Medium-indused modification of kaons spectra measured in SIDIS at HERMES

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Abstract. The predicted high sensitivity of the nuclear modification factor for K^- in SIDIS due to the QCD based effect of medium-induced flavour conversion in the fragmentation function is studied at HERMES experiment. Unlike π^+, π^- and K^+ nuclear modification factor for K^- is assumed to increase at high value of Bjorken variable x_B and a hadron fraction energy z. The experimental signature of this phenomenon is an enhanced K^- nuclear modification factor compared with those of K^+ for high x_B and z range. The z spectra of nuclear attenuation ratios for charged kaons in different slices of x_B extracted on Ne, Kr and Xe targets will be presented and discussed.

1 Introduction

In Semi-Inclusive Deep Inelastic Scattering (SIDIS) process at large values of the struck quark momentum fraction x_B (Bjorken variable), the virtual photon interacts mainly with the valence quarks (u and d) from the target of nucleus. Since K^- strange mesons consist of $(s, \bar{u})$ quarks they can only come from pair production in the shower evolution of the u and d quarks. Their spectra are particularly sensitive to the medium-induced flavor conversion during the propagation of the struck valence quark in the nucleus. Enhancement of K^- meson is a consequence of medium-induced flavor conversion [1], but this requires large values of x_B and z (fractional hadron energy), to counter the effect of parton energy loss in SIDIS. The nuclear modification factor $R^h_{A/D}$, which can be measured experimentally, is defined as the ratio of the number of hadrons h produced per Deep-Inelastic Scattering (DIS) event on a nuclear target with the atomic mass number A to that for a deuterium (D) target, and can be written as:

$$R^h_{A/D}(x_B, z, \nu, p_t^2) = \frac{\left(\frac{N^h(x_B,z,\nu,p_t^2)}{N^e(\nu,Q^2)}\right)_A}{\left(\frac{N^h(x_B,z,\nu,p_t^2)}{N^e(\nu,Q^2)}\right)_D} \quad (1)$$

where $N^h(x_B, z, \nu, p_t^2)$ is the number of semi-inclusive hadrons and $N^e(\nu, Q^2)$ is the number of inclusive DIS leptons. The ratio $R^h_{A/D}$ depends on leptonic variables: the energy of the virtual photon ν and its positive four-momentum square Q^2, and on hardonic variables: the fraction of the virtual-photon energy carried by the hadron z, and the square of the hadron momentum component transverse to the direction of the virtual photon p_t^2.

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2 The experiment

The measurements were performed with the HERMES spectrometer [2] using 27.6 GeV positron and electron beams stored in HERA at DESY. Detailed description of HERMES spectrometer are presented in [2], here only a brief summary is given. The HERMES setup included a forward spectrometer, in which the scattered lepton and the produced hadrons were detected within an angular acceptance of ±170mrad horizontally and ±(40 − 140)mrad vertically. The HERA beam lines passed through the spectrometer and were shielded in the magnet area by a horizontal iron plate, dividing the spectrometer into two symmetric halves above and below the ring plane, thereby limiting the vertical acceptance close to the beam line. The spectrometer consisted of a front and a rear part separated by a 1.5 T dipole magnet. Both parts contained tracking devices, while the back part also contained particle identification (PID) detectors. The tracking system had a momentum resolution of about 1.5% and an angular resolution of about 1mrad. The lepton identification was implemented by using the preshower scintillator counter(H2), the transition-radiation detector (TRD), and the electromagnetic calorimeter [3]. The particle-identification system included also a dual-radiator ring-imaging Cherenkov detector (RICH) [4] to identify hadrons. The RICH provided separation of pions, kaons and (anti)protons in the momentum range between 2 and 15 GeV with limited contamination from misidentified hadrons. Combining the responses of the detectors in the likelihood method leads to an average lepton-identification efficiency of 98%, with a hadron contamination of less than 1%.

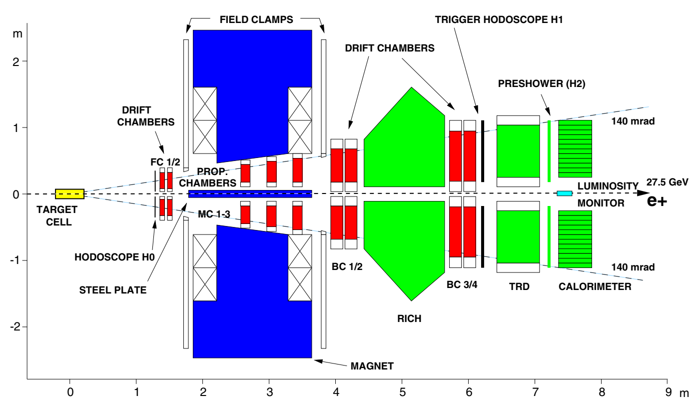

Figure 1. Schematic view of the HERMES spectrometer

3 Data analysis and kinematic requirements

The data analyzed for this work were collected in 2004 and 2005 with gaseous targets: deuterium, neon, krypton and xenon. Events with at least one lepton and one hadron detected in the coincidence are included in the final event sample to be analyzed, if they satisfy the following kinematic requirements. The DIS region is defined here by the kinematic constraints $Q^2 > 1$ GeV^2 and $W^2 > 10$ GeV^2, where W^2 is the squared invariant mass of the initial system of virtual photon and target nucleon. As a consequence of these requirements and the limited angular acceptance of HERMES, x_B is restricted to the ranges $0.023 < x_B < 0.5$. In addition to suppress the level of radiative corrections the restriction $y = E_h/\nu < 0.783$ is applied. The kinematic constraints imposed on the selected hadrons were: $p_h = 2 - 15$ GeV, $0.2 < z < 1.2$ where E_h/p_h is the hadron energy/momentum respectively. The main source of systematic uncertainties is the time dependent factor due to used data samples for different targets collected during different years: maximum $\sim 3(3.5)\%$ for positively(negatively) charged kaons. The radiative corrections for nuclear factor are estimated with Monte Carlo simulations taking into account the setup geometrical and momentum acceptance of the HERMES spectrometer to be maximal $\sim 3(3.5)\%$ for Kr/Xe and $\sim 2\%$ for Ne at lowest x_B.

4 Results and discussions

The results for $R^h_{A/D}(z)$ and $R^{K^-}_{A/D}(z)/R^{K^+}_{A/D}(z)$ are produced using double (x_B, z) binning (or slices). The x_B slices are the following: 0.023 - 0.1, 0.1 - 0.15, 0.15 - 0.25, 0.25 - 0.35, 0.35 - 0.41, and for z: 0.2 - 0.3, 0.3 - 0.4, 0.4 - 0.55, 0.55 - 1.2. The results for $R^{K^+}_{A/D}(z)$ at five x_B slices are shown in Fig. 2. For K^+ at first four x_B slices we can see that $R^{K^+}_{A/D}(z)$ trend to decrease with increasing of z value, especially for Kr and Xe. For the last x_B slice the constant behavior is observed.

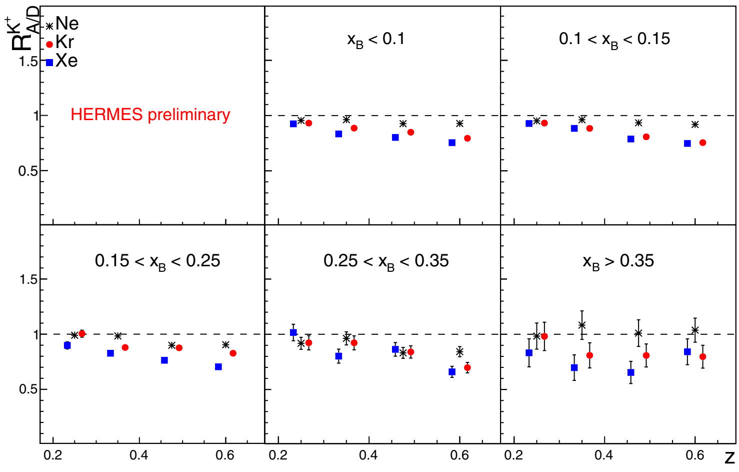

Figure 2. $R^{K^+}_{A/D}(z)$ dependences for positively charged kaons at five x_B slices, the error bars are squared sum of statistical and systematical uncertainties

The dependence of $R^{K^-}_{A/D}(z)$ for negatively charged kaons produced on neon, krypton and xenon targets at five x_B slices are shown on Fig. 3.

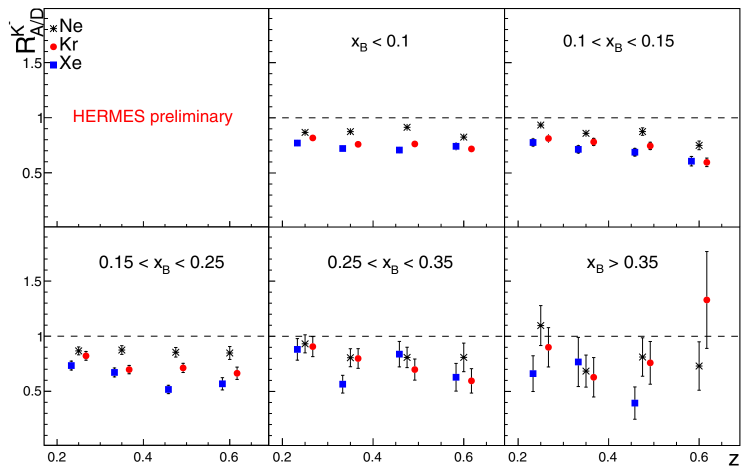

Figure 3. The same as in Fig. 2 for negatively charged kaons

To illustrate the expected [1] enhancement for negative kaons the super ratio of $R^{K^-}_{A/D}(z)/R^{K^+}_{A/D}(z)$ dependences for charged kaons at five x_B slices shown on Fig. 4 was also produced.

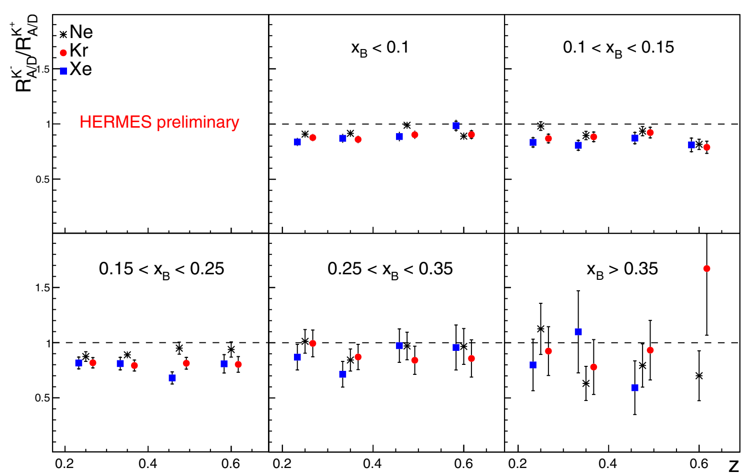

Figure 4. $R^{K^-}_{A/D}(z)/R^{K^+}_{A/D}(z)$ dependences for charged kaons at five x_B slices

For the K^- in case of the krypton target at x_B greater than 0.35 certain enhancement of the $R^h_{A/D}(z)$ with the increasing of z is observed. This ratio at the highest z becomes even greater than unity. Also, the super ratio $R^{K^-}_{A/D}(z)/R^{K^+}_{A/D}(z)$ at the highest z becomes remarkably greater than unity. We do not see any increasing behavior for the nuclear modification factor for negative kaons, as well as for the super ratio of the negative to positive kaons modification factors in case of neon with the relatively small value of the atomic mass number as was predicted in [1]. Unfortunately, due to the lack of statistics we did not extract both the $R^h_{A/D}(z)$

and $R^{K^-}_{A/D}(z)/R^{K^+}_{A/D}(z)$ at the highest x_B and z region for xenon, also one can note that for the xenon target we do not see the increasing trend for both mentioned observables with the increase of x_B and z, which can be caused by the complicated combination of the predicted effect and usual nuclear attenuation for hadrons in heavy nuclei with the increase of the atomic mass number.

5 Conclusion

Based on the HERMES data [5, 6] the first experimental attempt to check the QCD prediction [1] for the possible enhancement of negatively charged kaons on the heavy nuclear targets was made. The certain indication for the predicted effect is observed for the nuclear modification factor extracted with the krypton target.

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References

[1] Ning-Bo Chang, Wei-Tian Deng and Xin-Nian Wang, e-Print: arXiv:1411.7007 [hep-ph] (2014). Phys. Rev. C **92**(5), 055207 (2015)
[2] K. Ackerstaff et al. (HERMES), Nucl. Instr. and Meth. A **417**, 230 (1998)
[3] H. Avakian et al., Nucl. Instrum. Meth. A **417**, 69-78 (1998)
[4] N. Akopov et al. [HERMES Collaboration], Nucl. Instr. and Meth. A **479**, 511 (2002)
[5] A. Airapetian et al., Eur. Phys. J. A **47**, 113 (2011)
[6] A. Airapetian et al. (HERMES Collaboration), Nucl. Phys. B **780**, 1 (2007)