New Results on the Proton Structure Function from H1

Gaby Rädel

Deutsches Elektronen Synchroton, DESY
Hamburg, Germany

On behalf of the H1 collaboration

Abstract

We present a new measurement of the proton structure function F_2 in the region of 3.5 GeV^2 $\leq$ $Q^2 \leq 25$ GeV^2 with values of x_{Bj} down to $8 \cdot 10^{-5}$. The data analysed were taken in 1994 by the H1 experiment at HERA.

1. Introduction

The measurement of the proton structure in a wide and new kinematic range is one of the main goals for the experiments ZEUS and H1 at the first electron proton collider HERA at DESY. HERA is in operation since 1992, and results on F_2 were published, e.g. by H1 on 0.271 pb^{-1} of data taken in 1993 [1]. These data covered a range in Q^2 from 8.5 GeV^2 to 1000 GeV^2 and down to values of $x_{Bj} < 10^{-3}$. The results confirmed, now with higher statistical significance, the observation made in 1992, that F_2 is rising towards low x. However, recently a great interest has been expressed in the structure function at very low values of x and Q^2, since this is a region were new QCD phenomena could set in. In order to extend the measurement into this region the H1 collaboration requested to shift the nominal interaction vertex towards the direction of the incoming protons. Such, by a shift of 62 cm a gain in acceptance of about two degrees in the scattering angle of the electron could be reached, which opens the possibility to measure F_2 down to values of Q^2 of 2 GeV^2. In 1993 a test of these conditions was performed, enabling us to take 2.5 nb^{-1} of data at the shifted interaction vertex. This lead to a first measurement of F_2 down to 4.5 GeV^2, however, of marginal statistical significance. In 1994 HERA produced about 20 times the statistics at the shifted interaction vertex. We present here a preliminary analysis of these data in the Q^2 range of $3.5 - 25$ GeV^2, which includes a first significant measurement of F_2 below 8.5 GeV^2.

2. H1 Detector and Data Sample

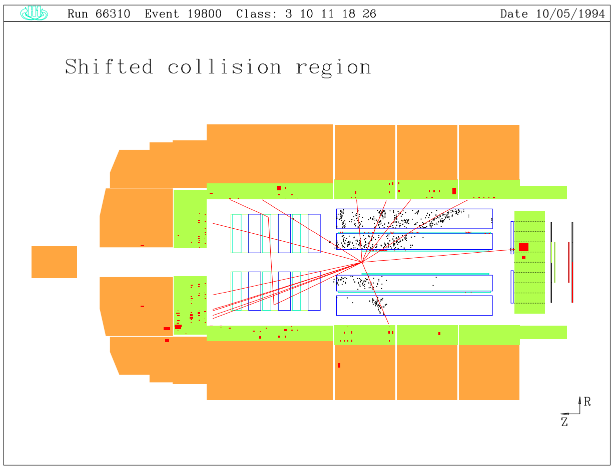

Figure 1. A deep inelastic event recorded at the shifted interaction region in the H1 detector.

Fig. 1 shows a schematic view of the H1 detector and a DIS event recorded at the shifted interaction point. In this figure the protons of 820 GeV incident from the right and the electrons (E_e = 27.6 GeV)

from the left. The interaction point of the collision is shifted by 62 cm in positive z-direction compared to the nominal interaction point. The interaction vertex is determined from tracks measured in the central tracking chambers. The electron is detected in the backward electromagnetic calorimeter (BEMC) at the right, which covers an angular range $155° < \theta < 177°$. The hadronic final state is detected in the fine grained liquid Argon calorimeter (lAr), which surrounds the tracking system and covers an angular range $3° < \theta < 155°$. A detailed description of the H1 detector can be found in [2].
For the analysis presented here several data samples, all recorded in 1994, were used:

1 data collected in a dedicated run with shifted interaction region: $\int \mathcal{L} = 58 \pm 3$ nb^{-1}.

2 data collected at the nominal interaction vertex, $\int \mathcal{L} = 2.2 \pm 0.03$ pb^{-1}, and

3 data from *satellite bunches*, i. e. during normal HERA operation some protons arrive 4.8 ns before the main proton bunch, and collide with the electrons at $z \approx 70$ cm in the H1 detector. The luminosity corresponding to this data sample is: $\int \mathcal{L} = 68 \pm 3 \pm 3$ nb^{-1}. The second error is due to the fact that the luminosity was determined from the measured luminosity for the shifted vertex data multiplied by the efficiency corrected event ratio in a kinematic region common to both data sets. This leads to the additional error on $\int \mathcal{L}$ of 5%.

Fig. 2 shows part of the data collected by H1 in 1994 in the (Q^2, x)-plane. Shown is only the data when the scattered electron was detected in the BEMC. The extension of the kinematic region by shifting the vertex is clearly seen.

3. Kinematic Reconstruction

In order to reconstruct the kinematics of the events different methods are possible, since the HERA experiments are designed to measure both the scattered electron and the hadronic final state. The kinematics can therefore be reconstructed from the scattered electron, the hadronic final state or a combination of both. For this analysis two methods were used:

1 the electron method (e-method), i.e. y and Q^2 are reconstructed from the measured scattering angle θ_e and the energy of the scattered electron E'_e:

$$Q^2 = 4E_e E'_e \cos^2(\frac{\theta_e}{2}), y = 1 - \frac{E'_e}{E_e}\sin^2(\frac{\theta_e}{2})$$

2 the Σ-method [3] combines y from the following expressions:

$$Q^2_\Sigma = \frac{E'^2_e \sin^2\theta_e}{1 - y_\Sigma}$$

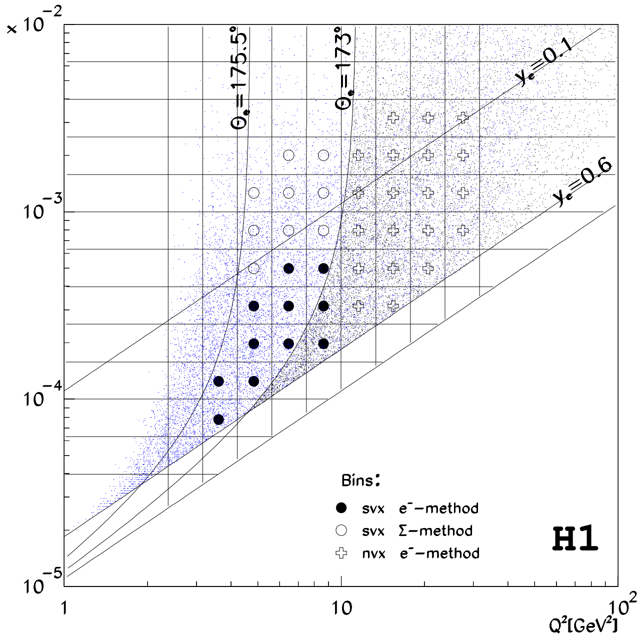

Figure 2. Distribution of the neutral current event sample in the (x, Q^2) plane. Shown are only data with the electron detected in the BEMC. The extension of the kinematic region by shifting the vertex by 62 cm is also shown. Furthermore the bins used for this analysis are indicated, specifying the reconstruction method and data sample used in each bin.

$$y_\Sigma = \frac{\Sigma_h (E - p_z)_h}{(E - p_z)_e + \Sigma_h (E - p_z)_h}$$

where the sum in the numerator includes all hadrons and includes all hadrons plus the scattered electron in the demoninator.

In this second method the energy of the incident electron in the interaction is reconstructed, which reduces drastically the sensitivity to the main radiative process. The resolution in x at low y is good enough to allow a measurement down to $y = 0.01$. The resolution at large y is worse but less sensitive to radiative corrections than for the pure e-method. The comparison of the results obtained with different methods is an important cross check of the systematic errors. A combination of the results ensures maximum coverage of the available kinematic range. The binning in x and Q^2 was chosen to match the resolutions in these variables and is shown in fig. 2.

4. Event Selection and Backgrounds

The events were obtained by a calorimetric trigger requiring an energy deposition of more than 6 GeV in the BEMC. The events are then off-line selected by requiring the presence of:

- a reconstructed vertex from the tracking system within ± 30 cm of the interaction position,
- an electron candidate with an energy $E'_e > 11$ GeV, in the well contained region of the calorimeter, corresponding approximately to the $\theta_e < 176°$ for the shifted vertex sample and $\theta_e < 173°$ for the nominal vertex sample.
- estimators to define an electron candidate :
  ϵ_1: the electron cluster radius, $\epsilon_1 < 5$ cm
  ϵ_2: the smallest distance from a track to the centroid of the electron cluster, $\epsilon_2 < 5$ cm.
- some additional conditions for non-ep background rejection as detailed in [1].

The main sources of non-ep background are due to proton beam interactions with residual gas and beam line elements upstream of the H1 detector. An efficient reduction of the remaining background is provided by the minimum energy and the vertex requirements discussed above. The residual background was estimated to represent less than 1% of the total number of selected events.

The only significant background to DIS from ep interactions is due to photoproduction events at $Q^2 \simeq 0$ where the scattered electron escapes the detector along the beam pipe but in which an energy cluster from the hadronic final state fakes an electron. About 10% of these events are identified as photoproduction background if the scattered electron is detected in the small angle electron tagger [1]. To estimate this background, photoproduction events were simulated corresponding to the luminosity of the data. The photoproduction background was subtracted statistically bin by bin, but the contamination never exceeds 15% in any bin.

5. Structure Function Measurement

The structure function F_2 can be derived from the one-photon exchange cross section:

$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}(2 - 2y + \frac{y^2}{1+R})F_2(x, Q^2), \qquad (1)$$

where $\frac{d^2\sigma}{dx\,dQ^2}$ is the Born cross section, i. e. corrected for radiative events. The structure function ratio $R = F_2/2xF_1 - 1$ has not yet been measured at HERA and was calculated using the QCD relation [4] and the GRV structure function parametrization [5]. The determination of the structure function requires the measured event numbers to be converted to the bin averaged cross section based on the Monte Carlo acceptance calculation. All detector efficiencies were determined from the data utilizing the redundancy of the apparatus. The bin averaged cross section was

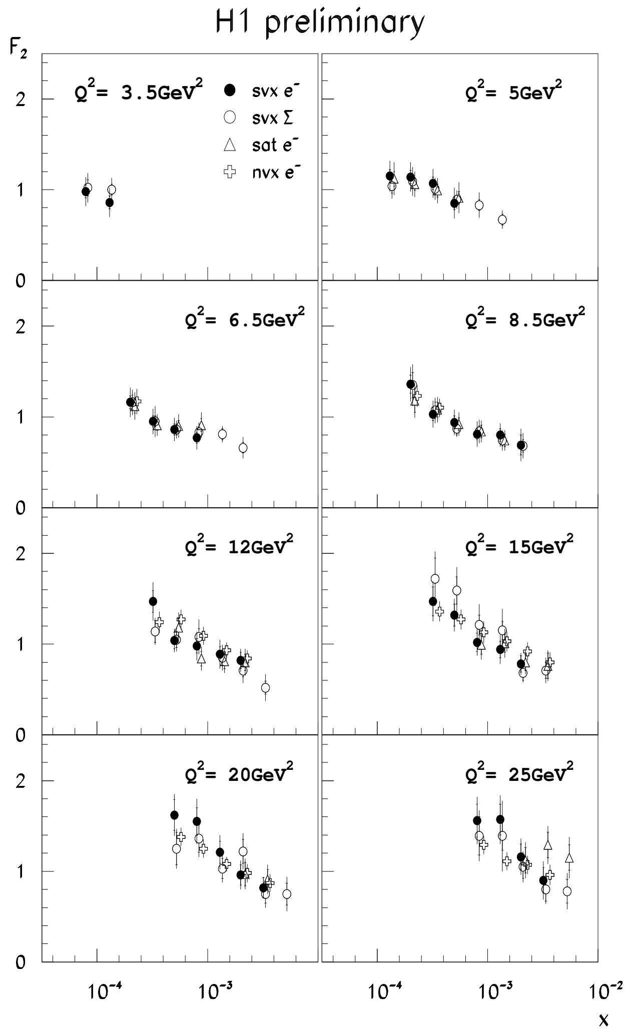

Figure 3. The proton structure function F_2 as measured by H1 using different data samples and different methodsto recosntruct the kinematics. (*svx:* shifted vertex data; *nvx:* nominal vertex data; *sat:* satellite bunch data). The full error represents the statistical and systematic errors added in quadrature not taking into account the systematic uncertainty on the luminosity (see text).

corrected for higher order QED radiative contributions. This determined the one-photon exchange cross section which according to eq. 1 led to the values for $F_2(x, Q^2)$. Due to the different data sets available: nominal vertex data, "shifted vertex" data and "satellite data", which have different acceptances and use for a given Q^2, x point different parts of the detectors, cross checks could be made in kinematic regions of overlap.

A list of the main systematic errors taken into account:

- A potential miscalibration of the electron energy by 1.7% in the BEMC.
- A 5% scale error for the hadronic energy in the LAr calorimeter.
- A shift of up to 2 mrad for the electron polar angle.

- An overall error of 4% was assigned due to the imperfect description of the various efficiencies. A larger error of $5-10\%$ was added to account for the vertex reconstruction efficiency variation at large x.
- An error of up to 3% in the radiative corrections.
- The structure function dependence of the acceptance and bin size corrections which was controlled to better than 3%.
- The uncertainty due to photoproduction background was assumed to be smaller than 30% of the correction applied, i.e. smaller than 5%. This affects only the highest y bins at lower Q^2.

These systematic uncertainties affect differently the F_2 measurement done with different methods. The main contributions, however, are in both cases the energy and angle determination and the uncertainty in the vertex efficiency. More studies are ongoing in these fields and the total systematic error is expected to be reduced soon.

The results on F_2 from the different data samples and both kinematic reconstruction methods (e and Σ) were found to be in very good agreement with each other as shown in fig. 3. This allows to combine the different measurements to a unique F_2 shown in fig. 4. The points for $Q^2 \leq 8.5$ GeV^2 are obtained from the data sample with the shifted vertex, using the electron method for $y > 0.15$ and the Σ-method for $y < 0.15$. The points with $Q^2 > 8.5$ GeV^2 were obtained with the e-method from the main data sample with nominal interaction vertex. Which reconstruction method and data sample were used for each bin can also be seen in fig. 2.
The result in in good agreement with the published result of the 1993 data [1] and shows that the strong rise at low x persists also down to the lowest x and Q^2 values reached by analysis. The H1 preliminary measurement is also compared to different parametrizations: GRV 94 [5], MRSG and MRSA' [6]. GRV 94 and MRSA' give a reasonable description of the data while MRSG is slightly disfavoured at low Q^2. For $Q^2 \leq 5$ GeV^2 also the Donnachie-Landshoff (DOLA) parametrization is shown [7] which is based on Regge theory assuming a soft pomeron. It is visible now that this parametrization does not describe the data even at the lowest Q^2 accessible so far.

6. Conclusion

H1 has measured the proton structure function in a new kinematic domain of Q^2 down to 3.5 GeV^2 and $x < 10^{-4}$. The results show that F_2 is still rising towards low x even at lowest Q^2. A comparison with different parametrizations shows that perturbative QCD is in agreement with our measurement in the full kinematic region. The analysis of the '94 data is, however, still going on and an extension of the measurement to even lower values of x and Q^2 is expected soon [8].

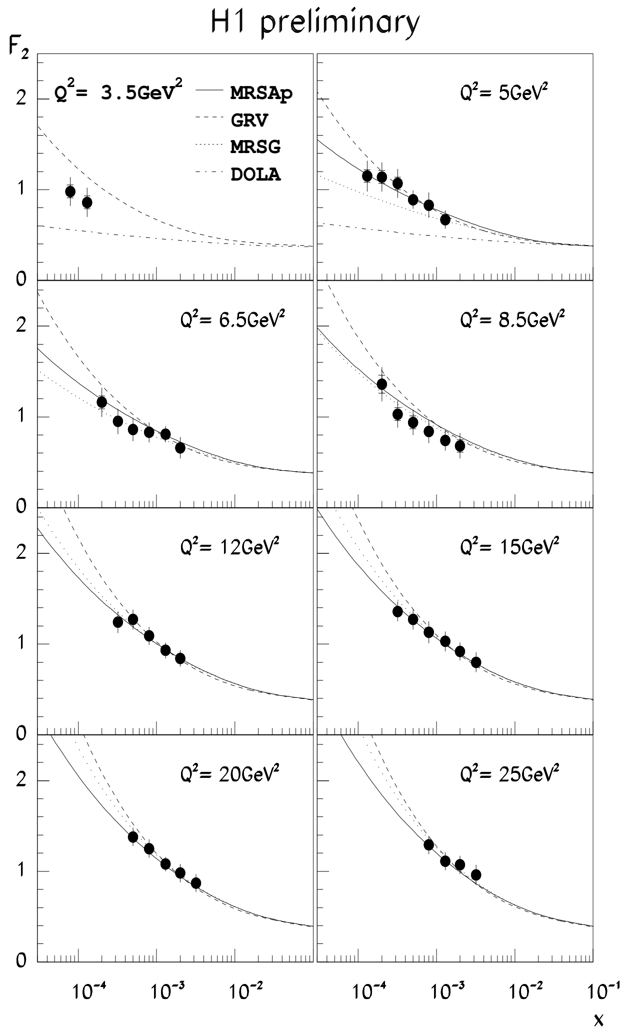

Figure 4. The structure function F_2 as measured by H1 compared to different parametrizations. The full error represents the statistical and systematic error added in quadraturenot taking into account the 1.5% systematic error on the luminostity measurement (4.5% for $Q^2 \leq 8.5$ GeV^2).

References

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