Reactions of the Type pp $\rightarrow$ ppK$^+$X near the $\left(\mathrm{K}^+\mathrm{K}^-\right)$–Threshold

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Studies of the $K\bar{K}$ channel in the proton–proton interaction may contribute to disentangle the structure of the scalar objects $f_0(980)$ and $a_0(980)$. Their nature has been subject of incessant discussions [1, 2, 3, 4] and is still being controversely interpreted from recent experimental data [5].

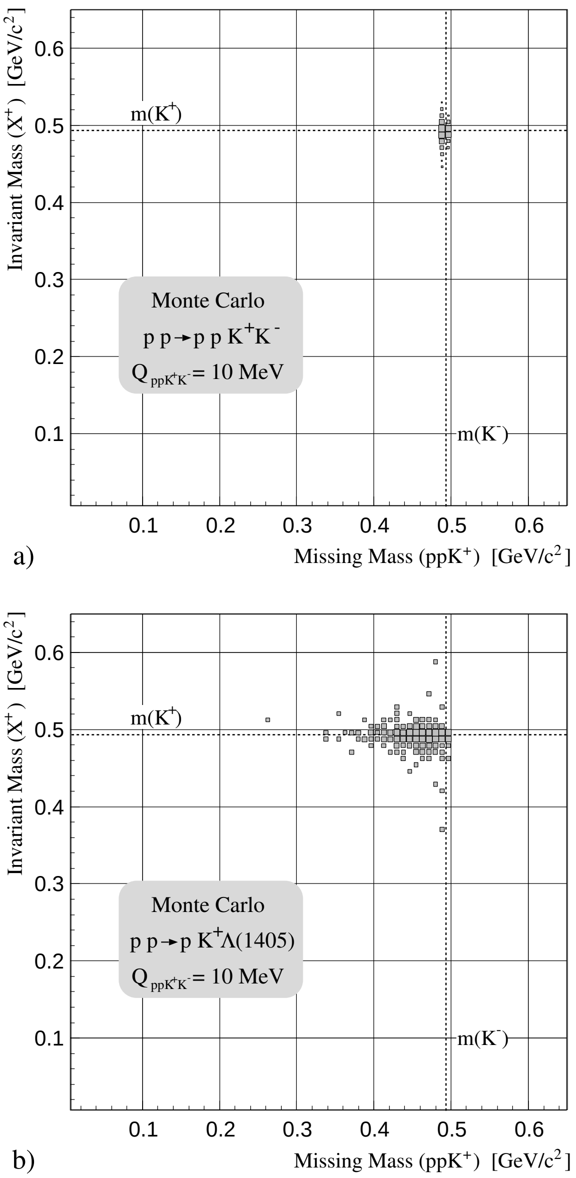

Fig. 1: Invariant mass of a third positively charged ejectile besides two identified protons in the exit channel versus the missing mass with respect to the (ppK^+) subsystem at $10\,\mathrm{MeV}$ excess energy above the (K^+K^-) threshold according to Monte Carlo simulations of the reactions $pp \rightarrow ppK^+K^-$ (a) and $pp \rightarrow pK^+\Lambda\,(1405)$ (b).

Results obtained within the framework of the Jülich meson exchange model [4] closely relate a $K\bar{K}$ molecule structure of the $f_0(980)$ with the strength of the $K\bar{K}$ interaction, which determines both shape and absolute value of the $\pi\pi \rightarrow K\bar{K}$ excitation functions [6]. A similar effect on kaon pair production cross sections in the proton–proton interaction is conceivable.

At the COSY–11 installation the four–momenta of positively charged particles are directly experimentally available. In addition, negative particles can be detected with reduced acceptance, which e.g. remains for the K^- detection at a level of more than 40 per cent at excess energies of $30\,\mathrm{MeV}$ with respect to the (K^+K^-) threshold. Details of the experimental technique in case of the (ppK^+K^-) final state are given in [7, 8, 9].

With no additional signal from a negatively charged particle being required the identification of a (ppK^+) subsystem leads to the reaction type

$$pp \rightarrow ppK^+X. \tag{1}$$

In this case the underlying reaction mechanism is not unambigous, as one of the identified protons may originate from the decay of a previously produced hyperon Y in $pp \rightarrow pK^+Y \rightarrow pK^+pX$. Thus, in reaction type (1), X denotes a system of one or more undetected particles.

In consequence, the missing mass with respect to the identified (ppK^+) subsystem may shift to values too small for a (ppK^+K^-) hypothesis as demonstrated by the simulations in figure 1. An experimental acceptance decreasing with increasing excess energy favours final states close to threshold, thus a dominant influence of the hyperons $\Sigma^0\,(1385)$ and $\Lambda\,(1405)$ is expected [9]. Furthermore, reactions of the type $pp \rightarrow pK^+\Lambda x \rightarrow pK^+p\pi^-x$ might contribute, i.e. reactions with up to two additional pions or a number of gammas (x) produced along with a hyperon.

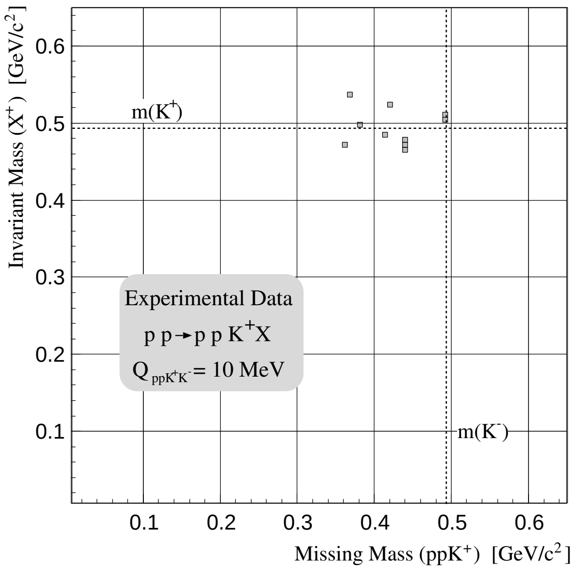

Fig. 2: Experimental data at an excess energy of $10\,\mathrm{MeV}$ with respect to the (K^+K^-) threshold. Axes are the same as in figure 1.

Experimental data at Q $=$ $10\,\mathrm{MeV}$ in excess of the (K^+K^-) threshold, when compared to the simulations

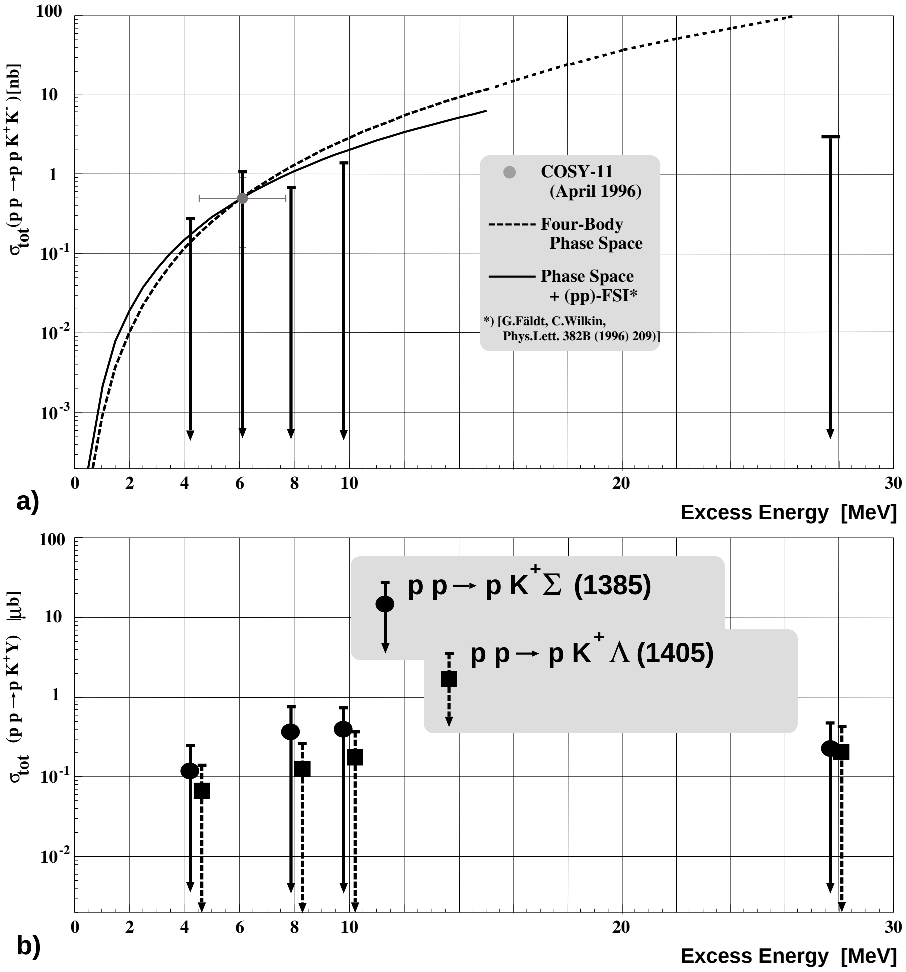

Fig. 3: Upper limits on the total cross section for the final states ppK^+K^- (a) and $pK^+\Sigma\,(1385)\,/\Lambda\,(1405)$ (b) at a confidence level of $95\,\%$. Only events within a range of $3\,\sigma\,=\,6\,\mathrm{MeV/c^2}$ around the kaon mass are accepted as (ppK^+K^-) candidates, based on a typical missing mass resolution $\leq\,2\,\mathrm{MeV/c^2}$ at COSY–11. In (a) predictions of the energy dependence from four–body phase space and phase space including proton–proton FSI are fixed at the data point at $\mathrm{Q} = 6.1\,\mathrm{MeV}$.

of figure 1, show a clear hint of the significance of the hyperon channels on the (ppK^+) system (fig. 2). The lack of at least 50 per cent of the expected number of hits which are consistent with a K^- interpretation in the data provides another piece of evidence.

With only a few ten events of the type (1) being identified in total, data taken at five different beam momenta up to excess energies of 30 MeV show no enhancement that can be considered a clear exclusive signal of one of the reaction channels previously discussed. Thus, at this stage of the analysis only upper limits of the total cross section for the charged kaon pair production and the hyperon channels of the $\Sigma\,(1385)$ and $\Lambda\,(1405)$, respectively, are available (fig. 3) [8, 9].

To unravel this situation, additional data have been taken at excess energies of $\mathrm{Q}\,=\,-3\,\mathrm{MeV}$ and $\mathrm{Q}\,=\,+3\,\mathrm{MeV}$, i.e. below and above the $\left(\mathrm{K^+K^-}\right)$ threshold, as well as at a higher Q value of 17 MeV in September 1998, the latter filling the obvious gap in figure 3.

A preliminary analysis of the data at $\mathrm{Q}\,=\,17\,\mathrm{MeV}$ suggests several events with additionally detected $\mathrm{K^-}$ mesons. Further evaluation of these data may result in an absolute value for the total cross section of the exclusive $pp \to ppK^+K^-$ channel in the vicinity of the $f_0(980)$.

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