Status of PDFs from HERA

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Recent HERA measurements of the inclusive Deep Inelastic Scattering (DIS) are presented. Combined cross-section measurements performed by the H1 and ZEUS collaborations are used in a QCD analysis to determine the HERAPDF1.0 set of parton densities. Cross-section results obtained for the reduced proton beam energy runs are combined for H1 and ZEUS and used to determine the structure function F_L. A combination of F_2^{cc} measurements performed by the H1 and ZEUS collaborations allows to reach precision of $5-7\%$. New H1 results using HERA-II data improve accuracy of the structure function measurements at high momentum transfers Q^2 and high Bjorken-x.

Measurements of the $e^{\pm}p$ scattering cross section at HERA provide unique information on the proton structure. Operating at the proton beam energy of $E_p = 920$ GeV and electron beam energy of $E_e = 27.55$ GeV, HERA reached center-of-mass energy of $S = 318$ GeV which allowed to study large values of absolute four momentum transfer squared $Q^2 \geq 10000$ GeV^2 and very low values of Bjorken-x. The HERA operation were divided in two periods, HERA-I and HERA-II. For the HERA-II period, luminosity were increased employing final focusing magnets and spin rotators allowed for longitudinal lepton beam polarization. The total time integrated luminosity reached about 500 pb^{-1} for each of the two experiments operating in the colliding mode, H1 and ZEUS.

Since both H1 and ZEUS collaborations performed measurements of the cross sections with comparable precision, an ultimate accuracy is achieved by combining the results of the two experiments. The first combination of the inclusive cross-section measurements based on the HERA-I data was published recently[1]. The data were combined taking into account correlation of systematic uncertainties following[2,3]. In total 1402 input data points were averaged to 741 cross-section measurements which have 110 independent correlated error sources. The data show very good consistency which is apparent from the combination $\chi^2/dof = 637/656$.

The combined data were subjected to a QCD analysis to determine the parton distribution functions (PDFs). The analysis was performed at the next-to-leading order (NLO) perturbation theory using the evolution program QCDNUM[4]. The heavy quark densities were treated using a generalized variable flavor number scheme (GVFNS) as implemented by RT[5]. The resulting parton densities, termed HERAPDF1.0, are shown for $Q^2 = 10$ GeV^2 in figure 1. The HERA data are very accurate at low x leading to a determination of the sea and gluon density with small experimental errors. HERAPDF1.0 set contains evaluation of model and parameterization uncertainties which become more important.

The last year of the HERA operation was used for special runs at reduced proton beam energies of $E_p = 460$ GeV and $E_p = 575$ GeV. Combined with the measurements at the nominal E_p,

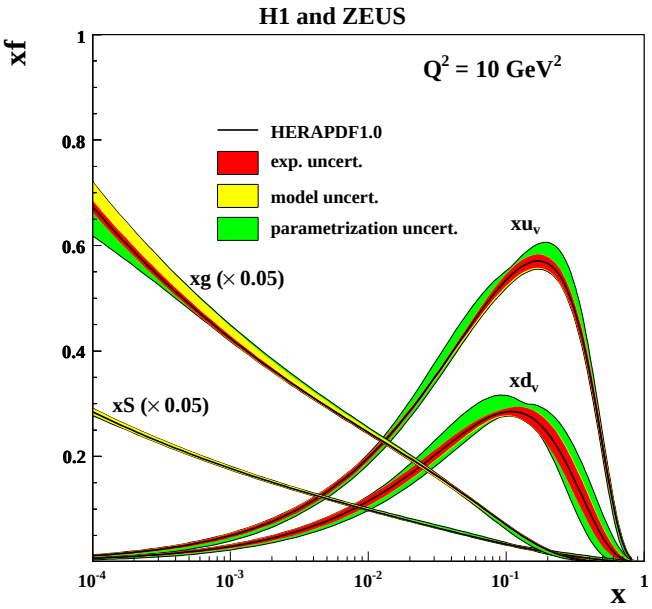

Figure 1: HERAPDF1.0 parton distribution functions evolved to $Q^2 = 10$ GeV^2. The red, yellow and green bands show experimental, model and parameterization uncertainties. The gluon xg and sea-quark xS densities are scaled down by factor $\times 0.05$. The valence-quark densities xu_v and xd_v dominate at high x.

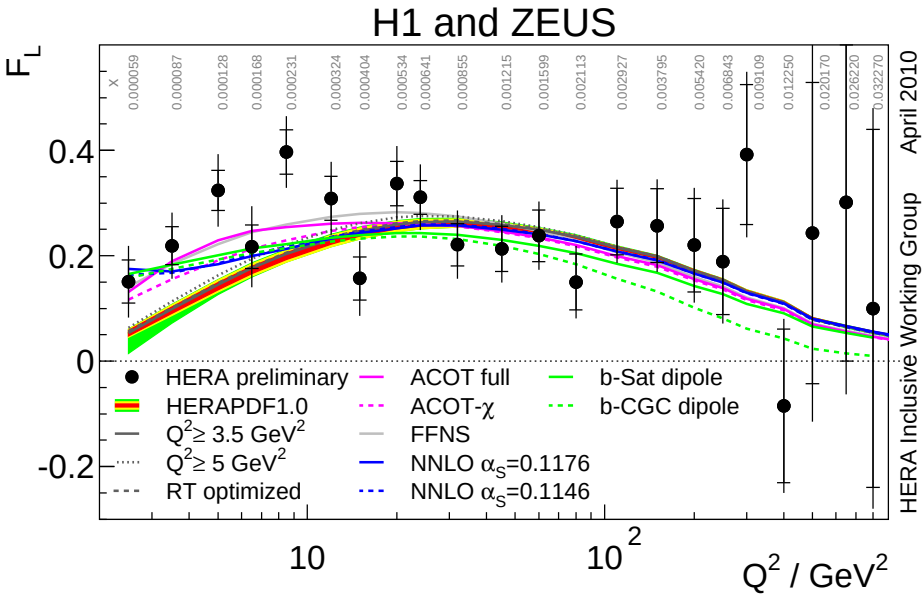

Figure 2: Preliminary combined measurement of the structure function F_L compared to predictions of various models. HERAPDF1.0 labels prediction of the HERAPDF1.0 fit with experimental, model and parameterization uncertainty shown as the red, yellow and green band, respectively. Green solid and dashed lines represent predictions of b-Sat and b-CGC dipole models. Other predictions are based on QCD fits to the combined inclusive HERA data, including the data from the reduced E_p runs. $Q^2 \geq 3.5$ GeV^2 and $Q^2 \geq 5$ GeV^2 lines are predictions from fits with default and increased kinematic cut on the data which use the RT GVNF scheme. RT optimized, ACOT full and ACOT-χ correspond to different variants of GVNF schemes. FFNS is a prediction of a fit using fixed flavor number scheme. NNLO $\alpha_S = 0.1176$ and $\alpha_S = 0.1146$ correspond to fits performed at NNLO with corresponding values of α_S.

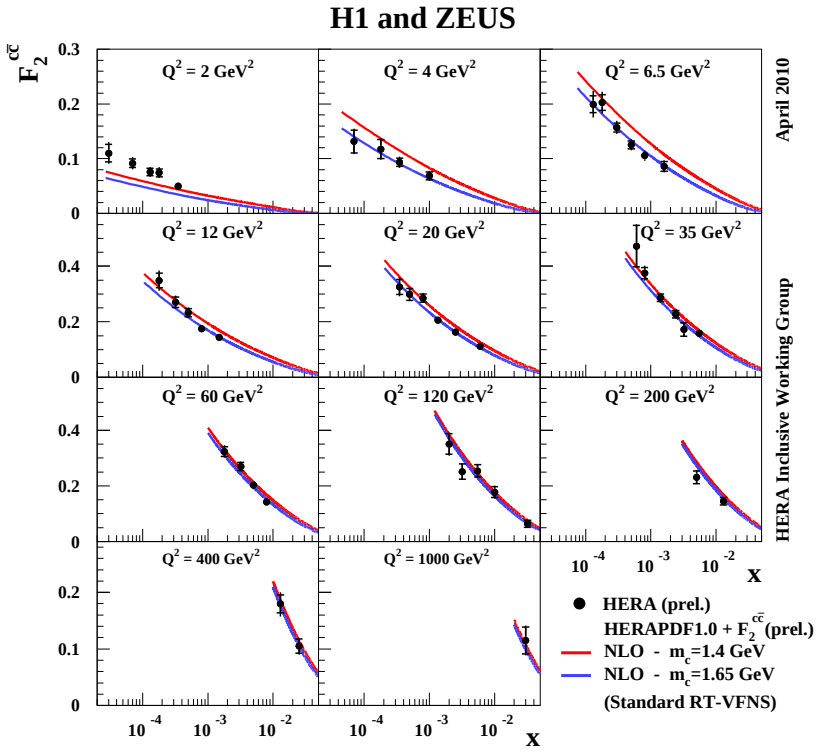

Figure 3: Preliminary combined measurement of the structure function F_2^{cc} compared to the HERAPDF1.0 prediction with different values of m_c, as indicated by the legend. Note that the HERAPDF1.0 fit starts from $Q^2_{min} \geq 3.5$ GeV^2, prediction for $Q^2 = 2$ GeV^2 is based on an extrapolation.

these data allow to decompose the inclusive cross section into contributions from the structure functions $F_2(x, Q^2)$ and $F_L(x, Q^2)$. Both H1 and ZEUS collaboration published the first measurements of F_L[6,7]. The H1 collaboration performed as well measurements in an extended Q^2 range[8,9]. The preliminary H1 and published ZEUS measurements of the inclusive cross section at reduced E_p were averaged and used to determine the structure function F_L which is shown in figure 2. The structure function is compared to the HERAPDF1.0 prediction as well as prediction from the dipole models, fits using different heavy flavor treatment and fits performed at NNLO. The predictions in general agree with each other and with the data for $Q^2 \geq 10$ GeV^2. For lower Q^2, however, predictions from the RT VFNS tend to undershoot the data.

The predictions for the contribution of the heavy flavors can be directly compared to the HERA data. Recently H1 and ZEUS performed a preliminary combination of their F_2^{cc} measurements [10] which is compared to the HERAPDF1.0 fit in figure 3. The predictions are shown for two values of the charm quark mass parameter, $m_c = 1.4$ and $m_c = 1.65$. The data precision reaches $5 - 7\%$ which allows to constrain the parameter variation. For $Q^2 \geq 4$ GeV^2, the prediction using $m_c = 1.65$ agrees well with the data. This value of m_c is considered in the HERAPDF1.0 set as an upper variation to estimate the model uncertainty due to the mass threshold parameter.

The combined HERAPDF1.0 data set provides a precise measurement of the DIS cross section at low x and low Q^2. At high Q^2, however, the precision of the measurement is limited by statistical uncertainties. Recently the H1 collaboration analyzed the data from the HERA-II running period. These data were combined with the HERA-I measurement providing a full statistics of the H1 inclusive cross-section results [11]. Compared to the HERA-I result, in

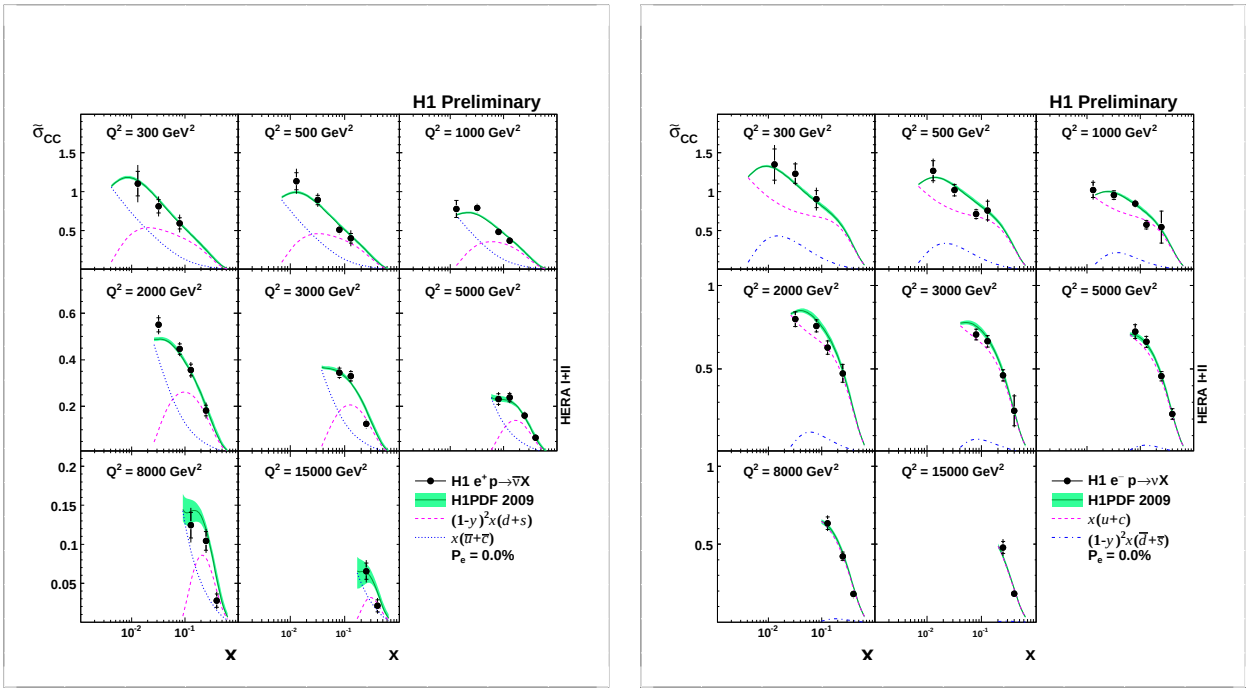

Figure 4: H1 combined measurement of the charged current e^+p (left) and e^-p (right) cross section compared to the prediction of the H1PDF 2009 fit. The contributions corresponding to different quark flavors are shown as dashed and dotted lines.

particularly large increase in precision is achieved for the e^-p data for which the integrated luminosity is increased by more than factor of ten. The combined results for the charged current cross section are compared in figure 4 to the prediction of the H1PDF2009 fit[12]. A good agreement between the predication and the measurement is observed. The new data should allow to improve precision of the PDF predictions in the high x region.

To summarize, the H1 and ZEUS experiments continue to provide significant updates on the proton structure. The combined HERA-I data were used to determine the HERAPDF1.0 set which has small experimental uncertainties at small x. The measurement of the structure function F_L gives an important check of the QCD dynamics. The contribution of the heavy flavors is directly tested by measuring the structure function F_2^{cc}. Results based on the complete available luminosity of HERA improve proton structure measurements at high Q^2 and x.

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