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STUDY OF THE K^+K^- INTERACTION AT COSY-11

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In this article we present studies of the near threshold $pp \to ppK^+K^-$ reaction in view of the K^+K^- final state interaction. The investigations include analysis of both the low-energy K^+K^- invariant mass distributions measured by COSY-11 collaboration at excess energies of Q = 10 MeV and Q = 28 MeV and the near threshold excitation function for the $pp \to ppK^+K^-$ reaction. As a result of these studies we have estimated the K^+K^- scattering length more precise compared to the previous analysis based only on the analysis of the differential cross sections.

Keywords: Final state interaction; near threshold kaon pair production; K^+K^- molecule.

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1. Introduction

Studies of the hadronic interaction of the K^+ and K^- mesons is of a great importance especially regarding the unknown nature of the $a_0(980)$ and $f_0(980)$ scalar resonances, which besides the standard interpretation as a quark-antiquark state[1] were also proposed to be a $K\bar{K}$ molecules.[2,3]

Due to lack of the kaonic targets we investigate experimentally the strength of the K^+K^- interaction for example in the near threshold $pp \to ppK^+K^-$ reaction where kaons are produced with low relative momenta.[4]

Measurements of the $pp \to ppK^+K^-$ reaction at the kinematical threshold have been made possible by beams of low emittance and small momentum spread available at storage ring facilities, in particular at the cooler synchrotron COSY at the research center in Jülich, Germany.[5] Early experiments at COSY conducted by means of the COSY-11 detector[6] revealed, however, that a possible influence from the f_0 or a_0 mesons on the K^+K^- pair production is too weak to be distinguished from the direct production of these mesons.[7] However, the combined systematic collection of data below[7–9] and above[10,11] the ϕ meson threshold reveal a significant signal in the shape of the excitation function which may be due to the K^-p and perhaps also to the K^+K^- interaction.

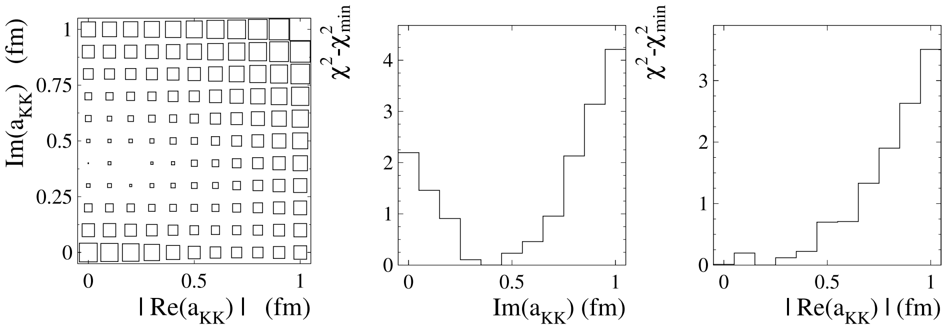

Fig. 1. χ^2 - χ^2_{min} distribution as a function of $|Re(a_{K^+K^-})|$ and $Im(a_{K^+K^-})$. χ^2_{min} denotes the absolute minimum with respect to parameters α, $|Re(a_{K^+K^-})|$, and $Im(a_{K^+K^-})$.

2. Study of the dynamics in the low energy ppK^+K^- system

The measurements of the $pp \to ppK^+K^-$ reaction were conducted at low excess energies by the collaborations ANKE,[10] COSY-11[7–9] and DISTO,[11] and revealed a significant discrepancy between obtained excitation function and theoretical expectations neglecting interaction of kaons in the final state. The inclusion of the pK^-–FSI, based on factorization ansatz introduced by the ANKE collaboration, reproduces the experimental data for excess energies down to Q = 28 MeV, but underestimates the data very close to threshold.[10,12] This indicates that in this energy region the influence of the K^+K^- interaction may be significant. Therefore, we have performed a more detailed analysis of the COSY-11 data at excess energies of Q = 10 MeV and 28 MeV including studies of the differential cross section distributions.[13] Based on the mentioned factorization ansatz with additional term describing interaction in the K^+K^- system we compared the experimental event distributions to the results of Monte Carlo simulations treating the K^+K^- scattering length as an unknown parameter, which has to be determined. Finally, based for the first time on the low energy K^+K^- invariant mass distributions and the generalized Dalitz plot analysis, we have estimated the K^+K^- scattering length.[13] Due to the low statistics the uncertainties of the determined scattering length are rather large, therefore we decided to combine Goldhaber Plot analysis of COSY-11 data with fitting to the experimental excitation function near threshold. We have constructed the χ^2 statistic:

$$\chi^2\left(a_{K^+K^-},\alpha\right) = 2\cdot\sum_i\left[\alpha N_i^s - N_i^e + N_i^e\ln\left(\frac{N_i^e}{\alpha N_i^s}\right)\right] + \sum_j\frac{\left(\sigma_j^{exp}-\alpha\sigma_j^{mod}\right)^2}{\left(\Delta\sigma_j^{exp}\right)^2}\ , \quad (1)$$

where N_i^e denotes the number of events in the ith bin of the experimental Goldhaber plot, N_i^s stands for the content of the same bin in the simulated distributions, σ_j^{mod} denotes the jth calculated total cross section, σ_j^{exp} is the jth experimental total cross section measured with uncertainty $\Delta\sigma_j^{exp}$, and α stands for the normalization factor. The obtained preliminary χ^2 distributions (suppressed by its minimum value) as a function of the real and imaginary part of the K^+K^- scattering length are presented in Fig. 1. The best fit to the experimental data corresponds to $|Re(a_{K^+K^-})| = 0.2\ ^{+0.8}_{-0.2}$ fm and $Im(a_{K^+K^-}) = 0.4\ ^{+0.6}_{-0.4}$ fm. This preliminary result is by a factor of five more precise than the previous one based only on the analysis of the differential cross section distributions.[13]

3. Conclusions

The analysis of the $pp \to ppK^+K^-$ reaction measured by COSY-11 collaboration at excess energy Q = 10 MeV and Q = 28 MeV has been extended to the determination of the differential cross sections in view of the K^+K^- final state interaction. To reduce the uncertainties on the K^+K^- scattering length we have performed combined analysis of both total and differential cross section distributions for the $pp \to ppK^+K^-$ reaction. The preliminary result of the analysis is by a factor of five more precise, however the determined scattering length is still consistent with zero within one standard deviation.

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