Jet rate and QCD fits in H1

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Abstract. An attempt to include consistently the jet rate measured in the H1 detector in a global NLO QCD fit procedure is described.

INTRODUCTION

In the past years, the H1 Collaboration has published [1,2] two determinations of the gluon density in deeply inelastic scattering (DIS) at small-x. Although the experimental error band could be reduced to a level of about 20% using the 1994 data sample ($\mathcal{L} = 2.7\text{pb}^{-1}$), a further reduction of this error can only be obtained by using other observables sensitive to the gluon density. Among the large class of the experimentally accessible observables, the (2+1) jet rate[1] in DIS e^+p scattering is one of the best candidates. It is theoretically known up to next-to-leading order (NLO); it is dominated by gluon induced processes (BGF) at small-x. The aim of this communication is to describe an attempt to include consistently the (2+1) jet rate observable into the H1 F_2 QCD fit analysis [3].

In section I, the global procedure is described. The jet rate measurement is shown in section II and the results are given in section III.

I GLOBAL FIT PROCEDURE

Our goal is to use the same procedure described in [3] with a new χ^2 definition, $\chi^2 = \chi^2(F_2) + \chi^2(jets)$, accounting for the jet rate measurement.

To define $\chi^2(jets)$ one must relate the measured jet rate and the NLO calculations of the cross-section ratios $\sigma_{2+1}/\sigma_{tot}$ knowing that, from an experimental point of view, the simulation of the detector response is a necessary information. But, in the available DIS Monte-Carlo (MC) programs, partons

[1]) Here "2" stands for two jets fully visible in the final state and "+1" stands for the jet associated with the proton remnant .

are generated according to the first order matrix elements and higher orders are approximated by parton cascades.

Since we want to compare the jet rate to an exact second order calculation, we have decided to restrict the MC corrections to the hadron level and to ignore the MC parton level.

By using the hadron level, we have to account for the non perturbative contribution also known as "power corrections".

All these considerations lead to the following expression of the jet rate as it is measured in H1:

$$R^{det.}_{2+1}(j) = \frac{\sum_i d(2,i;2,j)\sigma_{2+1}(i) + d(\bar{2},i;2,j)[\sigma_{tot}(i) - \sigma_{2+1}(i)]}{\sum_i d(i;j)\sigma_{tot}(i)} \tag{1}$$

where $R^{det.}_{2+1}(j)$ is the fraction of $2+1$ jet events observed in the kinematic bin j corresponding to a range $(\Delta_j x, \Delta_j Q^2)$. The $d(2,i;2,j)$ $[d(\bar{2},i;2,j)]$ is [are] determined using the full detector simulation and describe the probability of an event generated in a bin i with a 2+1 [everything but a 2+1] jet multiplicity at hadron level to be reconstructed as a $2+1$ jet event in the bin j at detector level. The purely kinematical migration probability $d(i,j)$ is also determined with the MC. $\sigma_{tot}(i)$ and $\sigma_{2+1}(i)$ are the cross-sections integrated over the bin range i.

The cross-section $\sigma_{2+1}(i)$ can be calculated using:

$$\sigma_{2+1}(i) = \int_{\Delta_i x}\int_{\Delta_i Q^2} dx dQ^2 \Big(\frac{d\sigma^{pert.}_{2+1}}{dx dQ^2} + h^{no.pert.}_{2+1}(x,Q^2)\Big), \tag{2}$$

where the first term of the r.h.s. of eq. (2) is the perturbative contribution and where $h^{no.pert.}_{2+1}$ is the non perturbative part that we choose *a priori* to be equal to $A/Q^2 + B\log(Q^2)/Q^2$ [4]. A and B are two unknown parameters to be determined from a fit to the experimental data.

In eq. (2) the perturbative contribution is a convolution product of the parton density functions (PDF) and some coefficients which are calculated using the DISENT program [5]. It is not a trivial task to perform numerically these convolutions at each step of an iterative χ^2 minimization and some details concerning the method that we use can be found in [6,7].

Another important point is the choice of a jet algorithm. The algorithm must be "factorizable" to ensure that the same PDF can be used to compute F_2 and $\sigma_{2+1}(i)/\sigma_{tot}(i)$ [8]. It must also be able to involve partons with a proton momentum fraction close to x at small-x. Consequently, a good candidate is the k_t algorithm defined in the Breit Frame [9]. To reduce higher order corrections without rejecting too many events, we choose to apply the one step k_t algorithm with $y_c = 0.5$ and the clustering scale Q^2.

II JET RATE MEASUREMENT

We have analysed the 1994 data corresponding to an integrated luminosity of 2.7 pb^{-1}. Our data selection follows the 1994 H1 F_2 analysis [2] requiring an identified scattered electron in the Backward Electromagnetic Calorimeter (BEMC) with an energy greater than 13 GeV and a reconstructed vertex. These requirements reduce both ep and non-ep backgrounds to a negligible level ($< 1\%$).

The selected events are stored into bins in x_Σ and $Q^2_{el.}$ where the subscripts indicate the experimental methods: the Σ method allows to reach very low y values of about 0.01 with a reasonable resolution for x [10] while the electron method leads to the best Q^2 resolution for any y. Eleven bins are thus defined in the kinematical range 10 $\mathrm{GeV}^2 < \mathrm{Q}^2 <$ 100 GeV^2 and $0.0002 < x < 0.02$. The bin boundaries are given in Fig. 2. We use a wider binning for MC events to account for all experimental migrations, *i.e.* the indices j and i of eq. (1) do not refer to the same binning.

Once the DIS events are selected, we boost the quadri-vectors of the measured calorimeter clusters into the Breit Frame and we apply the k_t algorithm. In order to reduce the effects of QED radiations [10] on the determination of the detector response functions we choose the Σ method to define the kinematical variables appearing in the boost vector expression and in the algorithm scale. According to that choice and because of weak bin migrations, the higher order QED correction to the jet rate is found to be less than 1% in all our bins.

Finally, we apply some acceptance cuts on the jet polar angle in the lab. frame: a forward cut $\theta_{jet} > 7^o$ necessary to avoid the beam pipe and the remaining proton remnant region and a backward cut $\theta_{jet} < 110^o$ to avoid the BEMC region and the first wheel of the LAr calorimeter which are not designed to detect hadrons. We found that the measurement was not sensitive to the latter cut but quite sensitive to the first one[2].

The achieved statistical accuracy varies between 3% and 8% depending on the kinematical bin number and the systematic errors were estimated following the procedure of ref. [2].

The dominating contribution comes from the uncertainty on the calorimeter hadronic energy scale yielding a systematic error on the jet rate between 3% and 13%. This uncertainty affects all the measurement in a fully correlated way and requires a special treatment as described in [3].

Fig. 1 shows a comparison between data and MC LEPTO 6.4 [11] (after detector simulation) concerning the shape of the main distributions of the 2+1 jet events sample.

A reasonable agreement is observed and a cut $z_p > 0.15$ (the definition of

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2) The forward θ_{jet} cut has been varied and the results of this study will not be reported here. All the details are described in [7].

z_p in given in the legend of Fig.1) further reduces the differences. One should notice that in our procedure the MC information appears only through the detector response functions of eq. (1). Thus, as we only rely on ratios of simulated events, a "good MC" is a MC which describes the distribution shapes: only LEPTO 6.4 is usable in our kinematical domain.

After this precaution, one can take a look at the comparison between the jet rate in data and MC (fig. 2). A noticeable discrepancy is visible and we checked that it could not be explained either by the background or by a possible contribution from resolved photons [12]. In the latter case, the p_t distribution of fig. 1 shows that we are dealing with low p_t jets ($p_t < Q$) ensuring that only the proton structure functions are sufficient to compute the perturbative jet rate.

At the end we are faced with the following questions: can we describe the discrepancies between data and MC by modifying the perturbative or (and) the non perturbative contribution(s) to eq. (2) ? What is the influence of the

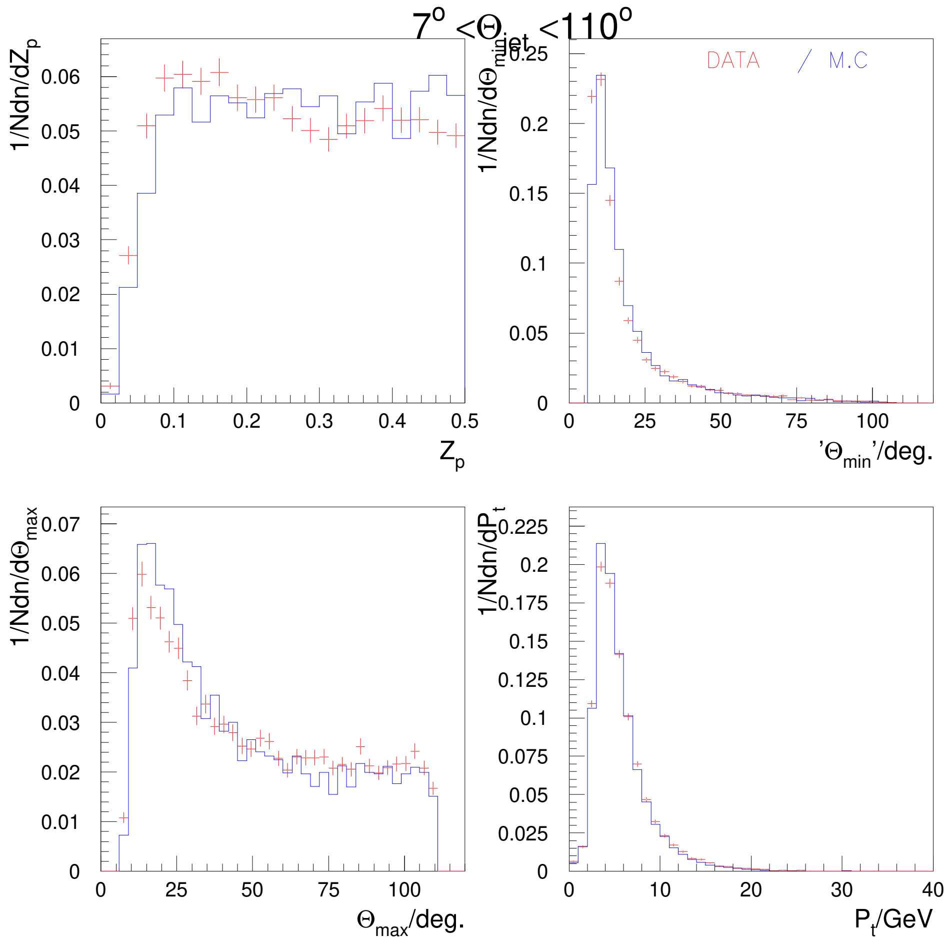

FIGURE 1. Comparison between data (error bars) and MC (histogram). Here $z_p = min\{E_i(1-\cos\theta_i)\}/\sum_i[E_i(1-\cos\theta_i)]$ with] $i = 1,2$ indicates the two jets.

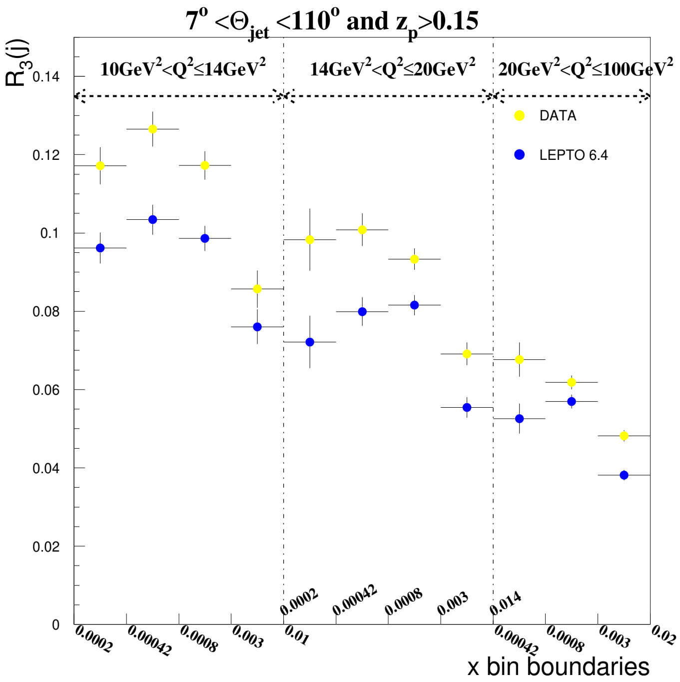

FIGURE 2. Jet rates in data and MC.

jet rate in the QCD fits ?

III GLOBAL FIT RESULTS

Before giving an answer to the previous questions, it is necessary to start the fit with a reasonable set of PDF. A fit to F_2^{ep} [2], $F_2^{\mu H}$ and $F_2^{\mu D}$ [13] was first performed requiring $Q^2_{data} > 10$ GeV^2 and fixing $\Lambda^{[4]}_{\bar{M}S} = 250$ MeV in order to simplify the minimization of $\chi^2 = \chi^2(F_2)$. The "systematic parameters" were also "fitted" as it is indicated in [3].

Once this fit was performed, we introduced the jet rate observable and minimized $\chi^2 = \chi^2(F_2) + \chi^2(R^{det.}_{2+1})$. The two parameters A and B describing the non perturbative contribution were also "fitted".

As a first result, we found $\chi^2(R^{det.}_{2+1}) > 200$ for the eleven measurements and no noticeable modifications of the starting PDF. We then decided to introduce an empirical function of x in the expression for the non perturbative jet rate cross-section (see eq. (2)): $h^{no.pert.}_{2+1}(x, Q^2) = (\alpha + \beta \log x + \gamma \log^2 x + \delta \log^3 x)/Q^2$ [3].

A third fit was then performed with the new free parameters $\alpha, \beta, \gamma, \delta$ leading to a very good $\chi^2(R^{det.}_{2+1}) < 10$ but still no modification of the starting

[3] We found no sensitivity of the fit to the $\log Q^2/Q^2$ term.

PDF. Furthermore, a study of the gluon error band showed that its size was only slightly reduced when including the jet rate in the fit.

From this study we conclude that the jet rate "does not help F_2" to determined the PDF at low-x. However, because of the presence of $H1$ small-x F_2 data in the fit, the empirical function $h(x)$ is extracted with a rather small experimental error band (see Fig. 3): $h(x)$ is of the order of 1 GeV^2 (which is an expected results for power corrections) and strongly dominates the jet cross-section[4] at low Q^2.

A surprising feature is that $h(x) < 0$ at high-x and it would be interesting to compare this result with some future theoretical calculations.

IV SUMMARY

We have designed a fully consistent procedure to analyse simultaneously F_2 structure function and jet rate data at HERA. Using the one step k_t algorithm with the scale Q^2 and $y_c = 0.5$, we found almost no sensitivity of the jet rate observable to the PDF in the kinematical range 10 GeV^2 < Q^2 < 100 GeV^2 – 0.0002 < x < 0.02.

Our results are finally dealing with the non-perturbative part of the 2+1 jet rate which dominates the jet cross-section at small-x, small-Q^2. We have empirically modelled this non-perturbative part and determined its contribution and the corresponding experimental error band.

Finally, it seems that a perturbative analysis of jet rate at small-Q^2 is somehow a nasty circle since small-Q^2 requires low-p_t jets to avoid the resolved photon contributions and low-p_t implies huge non-perturbative corrections. Keeping the k_t algorithm, the only remaining solution is to reach higher Q^2 values but this implies higher x values and therefore a reduced data sample.

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[4] The non perturbative contribution plotted in Fig. 3 is added to the perturbative contribution. We see that at 10 GeV^2 the contribution is of the order of 0.2. This has to be compared with the perturbative contribution which is one order of magnitude smaller.

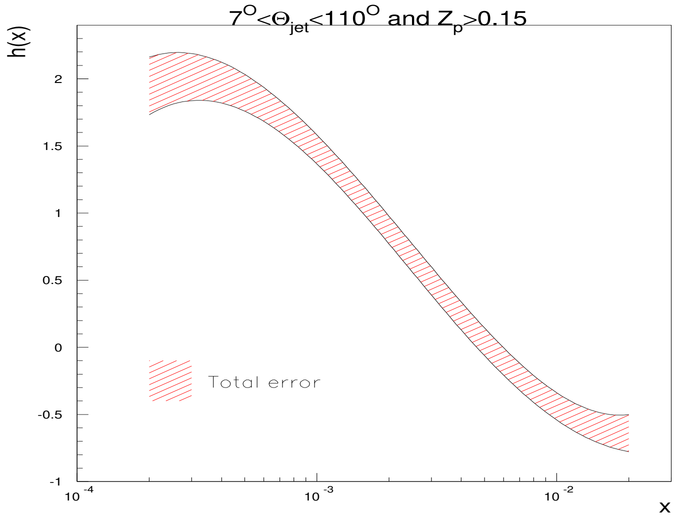

FIGURE 3. $h(x)$ error band (in GeV^2) obtained with the jet data sample measured applying the cuts written on the plot (see text, for more details).

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