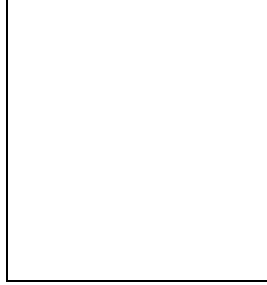


STRUCTURE FUNCTIONS AND EXTRACTION OF PDFS AT HERA

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Results from the HERA experiments, H1 and ZEUS, on $e^\pm p$ deep inelastic scattering (DIS) provide an important contribution to the knowledge of the proton structure and QCD. The data were collected in the years 1994-2000 (HERA I) and 2003-2006 (HERA II) in the center-of-mass energy of $\sqrt{s} = 300$ GeV in 1994-1997 and 319 GeV from 1998. During the HERA II period, the lepton beams were longitudinally polarised. The most recent results on neutral current (NC) and charge current (CC) DIS cross sections from HERA II data are presented. Results on Parton Density Functions (PDFs) and the strong coupling α_s extracted from HERA I data are discussed. Accounting for the correlation of electroweak parameters with PDFs, a combined electroweak and QCD analysis is performed for the first time at HERA.

1 Structure Functions and Cross Sections

NC DIS processes proceed via exchange of photons and Z^0 bosons. Photon exchange dominates and its contribution to the cross section is given in terms of the proton structure function $F_2(x, Q^2)$ which provides information on the total quark content of the proton at given values of the Bjorken scale variable x and of the modulus of the squared four-momentum transfer, Q^2 , carried by the exchanged boson. Both HERA experiments have confirmed Q^2 evolution of F_2 predicted by perturbative QCD (pQCD) over five orders of magnitude in Q^2 and x ^{1,2,3,4,5}. At low and medium Q^2 precision of F_2 is 2-3 % while at high Q^2 region is statistically limited. At $Q^2 \geq M_Z^2$, NC cross section for e^+p and e^-p scattering differ due to the electroweak effects, especially the $\gamma - Z$ interference. The difference is described by the proton structure function $xF_3(x, Q^2)$ which in pQCD is given by the difference between the quark and anti-quark density functions, thus providing information on the valence quark contribution in the proton. Uncertainties of the existing xF_3 measurements are dominated by the limited statistics of the e^-p sample.

Longitudinal structure function, F_L , is identically zero in lowest order QCD, but due to gluon

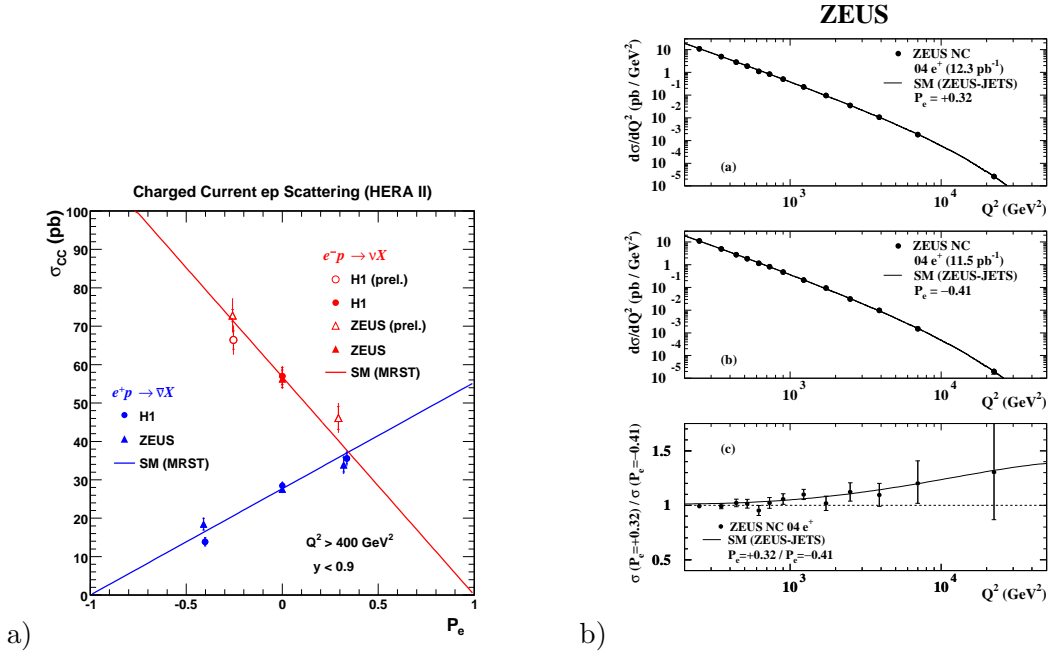


Figure 1: a) $e^\pm p$ CC cross sections measurements from HERA for different lepton polarisations. b) e^+p NC differential cross sections, $d\sigma/dQ^2$, obtained from ZEUS HERA II data.

radiation gets a non-zero value in pQCD. Measurements of F_L can thus provide constraints on the gluon PDF which are complementary to that obtained from the scaling violations of F_2 assuming DGLAP evolution¹¹. Indirect measurements of F_L performed by H1 collaboration suggest that F_L remains non-zero down to the lowest Q^2 values measured^{1,2,6}. Significant progress in F_L measurements at HERA can only be made by reducing the proton beam energy which provides its direct measurements⁷.

CC DIS processes are mediated by W^\pm bosons and provide complementary information about partonic composition of proton since they are sensitive to particular quark flavor with the certain charges to couple to the exchanged boson.

To increase luminosity, an upgrade of HERA in the H1 and ZEUS detector regions was performed in 2001. In order to increase the e^-p statistics, HERA has been running with e^-p beams since December 2004 and is expected to finish in summer 2006, when e^+p mode should start. Luminosity of HERA II e^-p sample is about 150 pb^{-1} roughly per experiment which is already about factor of 10 greater then achieved during HERA I period. End of HERA operation is planned for summer 2007.

First results for the cross sections for charged and neutral current deep inelastic scattering in $e^\pm p$ collisions with a longitudinally polarised lepton beams^{8,9} have been obtained at HERA. The CC cross section measurements depending on polarisation are presented on figure 1a. In the Standard Model (SM) only left-handed electrons and right-handed positrons take part in CC interactions and the CC cross section depends linearly on the polarisation P as: $\sigma^{CC}(P) = (1 + P)\sigma^{CC}(0)$. As can be seen from the figure, the data are found to be consistent with the absence of right handed charged currents as predicted by the SM. NC interactions are also sensitive to the lepton polarisation. Electromagnetic contribution which dominates at low Q^2 does not depend on polarisation. Polarisation dependence occurs mainly via interference between γ and Z boson exchanges. Figure 1b shows ZEUS measurements of the differential cross section $d\sigma/dQ^2$ for the NC DIS for positive and negative longitudinal polarisations and the ratio of the two cross sections. The measurements are consistent with the SM predictions evaluated

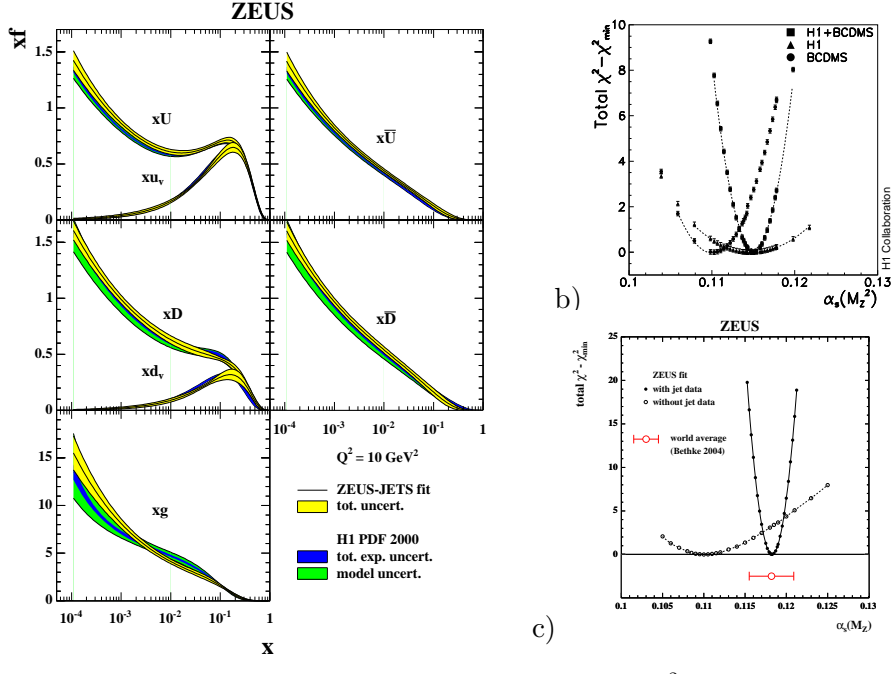


Figure 2: a) PDFs obtained from H1PDF2000 and ZEUS-JETS fits. b) χ^2 for α_s fits to the H1 ep and BCDMS μp data separately and for the fit using data of the two experiments combined. c) χ^2 profiles of the α_s ZEUS fits with and without jet data.

using the ZEUS-JETS PDFs (described in the next section) and are also consistent with the expectations of the electroweak SM for polarised NC DIS.

2 Determination of Parton Densities and α_s

The H1^{1,3} and ZEUS^{4,10} collaborations have performed QCD fits to extract parton densities using various combination of HERA and other data. The fits are based on the evolution of the PDFs with Q^2 using DGLAP equations in Next-to-Leading-Order (NLO). The precision and kinematic coverage of the H1 and ZEUS data allow to perform QCD analysis (H1PDF2000³, ZEUS-JETS¹⁰ fits) with HERA data alone. A fit within one ep experiment provides better control of the systematic uncertainties and avoids many theoretical uncertainties, arising from heavy target correction, higher-twist contribution or isospin symmetry assumptions. Currently fits based on HERA data only are limited by statistics for high- x domain and significant improvements are expected with inclusion of HERA II data.

In ZEUS-JETS fit, data on jet production were used to constrain the mid to high- x gluon density. The four combinations of up and down PDFs for $U = u + c$, $\bar{U} = \bar{u} + \bar{c}$, $D = d + s$, $\bar{D} = \bar{d} + \bar{s}$ and the gluon density function are shown in figure 2a as functions of x for fixed $Q^2 = 10 \text{ GeV}^2$. Valence densities are obtained from the previous combinations of up-type and down-type and their anti-quark-type distributions as $u_v = U - \bar{U}$ and $d_v = D - \bar{D}$. Results obtained by H1 and ZEUS are in fair agreement with each other. The residual differences may originate from the different functional forms of the parameterisations of PDFs, constraints imposed on the densities, phase space, Q^2 start scale, the treatment of heavy quarks, treatment of experimental uncertainties, the data sets used, etc.

The pQCD fits provide a precise determination of the running strong coupling constant, α_s , with the experimental uncertainty 2-3 %. Determination of α_s in the H1 collaboration¹ is obtained by combining the low- x data of H1 with μp scattering data of the BCDMS collaboration at large x which reduces uncertainties of the measurements which can be seen from figure 2b. The

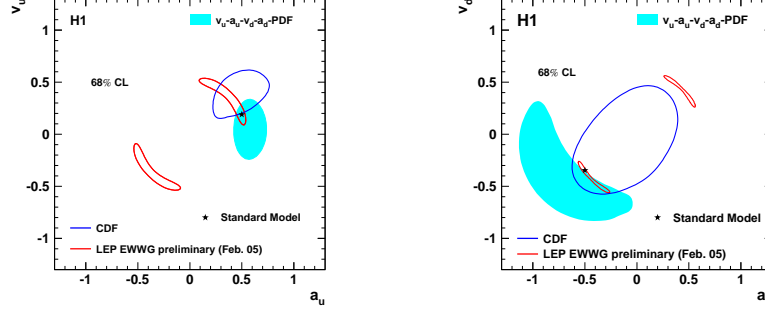


Figure 3: Results on the weak neutral current couplings of u and d quarks to the Z^0 boson from H1 compared with results from the CDF, LEP and the SM expectation.

additional constrain on the gluon PDF from the jet data in the ZEUS-JETS fit, has provided an improved determination of α_s which can be seen from figure 2c. The uncertainty in α_s due to terms beyond NLO has been estimated as $\Delta\alpha_s \simeq \pm 0.005$ by variation of the choice of scales.

3 Combined Electroweak and QCD Fit

The combined electroweak (EW) and QCD analysis¹², performed on data collected by H1 during HERA I with luminosity of 117 pb^{-1} , follow the same procedure as used in H1PDF2000 fit³. Taking into account dependence of the CC cross section on Q^2 , the propagator mass has been measured within the SM framework. The W mass has been also measured in the on-mass-shell scheme. The NC data have been used to extract the weak vector and axial-vector couplings of u and d quarks (v_u, a_u, v_d, a_d) to the Z^0 boson. In the fit $v_u - a_u - v_d - a_d - PDFs$, the vector and axial-vector couplings are treated as free parameters. The results at 68 % confidence level (CL) are shown in figure 3 together with results from CDF¹³ and preliminary results from LEP¹⁴. Results expected from the SM are also shown. Precision of HERA measurements is comparable to that from the CDF. These measurements are sensitive to u and d quarks separately and also resolve sign ambiguity of LEP measurement.

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