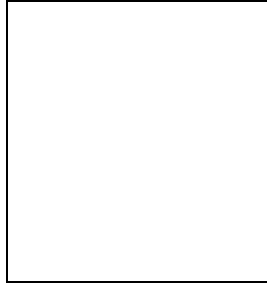


STRUCTURE FUNCTIONS AND PARTON DISTRIBUTION FUNCTIONS AT THE HERA ep COLLIDER

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Recent results on structure functions and parton distribution functions at HERA are presented. Results on the measurements of the structure functions F_2 , F_L and F_3 will be covered, as well as the results of the most recent QCD fits to determine the PDFs of the proton.

1 Introduction

At HERA, 27.5GeV electrons are collided with 920GeV protons^a. ZEUS¹ and H1² are the two general purpose detectors which operate on the HERA ring. The $e^\pm p$ scattering process is dominated by neutral current (NC) virtual γ exchange with charged current (CC) and NC Z_0 processes also providing a contribution at large scales. Events for which the virtuality of the exchanged photon, $Q^2 > 1\text{GeV}^2$ are classified as *Deep Inelastic Scattering* (DIS). Events for which $Q^2 < 1\text{GeV}^2$, whereby the exchanged photon is almost real, are classified as *Photo-production* (γp). Measurement of the $e^\pm p$ differential cross section (with respect to the bjorken scaling variable, x , and Q^2) yields information about the proton structure functions F_2, F_L and F_3 . Further, performing QCD fits to HERA cross section data allows the proton *Parton Distribution Functions* (PDFs) to be determined. Although the Q^2 dependence of the PDFs is calculable using the DGLAP^{3,4,5,6} formalism of pQCD, the x dependence has to be determined empirically. HERA PDFs extrapolate into the LHC region and their accurate determination are crucial to calculations of new physics measurements at the LHC.

^a 820GeV before and including 1997

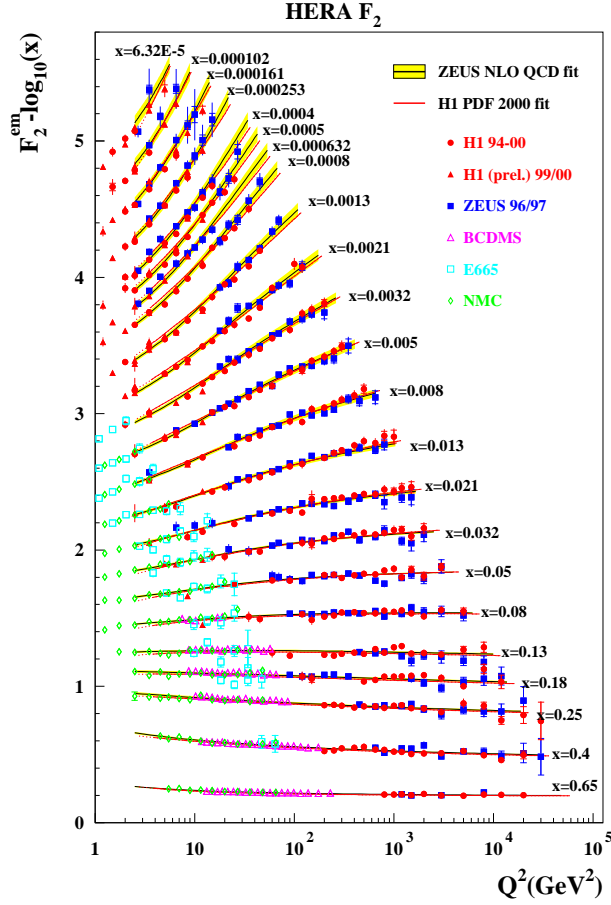


Figure 1: The most up-to-date measurements of F_2 from the H1 and ZEUS collaborations. Also shown are various heavy target F_2 results and the comparison of the measured structure functions with the H1 and ZEUS NLO PDF fits.

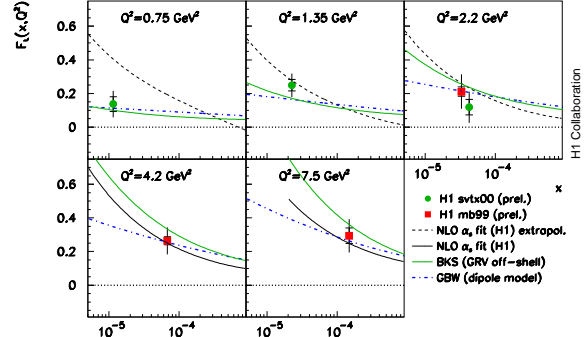


Figure 2: F_L measurements from the H1 collaboration using their 'shape method' for extraction

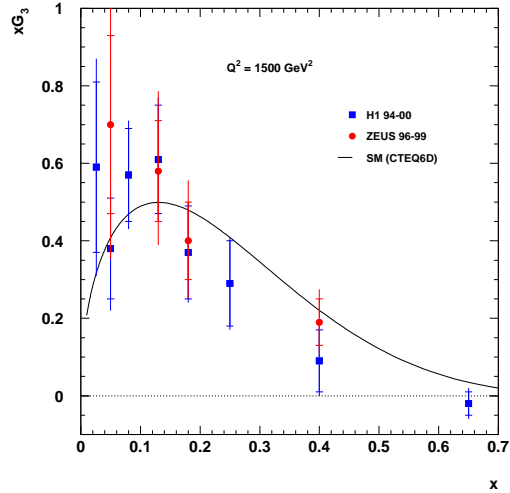


Figure 3: F_3 measurements from the H1 and ZEUS collaborations.

2 Measurements of the structure functions: F_2, F_L and F_3

2.1 Precision F_2 measurements

F_2 provides the dominant contribution to the neutral current $e^\pm p$ cross section. It is determined directly by measuring the so called reduced cross section. Both ZEUS and H1 have measured F_2 to a typical accuracy of 2 – 3%, across a broad kinematic range (approximately, 0.00001 – 1 in x and 1 – 30000 GeV^2 in Q^2) (see figure 1)⁷. F_2 is directly sensitive to the sum of all the quark and anti-quark distributions inside the proton. It is however, only indirectly sensitive to the gluon distribution via the phenomenon of scaling violations. The F_2 data is well described by NLO pQCD.

2.2 F_L measurements

Various measurements of F_L have been made at HERA^{8,9}, predominantly by the H1 collaboration. H1⁸ have successfully used a parameterised fitting method, called the 'shape method' to extract F_L points, in a variety of Q^2 bins, from measurements of the reduced cross-section.

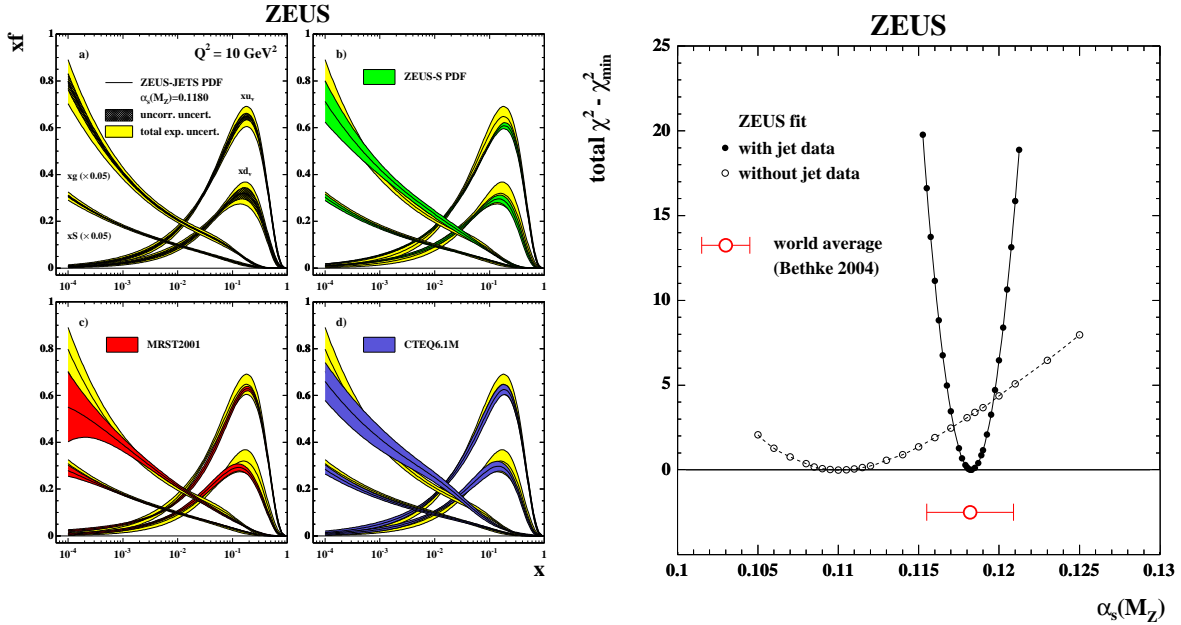


Figure 4: Comparison of the ZEUS-Jets PDFs with Figure 5: χ^2 profiles of the ZEUS fits with and without the inclusion of jet data in the fitted data set. (a) The H1 fits (b) The previous ZEUS fits (c) The MRST fits (d) The CTEQ fits

Some of the results of these measurements are shown in figure 2. At presently reached accuracy the F_L data is well described by NLO pQCD.

2.3 F_3 measurements

At high Q^2 the NC cross sections for electrons and positrons deviate. The difference between the cross sections is proportional to xF_3 and allows a direct measurement of this structure function to be made. The rather large errors on the extracted xF_3 are dominated by the statistical error of the electron sample. HERA has, to date, already built up significantly more electron luminosity which will allow much more precise xF_3 measurements to be made in the future. The xF_3 results from H1 and ZEUS are shown in figure 3.

3 NLO QCD fits

At ZEUS and H1, HERA data is used (along with external world data in the latter case) to determine the proton PDFs. The general method involves parametrising the PDFs at some input scale, Q_0^2 . These are then evolved to arbitrary Q^2 values using the DGLAP formalism and the resulting PDFs are used to calculate cross sections and compared to data. The starting parameters of the input distributions are then iteratively changed until a best fit is found.

In the past, global world F_2 data has been used in the fits. Valence quark distributions have been constrained by heavy target data (νFe and μD). This has led to a poor α_s and gluon extraction as the inclusive cross sections are only indirectly sensitive to the gluon via scaling violations.

3.1 ZEUS-Jets fit

The most recent fit to be performed at HERA is that which has been made by ZEUS, the so called ZEUS-Jets fit¹⁰. In the ZEUS-Jets fit no external experimental data has been used, other than some minimal information which is used to fix some of the initial parameters. High Q^2 NC and CC data constrain the valence quark distributions, removing the necessity for fixed

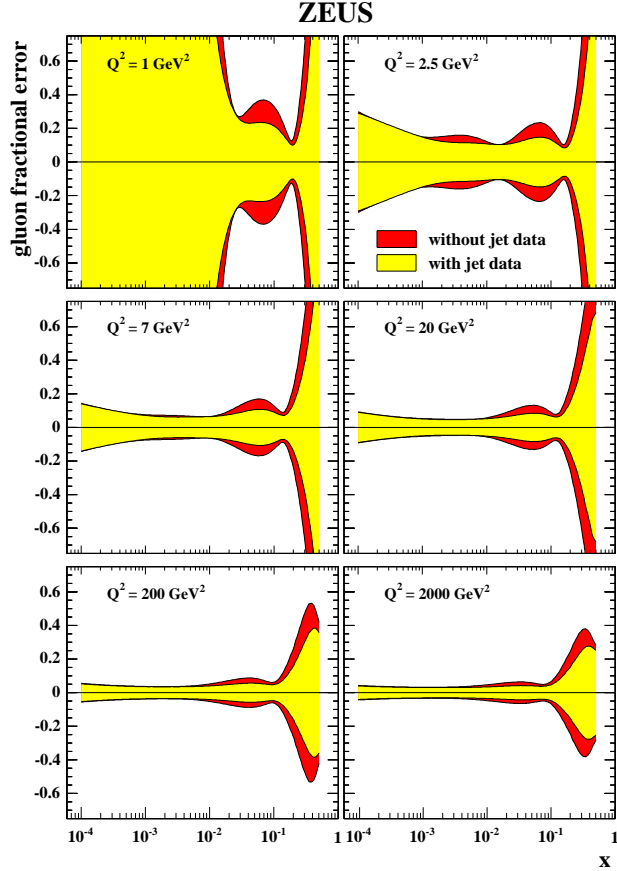


Figure 6: Fractional uncertainty of the extracted gluon distribution from the ZEUS-Jets fit at a range of Q^2 values. The inclusion of jet data in the fitted data set has let to a clear improvement in the precision of the extracted PDF.

4 Conclusion

HERA continues to produce important research on proton structure and provide a stringent testing ground for QCD. PDFs and α_s can now be extracted with minimal data from external experiments. A rigorous inclusion of jet data in to the fitted data sets has led to a significantly more precise gluon PDF and α_s to be extracted from HERA data alone. More generally, the HERA II program is well underway, which will give rise to evermore statistics enriched data sets which in turn will give rise to both new and more precise existing cross sections, thus paving the way for more accurate structure function, PDF and α_s measurements.

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^bThe running period up to 1997

target data to be included in the fits. Further, exclusive (jet) cross sections have been included in the fitted data set for the first time. More specifically, γp dijet data¹² and DIS inclusive jet data¹¹ from HERA \bar{p} have been included. This has led to a considerable improvement in the precision of the extracted gluon PDF. This is illustrated in figure 6. The PDFs, obtained from the ZEUS-Jets fit, are shown in figure 4.

The values of α_s extracted from the ZEUS and H1 fits are given below.

$$\alpha_s = 0.1150 \pm 0.0017(\text{exp}) \pm 0.0007(\text{model}) \quad (1)$$

for the most recent H1 fit and,

$$\alpha_s = 0.1183 \pm 0.0028(\text{exp}) \pm 0.0008(\text{model}) \quad (2)$$

for the ZEUS-Jets fit. Both values of α_s are characterised by a scale uncertainty of about ± 0.005 .

Evidence of the effect that the jet data has in constraining the extracted value of α_s in the ZEUS-Jets fit can be seen from figure 5. This figure shows the χ^2 profile of the ZEUS fit when the value of α_s is varied about its extracted value, with and without the inclusion of jet data in the fitted data set. A much tighter χ^2 profile is seen with the inclusion of the jet data, corresponding to a more constrained extracted α_s .

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