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New fits of the unintegrated gluon density using the high precision HERA data

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A new fit of the unintegrated gluon density has been performed to the most recent F_2 data from H1 and ZEUS. The fits have been carried out by using the CASCADE Monte Carlo generator and the fitting program PROFFIT. The increased precision of the new HERA data gives significantly harder restrictions to the fits, compared to the existing uPDFs, which were fitted to old HERA data. In order to improve the description of the new data additional freedom for the gluon has to be introduced in the gluon parameterization. The fitting approach used is based on describing the parameter dependence analytically before the fits are performed. This allows for very fast and flexible fits. In addition the different error sources of the data are treated in the fit.

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1. Introduction

The substructure of the proton is parameterized by parton density functions (PDFs). By construction the conventional parton density functions are independent of the transverse momentum of the partons in the hadron, k_t. This is sufficient when describing inclusive quantities such as the proton structure function, F_2. However, for a correct description of exclusive final states it is necessary to treat the dependence of the transverse momentum of the partons which take part in the reaction. This can be done by using unintegrated PDFs, which take k_t into consideration from start of the interaction.

The parameters in the uPDFs have to be determined by fits to data. In this proceedings the focus is on the determination of the parameters in the x-dependent part of the uPDF, where x is the fractional momentum of the proton carried by the parton. This is done by using the CASCADE Monte Carlo program [1], which uses the CCFM evolution equation to evolve the starting distribution for the uPDF to higher scales by emissions of gluons. The generation of single MC events is not used in these fits. Instead the MC program calculates F_2 at values of the Bjorken scaling variable, x_{Bj}, and photon virtualities, Q^2. The uPDFs are, for the first time, fitted to the new combined F_2-data from H1 and ZEUS [2].

2. The Unintegrated Gluon Density

The ansatz for the starting distribution of the unintegrated gluon density is parameterised as

$$A_0(x,k_t) = Nx^{-B}(1-x)^C(1-Dx)\exp{(k_t-\mu)^2/\sigma^2} \tag{2.1}$$

where x is the longitudinal momentum fraction of the proton carried by the gluon and k_t the gluon transverse momentum. Here the normalisation, N, the small x behavior, B, and the parameter D are determined. The rest of the parameters are fixed at the values: $C = 4$, $\mu = 0$ $\sigma = 1$. The starting distribution is evolved to higher scales by gluon emissions according to the CCFM evolution equation which impose angular ordering of the emitted gluons.

3. The Fitting Method

Here only a brief overview of the fitting approach is given, while a more detailed description can be found in [3]. The fit program PROFFIT, implements the approach together with a treatment of the errors of the data and the MC. The original method was used the first time in [4], and later also in [5].

In the first step of the fitting procedure a grid of MC predictions is build up in the parameter space $(p_1, p_2, \ldots, p_n)$ for each of the observables. Then, the MC grid is used to describe the parameter-observable space analytically, by fitting a polynomial to the parameter grid. In order to account for correlations between parameters the form of the polynomial has to be of at least second order. In the presented fit a third order polynomial is used, and the parameter space is well described.

Having determined the polynomial describing the parameter space, one can fit the parameters $p_1, p_2, \ldots$. This is done by minimizing the χ^2 between the polynomial prediction and the data. We use the χ^2 definition suggested by the CTEQ group in [6], which correctly treats the correlated and uncorrelated systematic errors of the measurement. In addition also the errors of the polynomial predictions are taken into account. These are calculated from the individual errors of the fitted polynomial coefficients by using the covariance matrix derived in the first step of the fitting procedure.

The method is very time efficient in particular since the MC grid points are generated simultaneously and instead of fitting MC to data, a fit of the polynomials is performed, which is much faster then running the MC subsequently. The method also allows for very fast refitting if one, for example, wants to study the exclusion of some experimental data points or use different starting values in the fit.

4. The fits

The original ansatz for the starting distribution is Eq. 2.1 with $D = 0$. It gives $\chi^2/\mathrm{ndf} = 2$ when fitting the old H1 F_2 data [7] in the range $x_{Bj} < 0.005, Q^2 > 4.5$ GeV^2 with the minimum $N = 0.81 \pm 0.03$, $B = 0.030 \pm 0.006$[3]. However, when the same starting distribution is used to fit the new combined HERA F_2 data [2] in the same kinematic range the best fit is $N = 0.83 \pm 0.02$ and $B = 0.017 \pm 0.003$ with $\chi^2/\mathrm{ndf} = 5.1$. It is worth noting that the minima for the two fits are very close, while the χ^2/ndf differs significantly. As expected, an increased precision of the data requires a higher accuracy of the model.

In [3] it is shown that by introducing the extra factor $(1 - Dx)$ in the starting distribution (Eq. 2.1) and in the fit, the description of the data is improved. The new combined HERA F_2 data can be described in the range $0.0001 < x_{Bj} < 0.005$, $2.0 < Q^2 < 50$ GeV^2 with $\chi^2/\mathrm{ndf} = 186.6/85 = 2.2$. The minimum is $N = 0.47 \pm 0.3$, $B = 0.11 \pm 0.01$, $D = -6.9 \pm 0.9$. Although still not a perfect fit, it is a clear improvement. As seen in Fig. 1 where the gluon density is drawn as a function of x, the new parametrisation of the uPDF gives a more pronounced gluon at low and high x. In Fig. 2 the data is compared to CASCADE using the fitted uPDF.

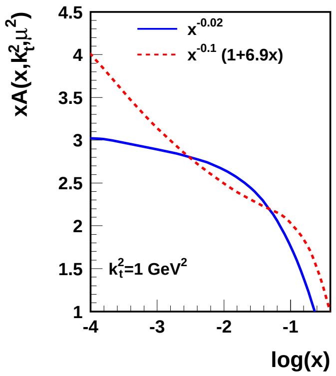

Figure 1: The uPDF as a function of the fractional proton momentum x, for fixed value of $k_t = 1$ GeV.

5. Summary and Conclusion

For the first time the new combined HERA data from H1 and ZEUS were used to determine the unintegrated gluon density using the CASCADE MC generator [1] and the fit program

PROFFIT [3]. The increased precision of the new HERA data implies significantly harder restrictions to the starting distribution of the uPDF, compared to what the old HERA data did. With a new parametrisation of the starting distribution a $\chi^2/\mathrm{ndf} \sim 2$ can be obtained for the range $0.0001 < x_{Bj} < 0.005$, $2.0 < Q^2 < 50\ \mathrm{GeV}^2$.

Given the simplicity of the model (using only gluons which are characterised by 3 parameters in the starting distribution) the results are quite satisfactory. The extension to larger Q^2 and to larger x requires the inclusion of quark contributions, which are foreseen for the future. Also interesting to investigate are the different forms of the non-Sudakov form factor and the scale of the running coupling [8].

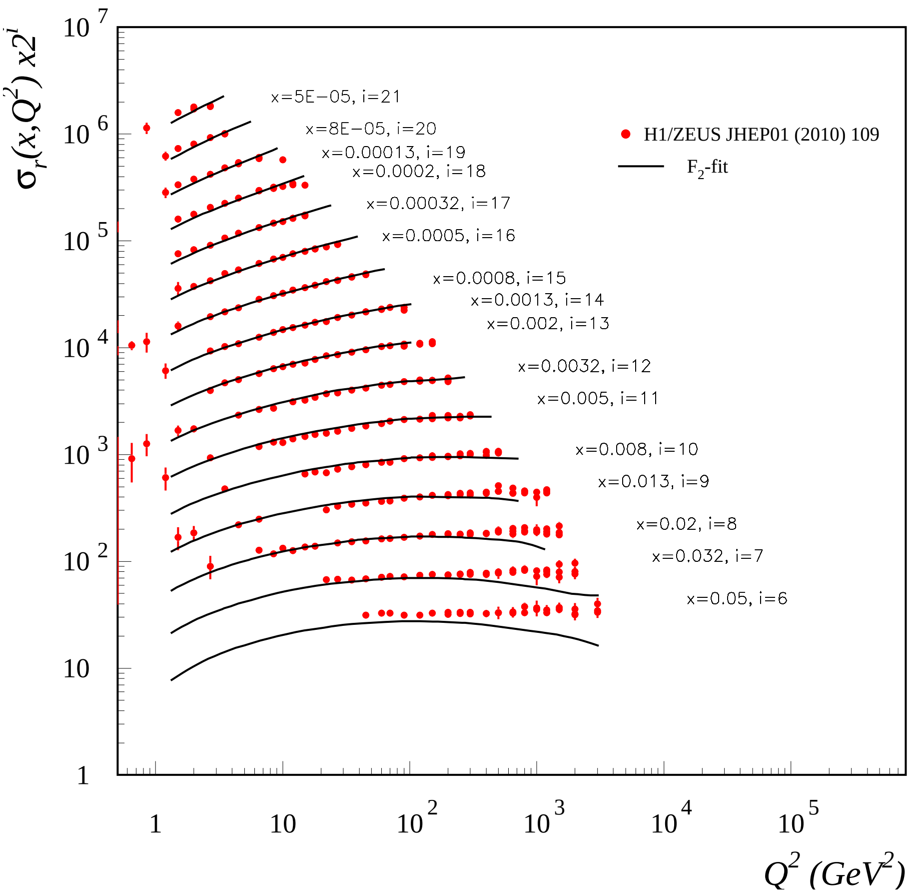

Figure 2: Comparison between data and predictions of the CASCADE MC generator run with the best fitted uPDF.

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