Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

TEST OF NLO BFKL KERNELS USING THE PROTON STRUCTURE FUNCTION F_2

CHRISTOPHE ROYON
DSM-DAPNIA-SPP, CEA Saclay
F91 191 Gif-sur-Yvette cedex, France
E-mail: royon@hep.saclay.cea.fr

We propose a new method to test the resummation schemes of the next-to-leading order (NLO) BFKL kernels using the proton structure function F_2 measured at HERA.

1 Introduction

The Balitsky Fadin Kuraev Lipatov (BFKL) evolution equation [1], based on the summation of leading logarithms of energy in the perturbative QCD expansion gives valuable tools for the investigation of deep inelastic scattering at small x_{Bj}. It was found recently that the NLO corrections to the BFKL equations [2] are quite large and they overshoot the expected phenomenological effect. However, it was realized [3] that the main problem comes from the existence of spurious singularities which are cancelled by an appropriate resummation at all orders of the perturbative expansion, as required by the QCD renormalization group. Indeed, various resummation schemes have been proposed for the NLO BFKL kernels [3,4] and we present in this paper a method to test the (resummed) BFKL predictions using the proton structure functions measured by the H1 and ZEUS collaborations at HERA.

2 BFKL prediction in Mellin space

The formulation of the proton structure functions in the leading order (LO) BFKL approximation can be expressed as follows [5]:

$$\begin{pmatrix} F_T \\ F_L \\ G \end{pmatrix} (x_{Bj}, Q^2) = \int \frac{d\gamma}{2i\pi} \left(\frac{Q^2}{Q_0^2} \right)^{\gamma} e^{\frac{\alpha_s N_c}{\pi} \chi^{LO}(\gamma) \ln(1/x_{Bj})} \begin{pmatrix} h_T(\gamma) \\ h_L(\gamma) \\ 1 \end{pmatrix} \Omega(\gamma) \qquad (1)$$

where the BFKL kernel is : $\chi^{LO}(\gamma) = 2\psi(1) - \psi(\gamma) - \psi(1-\gamma)$. In formula (1), F_T, F_L and G represents respectively the transverse, longitudinal and gluon structure functions ; α_s is the fixed coupling constant at leading order; $\Omega(\gamma)$ is the non-perturbative coupling to the proton and $h_T(\gamma)$ and $h_L(\gamma)$ correspond to the perturbative couplings to the photon (impact factors). The Mellin transform of relation (1) leads to a series of poles in j. Retaining the right most pole $\gamma^*(j)$, two model independent predictions can be drawn:

$$\frac{\partial \ln \tilde{F}_2(j,Q^2)}{\partial \ln Q^2} = \gamma^*(j) \tag{2}$$

$$\chi^{LO}(\gamma^*(j)) = \frac{(j-1)}{\bar{\alpha}} \tag{3}$$

where $F_2 = F_T + F_L$. These predictions remain valid for the NLO BFKL resummed kernels [7]:

$$\frac{\partial \ln \tilde{F}_2(j,Q^2)}{\partial \ln Q^2} = \gamma^*(j,Q^2) \tag{4}$$

$$\chi^{NLO}(\gamma^*(j,Q^2),j) = \frac{(j-1)}{\bar{\alpha}(Q^2)} \tag{5}$$

where the Q^2 dependence of $\bar{\alpha}$ comes from the renomrmalisation group equations (RGE).

In the following, we perform a test of these NLO predictions using the proton structure function F_2 measured at HERA.

3 Test of resummed NLO BFKL kernels using F_2

Since we cannot easily perform the Mellin transform of the proton structure function data directly, we decided to use parametrisations of F_2 which describe the data in the full range of the measurement. We thus use the GRV98, MRS2001, CTEQ6.1 and ALLM parmetrisations [6].

The first step is to compute the slope of F_2 in $\log Q^2$ in Mellin space for the four parametrisations given above for different values of $\omega = j-1$. We do not see large differences between the different parametrisations used in this analysis [7]. The slope gives directly the value of γ^* given in Fig. 1 in different bins of Q^2 for the four parametrisations.

After having determined the values of γ^*, it is possible to test if Formula (5) is verified or not at NLO using different resummation schemes.

For the scheme in Ref. [3], $\chi^{NLO}(\gamma^*(j))$ is given in Fig. 2. χ^{NLO} has been computed using the following formula:

$$\chi^{NLO}(\gamma,\omega) = \chi^{(0)}(\gamma-\frac{\omega}{2},\omega) + \bar{\alpha}\left(\chi_1(\gamma-\frac{\omega}{2}) - \chi_1^{(0)}(\gamma-\frac{\omega}{2})\right) \tag{6}$$

where $\bar{\alpha}$ is computed using the RGE. We notice in Fig. 2 that there are not many differences between the different parametrisations except at high values of Q^2 and that the linearity in Formula (2) is almost verified.

Using the results in Fig. 2, it is possible to determine α_{out} defined as

$$\chi^{NLO}(\gamma^*(j),\bar{\alpha}_{in}) = \frac{j-1}{\bar{\alpha}_{out}} \tag{7}$$

by plotting χ^{NLO} as a function of $(j-1)$. For $\bar{\alpha}_{in}$, we take α from RGE. We notice that we can describe χ^{NLO} using a linear fit with a good precision. However, the fit does not go through the origin and we need to add a constant term to the fit formula. On the other hand, the slope α_{out} is found to be closer to α_{in} at low Q^2

but more different from this value at higher values of Q^2. Both effects are due to higher order BFKL effects. To illustrate this fact, we show in Fig. 3 the values of α_{in} using the RGE equation (upper curve), and the values of α_{out} (lower curve) which are always smaller than the values of α_{RGE}.

To conclude, we have proposed a method which allows sensitive tests of resummed BFKL kernels at NLO. We have presented results for one correct scheme as an example. The fact that the predictions described above are not completely fulfilled shows the sensitivity on higher order BFKL resummation effects.

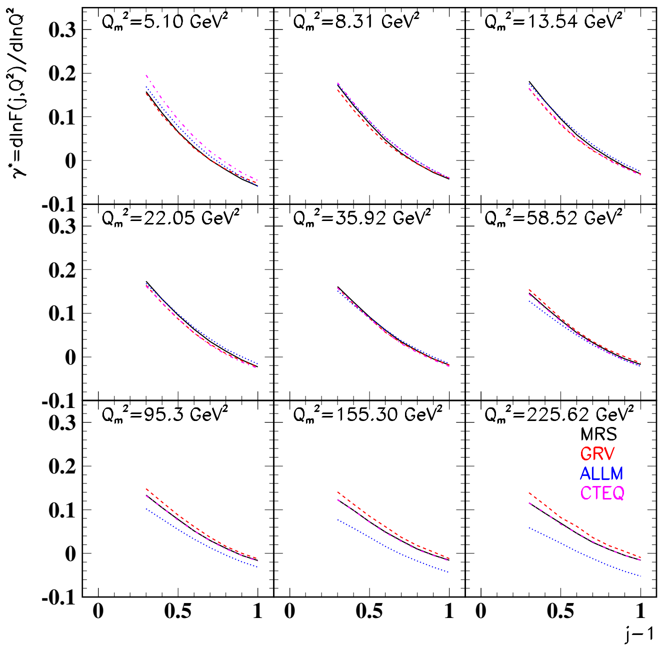

Figure 1. Derivation of the anomalous dimension $\gamma^*(j,Q^2)$ by computing the slope of $logF_2$ as a function of $logQ^2$ (MRS: full line, GRV: dashed line, ALLM: dotted line and CTEQ: dashed-dotted line).

Acknowledgments

These results come from a fruitful collaboration with Robi Peschanski and Laurent Schoeffel.

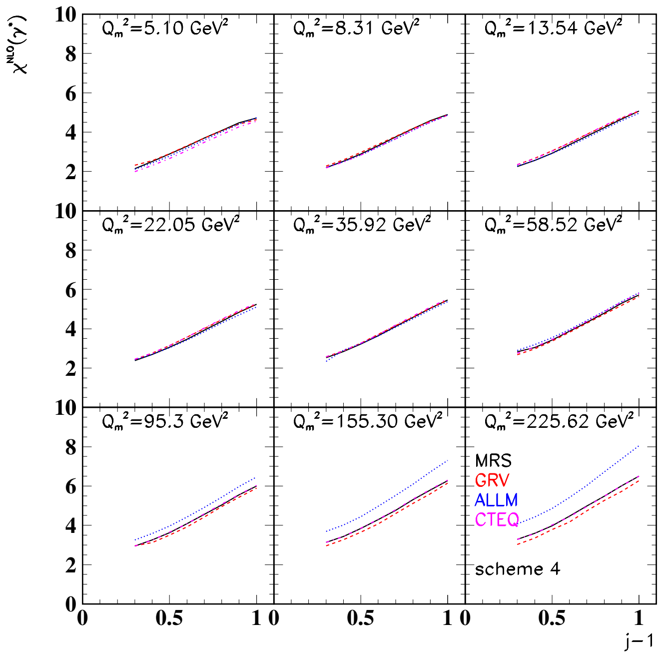

Figure 2. Determination of $\chi^{NLO}(\gamma^*(j))$ (MRS: full line, GRV: dashed line, ALLM: dotted line and CTEQ: dashed-dotted line).

References

1. L.N.Lipatov, Sov. J. Nucl. Phys. **23** (1976) 642; V.S.Fadin, E.A.Kuraev and L.N.Lipatov, Phys. lett. **B60** (1975) 50; E.A.Kuraev, L.N.Lipatov and V.S.Fadin, Sov.Phys.JETP **44** (1976) 45, **45** (1977) 199; I.I.Balitsky and L.N.Lipatov, Sov.J.Nucl.Phys. **28** (1978) 822.
2. V.S. Fadin and L.N. Lipatov, Phys. Lett. **B429** (1998) 127; M.Ciafaloni, Phys. Lett. **B429** (1998) 363; M. Ciafaloni and G. Camici, Phys. Lett. **B430** (1998) 349.
3. G.P. Salam, JHEP **9807** (1998) 019.
4. M. Ciafaloni, D. Colferai, G.P. Salam, Phys.Rev. **D60** 114036, JHEP **9910** (1999) 017; M. Ciafaloni, D. Colferai, G.P. Salam, A.M. Stasto, Phys. Lett. **B541** (2002) 314; S. J. Brodsky, V. S. Fadin, V. T. Kim, L. N. Lipatov, G. B. Pivovarov JETP Lett. **70** (1999) 155.
5. H Navelet, R.Peschanski, Ch. Royon, S.Wallon, Phys. Lett. **B385** (1996) 357.
6. A.D. Martin, R.G. Roberts, W.J. Stirling, R.S. Thorne, Eur.Phys.J. **C23** (2002) 73; M. Gluck, E. Reya, A. Vogt, Eur.Phys.J. **C5** (1998) 461; J. Pumplin

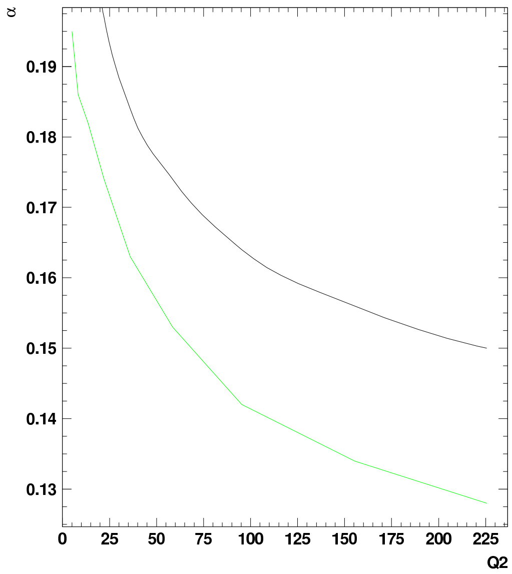

Figure 3. α as a function of Q^2: obtained by RGE (upper curve) or as an output of the fit (lower curve) (see text).

et al., JHEP **07** (2002) 12; H. Abramowicz, E. Levin, A. Levy, U. Maor, Phys. Lett. **B269** (1991) 465.

7. R.Peschanski, Act. Phys. Pol. **B34** (2003) 3001; R. Peschanski, C. Royon, L. Schoeffel, to appear.