F_2 Measurements at ZEUS and Phenomenological Studies

R. Yoshida[a] for the ZEUS Collaboration

[a]Argonne National Laboratory,
9700 S. Cass Ave., Argonne IL 60439, USA

Phenomenological studies of the behavior of the proton structure function F_2 from the ZEUS 1994 and 1995 data are presented. The low-x behavior of sea quarks and gluons is further studied using an NLO QCD fit to the same data. Finally, a preliminary the measurement of F_2 in the range of Q^2 from 1.5 GeV^2 to 20000 GeV^2 from the ZEUS 1996 and 1997 data are presented.

1. INTRODUCTION

One of the striking results from the HERA collider is the rapid rise of the proton structure function F_2 at low x. The QCD interpretation of this data is that the density of the sea quarks and, by implication, that of the gluon is rising rapidly as the Bjorken variable x decreases. Many DGLAP QCD fits to the HERA data have been successfully made and show the expected rapid rise of the gluon. It has also been found that these QCD fits work quite well to a rather low Q^2 scale, of order 1 GeV^2.

Since the kinematic range of the ZEUS measurements increased dramatically in x (down to 10^{-6}) and Q^2 (down to 0.1 GeV^2) by the use of special detectors in 1995, it is interesting to try to see if the data can show a breakdown of the perturbative QCD interpretation as we probe lower in Q^2. This talk is based on a recent ZEUS paper [1], where a complete set of references can be also found.

2. PHENOMENOLOGICAL STUDIES OF F_2 AT LOW x

Figure 1 shows the measured F_2 at HERA down to Q^2 of 0.60 GeV^2 and x of 10^{-5}. F_2 is seen to rise more rapidly at low x than the Regge–based predictions (labeled DL), even at the lowest Q^2. In order to make a quantitative study of the x slope, the ZEUS and E665 F_2 data below x of 0.01, in bins of Q^2, were fit to the form const.$\times x^{-\lambda}$. In the Regge type models, the parameter λ corresponds to the intercept of the pomeron trajectory of about 0.08. In leading order BFKL, λ is predicted to be 0.5.

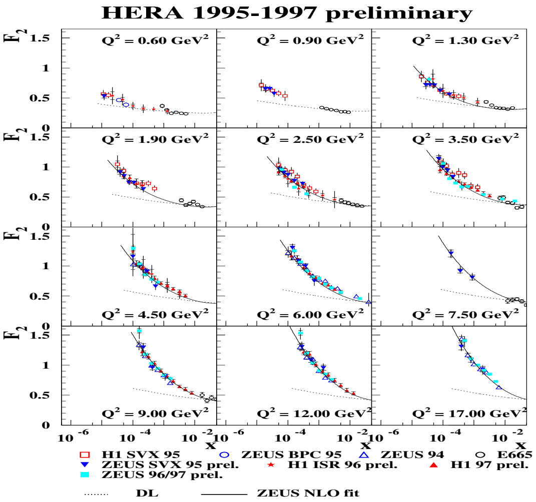

Figure 1. Recent HERA F_2 data at low Q^2. See text.

Figure 2 shows the results of the fit as a function of Q^2. Since the range in x of the available data in each Q^2 interval changes, due to the available kinematic range, the corresponding mean x for the measurement changes as a function of Q^2; the values of $\langle x \rangle$ are shown for each point at the top of the plot.

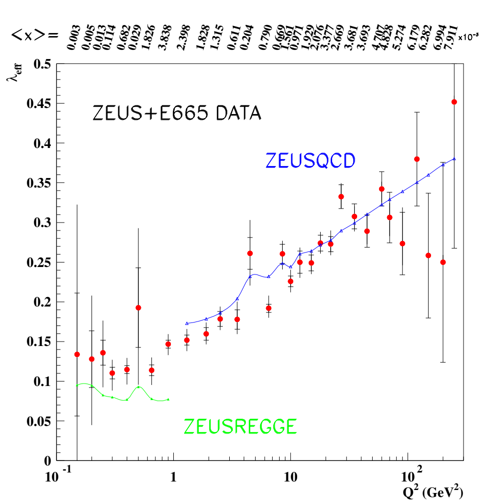

Figure 2. Results of the fits, in bins of Q^2, to F_2 from ZEUS and E665. See text.

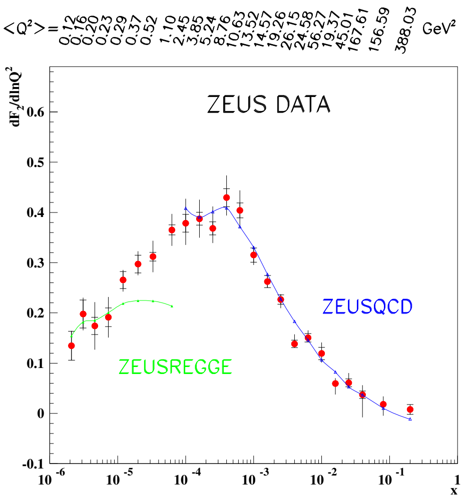

Figure 3. Results of straight line fits to ZEUS F_2 as a function of $\ln Q^2$. See text.

In the QCD interpretation of F_2, the structure function at low x mainly reflects the sea quark content. Thus Figure 2 can be interpreted as indicating the smooth decrease of the low x rise of the sea quarks.

Figure 3 shows the results of the fits of F_2 in bins of x to the form $a+b\ln Q^2$. As in the previous plot, the range of the fit in Q^2 changes at a given x, and the mean Q^2 for each x interval is shown at the top of the plot. There is an obvious turn over in the plot at x of around 3×10^{-4} and Q^2 of about 7 GeV^2. If the same procedure is used on the results of the fixed target experiments in the same range of Q^2 but at a x which is 2 orders of magnitude larger, no such turn over is observed. The slope continues to rise as Q^2 falls to below 1 GeV^2.

At Leading Order in QCD, $dF_2/d\ln Q^2$ at low x is roughly proportional to the gluon momentum density $xg(x,Q^2)$. Since the mean Q^2 at each x interval is falling as x becomes lower in Figure 3, the plot does not indicate any "turnover" in the gluon density as a function of x at a fixed Q^2. It does, however, show that the gluon density begins to fall rapidly at low x as a function of Q^2 below, about 7 GeV^2.

In summary, the study of the slopes of F_2 in x and Q^2 seems to indicate the sea quark distribution at low x which is smoothly falling with Q^2 on one hand and the gluon distribution which is falling rapidly with Q^2 below around 7 GeV^2. This seems to contradict a qualitative picture of the sea quarks being generated from gluons at low x. In order to study this further, we turn now to a DGLAP QCD fit with particular attention to the behavior at the lowest x and Q^2 range.

3. QCD FITS TO F_2 AT LOW Q^2

A DGLAP NLO QCD fit was made to the ZEUS F_2 data from 94 and 95, and the NMC and BCDMS data at $Q^2 > 1$ GeV^2 and $W^2 > 10$ GeV^2, where W is the virtual photon–proton center of mass energy.

The gluon, sea quark, and singlet distributions were parametrized in the form $Ax^\delta(1-x)^\eta\times$ (polynomial in $\sqrt{x}$), and the input valence u and d distributions were taken from the MRS(R2) distributions. The momentum sum rule was imposed giving 11 free parameters in the fit.

The fit describes the data well, and the resulting gluon distribution, xg, is shown in Figure 4. In the same figure, the sea quark distribution, $x\Sigma$, is also shown.

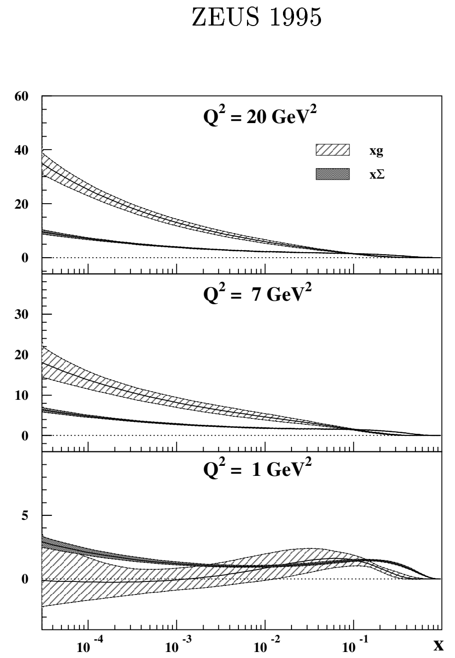

Figure 4. The gluon, xg, and the sea, $x\Sigma$, distributions from the ZEUS NLO QCD fit. See text.

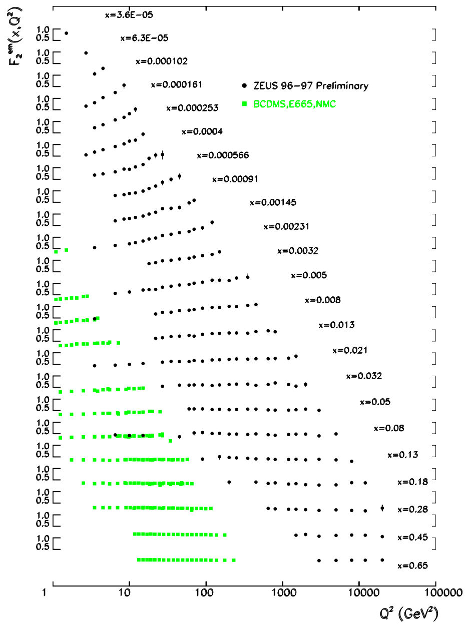

Figure 5. F_2^{em} as a function of Q^2. See text.

As can be seen, as Q^2 decreases, the gluon density falls more rapidly at low x than the sea quark density. At $Q^2 = 1$ GeV^2, the sea quarks are still rising at low x, whereas the gluon has become compatible with zero. These observations are in keeping with the expectation from the phenomenological studies of the F_2 slopes.

Other observations are: Although the gluon error band goes below zero at the lowest x and Q^2, the observables such as F_L and F_2^c remains positive. The basic conclusions are not changed if the minimum Q^2 of the data is raised to 4 GeV^2. The fit can be extended to ZEUS data down to Q^2 of 0.4 GeV^2, with no deterioration in the quality of the fit.

It is concluded that the NLO DGLAP fit to the currently available F_2 data does not break down, i.e., give a bad fit, even in the region where the formalism is suspect due to the very small value of the perturbative scale.

4. PRELIMINARY F_2 FROM 96–97 DATA

Approximately 27 pb^{-1} of e^+p data taken with the ZEUS detector in 1996 and 1997 are used for the extraction of the electromagnetic part of the proton structure function F_2^{em}[2]. Not all available data have been used for this preliminary result The double angle method was used to reconstruct the event kinematics.

The results are shown in Figure 5. The statistical errors are less than 2% below Q^2 of 100 GeV^2 and increases from 5 to about 15% above Q^2 of 800 GeV^2. The systematic errors are 3–4% except at high y where they grow to 12%.

REFERENCES

1. ZEUS Collaboration, Eur. Phys. J. **C7** (1999) 609.
2. ZEUS Collaboration, Paper 769 submitted to ICHEP98, Vancounver.