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K^+ production from *pp* and *pd* interactions*

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The K^+-production cross section in pn collisions is an important input parameter for model calculations of K^+ production in proton-nucleus and nucleus-nucleus interactions. Experimental data in the close-to-threshold region are not yet available and theoretical predictions give a wide scatter of numbers for the ratio of the total cross sections $\sigma_n^{K^+}/\sigma_p^{K^+}$.

K^+ production from pd interaction has been investigated using the magnetic spectrometer ANKE at COSY-Jülich at proton beam momenta 2.65, 2.81 and 3.46 GeV/c. For the extraction of $\sigma_n^{K^+}/\sigma_p^{K^+}$ from the pd data at low beam momenta, a naive phase-space approach has been used, assuming that $\sigma_d^{K^+} = \sigma_n^{K^+} + \sigma_p^{K^+}$. Double differential cross sections and missing mass spectra for proton-kaon correlations have also been analysed. Both methods give consistent result: $\sigma_n^{K^+}/\sigma_p^{K^+} \sim 3 - 5$.

During a recent beam time, experimental data have been collected at p_p = 3.46 GeV/c for both hydrogen and deuterium targets. A ratio $\sigma_d^{K^+}/\sigma_p^{K^+} \approx 2.96 \times \sigma_d^{\pi^+}/\sigma_p^{\pi^+}$ has been extracted from these data.

Keywords: kaon production, neutron/proton ratio

The K^+-production cross section in pn collisions is an important input parameter for model calculations of the strangeness production in pA and AA interactions. Experimental data on the K^+ production in pn interactions and on light nuclei are very poor. Different theoretical models obtain very different ratios for kaon production on the proton and neutron, depending on the underlying production mechanism. For example, an old pion-exchange model provides a ratio equal to one [1], a resonance model-two [2] , while the authors of Ref. [3] draw an analogy between K^+ and η meson production and deduce $\sigma_n^{K^+}/\sigma_p^{K^+} \approx 6$.

ANKE [4] is a magnetic spectrometer and detection system placed at an inter-

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nal target position of the COoler SYnchrotron COSY-Jülich [5]. The spectrometer consists of three dipole magnets that separate forward-going charged reaction products from the circulating beam and allows one to determine their emission angles and momenta. The spectrometer, with its detection and data acquisition systems, enables one to suppress a background 10^6 times higher and identify the rare production of K^+ with momenta in the range $100 < p_K < 600$ MeV/c. For the study of pp and pd interactions, a cluster-jet target with H_2 or D_2 as a target material has been used, providing areal densities of up to $\sim 5 \times 10^{14}$ cm^{-2}. The detectors and corresponding data-analysis procedures for the K^+ identification are described in detail in Ref. [6].

For the extraction of double differential cross sections for K^+ production in pd interactions at beam momenta of 2.65 and 2.81 GeV/c, a simple phase space approach has been used. This model is based on the assumption that beam protons interact independently with the nucleons inside deuteron target. Neglecting multiple scattering, the total production cross section on the deuteron is then just $\sigma_d^{K^+} = \sigma_n^{K^+} + \sigma_p^{K^+}$.

Six main reaction channels give significant contributions to strangeness production on the deuteron at 2.65 and 2.81 GeV/c (see Table 1). As a weight for each channel in this analysis we have used total cross sections, calculated using the parameterisation taken from [2] for protons and neutrons at rest (see Table 1). The Fermi motion of the nucleons inside the deuteron has been taken into account in the phase space event generator PLUTO [7]. A more detailed description of the model and the data is presented in a forthcoming publication [8].

Table 1. Relevant reaction channels for K^+ production on deuteron and the corresponding total cross sections [2].

Reaction	σ (μb)	
	1.83 GeV	2.02 GeV
$pp \to \Lambda K^+ p$	3.85	10.9
$pn \to \Lambda K^+ n$	7.12	19.4
$pp \to \Sigma^0 K^+ p$	0.005	1.36
$pn \to \Sigma^0 K^+ n$	0.008	1.68
$pp \to \Sigma^+ K^+ n$	0.001	0.52
$np \to \Sigma^- K^+ p$	0.010	2.78

The comparison of the results of the simulation with channels weights taken from Table 1 and experimental data is shown in Figure 1.a) by long-dashed line ($\sigma_n^{K^+}/\sigma_p^{K^+} = 2$). We repeated the simulation, keeping the relative weights of the three pp and pn channels constant, while treating $\sigma_n^{K^+}/\sigma_p^{K^+}$ as a free parameter. The best agreement between data and calculations was found for $\sigma_n^{K^+}/\sigma_p^{K^+} \sim 3$ at 2.65 GeV/c and $\sigma_n^{K^+}/\sigma_p^{K^+} \sim 4$ at 2.81 GeV/c. The results of the simulation, as well as the experimental points, are shown in the Fig. 1a for the higher beam

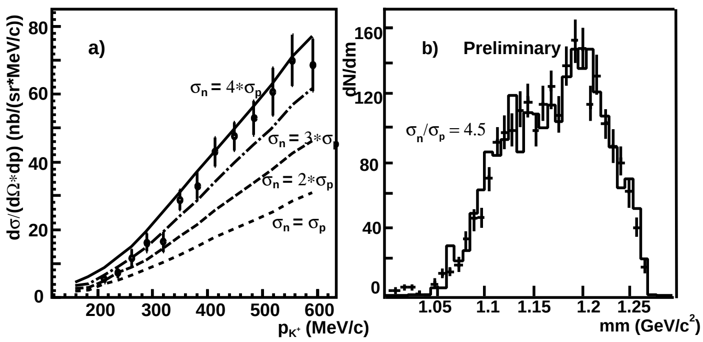

Fig. 1. a) Double-differential cross section for $pd \to K^+X$ production at 2.81 GeV/c compared with a model calculation [2]; b) $pN \to K^+pX$ correlation missing mass measured at 2.81 GeV/c compared with the simulation

momentum.

The analysis of the inclusive spectra has been confirmed by the study of the missing mass spectrum for the data at 2.81 GeV/c. A possible two-peak structure in this spectrum arises from direct protons which can only be produced in the *pp* reaction while for both targets there can be protons originally from the decay of the hyperon. The best agreement between experimental and simulated spectra has been obtained for $\sigma_n^{K^+}/\sigma_p^{K^+} \sim 4.5$, and this is illustrated in Fig. 1b.

K^+ production on hydrogen and deuterium targets has been measured during a recent beam time at a beam momentum of 3.46 GeV/c. A preliminary analysis of these data shows that in the ANKE momentum range the ratio $\sigma_d^{K^+}/\sigma_p^{K^+}$ does not depend on the kaon momentum and can be described by the simple formula $\sigma_d^{K^+}/\sigma_p^{K^+} = 2.96 \times \sigma_d^{\pi^+}/\sigma_p^{\pi^+}$. Due to the lack of experimental data on pion production on the proton and deuteron, we cannot yet draw firm conclusions on this kaon production ratio, though further analysis is in progress.

Summarizing the analysis of the missing mass and double differential cross sections it is found that K^+ production on the neutron is much stronger than on the proton. However, a precise value for the relative strength will require the analysis of additional data as well as further model developments.

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