Azimuthal emission pattern of K$^+$ and of K$^-$ in Heavy Ion Collisions at SIS energies

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Relativistic heavy ion collisions provide a unique opportunity to study both the behavior of nuclear matter at high densities as well as the properties of hadrons within this dense nuclear medium. In particullar strange mesons are considered to be sensitive to these in-medium effects.

The behavior of K^+ and K^- is expected to be different due to two characteristic properties:

(i) Their interaction with nuclear matter: K^+ are hardly absorbed in nuclear matter due to strangeness conservation. They contain an $\bar{s}$-quark and the probability that a K^+ encounters a Λ or Σ is negligible. K^- on the contrary, can easily be absorbed on a nucleon converting it into a Λ or Σ and a pion. Consequently, the propagation of K^+ and of K^- in nuclear matter is very different and should lead to different emission patterns for K^+ and for K^-. The strangeness-exchange channel ($\pi Y \leftrightarrow K^- N, Y = \Lambda, \Sigma$) can cause the absorption of K^- as well as an enhanced K^- production as suggested in [1, 2] and found in [3, 4].

(ii) K^+ and K^- experience different potentials in nuclear matter: While the scalar potential acts attractively on both kaon species, the vector potential repels K^+ and attracts K^-. For K^+ these two contributions mainly cancel each other leading to a small repulsive K^+N interaction. The superposition of both attractive interactions results in an strong attractive potential for K^- [5].

Our goal is to study the azimuthal distributions of K^+ and K^- in nucleus nucleus collisions which are expected to be a sensitive observable for in-medium properties. Indeed, the azimuthal distribution of K^+ and K^- turn out to be very different. For K^+ we have already reported an unexpected out-of-plane enhancement in Au+Au collisions at 1.0 A·GeV [6]. This result is confirmed by new measurements presented here. In addition we show first data on the azimuthal distribution of K^-.

Two new measurements have been performed with the KaoS spectrometer: Ni+Ni at 1.93 A·GeV(both for K^+ and for K^-) and Au+Au at 1.5 A·GeV(K^+ only). For comparison also the emission patterns of π^+ are presented. The measurements were performed using an Au beam of 1.5 A·GeV impinging on an Au target (0.96 g/cm^2) and a Ni beam of 1.93 A·GeV on a Ni target (0.68 g/cm^2). The phase-space coverage is shown in Fig. 1 for K^+ in Au+Au reactions at 1.5 A·GeV.

The particles were identified using the magnetic spectrometer KaoS and two hodoscopes were used for event characterization [7, 8]. The orientation of the event plane was reconstructed from the azimuthal emission angle of the charged projectile spectators with the transverse momentum method [9]. These particles were identified (up to $Z = 8$) by their energy loss and their time of flight as measured with the small-angle hodoscope which is about 7 m downstream from the target covering polar angles between 0.5° and 11°.

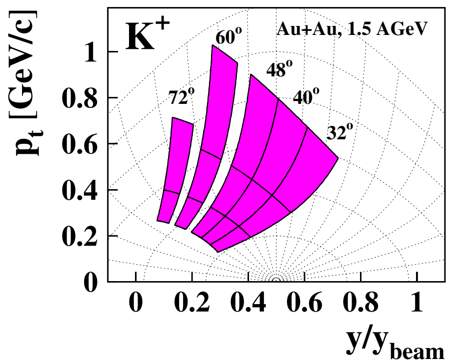

Figure 1: Phase-space coverage of K^+ for the measurements of Au+Au reactions at 1.5 A·GeV. Shown are the different laboratory angles measured.

Figure 2 shows the azimuthal distribution of K^+ and π^+ for semi-central Au+Au collisions at 1.5 A·GeV. The distribution is corrected for the angular resolution of the reaction plane determination [8], which is $\langle \Delta\Phi^2 \rangle^{1/2} = 37°$ for the Au-system and $\langle \Delta\Phi^2 \rangle^{1/2} = 61°$ for the Ni-system. The data are fitted using the function

$$\frac{dN}{d\Phi} \sim 2\,v_1 \cos(\phi) \; + \; 2\,v_2 \cos(2\phi) \qquad (1)$$

resulting in values for v_1 and v_2, as given in the figures. The coefficent v_1 is subject to a systematical error of 0.04.

Both π^+ and K^+ exhibit a pronounced out-of-plane enhancement. For π^+ this can easily be interpreted as rescattering and absorption in agreement with previous observations [8]. This explanation cannot hold easily for K^+ as their mean free path is rather long and one might expect only a moderate out-of-plane enhancement [10]. This experimental result is rather suggestive for a repulsive in-medium K^+N interaction [10, 11].

The study of Ni+Ni collisions has been performed at a higher incident energy of 1.93 A·GeV. The resulting higher production cross section for K^- provides an opportunity to study both kaon species. The data are shown in Fig. 3 along with π^+ for semi-central Ni+Ni collisions. Both π^+ and K^+ follow the same trend already observed in Au+Au collisions. The values for v_2 are smaller than in Au+Au as one might expect for the smaller system. In contrast to the π^+ and K^+, the K^- show an in-plane enhancement.

This "positive" (in-plane) elliptic flow of particles is observed for the first time in heavy-ion collisions at SIS energies. In contrast to this observation, one would expect

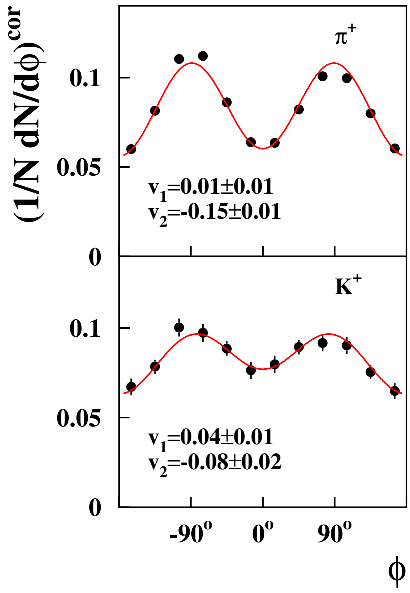

Figure 2: Azimuthal distribution of π^+ and K^+ for semi-central Au+Au collisions at 1.5 A·GeV. The data are corrected for the resolution of the reaction plane and correspond to impact parameters of 5.9 fm $< b <$ 10.2 fm, rapidities of $0.3 < y/y_{beam} < 0.7$ and momenta of 0.2 GeV/c $< p_t <$ 0.8 GeV/c. The lines are fits with function (1) resulting in the values for v_1 and v_2 as given in the figure.

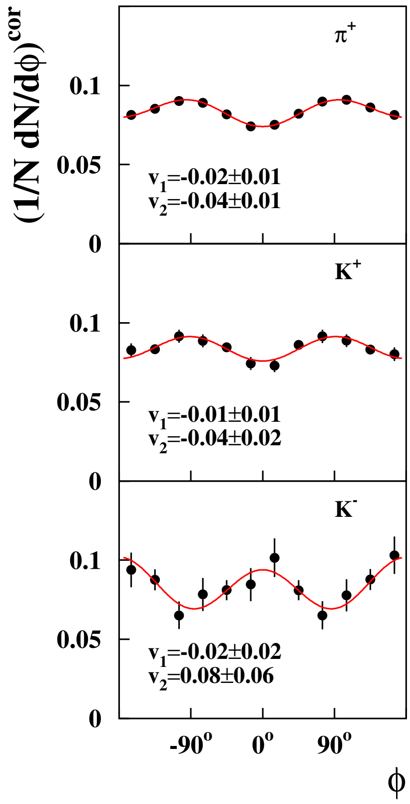

Figure 3: Azimuthal distribution of π^+, K^+ and K^- for semi-central Ni+Ni collisions at 1.93 A·GeV. The data are corrected for the resolution of the reaction plane and correspond to impact parameters of 3.8 fm$< b <$ 6.5 fm, rapidities of $0.3 < y/y_{beam} < 0.7$ and momenta of 0.2 GeV/c $< p_t <$ 0.8 GeV/c. The lines are fits with function (1) resulting in the values for v_1 and v_2 as given in the figure.

a preferential out-of-plane emission (negative elliptic flow) of K^- mesons due to their large absorption cross section in spectator matter. However, as shown recently, the K^- are produced predominantly via strangeness-exchange reaction $\Lambda\pi \rightarrow K^- N$ and consequently, the K^- are emitted later than the K^+ which are produced together with the Λ. Therefore, the shadowing spectator might have moved away when the K^- emission occurs which would lead to a flat azimuthal distribution. Nevertheless, a late emission of K^- mesons cannot explain their elliptic in-plane flow pattern.

Recent transport calculations find such an effect if an attractive in-medium K^- potential is taken into account [12]. A quantitative comparison of our data to transport calculations is presently beeing performed.

Recently, a new high-statistics measurement of the azimuthal distribution of K^- in Au+Au collisions at 1.5 A·GeV has been performed. These data are presently beeing analyzed.

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