

Inclusive K^+ production in $\pi^- + A$ collisions at 1.7 GeV/c

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Abstract. The production and properties of K^+ in nuclear reactions $\pi^- + A$ ($A = C, W$) at an incident beam momentum of 1.7 GeV/c has been studied with the HADES setup at SIS18/GSI. Phase space distributions of kaons produced off heavy and light nuclei can be studied to extract information about the KN potential. We present the analysis method, normalization procedure and first results on the ratio of inclusive (K^+) cross-sections in π^- -induced reactions on W and C targets in comparison to existing measurement by FOPI and ANKE.

1 Introduction

A modification of the kaon spectral function within nuclear matter is expected already at moderate densities caused by the repulsive KN interaction [1, 2]. This modification should manifest itself in the kaon kinematic distributions. In particular, the low momentum region should be sensitive to the influence of the KN potential, according to theoretical predictions (see Fig. 1 blue and red lines). However, there is a controversy between the strength of the KN potential among different experiments. While the data obtained by FOPI and ANKE in $\pi + A$ and $p + A$ reactions are best reproduced by models employing a potential of $\approx +20$ MeV [3, 4] as shown in Fig. 1, (transverse) momentum distributions in $p + A$ and $A + A$ collisions measured by HADES favor a potential of $\approx +40$ MeV [5, 6].

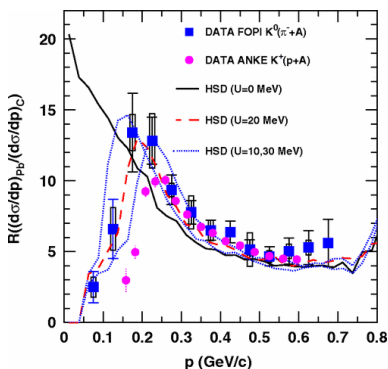


Figure 1. Ratio of inclusive K^0 (K^+) cross-sections produced by pions (protons) impinging on heavy and light targets as a function of the kaon momentum [3]. The full squares depict the ratio of K_s^0 produced on Pb and C targets measured by FOPI at an beam momentum of 1.15 GeV/c. While, the full circles show the ratio of K^+ produced on Au and C targets measured by ANKE in proton-induced reactions.

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2 The experiment

The experiment was performed with the **H**igh-**A**cceptance **D**i-**E**lectron **S**pectrometer (HADES) [7], currently located at the SIS18 accelerator (GSI, Darmstadt). The detector setup comprises six identical sectors surrounding the beam axis with almost full azimuthal coverage and a polar acceptance between 18° and 85° . Each sector is equipped with two layers of **M**ultiwire **D**rift **C**hambers (MDC), in front and behind a toroidal superconducting magnet, allowing for momentum reconstruction. In this experimental campaign, the first level (LVL1) trigger condition required a signal in the target- $T0$ detector [8] and a minimum multiplicity of two charged particles (M2) in the **M**ultiplicity and **E**lectron **T**rigger **A**rray (META) wall consisting of two time-of-flight detectors, RPC and TOF. In total, 1.0×10^8 and 1.3×10^8 events were collected in $\pi^- + C$ and $\pi^- + W$ collisions at $p_{\pi^-} = 1.7$ GeV/c, respectively.

3 Momentum distribution ratio with HADES

Insights on the mean-field KN potential can be deduced by comparing phase space distributions of kaons produced off heavy and light nuclei. Therefore, the ratio $R(\sigma_A/\sigma_C)$ as a function of the kaon momentum can be employed to study in-medium effects of the KN potential:

$$R(\sigma_A/\sigma_C) := \frac{\sigma_A^K}{\sigma_C^K} = \frac{N_A^K \sigma_A^R N_C^{evt}}{N_C^K \sigma_C^R N_A^{evt}}, \quad (1)$$

where σ^K denotes the kaon cross-section, N^K the number of reconstructed kaons, σ^R the total cross-section for pion-induced reactions and N^{evt} the number of events under the assumption that the spectrometer acceptance and trigger effects cancels out in the ratio.

The effect of the KN potential is increasing with increasing the nucleus size [4], since the kaons are exposed to higher density on average. The presence of a repulsive KN potential accelerates the kaons while escaping the nucleus leading to a suppression of the kaon production on heavy target with respect to the light one (C) at low kaon momenta. However, according to the effective Lagrangian the largest effect of the KN potential should be seen for large kaon momenta [5]. In addition, the propagation of charged kaons is affected by the (repulsive) Coulomb interaction. The depletion at low kaon momenta is followed by an excess in the intermediate range for heavier targets with respect to lighter ones.

3.1 Kaon reconstruction and normalization

The kaon candidates have been identified with the energy loss information from the MDCs, while the final yield has been extracted by fitting the measured mass distribution, separately for the two time-of-flight detectors, RPC and TOF (details in [9]). High statistics allowed for a two-dimensional analysis in two different kinematic sets (p, θ) and (p_T, y) . The extracted differential raw K^+ yields has been corrected for acceptance and efficiency effects based on simulations modeling the detector response in combination with GiBUU as an event generator.

The kaon production cross-section (σ^K) can be obtained on the basis of the following formula $\sigma^K = N^K / (N_{\text{beam}} \rho / A N_A d_{\text{target}})$, where N^K denotes the number of reconstructed kaons, N_{beam} the number of incident pions, ρ the density of the target material, A the mass number of the target nucleus, N_A the Avogadro constant and d_{target} the thickness of the solid target. The number of incident pions (N_{beam}) is extracted on the basis of hits in the target- $T0$ detector (N_{T0}). The number of hits in the target- $T0$ detector has to be corrected for the

deadtime (T_{dead}) of the data acquisition system and the geometrical acceptance of the solid targets. The latter correction factor is obtained from dedicated transport calculations (based on [8]). This results in $N_{\text{beam}} = N_{T0} (1 - T_{\text{dead}})$ (0.81 ± 0.10). The uncertainty is due to the systematic uncertainty of the transport simulation.

However, the ratio can also be evaluated without the need of absolute normalization. The total cross-section (σ^R) in pion-induced reaction at 1.7 GeV/c can be evaluated on the basis of measurements taken from [10]. Hence, the existing data points at 1.58 GeV/c and 2 GeV/c where linearly interpolated to obtain the total cross-section (σ^R) at 1.7 GeV/c. Moreover, since for the heavy target (W) no data is available, a power law function taken from [10] ($\sigma^R = C A^n$, where A is the mass number) was employed for the Sn and Pb target at 1.58 GeV/c and 2 GeV/c, respectively. In such way, a total cross-section in π^- -induced reaction at 1.7 GeV/c of $239.7 \mu\text{b}$ for the light target (C) and $1657.9 \mu\text{b}$ for the heavy target (W) was extracted. Only events originating from the target region and were no-pileup in the target- $T0$ detector was detected have been considered.

3.2 Results

The ratio of the inclusive K^+ (K^0) production cross-section $R(\sigma_A/\sigma_C)$ measured in collisions with heavy targets (W) with respect to lighter one (C) as a function of the kaon momentum is shown in Fig. 2 (circles). The full circles are extracted on the basis of an absolute normalization, while the open circles are obtained on the basis of the total reaction cross-section and number of events. Within the errors both methods are equivalent in terms of the ratio.

By comparing results from ANKE in p -induced reactions at 1.5 GeV (open triangles) and 2.3 GeV (full triangles) in Fig. 2, one can see that with increasing beam energy the suppression at low as well as the excess at intermediate kaon momenta is more pronounced. Although, the suppression at low momenta is outside the HADES acceptance, we observe a similar trend at the intermediate kaon momenta compared to observations by FOPI of the K^0 production at lower pion beam momentum of 1.15 GeV/c. However, due to the geometrical acceptance of HADES, a sensitive part of the distribution, the low kaon momentum region, to test the presence of the KN potential is outside the acceptance. Nevertheless, it is confirmed by the high statistics of our data that for $p > 0.6$ MeV/c the ratio goes up instead of going down. The fact that this enhancement of the ratio is observed could be linked to the repulsive KN potential.

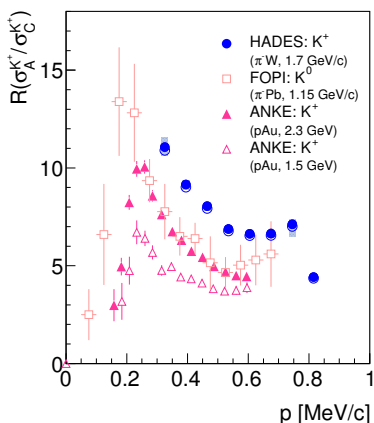


Figure 2. Ratio of inclusive K^+ (K^0) cross-sections produced by pions/protons on heavy and light targets as a function of the kaon momentum. The full (open) circle resembles the ratio of K^+ in this experiment. The open squares depict the ratio of K_s^0 produced on Pb and C targets measured by FOPI at a beam momentum of 1.15 GeV/c [3]. While, the full (open) triangle show the ratio of K^+ produced on Au and C targets of proton-induced reactions at 2.3 (1.5) GeV (ANKE) [4].

4 Summary

We have reported on the analysis of the K^+ production in $\pi^- + C$ and $\pi^- + W$ at 1.7 GeV/c with the HADES setup. The extracted double-differential kaon yields were absolutely normalized on basis of the number of beam particles as well as the target density and thickness. A ratio of inclusive K^+ cross-section as a function of the kaon momentum on the heavy (W) and light target (C) was extracted. In terms of the ratio another normalization method based on the total production cross-section in pion-induced reactions at 1.7 GeV/c was introduced. Within errors both methods are equivalent. The obtained results have been compared to existing pion-/proton-induced K^0 and K^+ production measured by FOPI and ANKE. Due to the rich statistics, we observe a rising ratio for $p > 0.6$ MeV/c, which could be linked to the moderate repulsive KN potential.

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