Subthreshold and near-threshold charged kaons production in proton-nucleus collisions*

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The study of kaon and antikaon production in proton-nucleus collisions at incident energies near or below the free nucleon-nucleon thresholds has received considerable interest in recent years (see, for example, [1–13]). This interest has been particularly motivated by the hope to extract from this study information about both the intrinsic properties of target nuclei (such as high-momentum components of the nuclear wave function) and the in-medium kaon and antikaon properties at the density of ordinary nuclei (mean-field nuclear potentials, their momentum dependences). Evidently, to draw firm conclusions on these properties from proton-induced reactions it is of principal importance to disentangle reliably the underlying reaction mechanisms, since if they are clearly identified the above quantities can be fixed by comparison with the data. Therefore, we focus on the different elementary processes that lead to the kaon and antikaon production at beam energies close to their production thresholds in free NN collisions (1.58 GeV for K^+ creation and 2.5 GeV for K^- creation in these collisions).

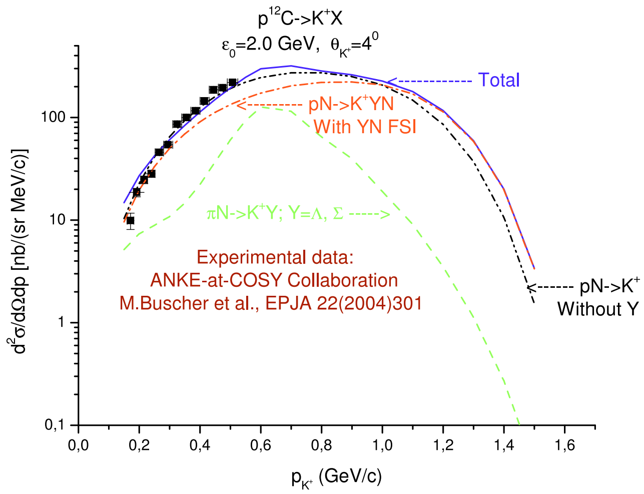

Fig. 1: Double differential cross sections for the production of K^+ mesons at an angle of 4° in the interaction of 2.0 GeV protons with the ^{12}C nuclei as functions of kaon momentum. The experimental data (full squares) are from [8]. The curves are our calculation. The dashed lines with one and two dots are calculations for the primary production processes $pN \to K^+YN$; $Y = \Lambda, \Sigma$ with and without including the FSI effects among the outgoing hyperons and nucleons. The dashed line is calculation for the secondary production processes $\pi N \to K^+Y$ with an intermediate pion. The solid line is the sum of the dashed and dash-dotted lines.

The inclusive K^+ meson production in proton-nucleus reactions in the near-threshold and subthreshold energy regimes is analyzed (see Fig. 1) with respect to the commonly used main one–step ($pN \to K^+YN$, $Y = \Lambda, \Sigma$) and two–step ($pN \to \pi X$, $\pi N \to K^+Y$) incoherent production processes on the basis of an appropriate folding model [5, 10], which takes into account only the struck target nucleon momentum distribution, extracted from the K^+ production experiment [5], and free elementary cross sections.

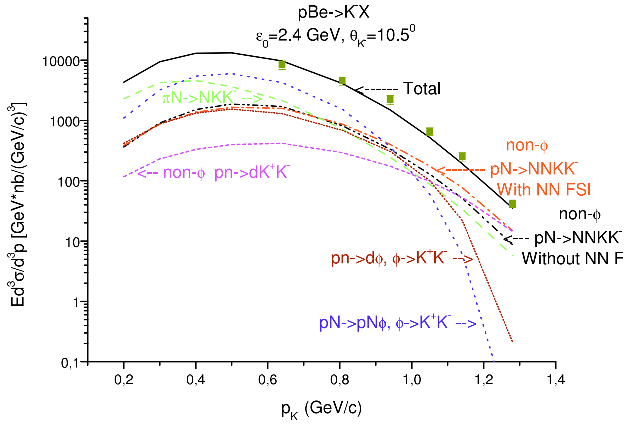

Fig. 2: Invariant cross sections for the production of K^- mesons at an angle of 10.5° in the interaction of 2.4 GeV protons with the ^{9}Be nuclei as functions of antikaon momentum. The experimental data (full squares) are obtained at the ITEP accelerator. The curves show our calculation. The dashed lines with one and two dots show the calculation for the primary production process $pN \to NNKK^-$ with and without including the FSI effects among the outgoing nucleons. The dashed and short-dashed lines represent the calculation, respectively, for the secondary production process $\pi N \to NKK^-$ and direct non-ϕ $pn \to dK^+K^-$ channel. The dotted and short-dotted lines show the calculation for the secondary creation processes $pN \to pN\phi$, $\phi \to K^+K^-$ and $pn \to d\phi$, $\phi \to K^+K^-$. The solid line is the sum of the dash-dotted, dashed, short-dashed, dotted and short-dotted lines.

The inclusive K^- meson creation in such reactions is investigated (see Fig. 2) within the same model not only with respect to the conventional direct ($pN \to NNKK^-$) and two–step ($pN \to \pi X$, $\pi N \to NKK^-$) antikaon production processes, but also using the new elementary reaction channels: $pN \to pN\phi$, $pn \to d\phi$, $\phi \to K^+K^-$; non-ϕ $pn \to dK^+K^-$. The total cross sections of the elementary reactions $pp \to pp\phi$, $pn \to d\phi$, non-ϕ $pn \to dK^+K^-$, needed for our calculations, have been recently measured in the threshold region by the ANKE-at-COSY Collaboration [14–16]. Figures 1 and 2 demonstrate that the agreement between our model calculations and the experimental data is quite good and, therefore, there is only little room left, for instance, for the subthreshold K^- production in pA reactions via other mechanisms, employed in [11]. Such good agreement with the experimental data is achieved, as may be seen from the figures 1 and 2, in particular, if we account for (in line with the corresponding Watson-Migdal theory) the final-state interaction (FSI) effects between, on the one hand, the hyperons and nucleons and, on the other hand, the nucleons originating, respectively, from the primary K^+ and K^- creation processes $pN \to K^+YN$ and $pN \to NNKK^-$. To reproduce the high-momentum part of the antikaon spectrum it was also important to take into consideration the contribution from the new K^- production channel non-ϕ $pn \to dK^+K^-$.

The results, obtained in our study, may be useful in the analysis of the future experimental data on near-threshold non-resonant and resonant (via ϕ decay) antikaon production in *pA* interactions from the ANKE-at-COSY detector system [17].

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* Supported by DFG