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Brief report on 'Radiative ϕ decays with derivative interactions'

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We study the line shapes of radiative ϕ-decays with a direct coupling of the ϕ meson to the $f_0(980)$ and $a_0(980)$ scalar mesons. The latter couple via derivative interactions to $\pi_0\pi_0$ and $\pi_0\eta$, respectively. Although the kaon-loop mechanism is usually regarded as the dominant mechanism in radiative ϕ decays, here we test a different possibility: we set the kaon-loop to zero and we fit the theoretical curves to the data by retaining only the direct coupling. Remarkably, satisfactory fits can be achieved, mainly due to the effects of derivative interactions of scalar with pseudoscalar mesons.

8th Conference Quark Confinement and the Hadron Spectrum
September 1-6 2008
Mainz, Germany

*poster session

PoS(Confinement8)163

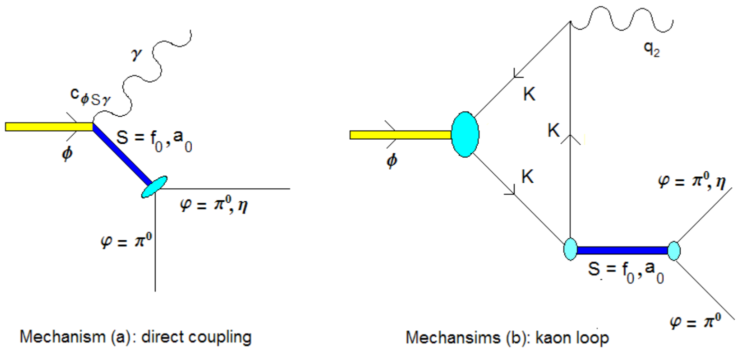

Figure 1: Different mechanisms contributing to the radiative ϕ decays.

The general Lagrangian describing the interactions of scalar and pseudoscalar mesons reads[1]:

$$\mathscr{L}_{int,f_0} = c_{f_0\pi\pi} f_0 \left(\partial_\mu \vec{\pi}\right)^2 + d_{f_0\pi\pi} M_\pi^2 f_0 \vec{\pi}^2 + c_{f_0KK} f_0 \left(\partial_\mu K^+\right)\left(\partial^\mu K^-\right) + d_{f_0KK} M_K^2 f_0 (K^+K^-) + \ldots \tag{1}$$

This is valid independently on the substructure of the enigmatic light scalar states. In the chiral limit ($M_\pi \to 0$, $M_K \to 0$) only the derivative interactions survive, but in general also non-derivative interactions appear.

The radiative decay $\phi \to f_0(980)\gamma \to \pi^0\pi^0\gamma$ (and similarly $\phi \to a_0(980)\gamma \to \pi^0\eta\gamma$) can occur by the two mechanisms depicted in Fig. 1: (a) the vector meson couples, via a point-like interaction with coupling $c_{\phi f_0 \gamma}$, to the scalar meson and to the photon. The scalar meson then decays into pseudoscalars via derivative and non derivative interactions as preliminarily studied in [2]. (b) The vector meson couples strongly to kaons. Then, via a kaon-loop a photon and the scalar mesons are generated.

The decay mode (b), widely studied in the literature, is usually considered as the dominant mechanism which contributes to the radiative decays $\phi \to S\gamma$ with $S = f_0, a_0$ [3] (see also [4] and Refs. therein). In Ref. [5], following the formalism developed in Ref. [6] extended to derivative interactions, we investigated a different point of view: we considered the possibility that, in agreement with large N_c expansion, the mechanism (a) is dominant. Moreover, we set in Eq. (1) $d_{f_0\pi\pi} = d_{f_0KK} = 0$ (and so for a_0), thus restricting the study to the chiral limit scenario, in which the scalars couple *only* via derivatives to the pseudoscalar mesons. The question we aimed to answer is: "can one in this scenario fit the line shapes $\phi \to \pi^0\pi^0\gamma$ and $\phi \to \pi^0\eta\gamma$ as measured in the SND and KLOE experiments [7, 8]?" Quite remarkably, as shown in Fig. (2), the answer is positive (see Ref. [5] for details). Some remarks are in order:

(i) When mechanism (b) is dominant, the amplitude of the process is proportional to the coupling of the scalar mesons to the pseudoscalars (as, for instance, c_{f_0KK} in Eq. (1)). However, when mechanism (a) is dominant, the coupling of the scalars to kaons appears only in the denominator of the scalar particles, see Fig. 1. Thus, it is more difficult to extract them from experiment .

(ii) Fits in the f_0 channel in the region between 0.6 and 1 GeV are acceptable, see Fig. 2, left panel. However, when the coupling to kaons is large, as suggested in Ref. [9], the quality

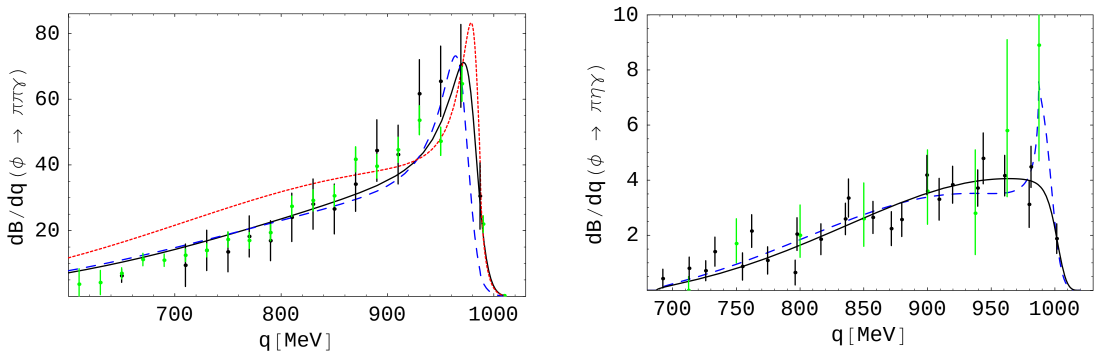

Figure 2: Left panel: Branching ratio $dB(\phi \to \pi^0\pi^0\gamma)/dq \cdot 10^8\ MeV^{-1}$ where q is the invariant $\pi^0\pi^0$ mass. We consider data sets from the SND and KLOE collaborations [7, 8] corresponding respectively to the black and green dots. The continuous line is the result of the fit by setting $c_{f_0KK} = 0$, the dashed blue line corresponds to the case $c_{f_0KK} = 12$ GeV^{-1}. The dotted red line corresponds also to $c_{f_0KK} = 12$ GeV^{-1} but only data points above 0.8 GeV are used in the fit. Right panel: $dB(\phi \to \pi^0\eta\gamma)/dq \times 10^7(MeV^{-1})$. Green points from [7] and black ones from [8]. The solid line corresponds to $c_{a_0KK} = 0$ while the dashed blue one -with the pronounced peak at threshold- to $c_{a_0KK} = 12$ GeV^{-1}.

of the fit decreases. Alternatively, one can satisfactory fits the data between 0.8 and 1 GeV, but then the theoretical curve overshoots data points below 0.8 GeV. This suggests the existence of the $\sigma \equiv f_0(600)$ meson, which is expected to generate a destructive interference with the f_0 meson in a similar way as presented in Ref. [8].

(iii) Fits in the a_0 channel for different values of the coupling c_{a_0KK} are good (Fig.2 , right panel) . Interestingly, when the latter is large, as found in Ref. [10], a very narrow peak is obtained close to threshold.

In summary, the results of the present study point out that derivative scalar-to-pseudoscalar interactions, being tailor-made to reproduce peaks close to threshold, can play an important role in the description of radiative ϕ decays. If, on the contrary, non-derivative interactions are used, worse fits are obtained. Future studies will show which one of the mechanisms of Fig. 1 (if any) is dominant.

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