Parton distribution functions and QCD fitting to F_2 at HERA

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Determination of the gluon density, strong coupling constant and valence quark densities from QCD analysis of the HERA data are presented.

1 Introduction

In this communication, results of QCD analysis applied to HERA data are reported. Covering more than four order of magnitude in x and Q^2, these data are playing a major role in the determination of the parton density functions (pdfs).

Two different kinematic regions are considered: the medium Q^2 range $\mathcal{O}(1\,\mathrm{GeV}^2) < Q^2 < \mathcal{O}(100\,\mathrm{GeV}^2)$ and the high Q^2 range $\mathcal{O}(100\,\mathrm{GeV}^2) < Q^2 < \mathcal{O}(10^4\,\mathrm{GeV}^2)$. In the former region, ep interactions are dominated by the one photon exchange while at high Q^2, Z^0 and W exchange also contribute.

The gluon density and the strong coupling constant α_s are determined by analysing the medium Q^2 data [1] and valence quark densities are obtained thanks to the high Q^2 data [2].

Typical statistical and systematic uncertainties of the medium Q^2 range data are presently at the percent and a few percents levels respectively. At high Q^2, the precision is still dominated by the statistics.

In section 2 the QCD analysis are presented and results on xg and α_s are shown. The determination of the pdfs is described in section 3.

2 Determination of xg and α_s

Two different but complementary approaches are used by the H1 and ZEUS Collaborations. In both cases the NLO DGLAP equations [3] are solved numerically. In H1 the fixed flavour scheme [4] is used to describe the heavy quarks production so that only data of the medium Q^2 region enter the fits. In ZEUS a variable flavour scheme [5] has been adopted and thus both medium and high Q^2 regions enter the fits.

In the H1 fit, only proton target data (H1 and BCDMS [6]) are considered. Only the gluon density, the singlet and non-singlet quark densities are then parameterised. In the ZEUS fit, proton, Deuterium and Iron target data (ZEUS, BCDMS, NMC [7], CCFR [8], E665 [9]) are used. The sea quark, u_v, d_v, $(\bar{u}-\bar{d})$ and the gluon densities are parameterised.

In both fits the following parameterisation form is used

$$xf(x) = Ax^B(1-x)^C(1+Dx+E\sqrt{x}) \tag{1}$$

where A, B, C, D, E are unknown parameters. Sum rule and counting rules are further applied. One of the main difference between the ZEUS and H1 fit is the number of parameters used for xg, $D=E=0$ for ZEUS and let free for H1. In all, 11 and 13 free parameters are introduced by ZEUS and H1 respectively.

Experimental uncertainties are consistently taken into account and error propagations are performed according to ref. [10].

Results of the best fits, where α_s is let free give

$$\begin{aligned} \mathrm{H1}\ &: \alpha_s(M_Z) = 0.1150 \pm 0.0017(exp) \pm 0.0012(model) \\ \mathrm{ZEUS}\ &: \alpha_s(M_Z) = 0.1172 \pm 0.0055 \end{aligned}$$

where the model uncertainty is estimated by varying all the fit ingredients: charm quark mass, starting scale of the DGLAP evolution, Q^2 rejection cut on data, data samples (NMC in/out), number of parameters for the pdfs. The value are competitive with other determinations and consistent with the world average [11]. However not including in the above H1 and ZEUS results is the renormalisation and factorisation scale uncertainties. They amount to 0.05 and are then the dominant source of uncertainty. It is to mention that these results are significantly higher than the former determination using BCDMS-SLAC data [12]. This is essentially due to the presence of the very precise small-x HERA data which constrain xg.

From these fits, the gluon density is determined and the error bands are computed. Results are shown in fig. 1. The relative accuracy reaches 3% at $Q^2 = 20$ GeV^2 and $x = 10^{-3}$ and is already dominated by the model uncertainties. Reasonable agreement is observed between the H1 and ZEUS fits. The difference between the central values comes from the number of parameters used to parameterise xg. The statistical significance of this difference is presently under discussion.

3 Constraints on the valence quark densities

From the ZEUS fit one can naturally extract the valence and sea quark. Results are shown in fig. 1. An overall good agreement is observed with the recent MRS [13] and CTEQ [14] parameterisations.

Let us mention again that d_v and the non strange sea quarks are essentially determined by the Deuterium and Iron target data in this fit. However, using the medium and high Q^2 charged current and neutral current cross sections measured with electron and positron beams one can also perform a fit to the HERA data alone. In this fit, the number of observable is enough to constrain the valence quark at high x and the sea quarks at small x. With this kind of analysis, nuclear effects are avoided.

Preliminary results are shown in fig. 2 for u_v and d_v. As expected u_v is much better determined than d_v but most of all, one can see that d_v is already constrained with a reasonable accuracy.

4 Summary

Determinations of pdfs and α_s from QCD fits including HERA data have been reported.

Accuracies on α_s and xg are already limited by the theoretical uncertainties. NNLO calculations are needed to increase the precision of these measurements.

Significant constraints on the valence quarks from a fit to HERA data alone have been obtained. This open a new field of global fits avoiding the nuclear target data.

With the HERA upgrade, the luminosity will be increased by a factor four and lepton beams will be longitudinally polarised. New and more accurate measurements will then be available to perform a precise determination of the pdfs inside the proton.

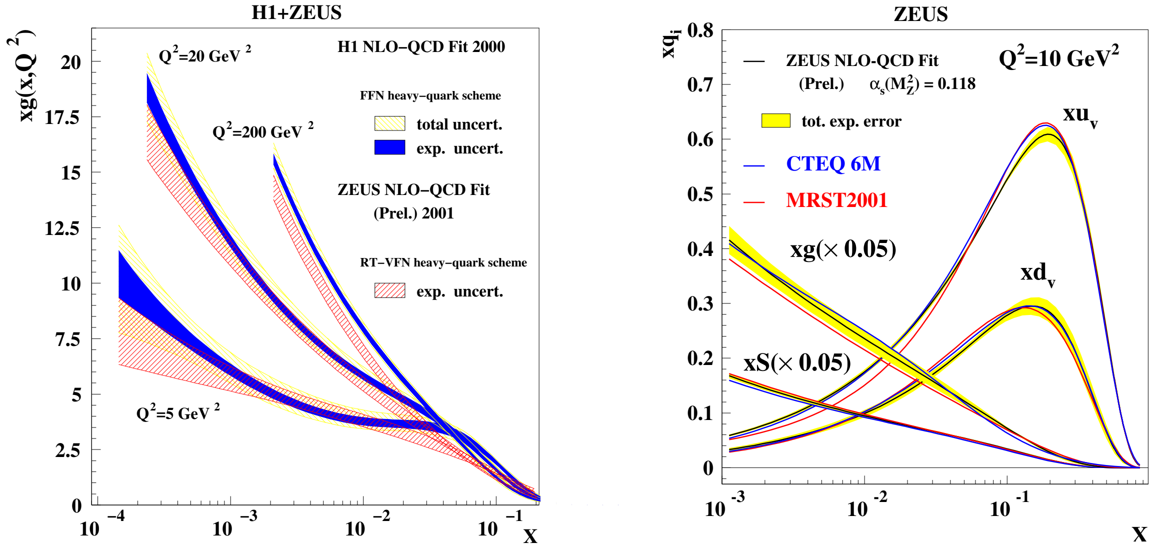

Figure 1: Left: error bands on xg as function of x for different Q^2 values. Results of H1 and ZEUS are shown. Right: error bands on the parton densities extracted from the ZEUS fit.

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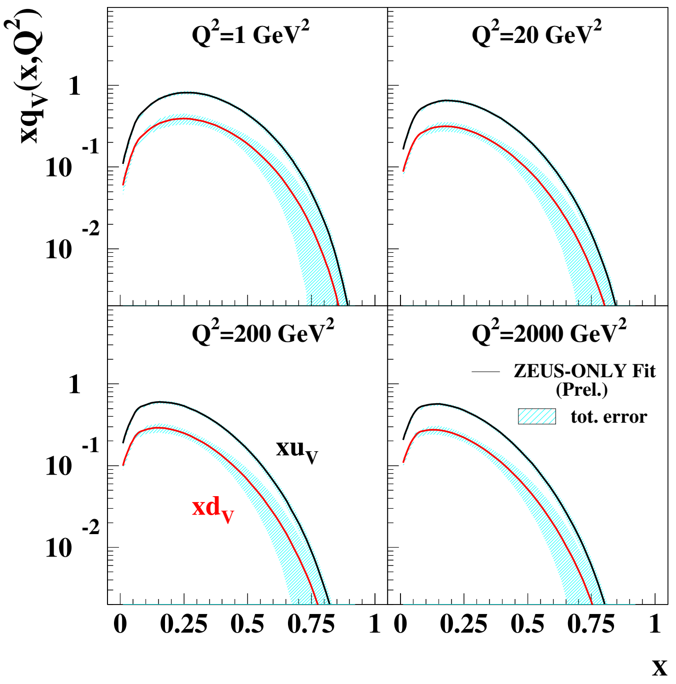

Figure 2: Results of a fit to the ZEUS data alone. u_v and d_v densities are shown, together with error bands, for different values of Q^2 as function of x.