Study of neutral kaon production in $p + p$ and $p +$ Nb reactions

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We report on the on-going analysis of the K^0 production in p+p and p+Nb collisions at $E_{kin} = 3.5$ GeV, aimed on the extraction of the in-medium kaon-nucleon potential at normal nuclear matter density.

1 Introduction

Modification of the kaon (antikaon) properties in the nuclear environment is a subject of permanent theoretical and experimental interest. Such an environment can be produced in heavy-ion collisions, where—at 1–2 AGeV kinetic beam energy—densities of up to 3 times normal nuclear matter density can be achieved. However, theory expects modifications of the kaon spectral function already at normal nuclear matter density [1], which can be explored with the production at nuclei, employing γ-, π- or proton-induced reactions.

It is predicted, that the kaon interaction with the nuclear environment is characterized by a repulsive potential, whereas for antikaons an attractive potential is favoured. The results of the flow analyses [2,3] support these expectations.

Resulting yields and phase space distributions of kaons in the final state reflect different aspects of kaon production and propagation, so it is challenging to find an observable that would be sensitive exclusively to the in-medium KN potential. As stressed in [4], one of the most promising observables to learn about the in-medium kaon-nucleon potential is the momentum distribution, in particular in the region of low momenta. Since a kaon is "repelled" from the ambient nucleus, the measured momentum distribution will be shifted to higher values as compared to the case where no sizeable effects of the potential are expected. Neutral kaons are particularly promising probes, since their kinematics is not distorted by the Coulomb interaction.

A number of experiments measured this observable. The ANKE collaboration studied K^+ production in proton-induced reactions at different nuclear targets in a small phase space at forward rapidities [6]; K^0 production in pion-induced reactions was explored by the FOPI collaboration [7]. Both collaborations presented the ratio of momentum distributions measured with heavy (silver, gold or lead) and light (carbon) targets: $\sigma_{Ag,Au,*124*Pb}(p_K)/\sigma_C(p_K)$. A characteristic depletion of the low momenta kaons ($p_K \leqslant 200$ MeV/c) and a peak-like structure at $p_K \approx 200$ MeV/c was observed in these ratio plots, in agreement with the theory-driven expectations. From a comparison with transport model calculations, an in-medium potential of $+20 \pm 5$ MeV (the value at normal nuclear matter density, for low kaon momenta) was extracted.

The HADES collaboration contributed with a K^0 measurement in a medium-sized colliding system Ar+KCl at a kinetic beam energy of 1.756 AGeV [8]. The obtained p_t-distribution at mid-rapidity was compared with the IQMD transport calculations. A larger value of the potential of $+40$ MeV was extracted from this analysis.

The difference between the results, obtained in p(π)+A and A+A experiments, supports our intention to continue the HADES studies of K^0's with a new measurement in p+^{93}Nb reactions. As a reference system, free of the effects of the finite nuclear matter density, we employ p+p reactions. As compared to the previous p+A experiments, the main feature of our study is the high acceptance of the HADES detector for the low-p_t kaons in a broad range of rapidities.

2 The Experiment

The **H**igh-**A**cceptance **D**i-**E**lectron **S**pectrometer (HADES) is a modern multi-purpose detector currently operating at the SIS18 heavy-ion synchrotron (GSI Helmholtzzentrum, Darmstadt) in the region of kinetic beam energies of 1–2 AGeV (A+A), up to 3.5 GeV in proton-induced reactions. The main components of the experimental set-up are a superconducting magnet, four planes of Multiwire Drift Chambers used for the tracking of charged particles, a Time-of-Flight wall and a hadron blind RICH detector, cf. [5] for details.

In 2007 a measurement of proton-proton collisions at a kinetic beam energy of 3.5 GeV was performed. The beam with an average intensity $\sim 1 \times 10^6$ particles/s was incident on a liquid hydrogen target with a columnar density of 0.35 g/cm^2 and a total interaction probability of $\sim$ 2%. In total, 1.2×10^9 events were collected. In 2008 the same beam was employed with a ^{93}Nb target. Overall 4×10^9 events had been taken. In both runs, the first level trigger (LVL1) required at least 3 hits in the Time-of-Flight wall in order to suppress the contribution from elastic p+p scattering.

3 K^0_S analysis in proton-proton and proton-niobium collisions

A K^0 is identified by its short-lived component K^0_S that decays weakly into a $\pi^+\pi^-$-pair. Charged pions are identified with help of measured energy losses in the HADES subdetectors. In order to suppress the background, a set of additional cuts is applied to the reconstructed event topology: a) a cut on the distance from the secondary to the primary vertex $d_1 > 25$ mm; b) a cut on the distance of closest approach between the pion tracks $d_2 < 7$ mm and c) a cut on the distance of closest approach between a pion track and the primary vertex $d_3 < 7$ mm.

The resulting $\pi^+\pi^-$ invariant mass spectra are presented in Fig. 1 for p+p (left) and p+Nb (right) collisions. For both reactions, a clear signal corresponding to the K_S^0 is visible on top of a combinatorial background.

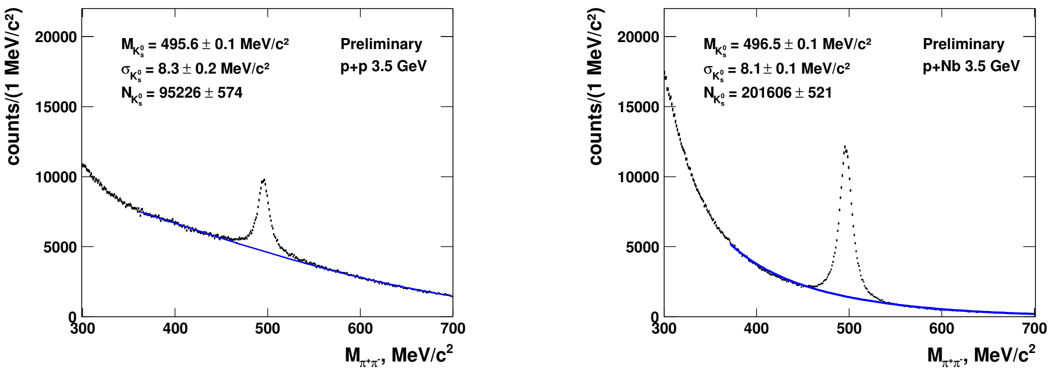

Figure 1: Black dots — data points of the invariant mass distribution of $\pi^+\pi^-$ pairs in p+p (left) collisions and p+Nb (right) collisions after applying event topology cuts; blue curves — combinatorial background (see text for details).

Several background reconstruction techniques were considered. In the p+p case the event mixing technique was found to be inapplicable. Instead, a simultaneous signal+background fit is performed, where the background is modeled as a sum of Landau and polynomial functions, and the signal as a sum of two Gaussians. The same method is applied to the p+Nb data, but in this case it was shown that the mixing event technique gives results consistent with the fitting procedure.

The large accumulated statistics of about 10^5 and 2×10^5 reconstructed K_S^0 for the p+p and p+Nb runs, respectively, allows to perform a differential analysis of the K^0 production. The signal was extracted for a set of rapidity ($\Delta y = 0.1$) and transverse momentum ($\Delta p_t = 75$ MeV$/c$) bins. The measured p_t-spectra at mid-rapidity are presented in Fig. 2. It can be seen that for both reactions our results reach the most interesting low-p_t region.

4 Summary

We reported on the ongoing study of the K^0 production in p+p and p+Nb collisions at a kinetic beam energy of 3.5 GeV. The obtained high-statistics sample of reconstructed kaons allows to analyze the low-p_t region, where the sensitivity to the in-medium kaon-nucleon potential is expected to be maximal. A comparison of the efficiency corrected p_t-distributions and their ratios with transport model calculations will give information about the KN potential.

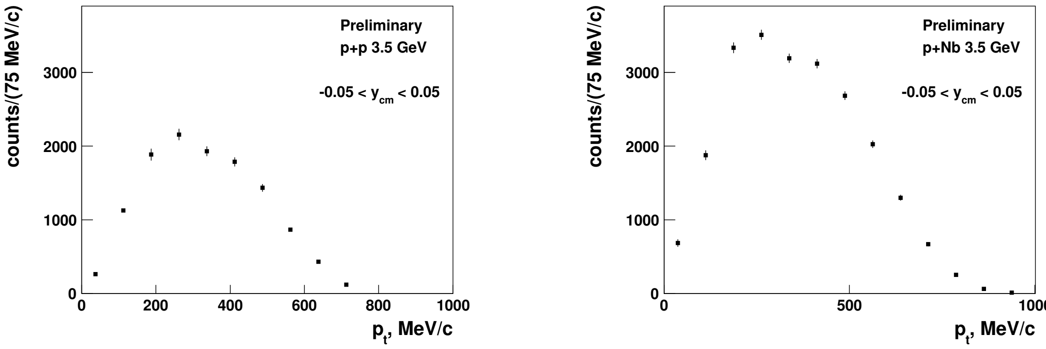

Figure 2: p_t-distributions of K^0_S's reconstructed in p+p (left) and p+Nb (right) collisions at mid-rapidity. No efficiency corrections were applied.

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