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Interjet Energy Flow in photoproduction at HERA

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Abstract

The cross sections for the photoproduction of dijet events, where the two jets of highest E_T are separated by a large gap in pseudorapidity, have been studied with the ZEUS detector using an integrated luminosity of 38.7 pb^{-1}. Rapidity-gap events have been defined in terms of the energy flow between the jets, such that the total summed transverse energy in this region is less than E_T^{CUT}. The fraction of dijet events with a rapidity gap measured differentially in the gap size, $\Delta\eta$, is presented and compared with the predictions of perturbative QCD which incorporate resummation of both global, and non-global logarithms.

1 Introduction

The production of events in hadronic collisions with two high transverse energy jets in the final state separated by a large rapidity interval provides an ideal environment to study the interplay between soft, non-perturbative and hard, perturbative QCD.

The dominant mechanism for the production of jets with high transverse energy in hadronic collisions is a hard interaction between partons in the incoming hadrons via a quark or gluon propagator. The exchange of colour quantum numbers generally gives rise to jets in the final state that are colour connected to each other and the remnants of the incoming hadrons. This leads to energy flow which populates the pseudo-rapidity region both between hadronic remnants and the jets themselves. Events with a large rapidity interval and little or no hadronic activity between the jets would then be a signature of the exchange of a colour singlet object.

The presence of high transverse energy jets provides a perturbative hard scale at each end of the colour singlet exchange, such that the cross section should be fully calculable in perturbative QCD [1].

Previous measurements have been made in $p\bar{p}$ collisions at the Tevatron [2, 3], and at HERA such events were first observed by ZEUS [4] and more recently by H1 [5] and ZEUS [6] in photoproduction events. In the most recent HERA studies [5,6], the data were compared with leading log Monte Carlo models including contributions from perturbative colour singlet exchange using the calculations of Mueller and Tang [7] in the leading log approximation of BFKL [8]. These suggested that some contribution of colour singlet exchange may be required, although the uncertainty on the contribution from standard QCD processes was large. In order to conclude anything more concrete about any possible colour singlet contribution, it is necessary to understand the standard QCD contribution more precisely.

In the calculation of the cross section using the infrared safe gap definition in terms of the energy flow, $E_T^{\rm GAP}$, within the gap [9], the emission of primary soft gluons into the gap gives rise to so-called global logarithms which can be resummed [9]. Recently, calculations of a new type of logarithm have been performed [10] for two-jet variables; so called non-global logarithms arise due to soft, secondary emission into the gap from gluons that are themselves not in the gap region.

In this paper the differential ratio of the cross section [6] for producing events with a rapidity gap, defined as in the publication from the H1 collaboration [5], is presented and compared to recent calculations [11] of the gap cross section within perturbative QCD. This calculation includes resummation of both these global and non-global logarithms, although without the inclusion of any explicit colour singlet exchange mechanism.

2 Data selection

The results presented in this paper correspond to 38.7pb^{-1} of data obtained using the ZEUS detector [12] during the 1996-1997 running period, where HERA collided positrons of 27.52 GeV with protons of 820 GeV at a centre of mass energy of $\sqrt{s} = 300$ GeV.

Details of the data selection and correction procedure can be found in a previous publication [6]. After correction the measured distributions correspond to the region of photon virtuality $Q^2 < 1$ GeV^2 and inelasticity $0.2 < y < 0.85$.

Jets were reconstructed using the k_T algorithm [13] in the longitudinally invariant inclusive mode [14]. In this mode, the algorithm merges all final state objects uniquely into a list of massless jets ordered in transverse energy, E_T. Events were selected where the two highest E_T jets satisfied the following criteria,

$$E_T^{\mathrm{jet1}} > 6 \text{ GeV}, \qquad E_T^{\mathrm{jet2}} > 5 \text{ GeV}, \tag{1}$$

$$|\eta^{\mathrm{jet1,2}}| < 2.4, \tag{2}$$

$$|\frac{1}{2}(\eta^{\mathrm{jet1}} + \eta^{\mathrm{jet2}})| < 0.75. \tag{3}$$

To ensure the jets were well separated in pseudo-rapidity space the additional requirement, on the absolute difference in pseudo-rapidity, $\Delta\eta \equiv |\eta^{\mathrm{jet1}} - \eta^{\mathrm{jet2}}|$,

$$2 < \Delta\eta < 4, \tag{4}$$

was also made. The asymmetric cut on jet E_T is to reduce the contribution from regions where next-to-leading order (NLO) QCD calculations may suffer from incomplete cancellation of real and virtual contributions.

The total energy flow between the two highest E_T jets, E_T^{GAP}, was calculated in an infrared safe way, as the sum of the transverse energy of all jets lying in the pseudo-rapidity region between the two jets [5],

$$E_T^{\mathrm{GAP}} = \sum_{i>2} E_T^{\mathrm{jet}i}, \qquad \eta^{\mathrm{jet}i} \in (\eta^{\mathrm{jet}}_{\mathrm{forward}}, \eta^{\mathrm{jet}}_{\mathrm{backward}}). \tag{5}$$

and the event designated as a *gap* event if this total transverse energy flow is less than some cut E_T^{CUT}. The *gap-fraction*, $f(E_T^{\mathrm{CUT}})$, at some E_T^{CUT} is then defined as the ratio of the cross section for events where $E_T^{\mathrm{GAP}} < E_T^{\mathrm{CUT}}$ to that for all events.

The data were corrected for detector effects using the Pythia [15] Monte Carlo generator including a model of multi-parton interactions. The gap fraction in each bin is calculated as the ratio of the integrated cross section for producing gap-events within each bin, to the integrated cross section for producing all events.

3 Resummed calculation

In the measurement of the gap cross section, the restriction of the transverse energy flow in the region between the jets introduces an additional scale and gives rise to large logarithms in the ratio of this additional scale to the hard scale for the interaction.

There are two sources of these large logarithms; primary (or global) logarithms are due to soft gluon emission directly into the gap, whereas secondary, (or non-global) logarithms are due to secondary soft emission into the gap from gluons, not themselves in the gap region.

A recent calculation from Appleby and Seymour [11] resums the global logarithms using the formalism of Collins, Soper and Sterman (CSS) [16]. Because the non-global logarithms are sensitive to the multigluon colour flows, not included in the CSS formalism, they cannot be incorporated into the resummation of the global logarithms. Instead, they are calculated using numerical methods in the limit of large N_C, the number of colours.

The calculation then provides a leading log resummed prediction with the global logarithms correct to all orders and the non-global logarithms correct in the limit of large N_C.

The possible uncertainty arising from unknown higher order contributions is estimated by allowing the renormalisation scale, μ_R, to vary between $\mu_0/2$ and $2\mu_0$ in the usual way, where $\mu_0 = E_T$.

4 Results

Figure 1 shows the gap fraction differentially in $\Delta\eta$ for four values of $E_T^{\mathrm{CUT}} = 0.5$, 1.0, 1.5 and 2 GeV compared to the resummed calculation. The shape of the data as a function of $\Delta\eta$ is reasonably well described by the calculation for all E_T^{CUT} and the normalisation is also consistent, although within the large theoretical uncertainty. For the lower value, $E_T^{\mathrm{CUT}} = 0.5$ GeV, the central prediction lies below the data, although still within the uncertainty. For the higher value, $E_T^{\mathrm{CUT}} = 2.0$ GeV, the central prediction lies slightly above the data such that the prediction tends to increase faster with increasing E_T^{CUT} than does the data.

The prediction including the global logarithms, but without the suppression factor from the non-global logarithms (not shown), generally lies above the limits of the prediction shown in Fig. 1 and is not consistent with the data.

5 Conclusions

The ratio of dijet events with large rapidity separation defined in terms of the level of transverse energy flow between the two jets to inclusive dijet production has been presented, differentially in $\Delta\eta$ for several values of E_T^{CUT}, and compared to the recent calculation of Appleby and Seymour.

When including the suppression due to the resummation of the non-global logarithms in the limit of large N_C, the data are reasonably well described by the calculation, although the current theoretical uncertainties are large and the trend with respect to E_T^{CUT} is not well reproduced.

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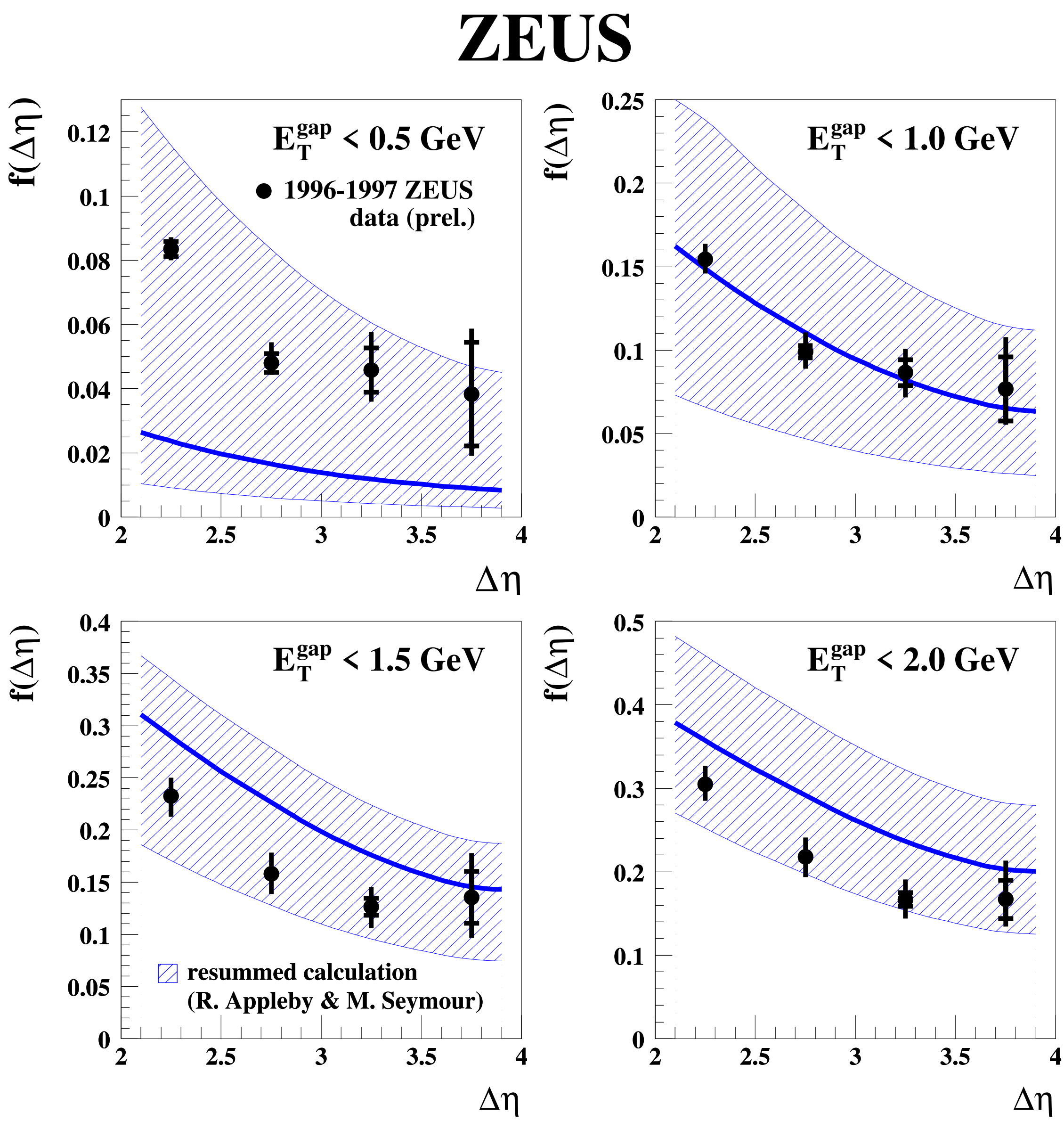

Figure 1: *The gap fraction, f, as a function of $\Delta\eta$ for four values of E_T^{CUT}, 0.5, 1.0, 1.5 and 2.0 GeV, compared to the resummed calculation of Appleby and Seymour. The data are shown as the points where the inner error bar shows the statistical uncertainty and the outer error bar shows the statistical and systematic uncertainty added in quadrature. The prediction is shown as the central curve with the renormalisation scale uncertainty shown as the shaded band. The data are plotted at the 4 bin centres in $\Delta\eta$, whereas the theory curve was produced by joining the bin centres for the ratios of the integrated cross sections for 10 bins in $\Delta\eta$.*