Multidimensional study of the hadron attenuation at HERMES

Gevorg Karyan[1] on behalf of the HERMES collaboration

[1]A.I. Alikhanyan National Science Laboratory, Alikhanian Brothers 2, 0036 Yerevan, Armenia

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Hadron multiplicity ratios in semi-inclusive deep-inelastic scattering have been measured on neon, krypton and xenon targets relative to deuterium using 27.6 GeV positron or electron beam at the HERMES experiment. They are presented for pions (π^+, π^-), kaons (K^+, K^-), protons and anti-protons as a function of the virtual photon energy ν, its virtuality Q^2, the fractional hadron energy z and the transverse component of hadron momentum p_t with respect to the direction of the virtual photon. Dependences are presented in a two-dimensional representation, i.e. in the form of detailed binning over one variable and three slices over the other variable. These results may help to understand some aspects of hadronization process.

1 Introduction

Semi-inclusive deep-inelastic scattering (SIDIS) of leptons off nuclei provides a tool to investigate a quark hadronization or fragmentation into hadrons[1][2]. In such a process, lepton transfers a certain amount of energy (ν) to the "struck" quark which then propagates through the nuclear medium, and looses part of it's energy by emiting a gluon. The time needed for this propagation is called the production time. After this time a colorless pre-hadron has formed, which evolves to the final hadron during the so-called formation time. To investigate a space-time development of this process, nuclei with different mass and size can be used. The suitable experimental observable is the nuclear attenuation ratio, which is a ratio between hadron multiplicities from a nuclear target with atomic mass (A) to those on the deuterium[3][4][5].

$$R_A^h(\nu, Q^2, z, p_t^2) = \frac{\left(\frac{N^h(\nu,Q^2,z,p_t^2)}{N^e(\nu,Q^2)}\right)_A}{\left(\frac{N^h(\nu,Q^2,z,p_t^2)}{N^e(\nu,Q^2)}\right)_D} \tag{1}$$

where N^h is the number of semi-inclusive hadrons in a given (ν,Q^2,z,p_t^2) bin and N^e is the number of inclusive deep-inelastic scattered leptons in the same (ν,Q^2) bin.

This ratio depends on leptonic variables such as the energy of virtual photon ν and it's virtuality Q^2 and on hadronic variables like the fraction z of the virtual photon energy carried by the hadron and the square of the hadron momentum component p_t^2 transverse to the virtual photon direction. The attenuation ratio, in general, depends also on azimuthal angle ϕ, which is the angle between the lepton-scattering plane and the hadron-production plane. In this measurement no ϕ dependence was observed within statistical accuracy. Thus the integration over ϕ

was performed. In order to study the nuclear attenuation effect in more detail the dependencies of R_A^h are presented in a two-dimensional form, using a detailed binning over one variable and a coarser binning in another variable.

2 Data Extraction and Results

The data were collected with the HERMES spectrometer using 27.6 GeV electron or positron beams stored in HERA at DESY[6]. To select deep-inelastic scattered (DIS) leptons the following requirements were used : $Q^2 > 1\ GeV^2$, $W^2 > 4\ GeV^2$ and $y = \nu/E < 0.85$, where W is the invariant mass of virtual photon-nucleon system and E is the beam energy. The cut on the invariant mass is imposed to suppress the resonance contribution and the constrain on y limits the magnitude of radiative corrections.

For charged hadron identification, dual-radiator ring-imaging Čerenkov detector (RICH) was used[7], which allows to identify charge separeted pions, kaons and (anti)proton in momentum range : $2 < p_h < 15.0\ GeV$. Hadrons were selected within the cuts : $x_F > 0$ and $z > 0.2$, where x_F is the Feynman variable which is defined as a ratio of the longitudinal momentum transferred to the hadron in the photon-nucleon centre-of-mass system to it's maximum possible value and z is the ratio of the hadron energy devided by ν.

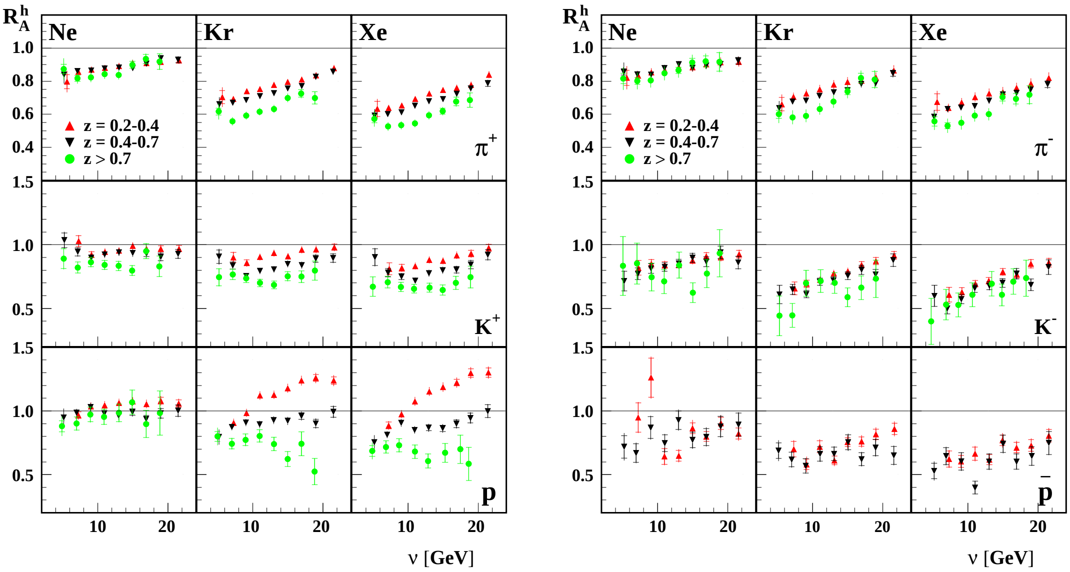

Figure 1: Dependence of R_A^h on ν for three slices in z.

In figure 1, the ν dependence of R_A^h is shown in three z slices. The scale uncertainties are estimated to be 3%, 5%, 4%, and 10% for pions, kaons, protons and atiprotons, respectively. With increasing ν a rise of R_A^h was observed for pions(π^+, π^-) and negatively charged kaons(K^-) which is consistent with fragmentation models that explain such a behaviour as a result of Lorentz dilation and/or a modification of the fragmentation function[8]. Compared to negatively charged kaons (K^-), the ν dependence of R_A^h for positively charged kaons (K^+) shows an enhancement for the lowest z-slice and it seems to be flatter for the high z values. For protons the behaviour of R_A^h is very different from those of the other hadrons. Particularly for the lowest z-slice it exceeds the unity at large ν values. This phenomena might be caused by the fact that protons can be knocked out off the nucleus while other hadrons are always the result of hadronization. This effect is stronger for heavy nuclei which is consistent with the assumption of large contribution from knock-out processes. Unlike protons, antiprotons are produced by hadronization only and show a similar behaviour as mesons.

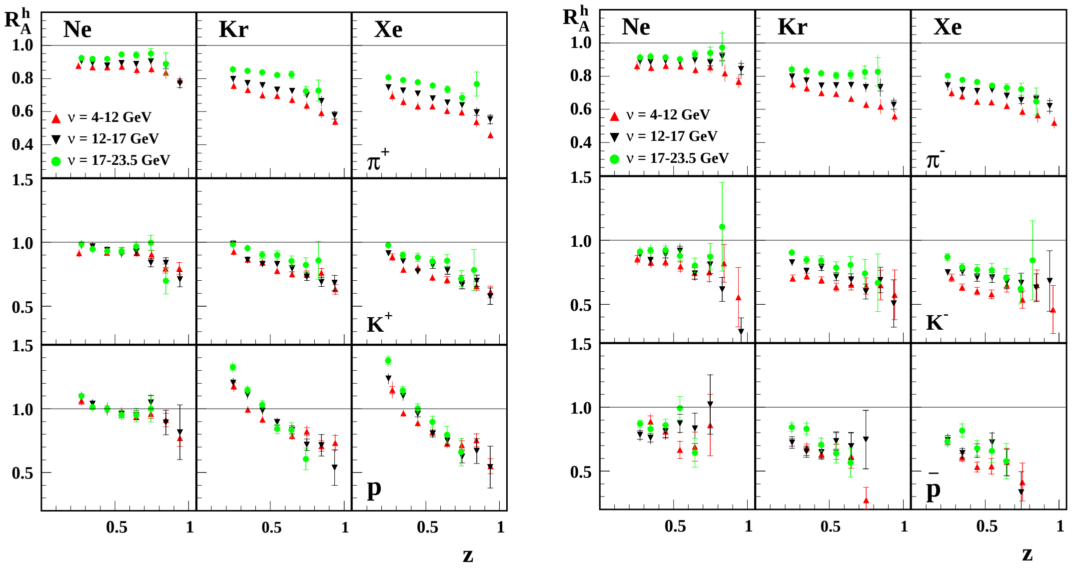

Figure 2: Dependence of R_A^h on z for three slices in ν.

In figure 2, the dependence of R_A^h on z for three slices in ν is presented. The R_A^h shows a slight change in different ν slices for π^+ and π^- and a strong dependence for protons on krypton and xenon targets. This behaviour for protons can be explained by a large contribution from final-state interaction at low z values.

The dependence of R_A^h on p_t^2 is shown in figure 3 for three slices in z. An increase of R_A^h was observed at high p_t^2 (the Cronin effect) which is larger for protons compared to mesons. For the highest z slice the Cronin effect is suppressed for mesons while the protons show a significant rise with p_t^2.

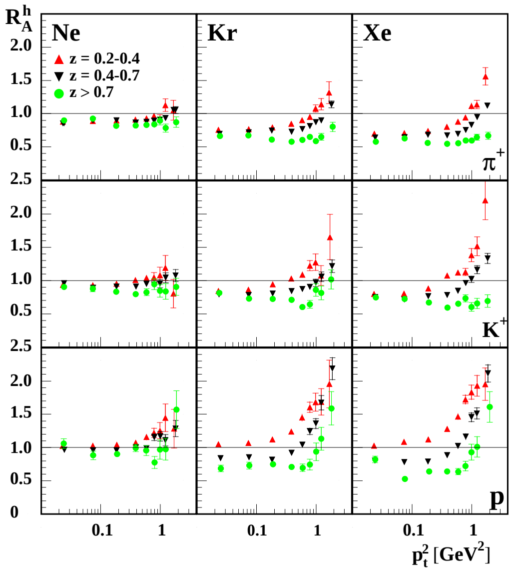

Figure 3: Dependence of R^h_A on p_t^2 for three slices in z.

3 Conclusions

The first two dimensional kinematic dependencies for hadron multiplicity ratio R^h_A have been presented for pions(π^+, π^-), kaons(K^+, K^-) and protons(p, $\bar{p}$) on neon, krypton and xenon targets relative to deuterium. For π^+ and π^- the behaviour of R^h_A is about the same within the experimental uncertainties. The dependence of $R^{K^+}_A$ on ν for positevely charged kaons was found to be different from $R^{\pi^+}_A$, $R^{\pi^-}_A$ and $R^{K^-}_A$ at high values of z which might be the result of final-state interactions. Proton data show a significant difference from the other hadrons which can be explained by a contribution of knock-out processes, in addition to the fragmentation process.

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