Extraction of the Gluon Density from F_2 and Jet Rates

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Abstract: An extraction method of the gluon density in leading order from a global fit to F_2 and jet rates is presented. Prospects are studied for an integrated luminosity of 250 pb^{-1} and 1000 pb^{-1}. This study is particularly focused on the gluon error band behavior. Only statistical errors are taken into account.

Introduction

Up to now the usual way to extract the gluon density from DIS events was mainly by the study of scaling violations of structure functions. With HERA experiments one has the opportunity to measure the hadronic final states [1, 2, 3, 4]. Given this, new methods are possible, for example the (2+1) jet cross-section measurement (or the jet rate R_{2+1}) as a physical observable to extract the gluon density [5, 6].

The advantage of using the (2+1) jet cross-section ($\sigma_{(2+1)}$) comes from the fact that the latter is directly dependent on the gluon density and this gluon-induced part is expected to dominate in the HERA kinematical range. So far all methods using $\sigma_{(2+1)}$ or R_{2+1} treat the quark-induced part of the cross-section by fixing the quark densities. Such a hypothesis does not necessarily change the result itself, but surely the error treatment, since quark densities are coupled to the gluon via the DGLAP [7] equations. In order to avoid this problem, one should use a measured quantity which can give strong constraints on the quark densities, e.g. an F_2 measurement. In this way, we can have a correct treatment of the gluon density, taking in account correlations between quarks and gluons.

1 Method and jet cross-section computation

Basically, the method is a global QCD fit as usually made in DIS. The differences comes from incorporating R_{2+1}. The problem is to compute the time-consuming $\chi^2_{R_{(2+1)}}$ many times. Already in leading order (LO) each term of the (2+1) jet cross-section is a convolution of a parton density with hard matrix elements [8]. These integrations are time consuming and a straightforward calculation is not really suited best for a fit program. In next-to-leading order (NLO) [9, 12, 11] this problem becomes much more important, and the existing programs [10, 11] cannot be used without modifications. One way to overcome this has been proposed in Ref. [13] by use of the Mellin transform. Here we develop a procedure using cubic spline interpolation. We illustrate this method with the BGF term of the cross-section:

$$\sigma_g \sim \int d\xi C_q(\xi, x, Q^2, y_{cut})\xi g(\xi, Q^2). \tag{1}$$

First, we define a network $\{\xi_1, \ldots, \xi_{N_x}\}$ in ξ. Then we define a set of basis functions $\phi_i(\xi)$ such that the $\phi_i(\xi)$ are continuous and $\phi_i(\xi_k) = \delta_{ik}$. If we interpolate the $\phi_i(\xi)$'s with cubic splines, then we can expand

$$\xi g(\xi, Q^2) = \sum_{i=1}^{N_x} \xi_i g(\xi_i, Q^2)\phi_i(\xi). \tag{2}$$

With such an expansion Eq. (1) becomes :

$$\sigma_g \sim \sum_{i=1}^{N_x} \xi_i g(\xi_i, Q^2) \int d\xi C_q(\xi, x, Q^2, y_{cut})\phi_i(\xi). \tag{3}$$

Now we can compute all integrals since they are not affected by the parton densities changes in the fit. We calculate them before the χ^2 minimization procedure. At each step of the fit we only have to perform a vector product instead of a integral.

It is very easy to extend this procedure to NLO. In LO the analytical results from [8] have been used, but in NLO this cannot be done so easily, one has to use theoretical programs [10, 11]. The best suited program for this job is the DISENT [12] program since it allows to have only the coefficient functions and convolute them with any arbitrary function.

2 Choice of the data points

The "data points" which we use were extracted as follows. We choose a binnning in x with two samples of low and high Q^2. This binning corresponds to reasonable statistics for 1994 luminosity (2.5 pb^{-1}). Considering this binning we compute the jet rate R_{2+1} using parton densities obtained *from the fit to F_2 1994 data.* The justification of such a procedure comes from the fact that no real difference was seen from the gluon obtained from F_2 fit alone and the combined F_2 &R_{2+1} fit. The statistical errors are computed according to the desired luminosity. We used two jet definitions :

- mJADE [14]
  - $\cdot$ $m_{ij} > y_{cut}W^2$ $(y_{cut} = 0.02)$
- k_t [15]
  - $\cdot$ $d_{ip} > y_{cut}Q^2$
  - $\cdot$ $d_{ij} > y_{cut}Q^2$ $(y_{cut} = 0.5)$

The data points used are shown in Fig. 1.

3 Fit with F_2 and R_{2+1}

Using F_2 and R_{2+1} to fit the gluon density, we expect to include the maximum information about parton densities. Figure 2 shows the gluon error bands for three kinds of fits: F_2 only, F_2 and R_{2+1}^{mJADE}, F_2 and $R_{2+1}^{k_t}$; with errors computed on the basis of 1994 statistics. While there is no improvement with mJADE one can see a small improvement with k_t. We hope that this improvement increases with luminosity. These results are not surprising considering the fact that for mJADE we have $\xi \gtrsim y_{\mathrm{cut}}$ whereas for k_t we have $\xi \gtrsim x/y_{\mathrm{cut}}$. Adding the fact that we have much more statistics at low x for k_t, we could have expected such an improvement.

Now if we use the k_t and take statistical errors corresponding to $250\,\mathrm{pb}^{-1}$ and $1000\,\mathrm{pb}^{-1}$ (Fig. 4), we see that we have a real improvement at medium and high x. We could also have expected this result since the bulk of the statistics for the jet rates corresponds to this region of ξ. Going to $1000\,\mathrm{pb}^{-1}$ does not improve the result substantially.

4 Conclusions

This study shows that running HERA can substantially improve the precision on gluon density knowledge. The gain is not so important at low x but it seems that at high x we can learn something. Of course, to be complete this study should be redone in NLO, and maybe we can have new information about gluon and not only increase the precision.

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References

[1] A.D. Martin, W.J. Stirling, R.G. Roberts, Phys. Lett. **B252** (1990) 653.

[2] CTEQ Collaboration: J. Botts *et al.*, Phys. Lett. **B304** (1993) 159.

[3] H1 Collaboration: DESY preprint 96-039.

[4] ZEUS Collaboration: Phys. Lett. **B345** (1995) 576.

[5] H1 collaboration: S. Aid *et al.*, Nucl. Phys. **B449** (1995) 3.

[6] D. Graudenz, M. Hampel, A. Vogt, these Proceedings.

[7] V.N. Gribov and L.N. Lipatov, Sov. Journ. Nucl. Phys. **15** (1972) 438 and 675;
G. Altarelli and G. Parisi, Nucl. Phys. **B126** (1977) 297;
Yu.L.Dokshitzer, Sov. Phys. JETP **46** (1977) 641.

[8] J.G. Körner, E. Mirkes, G.A. Schuler, Int. J. Mod. Phys. **A4** (1989) 1781.

[9] D. Graudenz, Phys. Rev. **D49** (1994) 3291.

[10] D. Graudenz, Comput. Phys. Commun. **92** (1995) 65.

[11] E. Mirkes, D. Zeppenfeld, Phys. Lett. **B380** (1996) 205.

[12] S. Catani, M.H. Seymour, Phys. Lett. **B378** (1996) 287;
S. Catani, M.H. Seymour, CERN preprint, CERN-TH-96-029.

[13] D. Graudenz, M. Hampel, A. Vogt, C. Berger, Z. Phys. **C70** (1996) 77.

[14] D. Graudenz, N. Magnussen, in: Proceedings of the HERA Workshop 1991, DESY (eds. W. Buchmüller, G. Ingelman).

[15] S. Catani, Yu.L. Dokshitser, Phys. Lett. **B285** (1992) 291.

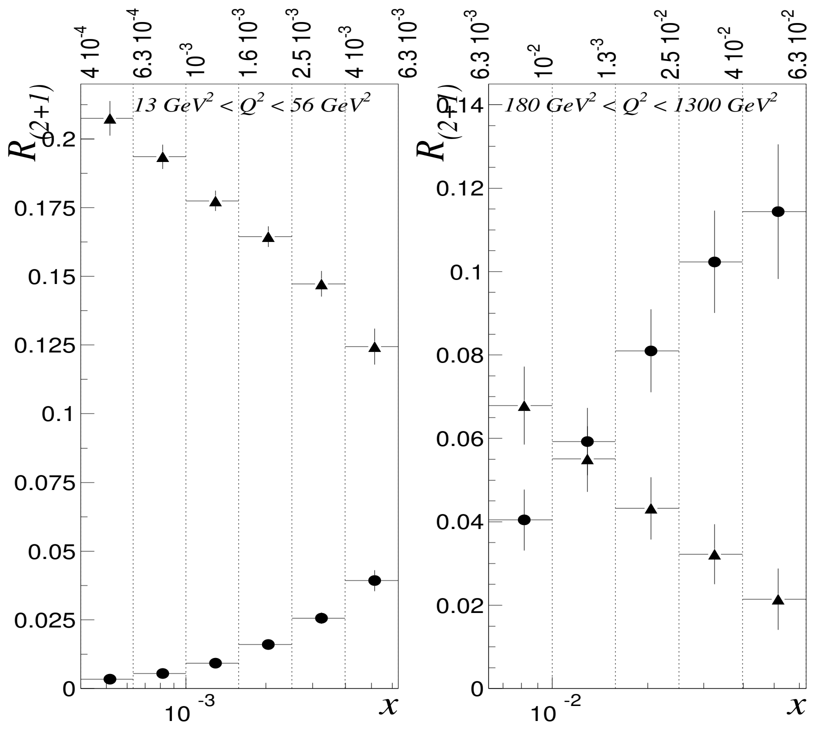

Figure 1: $R_{(2+1)}$ *"data points" used for this study as a function of* x*. The circles represent the jet rate obtained with the mJADE algorithm. The triangles represent the jet rate for the* k_t *algorithm. The first plot is the low* Q^2 *sample (*$13\ GeV^2 < Q^2 < 56\ GeV^2$*), the second is the high* Q^2 *sample (*$180\ GeV^2 < Q^2 < 1300\ GeV^2$ *).*

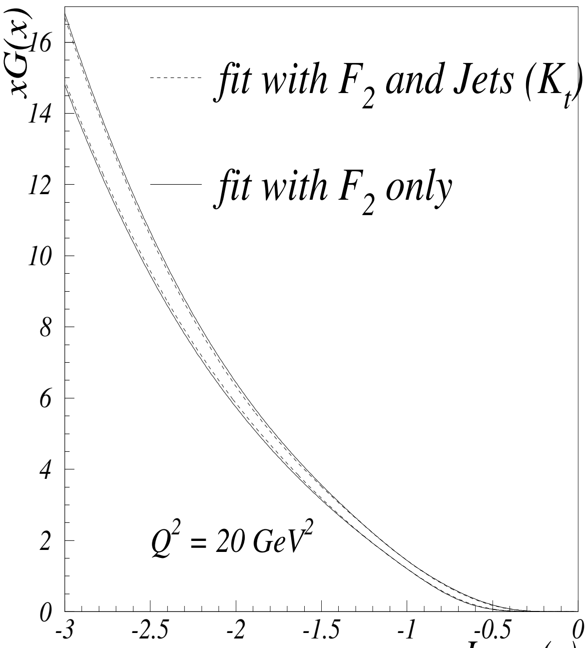

Figure 2: *Gluon errors bands from a fit to* F_2 *only (full line) and from a fit to* F_2 *and* R_{2+1} *(*k_t *algorithm) (dotted line) (The fit with the mJADE algorithm lies exactly on the full line).*

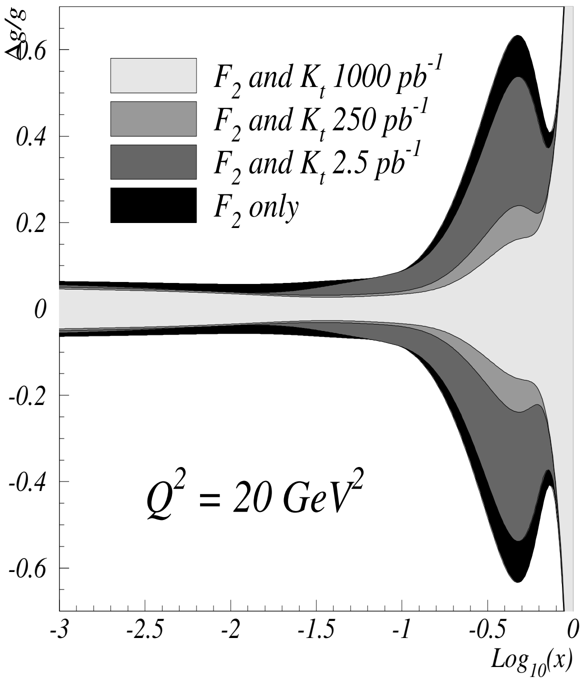

Figure 3 : *Relative gluon error bands, obtained from various fits to* F_2 *and* R_{2+1} *for three sets of luminosity: 2.5* pb^{-1} *(dark grey), 250* pb^{-1} *(grey) and 1000* pb^{-1} *(light grey). The black area is a fit to* F_2 *only.*