PROCEEDINGS OF SCIENCE

Physics with leading neutrons

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H1 and ZEUS results on leading neutron production in *ep* scattering are presented. The data are compared to predictions of pion exchange models. Predictions of rescattering models are also tested.

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1. Introduction

Events with a neutron carrying a large fraction of the proton energy have been observed in *ep* scattering at HERA [1]. The dynamical mechanisms for their production are not completely understood. They may be the result of hadronization of the proton remnant, conserving baryon number in the final state. Exchange of virtual isovector mesons is also expected to contribute, predominantly the exchange of low mass π^+ mesons [2]. In this picture the proton fluctuates into a virtual n-π^+ state. The virtual π^+ scatters with the projectile lepton, leaving the fast forward neutron in the final state. Depending on the virtuality of the exchanged photon, which is a measure of how pointlike the photon is, the neutron may also rescatter with it and escape detection, leading to a depletion of neutrons in some kinematic regions [3].

Both the H1 and ZEUS experiments at HERA have forward neutron calorimeters (FNC) in the proton beam direction. They measure the fraction of the beam energy carried by the neutron, x_L, and the transverse momentum transferred to the neutron, p_T. Here we report results on leading neutron production, in both photoproduction, where the photon virtuality Q^2 is nearly zero, and in deep inelastic scattering (DIS), where Q^2 is greater than a few GeV^2. Further studies are performed by requiring that the hadronic final state contain two jets with large transverse energy. Comparisons are made to Monte Carlo models, some of which incorporate the pion exchange mechanism.

2. Results

Figure 1 shows the energy spectra measured in the FNC for photoproduction and DIS with the dijet requirement. Also shown are the predictions of several Monte Carlo models. RAPGAP-π, which incorporates pion exchange, gives a good description of both data sets. The standard photoproduction generator PYTHIA also describes reasonably the photoproduction data; when multiple interactions are included (PYTHIA-MI) it predicts too high a rate at lower neutron energies. The standard DIS generators RAPGAP and LEPTO, the latter both with and without soft color interactions, predict too low a rate of neutrons.

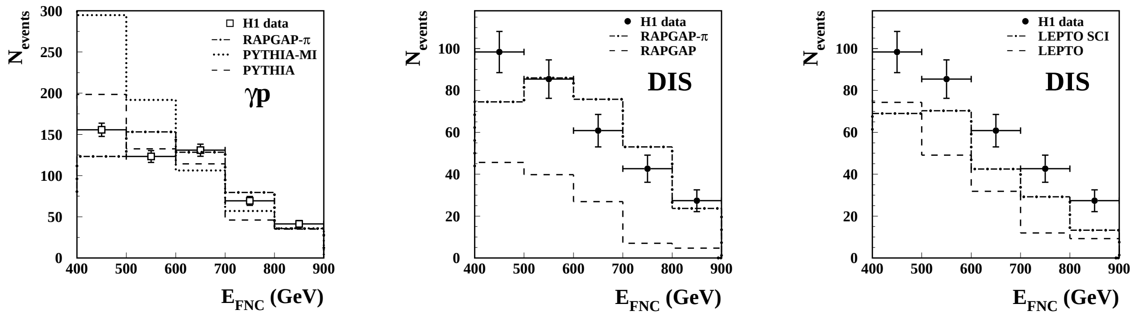

Figure 1: Energy distributions observed in the FNC for photoproduction and DIS events with the dijet requirement, compared to Monte Carlo models normalized to the integrated luminosity of the data samples.

The ratios of dijet events in photoproduction with and without the requirement of a leading neutron, f_{LN}, are shown in Fig. 2. If the hard interaction is independent of the neutron production, as in the pion exchange picture, f_{LN} should be essentially independent of the jet kinematics which

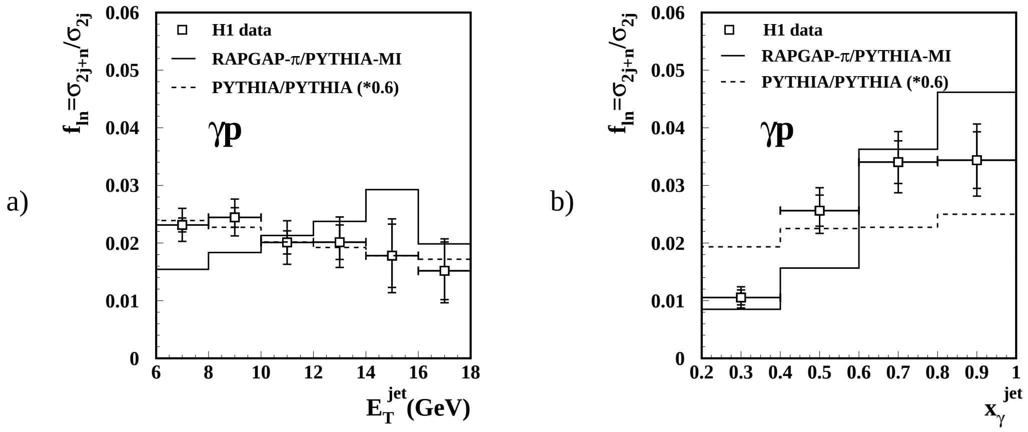

Figure 2: a) Fraction of dijet events with a leading neutron versus jet transverse energy. b) Fraction of dijet events with a leading neutron versus x_γ, the fraction of photon momentum participating in hard scattering.

reflect the hard process. Figure 2a shows that f_{LN} is, within errors, independent of the jet transverse energy E_T. However Fig. 2b shows some dependence on x_γ, the fraction of photon momentum participating in the hard scattering. These dependencies can only partly be reproduced by the PYTHIA model, which provides some estimate of possible phase space effects. A better description is given by the pion exchange model RAPGAP-π for the leading neutron data and PYTHIA-MI for the inclusive dijet data.

The p_T^2 distributions of neutrons in DIS are shown in Fig. 3a. They are well described by exponentials $\exp(-bp_T^2)$. The slopes b are shown as a function of x_L in Fig. 4a. They rise linearly in the range x_L =0.4-0.85, and drop slightly at higher x_L. Also shown are the predictions of several pion exchange models. None give a good description of the data.

The p_T^2 distributions of neutrons in photoproduction and DIS are shown in Fig. 3b, normalized to unity at $p_T^2 = 0$. The distributions for photoproduction are steeper in the range x_L =0.6-0.9. This is summarized in Fig. 4b, where the difference $\Delta b = b(\gamma p) - b(DIS)$ is plotted. In rescattering models small n-π separations, corresponding to large p_T, undergo more rescattering. The depletion of neutrons at high p_T^2 in photoproduction is qualitatively consistent with this picture.

3. Conclusions

Leading neutron production was studies in DIS and photoproduction, also with the requirement of dijets in the final state. The neutron energy spectra were compared to Monte Carlo models, and the best agreement was found with models incorporating pion exchange. However, the neutron p_T spectra in DIS differ from the pion exchange models. Effects qualitatively consistent with rescattering models were observed in photoproduction.

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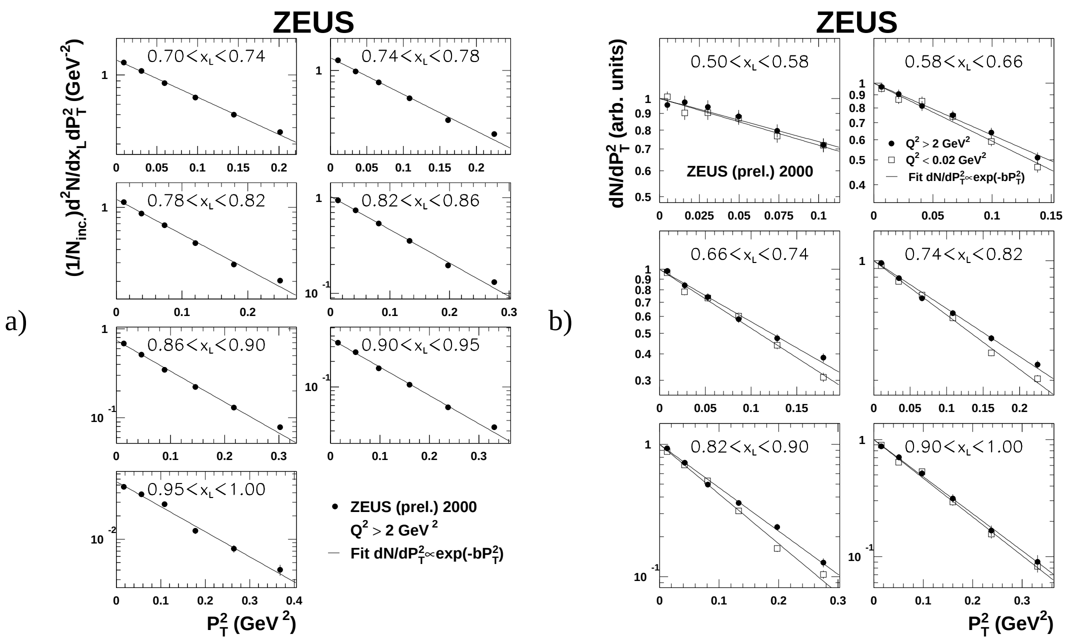

Figure 3: a) Leading neutron p_T^2 distributions for the DIS sample. The curves are fits to the form $\exp(-bp_T^2)$. b) Leading neutron p_T^2 distributions for the DIS and photoproduction samples, normalized to unity at p_T^2=0.

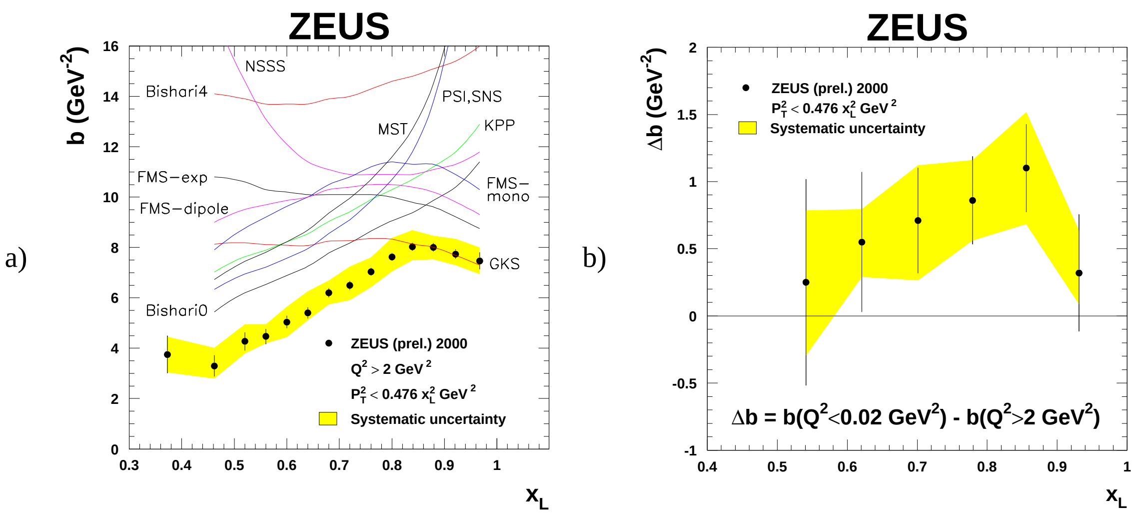

Figure 4: a) The slopes b from Fig. 3a. b) The differences of the slopes b in Fig. 3b.

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