Measurement of Dijets with a Leading Neutron in ep Interactions at HERA

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Abstract. Measurements are reported of the production of dijet events with a leading neutron in ep interactions at HERA. Differential cross sections for photoproduction and DIS are presented. LO QCD simulation programs and NLO perturbative QCD calculations are compared with the measurements. Models in which the real or virtual photon interacts with a parton of an exchanged pion are found to be in good agreement with the measured cross sections. The fraction of leading neutron dijet events with respect to all dijet events is also determined.

Keywords: leading neutron, pion exchange, jets
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INTRODUCTION

Previous HERA measurements [1, 2] show that the cross section for the semi-inclusive ep scattering process, $e+p \to e+n+X$, where the leading neutron carries a large fraction of the proton energy, is described by the pion exchange mechanism [3] in which the virtual photon interacts with a parton from the pion. In the present analysis [4], the leading neutron production mechanism is investigated further in both photoproduction ($0.3 < y < 0.65$, $Q^2 < 10^{-2}$ GeV^2) and DIS ($2 < Q^2 < 80$ GeV^2, $0.1 < y < 0.7$) regimes by requiring that the hadronic final state contain two jets with transverse energies above 7 GeV and 6 GeV, respectively, measured in the $\gamma^* p$ centre-of-mass frame. Events with a leading neutron are selected from the inclusive dijet samples by requiring an energetic cluster in the forward neutron calorimeter (FNC).

RESULTS

Figure 1 shows the energy spectra as measured in the FNC, together with the predictions from Monte Carlo models. In addition to the models for inclusive jet production, PYTHIA [5] for photoproduction and RAPGAP [6] and LEPTO [7] for DIS, RAPGAP is also used to model the hard interaction assuming that it proceeds via π-exchange.

For neutron energies $E_n > 400$ GeV, the photoproduction data are described by the π–exchange model RAPGAP-π, as well as by PYTHIA without multiple interactions. If multiple interactions are included, PYTHIA predicts a rate which is too high for lower neutron energies. In DIS, the RAPGAP-π model describes the distribution, while the

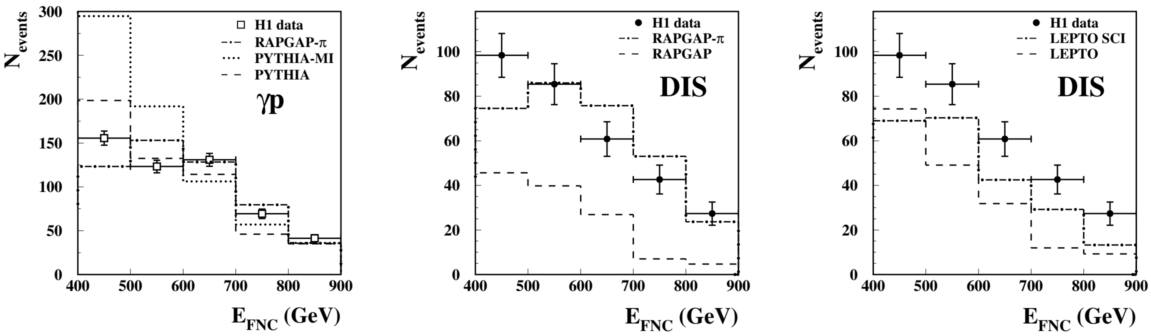

FIGURE 1. Energy distributions observed in the FNC for dijet events compared with the Monte Carlo model predictions normalized to the integrated luminosity of the corresponding data samples.

rates predicted by the standard DIS programs- LEPTO and RAPGAP- are too low. The LEPTO predictions are somewhat increased if soft colour interactions [8] are included.

The differential cross sections are measured at the hadron level for neutron energies $E_n > 500$ GeV. In Fig. 2 the cross sections are shown in the DIS regime. The RAPGAP-π model describes the measured distributions well, while the standard DIS processes, as simulated by LEPTO, lie below the data. In Fig. 3 the jet cross sections are shown in the photoproduction regime. Here, x_γ^{jet} and x_π^{jet} are the fractions of the 4-momentum of the photon and of the pion which participate in the hard interaction. Within the 20% normalization uncertainties the data are well described by the RAPGAP-π model, as well as by the NLO QCD calculation of dijet production in photon–pion collisions [9]. PYTHIA without multiple interactions, which does not include pion exchange, also provides a good description of the photoproduction data. Predictions of PYTHIA with multiple interactions are too high for low values of E_T^{jet} and for $x_\gamma^{jet} < 0.6$.

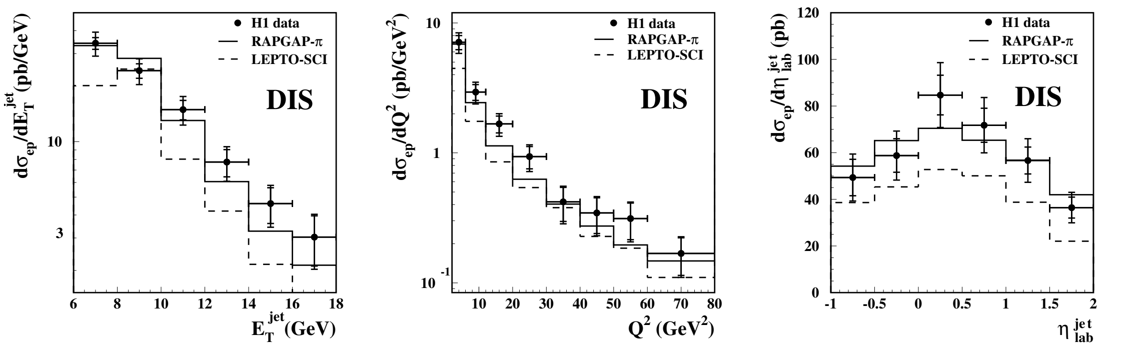

FIGURE 2. The measured differential ep cross sections as a function of E_T^{jet}, Q^2 and η_{lab}^{jet} for dijet events with a leading neutron in DIS.

The measured ratios of the dijet cross sections with and without the requirement of a leading neutron, f_{ln}, are shown in Figs.4 and 5. If the hard interaction is independent of the neutron production, f_{ln} should be essentially independent of the jet kinematics which reflect the hard process. For the photoproduction data, f_{ln} is, within errors, independent

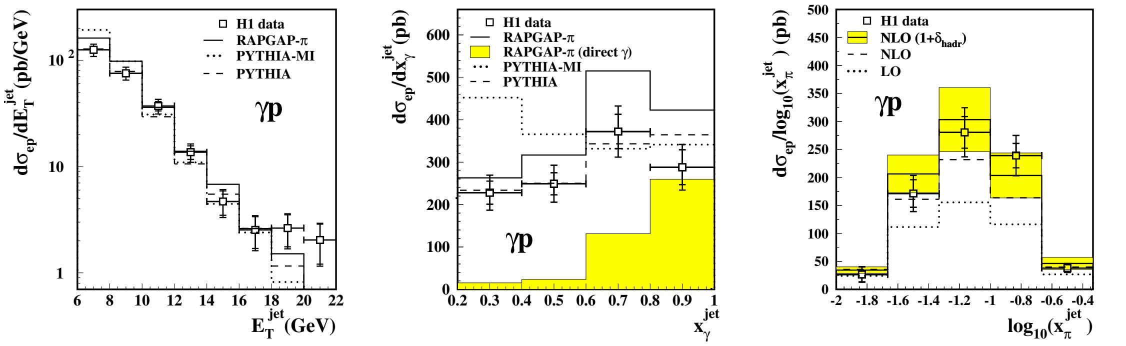

FIGURE 3. The measured differential ep cross sections as a function of E_T^{jet}, x_γ^{jet} and x_π^{jet} for dijet events with a leading neutron in photoproduction.

of E_T^{jet} and has an average value of about 2.3%. However, f_{ln} shows a dependence on other variables. These dependences can only partly be reproduced by the PYTHIA model, which provides some estimate of the size of possible phase space effects. A better description of the ratio in Fig. 4 is possible if the leading neutron data are described by the π-exchange model, RAPGAP-π, and the inclusive dijet data by PYTHIA-MI.

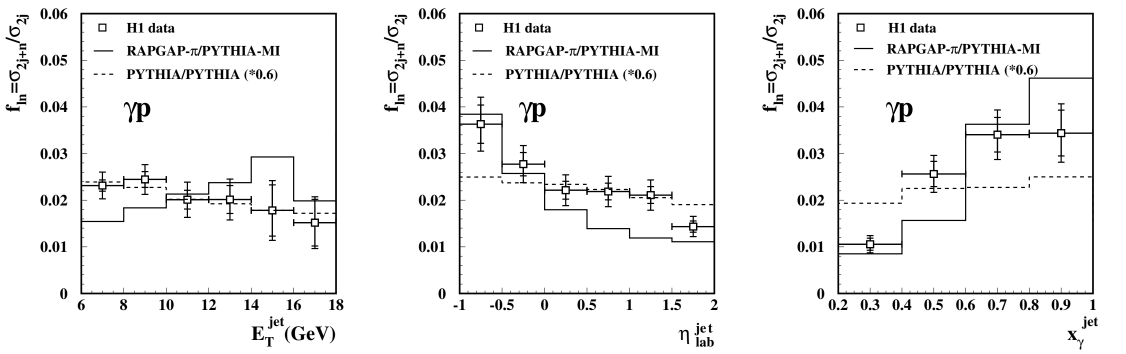

FIGURE 4. The ratio of the cross section for dijet photoproduction with a leading neutron to that for inclusive dijet photoproduction, as a function of E_T^{jet}, η^{jet} and x_γ^{jet}. Monte Carlo predictions for the ratios are obtained by using either RAPGAP-π for the leading neutron cross sections and PYTHIA-MI for the inclusive cross sections, or by using PYTHIA in both cases.

The Q^2 dependence of the ratio f_{ln} is shown in Fig. 5. Within errors, the RAPGAP model describes the measured ratio, when the leading neutron and the inclusive dijet data are represented by RAPGAP-π and standard RAPGAP, respectively. However, there is some tendency for the measured ratio to increase with Q^2, for Q^2 below 20 GeV^2.

CONCLUSIONS

It was observed in [1, 2] that pion exchange provides a good description of the semi-inclusive DIS process in which a leading neutron is produced. The present results demonstrate that this is also the case for the small subsample of leading neutron events

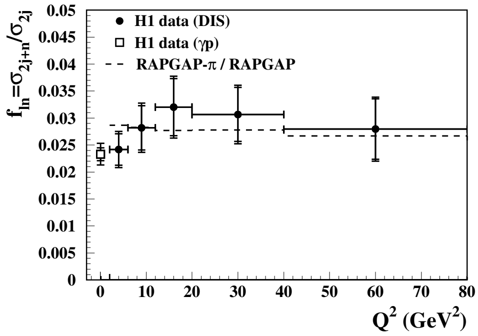

FIGURE 5. The ratio of the cross section for dijet production with a leading neutron to that for inclusive dijet production, as a function of Q^2. The Monte Carlo prediction, shown only for DIS, is obtained by using RAPGAP-π for the leading neutron cross section and RAPGAP for the inclusive cross section.

in which a dijet system is produced, in both DIS and photoproduction. Both the cross section measurements and the neutron energy spectrum are reasonably well described by pion exchange models.

For DIS, the standard Monte Carlo models for the simulation of the hadronic final state, such as LEPTO and RAPGAP, predict cross sections for the production of dijets with a leading neutron which are too small. The increase of the leading neutron rate in dijet production caused by the introduction of non-perturbative soft colour interactions in LEPTO-SCI is not large enough to provide a good description of the measurements.

For the photoproduction sample, the predictions of PYTHIA-MI clearly fail to describe the leading neutron data. This discrepancy between the data and PYTHIA-MI predictions, which on the other hand describe the inclusive jet production [10], suggests that the leading neutron dijet data have a lower fraction of resolved photon processes than do the inclusive dijet data. The decrease of the ratios of the dijet cross sections with and without the leading neutron requirement with decreasing x_γ^{jet} can be explained by the contribution of multiple interactions in inclusive dijet production. There is no evidence for a strong dependence of the ratio on Q^2.

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