Experimental studies of the near threshold production of K^+K^- pairs at COSY-11

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Abstract. This paper sums up experimental studies of the near threshold production of K^+K^- pairs at COSY-11. The total cross section of the reaction $pp \rightarrow ppK^+K^-$ has been measured at five excess energies below the ϕ production threshold with the magnetic spectrometer COSY-11. The new data show a significant enhancement of the total cross section compared to pure phase space expectations.

Keywords: kaon production, near threshold cross section
PACS: 13.60.Le, 13.75.Jz, 13.75.Lb, 14.40.Aq

PHYSICAL MOTIVATION

One of the main reasons to study the near threshold K^+K^- production is unknown nature of scalar mesons $f_0(980)$ and $a_0(980)$. Their masses are very close to the sum of K^+ and K^- masses. Besides the interpretation as a $q\bar{q}$ meson [1], these resonances were also proposed to be $qq\bar{q}\bar{q}$ states [2], $K\bar{K}$ molecules [3, 4], hybrid $q\bar{q}$/meson-meson systems [5] or even quark-less gluonic hadrons [6]. Especially for the formation of a molecule, the strength of the $K\bar{K}$ interaction is a crucial quantity and it can be probed in the K^+K^- production close to threshold [7].

Information about the KN system is of equal importance especially in view of the actual discussion on the structure of the excited hyperon $\Lambda(1405)$ which is considered as a 3 quark system or a KN molecular state [8].

Investigation of K^+K^- production in pp collisions is also important for description of kaons production in heavy-ion collisions. One can also learn something about properties of strange particles immersed in dense baryonic matter. There are also some astrophysical aspects of such studies. Typical observed mass of neutron stars in the universe is less than 1.5 $M_\odot$. Maximum mass of neutron stars in conventional nuclear Equation of State (EoS) is above 2 $M_\odot$. There are some EoS modifications that show, that if kaon interaction with nucleon is introduced, maximum mass of neutron star can be reduced to about 1.5$M_\odot$, as is shown in the left part of figure 1 [9].

$pp \rightarrow ppK^+K^-$ MEASUREMENTS AND RESULTS

COSY-11 [10] experimental setup used for kaon pairs production studies is shown in the right part of figure 1. ppK^+ system is easily identified by using drift chambers and TOF technique. For each identified ppK^+ system, the positions, at which the K^- tracks should be registered in a silicon and scintillator detectors inside the dipol magnet

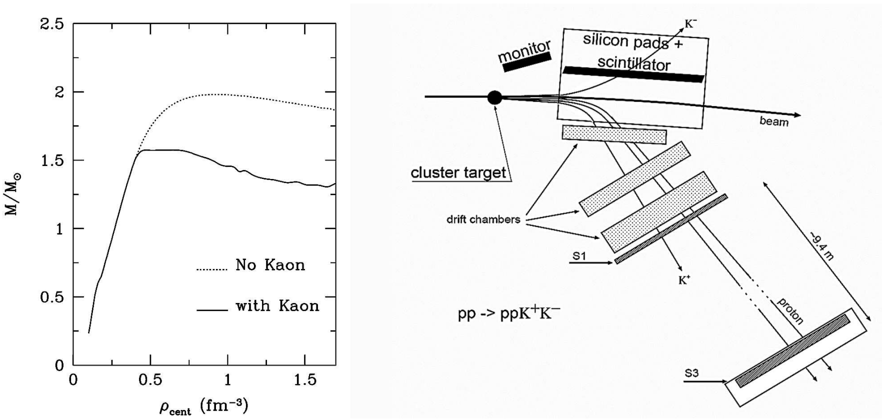

FIGURE 1. (left) Neutron star mass as a function of central density [9]. (right) Schematic top view of the COSY-11 detection setup with only the relevant parts for the measurement of the reaction $pp \to ppK^+K^-$ [12].

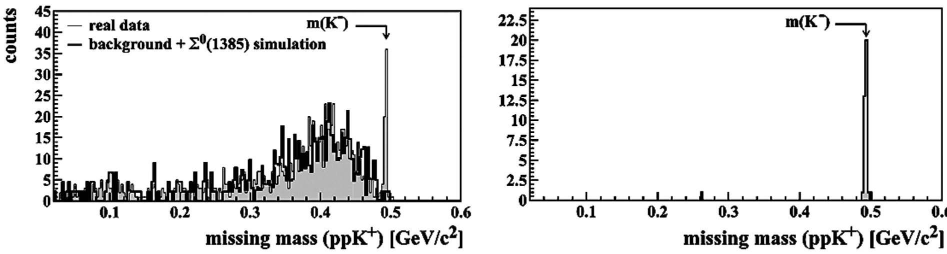

FIGURE 2. Missing mass distributions of the ppK^+ system at an excess energy of 17 MeV above the threshold. The picture on the left presents events with two identified protons and one K^+ meson (thin solid line). Thick solid line is a reproduction of the background distribution. The right spectrum represents events with an additional hit of the K^- mesons in the silicon pad detector [12].

are predicted. Checking if there are corresponding signals, all ppK^+K^- system can be identified. Using this technique the background is reduced, as is shown in figure 2.

The total cross sections obtained in our previous measurements as a function of the excess energy are shown in the left part of figure 3. There is also one more point from DISTO collaboration. The lines show theoretical calculations normalized to the DISTO point. Dashed line presents expectations of pure phase space for the four body system. The solid line is a result of calculations of pure phase space weighted with the pp-FSI factor. There is an enhancement of the total cross section near the threshold - even for phase space with pp-FSI [14]. This is different situation compared with the data for $pp \to pp\eta'$ cross sections which are shown in the right part of figure 3. The later data are in a good agreement with the pure three body phase space weighted with the pp-FSI enhancement factor. This effect can be caused by some additional interaction in the ppK^+K^- system.

Besides total cross section analysis one can also made some differential spectra. The left part of figure 4 shows invariant mass for the system pK^- divided by that for the pK^+ system. As one can see there is an enhancement near the threshold - what can be caused

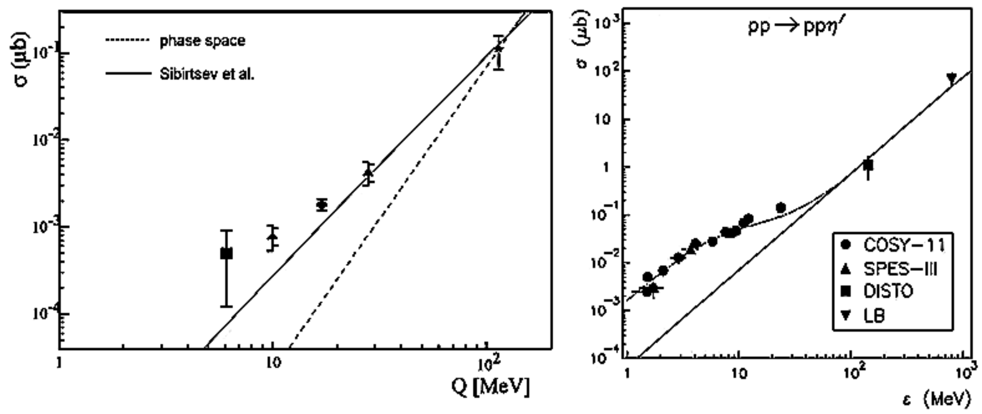

FIGURE 3. (left) Results of $pp \rightarrow ppK^{+}K^{-}$ measurements, data are from [11, 12, 13, 14], the dashed line represents an arbitrarily normalized phase space integral and the solid line incorporates the pp-FSI [14]. (right) Results of $pp \rightarrow pp\eta'$ measurements, data are from [15, 16, 17, 18, 19], the solid line represents calculation without inclusion of the FSI and the dotted line incorporates the pp-FSI [20].

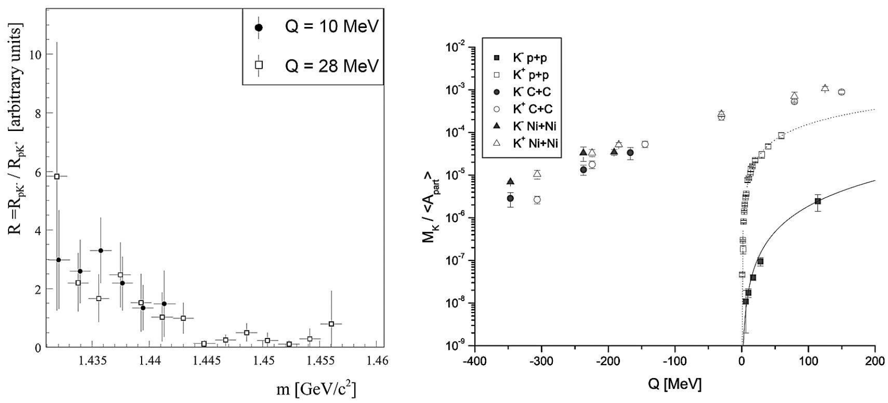

FIGURE 4. (left) Invariant mass spectrum for the system pK^{-} divided by that for the pK^{+} system [14]. (right) Multiplicity of kaon and anti-kaon production per participating nucleon for $C+C$ [21], $Ni-Ni$ [22, 23] and proton-proton collisions [12, 24, 25, 26, 27, 28].

by the pK^{-} interaction, maybe connected with $\Lambda(1405)$.

Another interesting issue is to compare results from elementary proton-proton collisions with heavy-ion experiments [29]. As is shown in the right part of figure 4, for systems like $C+C$ and $Ni+Ni$ the multiplicity of K^{+} and K^{-} are almost the same for the same excess energy. In the pp collisions there are about two orders of magnitude more K^{+} than K^{-} produced. This can be caused by some in medium effect. This effect can be explained as difference of kaon masses in medium. According to calculations of G.Q. Li, C.-H. Lee and G.E. Brown [9] mass of K^{-} drops from 500 MeV to 400 MeV and mass of K^{+} slightly grows in nuclear medium inside neutron stars, as is shown in figure 5.

In order to test the interaction in the four-body $ppK^{+}K^{-}$ system, which is expected to show up at Q lower than 10 MeV, measurement of the $pp \rightarrow ppK^{+}K^{-}$ reaction at

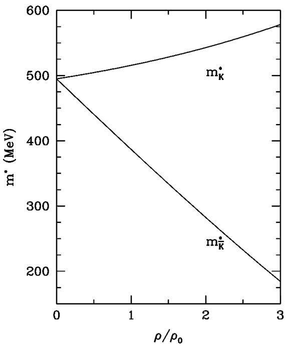

FIGURE 5. Effective masses of kaon and antikaon in nuclear medium [9].

Q = 4.5 MeV was made in October 2005. Presently the analysis is in progress.

ACKNOWLEDGMENTS

We acknowledge the support of the Polish Ministry of Science and Higher Education (grant No. 3240/H03/2006/31) and the German Research Foundation (DFG).

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