KAON AND ANTIKAON PRODUCTION IN PROTON NUCLEUS COLLISIONS*

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For the first time, a systematic study of differential production cross sections of antikaons in proton nucleus collisions close to threshold has been performed, using the first proton beam at GSI. Preliminary results on K^+ and K^- production in p+Au collisions at a beam energy of 2.5 GeV are presented.

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1. Introduction and motivation

During several years the KaoS collaboration collected data on double differential kaon and antikaon production cross sections in heavy ion collisions. These investigations were performed at beam energies between 0.6 and 2 AGeV, mostly with symmetric systems from C+C to Au+Au. The baryon density reached during the collisions was significantly higher than the typical density of an atomic nucleus. Compared to the elementary (inclusive) cross sections in $p+p$, the yield of antikaons was found to be much stronger enhanced than the one for kaons [3]. It was an intriguing question what would happen in the system $p+A$. Here, the density remains constant at the normal nuclear density and does not vary with time.

In $A+A$, the K-meson yield arises in part from secondary processes such as pion nucleon or hyperon nucleon collisions. In particular, antikaons are produced in strangeness exchange reactions $\pi Y \rightarrow K^- N$ with $Y = \Lambda, \Sigma$. This process is expected to be dominating in $A+A$ but should be suppressed in $p + A$ collisions.

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Thus, the $p + A$ system represents the missing link between $p + p$ and $A + A$ experiments.

2. Experimental setup

The experiment was performed with the Kaon Spectrometer (KaoS) [1], a magnetic spectrometer at the heavy ion synchrotron SIS. It is equipped with scintillator hodoscopes for time-of-flight measurements and three multi-wire proportional chambers to reconstruct particle trajectories, allowing the determination of particle momenta and masses. In addition to the usual time-of-flight condition a newly developed second level trigger was used during the $p + A$ experiment. It consists of a programmable unit that reconstructs reasonable tracks from hits in three scintillator hodoscopes.

This method improved background suppression by about one order of magnitude. Because of the reduced background, it was possible to raise the beam intensity above $10^9\,\mathrm{s}^{-1}$ which led to extraordinarily high detection rates: more than 1300 K^- and 40000 K^+ per hour. The data were

TABLE I

Survey of kaon scattering angle, beam energy and target composition

		32°	40°	48°	56°	64°
$\boldsymbol{K^+}$	1.6 GeV	–	C, Ni, Au	C, Au	C, Au	C, Au
	2.5 GeV	C, Au	C, Ni, Au	C, Au	C, Au	C, Au
	3.5 GeV	C, Au	C, Au	C, Au	C, Au	–
$\boldsymbol{K^-}$	2.5 GeV	C, Au	C, Ni, Au	C, Au	C, Au	–
	3.5 GeV	C, Au	C, Au	C, Au	C, Au	–

taken at energies near and above the respective production threshold for K^+ (1.58 GeV) and K^- (2.5 GeV) for NN collisions, both with at least two nuclear targets and several polar angles (Table I).

According to a preliminary estimate, the K^- statistics for the entire experiment, integrated over all observation angles, is about 11000 K^- at 2.5 GeV and 25000 K^- at 3.5 GeV. The numbers for K^+ production are larger by one order of magnitude.

3. Results

Fig. 1 shows the preliminary K^+ and K^- differential cross sections at 2.5 GeV p+Au at a polar angle of 40°. The solid lines represent Boltzmann distributions fitted to the data in the nucleon–nucleon center-of-mass system: $d^3\sigma/dp^3 \propto \exp(-E/T)$. Only the high momentum part of the K^+

spectrum can be described by this distribution, so the fit was done only for momenta $\geq$ 475 MeV/c (K^+) and $\geq$ 425 MeV/c (K^-), respectively. The low momentum part exhibits an enhancement compared to the Boltzmann function. The further analysis will show whether this is merely caused by an anisotropic angular distribution. The resulting inverse slope parameters are $T = 62.1(4)$ MeV for K^+ and $T = 34.4(30)$ MeV for K^- mesons. The K^-/K^+ ratio of the spectra measured at $\theta_{\mathrm{Lab}} = 40°$ is $\sim 10^{-2}$.

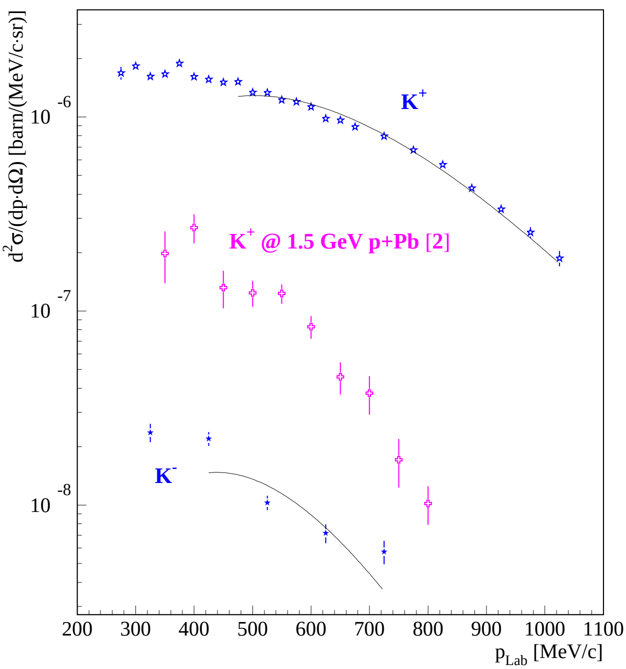

Fig. 1. Preliminary $K^{\pm}$ differential cross section for p (2.5 GeV) +Au and p (1.5 GeV) +Pb [2]. All data sets are for a laboratory angle of (40°).

In order to illustrate possible in-medium effects in K^- production we compare the K$^-/K^+$ ratio measured at beam energies equivalent with respect to the NN thresholds. The beam energy of 2.5 GeV is the threshold energy for K^- production. The equivalent energy for K^+ production is 1.58 GeV. The latter data have not been analyzed yet. Therefore, we compare the K^- data taken in p+Au at 2.5 GeV to K^+ data from p+Pb at 1.5 GeV also taken at $\theta_{\mathrm{Lab}} = 40°$ [2] (see Fig. 1). It can be seen that these two data sets differ by one order of magnitude in yield. In contrast to that, the cross section in heavy ion collisions [3] is of the same order of magnitude for both K^+ and K$^-$, at various energies around threshold. On the other hand, in $p + p$ reactions, the K^-/K^+ ratio (still at equivalent energies) becomes very small when approaching the threshold energy [4] so that the following systematics emerges:

System	$p+p$	$p+A$	$A+A$
K^-/K^+	$\leq 10^{-2}$	10^{-1}	10^0

The K^-/K^+ ratio is larger in p+Au than in $p+p$ collisions although the K^- mesons are expected to be absorbed with a high probability (in contrast to K^+ mesons). The mean free path of K^- mesons is about 1.5 fm in normal nuclear matter ($\rho = \rho_0$). This effect can be estimated by comparing the K^-/K^+ ratio in p+Au and p+C collisions once the latter data are analyzed. In heavy ion collisions most of the K^- are believed to be produced in pion hyperon reactions [5]. This channel is suppressed in proton nucleus collisions. Therefore, the enhanced K^-/K^+ ratio in p+Au as compared to $p+p$ cannot be due to the strangeness exchange reaction $\pi Y \to K^- N$ (the process $YN \to K^- NN$ is negligible).

4. Summary and outlook

Systematic measurements of K^+ and K^- cross sections in proton nucleus collisions close to threshold have been performed for the first time. In a preliminary analysis of p+Au collisions at 2.5 GeV beam energy, K^+ and K^- double differential cross sections have been obtained for $\theta_{\mathrm{Lab}} = 40°$. The K^-/K^+ ratio at equivalent energies is about 0.1 and hence one order of magnitude larger than for $p+p$ collisions. The analysis of the entire data yet measured will provide new and important information on the properties of antikaons in nuclear matter at saturation density.

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