RAPIDITY GAPS BETWEEN JETS AT H1*

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Dijet events in photoproduction with a large rapidity separation between the two highest E_{T} jets have been measured using the H1 detector at HERA. Rapidity gap events are defined as events where the sum of the transverse energy with a rapidity between the two highest E_{T} jet axes, $E_{\mathrm{T}}^{\mathrm{gap}}$, is less than $E_{\mathrm{T}}^{\mathrm{cut}}$ for $E_{\mathrm{T}}^{\mathrm{cut}} = 0.5, 1.0, 1.5, 2.0$GeV. An excess is seen over predictions from standard photoproduction models for small values of $E_{\mathrm{T}}^{\mathrm{cut}}$. The gap fraction, defined as the ratio of dijet events with a rapidity gap to the inclusive dijet cross section, is plotted differentially in the rapidity separation of the dijets, $\Delta\eta$, and the fraction of the photon and proton momentum participating in the production of the dijets, $x_{\gamma}^{\mathrm{jets}}$ and x_{p}^{jets}, respectively. Comparisons are made to models containing a colour singlet exchange.

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1. Introduction

A class of events, characterised by a large rapidity gap in the hadronic final state and a large momentum transfer across the gap, have been observed at the Tevatron [1,2] and HERA [3]. These events are classified by two high E_{T} jets in the hadronic final state, separated by a large rapidity interval with little or no energy flow between the two jets. The large momentum transfer between the incident partons provides a hard scale to allow the exchange to be interpreted within perturbative QCD. However, spectator partons to the hard scatter may interact to destroy the gap between the two jets, forming a potentially large non-perturbative correction to the cross section calculation. This problem can be avoided by defining rapidity gap events in terms of the energy flow in the pseudorapidity region between

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the two jets, $E_{\mathrm{T}}^{\mathrm{gap}}$, such that $E_{\mathrm{T}}^{\mathrm{gap}} \gg \Lambda_{\mathrm{QCD}}$. A perturbative calculation of the cross section is then possible [4]. Alternatively the whole interaction can by modelled using purely non-perturbative models such as the Colour Evaporation Model [5].

2. Event selection and kinematic reconstruction

This analysis is based on an integrated luminosity of 6.6 pb^{-1} of data collected in the 1996 running period by the H1 detector [6], from collisions of 27.6 GeV positrons with 820 GeV protons at HERA. Photoproduction events were selected with $Q^2 < 0.01\ \mathrm{GeV}^2$ and photon-proton centre of mass $165 < W < 233$ GeV by detecting the scattered electron in a low angle tagger downstream of the interaction.

The inclusive k_{t} jet algorithm [7] was applied to the hadronic final state, using the covariant p_{T} scheme. Within this scheme all final state objects are merged into massless jets which are ordered in p_{t}. The inclusive event sample was selected by requiring two or more jets, with the two highest E_{T} jets having transverse energy $E_{\mathrm{T}}^{\mathrm{jet},1} > 6.0$ GeV and $E_{\mathrm{T}}^{\mathrm{jet},2} > 5.0$ GeV. Additionally their rapidities were selected in the range $\eta^{\mathrm{jet},1}, \eta^{\mathrm{jet},2} < 2.65$, with $2.5 < \Delta\eta \equiv |\eta^{\mathrm{jet},1} - \eta^{\mathrm{jet},2}| < 4.0$.

The total transverse energy between the two highest E_{T} jets, $E_{\mathrm{T}}^{\mathrm{gap}}$, is defined as the sum of the transverse energy of all jets whose rapidity lies between those of the two leading jets, *i.e.* $E_{\mathrm{T}}^{\mathrm{gap}} = \sum_{i>2} E_{\mathrm{T}}^{\mathrm{jet},i}$, where $\eta_{\mathrm{forward}}^{\mathrm{jet}} > \eta^{\mathrm{jet},i} > \eta_{\mathrm{backward}}^{\mathrm{jet}}$.

Two further kinematic variables, $x_{\gamma}^{\mathrm{jets}}$ and x_{p}^{jets}, are defined as the fractional momentum of the incident photon and proton participating in the production of the two highest E_{T} jets, respectively.

3. Results and model comparisons

The PYTHIA 5.7 [8] and HERWIG 6.1 [9] Monte Carlo generators were used to correct the data for detector effects and for model comparisons. The HERWIG generator includes the BFKL LLA colour singlet exchange cross section for elastic scattering of two partons, as calculated by Mueller and Tang [10]. In the LLA α_{s} is a free parameter and was chosen to be 0.18. No BFKL exchange has been included in PYTHIA, so to model colour singlet exchange the exchange of a high-t photon, scaled by a factor of 1200, was considered. This should not be a candidate for the colour singlet exchange, as it is not a strongly interacting process, but it does allow the sensitivity of the data to the underlying process to be tested. Specifically, photons couple only to quarks, whereas gluonic objects such as the BFKL pomeron considered here couple preferentially to gluons.

PYTHIA was used with a transverse momentum cut of $P_{\mathrm{T}}^{mp} = 1.5$ GeV on multiple interactions. HERWIG was used with JIMMY [11] to simulate multiple interactions with the value $P_{\mathrm{T}}^{mp} = 1.8$ GeV.

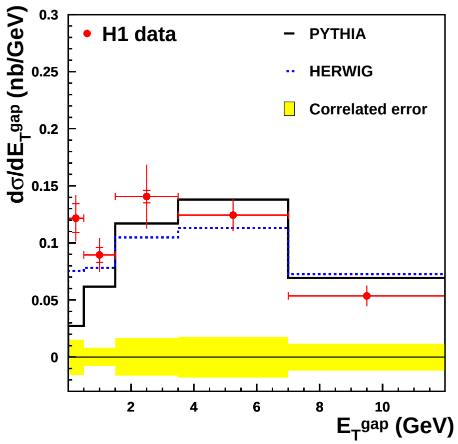


Fig. 1. Dijet cross section differentially in $E_{\mathrm{T}}^{\mathrm{gap}}$ compared to HERWIG and PYTHIA predictions without a colour singlet component.

Figure 1 shows the positron-proton inclusive cross section differentially in $E_{\mathrm{T}}^{\mathrm{gap}}$ with the cuts specified previously. The inner error bars show the statistical error and the outer error bars show the statistical and uncorrelated errors added in quadrature. The predictions from HERWIG and PYTHIA are without the additional colour singlet exchange models. There is a clear excess in the data for $E_{\mathrm{T}}^{\mathrm{gap}} < 0.5$ GeV, where the colour singlet exchange events are expected to lie. To examine this excess more closely the gap fraction, defined as the ratio of dijet events with $E_{\mathrm{T}}^{\mathrm{gap}} < E_{\mathrm{T}}^{\mathrm{cut}}$ to the inclusive dijet cross section, was considered for $E_{\mathrm{T}}^{\mathrm{cut}} = 0.5, 1.0, 1.5, 2.0$ GeV. By using this quantity the majority of systematic errors cancel. Figure 2(a) shows the gap fraction differentially in $\Delta\eta$ compared to HERWIG and PYTHIA predictions without colour singlet exchange. A clear excess over the PYTHIA prediction can be seen up to the highest $E_{\mathrm{T}}^{\mathrm{gap}}$ value and increases with $\Delta\eta$. The data, however, are either flat or rising indicating a colour singlet exchange component. The HERWIG prediction is flatter, but still does not describe the data. The difference between the two generators is due to the hadronisation models used. PYTHIA uses the JETSET [8] model whereas HERWIG uses the cluster fragmentation model [9]. At the level of parton showering both generators show an exponential fall of the gap fraction with increasing $\Delta\eta$. This is expected in events without a colour singlet exchange if the assumption is made that multiplicity fluctuations in the hadronic final state obey Poisson statistics.

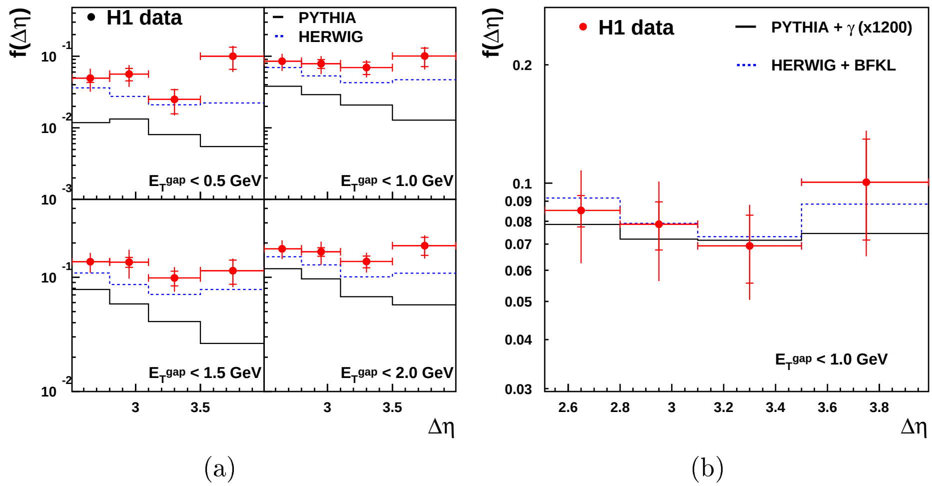
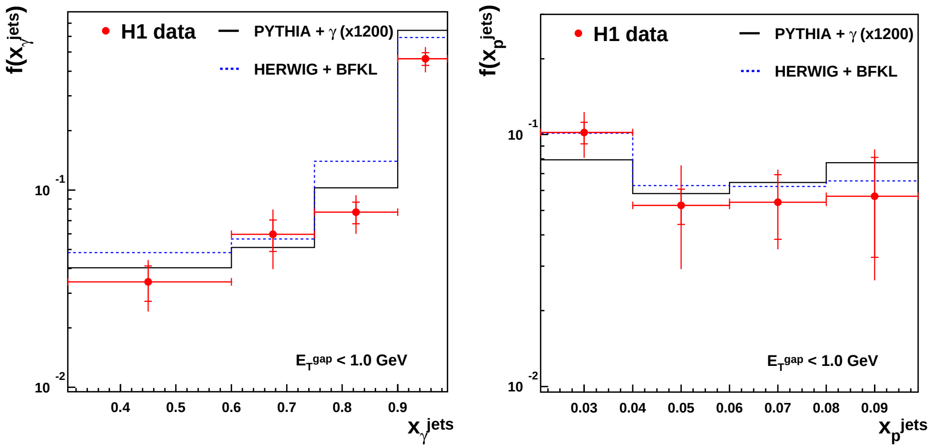


Fig. 2. (a) Gap fraction differentially in $\Delta\eta$ compared with predictions without a colour singlet component, for varying $E_T^{\rm cut}$. (b) Gap fraction for $E_T^{\rm cut} < 1.0$ GeV compared to two different colour singlet exchange predictions (see text).

Figure 2(b) shows the gap fraction differentially in $\Delta\eta$ compared to HERWIG and PYTHIA predictions with colour singlet exchange contributions included for $E_T^{\rm gap} < 1.0$ GeV. The BFKL contribution in the HERWIG prediction was not scaled to fit the data, but has the normalisation set by the choice of $\alpha_s = 0.18$. The PYTHIA high-t photon sample has been scaled by a factor of 1200. Both models are consistent with the data.

Figure 3(a) shows the gap fraction differentially in $x_\gamma^{\rm jets}$ compared to HERWIG and PYTHIA predictions with colour singlet exchange for $E_T^{\rm gap} <$ 1.0 GeV. Both models describe the data for $x_\gamma^{\rm jets} < 0.75$, but the prediction is too high for large $x_\gamma^{\rm jets}$. The rise in gap fraction for large values of $x_\gamma^{\rm jets}$ is reproduced by both generators. This is due to, in leading order QCD, direct photoproduction events (high $x_\gamma^{\rm jets}$) having quark propogators between the outgoing partons participating in the hard scatter, whereas resolved events (low $x_\gamma^{\rm jets}$) mainly have gluon propogators. Quark propogators lead to a lower probability of radiation into the rapidity region between the jets than gluon propogators, therefore the gap fraction increases at high values of $x_\gamma^{\rm jets}$.

Figure 3(b) shows the gap fraction differentially in $x_p^{\rm jets}$ compared to HERWIG and PYTHIA predictions with colour singlet exchange for $E_T^{\rm gap} <$ 1.0 GeV. The predictions of both models are consistent with the data.



(a) (b)

Fig. 3. Gap fraction differentially in (a) $x_\gamma^{\rm jets}$ and (b) $x_p^{\rm jets}$ for $E_{\rm T}^{\rm cut} < 1.0$ GeV compared to two different colour singlet exchange predictions (see text).

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