Structure function results from H1

Z. Zhang[a]*

[a]Laboratoire de l'Accélérateur Linéaire, BP 34, IN2P3-CNRS et Université de Paris-Sud, 91898 Orsay Cedex, France

New structure function results from H1 are presented. The measurements cover a huge kinematical range for Q^2, the four momentum transfer squared, from $0.35\,\mathrm{GeV}^2$ to $30\,000\,\mathrm{GeV}^2$, and for Bjorken x between $\sim 5\cdot 10^{-6}$ and 0.65. At $Q^2 > 100\,\mathrm{GeV}^2$, full HERA I data have been analyzed. The data are compared with a new QCD analysis. The impact of the HERA I data on the parton density functions is discussed.

1. INTRODUCTION

Deep inelastic scattering (DIS) experiments have played an important role in the understanding of the partonic structure of matter and in establishing the strong interaction sector of the Standard Model (SM): QCD.

In the past decade, the HERA experiments H1 and ZEUS have been providing more and more precise data for modern global fits allowing parton density functions (PDFs) be determined with steadily increasing precision. The precision of the PDFs is of importance as it is needed to have reliable predictions for precision measurements and for new physics searches at future hadron colliders such as LHC.

In this talk, I shall first present the latest new structure function measurements from H1, then try to answer two following questions: i) Can HERA I cross section or structure function (SF) data measured so far be described by QCD? and ii) What is the impact of the HERA I data?

2. NEW MEASUREMENTS AND IMPACT OF HERA I DATA

Four new preliminary measurements [1] from H1 have been submitted to this conference. Thanks to the increased proton beam energy from 820 GeV to 920 GeV since 1998 (the center-of-mass energy $\sqrt{s}$ is accordingly increased from 300 GeV to 320 GeV), the fully installed backward silicon tracker, the new capability of triggering low energy scattered electrons[2] down to 3 GeV, and the special runs where data were taken by shifting the nominal interaction vertex in the proton beam direction by 70 cm, the kinematical domain has been substantially extended with respect to previous measurements both to lower Q^2 and to smaller x. On the other extreme at high Q^2 and large x, the new measurements of both neutral current (NC) and charged current (CC) processes are obtained with improved precision using the highest data sample taken before the HERA machine was upgraded for the second phase.

Part of the new measurements at low Q^2, the so-called reduced cross sections $\tilde{\sigma}$ (or $\sigma_{\rm r}$), are shown in Fig. 1. The reduced cross section for the NC interaction may be expressed in terms of SFs as

$$\tilde{\sigma}_{\rm NC}(e^\pm p) = F_2 - \frac{y^2}{Y_+}F_L \mp \frac{Y_-}{Y_+}xF_3 \qquad (1)$$

where $Y_\pm = 1 \pm (1-y)^2$ with $y = Q^2/(xs)$, F_2 is the dominant contribution, the contribution of the longitudinal SF F_L is suppressed at low y by y^2/Y_+, and the SF xF_3, which arises mainly from the photon-Z^0 interference and has been previously determined [5] at $Q^2 \geq 1500\,\mathrm{GeV}^2$, becomes non-negligible only at such large Q^2 values. The reduced cross section differs from the experimentally measured double differential cross

*On behalf of the H1 collaboration.

[2]It refers generically to both electrons and positrons unless stated otherwise.

section $\mathrm{d}^2\sigma/\mathrm{d}x\mathrm{d}Q^2$ by a kinematical factor of $2\pi\alpha^2 Y_+/xQ^4$, where α is the fine structure constant.

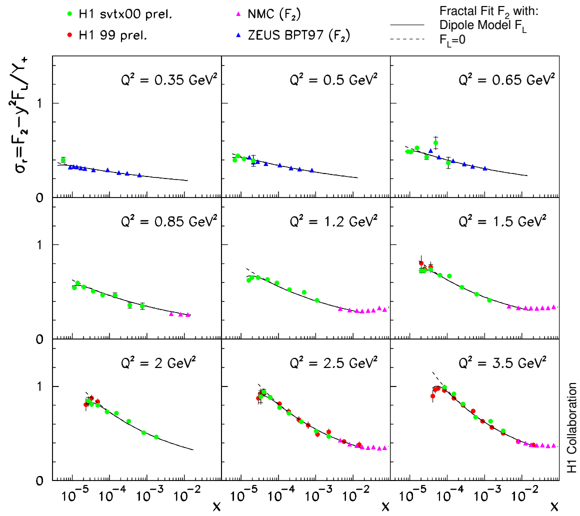

Figure 1. Preliminary reduced cross section (see text) measurements from H1 shown as a function of x for $Q^2 \leq 3.5\,\mathrm{GeV}^2$. Also shown are measurements from NMC [2] and ZEUS [3] and expectations based on a phenomenological model [4].

From Fig. 1, one observes that the new measurements extend now down to $x \sim 5\cdot 10^{-6}$ at $Q^2 = 0.35\,\mathrm{GeV}^2$. The rise of F_2 as x decreases, the first important observation at HERA and being related to increasing gluon density xg at small x, persists even at $Q^2 < 1\,\mathrm{GeV}^2$ although with a reduced magnitude. The same observation is also obtained from the measurement of $\mathrm{d}\ln F_2/\mathrm{d}\ln x$ (not shown here).

As Q^2 increases, the measured σ_{r} is observed to deviate from the dashed curves at high y in which the F_L is set to zero, but agree with the full curves where a non-zero F_L according to a dipole model is included. Such a sensitivity to F_L has been exploited by H1 to determine experimentally F_L, which is shown in Fig. 2. The new determination (shown in triangle) thus extends the previous determination [6] to smaller x and higher Q^2. It should be pointed out that such a determination, though not a direct measurement which needs different beam energies, does provide a non-trivial consistency test as the determination gives a direct measure of xg while the expectation from a QCD fit was based on an indirect xg derived from the scaling violation of the F_2.

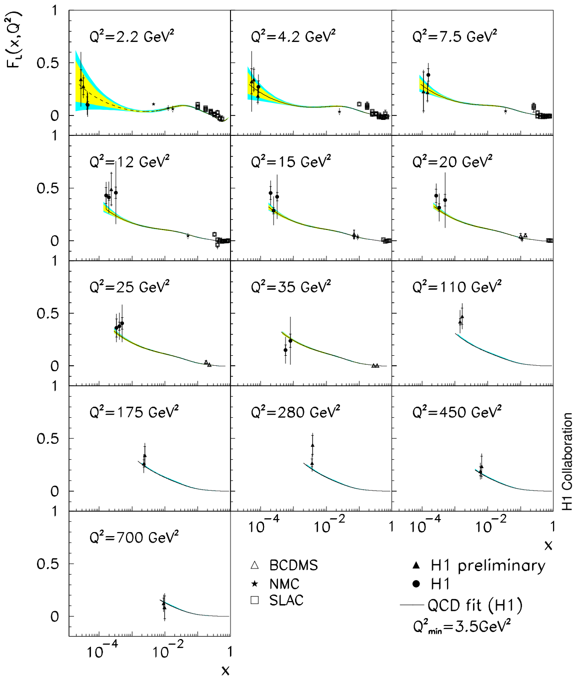

Figure 2. Preliminary determination of F_L shown together with those by H1 [6] and BCDMS, NMC, and SLAC [7]. Also shown is the SM expectation - QCD fit (H1) [6].

Moving to even higher Q^2 (100–$30\,000\,\mathrm{GeV}^2$) region, new preliminary cross section measurements based on the e^+p 1999-2000 at $\sqrt{s} = 320\,\mathrm{GeV}$ [1] are combined with those measured with the e^+p 1994-1997 at 320 GeV [8] taking into account a small correction due to the increased $\sqrt{s}$. The combined cross sections in e^+p scattering can be compared with those in e^-p scattering [5]. In Fig. 3, the single differential NC and CC cross sections from H1 [1,5] and ZEUS [10,5] are shown and compared with the SM expectation from a global QCD fit (CTEQ5 [9]). While the NC e^+p and e^-p cross sections are undistinguishable at low Q^2 as expected from the photon

(γ) exchange, they are different at high Q^2 due to the positive (negative) γZ^0 exchange in $e^-p(e^+p)$ interactions. The CC e^+p and e^-p cross sections are different over the entire Q^2 region measured originating from different quarks probed by negatively and positively charged W bosons exchanged in the interactions and from different helicity structures involved. At $Q^2 \sim M^2_{Z,W}$, all four cross sections (NC, CC and e^+p, e^-p) are comparable demonstrating the universal coupling strength of electroweak interactions. It is also remarkable that the cross sections which vary over many orders of magnitude are described by the global fit which to some extent is independent of the data.

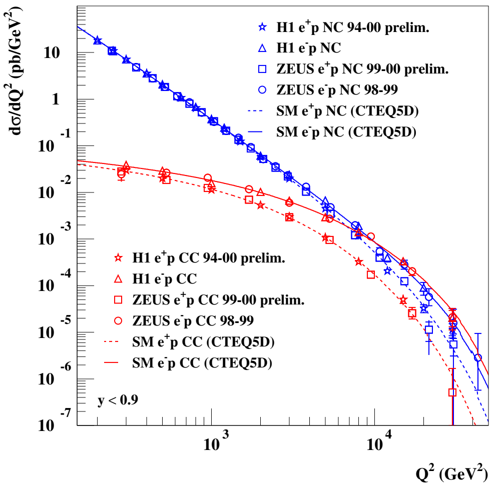

Figure 3. NC and CC cross sections $d\sigma/dQ^2$ measured with e^+p and e^-p data by H1 [1,5] and ZEUS [10,5] in comparison with the SM expectations from CTEQ5 [9].

HERA data have been important for constraining the gluon density xg at small x. Indeed, in an earlier QCD analysis performed by H1 using the H1 low Q^2 precision data and part of the H1 high Q^2 e^+p data available then, the gluon density xg was determined with an experimental precision of about 3% [6]. In addition, the strong coupling constant α_s was determined with an experimental uncertainty of 1.5% [6] using the same data together with the proton data from BCDMS [11] for constraining xg at large x. This determination at next-to-leading order (NLO) is unfortunately limited theoretically by the large scale uncertainty showing the necessity of having next-to-NLO calculations for improvements.

Presented at this conference is a further NLO QCD analysis performed by H1 using the low Q^2 precision data and all high Q^2 cross section data. The analysis aims at a determination of the quark momentum distributions, besides xg. A novel feature of the analysis is the way in which the various structure functions are decomposed in terms of different parton densities. The quark densities used by H1, the upper and down types of quarks (xU, xD) and their anti-quarks ($x\overline{U}$, $x\overline{D}$), directly enter the NC and CC cross sections contrary to an effective sea distribution or valence quark distributions. The latter follow from the differences $u_v = U - \overline{U}$ and $d_v = D - \overline{D}$. The initial distributions are parametrized in an MRST-like functional form for Q_0^2 at $4\,\mathrm{GeV}^2$. The results of the fit are shown in Fig. 4 as a function of x. In the fit with the full HERA I data plus the BCDMS proton and deuterium data [11], the experimental uncertainty shown in dark error band reaches a precision of a few percent. Shown in light error band is the model uncertainty, which includes variation of Q_0^2 and other parameters in the fits. The results of the fit using the H1 data only is shown with the solid curves. It is remarkable that the fit using HERA data only is able to give consistent results on the parton density functions with the combined fit which uses additional data at low Q^2 and large x.

The impact of the HERA I data at large x is best seen on the u and d quark densities at valence quark region, determined by two complementary methods (Fig. 5). In one method, the densities are determined from the fit, where the precision is optimal, while in the second method, the densities ($xq_{\rm exp}$) are extracted locally from the measured cross sections $\tilde{\sigma}_{\rm meas}(x, Q^2)$, $xq_{\rm exp} = \tilde{\sigma}_{\rm meas}[xq/\tilde{\sigma}]_{\rm fit}$. The latter method has the advantage that the resulting u and d densities do not depend on the Q^2 evolution and are thus free from any nuclear corrections.

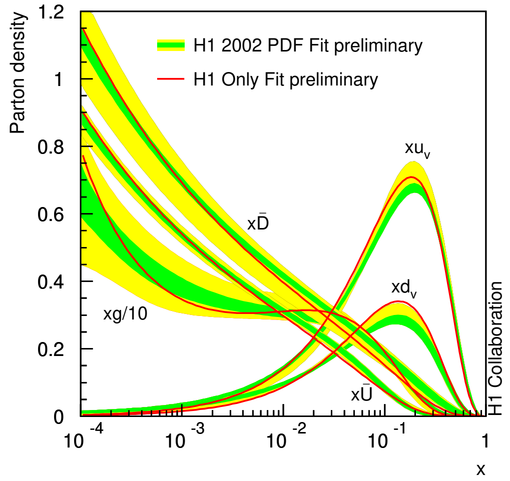

Figure 4. The valence quark densities xu_v, xd_v, the anti-up and down type densities $x\overline{U}, x\overline{D}$ and the gluon density xg (reduced by a factor of 10), from the combined fit (error bands) using the H1 and BCDMS data [11] are compared with those from the fit (solid curves) using the H1 data only.

3. CONCLUSION

To conclude, the structure function data from almost a decade's operation in HERA phase I have enabled the theory of QCD be tested to a new level of precision in deep inelastic scattering and revealed its impact on the parton densities both for the gluon at small x and for the u and d at large x. The full HERA I data at large x and high Q^2 are still statistically limited. New data to be taken during the next years in HERA phase II are therefore important not only to improve the precision of the structure functions but also to fully explore the very high Q^2 region up to the kinematical limit $s \sim 10^5\,\mathrm{GeV}^2$.

REFERENCES

1. H1 Collab., "A new measurement of the DIS cross section and of F_L at low Q^2 and Bjorken x at HERA", contri. paper # 799; "Measurement of the inclusive DIS cross section at $Q^2 \sim 1\,\mathrm{GeV}^2$ with the H1 experiment", contri. paper # 975; "Measurement of the proton structure function using radiative events at HERA", contri. paper # 976; "Measurement of inclusive DIS at high Q^2 and large x", contri. paper # 978.

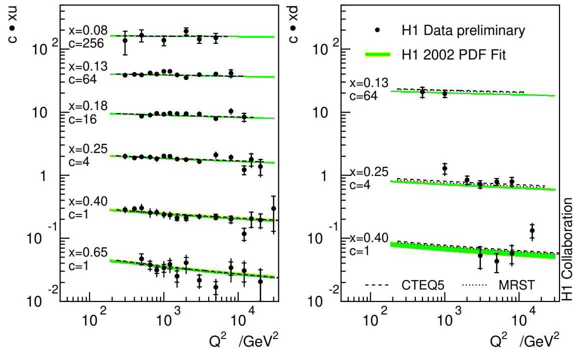

Figure 5. The u and d quark densities determined from the local extraction method (full points) and from the fit are compared with those from CTEQ5 [9] and MRST [12]. For displaying purpose, the densities are scaled by different factors c for fixed x values.

2. NMC Collab., A. Arneodo et al., Phys. Lett. **B364** (1997) 107, Nucl. Phys. **B483** (1997) 3.
3. ZEUS Collab., J. Breitweg et al., Phys. Lett. **B487** (2000) 53.
4. T. Lastovicka, hep-ph/0203260.
5. H1 Collab., C. Adloff et al., Eur. Phys. J. **C19** (2001) 269; ZEUS Collab., DESY-02-113.
6. H1 Collab., C. Adloff et al., Eur. Phys. J. **C21** (2001) 33.
7. BCDMS Collab.,A. C. Benvenuti et al., Phys. Lett. **B223** (1989) 485; NMC Collab., 2nd ref. of [2]; L. W. Whitlow et al., Phys. Lett. **B250** (1990) 193.
8. H1 Collab., C. Adloff et al., Eur. Phys. J. **C13** (2000) 609.
9. CTEQ Collab., http://www.phys.psu.edu/~cteq.
10. ZEUS Collab., J. Breitweg et al., Eur. Phys. J. **C11** (1999) 427, **C12** (2000) 411.
11. BCDMS Collab., 1st ref. of [7].
12. A. D. Martin et al., Eur. Phys. J. **C4** (1998) 463.