Forward neutron p_T distributions and forward photon spectra measured in the FNC

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Abstract. Recent measurements of the forward neutron and forward photon production in deep-inelastic scattering obtained by the H1 Collaboration using the Forward Neutron Calorimeter are presented. Results are compared with different Monte Carlo models used commonly in deep-inelastic scattering or cosmic ray air showers.

Keywords: leading neutron, forward neutron, pion exchange, forward photon, cosmic ray hadronic interactions
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INTRODUCTION

Measurements of particle production at very small angles with respect to the proton beam direction (forward direction) in ep collisions are important for the theoretical understanding of proton fragmentation. Measurements of forward particle production also provide important constraints for the modelling of the high energy air showers and thereby are very valuable for the understanding of high energy cosmic ray data.

FORWARD NEUTRON p_T DISTRIBUTIONS IN DIS

The production of forward neutrons, which carry a large fraction x_L of the incoming proton's longitudinal momentum, is studied in deep-inelastic e^+p scattering (DIS) at HERA [1]. The data are taken with the H1 detector in the years 2006 and 2007 and correspond to an integrated luminosity of 122 pb^{-1}. The neutrons are measured in Forward Neutron Calorimeter (FNC) of the H1 Experiment. The semi-inclusive double differential cross sections are measured as function of the neutron longitudinal momentum fraction x_L and transverse momentum squared p_T^2 in the phase space defined by the photon virtuality 6 GeV$^2 < Q^2 <$ 100 GeV^2, the inelasticity $0.05 < y < 0.6$, the longitudinal momentum fraction $0.32 < x_L < 1.0$ and transverse momentum $p_T < x_L \cdot 0.69$ GeV of the neutron.

Monte Carlo (MC) simulations are used to correct the data for the effects of detector acceptance and QED radiation. The programs DJANGOH [2] (standard fragmentation) and RAPGAP [4] (π^+-exchange) are used to simulate DIS events. The best description of the data is achieved if the MC simulations are combined, using weighting factors. The weighting factors obtained from fit to the x_L distribution [3] also describe p_T^2 distributions well.

The left side of Fig. 1 shows the measurement of the semi-inclusive double differential cross section of forward neutron production as a function of p_T^2 and x_L and it's comparison with the MC simulations. The p_T^2 slopes predicted by DJANGO are roughly constant with x_L, while RAPGAP-π^+ predicts slopes increasing with x_L

The fit of the p_T^2 distributions by an exponential function $a(x_L)\exp(-b(x_L)p_T^2)$ in each x_L bin are shown in the right side of Fig. 1. The obtained values of the p_T^2 slopes (parameter $b(x_L)$) are shown in Fig. 2 together with the several parametrisations of the pion flux. Most of the shown predictions describe the data within uncertainties.

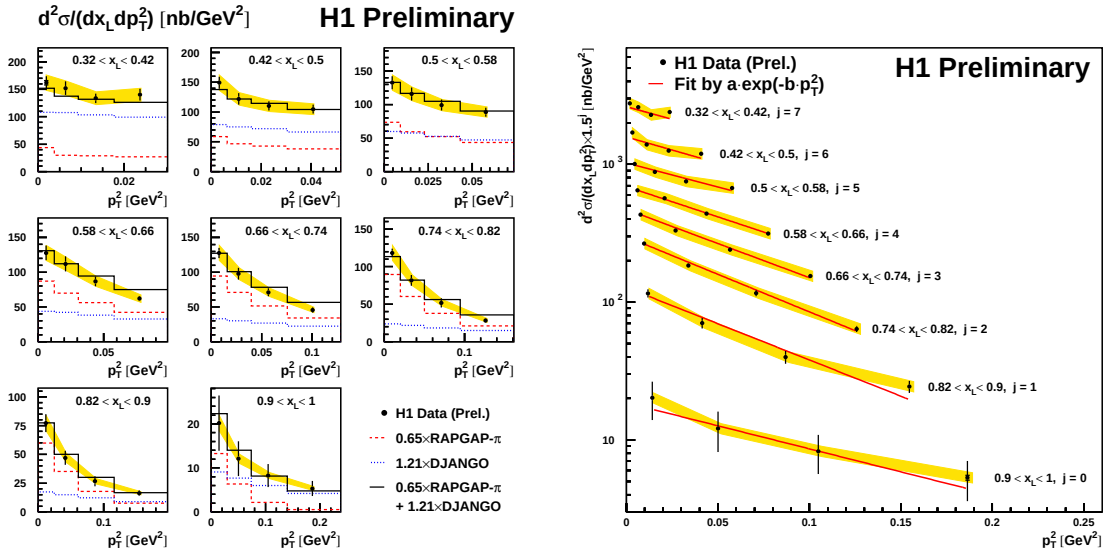

FIGURE 1. Double differential cross section of forward neutron production as a function of p_T^2 and x_L of the forward neutron. On the left: data compared to predictions of the RAPGAP pion exchange (dashed line) and DJANGO (dotted line) MC simulations as well as combination of those two simulations (full line). Right: the cross sections are fitted by an exponential function in each x_L bin.

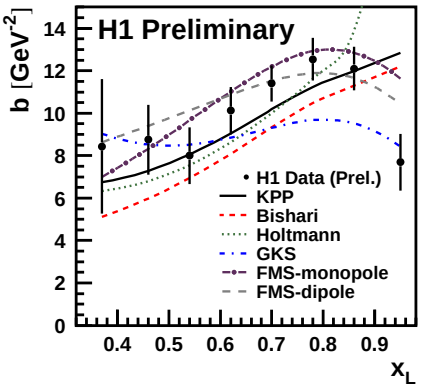

FIGURE 2. b-slopes of the p_T^2 distributions of forward neutrons compared with the known pion flux parametrisations

FORWARD PHOTON SPECTRA IN DIS

The production of photons at very small angles with respect to the proton beam direction is studied in deep-inelastic positron-proton scattering at HERA [5]. The data are taken with the H1 detector in the years 2006 and 2007 and correspond to an integrated luminosity of 126 pb^{-1}. The analysis covers the kinematic range of 6 GeV^2 $< Q^2 <$ 100 GeV^2 and $0.05 < y < 0.6$. The forward photons are measured in the FNC of the H1 Experiment.

The DJANGOH [2] program is used to generate inclusive DIS events. Higher order QCD effects are simulated using leading log parton showers as implemented in LEPTO [6], or using the Colour Dipole Model (CDM) as implemented in ARIADNE [7].

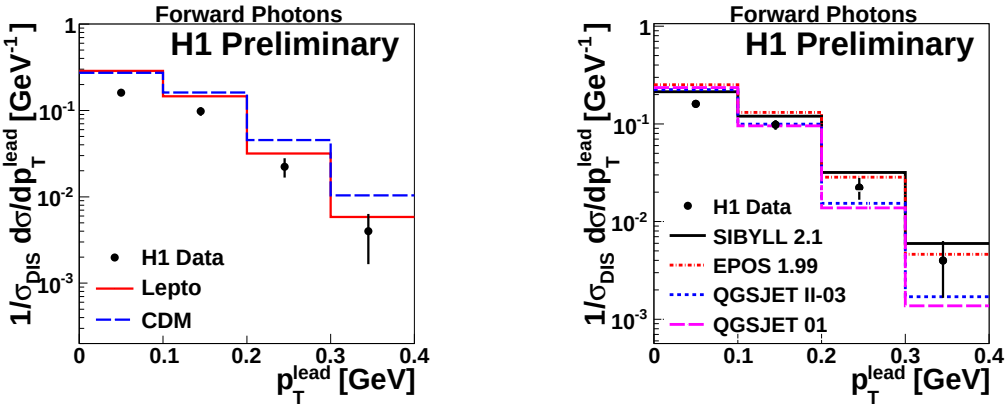

FIGURE 3. The normalised cross sections for the production of forward photons as a function of p_T^{lead}.

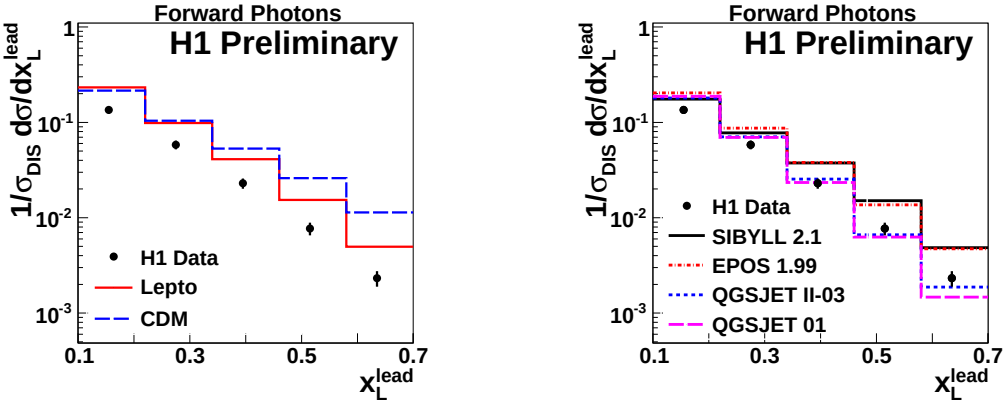

FIGURE 4. The normalised cross sections for the production of forward photons as a function of x_L^{lead}.

Figures 3 and 4 show cross sections measured for the most energetic photon with pseudorapidity $\eta > 7.9$ as a function of its transverse momentum p_T^{lead} and longitudinal momentum fraction of the incoming proton x_L^{lead}. The data are compared to LEPTO and CDM MC predictions. The measurements are also compared with the predictions

of several hadronic interaction models which are commonly used for the simulation of cosmic ray air shower cascades: EPOS [8], QGSJET 01 [9, 10], QGSJET II [11, 12] and SIBYLL [13, 14].

All models overestimate the total rate of forward photons. The shapes of all measured distributions are well described by LEPTO. CDM predicts harder x_L and p_T spectra. The QGSJET models predict slightly softer spectra in x_L and p_T. The EPOS and SIBYLL models predict harder x_L spectra, but reasonably describe the shape of p_T distribution.

SUMMARY

The production of forward neutrons and forward photons has been studied in DIS as a function of longitudinal momentum fraction x_L and transverse momentum p_T.

There is clear evidence that both contributions from fragmentation processes and from the exchange of colour-neutral particles such as π^+ are required to describe the forward neutron data. The p_T^2 spectra of forward neutrons are sensitive to the pion flux parametrisations.

Predictions of Monte Carlo models overestimate the rate of forward photon production. All these models predict different spectra in x_L and p_T. None of them can describe the photon data in rate and in shape.

The present measurements may lead to further understanding of proton fragmentation in collider and cosmic ray experiments.

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