H1 results on high p_t hadronic final states in DIS

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Abstract. Recent results on high p_t hadronic final states in DIS from the H1 experiment at the ep-collider HERA are presented. Measured observables are: dijet rates, forward jet cross sections and charged particle transverse momentum spectra. In all cases we observe increased cross sections that are not described by DGLAP models and/or $\mathcal{O}(\alpha_s^2)$ calculations.

INTRODUCTION

High p_t hadronic final states in deep inelastic scattering (DIS) are sensitive to the dynamics of the strong interaction and allow to test the validity of various theoretical approximations. In this talk, measurements of dijet rates, the production of forward jets and of high p_t charged particles from the H1 experiment at HERA are presented. These analyses are performed in the kinematical region given by $5\ \mathrm{GeV}^2 \lesssim Q^2 \lesssim 100\ \mathrm{GeV}^2$ and $10^{-4} \lesssim x_{\mathrm{Bj}} \lesssim 10^{-2}$. In all cases the measured distributions are corrected for detector effects (to hadron level) and compared to models based on QCD phenomenology and/or fixed order $\mathcal{O}(\alpha_s^2)$ calculations.

HIGH P_T HADRONIC FINAL STATES

The dynamic features of high p_t hadronic final states have been calculated in various approximations of QCD. Fixed order calculations for dijet and forward jet production are available in next to leading order (NLO) of the strong coupling constant ($\mathcal{O}(\alpha_s^2)$) and implemented in Monte Carlo programs (MEPJET [1], DISENT [2]). Other approaches include the resummation of leading logarithms of either the four momentum transfer $(\alpha_s\ \ln(Q^2/Q_0^2))^n$ (DGLAP parton evolution equations) or of the inverse of the Bjorken scaling variable $(\alpha_s\ \ln(1/x_{\mathrm{Bj}}\ ))^n$ (BFKL equation). The DGLAP approach is used in the event generators LEPTO [3] and HERWIG [4] where leading log parton showers are added to leading order matrix elements (MEPS) in combination with string or cluster fragmentation models.

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So far analytical BFKL calculations have been carried out on the parton level but are not yet available in Monte Carlo event generators. One fundamental difference between the BFKL and the DGLAP evolution is the ordering of the transverse momenta k_t of subsequent parton emissions. While these are strongly ordered in the DGLAP approach, there is no k_t ordering in the BFKL evolution. The latter is also a feature in the colour dipole model (CDM) as implemented in the event generator ARIADNE [5], where gluons emitted by the dipoles do not obey k_t ordering.

Dijet Rates

Jets are defined by a snowmass cone algorithm in the hadronic centre of mass frame (hcm) with a cone radius of $R_{\rm cone} = 1$. Events with exactly two jets with transverse energies above $E^*_{t,\rm min} = 5$ GeV are selected if the difference in pseudorapidity of the jets in the hcm is below $\Delta\eta^*_{\rm max} = 2$. The dijet rate is given by the ratio of two-jet events to the total number of DIS events in the same kinematical region. In figure 1 the results [6] are presented as a function of Q^2 and $x_{\rm Bj}$ and compared to the LEPTO and the ARIADNE hadron level predictions. Since the hadronization corrections (as estimated by these models) are below 25% over the whole range, the NLO parton level prediction is also included in this plot. It is clearly visible that the observed dijet rate is much larger than the predictions from LEPTO and NLO (which are in good agreement with each other) while it is described by ARIADNE.

Forward jet production

It has been suggested [7] that the production of jets in the region away from the struck quark towards the proton remnant region (forward region) is sensitive to the discrimination between DGLAP and BFKL dynamics. While the phase space for DGLAP evolution is strongly suppressed for forward jets with $p^2_{t,\rm jet} \approx Q^2$, the phase space for BFKL evolution is maximized when the momentum fraction ($x_{\rm jet} = E_{\rm jet}/E_{\rm proton}$) is required to be large compared to Bjorken x ($x_{\rm jet} \gg x_{\rm Bj}$). In this analysis [8], events with forward jets are selected using a cone algorithm in the HERA frame with a cone radius of $R_{\rm cone} = 1$ in the kinematical region defined by:

$$7^\circ < \theta_{\rm jet} < 20^\circ \ , \quad p_{t,\rm jet} > 3.5\,{\rm GeV} \ , \quad x_{\rm jet} > 0.035 \ , \quad 0.5 < p^2_{t,\rm jet}/Q^2 < 2 \ .$$

In figure 2 the corrected data are compared to Monte Carlo models. Also shown is the parton level prediction of these models together with NLO and BFKL [9] parton level predictions (for the BFKL calculation the absolute normalization is unknown). ARIADNE gives a reasonable description of the data. The LEPTO result is lower and shows a strong dependence on the hadronization model (with or without soft colour interaction - SCI) which makes it difficult to extrapolate the NLO and BFKL predictions to hadron level.

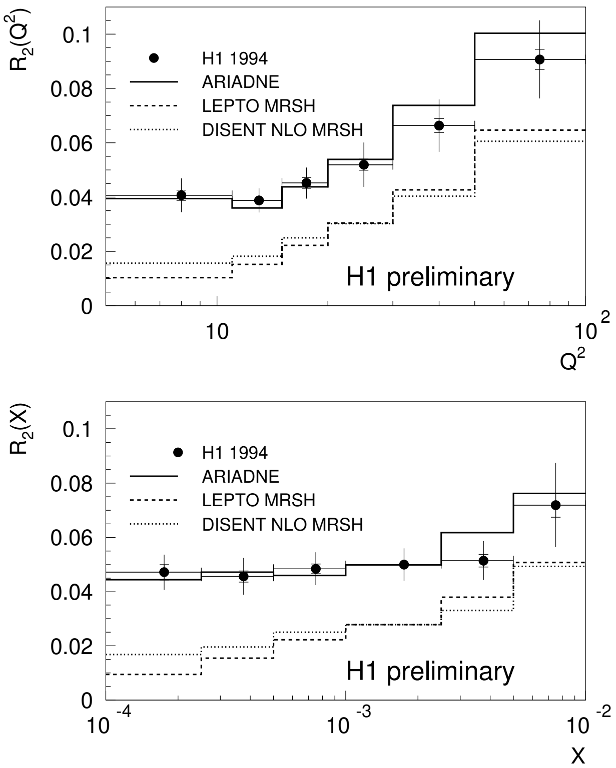

FIGURE 1. Dijet rates as a function of Q^2 (top) and x_{Bj} (bottom): H1 data are compared to the predictions of LEPTO and ARIADNE (hadron level) and to NLO parton level.

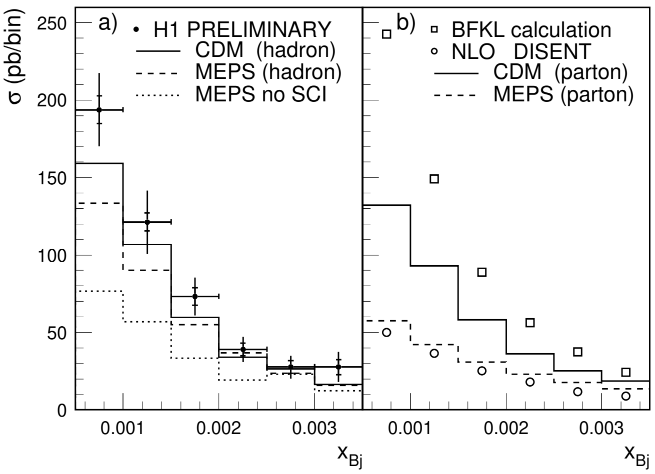

FIGURE 2. Cross section for forward jet production. H1 data are compared to the hadron level of LEPTO (MEPS) and ARIADNE (CDM) (left). Also the comparison of the parton level predictions of these models to NLO and BFKL parton level predictions is shown (right). In all calculations MRSH parton densities were used.

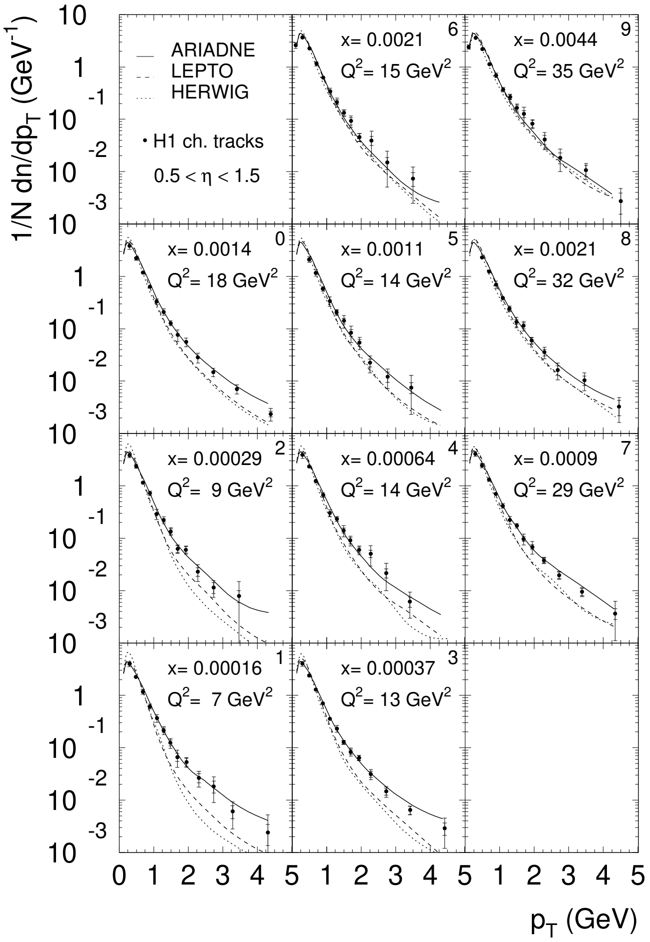

FIGURE 3. The transverse momentum spectra of charged particles, measured in the hcm in the pseudorapidity interval $0.5 < \eta^* < 1.5$ together with the model predictions of ARIADNE, LEPTO and HERWIG.

Charged particle transverse momentum spectra

As a further sensitive test of BFKL evolution single particle transverse momentum spectra have been proposed [10]. It was shown that the hard tail of the p_t spectrum stems from parton radiation while the production of hard particles from hadronization is suppressed. Since parton emissions in the central region in the hcm are less restricted for a k_t unordered scenario, a harder p_t spectrum is expected here as compared to the k_t ordered evolution.

The measured charged particle spectra [11] (in the pseudorapidity interval $0.5 < \eta^* < 1.5$ in the hcm) are shown in figure 3. While at larger values of x_{Bj} and Q^2 all models provide a good description of the data, the MEPS models (LEPTO, HERWIG) are not able to describe the high p_t tail at small x_{Bj} . ARIADNE gives a good description of the data over the full kinematic range.

SUMMARY AND CONCLUSIONS

For all three measurements presented here we observe cross sections significantly above the NLO and MEPS model predictions. Since the influence of hadronization corrections for these observables is small this is a clear indication of increased partonic activity from hard processes.

To draw firm conclusions from measured cross sections on the observation of BFKL dynamics it will be very important to have a BFKL based Monte Carlo event generator.

It remains an open question if the good description of all distributions by ARIADNE is purely based on the absence of k_t ordering and to what extent this good description can be interpreted as a signature of BFKL dynamics in the data. It has been pointed out [12] that it is not the absence of k_t ordering in ARIADNE that causes the large dijet cross section but some 'unorthodox' technique which leads to a larger enhancement than expected from BFKL dynamics. The BFKL expectation leads to an enhancement of the dijet cross section for large rapidity differences ($\Delta\eta^*$) between the jets – but the shape of the $\Delta\eta^*$ distribution (not shown here) was seen to be well described also by LEPTO.

In my opinion, the dijet rate will play a crucial role for the explanation of the observed discrepancies. Starting at larger values of Q^2 where observed dijet rates [13] are described by all models and by NLO calculations one should try to find the point where NLO predictions start to fail. Once we have found an explanation for the excess of dijet events it will most certainly shed new light on the interpretation of the measured forward jet cross section and the charged particle transverse momentum spectra.

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