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PHOTOPRODUCTION OF $\pi\pi$ AND $K\overline{K}$ PAIRS*

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S-wave photoproduction of $\pi^+\pi^-$ and K^+K^- pairs on hydrogen is studied. Coupled channel final state interactions between different pseudoscalar mesons are included. Effective mass and momentum transfer distributions as well as total cross sections are calculated. Effective mass distributions in the Born approximation are structureless but the final state interactions produce peaks and dips near the energies corresponding to the scalar resonances $f_0(980)$ and $f_0(1400)$. Calculations are performed in the effective mass region between the $\pi\pi$ threshold and 1.6 GeV in the range of the momentum transfer squared up to 2 (GeV/c)^2. The photon energy dependence of the total cross sections is studied between 2 and 15 GeV. Valuable information on the $f_0(980)$ resonance structure can be extracted from data. These calculations are closely related to the experimental program of the CEBAF accelerator in USA.

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Properties of scalar mesons can be studied in photoproduction and electroproduction processes. Asymmetry in the K^+K^- angular distribution near threshold was previously measured at Daresbury [1] and Hamburg [2] and interpreted as an interference of the dominant P-wave from the decay of the $\phi(1020)$ meson and an S-wave from the decay of the $f_0(980)$ resonance. The existing data are imprecise and even controversial. This situation may be improved in near future when a new program of the $f_0(980)$ electroproduction experiments on the CEBAF accelerator at the Thomas Jefferson National Accelerator Facility (TJNAF) is realized. Therefore we have performed a coupled channel analysis of the S-wave $\pi^+\pi^-$ and K^+K^- photoproduction on hydrogen [3].

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We expect that at high photon energies ($E_\gamma \geq 4$ GeV) mostly the t-channel ρ and ω exchanges become important in the peripheral $\pi^+\pi^-$ and K^+K^- production. Five Feynman diagrams are considered to calculate the Born amplitude for the $\pi^+\pi^-$ production, three of them correspond to $\pi^\pm$ and ρ^0 exchange and two to $\rho^\pm$ and ω exchange. For the six diagrams of K^+K^- production, three of them correspond to $K^\pm$ and ρ^0 exchange and three to $K^\pm$ and ω exchange. We require 8 hadronic ($g_{\rho\pi\pi}$, $g_{\rho KK}$, $g_{\omega KK}$, $g_{\omega\rho\pi}$, G_V^ρ, G_T^ρ, G_V^ω, G_T^ω) and 2 electromagnetic ($g_{\rho\pi\gamma}$, $g_{\omega\pi\gamma}$) vector meson coupling constants. From the $\rho \to \pi\pi$ decay width, we find the coupling constant $g_{\rho\pi\pi} = 6.05$. We use the SU(3) relations $g_{\rho K\bar{K}} = g_{\omega K\bar{K}} = \frac{1}{2} g_{\rho\pi\pi}$ to fix the kaon couplings and $g_{\omega\rho\pi} = 14.0$ GeV^{-1}, close to the value reported in Ref. [5]. For the ρ meson vector and tensor couplings to nucleon, the values corresponding to the Bonn potential ($G_V^\rho = 2.27$, $G_T^\rho = 13.85$,$G_T^\omega = 0$ and $G_V^\omega = 11.54$) are applied [4]. Finally, we fit the radiative decay constants of the ρ and ω to the $\Gamma_{\rho\to\pi\gamma}$ and $\Gamma_{\omega\to\pi\gamma}$ decay widths yielding $g_{\rho\pi\gamma} = 0.75e/m_\rho$ and $g_{\omega\pi\gamma} = 1.82e/m_\omega$ with $e = 0.30282$.

The full photoproduction amplitude including final state interactions (FSI) can be written in the operator form as

$$\hat{T} = \hat{V} + \hat{t}\,\hat{G}\,\hat{V}\,, \tag{1}$$

where $\hat{V}$ is the photoproduction potential, $\hat{t}$ is the strong FSI matrix, and $\hat{G}$ is the propagator of the intermediate state. The matrix elements of $\hat{V}$ are obtained through an off-shell extension of the Born amplitudes.

As shown in references [6,7], several intermediate channels can contribute to the production of a given final meson pair. Thus, the final state interaction leads to a coupled channel problem for $\hat{T}$ in Eq. (1). The isospin decomposition of each final state requires the inclusion of other possible meson pairs such as $\pi^0\pi^0$ and $K^0\bar{K}^0$ and thus one has to consider all four channels ($\pi^0\pi^0$, $\pi^+\pi^-$, K^+K^- and $K^0\bar{K}^0$) as the intermediate states. Explicit expressions for the $I=0$ matrix elements can be found in the Appendix A of Ref. [6]. Parameterization of the $I=2$ elastic $\pi\pi$ amplitude is given in Ref. [8]. For the $I=0$ $\pi^+\pi^-$ amplitude we use parameters obtained in a recent analysis of the $\pi^- p_\uparrow \to \pi^+\pi^- n$ reaction on polarized target [9]. They correspond to the two–channel fit to the so–called “down–flat” $\pi^+\pi^-$ phase shift solution of Ref. [8].

In Fig. 1 we show the S-wave $\pi^+\pi^-$ invariant mass distribution at $E_\gamma^{\rm lab} = 4.0$ GeV and $t = -0.2$ GeV^2. The Born effective mass distributions are structureless while the final state interactions produce dips and peaks near the resonances. In particular near 1 GeV we can notice a very clear maximum corresponding to the $f_0(980)$ resonance. This signal should be experimentally measurable in the photoproduction process at the

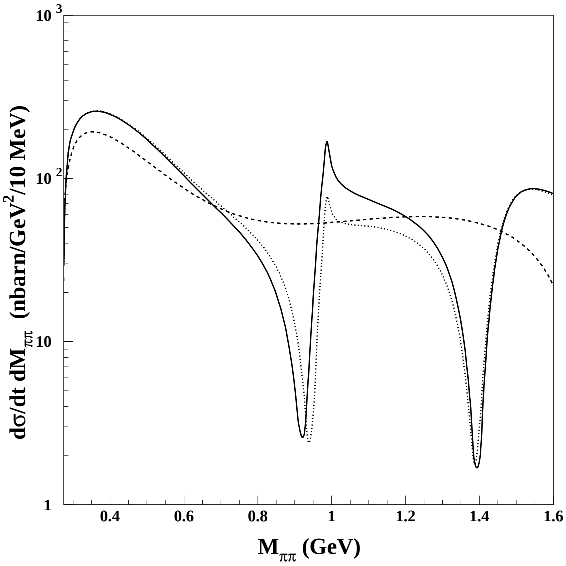

Fig. 1. S-wave $\pi^+\pi^-$ invariant mass distribution. The solid line shows the full FSI result (on–shell and off–shell) with both $\pi\pi$ and $K\bar{K}$ intermediate channels, the dotted line represents the result with no $K\bar{K}$ coupling and the dashed line corresponds to the Born cross section.

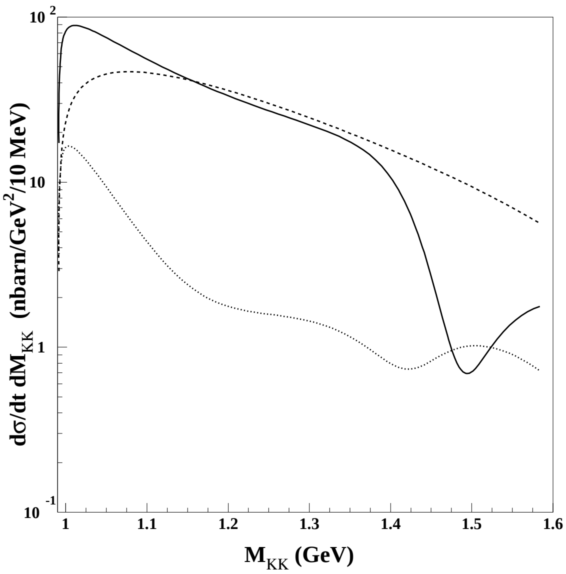

Fig. 2. S-wave K^+K^- invariant mass distribution. The dotted line represents the result with no $\pi\pi$ coupling, for description of other lines see Fig. 1.

photon energies of a few GeV. In Fig. 2 we show the corresponding K^+K^- invariant mass distribution.

We see that the coupled channel FSI give a substantial enhancement relative to the Born cross section just above the $K\bar{K}$ threshold that is absent in the result for the single channel FSI. This enhancement of the cross section in two kaon and two pion photoproduction at the $f_0(980)$ resonance makes direct measurements of f_0 properties an interesting possibility at TJNAF. The differential cross section for the S-wave two kaon or two pion photoproduction has a dip at t-values close to 0 (forward production) and then rises reaching a maximum at higher values of t. Calculations performed with Regge ρ and ω propagators show a characteristic minimum at $t \approx -0.5$ GeV^2 related to the zeroes of the Regge trajectories. In order to see the interference effect between S and P wave contributions, one should not limit the range of $|t|$ below 0.2 GeV^2 as in Ref. [2] but go up to higher values such as 1.5 GeV^2 in [1].

Our predictions of the total cross sections indicate that the $\pi^+\pi^-$ and K^+K^- photoproduction processes are experimentally measurable in the photon energy range of a few GeV. The S-wave K^+K^- cross section near 1 GeV is, however, lower than the Φ production cross section. Nevertheless, by a careful experimental study in small bins of $\pi\pi$ and $K\bar{K}$ masses, one can obtain valuable information on the positions and widths of scalar resonances, especially the $f_0(980)$ meson. Additionally, the accurate measurements of the neutral pion pairs $\pi^0\pi^0$ and $K^0\bar{K}^0$ photoproduction will be crucial to separate the different isospin contributions of $I = 0, 1$ and 2 states.

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