Forward π°-meson production at HERA

T. Wengler [a] – talk given on behalf of the H1 collaboration at DIS99, Zeuthen

[a]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

The production of high transverse momentum π°-mesons has been measured in deep-inelastic e-p scattering events at low Bjorken-x taken with the H1 detector at HERA. The production of high p_T particles is strongly correlated to the emission of hard partons in QCD and is therefore sensitive to the dynamics of the strong interaction. For the first time the measurement of single particles has been extended to the region of small angles w.r.t. the proton remnant (forward region) and down to very low values of $x \approx 5{\cdot}10^{-5}$. This region is expected to be particularly sensitive to QCD evolution effects in final states. Differential cross sections of inclusive π°-meson production have been measured as a function of Bjorken-x and the four-momentum transfer Q^2, and also as a function of the transverse momentum and the polar angle of the π°-mesons. A recent BFKL calculation and QCD models based on the DGLAP splitting functions are compared to the data. The best description of the data is achieved by the BFKL calculation.

1. INTRODUCTION

It is the unique kinematical reach of the ep collider HERA which has enabled us to study deep-inelastic scattering (DIS) at values of Bjorken-x down to $x \sim 10^{-6}$ as well as at momentum transfers up to $Q^2 \sim 30000$ GeV^2.

In the classical DIS picture a parton in the proton can undergo a QCD cascade resulting in several parton emissions before the final parton interacts with the virtual photon. Differences between different dynamical assumptions on the parton cascade are expected to be emphasized in the region towards the proton remnant direction, i.e. away from the scattered quark in the HERA kinematical range. In the HERA laboratory frame this has been termed the forward region.

In this paper we study forward single π° production for a considerably larger data sample and in an enlarged kinematical range as compared to a previous publication by the H1 collaboration [1]. The production of high p_T particles is strongly correlated to the emission of hard partons in QCD [2] and is therefore sensitive to the dynamics of the strong interaction.

2. MEASUREMENT

The analysis is based on data representing an integrated luminosity of $\mathcal{L}= 5.8$ pb^{-1} taken by H1 during the 1996 running period. Deep-inelastic scattering events are selected in the range $0.1 < y < 0.6$ and $2 < Q^2 < 70$ GeV^2. About 600k events remain after the selection.

The π°-mesons are measured using the dominant decay channel $\pi^\circ \to 2\gamma$. The π° candidates are selected in the region $5^\circ < \theta_\pi < 25^\circ$, where θ_π is the polar angle of the produced π°. Candidates are required to have an energy of $x_\pi = E_\pi / E_{\mathrm{proton}} > 0.01$, with E_{proton} the proton beam energy, and a transverse momentum in the hadronic cms, $p_{T,\pi}$, greater than 2.5 GeV. At the high π° energies considered here, the two photons from the decay cannot be separated, but appear as one object (cluster) in the calorimetric response. The standard method of reconstructing the invariant mass from the separate measurement of the two decay photons to identify the π°-meson is hence not applicable. Instead, a detailed analysis of the longitudinal and transverse shape of the energy depositions is performed [2]. This approach is based on the compact nature of electromagnetic showers as opposed to showers of hadronic origin, which are broader. The main experimental challenge in this analysis is the high particle and energy density in this region of phase space, with hadronic showers 'obscuring' the clear electromagnetic signature provided by the two photons of a π° decay. This overlap is mainly respon-

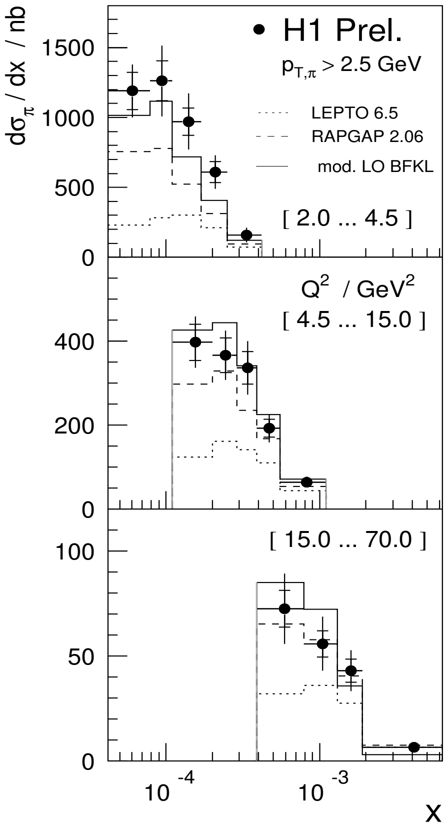

Figure 1. *Inclusive π°-meson cross sections as a function of x for $p_{T,\pi}(hcms) > 2.5$ GeV, $0.1 < y < 0.6$, $5^\circ < \theta_\pi < 25^\circ$ and $x_\pi = E_\pi / E_{\rm proton} > 0.01$. RAPGAP (dir+res) and LEPTO are compared to the data as well as the prediction of the modified LO BFKL calculation [3]*

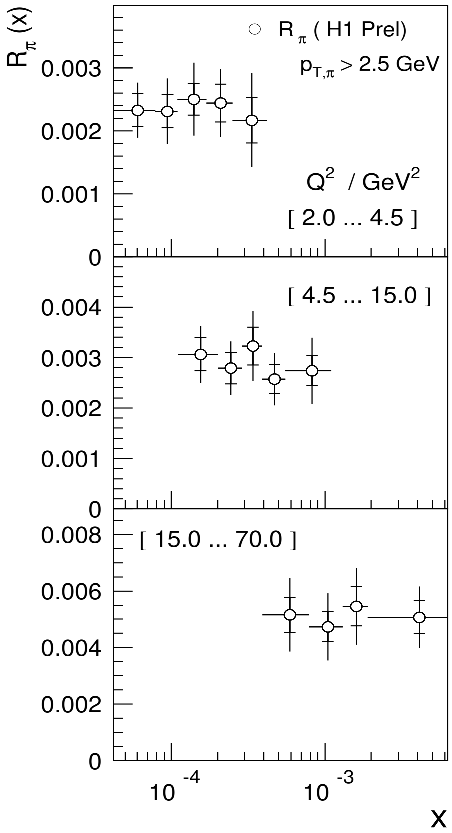

Figure 2. *The rate of π°-meson production in DIS as a function of x obtained by dividing the cross section shown in Figure (a) by the inclusive ep cross-section in each bin of x,y and Q^2.*

sible for losses of π° detection efficiency, since the distortion of the shape estimators it causes will in many cases lead to the rejection of the cluster candidate. With this selection about 1700 π° candidates are found with a detection efficiency above 45%.

Monte Carlo studies using a detailed simulation of the H1 detector yield a purity of about 70% for the selected π°-meson sample, with impurities from misidentified hadrons from the main vertex, partly (10%) also from secondary vertices in dead material of the tracking detector.

3. RESULTS

The final experimental results of the analysis are obtained as differential cross sections of forward π°-meson production as a function of Q^2, and as a function of x, η_π and $p_{T,\pi}$ in three regions of Q^2 for $p_{T,\pi} > 2.5$ GeV. In addition the π° cross sections as a function of x and Q^2 are measured for $p_{T,\pi} > 3.5$ GeV. The phase space is given by $0.1 < y < 0.6$, $2 < Q^2 < 70$ GeV^2, $5^\circ < \theta_\pi < 25^\circ$ and $x_\pi = E_\pi / E_{\rm proton} > 0.01$ in addition to the $p_{T,\pi}$ thresholds given above. θ_π and x_π are taken in the H1 laboratory frame, $p_{T,\pi}$ is calculated in the hadronic cms. The measurement extends down to values of $x > 5{\cdot}10^{-5}$, covering two orders of magnitude in x. Of these cross sections [4] only $d\sigma_\pi/dx$ for $p_{T,\pi} > 2.5$ GeV are shown here. All observables are corrected for detector effects and for the influence of QED radiation by a bin-by-bin unfolding procedure. The typical systematic uncertainty is 15-25%, compared to a statistical uncertainty of about 10%. Contributions to the systematic error include among others the energy scales of the calorimeter, uncertainties in the selection of π°-mesons and the model dependence of the bin-by-bin correction procedure.

The cross sections as a function of x shown in Figure 1 exhibit a strong rise towards small x. An interesting observation is that this rise corresponds to the rise of the inclusive ep cross section. The ratio of the two cross sections is shown in Figure 2 and shows no dependence on x in the three regions of Q^2. The production rates do decrease with decreasing Q^2 for fixed x. The inclusive ep cross section for this comparison is obtained by integrating the H1 QCD fit to the 1996 structure function data as presented in [5] for every bin of the present measurement of inclusive π°-meson cross sections.

The DGLAP prediction for pointlike virtual photon scattering only, represented by LEPTO [6], falls clearly below the data. The mechanism of emitting partons according to the DGLAP splitting functions, combined with pointlike virtual photon scattering only, is clearly not supported by the data in particular at low x. A considerable improvement of the description of the data is achieved by considering processes where the virtual photon entering the scattering process is resolved. Such a prediction is provided by RAPGAP [7]. All predicted cross sections increase by up to 30% when the scale in the hard scattering is increased to $Q^2 + 4p_T^2$ from $Q^2 + p_T^2$ [2], and hence does not improve the overall description. Whether this mechanism is adequate to describe the π° cross sections down to the lowest available x therefore cannot finally be decided by RAPGAP.

Next we compare with a calculation following the BFKL formalism in order $\mathcal{O}(\alpha_s)$. Fragmentation functions are used to calculate the π°-meson cross sections from the partonic final state. The predictions obtained with these calculations turn out to be in good agreement with the neutral pion cross sections measured in the entire available phase space with a slight tendency to be below the data at the lowest values of x available.

4. CONCLUSIONS

With the present measurement of inclusive π°-meson cross sections it has become possible for the first time to measure observables of the hadronic final state in this region of the phase space with relatively small experimental uncertainties. It provides testing ground for any theory that claims to describe processes at small x with large phase space for parton emissions and a reasonably hard scale.

Models using $\mathcal{O}(\alpha_s)$ QCD matrix elements and parton cascades according to the DGLAP splitting functions cannot describe the differential neutral pion cross sections at low x. Including processes in which the virtual photon is resolved leads to an improved description of the data. Renormalization and factorization scale uncertainties however limit the precision of the predictions. A calculation based on the BFKL formalism is in good agreement with the data. Considering the relatively small uncertainties [3] given for this calculation it is the best available approximation of QCD in the considered phase space.

REFERENCES

1. H1 Collab., C. Adloff et al., Nucl.Phys. **B538** (1999) 3-22.
2. T. Wengler, PhD thesis, University of Heidelberg, January 1999, DESY-THESIS-1999-011.
3. J. Kwiecinski, A.D. Martin, J.J. Outhwaite, hep-ph/9903439, to be published in Eur. Phys. J. **C**.
4. E. Elsen, talk given at the Physics Research Committee at DESY, Hamburg, January 13, 1999.
5. H1 Collab., C. Adloff et al., Contribution to HEP97 Jerusalem, August 9-26, 1997.
6. G. Ingelman, A. Edin and J. Rathsman, Comp. Phys. Comm. **101** (1997) 108.
7. H. Jung, Comp. Phys. Comm. 86 (1995) 147.