Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

FORWARD π° PRODUCTION IN DIS

LIDIA GOERLICH
FOR THE H1 COLLABORATION
Institute of Nuclear Physics
Polish Academy of Sciences
Radzikowskiego 152, 31-342 Kraków, Poland
E-mail: lidia.goerlich@ifj.edu.pl

Deep inelastic events at low values of Bjorken-x containing high transverse momentum π° mesons, produced close to proton remnant in the laboratory frame, are studied with the H1 experiment at HERA. The data are used to discriminate between QCD models with different parton evolution schemes.

1 Introduction

In deep-inelastic scattering (DIS) at HERA the large $\gamma^* p$ centre of mass energy available at small x gives rise to a large phase space for gluon cascades exchanged between the proton and the photon. Several perturbative QCD-based prescriptions are available to describe succesive parton emmisions. The standard DGLAP evolution equations[1] resum leading $\ln(Q^2)$ terms and ignore $\ln(1/x)$ terms. In this approach gluon emissions are strongly ordered in transverse momentum. At asymptotically high energies and thus in the region of very small x, it is believed that the theoretically correct description is given by the BFKL[2] evolution. In this approximation large leading $\ln(1/x)$ terms dominate the evolution and there is no ordering in transverse momentum of the partons along the ladder. A parton chain without transverse momentum ordering is also provided by allowing the virtual photon to have a partonic structure. In this picture two DGLAP cascades are initiated: one from the proton and one from the photon. In CCFM[3] evolution angular ordering of the emitted partons results from colour coherence. In the limit of asymptotic energies the CCFM evolution equation is almost eqiuvalent to BFKL and for large x and high Q^2 it behaves like the DGLAP approximation.

One of the important questions in high energy collisions at HERA is whether deviations from DGLAP type predictions can be observed and whether there is a need for small-x effects. Studies of the hadronic final state in DIS produced close to the proton remnant direction in the laboratory frame (LAB), the so-called forward region, are considered to be especially sensitive to the QCD dynamics at low x. Typical measurements of forward jets or single forward particles, inspired by the proposal of Mueller[4], are restricted to the phase space region where their values of transverse momentum squared are of similar magnitude to Q^2 to suppress DGLAP evolution. In addition the fraction of the proton's energy carried by the particle or jet is required to be greater than Bjorken-x to enhance the phase space for BFKL effects.

© Institute of Experimental Physics SAS, Košice, Slovakia

An advantage of using single particles rather than jets is that ambiguities due to the choice of jet algorithm are removed. There is also the potential to reach angles closer to the proton remnant direction. Especially in the H1 detector, forward π^0-mesons can be identified at very low angles. A disadvantage is that the cross section for the process is supressed in comparison to forward jet production, and that the fragmentation effects are more significant.

In this analysis we present recent results of the H1 Collaboration on high transverse momentum forward π°-mesons produced in DIS at low x[5]. The data are compared to various QCD-based models.

2 Inclusive Forward π° Cross Sections and Transverse Energy Flow

The data used in this analysis correspond to a total integrated luminosity of 21.2 pb^{-1}. The results are based on a data sample which is more than three times larger than that used for earlier studies[6] and thus the measurement of more differential distributions and additional final state observables is possible. The analysis is restricted in the kinematic range $2 < Q^2 < 70$ GeV^2, $0.1 < y < 0.6$, $5^\circ < \theta_\pi < 25^\circ$, $x_\pi = E_\pi/E_p > 0.01$ and $p^*_{T,\pi} > 2.5$ or 3.5 GeV, where $E_\pi(E_P)$ denotes the energy of the forward π(proton) in LAB and $p^*_{T,\pi}$ is defined in the photon-proton centre-of-mass system (CMS). The resulting range in Bjorken-x extends down to $x \approx 4 \cdot 10^{-5}$.

Inclusive forward π^0 cross sections are shown as a function of Bjorken-x for dif-

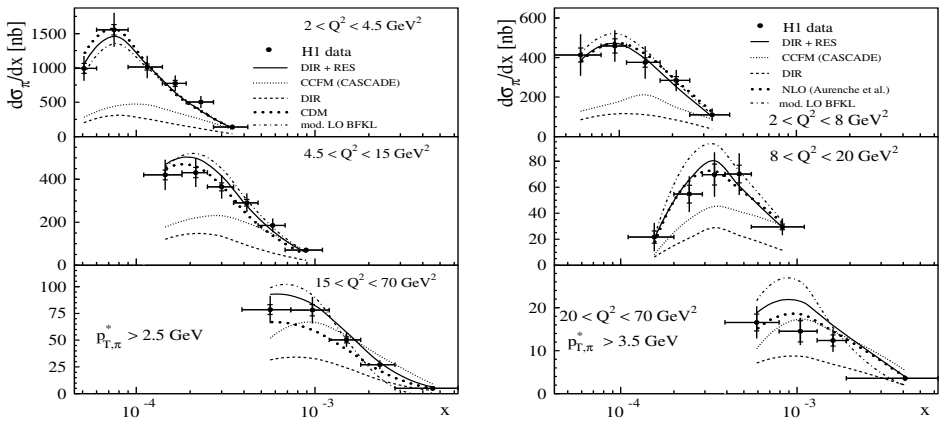

Figure 1. Inclusive forward π° production cross section as a function of x in three regions of Q^2 for $p^*_{T,\pi} > 2.5$ GeV (left) and $p^*_{T,\pi} > 3.5$ GeV (right).

ferent regions of Q^2 in Fig. 1 for $p^*_{T,\pi} > 2.5$ GeV and $p^*_{T,\pi} > 3.5$ GeV. The data are compared with hadron level Monte Carlo (MC) calculations which implement various QCD models. RAPGAP[7] matches first-order QCD matrix elements to DGLAP based leading-log parton showers. In addition to the direct photon pro-

cesses, labelled DIR, RAPGAP simulates resolved photon interactions, in which the virtual photon is assumed to have structure. Here, the sum of the direct and resolved processes is marked DIR+RES. For the predictions presented here, the renormalisation and factorisation scales are set to $Q^2 + 4p_T^2$, where p_T is the transverse momentum of the partons taking part in the hard scattering process. The prediction of RAPGAP with a point-like photon is well below the data. The addition of a resolved photon contribution gives a reasonable description although it is necessary to use rather large scales in order to get a sufficiently large resolved photon component. In CASCADE[9] off-shell QCD matrix elements are supplemented with parton emissions based on the CCFM equation. The predictions of CASCADE agree with the data at the highest values of Q^2, however, they fail to match the measured π^0 cross section at low values of x and Q^2. The Color Dipole Model as implemented in ARIADNE[8], marked CDM, also gives a reasonable description of the measurement for $p^*_{T,\pi} > 2.5$ GeV as shown in Fig. 1. Predictions of the CDM (not shown) overestimate the data at the lowest values of Q^2 and x for measurements with $p^*_{T,\pi} > 3.5$ GeV. In the CDM the parton emissions perform a random walk in transverse momentum, leading to a situation similar to that expected in BFKL. Analytical calculations based on LO BFKL with a consistency constraint which mimics higher order BFKL effects have been discussed in [10] for DIS events containing a forward jet or π^0. Predictions of the π^0 cross section at the parton level convoluted with π^0 fragmentation functions from [11], labelled mod. LO BFKL, are also shown in Fig. 1. The data are well described in the lowest Q^2 region; some deviations are seen for higher Q^2. However, these predictions are very sensitive to the choice of scale for α_s and the infra-red cut-off.
Recently, NLO calculations of the cross section for the production of high transvere momentum hadrons in DIS interactions have been made by Aurenche et al.[12]. In these calculations, a large part of the cross section is generated by higher order contributions which correspond to lowest order BFKL and resolved photon processes. The prediction of the NLO calculation is also shown in Fig. 1 and describes the data well. However, these calculations are also sensitive to the renormalisation and factorisation scales.

Studies of transverse energy flow provide a complementary means of investigating QCD processes. The transverse energy flow in the CMS, $\frac{1}{N} dE^*_T/d(\eta^* - \eta^*_\pi)$, in events containing at least one forward π° is shown in Fig. 2. The energy flow, which includes the contribution from the forward π°, is plotted as a function of the distance in pseudorapidity $\Delta\eta^* = (\eta^* - \eta^*_\pi)$ from the forward π°. The spectra are presented in three intervals of the π° pseudorapidity ranging from close (Fig. 2a) to far (Fig. 2c) from the proton direction. The QCD-based models except CDM all describe the transverse energy flow around the π° but give different predictions in the current region. The differences between the models can be qualitatively understood as a consequence of the ordering or otherwise of the transverse momentum in the parton cascades implemented within MC models. Calculations which include resolved photon processes tend to agree better with the data. The CDM predicts too much transverse energy in the vicinity of the π°, which is a consequence of the overly hard π° transverse momentum distribution predicted by this model.

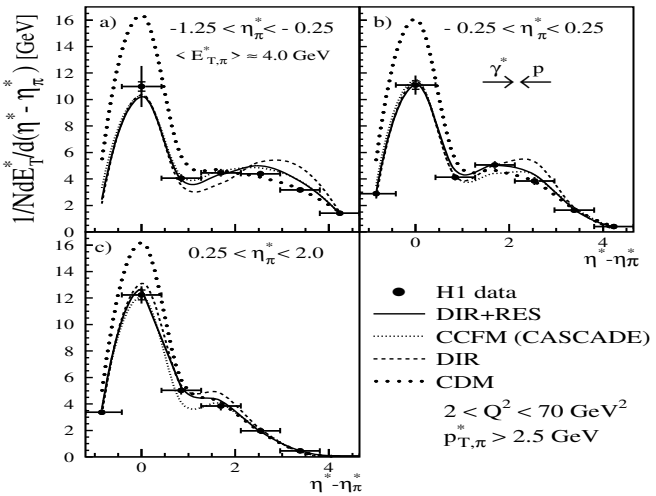

Figure 2. Transverse energy flow relative to the π° in various ranges of η^*_π.

3 Conclusions

The measurements presented are sensitive to the dynamics of parton evolution. The data show deviations from the LO DGLAP predictions. The inclusion of resolved photon processes improves the overall description. In some regions of phase space the BFKL and CCFM predictions are compatible with the data. However, the correct description of the data at small x is still a challenge for theory and experiment.

References

1. V. Gribov, L. Lipatov, Sov. J. Nucl. Phys. **15** (1972) 438 and 675; G. Altarelli, G. Parisi, Nucl. Phys. **B 126** (1977) 298; Y. Dokshitser, Sov. Phys. JETP **46** (1977) 641.
2. E. Kuraev, L. Lipatov and V. Fadin, Sov. Phys. JETP **45** (1977) 199; Y. Balitsky, L. Lipatov, Sov. J. Nucl. Phys. **28** (1978) 822.
3. M. Ciafaloni, Nucl. Phys. **B 296** (1988) 49; S. Catani, F. Fiorani, G. Marchesini, Phys. Lett. **B 234** (339) 1990 and Nucl. Phys. **B 336** (1990) 18.
4. A.H. Mueller, Nucl. Phys. **B** (Proc. Suppl.) **C18** (1990) 125.
5. H1, A. Aktas *et al.*, DESY 04-051, submitted to Eur. Phys. J. C.
6. H1, C. Adloff *et al.* Nucl. Phys. **B 538** (1999) 3.
7. H. Jung, Comp. Phys. Commun. **86** (1995) 147.
8. L. Lönnblad, Comp. Phys. Commun. **71** (1992) 15.
9. H. Jung, Comp. Phys. Commun. **143** (2002) 100.
10. J. Kwieciński, A. Martin, J. Outhwaite, Eur. Phys. J. **C9** (1999) 611.
11. B.A. Kniehl, G. Kramer, B. Pötter, Nucl. Phys. **B 597** (2001) 337.
12. P. Aurenche, R. Basu, M. Fontannaz and R. Godbole, Eur. Phys.J. **C 34**(2004) 277 and M. Fontannaz, private communication