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Radiative widths of neutral kaon excitations

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Abstract. We observe 147 events of the axial vector pair $K_1(1270)$–$K_1(1400)$ produced in the Coulomb field of a Pb target and measure the radiative widths $\Gamma(K_1(1400) \rightarrow K^0 + \gamma) = 280.8 \pm 23.2(\text{stat.}) \pm 40.4(\text{syst.})$ keV and $\Gamma(K_1(1270) \rightarrow K^0 + \gamma) = 73.2 \pm 6.1(\text{stat.}) \pm 28.3(\text{syst.})$ keV. These first measurements are lower than the quark-model predictions. We also place upper limits on the radiative widths for $K^*(1410)$ and $K_2^*(1430)$ and find that the latter is very small in accord with $SU(3)$ invariance in the naive quark model.

Keywords. Radiative width; kaon; Primakoff.

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The rates of radiative transitions between mesons are sensitive to the magnetic moments of the constituent quarks [1]. The radiative decay widths of mesonic excitations, $\Gamma_{\rm r}(M^*) = \Gamma(M^* \rightarrow M + \gamma)$, have been calculated using both a dynamic quark model [2] and a relativistic quark model [3,4]. Only $\Gamma_{\rm r}(K^*(892))$ has been measured so far [5].

Since the radiative decay widths of strange mesons are much smaller than the total widths, direct observation of decays such as $K^* \rightarrow K + \gamma$ is difficult. However, the inverse reaction $K + \gamma \rightarrow K^*$ is experimentally accessible as a subreaction of the process K_L + nucleus $\rightarrow K^*$ + Nucleus, and can be used to measure the radiative width. This Coulomb process is also known as Primakoff production [6].

We observe 147 events of the mixed axial vector pair $K_1(1270)$–$K_1(1400)$ with decay sequence [5] $K_1(1270/1400) \rightarrow K^*(892)\pi^0 \rightarrow [K_S\pi^0]\pi^0 \rightarrow [(\pi^+\pi^-)(\gamma\gamma)](\gamma\gamma)$ (i.e., the $K^*(892)\pi^0$ channel). With this sample, we measure the radiative widths $\Gamma_r(K_1(1400))$ and $\Gamma_r(K_1(1270))$ for the first time. We also place upper limits on the radiative widths for the vector $K^*(1410)$ and the tensor $K_2^*(1430)$: $K^*(1410)/K_2^*(1430) \rightarrow K_S\pi^0 \rightarrow (\pi^+\pi^-)(\gamma\gamma)$ (i.e., the $K_S\pi^0$ channel).

KTeV detected $\pi^+\pi^-$ tracks from K_S decays and photons from π^0 decays. We isolate forward production by requiring a small transverse momentum (p_t^2) for $\pi^+\pi^-\gamma\gamma$. The resulting sample of 29,399 $K^*(892) \rightarrow K_S\pi^0$ decays is used for normalization. In the $K^*(892)\pi^0$ channel, the $K_S\pi^0$ mass for the daughter $K^*(892)$ is required to be consistent with the $K^*(892)$ mass. The resulting 147-event sample of $(K_S\pi^0)\pi^0$ decays (figure 1) shows the resonant signature and also confirms the forward Primakoff production.

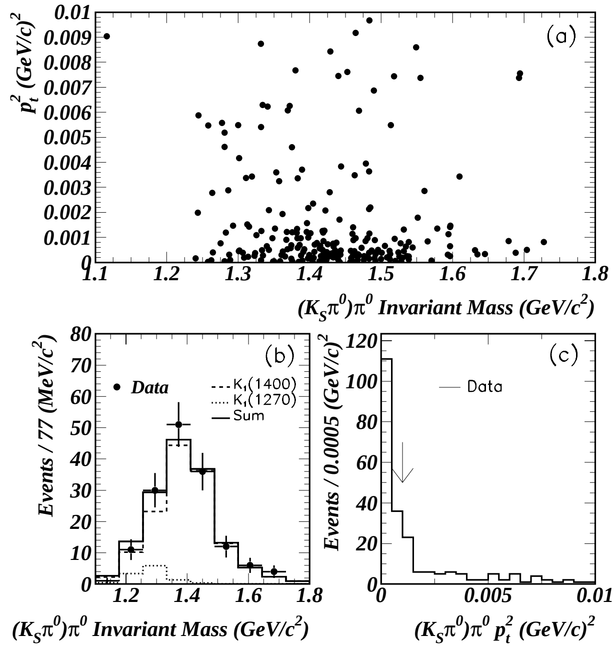

Figure 1. (**a**) $(K^*(892)\pi^0)p_t^2$ vs. invariant mass after all other cuts. (**b**) Mass projection with decomposition into $K_1(1270)$ and $K_1(1400)$. (**c**) p_t^2 projection shows the forward Primakoff production.

Of the six possible candidates for the observed sample, $K_0^*(1430)$ and $K(1460)$ are ruled out because of spin-parity and the $J = 0 \not\to J = 0$ rule, respectively. $K^*(1410)$ and $K_2^*(1430)$ are eliminated because they are absent in the $K_S\pi^0$ channel. Thus, the observed signal is due to the axial vector pair $K_1(1270)$–$K_1(1400)$, which is a mixture of the singlet $^1P_1$ and the triplet $^3P_1$ states. Since the Coulomb field excites only the singlet component and the mixing angle has been measured, we resolve the observed signal into 11.4 ± 1.0(stat.) $\pm$ 4.1(ext syst.) $K_1(1270)$ events and 134.4 ± 11.1(stat.)∓ 4.1(ext syst.) $K_1(1400)$ events. This decomposition is also depicted in figure 1.

Using the $K^*(892)$ sample for normalization, we obtain $\Gamma_r(K_1(1270)) = 73.2 \pm 6.1$(stat.) $\pm$ 8.2(int syst.) $\pm$ 27.0(ext syst.) keV and $\Gamma_r(K_1(1400)) = 280.8 \pm 23.2$(stat.)$\pm 31.4$(int syst.)$\pm 25.4$(ext syst.) keV. The quoted systematic errors and backgrounds are discussed in [7]. The predicted radiative widths for the axial vector mesons [8], are 538 keV for $K_1(1400)$ and 175 keV for $K_1(1270)$. While our measured values appear to be on the smaller side, note that the predictions [8] are given without uncertainties.

Next, using the absence of a resonance in the $K_S\pi^0$ channel near 1.4 GeV/c^2, we limit the radiative widths $\Gamma_r(K^*(1410))$ and $\Gamma_r(K_2^*(1430))$ to 52.9 and 5.4 keV, respectively, at 90% CL. While there is no prediction for $\Gamma_r(K^*(1410))$, Babcock and Rosner [9] used $SU(3)$ invariance to predict that excitations with $J^{\mathrm{PC}} = 1^{++}$ or 2^{++} would have vanishing radiative widths. In the limit of $SU(3)$, $K_2^*(1430)$ has $C = +1$; thus, our stringent limit of 5.4 keV confirms this prediction.

In conclusion, we have used the Primakoff effect to measure the radiative widths for the mixed axial vector pair $K_1(1270)$–$K_1(1400)$ and placed an upper limit on the radiative width for $K^*(1410)$. These radiative widths have been studied for the first time. Our finding that the radiative width for $K_2^*(1430)$ is vanishingly small probes the naive quark model and $SU(3)$-breaking.

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