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EXCLUSIVE π^+ PRODUCTION AT HERMES

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Hard exclusive production in deep inelastic lepton scattering provides access to the unknown Generalized Parton Distributions (GPDs) of the nucleon. At HERMES, different observables for hard exclusive π^+ production have been measured with a 27.6 GeV positron beam on an internal hydrogen gas target. First preliminary results for the unpolarized $ep \rightarrow en\pi^+$ total cross section for $1.5 < Q^2 < 10.5$ GeV^2 and for $0.02 < x < 0.8$ are presented and compared to GPD calculations. The final result for the single-spin asymmetry using a longitudinal polarized target is also reported.

1 Introduction

The interest in the hard exclusive electroproduction of mesons has grown since a QCD factorization theorem was proved in the case of longitudinal photons [1]. It was shown that at large Q^2 and low t, the amplitude for such reactions can be factorized into a hard lepton scattering part, which can be calculated in perturbative QCD, and two soft parts which parametrize the produced meson by a distribution amplitude and the target nucleon by four Generalized Parton Distributions (GPDs) [2]. The quantum numbers of the produced meson select different GPDs. While exclusive vector meson production is only sensitive to unpolarized GPDs (H and E), pseudoscalar meson production is sensitive to polarized GPDs ($\tilde{H}$ and $\tilde{E}$) without the need for a polarized target or beam. Moreover, in the case of π^+ production, the pseudoscalar contribution $\tilde{E}$ is dominated at low t by the pion-pole exchange, and therefore $\tilde{E}$ is related to the pion form factor. Different observables, like cross section and single-spin asymmetry are able to select different combinations of GPDs.

In this paper, the first preliminary measurement of the total cross section for the exclusive π^+ production is reported. The final result for the single-spin asymmetry on a longitudinally polarized target is also presented. The data were collected using an internal hydrogen gas target in the 27.6 GeV HERA positron storage ring at DESY.

2 Total cross section measurement

The scattered positron and the produced hadron were detected by the HERMES spectrometer [3] which features excellent lepton-hadron separation and good pion identification for momenta between 2.5 and 15 GeV. The kinematic requirements imposed on the scattered positrons were: $Q^2 > 1$ GeV^2, $0.02 < x < 0.8$ and an

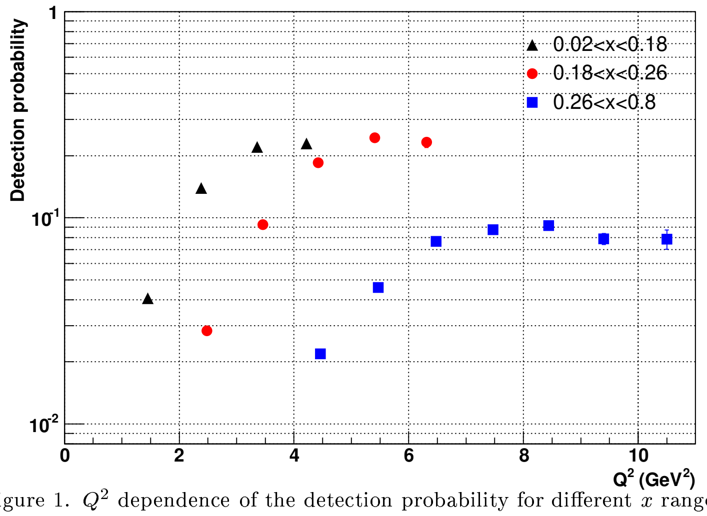

Figure 1. Q^2 dependence of the detection probability for different x ranges.

invariant mass squared of the initial photon-nucleon system $W > 2$ GeV. The recoiling neutron was not detected, and exclusive production of mesons was selected by requiring that the missing mass square (M_X^2) of the reaction $ep \to e\pi^+X$ correspond to the nucleon mass square. Due to the limited experimental resolution, the exclusive π^+ reaction cannot be separated from the neighboring channels (defined as non-exclusive) which can be smeared into the exclusive region. Therefore the process $ep \to e\pi^-X$ was used to subtract non-exclusive channels [4]. Indeed, exclusive production of π^- on a hydrogen target with a recoiling nucleon in the final state is forbidden due to charge conservation. The background correction procedure was also tested using a small data sample taken with a 12 GeV beam energy where the relative experimental resolution was higher. The exclusive peak resulting from the background correction was centered at the nucleon mass for both 12 and 27.6 GeV data samples, confirming the reliability of the procedure.

For the total cross section measurement, data from 1996 to 2000 on unpolarized and polarized hydrogen targets were used. Approximately 3.5 k exclusive π^+ were selected. The Q^2 dependence of the cross section has been determined for three different bins in x following:

$$\sigma^{\gamma^* p \to n\pi^+}(x, Q^2) = \frac{N_{\pi^+}^{excl}(x, Q^2)}{L\Delta x \Delta Q^2 \Gamma_V(\langle x\rangle, \langle Q^2\rangle)\kappa(x, Q^2)}$$

where $N_{\pi^+}^{excl}$ is the number of π^+ corrected for background, Γ_V is the virtual photon flux factor and κ is the probability to detect the scattered positron and the produced π^+ with the HERMES spectrometer. These quantities were determined for each Q^2 and x bin. L is the integrated luminosity and the symbol Δ is related to the size of the bin. The detection probability has been determined using two exclusive Monte Carlos based on two different GPD parametrizations [5] [6]. The t distribution, which is the most relevant observable for exclusive production, is well described by both Monte Carlos. The Q^2 and x distributions are better described by [6].

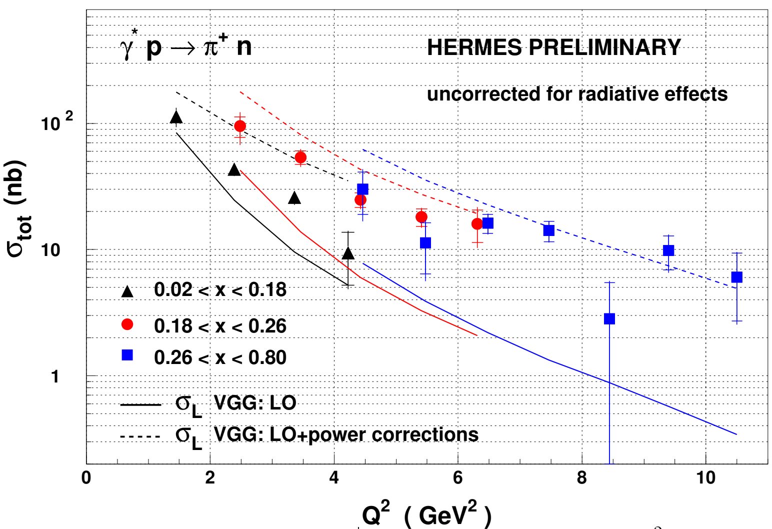

Figure 2. Total cross section for exclusive π^+ production as function of Q^2 for three different x ranges and integrated over t. The inner error bars represent the statistical uncertainty and the outer error bars the quadratic sum of statistical and systematic uncertainty. The curves represent calculations based on a GPD-model [6].

For this reason, the latter parametrization was used to determine the detection probability and the parametrization by [5] served to estimate the systematic error. The calculated detection probability is shown in Fig. 1. It varies between 0.02 and 0.25 according to the Q^2 and x bin with a relative systematic error evaluated to be lower than 15%. The total systematic error on the total cross section is dominated by the uncertainty on the background subtraction, and by the uncertainty on the efficiency correction due to different detector resolutions between 1996 and 2000. Fig. 2 shows the Q^2 dependence of the total cross section for three different x ranges. These preliminary data have not yet been corrected for radiative effects. This correction has been roughly estimated to be as large as 20% showing almost no dependence on x or Q^2. The data have been compared to calculations for the longitudinal part of the cross section computed by GPD-model [6]. The total cross section can be written as $\sigma = \sigma_T + \epsilon\sigma_L$ where σ_T (σ_L) is the transverse (longitudinal) virtual photons contribution and ϵ is the virtual photon polarization parameter. At HERMES the separation of the transverse and longitudinal component of the cross section is not feasible. However, since the transverse contribution is predicted to be suppressed by a power of $1/Q^2$ with respect to the longitudinal one [1] and since ϵ ranges from 0.8 to 0.95, the data at larger Q^2 are expected to be dominated by the longitudinal part. The full lines in Fig. 2 show the leading-order calculation computed for the mean x and Q^2 corresponding to the data and integrated over t. The dashed lines include power corrections due to intrinsic transverse momenta of the partons in the nucleon and due to soft overlap type contributions. The Q^2 dependence is in general agreement with the theoretical expectation. While the leading-order calculations underestimate the data, the evaluation of the power corrections appears too large.

3 Single-Spin Asymmetry measurement

It has been predicted [7] that for the exclusive production of π^+ mesons from a transversely polarized target by longitudinal virtual photons, the interference between the pseudoscalar ($\tilde{E}$) and pseudovector ($\tilde{H}$) amplitudes leads to a large target single-spin asymmetry. While the unpolarized cross section depends on a quadratic combination of the two polarized GPDs, a linear dependence of these distributions appears in the single-spin asymmetry. Polarization is therefore needed in order to disentangle the different contributions. Moreover, the scaling region of the asymmetry (where corrections proportional to powers of $1/Q$ are small) is expected to be reached at lower Q^2 than for the absolute cross section. It has also been shown that corrections that are next-to-leading order (NLO) in α_s cancel in the transverse asymmetry [8].

Since 2002, data have been collected at HERMES using a transversely polarized hydrogen gas target [9]. This running period will continue till 2005 and the expected 5 millions deep inelastic scattering events will allow one, with more than 10^3 resulted exclusive π^+ events, to measure the single-spin asymmetry on a transversely polarized target.

HERMES has already measured the single-spin asymmetry in the exclusive production of π^+ using a *longitudinally* polarized hydrogen target with data collected in 1997 [4]. The cross section asymmetry for exclusively produced π^+ is defined by

$$A(\phi) = \frac{1}{|S|}\frac{N_e^{\uparrow}(\phi) - N_e^{\downarrow}(\phi)}{N_e^{\uparrow}(\phi) + N_e^{\downarrow}(\phi)}.$$

where N_e represents the yield of exclusive π^+, the superscript $\uparrow$ ($\downarrow$) denotes a target polarization direction anti-parallel (parallel) to the positron beam momentum, and S is the degree of polarization of the target protons of 0.88 ± 0.04. Here ϕ is the azimuthal angle of the pion around the virtual photon momentum relative to the lepton scattering plane. The cross section asymmetry integrated over x, Q^2 and t is shown in Fig 3 .The average values of the kinematic variables are $\langle x \rangle = 0.15$, $\langle Q^2 \rangle = 2.2$ GeV^2 and $\langle t \rangle = -0.46$ GeV^2. The data show a large asymmetry in the distribution versus azimuthal angle ϕ, with a clear $\sin\phi$ dependence. A fit to this dependence of the form $A(\phi) = A_{\mathrm{UL}}^{\sin\phi} \cdot \sin\phi$ yields $A_{\mathrm{UL}}^{\sin\phi} = -0.18 \pm 0.05 \pm 0.02$.

In the case of electroproduction from a target polarized *longitudinally* with respect to the lepton beam momentum, the data are dominated by the contribution from the longitudinal target polarization component with respect to the virtual photon direction, therefore a comparison to the predictions for a *transversely* polarized target would require a calculation with the inclusion of next-to-leading twist contributions [8].

4 Conclusion and prospects of exclusive pseudoscalar measurements at HERMES

Results have been presented for hard exclusive π^+ production performed with the HERMES spectrometer. The preliminary total cross section has been measured as a function of Q^2 for different x values and has been compared to calculations based on

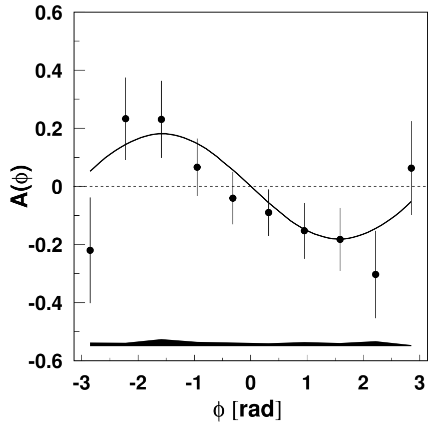

Figure 3. Cross section asymmetry for the reaction $e\vec{p} \rightarrow en\pi^+$. The curve is a fit to the data by $A_{\mathrm{UL}}(\phi) = A_{\mathrm{UL}}^{\sin\phi} \sin\phi$ which yields $A_{\mathrm{UL}}^{\sin\phi} = -0.18 \pm 0.05 \pm 0.02$.

a GPD-model. Also, a significant negative single-spin asymmetry has been observed with a longitudinally polarized target. The running period with a transverse target polarization which will continue till 2005 will allow one to measure the target-spin azimuthal asymmetry for exclusive π^+ and to make a direct comparison to the GPD-model predictions. Furthermore, with the installation of the recoil detector around the target in 2005, it will become possible to detect the recoil proton. This will allow one to measure neutral pseudoscalar meson exclusive reactions on hydrogen and to better identify the charged meson ones. In particular, the study of the ratio for different pseudoscalar mesons (π^+ over π^0, π^0 over η, ...) will provide information on the different contributions with respect to the nature of the produced mesons.

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