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Kaon pair production close to threshold

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Abstract

The total cross section of the reaction $pp \to ppK^+K^-$ has been measured at excess energies $Q = 10$ MeV and 28 MeV with the magnetic spectrometer COSY-11. The new data show a significant enhancement of the total cross section compared to pure phase space expectations or calculations within a one boson exchange model. In addition, we present invariant mass spectra of two particle subsystems. While the K^+K^- system is rather constant for different invariant masses, there is an enhancement in the pK^- system towards lower masses which could at least be partially connected to the influence of the $\Lambda(1405)$ resonance.

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1. Introduction

The strength of the kaon–antikaon interaction appears to be very essential with respect to different physics topics. It is an important parameter in the ongoing discussion on the nature of the scalar resonances a_0 and f_0 in the mass range of $\sim$1 GeV/c^2. 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 $K\bar{K}$ production close to threshold [7].

Due to the unavailability of kaon targets for the analysis of $K\bar{K}$ scattering, the kaon pair production in multi particle exit channels like $pp \to ppK^+K^-$ is the only possibility to study this interaction by selecting the appropriate kinematic region of the phase space distribution. Besides the $K\bar{K}$ subsystem, 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]. Up to now the scattering length a_{K^-p} has been mainly determined on kaonic hydrogen. But the situation is not yet clarified since first, the results of former measurements [9–12] and preliminary results at DEAR [13,14] are in disagreement and second, it has been shown that

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contrary to pionic hydrogen, the isospin violating correction cannot be neglected in the kaonic case [15]. Due to these still open questions and the fact that the analysis of former KN data (cf. Fig. 22 in [12] and references therein) have a rather large variation, new low energy pK^- scattering data can provide an independent contribution to this important issue.

Furthermore, a precise knowledge of the $K^\pm$ cross sections and a good understanding of the kaon and antikaon interaction with the nucleon is an essential ingredient for calculations of medium effects [16] being related to open questions of astrophysics [17]. This is because in dense matter processes there are secondary production mechanisms on hyperons such as $\pi Y \to K^- N$ making it necessary to understand the production above threshold [18].

While the database on the elementary K^+ creation covers a wide energy range [19–24], low energy data on the K^- production are less available [25–27]. In the near-threshold regime, the excitation function might show a significant difference compared to the expectation of a pure phase space because final state interaction effects are predominant at low relative energies of the outgoing particles [28].

Due to the mentioned aspects together with the tendency becoming apparent that the available data seem to lie above theoretical expectations, we performed two new measurements of the total cross section of the reaction $pp \to ppK^+K^-$ at excess energies of $Q = 10$ MeV and 28 MeV [29] in order to further study this enhancement and its strength. In the next section, we describe the experimental technique followed by the presentation of the results.

2. Experiment

The measurements of the $pp \to ppK^+K^-$ reaction were performed with the internal experiment COSY-11 [30] at the COoler SYnchrotron COSY [31] in Jülich with beam momenta of $p = 3.333$ GeV/c and 3.390 GeV/c corresponding to excess energies of $Q = 10$ MeV and 28 MeV, respectively. Both energies are below the $\phi(1020)$ meson production threshold. The detector which is shown in Fig. 1 is designed as a magnetic spectrometer. Using a hydrogen cluster target [32] in front of one of the COSY dipole magnets, positively charged particles in the exit channel are bent more—compared to the remaining beam protons—towards the interior of the ring where they are detected in a set of three drift chambers [33]. Tracing back the reconstructed trajectories through the known magnetic field [34] to the interaction point allows for a momentum determination. In combination with a subsequent time of flight measurement over a distance of 9.4 m between two scintillation hodoscopes S1 and S3, these particles are identified via their invariant masses. Due to the decay of the kaon, the probability that it reaches the stop counter S3 is in the order of a few percent. Therefore, an indirect reconstruction of the time of flight is used. After the determination of the two protons' four-momenta in combination with the known length of their flight path from the target to the S1 detector, the time of the interaction is calculated. This time is then used as the start for the kaon's time of flight between the point of interaction and the crossing in the S1 scintillator in order to derive the four-momentum of the K^+.

Two additional detector components are mounted in front of the dipole magnet close to the target and inside the dipole gap both consisting of a scintillator and silicon pads. While the first is used to measure the coincident proton of the pp-elastic scattering, the array in the dipole gap serves to detect the K^-.

The analysis for the reaction $pp \to ppK^+K^-$ proceeds in several steps. First, events with less than three reconstructed tracks are rejected. For the remaining data, Fig. 2 shows the squared invariant masses for those two tracks that could be assigned to a hit in the S3 scintillator. A clear separable peak for two protons is visible. With the described indirect method for the time of flight, the four-momentum of the third positive par-

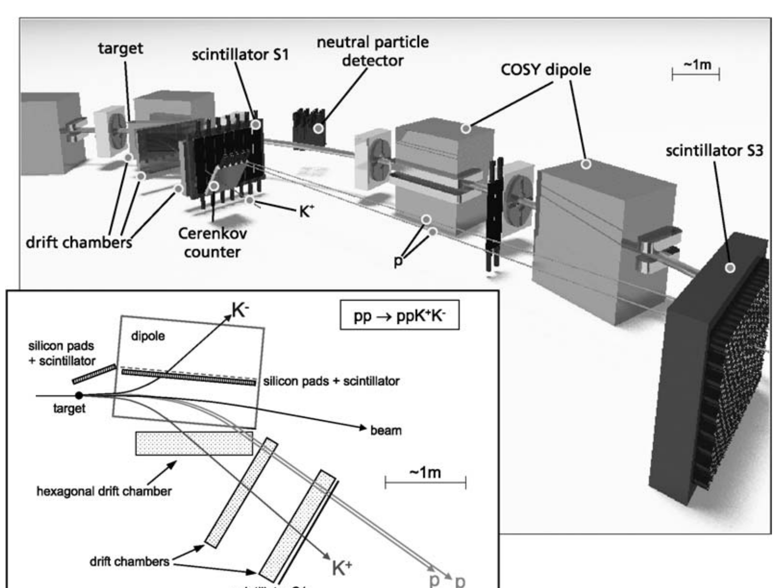

Fig. 1. The experiment COSY-11 with the main components. The overlayed box shows a schematic view for an exemplary event of the reaction channel $pp \to ppK^+K^-$. The sudden stop of the kaon track in the three-dimensional picture indicates its decay.