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 $\Gamma(K_1(1400) \to K^0 + \gamma) = 280.8 \pm 23.2 \text{ (stat.)} \pm 40.4 \text{ (syst.)} \text{ keV}$ and $\Gamma(K_1(1270) \to K^0 + \gamma) = 73.2 \pm 6.1 \text{ (stat.)} \pm 28.3 \text{ (syst.)} \text{ keV}$. 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, $\Gamma_r(M^* = M + \gamma)$, have been calculated using both a dynamic quark model [2] and a relativistic quark model [3,4]. Only $\Gamma_r(K^*(892))$ 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 $K^* \to K + \gamma$ is difficult. However, the inverse reaction $K + \gamma \to K^*$ is experimentally accessible as a subtraction of the process $K_L + \text{nucleus} \to K^* + \text{Nucleus}$, 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] $K_1(1270/1400) \to K^*(892), \pi^0 \to K_S\pi^0, \pi^0 \to (\pi^+ \pi^-)(\gamma)(\gamma)$ (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 $K^*_2(1430)$:

$K^*(1410)/K^*_2(1430) \to K_S\pi^0 \to (\pi^+ \pi^-)(\gamma)$ (i.e., the $K_S\pi^0$ channel).

KTeV detected $\pi^+ \pi^-$ tracks from $K_2$ decays and photons from $\pi^0$ decays. We isolate forward production by requiring a small transverse momentum ($p_T^2$) for $\pi^+ \pi^- \gamma$. The resulting sample of 29,399 $K^*(892) \to K_S\pi^0$ 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.
Of the six possible candidates for the observed sample, $K^+_S(1430)$ and $K(1460)$ are ruled out because of spin-parity and the $J = 0 \neq J = 0$ rule, respectively. $K^*(1410)$ and $K^*_2(1430)$ are eliminated because they are absent in the $K_S^0\pi^0$ 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 $11.4 \pm 1.0 \text{(stat.)} \pm 4.1 \text{(ext syst.)}$ $K_1(1270)$ events and $134.4 \pm 11.1 \text{(stat.)} \pm 4.1 \text{(ext syst.)}$ $K_1(1400)$ events. This decomposition is also depicted in figure 1.

Using the $K^*(802)$ sample for normalization, we obtain $\Gamma_1(K_1(1270)) = 73.2 \pm 6.1 \text{(stat.)} \pm 8.2 \text{(int syst.)} \pm 27.0 \text{(ext syst.)}$ keV and $\Gamma_1(K_1(1400)) = 280.8 \pm 23.2 \text{(stat.)} \pm 31.4 \text{(int syst.)} \pm 25.4 \text{(ext syst.)}$ 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 $K_S^0\pi^0$ channel near 1.4 GeV/c$^2$, we limit the radiative widths $\Gamma_5(K^*(1410))$ and $\Gamma_5(K^*_2(1430))$ to 52.9 and 5.4 keV, respectively, at 90% CL. While there is no prediction for $\Gamma_5(K^*(1410))$, Babcock and Roener [9] used $SU(3)$ invariance to predict that excitations with $J^{PC} = 1^{++}$ 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.

Figure 1. (a) $(K^*(892)\pi^0)\mathbf{p}_t^2$ 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.

Sunil V Somalwar

Radiative widths of neutral kaon excitations

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.

References