Talk presented at the XI International Workshop on Deep Inelastic Scattering, St. Petersburg, 23-27 April 2003

ZEUS results on high Q^2 DIS cross sections and QCD fits

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Single and double differential cross sections $d\sigma/dQ^2, d\sigma/dx, d\sigma/dy$ and $d^2\sigma/dQ^2dx$ of the inclusive neutral current (NC) measurement from the 98/99 e^-p and the charged current (CC) measurement from the 99/00 e^+p data sets are presented. With the previously published e^+p NC ZEUS measurement xF_3 and xG_3, and with the e^-p CC ZEUS measurement F_2^{CC} are extracted. The results are compared to the prediction of the Standard Model (SM) using parton density functions (PDFs) of the ZEUS next-to-leading-order (NLO) QCD analysis which is reviewed.

Introduction For longitudinally unpolarized beams the deep inelastic scattering (DIS) cross section for $ep \to l'X$ can be written in leading order of the electroweak interaction:

$$\frac{d^2\sigma_{\rm Born}}{dxdQ^2} = A \cdot [Y_+ F_2(x,Q^2) - y^2 F_{\rm L}(x,Q^2) - Y_- xF_3(x,Q^2)],$$

where Q^2 is the negative square of the four-momentum transfer, x the Bjorken scaling variable, y the inelasticity and $Y_\pm = 1 \pm (1-y)^2$. The coefficient A containing couplings and propagator is $A^{\rm NC} = \frac{2\pi\alpha^2}{xQ^4}$ for NC and $A^{\rm CC} = \frac{G_{\rm F}^2}{4\pi x}\frac{M_W^4}{(Q^2+M_W^2)^2}$ for CC where $G_{\rm F}$ is the Fermi constant and M_W the W boson mass. At leading order in QCD the structure functions F_2 and xF_3 may be written in terms of sums and differences of quark and antiquark PDFs, but for CC depend on the charge of the incoming lepton:

$$F_2^{\rm NC} = x\sum_{q=u\dots b} A_f\,[q+\bar{q}] \qquad F_{2,e^+p}^{CC} = x[d+s+\bar{u}+\bar{c}]$$
$$F_3^{\rm NC} = x\sum_{q=u\dots b} B_f\,[q-\bar{q}] \qquad xF_{3,e^+p}^{CC} = x[d+s-\bar{u}-\bar{c}]\ .$$

In case of the electromagnetic (γ) and weak (Z) NC processes the flavor-dependent couplings are included as coefficients A_f and B_f, while for the purely weak ($W^\pm$) CC process the couplings are global and included in $A^{\rm CC}$. For NC

*Supported by the German Federal Ministry for Education and Research (BMBF) under contract number HZ1PDA 5

the t-quark and for CC both third generation quarks can be ignored at HERA center-of-mass energies. The longitudinal structure function, F_{L}, is zero at leading order QCD and negligible at NLO except at values of y close to 1. The reduced cross sections are defined as:

$$\tilde{\sigma}^{\mathrm{NC}} = \frac{xQ^4}{2\pi\alpha^2 Y_+}\frac{d^2\sigma^{\mathrm{NC}}}{dxdQ^2} \qquad \tilde{\sigma}^{\mathrm{CC}} = \frac{2\pi x}{G_{\mathrm{F}}^2}\frac{(Q^2+M_W^2)^2}{M_W^4}\frac{d^2\sigma^{\mathrm{CC}}}{dxdQ^2} \, .$$

ZEUS NLO QCD fits The ZEUS data can be used to determine the input parameters, i.e. the PDFs and the value of the strong coupling constant, α_s, of the DGLAP evolution which describes DIS measurements over a broad kinematic range. The ZEUS-S fit [1] uses ZEUS data from 96/97 [2] together with fixed-target data to extract PDFs. Including α_s as a free parameter (ZEUS-α_s fit) correlations between the PDFs and α_s are fully taken into account, yielding $\alpha_s(M_Z) = 0.1166 \pm 0.0053$(tot.). The ZEUS-O fit explores the power of ZEUS data only by using ZEUS CC e^+p data from 94-97 [3], and the CC and NC e^-p data from the 98/99 runs [4, 5] together with the 96/97 e^+p NC data. The cut $Q^2 \geq 2.5\,\mathrm{GeV}^2$ ensures the applicability of pQCD while the cut $W^2 > 20\,\mathrm{GeV}^2$ reduces target mass and higher twist sensitivity. The kinematic range covered by the input data to the fits is $6.3 \times 10^{-5} \leq x \leq 0.65$ and $2.5 \leq Q^2 \leq 30\,000\,\mathrm{GeV}^2$. The calculations were performed at leading twist using the $\overline{\mathrm{MS}}$ -scheme and the TRVFN treatment of heavy quarks. The PDFs u valence, $xu_v(x)$, d valence, $xd_v(x)$, total sea, $xS(x)$, gluon, $xg(x)$, and the difference between the d and u contributions to the sea, $x\Delta = x(\bar{d} - \bar{u})$, were parameterized at $Q_0^2 = 7\,\mathrm{GeV}^2$ by:

$$xf(x) = p_1 x^{p_2}(1-x)^{p_3}(1+p_5 x)$$

Additional constraints, e.g. number or momentum sum rule, fix 9 of 20 parameters, given in brackets (without uncertainties) when constrained (fixed) below, leaving 11 free. The results of the ZEUS-S fit given with first (second) statistical and uncorrelated (correlated) uncertainties are:

	p_1	p_2	p_3	p_5
xu_v	($1.69 \pm 0.01 \pm 0.06$)	0.5	$4.00 \pm 0.01 \pm 0.08$	$5.04 \pm 0.09 \pm 0.64$
xd_v	($0.96 \pm 0.01 \pm 0.08$	0.5	$5.33 \pm 0.09 \pm 0.48$	$6.2 \pm 0.4 \pm 2.3$
xS	$0.603 \pm 0.007 \pm 0.048$	$-0.235 \pm 0.002 \pm 0.012$	$8.9 \pm 0.2 \pm 1.2$	$6.8 \pm 0.4 \pm 2.0$
xg	($1.77 \pm 0.09 \pm 0.49$)	$-0.20 \pm 0.01 \pm 0.04$	$6.2 \pm 0.2 \pm 1.2$	0
$x\Delta$	$0.27 \pm 0.01 \pm 0.06$	0.5	($10.9 \pm 0.2 \pm 1.2$)	0

In Fig. 1 $xg(x)$ and $xS(x)$ are displayed for the ZEUS-S and ZEUS-O results with uncertainty bands, where the correlated systematic uncertainties are dom-

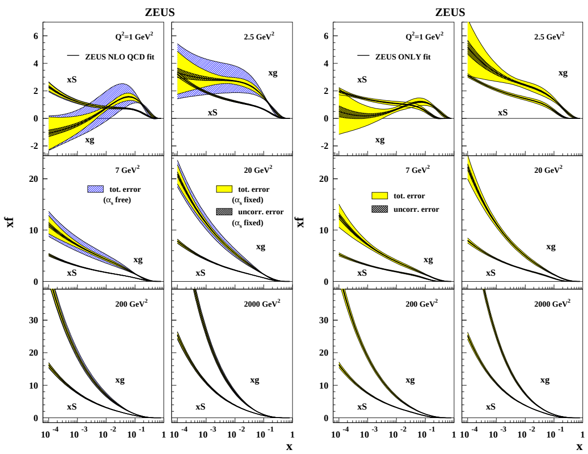

Figure 1: Gluon and sea distributions from ZEUS-S (a) and ZEUS-O (b) for various Q^2 values with statistical and uncorrelated systematic uncertainty (cross-hatched) including correlated systematic uncertainties (grey) and in (a) the total experimental uncertainty from ZEUS-α_s (hatched).

inant. The gluon density is found not to rise towards low x as dramatically as expected for low Q^2. For ZEUS-S it even becomes negative. Since $xg(x)$ is not an observable like a structure function this is not unphysical, but might indicate that NLO-pQCD is inadequate. While uncertainties for the ZEUS-O fit are considerable larger than for ZEUS-S, a preliminary fit result including in addition the high luminosity data from 99/00 yields compatible uncertainties without including the fixed-target data.

e^-p NC measurement The measurement [5] is based on the e^-p 98/99 running period coresponding to an integrated luminosity of 16 pb^{-1} in the kinematic region $185\,\mathrm{GeV}^2 < Q^2 < 50\,000\,\mathrm{GeV}^2$ and $0.0037 < x < 0.75$. The kinematic variables are reconstructed using the double angle method. The event selection is based on identifying the scattered electron fullfilling criteria on isolation, track matching, energy and transverse momentum. Background is suppressed by requiring a proper event vertex, transverse ($P_T/\sqrt{E_T} < 4\sqrt{\mathrm{GeV}}$) and longitudinal ($38\,\mathrm{GeV} < E - p_z < 65\,\mathrm{GeV}$) momentum conservation. Restricting y ($y_E < 0.95$) excludes photoproduction. The measured cross sections in Fig. 2 show excellent agreement with the SM using ZEUS-S. Comparing the e^-p to the e^+p reduced cross sections in Fig. 3 the parity violating effect of the weak Z exchange (and γ-Z interference) becomes visible at high Q^2. From the difference, xF_3 is extracted, shown in the same figure. Separating xF_3 in

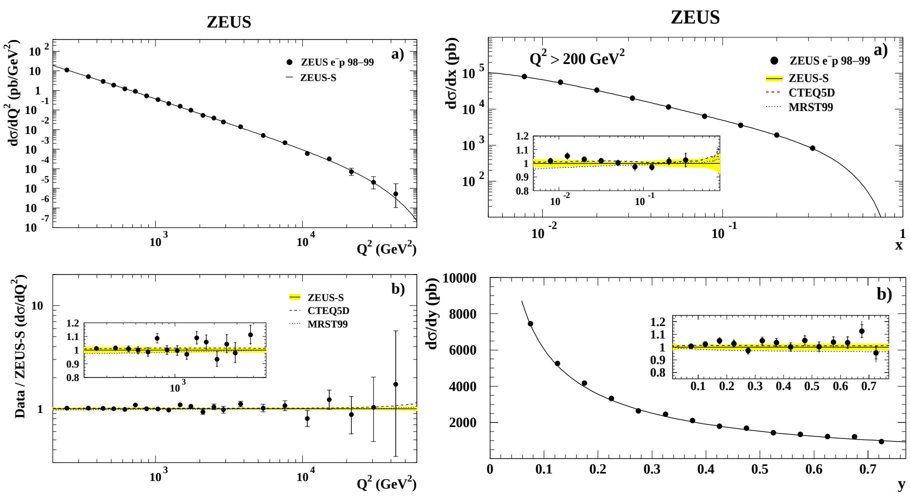

Figure 2: NC cross sections $d\sigma/dQ^2, d\sigma/dx$ and $d\sigma/dy$ and ratio to SM using ZEUS-S PDFs.

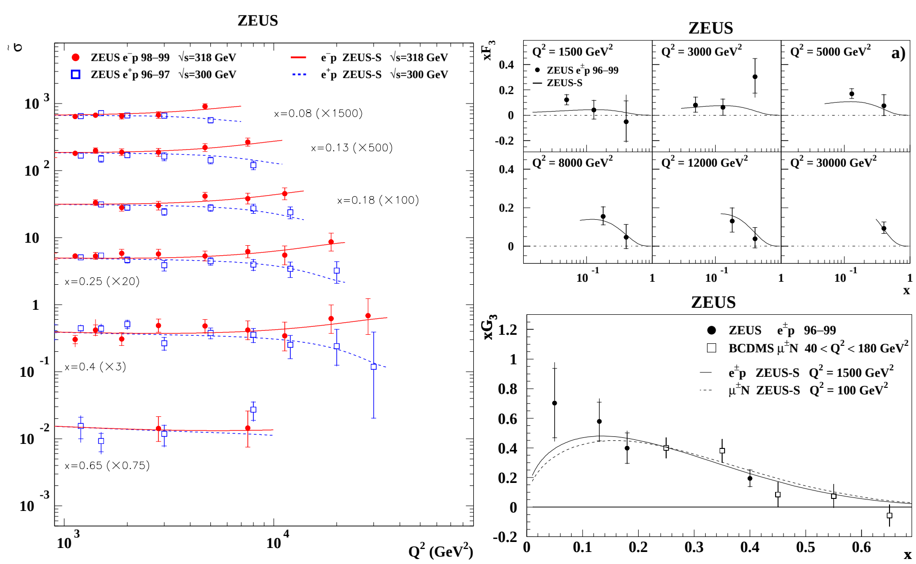

Figure 3: NC reduced cross section $\tilde{\sigma}^{\mathrm{NC}}$ for e^-p and e^+p data sets, and the extracted xF_3 and xG_3.

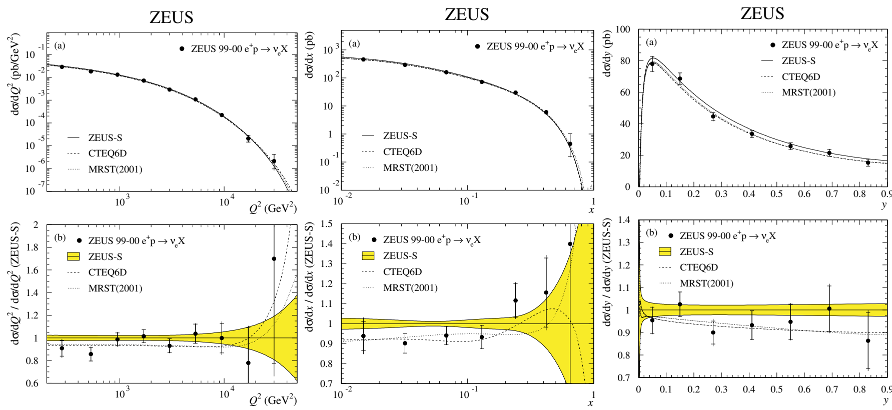

Figure 4: CC cross sections $d\sigma/dQ^2, d\sigma/dx$ and $d\sigma/dy$ and ratio to SM using ZEUS-S PDFs.

interference and Z exchange terms yields structure functions xG_3 and xH_3:

$$xF_3 = -a_e \chi_Z xG_3 + 2a_e v_e \chi_Z^2 xH_3, \quad \chi_Z = \kappa_W \cdot Q^2/(M_Z^2 + Q^2).$$

The second term can be neglected to reconstruct xG_3 which extends the low Q^2 muon-carbon measurements from BCDMS to higher Q^2, as shown in Fig. 3.

e^+p CC measurement The CC measurements [6] are based on the e^+p data from 99/00 corresponding to an integrated luminosity of 61 pb^{-1}. CC events are selected by missing transverse momentum due to the undetected neutrino and by vetoing events with a candidate scattered electron. For a sample of large hadronic angle $\gamma_{\text{had}} > 0.4$ rad the acceptance of the central tracking detector allows for efficient background suppression, while for a sample of low γ_{had} the cuts on the calorimetric quantities are raised. The excellent agreement of the measured cross sections with the SM using ZEUS-S is shown in Fig. 4. Using the previously published e^-p CC ZEUS results [4] the singlet structure function F_2^{CC} is extracted and extends the CCFR measurement in Fig. 5 by two orders towards higher Q^2. The dependence of the cross section on the propagator mass is used to extract M_W in the space-like region in a fit to $d\sigma^{\text{CC}}/dQ^2$:

$$M_W = \big(78.9 \pm 2.0(\text{stat.}) \pm -1.8(\text{syst.})^{+2.0}_{-1.8}(\text{PDF})\big)\ \text{GeV},$$

This is in good agreement with the more precise time-like measurements giving $M_W = 80.422 \pm 0.047$ GeV [7].

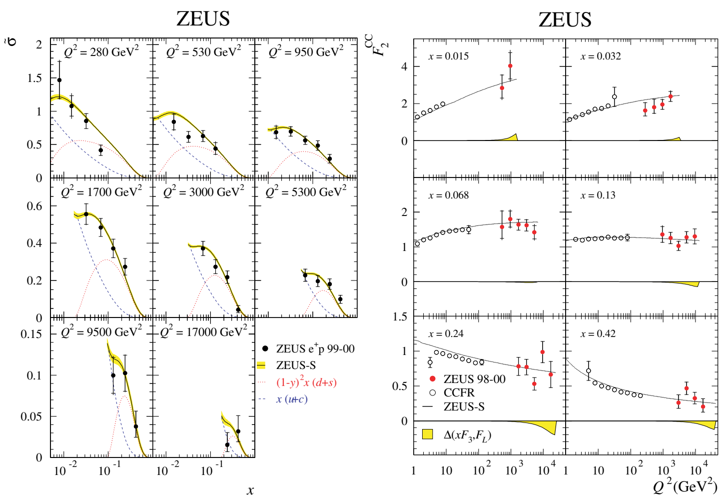

Figure 5: Reduced CC cross sections $\tilde{\sigma}^{\mathrm{CC}}$ for fixed values of Q^2 (left), and F_2^{CC} for fixed values of x together with BCDMS data (right), both with SM prediction using ZEUS-S PDFs.

Summary The inclusive NC measurement from the 98/99 e^-p data set coresponding to an integrated luminosity of 16 pb^{-1} and the CC measurement from the 99/00 e^+p data set of 61 pb^{-1} are presented. With the e^+p NC ZEUS measurement xF_3 and xG_3, and with the e^-p CC ZEUS measurement F_2^{CC} are extracted. All measurements are in excellent agreement with the SM prediction using the ZEUS-S PDFs from the ZEUS NLO QCD analysis.

References

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