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Scalar f_0 and a_0 mesons in radiative $\phi \to K^+K^-\gamma$ decay

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ABSTRACT

We study the radiative $\phi \to K^+K^-\gamma$ decay within a phenomenological framework by considering the contributions of the $f_0(980)$ and $a_0(980)$ scalar resonances. We consider the kaon-loop model and the no-structure model to evaluate these contributions and compare the results obtained in two models.

1. Introduction

The low-mass scalar mesons are of fundamental importance in hadron physics. On the one hand, they have an essential role in understanding the theory and the phenomenology of low energy QCD. On the other hand, these scalar mesons play an important role in the mechanisms of different reactions in hadron physics, in particular in hadron electrodynamics. One such category of reactions are the radiative decay processes of vector mesons into a pair of pseudoscalar mesons and a photon.

It has been argued that the experimental and theoretical studies of the radiative decays $\phi \to f_0\gamma \to \pi\pi\gamma$ and $\phi \to a_0\gamma \to \pi\eta\gamma$ can help to clarify the controversial subject of the nature and the quark substructure of $f_0(980)$ and $a_0(980)$ scalar mesons in hadron spectroscopy [1]. It has first suggested by Achasov et al. [2] that the mechanism of the scalar meson production in the radiative decays $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$ are the one-loop, or the charged kaon-loop, mechanism where the scalar mesons couple to the initial ϕ meson through a kaon-loop which can be symbolized as $\phi \to K^+K^- \to f_0\gamma$ and $\phi \to K^+K^- \to a_0\gamma$. Since the vector meson dominance mechanism also makes a contribution to the amplitudes of the reactions $\phi \to \pi\pi\gamma$ and $\phi \to \pi\eta\gamma$ [3], the experimental data of these radiative reactions have been studied using the $\phi \to (f_0\gamma + \pi\rho) \to \pi\pi\gamma$ and $\phi \to (a_0\gamma + \pi\rho) \to \pi\eta\gamma$ models for the reaction mechanisms. The confrontation of the theoretical analysis with the experimental data for the radiative decays $\phi \to \pi\pi\gamma$ and $\phi \to \pi\eta\gamma$ along with the decays $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$ have been used to provide evidence for the structure of the scalar f_0 and a_0 mesons [4]. Although not generally accepted yet, these analysis seem strongly to suggest the $q^2\bar{q}^2$ structure for scalar mesons [5]. Moreover, Achasov et al. [5] have shown that the processes $\phi \to \pi\rho \to \pi\pi\gamma$ and $\phi \to \pi\rho \to \pi\eta\gamma$ have negligible influence on the analysis of the reactions $\phi \to \pi\pi\gamma$ and $\phi \to \pi\eta\gamma$ both through their direct contributions and through their interference with the $\phi \to f_0\gamma \to \pi\pi\gamma$ and $\phi \to a_0\gamma \to \pi\eta\gamma$ amplitudes where scalar mesons are coupled to the initial ϕ meson by the charged kaon-loop, respectively, over a wide range of photon energy region. It should be mentioned that the sign of the interference in these analysis are determined by fitting the experimental data using the values of the coupling constants suggested by the $q^2\bar{q}^2$ model.

The study of the rare radiative decay $\phi \to K^+K^-\gamma$ can provide further evidence to elucidate the role of scalar mesons in the mechanisms of the radiative decays of vector mesons [6]. The amplitude of this radiative decay has contributions coming from two mechanisms. The first one is the internal bremsstrahlung where one of the charged kaons from the decay $\phi \to K^+K^-$ emits a photon, and the second one is the structural radiation which involves the scalar mesons f_0 and a_0 in the intermediate state as $\phi \to (f_0\gamma + a_0\gamma) \to K^+K^-\gamma$. The bremsstrahlung amplitude is well described by quantum electrodynamics, and the relative sign between this amplitude and the $\phi \to (f_0\gamma + a_0\gamma) \to K^+K^-\gamma$ amplitude in the charged kaon-loop model for the mechanism of the intermediate state scalar meson contribution is fixed, therefore the kaon-loop model predicts a definite interference between these two amplitudes for the radiative $\phi \to K^+K^-\gamma$ decay. However, there is a recently proposed no-structure formulation [7] where the coupling describing the $\phi f_0\gamma$ and $\phi a_0\gamma$ vertices is point like. This no-structure, or the point-coupling, model has been intro-

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duced to study the basic Φ-meson factory observables, such as $e^+e^- \to PP'\gamma$ cross sections where P, P' denote pseudoscalar mesons, because a possibly model-independent description of all the components of these reactions are very valuable in order to obtain information about the low-mass scalar mesons.

In this work, we attempt to study the radiative $\phi \to K^+K^-\gamma$ decay using both the kaon-loop model, and the point-coupling or the no-structure model for the coupling of the scalar f_0 and a_0 mesons in the intermediate state to the initial vector ϕ meson. We calculate the photon spectra, the kaon energy spectra, and the resulting branching ratios in both approaches, and compare the results.

2. Formalism

The invariant amplitude $\mathcal{M}$ representing the radiative $\phi(p) \to K^+(q_1) + K^-(q_2) + \gamma(k)$ decay, where we indicate the four-momenta of the particles, can be taken to be a function of K^+ meson energy E_1 and the photon energy E_γ in the rest frame of the decaying ϕ meson. The invariant amplitude $\mathcal{M}(E_1, E_\gamma)$ will be calculated using two approaches utilizing the kaon-loop model (KL) and the no-structure model (NS) for the contributions of the scalar mesons.

In terms of the invariant amplitude $\mathcal{M}(E_1, E_\gamma)$ the differential decay probability for an unpolarized ϕ meson at rest is given by

$$\frac{d\Gamma}{dE_\gamma\, dE_1} = \frac{1}{(2\pi)^3}\frac{1}{8M_\phi}|\mathcal{M}|^2, \tag{1}$$

where we perform an average over the spin states of ϕ meson and a sum over the polarization states of the photon. The decay width $\Gamma(\phi \to K^+K^-\gamma)$ is obtained by integration

$$\Gamma = \int_{E_{\gamma,\min}}^{E_{\gamma,\max}} dE_\gamma \int_{E_{1,\min}}^{E_{1,\max}} dE_1 \frac{d\Gamma}{dE_\gamma\, dE_1}. \tag{2}$$

The maximum photon energy $E_{\gamma,\max}$ is given as $E_{\gamma,\max} = (M_\phi^2 - 4M_K^2)/2M_\phi$ which is equal to $E_{\gamma,\max} = 31.5$ MeV. The minimum photon energy is kinematically equal to zero, however in our calculation we consider the experimentally detected minimum photon energy which we use as $E_{\gamma,\min} = 5$ MeV and 10 MeV. The maximum and minimum values for K^+ meson energy E_1 are given by

$$E_{1\,\max,1\,\min} = \frac{1}{2(2E_\gamma M_\phi - M_\phi^2)}\Big\{-2E_\gamma^2 M_\phi + 3E_\gamma M_\phi^2 - M_\phi^3 \pm E_\gamma\sqrt{\big(-2E_\gamma M_\phi + M_\phi^2\big)\big(-2E_\gamma M_\phi + M_\phi^2 - 4M_K^2\big)}\Big\}.$$

The invariant amplitude $\mathcal{M}(E_1, E_\gamma)$ can be obtained from the Feynman diagrams describing the mechanism of the $\phi \to K^+K^-\gamma$ decay in the particular (KL) or (NS) approach. The intermediate scalar meson states in these diagrams are represented by the scalar meson propagator $D(q) = i/(q^2 - M_S^2 + i\epsilon)$ in the corresponding amplitude. Since the scalar mesons f_0 and a_0 are unstable with a finite lifetime and they are broad, we use the Breit–Wigner prescription in the propagators of these resonances. In the scalar meson propagators we make the replacement $q^2 - M_S^2 \to q^2 - M_S^2 + i\sqrt{q^2}\Gamma_S(q^2)$ where the energy dependent widths for these scalar resonances are given as

$$\begin{aligned}\Gamma_{f_0}(q^2) &= \frac{g^2_{f_0K^+K^-}}{16\pi\sqrt{q^2}}\sqrt{1-\frac{4M^2_{K^+}}{q^2}}\,\theta\big(\sqrt{q^2}-2M_{K^+}\big) + \frac{g^2_{f_0K^0\bar{K}^0}}{16\pi\sqrt{q^2}}\sqrt{1-\frac{4M^2_{K^0}}{q^2}}\,\theta\big(\sqrt{q^2}-2M_{K^0}\big)\\ &\quad + \frac{2}{3}\Gamma_{f_0}\frac{M_{f_0}}{\sqrt{q^2}}\frac{\sqrt{1-\frac{4M^2_{\pi^0}}{q^2}}}{\sqrt{1-\frac{4M^2_{\pi^0}}{M^2_{f_0}}}}\theta\big(\sqrt{q^2}-2M_{\pi^0}\big),\end{aligned} \tag{3}$$

$$\begin{aligned}\Gamma_{a_0}(q^2) &= \frac{g^2_{a_0K^+K^-}}{16\pi\sqrt{q^2}}\sqrt{1-\frac{4M^2_{K^+}}{q^2}}\,\theta\big(\sqrt{q^2}-2M_{K^+}\big) + \frac{g^2_{a_0K^0\bar{K}^0}}{16\pi\sqrt{q^2}}\sqrt{1-\frac{4M^2_{K^0}}{q^2}}\,\theta\big(\sqrt{q^2}-2M_{K^0}\big)\\ &\quad + \Gamma_{a_0}\frac{M_{a_0}}{\sqrt{q^2}}\frac{\sqrt{[1-\frac{(M_{\pi^0}+M_\eta)^2}{q^2}][1-\frac{(M_{\pi^0}-M_\eta)^2}{q^2}]}}{\sqrt{[1-\frac{(M_{\pi^0}+M_\eta)^2}{M^2_{a_0}}][1-\frac{(M_{\pi^0}-M_\eta)^2}{M^2_{a_0}}]}}\\ &\quad \times\theta\big(\sqrt{q^2}-(M_{\pi^0}+M_\eta)\big),\end{aligned} \tag{4}$$

and we use the experimental values for the widths Γ_{f_0} and Γ_{a_0} of the scalar resonances in the above expressions [8].

In the kaon-loop model, the processes contributing to the $\phi \to K^+K^-\gamma$ amplitude are represented diagrammatically in Fig. 1. The Feynman diagrams shown in Fig. 1(a), (b), (c) correspond to the internal bremsstrahlung amplitude $\mathcal{M}_B$ where the diagram in Fig. 1(c) is added to establish gauge invariance. The contribution $\mathcal{M}_{\rm KL}$ coming from the scalar mesons taken into account through the coupling of the scalar mesons to ϕ meson by a charged kaon-loop is obtained from the Feynman diagrams shown in Fig. 1(d), (e), (f) where the last diagram results from the minimal coupling for gauge invariance. Therefore, in the kaon-loop model the amplitude $\mathcal{M}(\phi \to K^+K^-\gamma)$ can be written as $\mathcal{M} = \mathcal{M}_B + \mathcal{M}_{\rm KL}$ where the relative sign between $\mathcal{M}_B$ and $\mathcal{M}_{\rm KL}$ is fixed.

The amplitude $\mathcal{M}_B$ can be calculated using quantum electrodynamics. In the evaluation of the amplitude $\mathcal{M}_{\rm KL}$ we describe the ϕK^+K^- vertex phenomenologically by the effective Lagrangian

$$\mathcal{L}_{\phi K^+K^-} = -ig_{\phi K^+K^-}\phi^\mu\big(K^+\partial_\mu K^- - K^-\partial_\mu K^+\big). \tag{5}$$

We then use the experimental value for the branching ratio $B(\phi \to K^+K^-)$ [8] to determine the coupling constant $g_{\phi K^+K^-}$ as $g_{\phi K^+K^-} = 4.47$. Similarly, we describe the SK^+K^- vertex where $S = f_0$ or a_0 by the phenomenological Lagrangian

$$\mathcal{L}_{SK^+K^-} = -g_{SK^+K^-}K^+K^-S. \tag{6}$$

We therefore obtain the amplitude $\mathcal{M}_{\rm KL}$ coming from the contribution of scalar mesons in the kaon-loop model to the decay $\phi \to K^+K^-\gamma$ as

$$\begin{aligned}&\mathcal{M}_{\rm KL}\big(\phi \to K^+K^-\gamma\big)\\ &\quad = -\frac{eg_{\phi K^+K^-}}{i2\pi^2M^2_{K^+}}\big[(p\cdot k)(\epsilon\cdot u) - (p\cdot\epsilon)(k\cdot u)\big]\\ &\qquad \times\mathcal{I}(a,b)\mathcal{M}\big(K^+K^- \to K^+K^-\big)\end{aligned} \tag{7}$$

where (u, p) and (ϵ, k) are the polarization vector and four momenta of the ϕ meson and the photon, respectively. The invariant loop function $\mathcal{I}(a, b)$ has been calculated [9] in the form

$$\mathcal{I}(a,b) = \frac{1}{2(a-b)} - \frac{2}{(a-b)^2}\left[f\left(\frac{1}{b}\right) - f\left(\frac{1}{a}\right)\right] + \frac{a}{(a-b)^2}\left[g\left(\frac{1}{b}\right) - g\left(\frac{1}{a}\right)\right], \tag{8}$$

$$f(x) = \begin{cases} -[\arcsin(\frac{1}{2\sqrt{x}})]^2, & x > \frac{1}{4},\\ \frac{1}{4}[\ln(\frac{\eta_+}{\eta_-}) - i\pi]^2, & x < \frac{1}{4},\end{cases}$$

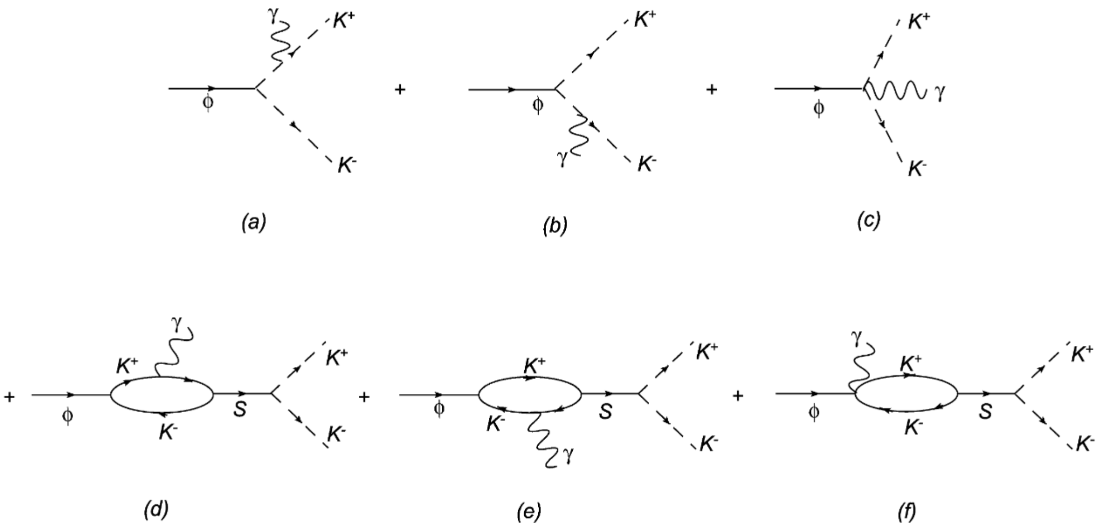

Fig. 1. Feynman diagrams for the decay $\phi \to K^+K^-\gamma$ in the kaon-loop model, where S denotes the scalar f_0 or a_0 meson.

$$g(x) = \begin{cases} (4x-1)^{\frac{1}{2}} \arcsin(\frac{1}{2\sqrt{x}}), & x > \frac{1}{4}, \\ \frac{1}{2}(1-4x)^{\frac{1}{2}}[\ln(\frac{\eta_+}{\eta_-}) - i\pi], & x < \frac{1}{4}, \end{cases}$$

$$\eta_\pm = \frac{1}{2x}\left[1 \pm (1-4x)^{\frac{1}{2}}\right] \tag{9}$$

where $a = M_\phi^2/M_{K^+}^2$, $b = M_{KK}^2/M_{K^+}^2$ and $M_{KK}^2 = (p-k)^2 = q^2$ is the invariant mass of the final K^+K^- system. The amplitude $\mathcal{M}(K^+K^- \to K^+K^-)$ contains the scalar f_0 and a_0 resonances and it is given by

$$\mathcal{M}\left(K^+K^- \to K^+K^-\right) = -g_{SK^+K^-}^2 D_S\left(q^2\right), \tag{10}$$

where $D_S(q^2)$ is the propagator of the scalar resonances f_0 and a_0 obtained with the prescription outlined in Eqs. (3) and (4), respectively.

The decay rate $\Gamma(\phi \to S\gamma)$ of the radiative decay $\phi \to S\gamma$ can be obtained in the kaon-loop model as

$$\Gamma(\phi \to S\gamma) = \frac{\alpha g_{\phi K^+K^-}^2 g_{SK^+K^-}^2}{3(2\pi)^4} \frac{E_\gamma}{M_\phi^2} \left|(a-b)\mathcal{I}(a,b)\right|^2, \tag{11}$$

where in the evaluation of the loop function $\mathcal{I}(a,b)$ the parameter b is now taken to be $b = M_s^2/M_{K^+}^2$. We then obtain the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$ by utilizing Eq. (11) and the experimental values of the branching ratios $B(\phi \to f_0\gamma)$ and $B(\phi \to a_0\gamma)$ [8] as $g_{f_0K^+K^-} = 4.60$ GeV and $g_{a_0K^+K^-} = 2.23$ GeV.

No-structure model (NS), or point-coupling model, involves the direct coupling of the intermediate state scalar mesons to the initial vector ϕ meson. Therefore, in this model the mechanism of the radiative $\phi \to K^+K^-\gamma$ decay is described by Feynman diagrams shown in Fig. 2. The amplitude $\mathcal{M}$ of the decay is then obtained as $\mathcal{M} = \mathcal{M}_B + \mathcal{M}_{\mathrm{NS}}$ where the amplitude $\mathcal{M}_B$ characterizing the internal bremsstrahlung mechanism is calculated using the diagrams given Fig. 2(a), (b), (c), and the amplitude $\mathcal{M}_{\mathrm{NS}}$ characterizing the contribution of the scalar mesons f_0 and a_0 in the intermediate state are calculated from the diagrams of Fig. 2(d), (e). In the evaluation of the relevant Feynman diagrams we describe the $\phi S\gamma$-vertex by the gauge invariant effective Lagrangian

$$\mathcal{L}_{\phi S\gamma} = \frac{e}{M_\phi} g_{\phi S\gamma} \partial^\mu \phi^\nu [\partial_\mu A_\nu - \partial_\nu A_\mu] S, \tag{12}$$

where ϕ^μ denotes the ϕ meson field, A^μ is the photon field, S denotes scalar meson f_0 or a_0 field, and $g_{\phi S\gamma}$ is the coupling constant characterizing the point-coupling of ϕ meson, scalar meson and the photon. The decay rate $\Gamma(\phi \to S\gamma)$ resulting from this Lagrangian is given as

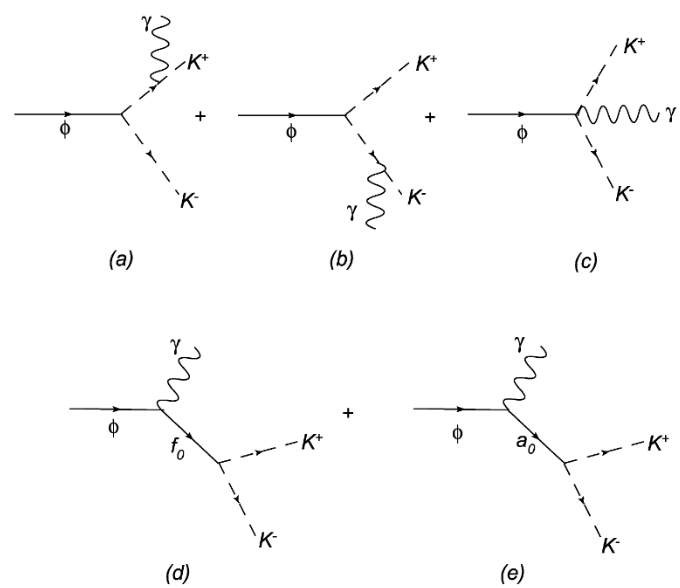

Fig. 2. Feynman diagrams for the radiative $\phi \to K^+K^-\gamma$ decay in the no-structure model.

$$\Gamma(\phi \to S\gamma) = \frac{\alpha}{24\pi} g_{\phi S\gamma}^2 \frac{(M_\phi^2 - M_s^2)^3}{M_\phi^5}. \tag{13}$$

We then use the experimental branching ratios $B(\phi \to f_0\gamma)$ and $B(\phi \to a_0\gamma)$ [8], and obtain the coupling constants $g_{\phi f_0\gamma}$ and $g_{\phi a_0\gamma}$ as $g_{\phi f_0\gamma} = -3.18$ and $g_{\phi a_0\gamma} = -1.86$. We note that if isoscalar σ meson, isoscalar f_0 meson and isovector a_0 meson are assigned to a unitary $SU(3)$ nonet, then it follows that $g_{\phi f_0\gamma} < 0$ and $g_{\phi a_0\gamma} < 0$ [10]. However, since there are no direct experimental information that we can employ to determine the point-coupling of scalar mesons to a charged K^+K^- kaon final state we use the results for these coupling constants that are obtained through QCD sum rules techniques. The values of the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$ determined through studies using light cone QCD sum rule method are $g_{f_0K^+K^-} = 7.14$ GeV [11], and $g_{a_0K^+K^-} = -5.08$ GeV [12].

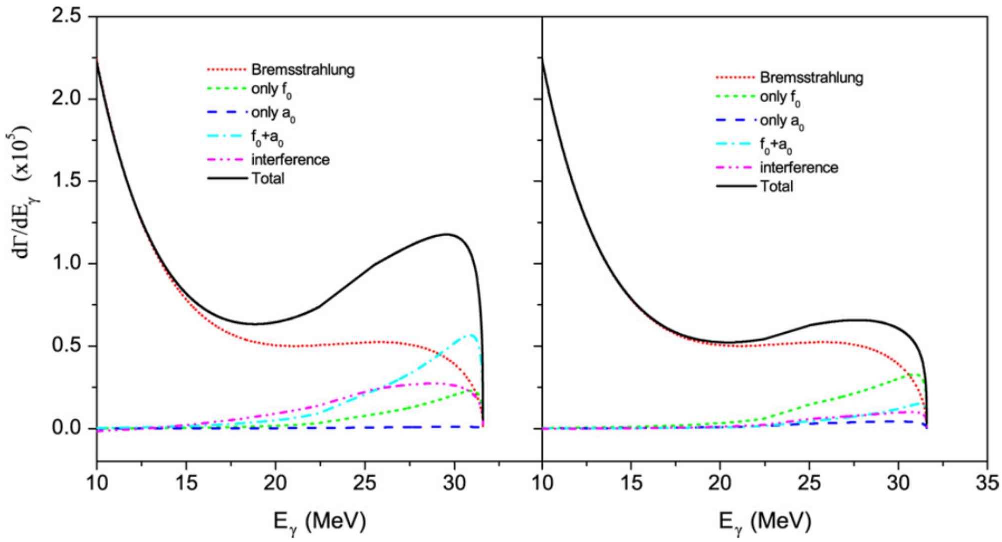

Fig. 3. The photon spectra for the decay width of $\phi \to K^+K^-\gamma$ in the kaon-loop model (left) in the no-structure model (right). The contributions of different terms are indicated.

3. Results and discussion

The amplitude $\mathcal{M}$ of the radiative $\phi \to K^+K^-\gamma$ decay is of the form $\mathcal{M} = \mathcal{M}_B + \mathcal{M}_S$ where $\mathcal{M}_B$ is the amplitude describing the internal bremsstrahlung and $\mathcal{M}_S$ is the amplitude characterizing the contribution of the f_0 and a_0 scalar mesons in the intermediate state to the reaction mechanism. This contribution is represented by the amplitude $\mathcal{M}_{\mathrm{KL}}$ in the kaon-loop model and by the amplitude $\mathcal{M}_{\mathrm{NS}}$ in the no-structure, or the point-coupling, model. The crucial difference between these f_0 and a_0 intermediate state amplitudes is that $\mathcal{M}_{\mathrm{KL}}$ in the kaon-loop model depends quadratically on the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$, whereas $\mathcal{M}_{\mathrm{NS}}$ of the no-structure model depends linearly on the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$. Therefore, the relative sign between these coupling constants has a profound effect for the contribution of f_0 and a_0 scalar meson amplitudes to the total amplitude of the radiative $\phi \to K^+K^-\gamma$ decay, and thus to the physical observables of this reaction calculated using this amplitude.

In Fig. 3 we show the photon spectra of the decay width of the radiative $\phi \to K^+K^-\gamma$ decay calculated using the kaon-loop and the no-structure models for including the effects of the intermediate state f_0 and a_0 scalar mesons. The contributions of internal bremsstrahlung and structural radiation amplitude calculated with the f_0 and a_0 scalar meson intermediate states as well as the contribution of the interference of the bremsstrahlung amplitude with the total structural radiation amplitude of the both scalar mesons are shown as a function of photon energy. In the figures we use the minimum photon energy as $E_{\gamma,\min} = 10$ MeV. In the kaon-loop model, the contribution of the scalar meson amplitudes becomes increasingly important in the region of high photon energies and the interference is constructive, therefore in the region of high photon energies the shape of the photon spectra curve is considerably modified and it is quite different from that obtained using only the bremsstrahlung amplitude. On the other hand, in the no-structure model the contribution of scalar mesons is not as pronounced so that the shape of the photon spectra does not deviate significantly from that of the bremsstrahlung mechanism.

For the branching ratio of the radiative $\phi \to K^+K^-\gamma$ decay we obtain the values $B(\phi \to K^+K^-\gamma) = 4.95 \times 10^{-5}$ in the kaon-loop model and $B(\phi \to K^+K^-\gamma) = 3.78 \times 10^{-5}$ in the no-structure model for the minimum photon energy $E_{\gamma,\min} = 10$ MeV. These values become $B(\phi \to K^+K^-\gamma) = 1.05 \times 10^{-4}$ and $B(\phi \to K^+K^-\gamma) = 9.30 \times 10^{-5}$ for the minimum photon energy $E_{\gamma,\min} =$ 5 MeV in the kaon-loop model and in the no-structure model, respectively.

In order to test the degree of dependence of the observations we note about the no-structure model on the coupling constants we use, we repeat our calculations using the no-structure model with the coupling constants that are obtained through experimental fits. The KLOE Collaboration has studied the decays $\phi \to \pi^+\pi^-\gamma$ [14] and $\phi \to \pi\eta\gamma$ [15], and using the no-structure model to fit the experimental spectrum of the relevant decays has extracted the coupling constants of f_0 meson as $g_{f_0K^+K^-} =$ 1.73 GeV, $|g_{\phi f_0\gamma}| = 1.48$ GeV^{-1}, and the coupling constants of a_0 meson as $g_{a_0K^+K^-} = 1.57$ GeV, $|g_{\phi a_0\gamma}| = 1.61$ GeV^{-1}. We use these coupling constants in our calculation of $\phi \to K^+K^-\gamma$ decay using the no-structure model as $g_{\phi f_0\gamma} = -1.48 M_{f_0}$ and $g_{\phi a_0\gamma} = -1.61 M_{a_0}$ where we multiply the values determined by the KLOE group by the appropriate masses to confirm with our convention of Eq. (12). Our choice of the signs for the coupling constants are in accordance with the assumption that the scalar mesons from a unitary $SU(3)$ nonet [10]. Furthermore, we consider two different relative sign choices between the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$, one where we choose $g_{f_0K^+K^-} > 0$ and $g_{a_0K^+K^-} < 0$ which is the sign consistent with the assumption that f_0 and a_0 scalar mesons have $q^2\bar{q}^2$ structure [2,13], and the other $g_{f_0K^+K^-} > 0$ and $g_{a_0K^+K^-} > 0$ if the mesons have $q\bar{q}$ structure [2,16]. The results of our calculation for the photon spectra for the decay width of the $\phi \to K^+K^-\gamma$ decay in the no-structure model for these two sign conventions for the coupling constants $g_{f_0K^+K^-}$ and $g_{a_0K^+K^-}$ are shown in Fig. 4. We note that in the no-structure model with these different coupling constants our earlier conclusion does not change, that is in this model for the reaction mechanism of the $\phi \to K^+K^-\gamma$ decay, the contributions coming from the intermediate scalar meson states do not modify the bremsstrahlung spectrum in a significant way. Moreover, the small modification of the spectrum will not probably allow a possible distinction between $q^2\bar{q}^2$ and $q\bar{q}$ models for the structure of the scalar mesons. The resulting branching ratios are $B(\phi \to K^+K^-\gamma) = 9.17 \times 10^{-5}$ and $B(\phi \to K^+K^-\gamma) = 9.38 \times 10^{-5}$ for $E_{\gamma,\min} = 5$ MeV, and $B(\phi \to K^+K^-\gamma) = 3.66 \times 10^{-5}$ and $B(\phi \to K^+K^-\gamma) = 3.88 \times 10^{-5}$ for $E_{\gamma,\min} = 10$ MeV for the signs of the coupling constants $g_{f_0K^+K^-} > 0$, $g_{a_0K^+K^-} < 0$ and $g_{f_0K^+K^-} > 0$, $g_{a_0K^+K^-} > 0$, respectively.

In this work, we study the role of $f_0(980)$ and $a_0(980)$ scalar mesons in the reaction mechanism of the radiative $\phi \to K^+K^-\gamma$

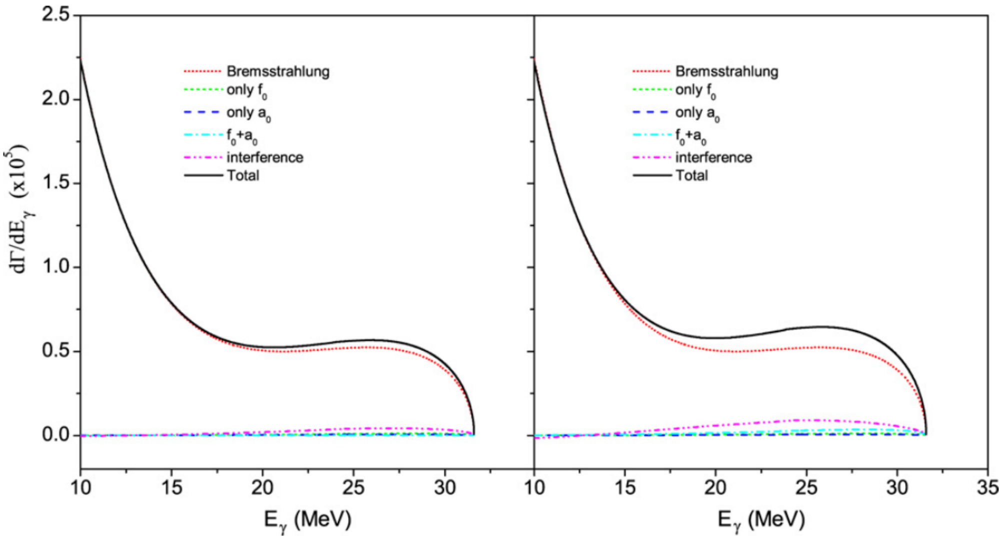

Fig. 4. The photon spectra for the decay width of $\phi \to K^+K^-\gamma$ in the no-structure model with $g_{f_0K^+K^-} > 0$, $g_{a_0K^+K^-} < 0$ (left) and $g_{f_0K^+K^-} > 0$, $g_{a_0K^+K^-} > 0$ (right). The contributions of different terms are indicated.

decay using the kaon-loop model and the no-structure model for the contributions of the scalar mesons in the intermediate states. The values we obtain for the branching ratios in two models are not sufficiently different from each other as to allow an experimental measurement of the branching ratio to distinguish between two models. On the other hand, the photon spectrum is sensitive to the model that is used, and in the kaon-loop model the bremsstrahlung spectrum is considerably modified by the contributions coming from the scalar meson intermediate states, whereas this modification is not significant in the no-structure model. However, since the photon spectrum for the rare decay $\phi \to K^+K^-\gamma$ is very difficult to measure experimentally, this particular decay does not seem to have the potential to provide information about the role of scalar mesons in the reaction mechanisms of such reactions in hadron electrodynamics.

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