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Hadron Multiplicities at HERMES

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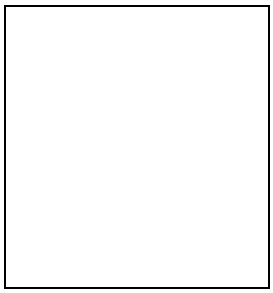
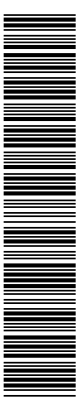


Hadron multiplicities of π^-, π^+, K^- and K^+ have been measured in the deep-inelastic scattering of 27.5 GeV positrons off a hydrogen target. The data used in this analysis have been collected during the 2000 HERA running period. The multiplicities were obtained for $0.15 < z < 0.9$ for $< Q^2 > = 2.5$ GeV^2.

1 Introduction

The semi-inclusive production of mesons in Deep-Inelastic Scattering (DIS) is a good tool to test the quark-parton model and QCD. A schematic diagram and the relevant variables for the process are shown in Figure 1. In the proton rest frame, the energy of the exchanged virtual photon γ^* is $\nu = E - E'$ (E and E' being the energies of the incident and scattered positrons



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respectively), while its negative squared four-momentum is Q^2. The quantity $x = Q^2/2M\nu$, where M is the proton mass, is (in the Breit reference frame) the fraction of the momentum of the nucleon carried by the struck quark.

The parton distribution function q_f describes the momentum distribution of quarks in the nucleon, while the fragmentation function D_f^h is a measure of the probability that a quark of flavor f fragments into a hadron of energy $E_h = z\nu$. The quantity $d\sigma_f$ is the cross-section for the absorption of the virtual photon by the struck quark. The quantity of interest in this paper is the hadron differential multiplicity, or the number N^h of hadrons produced in DIS, normalized to the total number (N_{DIS}) of inclusive DIS events. In the QCD improved quark-parton model, it is given by the expression:

$$\mathcal{M}^h = \frac{1}{N_{\rm DIS}(Q^2)} \cdot \frac{dN^h(z,Q^2)}{dz} = \frac{\sum_f e_f^2 \int_0^1 dx\, q_f(x,Q^2) D_f^h(z,Q^2)}{\sum_f e_f^2 \int_0^1 dx\, q_f(x,Q^2)}, \tag{1}$$

where the sum is over quarks and anti-quarks of flavor f, and e_f is the quark charge in units of the elementary charge.

The measurements described here were performed with the HERMES experiment using the 27.5 GeV positron beam stored in the HERA ring at DESY. The HERMES detector is an open forward spectrometer consisting of two identical halves above and beneath the HERA beam pipe. It has three main components: the spectrometer magnet, the tracking system consisting of three sets of tracking chambers in front of, inside and behind the spectrometer magnet, and a particle identification system. The particle identification (PID) system, which is essential for this analysis, consists of four detectors: a lead glass calorimeter, a preshower detector, a transition radiation detector (TRD) and a ring imaging Cherenkov counter (RICH). A detailed description of the detector components can be found in reference [1,2]. The data used in this analysis were collected during the 2000 HERA running period. The hydrogen gas target internal to the positron storage ring was operated in unpolarized mode.

2 Data Analysis

The identification of the scattered positron was accomplished using a probability algorithm utilizing the response of the four PID detectors. This system provided positron identification with an average efficiency of 98 % and a hadron contamination of less than 1 %. Events were selected by imposing the kinematic restrictions $Q^2 \geq 1$ GeV^2 and $y \leq 0.85$, where $y = \nu/E$ is the virtual photon fractional energy. In order to exclude effects from nucleon resonances as well as kinematic regions with inadequate geometrical acceptance, the additional requirement $W^2 \geq 10$ GeV^2 was imposed for this analysis. The data cover the region of $0.15 < z < 0.9$.

The RICH detector[2] identifies pions, kaons, and protons in a momentum range 2 GeV $< p <$ 15 GeV. The performance of the RICH system is summarized by a matrix P with elements P_t^i, being the probabilities for identifying the true particle type t as type i. The off-diagonal elements of P, i.e. the misidentification probabilities, are typically less than 3 %. For this analysis an unfolding procedure was done by using event weighting with the elements of P^{-1} to obtain the hadron multiplicities at the true π and K fluxes.

In a second step of the analysis the particle count rates were corrected for charge symmetric background processes (e.g. $\gamma \to e^+ + e^-$). The number of events with an opposite sign lepton is an estimate of the number of charge symmetric events that masquerade as DIS or SIDIS events. The overall background fraction from this source was 1.4 %.

The contribution of diffractive processes to the inclusive and semi-inclusive data were determined with the help of a Monte-Carlo simulation. This simulation is based on Pythia 6 [3], modified by HERMES to describe the cross section and the angular distribution of the two meson

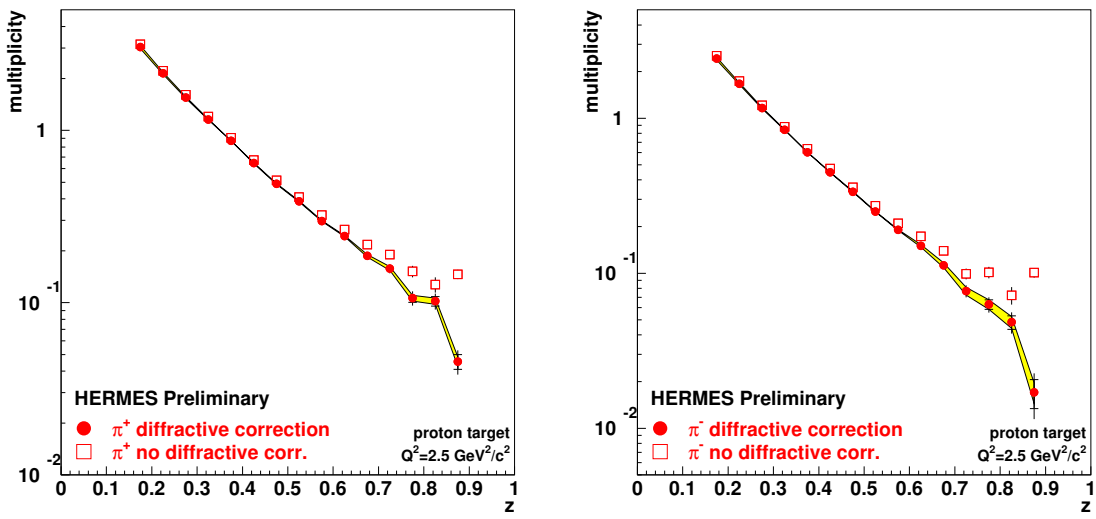

Figure 2: π^+ and π^- multiplicities vs z at an average $Q^2 = 2.5$ GeV^2.

decay (e.g. $\rho \to 2\pi$ and $\phi \to 2K$) correctly. It turned out that this contribution is significant for the HERMES kinematic especially for the charged π multiplicities. The correction is as large as 40 % for the highest z-bins.

Furthermore the count rates were corrected for detector acceptance and smearing and QED radiative effects to obtain the Born multiplicities in 4π. The corrections were applied using an unfolding algorithm that accounts for the kinematic migration of the events. A description of the unfolding algorithm is found in reference [4].

As the HERMES detector has a rather limited acceptance, the average Q^2 for each z-bin changes. The multiplicities were evolved to a common $Q^2 = 2.5$ GeV^2 using a multiplicative factor in each bin. The Q^2-evolution was performed using equation (1). The PKH parameterization [5] for the fragmentation function and the CTEQ6 parameterization [6] for the parton distribution functions were used as input for the calculation. The correction factor is ≈ 1 %. The contribution to the systematic error is very small, 2 % in the lowest z-bin and negligible for the rest of the bins.

3 Results

Figure 2 shows the extracted positive (left plot) and negative (right plot) pion multiplicities as a function of z for a hydrogen target. The data, with very small errors bars, show the expected exponential decrease. The inner error bars represent the statistical error. The error band shows the systematic error from the RICH misidentification. The error outside the tick marks is the total systematic error except the one from the RICH. The differences between the filled symbols and the open symbols, which show the multiplicities without diffractive correction, demonstrate the impact of this correction especially at higher z-values. This step in the analysis is a significant improvement compared to the previous HERMES publication [7]. The extracted multiplicities evolved to $Q^2 = 25$ GeV^2 are in nice agreement with EMC results [8].

The charged pion multiplicities for HERMES can also be determined as a function of x and Q^2 for four different z-bins. For this analysis, only data in the range of $0.25 < z < 0.75$ were considered. They show only a weak x- and Q^2-dependence.

The charged kaon multiplicities show the same behavior like for the charged pion multiplicities. They are plotted in figure 3 as a function of z. For the K^- the range is restricted to

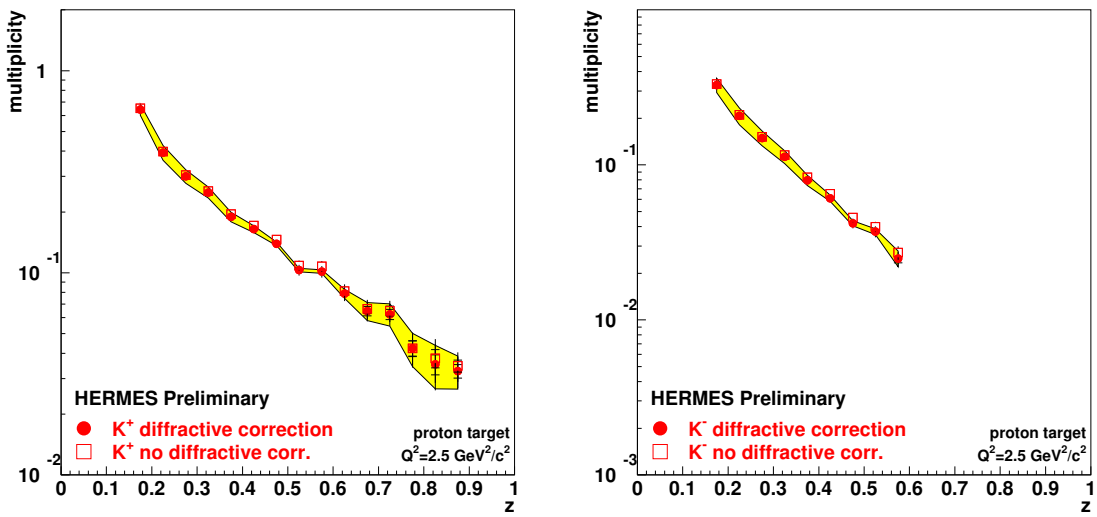

Figure 3: K^+ and K^- multiplicities vs z at an average $Q^2 = 2.5$ GeV^2.

$z < 0.6$, due to the limited statistics. The errors of the measurements are dominated by the systematic error coming from the RICH kaon misidentification.

4 Outlook

The charged pion and kaon multiplicities in semi-inclusive scattering at 27.5 GeV on hydrogen have been measured by the HERMES collaboration. The measurements provide data in the lower Q^2-range at an average $Q^2 = 2.5$ GeV^2 and in the range of $0.023 < x < 0.6$. The measured multiplicities will allow the extraction of fragmentation functions in the range of $0.15 < z < 0.9$.

HERMES will repeat the extraction of hadron multiplicities for the data taken with an unpolarized deuterium target. A combined analysis of the hydrogen and deuterium multiplicities will yield favored and unfavored fragmentation functions independent of parton distribution functions.

5 References

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