Measurement of the Structure Functions F_2 and F_L at Low x

V. Arkadov[a] (on behalf of the H1 Collaboration at HERA)

[a]Deutsches Elektronen Synchrotron, DESY Zeuthen, Platanenallee 6,D-15738, Germany
E-mail: arkadov@ifh.de

A preliminary measurement of the proton structure function F_2 is presented for momentum transfers squared $2 \leq Q^2 \leq 120\ GeV^2$ and for Bjorken-x values $3 \cdot 10^{-5} < x < 0.1$. The longitudinal proton structure function F_L is determined for low x values in the range of $3 \leq Q^2 \leq 35\ GeV^2$, using two independent methods. The analysis is based on data collected by the HERA experiment H1 in 1997, with a luminosity of 15 pb^{-1} for $Q^2 > 10\ GeV^2$ and of 2 pb^{-1} taken in a dedicated run for $Q^2 < 10\ GeV^2$. This measurement uses in the low Q^2 region the new backward silicon tracker. The accuracy is by nearly a factor of two better than previous results.

1. CROSS SECTION MEASUREMENT

The inclusive deep inelastic scattering (DIS) cross section for $Q^2 \ll M_Z^2$ is described by one photon exchange and defined as

$$\frac{1}{k}\frac{d^2\sigma}{dxdQ^2} = F_2(x,Q^2) - \frac{y^2}{Y_+} \cdot F_L(x,Q^2) = \sigma_r \quad (1)$$

with $Y_+ = 1 + (1-y)^2$ and $k = \frac{2\pi\alpha^2 Y_+}{Q^4 x}$. Here σ_r is the so-called reduced DIS cross section, given by the two proton structure functions $F_2(x,Q^2)$ and $F_L(x,Q^2)$. The σ_r is dominated by F_2 with the exception of the high y region. Here the extraction of F_L is possible.

1.1. H1 Detector

The H1 detector [1] is a nearly hermetic apparatus built to investigate high-energy ep scattering at HERA. Due to the redundancy of the final state measurement, it allows to use various reconstruction methods which are exploited in specific kinematic regions.

For polar angles of the scattered positron $\theta_e > 153^o$ the backward electromagnetic calorimeter (SPACAL [2]) is used for the energy reconstruction. Here θ is defined with respect to the proton beam direction. Its measurement makes use of a backward drift chamber (BDC) and a backward silicon strip detector (BST) [3] situated in front of the SPACAL.

In 1997, the BST was a 4 plane silicon strip detector telescope built of 64 wedge shaped detectors having 96 μm readout pitch. They are arranged concentric around the beam axis and cover the angular range between 172^o and 177^o.

The hadronic final state is reconstructed using the Liquid Argon calorimeter (LAr), the tracking system and the SPACAL. The event vertex is determined with the central trackers by the hadronic final state particles. At low Q^2 and y the interaction vertex is measured with the BST.

1.2. Event Selection and Data Analysis

The data are triggered by the requirement of total energy deposited in SPACAL to be bigger than 5 GeV. A special "high y" **trigger** for electron energies down to 2 GeV was utilized in a specific fiducial volume with a valid vertex trigger in the central proportional chambers. The efficiency of all trigger elements was more than 96 % with an accuracy of 0.5-1 %.

Positron identification used the cluster with maximum transverse momentum p_t for large Q^2 and the cluster with maximum energy deposition for low Q^2. The systematic error for positron identification is estimated to be $1 - 2$ %.

γp **rejection**. The main part of the background is due to $\pi^0 \to 2\gamma$ decays. This source of background is removed to a large extent by requiring a track linked to the SPACAL cluster. The background from the charged hadrons was also significantly removed requiring a positive track in central jet chamber (CJC) and also the cluster radius to be less than 4 cm. Outside the CJC acceptance, only the last criterion could be applied.

Radiative corrections are small due to the imposed requirement on energy-momentum conservation ($E - P_z > 35\, GeV$). Their contribution is reduced down to less than 5 % within the high y region. The uncertainty of the radiative corrections is $1 - 2$ %.

The **Monte Carlo** [8,9] events generated with the DJANGO [8] and PHOJET [9] programs were processed with the same reconstruction and analysis chain as the data.

1.3. Cross Section at High y

The event kinematics at large y is reconstructed using the measurement of the angle and energy of the scattered positron. The electromagnetic energy scale was calibrated with 0.5%(3%) accuracy at high (low) positron energies. The hadronic scale uncertainty was 4/3/5 % for the contribution from LAr, tracks and hadronic SPACAL. The polar angle error is estimated to be 0.5 mrad from a comparison of BDC-vertex and BST θ measurements. The γp background is simulated with the PHOJET event generator and controlled by the tagged events. The systematic errors of this cross section measurement are about 4% with no single error source dominating. The systematic errors for high y reach up to 8 % due to photoproduction background uncertainties.

2. STRUCTURE FUNCTIONS F_2 AND F_L

The measured F_2 structure function shows good agreement with the fixed target experiments. The NLO QCD fit performed including the BCDMS [4] and NMC [5] results describes very well the H1 preliminary F_2 results (see [6] and [10]). It reveals a strong rise of F_2 towards low x which is decreasing with decreasing Q^2. This feature is utilized to determine F_L at low Q^2 as described below.

2.1. F_L Determination

The determination of the structure function F_L has to be based on assumptions about the structure function F_2. It is determined by two independent methods. The first one, introduced previously [7], uses the extrapolation of F_2 fitted at $y < 0.35$ to the high y region and subtraction of F_2 from σ_r (see Eq. 1).

The second method is based on the cross section derivative defined as:

$$\frac{\partial \sigma_r}{\partial \log y} = \frac{\partial F_2}{\partial \log y} - F_L \cdot f'(y) - \frac{\partial F_L}{\partial \log y} \cdot f(y) \quad (2)$$

with $f'(y) = 2y^2(2-y)/Y_+^2$ for $f(y) = y^2/Y_+$. This derivative is a linear function of log$y$ (see [10]) for low y. For each Q^2 the cross section derivative was defined with a straight line fit for $y < 0.2$ and extrapolated to high y. F_L is then calculated according to Eq. 2, thereby assuming that $\partial F_2/\partial \log y$ is a linear function of $\log y$ up to large y. The contribution from the F_L derivative is estimated to be very small.

In the experimental procedure to measure the binwise derivative those systematic errors cancel which do not depend on y. The remaining errors are mainly due to the γp background. The derivative method is more sensitive to F_L and allows its determination at low Q^2, since it has no assumption on the Q^2 dependence of the cross section. The comparison of the results for F_L obtained by the described two methods is shown in Fig. 1. Both results, obtained from the same data, are consistent within the errors, which have partially different origin by construction. The band on Fig. 1 represents the F_L calculated from the NLO QCD fit to F_2 at low y [10]. The width of the band is the uncertainty of the fit including possible errors of α_s and m_c. The measured results are consistent with this calculation.

3. SUMMARY

A new, preliminary measurement of the deep inelastic positron-proton scattering cross section by the H1 collaboration has been presented. The obtained cross section is nearly twice more accurate than the previous one and consistent with the NLO QCD fit down to $Q^2 = 2\, GeV^2$. The structure function F_L has been determined in the range $3 \le Q^2 \le 35\, GeV^2$ and $4 \cdot 10^{-5} \le x \le 6 \cdot 10^{-4}$ with two methods. Both results show good agreement within the systematic errors. The "derivative" method made it possible to extract F_L at low Q^2 where the high y values have been accessed with the use of the BST.

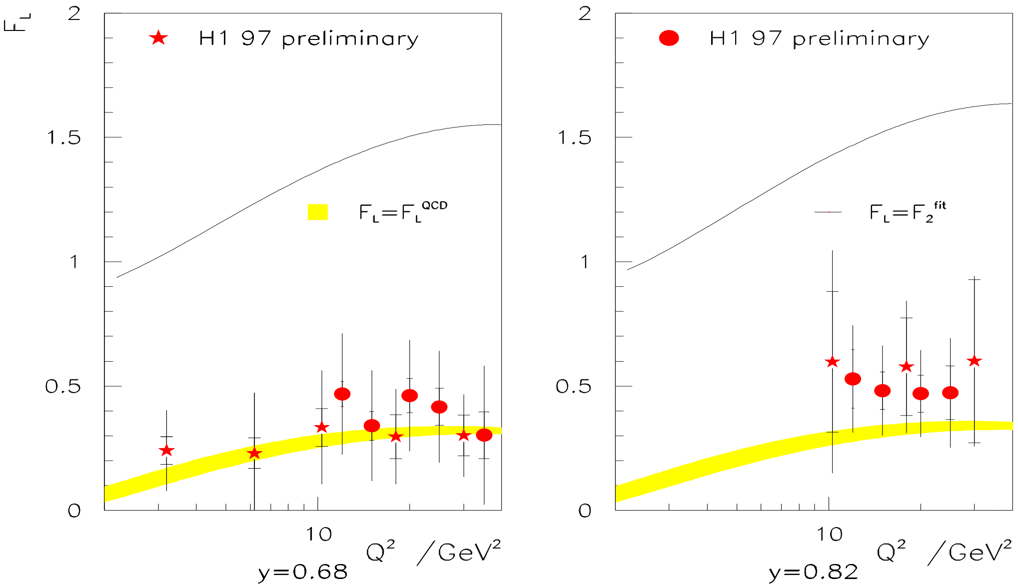

Figure 1. Determination of the longitudinal structure function F_L using the subtraction method (closed points) and the derivative method (stars) which extends to lower Q^2. The quoted y values apply to the closed points. The stars belong to somewhat lower y values as they are derived from a difference of cross section measurements.

The obtained F_L is consistent with NLO QCD calculations based on the cross section measured at low y.

REFERENCES

1. H1 Collaboration, I. Abt et al., Nucl. Instr. and Meth. **A386** (1997) 310 and **A386** (1997) 348.
2. R. Appuhn et al., Nucl. Instr. and Meth. **A 386** (1997) 397.
3. W. Eick et al., Nucl. Instr. and Meth. **A386** (1997) 81.
4. BCDMS Collaboration, A.C. Benvenuti et al., Phys. Lett. **B223** (1989) 485; CERN preprint CERN-EP/89-06.
5. NMC Collaboration, M. Arneodo et al., Nucl. Phys. **B483** (1997) 3.
6. J.Zacek, this proceedings
7. H1 Collaboration, S. Aid et al., Phys. Lett. **B393** (1997) 452.
8. G.A.Schuler and H.Spiesberger, Proceedings of the Workshop Physics at HERA, vol. 3, eds. W.Buchmüller, G.Ingelmann, DESY (1992) 1419
9. R.Engel and J.Ranft, Phys. Rev. **D54** (1996) 4244
10. H1 Collaboration,"Precision Measurement of the Inclusive Deep Inelastic *ep* Scattering Cross Section at Low Q^2", Paper 534, submitted to the Vancouver Conference, 1998, unpublished.