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SCALAR $K\bar{K}$ PRODUCTION CLOSE TO THRESHOLD AT ANKE *

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The production of $(K\bar{K})_{I=1}$ pairs has been investigated at ANKE (COSY-Jülich) in the reaction $pp \to dK^+\bar{K}^0$ at excitation energies Q of 47.4 and 104.7 MeV. Partial wave analyses of the invariant mass and angular spectra show the dominance of the a_0-channel ($[(K\bar{K})_s d]_p$ configuration).

In the non-isospin selective $pn \to dK^+K^-$ reaction the scalar $K\bar{K}$ production is strongly suppressed with respect to ϕ vector mesons.

A measurement of the isoscalar $K\bar{K}$ production in the isospin selective reaction $dd \to \alpha K^+K^-$ has been performed in April 2006.

Keywords: Scalar mesons; kaon production.

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1. Introduction

$K\bar{K}$ pair production is strongly connected with the problem of the light scalar resonances $a_0(980)$ and $f_0(980)$ ($J^P = 0^+$). Although these resonances have been oberved in Kp, $p\bar{p}$, πp and $\gamma\gamma$ interactions, their nature and fundamental properties, like widths and coupling to $K\bar{K}$, are poorly known.

The production of the $a_0/f_0(980)$ in pp, pn and dd interactions is under investigation at the ANKE spectrometer [1], where their strangeness decays into $K\bar{K}$ can be observed. The final goal of these studies, which will later be supplemented by measurements of the non-strange decays with the WASA detector [2], is to learn about the nature of these states, about isospin violating processes in the a_0/f_0 system and the FSI effects between kaons and light nuclei.

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2. The reaction $pp \to dK^+\bar{K}^0$ at Q = 47.4 and 104.7 MeV

The first two experiments on $a_0^+(980)$ production have been performed in pp collisions at $T_p = 2.65$ GeV (2001) [3] and $T_p = 2.83$ GeV (2002) [4]. Events of the type $pp \to dK^+X$ (where contributions of the $f_0(980)$ must be absent) have been measured at ANKE, identifying the $\bar{K}^0$ by a missing-mass analysis. Contributions from misidentified events, which are around 13%, have been subtracted in the differential spectra. In order to improve the invariant-mass and angular resolutions a kinematic fit has been applied to the data. As a result of the fit, the $K\bar{K}$ invariant-mass resolution is less than 3 MeV/c^2 in full range for Q = 47.4 MeV data and less then 10 MeV/c^2 for Q=104.7 MeV.

Scince the data have been obtained close to the threshold, we have restricted the data analysis to the lowest allowed partial waves, *i.e.* s-wave in the $K\bar{K}$ system accompanied by a p-wave of the deuteron with respect to the meson pair ($a_0^+(980)$-channel), and p-wave $K\bar{K}$ production with an s-wave deuteron (non-resonant channel). Under this assumption the square of the spin-averaged transition matrix element can be written as:

$$|\bar{\mathcal{M}}|^2 = C_0^q q^2 + C_0^k k^2 + C_1(\hat{\vec{p}}\cdot\vec{k})^2 + C_2(\hat{\vec{p}}\cdot\vec{q})^2 + C_3(\vec{k}\cdot\vec{q}) + C_4(\hat{\vec{p}}\cdot\vec{k})(\hat{\vec{p}}\cdot\vec{q})\ . \quad (1)$$

Here $\vec{k}$ is the deuteron momentum in the overall CMS, $\vec{q}$ denotes the K^+ momentum in the $K\bar{K}$ system, and $\hat{\vec{p}}$ is the unit vector of the beam momentum. Only $K\bar{K}$ p-waves contribute to C_0^q and C_2, only $K\bar{K}$ s-waves to C_0^k and C_1, and only s-p interference terms to C_3 and C_4. The coefficients C_i can be determined from the data by a simultaneous fit of Eq.(1) to the six measured differential distributions, which are not corrected to the ANKE acceptance (three of them are shown in Fig 1). The fit has been done using a large sample of simulated events, covering the full phase space, which are tracked through a GEANT model of ANKE.

The coefficients C_i define the initial differential distributions. These allow one to calculate the total acceptance and the total cross sections in the next step of the analysis . For the higher energy, a value of $\sigma(pp \to dK^+\bar{K}^0) = (190\pm4_{\rm stat}\pm39_{\rm syst})$ nb has been obtained [4].

Table 1. Results for C_i of the fit to the data using Eq.(1) with and without limitation for C_0^q.

Q, MeV	C_0^k	C_0^q	C_1	C_2	C_3	C_4	χ^2/ndf
47.4	1	$-0.34^{+0.26}_{-0.21}$	$-0.14^{+0.14}_{-0.13}$	$1.23^{+0.32}_{-0.32}$	$-0.44^{+0.16}_{-0.16}$	$-0.76^{+0.30}_{-0.33}$	1.38
	1	$0.0^{+0.11}$	$-0.13^{+0.14}_{-0.12}$	$0.80^{+0.16}_{-0.15}$	$-0.60^{+0.12}_{-0.11}$	$-0.61^{+0.28}_{-0.21}$	1.44
104.7	1	$-0.07^{+0.14}_{-0.24}$	$-0.22^{+0.12}_{-0.11}$	$1.04^{+0.36}_{-0.19}$	$-1.45^{+0.20}_{-0.12}$	$0.09^{+0.25}_{-0.55}$	1.10
	1	$0.0^{+0.11}$	$-0.22^{+0.11}_{-0.11}$	$0.96^{+0.14}_{-0.20}$	$-1.47^{+0.07}_{-0.11}$	$0.10^{+0.25}_{-0.22}$	1.12

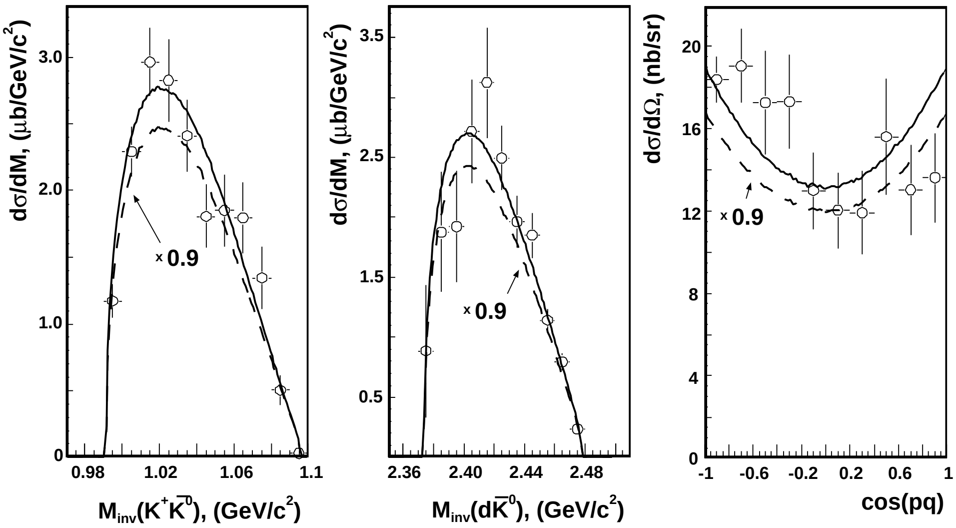

Fig. 1. Angular and invariant mass distributions for $Q = 104.7$ MeV. The solid line corresponds to the fit, in which all C_0^q are allowed. The dashed line corresponds to the fit with positive C_0^q; this distribution is scaled by the factor 0.9 for better readability.

3. Fit results for the coefficients C_i

Due to unitarity C_0^q and C_0^k must be positive. In all fits C_0^k has been fixed to 1.0 since the overall normalization of all coefficients is given by the total cross-sections. We have done two versions of fit for both Q values, first without restrictions on C_0^q and second with positive C_0^q only. The results of the fit are shown in Table 1. All fits show the dominance of the a_0-channel (around 90% of $[(K\bar{K})_s d]_p$ configuration). See Ref.[3] for details

In Fig.1 one can see that both sets of C_i coefficients reproduce the shapes for different initial invariant-mass and angular distributions.

4. Properties of the $a_0^+(980)$ meson

In principle, the contribution of the $a_0^+(980)$ resonance should be visible in the invariant mass distribution of the scalar $K\bar{K}$ channel.

Figure 2a shows the two-dimentional invariant-mass distribution for Q=104.7 MeV, corrected for the ANKE acceptance. The distribution is basically flat, without an indication of a resonant structure. The enhancement in the upper-right region is a consequence of a small number of events and the small acceptance, thus, these bins have a large statistical error.

In Fig.2b the $K\bar{K}$ invariant-mass distribution is shown for Q=104.7 MeV. A Flatte distribution (described in [5]) is added to the $a_0^+(980)$-channel ($[(K\bar{K})_s d]_p$ partial wave configuration). The mass of the $a_0(980)$ has been taken as 984.7 MeV. From this figure one can see that in order to discribe our experimental data, a

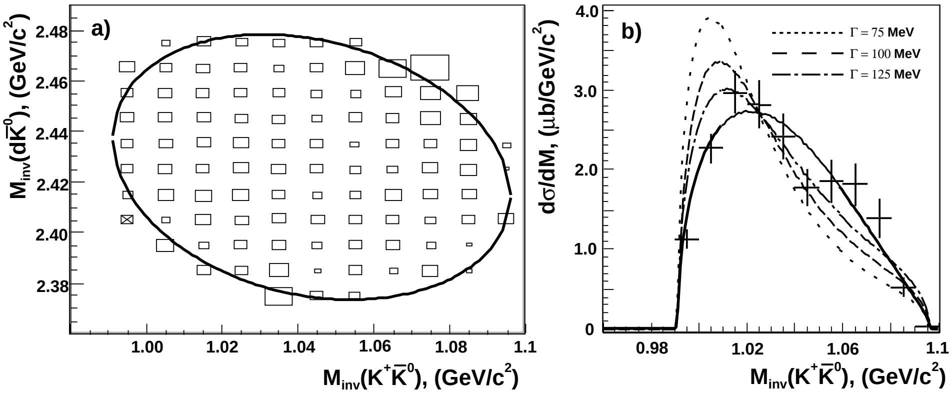

Fig. 2. a) 2-dimentional invariant-mass distribution for Q=104.7 MeV. The lines denote the kinematically allowed region. b) $K\bar{K}$ invariant-mass distribution for Q=104.7 MeV. Solid line corresponds to the fit result. Dotted, dashed and dash-dotted lines coresponds to the fit result plus Flatte distribution to the $[(K\bar{K})_s d]_p$ term with different widths of $a_0^+(980)$.

rather large width of $a_0(980)$ resonance is needed. One can conclude that either the $a_0^+(980)$ has a large width, or it has a very week coupling to the scalar $K\bar{K}$ channel, at least for the investigated reaction.

5. Outlook

The non-isospin selective $pn \to dK^+K^-$ reaction has been measured at the $T_p = 2.65$ GeV in February 2004. The data sindicates that the scalar $K\bar{K}$ production is significantly smaller respect to vector ϕ mesons[6] (see also the contribution of M.Hartmann). The features of a small enhancement at low K^+K^- masses are currently under study.

A measurement of the isoscalar $K\bar{K}$ production in the isospin selective reaction $dd \to \alpha K^+K^-$ has been performed in April 2006. According to a first rough analysis we expect less than a total of 30 $dd \to \alpha K^+K^-$ events in the data.

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