DIJET PRODUCTION AT LOW BJORKEN-X IN DIS

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Dijet production in deep inelastic ep scattering is investigated in the region of low values of the Bjorken-variable x ($10^{-4} < x < 10^{-2}$) and low photon virtualities Q^2 ($5 < Q^2 < 100$ GeV^2). The measured dijet cross sections are well described by perturbative QCD calculations in next-to-leading order including the region of very low x. However, large differences are observed for events with small separation in azimuth between the two leading jets. These are described better by predictions based on the CCFM evolution equation, which incorporates k_t factorized unintegrated parton distributions. Reasonable description is also obtained by the Color Dipole Model.

1 Introduction

At low values of the Bjorken-variable x in deep inelastic lepton-proton scattering at HERA, dijet data may be used to gain insight into the dynamics of the parton cascade typically exchanged in low-x lepton-proton interactions. Since in this region of phase space photon-gluon fusion is the dominant underlying process for dijet production, such measurements open the possibility of studying the effects of the unintegrated gluon distribution, first introduced in [1, 2]. The cross section depends on the fractional momentum x of the incoming parton, where the probability distribution of x is given by the parton density functions (PDFs) of the proton. The evolution of the PDFs with the factorization scale, μ_f^2, is generally described by the DGLAP equations [3]. To leading logarithmic accuracy this is equivalent to the exchange of a parton cascade, with the exchanged partons strongly ordered in virtuality up to Q^2, the negative four momentum of the photon exchanged in the ep scattering. The

DGLAP approximation is, however, expected to break down at low x, as it only resums leading logarithms in Q^2 and neglects contributions from $\log 1/x$ terms, which are present in the full perturbative expansion.

At very low values of x it is believed that the theoretically most appropriate description is given by the BFKL evolution equations [2, 4]. These resum large logarithms of $1/x$ up to all orders and impose no restriction on the ordering of the transverse momenta within the parton cascade. Thus off-shell matrix elements have to be used together with an unintegrated gluon distribution function, $f(x, \tilde{\mu}_f^2, k_t)$, which depends on the gluon transverse momentum k_t as well as x and a hard scale $\tilde{\mu}_f$. A promising approach to parton evolution at both small and large values of x is given by the CCFM [6] evolution equation, which, by means of angular-ordered parton emission, is equivalent to the BFKL ansatz for $x \to 0$, while reproducing the DGLAP equations at large x.

2 Results

The measurement covers the kinematic region of $5 < Q^2 < 100$ GeV^2 and $10^{-4} < x < 10^{-2}$. Jets are measured in the hadronic center-of-mass frame. At least two jets with a transverse energy of $E_T^* > 5$ GeV are required. In addition, the highest transverse momentum jet, $E_{T,1}^* \equiv E_{T,\max}^*$ must exceed 7 GeV to avoid sensitivity of the NLO calculations to soft gluon radiation [7, 8, 9].

Dijet cross sections as a function of Bjorken-x, Q^2, $E_{T,\max}^*$ and the pseudorapidity distance $|\Delta\eta^*|$ between the jets are shown in Figure 1. Within the quoted uncertainties good agreement between data and next-to-leading order calculations made with the DISENT [11] program is observed, even at small values of $E_{T,\max}^*$ and $|\Delta\eta^*|$, i.e. in a kinematic region, in which effects due to small-x dynamics should be most prominent [10].

Insight into small-x dynamics can be gained from inclusive dijet data by studying the behavior of events with a small azimuthal separation, $\Delta\phi^*$, between the two hardest jets as measured in the hadronic center-of-mass system [12, 10, 13]. Partons entering the hard scattering process with negligible transverse momentum, k_t, as assumed in the DGLAP formalism, lead at leading order to a back-to-back configuration of the two outgoing jets with $\Delta\phi^* = 180°$. Azimuthal jet separations different from $180°$ occur due to higher order QCD effects. However, in models which predict a significant proportion of partons

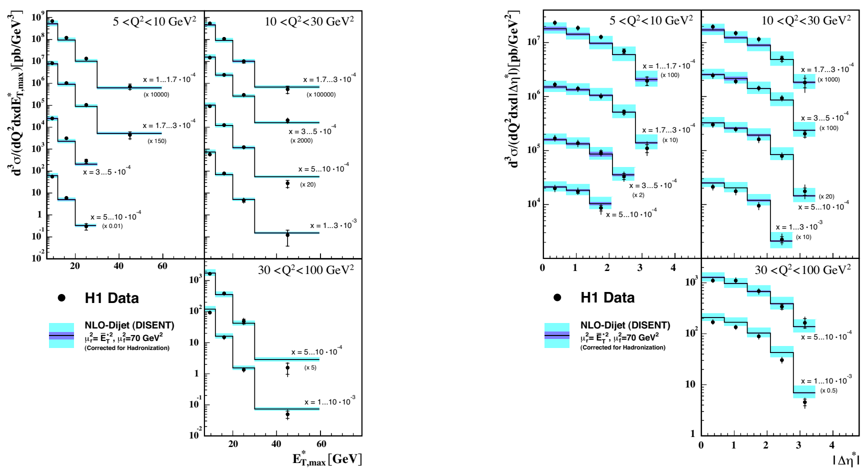

Figure 1: Inclusive dijet cross section averaged over Bjorken-x, Q^2 and $E^*_{T,\max}$ (left) and $|\Delta\eta^*|$ (right) compared with NLO dijet QCD predictions.

entering the hard process with large k_t, the number of events with small $\Delta\phi^*$ should increase.

Here we present a measurement of the ratio

$$S = \frac{\int_0^{120^\circ} N_{\text{dijet}}(\Delta\phi^*, x, Q^2)\mathrm{d}\Delta\phi^*}{\int_0^{180^\circ} N_{\text{dijet}}(\Delta\phi^*, x, Q^2)\mathrm{d}\Delta\phi^*},$$

of the number of events N_{dijet} with an azimuthal jet separation of $\Delta\phi^* < 120^\circ$ relative to all dijet events. The observable was proposed in [13] and is considered to be directly sensitive to small-x effects.

Figure 2 presents the S-distribution as a function of x for different Q^2. It is of the order of 5% and increases with decreasing x. This rise of S is most prominent in the lowest Q^2 bin, where the smallest values of x are reached. The NLO dijet QCD calculations predict S-values of only $\sim$1% and show no rise towards small x. NLO 3-jet predictions by the program NLOJET [14] give a good description of the data at large Q^2 and large x, but still fail to describe the increase towards low x, particularly in the lowest Q^2 range.

In Figure 2 the data are also compared to the predictions of the ARIADNE [15] and CASCADE [16] Monte Carlo programs. For CASCADE, the two predictions presented are based on the JS2001 [16] and set 2 of the

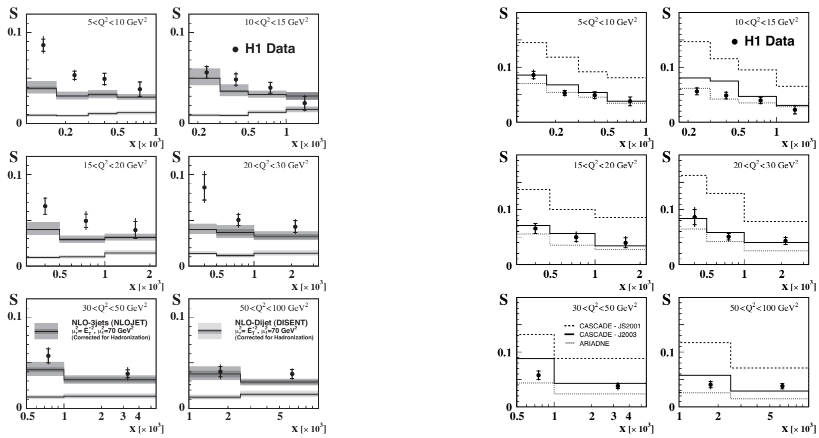

Figure 2: The observable S given as a function of Bjorken-x and Q^2 compared with NLO QCD predictions (left) and various model predictions (right, see text).

J2003 [17] unintegrated parton distributions, which differ in the way the small k_t region is treated. Whereas the prediction for S using JS2001 lies significantly above the data, that based on set 2 of J2003 describes the data rather well. Both PDF sets are able to describe the inclusive proton structure function F_2. Hence, the measurement of the ratio S is particularly sensitive to the details of the unintegrated gluon distribution. A good description of the S-distribution at low x and low Q^2 is also provided by the color dipole model [18] incorporated in ARIADNE. At higher Q^2 ARIADNE falls below the measured S-values.

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