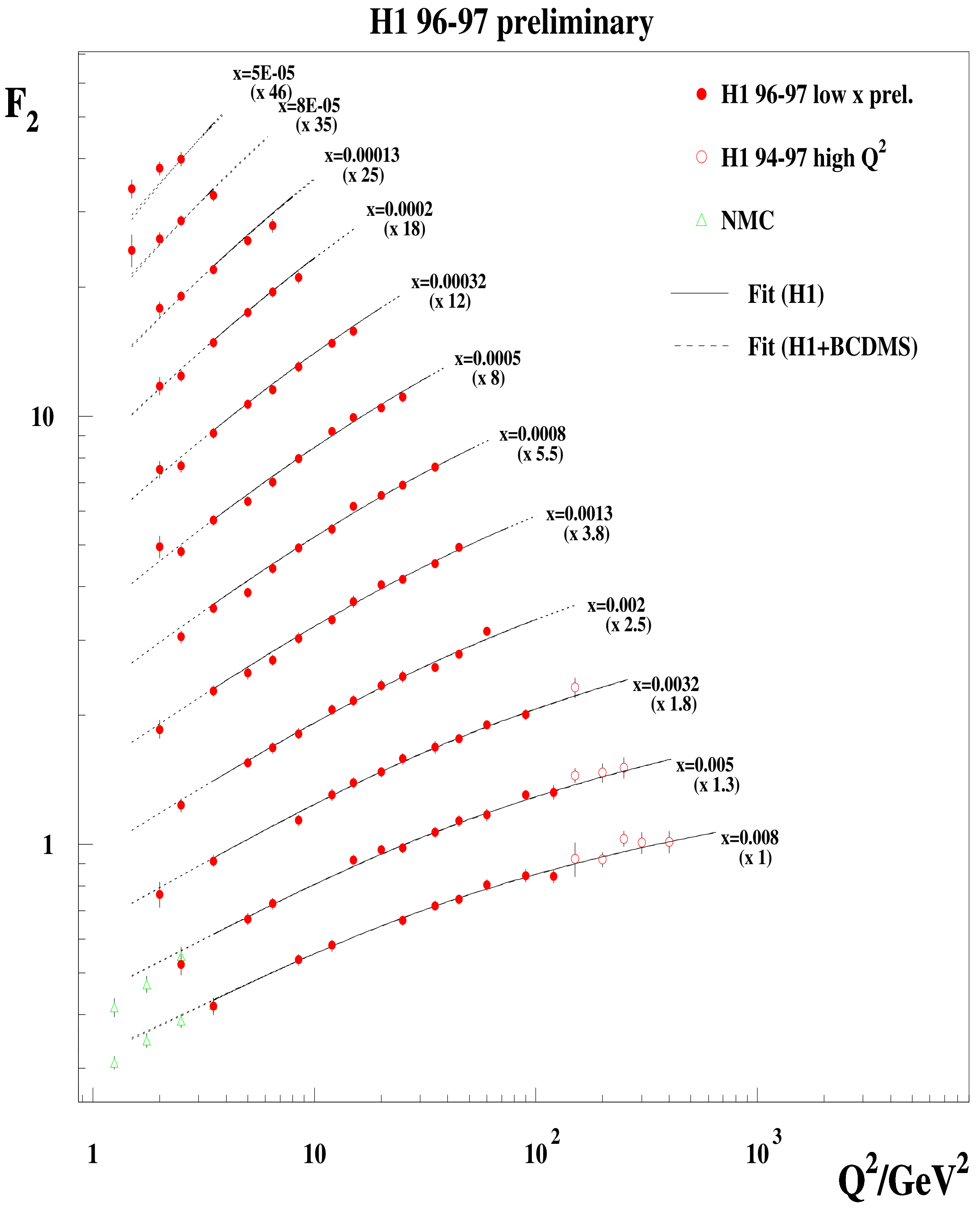

Figure 14: *Structure function measurements by H1 and the NMC experiment. Solid curves: NLO DGLAP QCD fit to the H1 cross-section data. Overlayed as dashed curves is the QCD fit to the H1 ep and BCDMS μp data, for $y_{BCDMS} < 0.3$, which is nearly indistinguishable from the pure H1 fit. Dotted curves represent the fit extrapolations at fixed x into the region below $Q^2 = 3.5\ GeV^2$.*

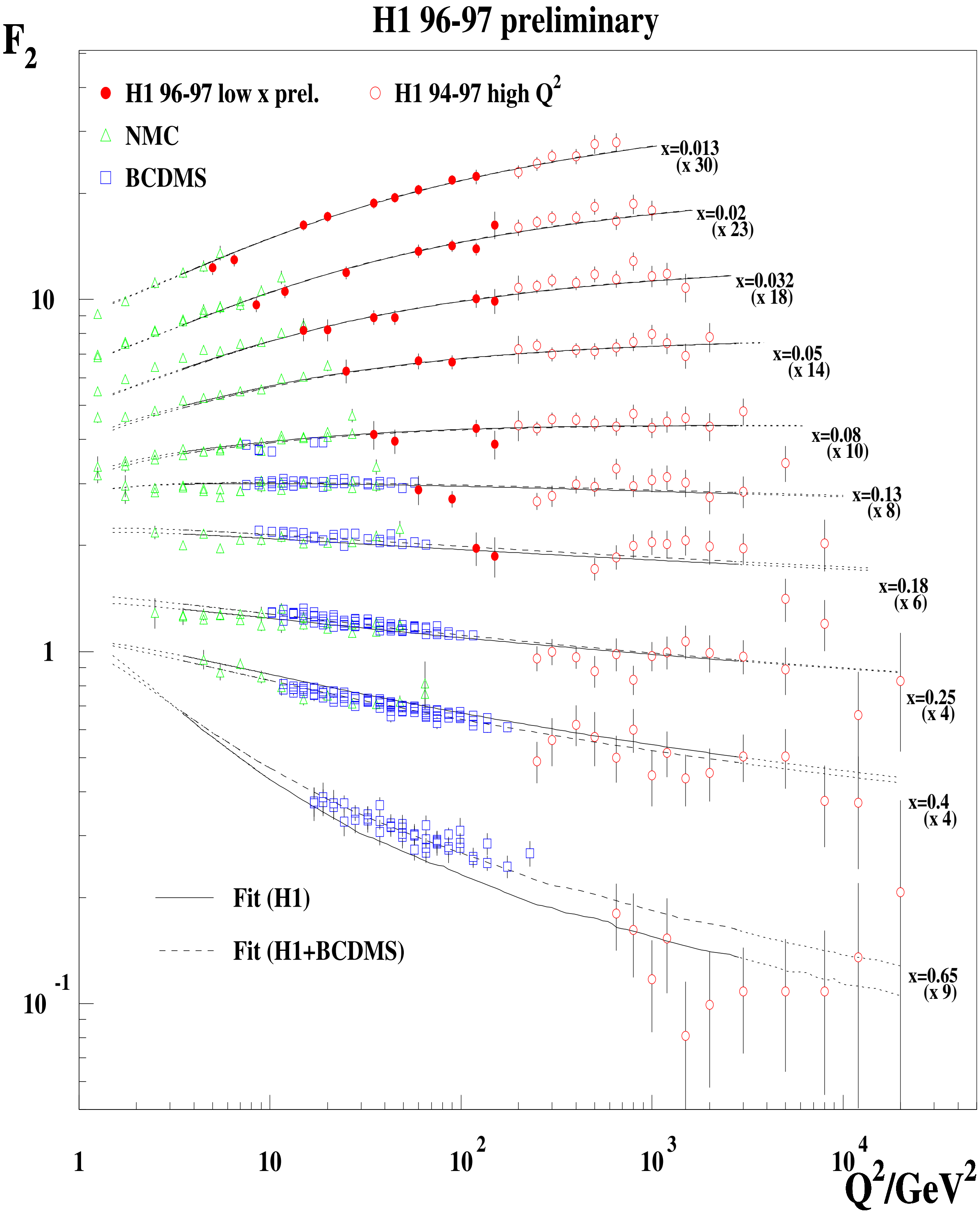

Figure 15: *Structure function measurements by H1 and fixed target muon-proton scattering experiments. Solid curves: fit to the H1 cross-section data. Dashed curves: fit to the H1 ep and BCDMS μp data, for $y_{BCDMS} < 0.3$. Dotted curves represent the extrapolations at fixed x into the region below $Q^2 = 3.5$ GeV^2 and beyond the maximum $Q^2 = 3000$ GeV^2 included in the fit.*

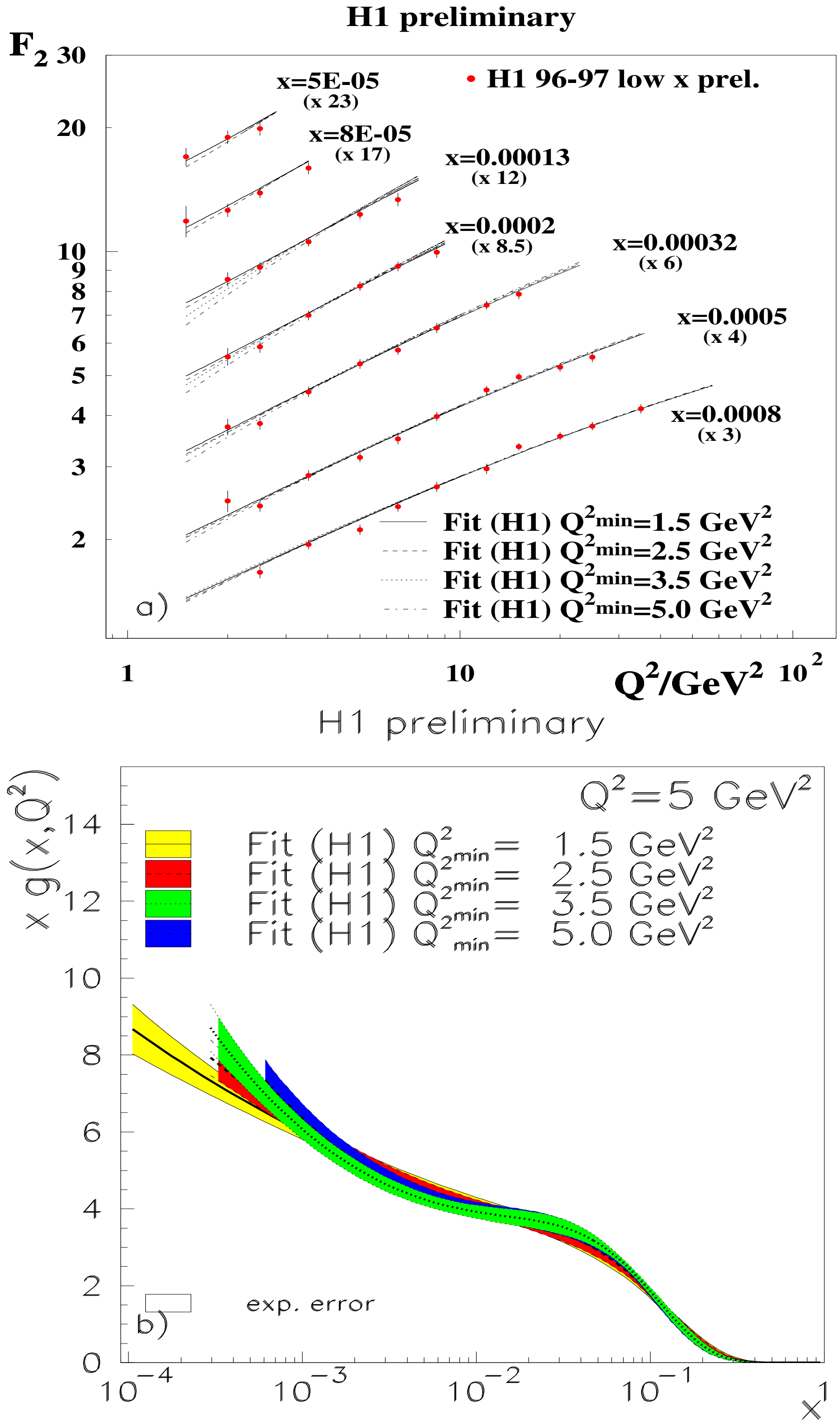

Figure 16: *Effect of the Q^2_{min} cut applied in the DGLAP QCD fit to the H1 data on a) the structure function F_2 and b) the gluon distribution at $Q^2 = 5$ GeV^2. The experimental error bands for $xg(x, Q^2)$ extend to twice the minimum x values of the data [2], depending on Q^2_{min}, which allow a Q^2 slope to be measured from at least three data points at fixed x.*

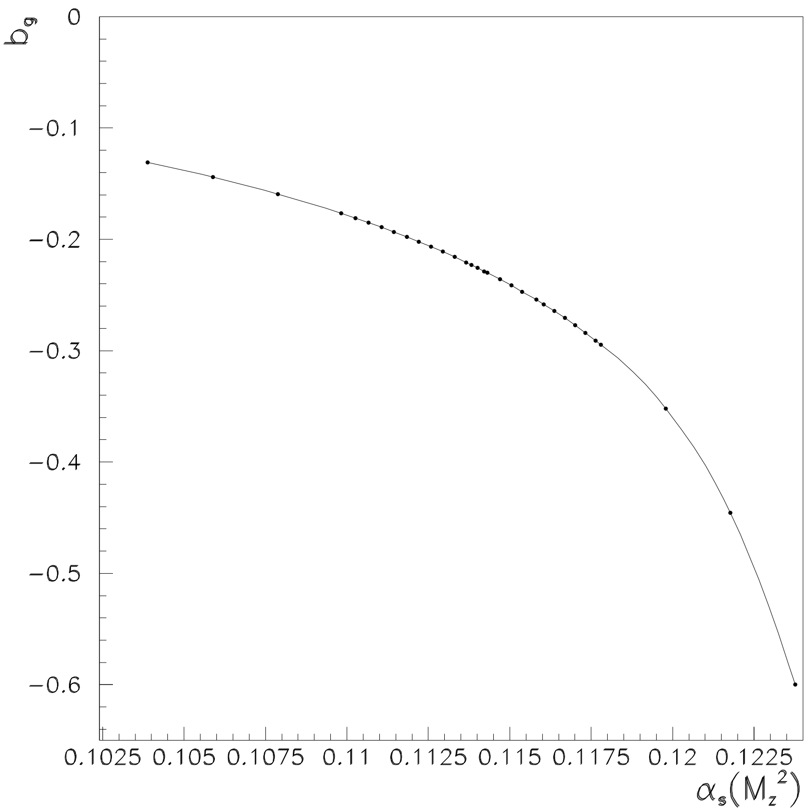

Figure 17: *Correlation of the gluon distribution parameter* b_g *with* $\alpha_s(M_Z^2)$ *in the fit to H1 and BCDMS data. This parameter governs the low* x *behaviour of* $xg \propto x^{b_g}$.

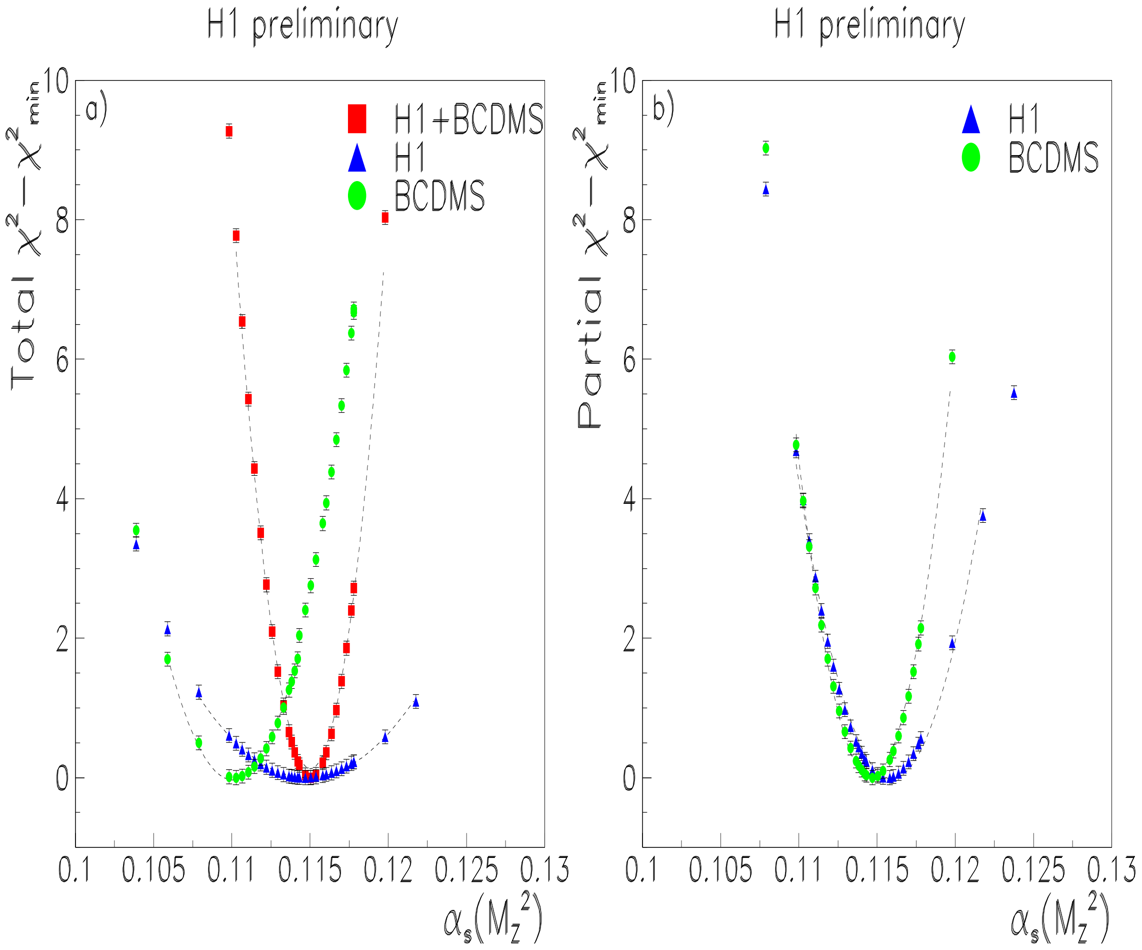

Figure 18: *Determination of the strong coupling constant $\alpha_s(M_Z^2)$ in NLO DGLAP QCD. a) Total χ^2 for fits to the H1 ep and BCDMS μp data and a fit using data of the two experiments. b) χ^2 contributions H1 and BCDMS data in the fit using both experiments.*

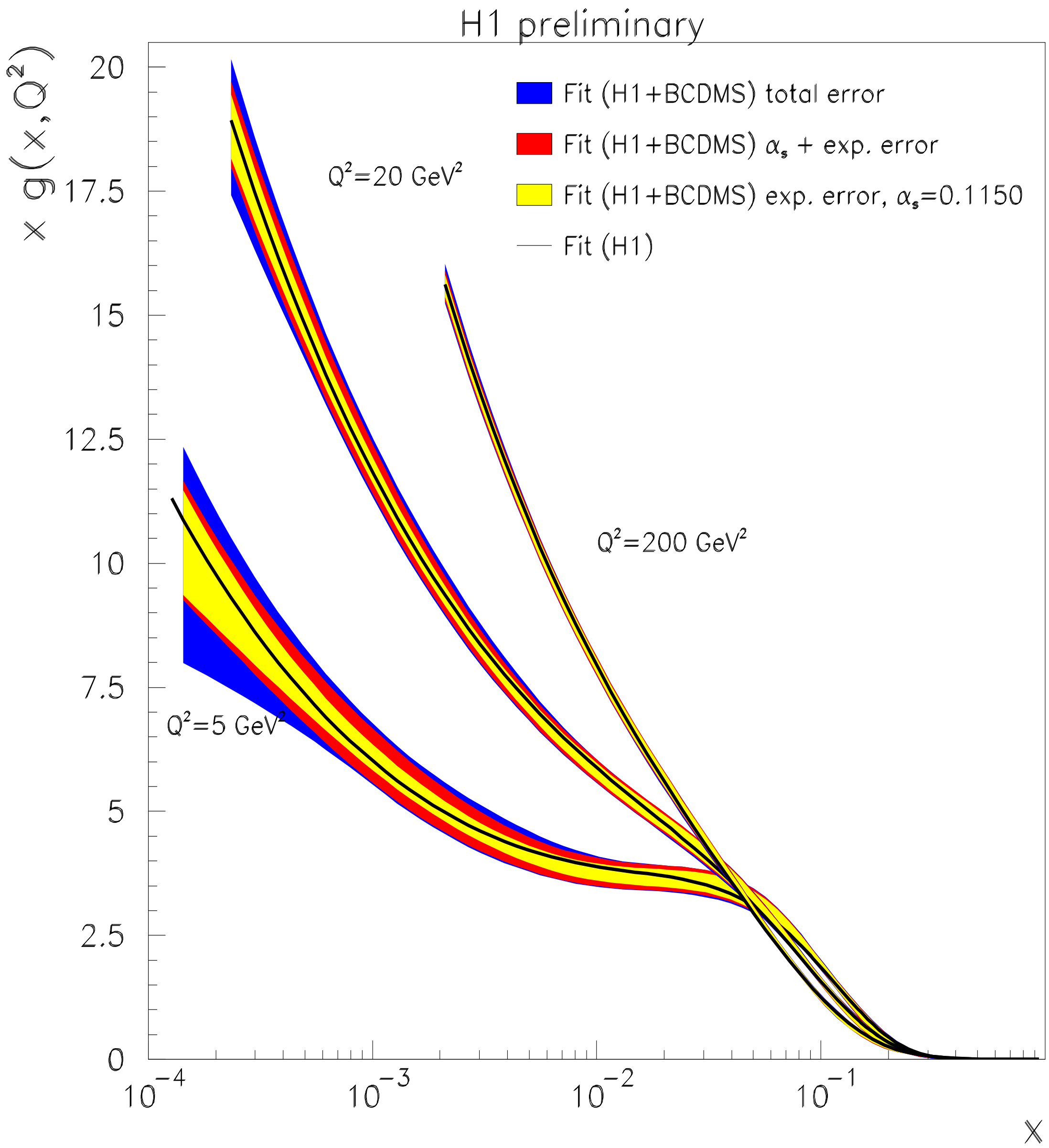

Figure 19: *Gluon distribution for* $\alpha_s(M_Z^2)$ *=0.1150 resulting from the NLO DGLAP QCD fit in the massive heavy flavour scheme to H1* e^+p *and BCDMS* μp *cross-section data using* $Q^2_{min} = 3.5$ *GeV*^{2}, $Q^2_0 = 4$ *GeV*^{2}. *The distribution is shown for different* $Q^2 = 5, 20$ *and* 200 *GeV*^{2}. *The innermost error bands represent the experimental error for fixed* α_s. *The middle error bands include in addition the contribution of fitting* α_s. *The outer error bands are due to the uncertainties related to the QCD model and data range. The solid lines inside the error band represent the gluon distribution obtained in the fit to the H1 data alone.*

References

[1] M. Arneodo et al., NMC Collaboration, Phys. Lett. **B309** (1993) 222.

[2] K. Prytz, Phys. Lett. **B311** (1993) 286.