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Fractions of K^+K^- pairs with K^+ or K^- mesons from the resonance decays in pp interactions at 24 GeV/c

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Abstract

The Coulomb K^+K^- correlations might be sensitive to non point-like K^+K^- pair production due to influence of kaons from decays of resonances with relatively small widths. The relative fractions of K^+K^- pairs with the K^+ or K^- mesons from decays of the $K^*(892)$, $\Lambda(1520)$ and ϕ produced in pp interactions at 24 GeV/c are determined using the experimental or estimated cross sections of these resonances.

In an attempt to estimate the number of produced K^+K^- atoms, $A_{K^+K^-}$, in proton-nucleus collisions at 24 GeV/c in the DIRAC experiment at the CERN PS by studying the Coulomb K^+K^- correlations, it might be important to take into account non point-like K^+K^- pair production. Indeed if one of kaons in K^+K^- pair is the decay product of relatively narrow resonance, such as $\Lambda(1520)$ or ϕ, the diistance between K mesons in their center-of-mass system (with $c\tau \approx 12.6$ fm and 46 fm for, respectively, $\Lambda(1520)$ and ϕ) is although smaller but still not drastically different from the Bohr radius (109 fm) of $A_{K^+K^-}$. In this case the Coulomb correlations are weaker than for the point-like pair production. In order to take this into account it is necessary to know the fractions of K^+K^- pairs with K^+ or K^- from such resonance decays. In this note, we determine the fractions of such K^+K^- pairs with K^+ or K^- from the $K^*(892)$ (with $c\tau \approx 4.2$ fm), $\Lambda(1520)$ and ϕ decays in pp interactions at 24 GeV/c.

The cross section of K^+K^- pair production in pp interactions at 24 GeV/c has been estimated in [1]:

$$\sigma(K^+K^-) = (0.500 \pm 0.028) \text{ mb}. \tag{1}$$

The cross sections of ϕ, $\Lambda(1520)$ and $K^*(892)$ in pp interactions at 24 GeV/c, either measured or estimated, are collected in Table 1.

Production mechanisms of the $\Lambda(1520)$ and $\Sigma^{*+}(1385)$ in proton fragmentation processes are very similar (as it is evident from the corresponding quark diagrams in Fig. 1). Therefore the $\Lambda(1520)$ cross section was estimated in [4] from the measured $\Sigma^{*+}(1385)$ cross section in pp interactions at 24 GeV/c, (0.276 ± 0.026) mb [6], assuming the same ratio of the $\Lambda(1520)$ and $\Sigma^{*+}(1385)$ cross sections, $(0.56 \pm 0.10)/(0.67 \pm 0.08) = 0.836 \pm 0.180$, as measured in pp interactions at 400 GeV/c [7].

The $\bar{K}^{*0}(892)$ cross section at 24 GeV/c is assumed [5] equal to the measured $K^{*-}(892)$ cross section [3], as it is supported by results of pp experiment at 400 GeV/c [7], where $\sigma(\bar{K}^{*0}(892)) = (2.96 \pm 0.54)$ mb and $\sigma(K^{*-}(892)) = (2.87 \pm 0.39)$ mb. The $K^{*0}(892)$ cross section at 24 GeV/c was estimated as explained in details in [5].

Other numerous resonances, some of which are observed only in the phase-wave analyses, either have large widths or small branching ratios into the final states with kaons and/or small production

Table 1: Mesured cross sections of ϕ [2], $K^{*+}(892)$ and $K^{*-}(892)$ [3] and estimated cross sections of $\Lambda(1520)$ [4], $K^{*0}(892)$ and $\bar{K}^{*0}(892)$ [5] in pp interactions at 24 GeV/c.

Resonance	ϕ	$\Lambda(1520)$	$K^{*+}(892)$	$K^{*-}(892)$	$K^{*0}(892)$	$\bar{K}^{*0}(892)$
σ (mb)	0.158 ± 0.035	0.231 ± 0.054	0.66 ± 0.06	0.19 ± 0.09	0.44 ± 0.04	0.19 ± 0.04

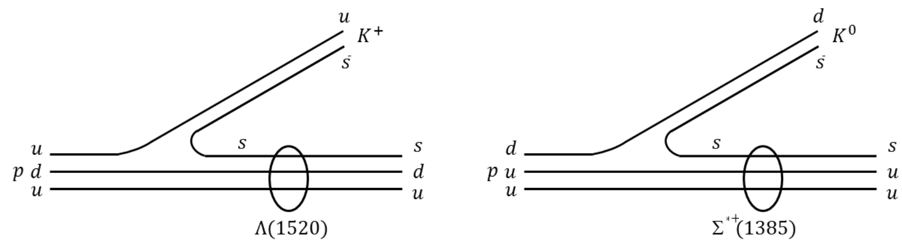

Figure 1: Quark diagrams of the $\Lambda(1520)$ and $\Sigma^{*+}(1385)$ production in proton fragmentation processes.

rates (such as $f_1(1285)$ with $\Gamma \approx 24$ MeV/c^2 and $Br(K\bar{K}) \approx 9\%$ or f'(1525) with $\Gamma \approx 73$ MeV/c^2 and $Br(K\bar{K}) \approx 89\%$) and therefore are not relevant to the present analysis.

The fraction of K^+K^- pairs with the K^- from the $\bar{K}^{*0}(892)$ decay is

$$f_{\bar{K}^{*0}}(K^+K^-) = Br(\bar{K}^{*0} \to K^-\pi^+)\sigma(\bar{K}^{*0})/\sigma(K^+K^-) = 25.3 \pm 5.5)\%. \quad (2)$$

The cross sections of $K^{*+}(892)$ and $K^{*0}(892)$ are much higher than those of $K^{*-}(892)$ and $\bar{K}^{*0}(892)$. However it was explained [1] by proton fragmentation into K^+ (or $K^{*+}(892)$, $K^{*0}(892)$) and hyperons. The associated production of such $K^{*+}(892)$, $K^{*0}(892)$ with the $K\bar{K}$ pair production is presumably small. Therefore it is reasonably safe to assume that the fraction of K^+K^- pairs with the K^+ from the $K^{*0}(892)$ decay is the same as in (2):

$$f_{K^{*0}}(K^+K^-) = f_{\bar{K}^{*0}}(K^+K^-) = (25.3 \pm 5.5)\%. \quad (3)$$

The fractions (3) are quite large. However, the K^+K^- pairs with K^+ or K^- from decays of the $K^{*0}(892)$ or $\bar{K}^{*0}(892)$ can not contribute significantly to non point-like K^+K^- pair production because of relatively large $K^*(892)$ width.

The fraction of K^+K^- pairs with the K^- from the $\Lambda(1520)$ decay amounts to

$$f_{\Lambda(1520)}(K^+K^-) = \epsilon \cdot Br(\Lambda(1520) \to pK^-) \cdot \frac{\sigma(\Lambda(1520))}{\sigma(K^+K^-)} = (8.07 \pm 2.00)\%, \quad (4)$$

where the branching ratio $Br(\Lambda(1520) \to pK^-) = \frac{1}{2}(0.45 \pm 0.01)$ and factor ϵ takes into account that proton may fragment either into $\Lambda(1520)$ and K^+ or into $\Lambda(1520)$ and $K^0\pi^+$. If the latter process is ignored, then $\epsilon = 1$. If production rates of both processes are equal, then $\epsilon = 1/2$. The ϵ value in (4) was determined using ratio of the measured cross sections of similar processes $\sigma(K^+\Lambda) = (1.274 \pm 0.040)$ mb and $\sigma(K^0\Lambda) = (0.820 \pm 0.028)$ mb [1]. This gave $\epsilon = 0.777 \pm 0.036$. Presumably small contribution of associated production of $\Lambda(1520)$ with the "central" $K\bar{K}$ pairs was ignored.

With the known ϕ and K^+K^- pair cross sections and branching ratio $Br(\phi \rightarrow K^+K^-) = 0.489 \pm 0.005$, the fraction of K^+K^- pairs with K^+ and K^- mesons from the ϕ decay is

$$f_\phi(K^+K^-) = Br(\phi \rightarrow K^+K^-) \cdot \frac{\sigma(\phi)}{\sigma(K^+K^-)} = (15.45 \pm 3.53)\%. \quad (5)$$

However, if dominent mechanism of the ϕ production is similar to the J/ψ production (as shown in Fig. 2), then K^+K^- pairs with both K^+ and K^- from the ϕ decay can not contribute to non point-like K^+K^- pair production.

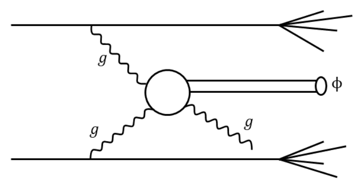

Figure 2: Quark diagram of the ϕ production similar to the J/ψ production.

The K^+K^- pairs with one kaon from the ϕ decay and another from other sourses (see quark diagrams in Fig. 3) could contibute to non point-like K^+K^- pair production. Such mechanism of the ϕ production associated with pair of strange particles (dominantly kaons) has been shown to be supressed in pp interactions at 24 GeV/c, with estimated cross section $\sigma_{ass}(\phi) = (0.018 \pm 0.004)$ mb [2]. Then the fraction of K^+K^- pairs with K^+ (or K^-) mesons from such ϕ decay and associated K^- (or K^+) mesons is

$$f_\phi(K^+K^-) = Br(\phi \rightarrow K^+K^-) \cdot \frac{\sigma_{ass}(\phi)}{\sigma(K^+K^-)} = (1.8 \pm 0.4)\%, \quad (6)$$

assuming equal contribution of the ϕK^+K^-, $\phi K^+\bar{K}^0$, ϕK^-K^0 and $\phi K^0\bar{K}^0$ final states.

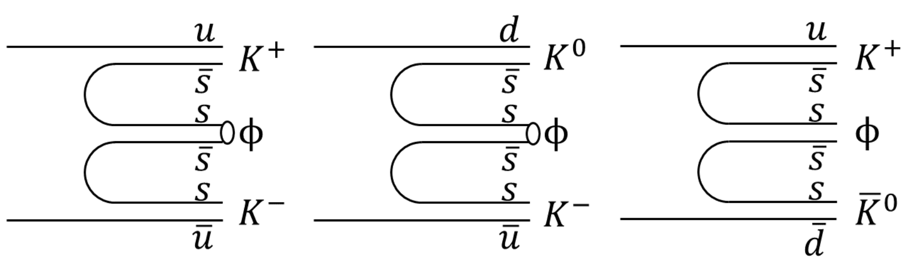

Figure 3: Quark diagrams of the ϕ production in association with two kaons.

Thus, in summary, main contribution to non point-like K^+K^- pair production arises from the $\Lambda(1520)$ decays. Smaller contribution is due to the ϕ decays, when the ϕ is produced in association with the pair of kaons..

However, this concusion must be treated with great caution, since the fraction of ϕ associated with any strange particle in pp interactions at 400 GeV/c is found to be 0.91 ± 0.11 [7], in excellent agreement with OZI selection rule [8] and in contradiction with much smaller value of $\sigma_{ass}(\phi)/\sigma(\phi) = 0.11 \pm 0.04$ at 24 GeV/c [2]. If this difference is not due to energy dependence, but can be explained by poor statistics and absence of particle identification in the bubble chamber experiment at 24 GeV/c, one is forced to admit that influence of ϕ on non point-like K^+K^- pair production at 24 GeV/c can be comparable with that of $\Lambda(1520)$.

These observations can be important in attempt to estimate the number of K^+K^- atoms in the data already accumulated by the DIRAC experiment.

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