

Different Contributions of the Decay $\rho \rightarrow \pi^0 \pi^0 \gamma$

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Abstract. The radiative decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ is re-examined within the framework of a phenomenological approach in which the f_2 meson and σ are combined with the processes involving the vector meson intermediate states and the pion-loops. In order to obtain the scalar σ meson contribution we consider pion-loop model and no structure model, and then compare the results obtained in two models. Furthermore, using the experimental branching ratio for the radiative decay $\rho \rightarrow \pi^0 \pi^0 \gamma$, we estimate the coupling constant $g_{\rho\sigma\gamma}$ for a set of values of σ meson parameters M_σ and Γ_σ .

1. Introduction

The radiative decays of low-mass vector mesons into a pair of neutral pseudoscalars are useful tool for investigating the nature and extracting the properties of the scalar meson resonances. One of these decays which is the decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ should be considered as an ideal process for analyzing the controversial and not well established scalar meson σ . For the radiative decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ there are a number of experimental and theoretical studies. The recent measured branching ratio of the decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ is $\text{BR}(\rho \rightarrow \pi^0 \pi^0 \gamma) = 4.5 \pm 0.8 \times 10^{-5}$ [1]. On the theoretical side, this decay is studied using the vector meson dominance (VMD) model [2], the chiral perturbation theory [3], and the unitarized chiral perturbation theory (UChPT) [4,5].

2. Formalism

In this work, we follow a phenomenological approach which is also used to the similar calculations in [6,7] and attempt to calculate the decay rate for the decay $\rho \rightarrow \pi^0 \pi^0 \gamma$. We assume that the radiative decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ proceeds through the reactions $\rho \rightarrow \omega \pi \rightarrow \pi^0 \pi^0 \gamma$, $\rho \rightarrow \sigma \gamma \rightarrow \pi^0 \pi^0 \gamma$, $\rho \rightarrow f_2 \gamma \rightarrow \pi^0 \pi^0 \gamma$ and $\rho \rightarrow \pi^+ \pi^- \gamma \rightarrow \pi^0 \pi^0 \gamma$. For the contribution of the scalar σ meson, we use both the pion-loop model, and the no-structure model.

3. Results

We also estimate the coupling constant $g_{\rho\sigma\gamma}$ depending on a set of values of the σ meson parameters [8,9], as shown in table 1. Our estimations are in general quite different than the values existing in the literature, such as $g_{\rho\sigma\gamma} = 2.71$ [10], $g_{\rho\sigma\gamma} = 3.2 \pm 0.6$ [11] and $g_{\rho\sigma\gamma} = 2.2 \pm 0.4$ [12]. We also obtain for the branching ratios for different contributing reactions to the radiative decay $\rho \rightarrow \pi^0 \pi^0 \gamma$ as $\text{BR}(\rho \rightarrow \omega \pi \rightarrow \pi^0 \pi^0 \gamma) = 1.15 \times 10^{-5}$, $\text{BR}(\rho \rightarrow \pi^+ \pi^- \gamma \rightarrow \pi^0 \pi^0 \gamma) = 1.07 \times 10^{-5}$, $\text{BR}(\rho \rightarrow f_2 \gamma \rightarrow \pi^0 \pi^0 \gamma) = 1.38 \times 10^{-6}$ for $G_{f\pi\pi} = 3.14$ and $\text{BR}(\rho \rightarrow f_2 \gamma \rightarrow \pi^0 \pi^0 \gamma) = 1.712 \times 10^{-5}$ for $G_{f\pi\pi} = 5.89$. For the contribution of the σ , the obtained values are shown in table 2 and table 3.

Table 1. The values of the coupling constants, $g_{\sigma\pi\pi}$ and $g_{\rho\sigma\gamma}$ depending on the σ parameters.

M_σ (MeV)	Γ_σ (MeV)	$g_{\sigma\pi\pi}$	$g_{\rho\sigma\gamma}$
478	263	4.72	(-0.44) and (3.47)
441	544	7.23	(-0.23)
500	600	6.91	(0.11) and (-2.95)

Table 2. The branching ratios depending on the coupling constant $g_{\rho\sigma\gamma}$ of the decay $\rho \rightarrow \pi^0\pi^0\gamma$ are shown. In each value the predictions without and with the f_2 meson are given with different value of the $G_{f\pi\pi}$.

$g_{\rho\sigma\gamma}$	σ (VMD)	Total (without f_2)	Total(with f_2) $G_{f\pi\pi} = 3.14$	Total(with f_2) $G_{f\pi\pi} = 5.89$
-0.44	1.40×10^{-5}	4.35×10^{-5}	4.49×10^{-5}	6.07×10^{-5}
-0.23	0.13×10^{-5}	2.76×10^{-5}	2.89×10^{-5}	4.73×10^{-5}
0.11	0.05×10^{-5}	1.52×10^{-5}	1.66×10^{-5}	3.23×10^{-5}
0.58	0.63×10^{-5}	1.24×10^{-5}	1.38×10^{-5}	2.95×10^{-5}

Table 3. The branching ratios depending on the σ parameters of the decay $\rho \rightarrow \pi^0\pi^0\gamma$ are shown. In each value the predictions without and with the f_2 meson are given with different value of the $G_{f\pi\pi}$.

M_σ (MeV)	Γ_σ (MeV)	σ (pion-loop)	Total (without f_2)	Total(with f_2) $G_{f\pi\pi} = 3.14$	Total(with f_2) $G_{f\pi\pi} = 5.89$
478	263	4.17×10^{-5}	4.50×10^{-5}	4.64×10^{-5}	6.21×10^{-5}
478	258	4.13×10^{-5}	4.47×10^{-5}	4.61×10^{-5}	6.18×10^{-5}
441	544	8.88×10^{-5}	8.42×10^{-5}	8.56×10^{-5}	10.13×10^{-5}
800	600	1.80×10^{-5}	1.95×10^{-5}	2.09×10^{-5}	3.66×10^{-5}

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