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An influence of ω and ϕ on the $K^-\pi^+$ and $K^+\pi^-$ pairs in reactions pp$\to K^\pm\pi^\mp$ at 24 GeV/c

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The K^+ and K^- averaged production rates per inelastic collision in pp interactions at 24 GeV/c, $\langle K^+\rangle = 0.0766 \pm 0.0077$ and $\langle K^-\rangle = 0.0218 \pm 0.0022$, were estimated in [1] from the energy evolution of the K^+, K^- and K^0 averaged production rates presented in [2]. The large difference in the K^+ and K^- production rates, with $\langle K^+\rangle/\langle K^-\rangle = 3.5$, results from associated K^+ production with Λ, Σ and other strange baryons in the proton fragmentation processes.

The associated K^- production with strange antibaryons is expected to be small. Indeed, with the $\bar{\Lambda}$ production cross section $0.021\pm^{0.004}_{0.010}$ mb and the total inelastic cross section $\sigma_{inel} = 30.60 \pm 0.25$ mb measured in pp collisions at 24 GeV/c [3], one has $\langle\bar{\Lambda}\rangle \approx 0.00068$ and $\langle\bar{\Lambda}\rangle/\langle K^-\rangle \approx 0.03$. However the $\bar{\Lambda}$, as well as other strange antibaryons, can also be produced in association with the $\bar{K}^0$ or with the strange baryons, so that the associated K^- production with strange antibaryons can only account for a small fraction ($\approx$ 1-2%) of the total K^- rate.

Therefore, contrary to the K^+ mesons, the K^- mesons are dominantly produced as the K^-K^+ and K^-K^0 pairs.

Presumably some K^- mesons can be produced, similarly to K^+ mesons, in the proton fragmentation processes as decay products of numerous Λ and Σ resonances. These resonances are mainly established from partial-wave analyzes and therefore their production rates are not known. The only exception is the relatively narrow $\Lambda(1520)$ (with $\Gamma = 15.6 \pm 0.3$ MeV). Its averaged production rate in pp collisions at 24 GeV/c can be estimated from the $\Lambda(1520)$ and $\Sigma^{*+}(1385)$ cross sections 0.56 ± 0.10 mb and 0.67 ± 0.08 mb, respectively, measured in pp interactions at 400 GeV/c [4] (see also [5]) and the averaged $\Sigma^{*+}(1385)$ production rate $\langle\Sigma^{*+}(1385)\rangle = 0.00902\pm0.00085$ at 24 GeV/c [6] at a reasonable assumption that the ratios $\langle\Lambda(1520)\rangle/\langle\Sigma^{*+}(1385)\rangle$ at 400 and 24 GeV/c are the same. This gives:

$$\langle\Lambda(1520)\rangle = (0.00902 \pm 0.00085)(0.56 \pm 0.10)/(0.67 \pm 0.08) = 0.0075 \pm 0.0018. \quad (1)$$

With the branching ratio $BR(\Lambda(1520) \to N\bar{K}) = 0.45 \pm 0.01$ [9], the fraction of the K^- mesons resulting from the $\Lambda(1520) \to pK^-$ decay is

$$\langle\Lambda(1520) \to pK^-\rangle/\langle K^-\rangle = 0.5(0.45 \pm 0.01)(0.0075 \pm 0.0018) = 0.078 \pm 0.020. \quad (2)$$

This value suggests that the proton fragmentation processes involving the formation and consequent decays of the Λ and Σ resonances is indeed responsible for important part of the

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K^- mesons produced in pp interactions at 24 GeV/c. However since all of these resonances have rather large widths, the K^- mesons from their decays can be considered as originated from short-lived sources.

Most of meson resonances, such as the strange vector $K^*(890)$, $\bar{K}^*(890)$ and tensor $K_2^*(1430)$, $\bar{K}_2^*(1430)$ mesons decaying into $K\pi$ or numerous resonances with decay products containing $K\bar{K}$, such for example as the $f_1(1420)$ and $f_2'(1525)$, have large widths and can also be considered as the short-lived sources of the $K^\pm$ mesons or $K^+\pi^-$ and $K^-\pi^+$ pairs. The only exception, apart from the ω and η', accounted for in the $\pi^+\pi^-$ atom analyzes [7, 8], is the ϕ meson with the width $\Gamma_\phi = 4.26 \pm 0.04$ MeV (twice smaller than the ω width $\Gamma_\omega = 8.49 \pm 0.08$ MeV) and the branching fractions $BR(\phi \to K^+K^-) = (48.9 \pm 0.5)\%$ and $Br(\phi \to \rho\pi + \pi^+\pi^-\pi^0) = (15.3 \pm 0.3)\%$ [9]. The average ϕ rate per inelastic pp collision at 24 GeV/c measured in [10] is

$$\langle\phi\rangle = 0.0052 \pm 0.0011. \qquad (3)$$

From this it follows that

$$\langle\phi \to K^+K^-\rangle/\langle K^-\rangle = 0.12 \pm 0.03. \qquad (4)$$

This value can be compared with the ratio

$$\langle\omega \to \pi^+\pi^-\pi^0, \pi^+\pi^-\rangle/\langle\pi^+\rangle = 0.051 \pm 0.007 \qquad (5)$$

obtained from the ω cross section in pp collision at 24 GeV/c, $\sigma(\omega) = 3.21 \pm 0.42$ mb, estimated in [8], the branching fraction $Br(\omega \to \pi^+\pi^-\pi^0 + \pi^+\pi^-) = (90.7 \pm 0.7)\%$ [9] and $\sigma(\pi^+) = 56.8 \pm 0.9$ mb measured in [3].

For reaction pp$\to K^-\pi^+ + X$ with $K^-\pi^+$ pairs (and atoms) in the final states, the ratios $\langle\phi \to K^+K^-\rangle/\langle K^-\rangle$ and $\langle\omega \to \pi^+\pi^-\pi^0, \pi^+\pi^-\rangle/\langle\pi^+\rangle$ are expected to be different from the values (4) and (5), since for such reactions only the final states with associated production of K^- (including K^- from ϕ decay) with π^+ (including π^+ from ω and pionic ϕ decays) must be considered. Such channels as pp$\to (\phi \to K^+K^-)$pp$(m\pi^0)$ (with $m \geq 0$) without π^+ in the final states (where by definition $(\phi \to K^+K^-)/K^- = 1$) do not contribute to reaction pp$\to K^-\pi^+ + X$. Therefore the ratio $\langle\phi \to K^+K^-\rangle/\langle K^-\rangle$ for this reaction will be smaller than (4). No estimates of the ratio $\langle\omega \to \pi^+\pi^-\pi^0, \pi^+\pi^-\rangle/\langle\pi^+\rangle$ for reaction pp$\to K^-\pi^+ + X$ can be made since there are no experimental data on reactions pp$\to K^- + \omega + X$ and pp$\to K^- + \pi^+ + X$.

For reactions with K^+ in the final states the overall ratio $\langle\phi\rangle/K^+$ is of course expected to be smaller than (4) since $\langle K^+\rangle/\langle K^-\rangle = 3.5$. However for reactions with the $K^+\pi^-$ and $K^-\pi^+$ pairs in the final states the difference in the $\langle\phi\rangle/K^+$ and $\langle\phi\rangle/K^-$ ratios is not as large as 3.5. This is because an important fraction of the K^+'s (but not the K^-'s) can be produced in reactions with 2-prongs in the final states such as pp$\to K^+\bar{K}^0$pn, $K^+\bar{K}^0\pi^+$nn, ΛK^+p, $\Lambda K^+\pi^+$n, $\Lambda K^+K^0\bar{K}^0$p and $\Lambda K^+K^0\bar{K}^0\pi^+$n (with or without neutral pions in these final states and without π^-'s). For reaction pp$\to K^+\pi^- +$ *anything*, contribution of these states to the K^+ rate will not be counted.

Besides, from all possible reactions with the kaon pairs (K^+K^-, $K^+\bar{K}^0$, K^-K^0) in 4-prong events (with the highest topological cross section) the $K^+\pi^-$ pair can only be produced in reactions with the $K^+\bar{K}^0$ in the final states, i. e. in reactions pp$\to K^+\bar{K}^0\pi^-$pp, $K^+\bar{K}^0\pi^+\pi^-$pn and $K^+\bar{K}^0 2\pi^+\pi^-$nn (with or without π^0's in these final states). Notice again that the $\pi^+\pi^-\pi^0$ in two of these final states can be the ϕ or ω decay products). The K^+'s in the reactions pp$\rightarrow K^+K^-$pp, $K^+K^-\pi^+$pn and $K^+K^-2\pi^+$nn in 4-prong events will not contribute to the reaction pp$\rightarrow K^+\pi^- + anything$.

Thus we see that for point-like production, dependence of the Coulomb $K^+\pi^-$ and $K^-\pi^+$ pair production on the relative momentum in the $K^+\pi^-$ and $K^-\pi^+$ center-of-mass systems should be corrected not only for π^+ and π^- mesons originating from the ω and η' decays (as it was done in the $\pi^+\pi^-$-atoms analysis) but as well for K^+ and K^- mesons originating from the $\phi \rightarrow K^+K^-$ decay and for π^+ and π^- from the pionic ϕ decays[2]. As it is seen from (4) and (5) (even if they have been obtained from the total rates) the influence of the ϕ on K^- seems to be even stronger that the ω on π^+. But in fact it is presumably even much more stronger since the ϕ is twice narrower than the ω and thus have to be properly accounted for not only at determining the $K^-\pi^+$ atom lifetime but also at extraction of the $K^-\pi^+$ atom signal.

The aim of this note was to draw attention to all this. Still the estimates of the ϕ and ω influence presented above and based on the total ϕ, ω, K^- and π^+ rates should be considered as the first approximation only since there are no experimental data on inclusive pp reactions with several particles in the final states. More reliable estimates of the ϕ and ω influence in reactions pp$\rightarrow K^\pm\pi^\mp + X$, can only be obtained by simulation. In such simulation one have to determine the fractions of K^+ and K^- mesons from $\phi \rightarrow K^+K^-$ decays and fractions of π^+ and π^- from decays of ω and pionic ϕ decays in reactions pp$\rightarrow K^\pm\pi^\mp + X$, i. e. determining the origin of each generated $K^+\pi^-$ and $K^-\pi^+$ pair in the final states. The Monte Carlo generator to be used in such simulation have to be properly tuned to describe at least the known total production rates of pions, kaons, ϕ, ω, η and η' which are either given here or can be found in references [1, 3, 8, 10].

[2]In the previous $\pi^+\pi^-$-atom analysis, the influence of the $\phi \rightarrow \rho\pi + \pi^+\pi^-\pi^0$ decay has been ignored because of small ϕ rate. This is not the case for the $K\pi$-atoms.

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