F_2^{P} AT LOW Q^2 AND THE TOTAL γP CROSS SECTION AT HERA

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New precise measurements of the neutral current cross section at HERA are presented in different Q^2 regimes. In the photoproduction limit the total γp cross section is found to be in agreement with the universal soft Pomeron prediction. At medium scales $1.5 \lesssim Q^2 \lesssim 150$ GeV^2 both the F_2 and the F_L structure functions are determined. These data are well described by NLO pQCD. The gluon density in the proton has been extracted from the scaling violation of F_2 at low x. The transition between the two regimes occurs at around $Q^2 \simeq 1$ GeV^2.

1 Introduction

Half a century of the extensive studies of strong interactions resulted in two different approaches to the problem: Reggeon field theory (RFT)[1] and QCD. RFT, the S-matrix theory based on the most general physical principles, has proven to be very successful in describing soft peripheral processes ($t/s \ll 1$) at high energies ($s \to \infty$). There is however no microscopic picture of underlying dynamics in it. On the other hand QCD, being *the* theory of strong interactions, has technical problems in the non-perturbative regime. pQCD is applicable to hard processes only. Lepton-proton scattering experiments at HERA have the unique possibility to contribute to the successful merging of those two approaches by performing the scan over the large available range of the photon virtuality, Q^2, and studying the interplay of short and long distance physics.

In this talk the following questions are discussed, using high statistics Neutral Current (NC) data recorded in the years 1994 to 1997 with the H1 and ZEUS apparatus in e^+p collisions at $\sqrt{s} = 300$ GeV:

1. How far up in Q^2 can one get with Regge theory starting from photoproduction?
2. How far down in Q^2 can one go with pQCD?
3. Where in Q^2 is the transition region?

2 Photoproduction limit

The total γp cross section is measured at HERA by detecting scattered positrons under very small angles $\theta < 5$ mrad with respect to the incoming e^+ beam, in a special calorimeter installed in the tunnel. This ensures $Q^2 < 0.02$ GeV^2 (with the average value of 10^{-4} GeV^2) and justifies the use of pure transverse photon flux in the equivalent photon approximation relating the ep cross section with $\sigma_{\mathrm{tot}}^{\gamma p}$. Major systematics is approximately equally shared between the positron detector acceptance uncertainty and the precision of the hadronic final state modelling.

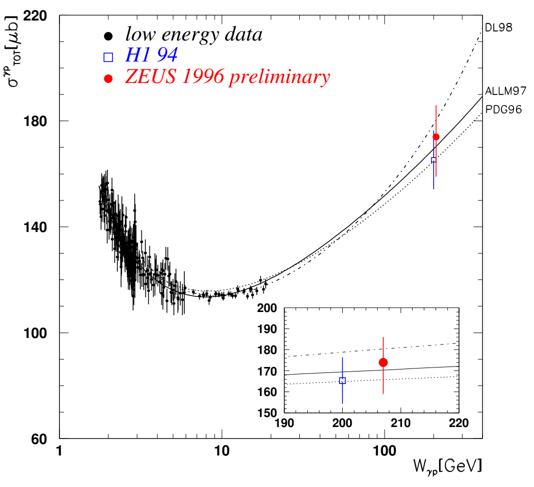


Figure 1. The total photon-proton cross section as a function of centre-of-mass energy. The insert magnifies HERA results.

New measurement of the total γp cross section at average centre-of-mass energy $W_{\gamma p} = 207$ GeV has been presented by the ZEUS collaboration [2]. Their result of $\sigma_{\rm tot}^{\gamma p} = 172 \pm 1(stat.)^{+13}_{-15}(syst.)$ μb is shown in Fig. 1 together with the published H1 measurement [3] and the low-energy data. Also shown are three Regge motivated parameterizations [4]. In two of them the high energy behavior of $\sigma_{\rm tot}^{\gamma p}$ is driven by the universal soft Pomeron, while the DL98 parameterization has additionally a hard Pomeron term.

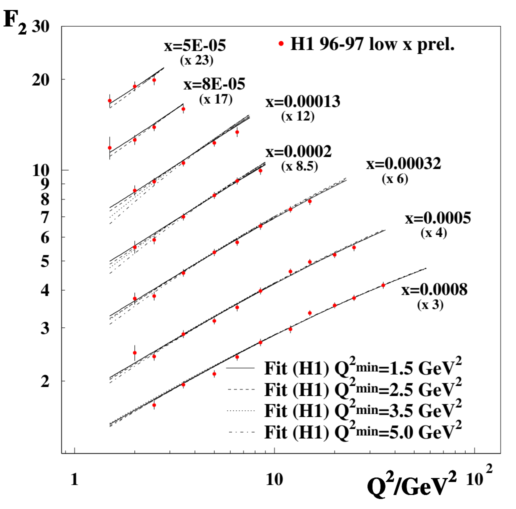
3 NC cross section in DIS regime

New measurements of the deep inelastic NC cross section are available from both the H1 [5] and ZEUS [6] collaborations. High statistics data span the kinematic region of $1.5 \leq Q^2 \leq 150$ GeV^2 and Bjorken-x values $0.00003 \leq x \leq 0.2$. Using improved detection capabilities and increased HERA luminosity a high precision of typically 3% is achieved. This allowed, for the first time, to perform NLO QCD analysis of the inclusive cross section measurements using H1 data alone [5]. The gluon density at low x has been determined from the large positive scaling violation of F_2 (see Fig. 2). It was found, that NLO QCD fit describes all low x data well. Some dependence is observed however of the fit parameters on the value of Q^2_{min} – the minimum Q^2 of the H1 data used in the fit. This is directly reflected in the steepness of the gluon density, as seen in Fig. 2,b.

In order to reduce such ‘flexibility’ of the QCD fit additional constraints may be imposed. Potentially powerful is the longitudinal structure function F_L, which contains independent information about gluon distribution. $F_L(x, Q^2)$ as determined using two different methods [5] is shown in Fig. 3 together with the fixed target results. The increase of $F_L(x, Q^2)$ towards low x reflects the rise of the gluon momentum distribution and is consistently described by NLO QCD fit.

4 Transition region: closing the gap

To summarize, HERA has verified that RFT works in photoproduction ($\sigma_{\rm tot}^{\gamma p}$). New precision results also demonstrate that in DIS regime pQCD describes inclusive NC cross section (F_2, F_L). But where is the transition between the two? And how does it happen?



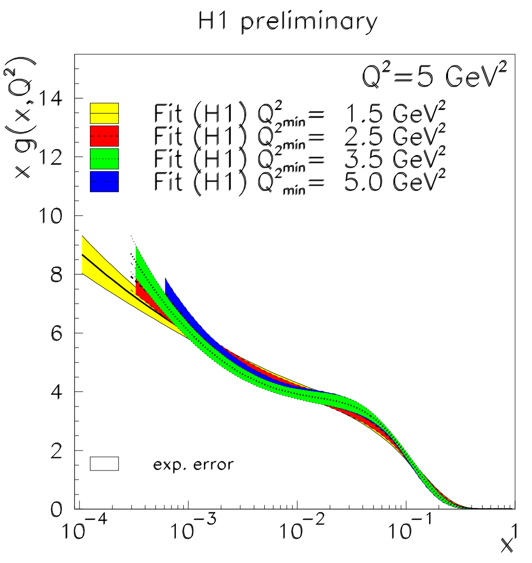


Figure 2. Effect of the Q^2_{min} cut applied in DGLAP QCD fit to the H1 data on a) the structure function F_2 at low Q^2 and b) the gluon distribution at $Q^2 = 5$ GeV^2.

New low Q^2 ZEUS data [7] at $0.045 \leq Q^2 \leq 0.65$ GeV^2 almost completely closed the gap

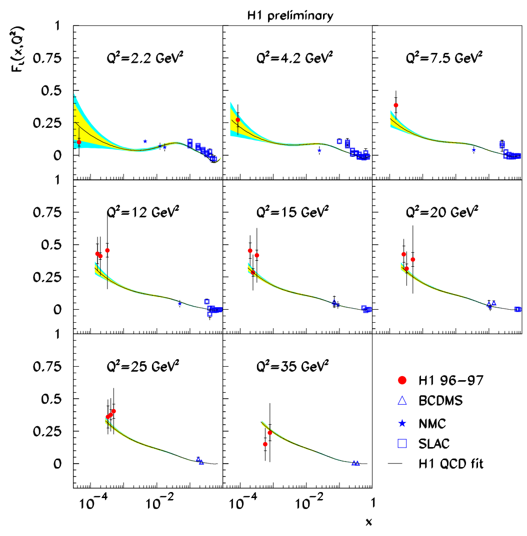


Figure 3. The longitudinal structure function $F_L(x, Q^2)$. The error bands are due to the experimental (inner) and model (outer) uncertainty of the F_L calculation using NLO QCD fit to the H1 data for $y < 0.35$ and $Q^2 > 3.5$ GeV^2.

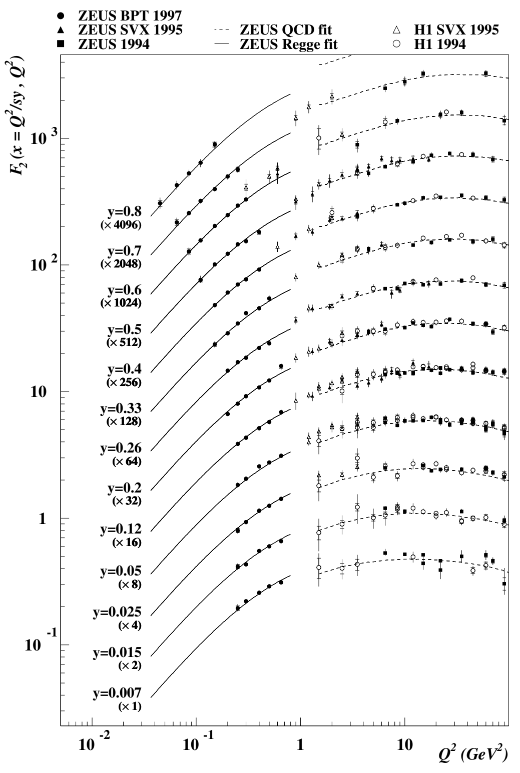


Figure 4. Measured $F_2(Q^2)$ in bins of y.

between photoproduction and DIS. They are shown in Fig. 4 together with previous HERA measurements at higher Q^2. It is seen that low Q^2 points are described adequately by the Regge motivated fit (solid lines) while pQCD fits the data above 1.5 GeV^2 (dashed lines). The data exhibit a smooth transition at around $Q^2 \approx 1$ GeV^2 while the matching between the two theoretical fits is not perfect yet.

5 Conclusions

New precise HERA data have been used to study how the properties of strong interactions evolves with Q^2. In the photoproduction limit $\sigma_{\rm tot}^{\gamma p}$ exhibits mild rise similar to that of hadron-hadron scattering. It is well described by the conventional Regge theory with universal soft Pomeron. Regge parameterization also describes the data in the low $Q^2 < 0.7$ GeV^2 region. In DIS regime NLO QCD is able to describe F_2 data all the way down to $Q^2 \simeq 1.5$ GeV^2. A smooth transition from partonic to hadronic degrees of freedom occurs at around $Q^2 \simeq 1$ GeV^2. The details of the underlying dynamics is still a challenge for theory.

References

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