RADIATIVE DECAYS INVOLVING LIGHT SCALAR MESONS

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We present a vector dominance model to describe radiative decays involving the light scalar mesons. Assuming that the light scalar mesons form a nonet this model gives relations among various decay amplitudes of the form $S \rightarrow \gamma\gamma$, $V \rightarrow S\gamma$ and $S \rightarrow V\gamma$, where S and V denote scalar and vector mesons. By comparing with experimental radiative decay rates, including those recently measured for $\phi \rightarrow PP'\gamma$, we obtain various predictions. We discuss briefly ongoing extensions of the present work in an attempt to describe the radiative ϕ decay measurements in detail.

1. Introduction

The scalar mesons are of considerable current interest. In particular, below 1 GeV there is, in addition to the well-established $f_0(980)$ and $a_0(980)$, evidence of both experimental and theoretical nature for very broad $\sigma(600)$ and $\kappa(900)$ resonances. The identification of the latter two states is controversial as they appear to be of non Breit-Wigner type, signalling strong interference with the non-resonant background (see discussion of experimental and theoretical status in ¹).

The existence of a σ and κ would mean that, together with the a_0 and f_0 , there is a group of states with the quantum numbers of an SU(3)

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nonet, all with masses below 1 GeV. Such a nonet would most likely represent meson states more complicated than quark-antiquark type and hence would be of great importance for a full understanding of QCD in its non-perturbative low energy regime. In the literature, besides conventional $q\bar{q}$ models, $qq\bar{q}\bar{q}$ models, meson-meson “molecule” models and unitarized meson-meson models have been investigated.

2. Chiral Lagrangian Model

Clearly it is important to study the properties of the $f_0(980)$ and $a_0(980)$ from the point of view of how they fit into a putative nonet family. In particular, the rare decays $\phi \rightarrow \pi^0\pi^0\gamma$ and $\phi \rightarrow \pi^0\eta\gamma$ have recently been observed ² with good accuracy and are considered as useful probes of scalar properties. Most theoretical models assume that these decays are dominated by the coupling of the ϕ to two charged kaons, which form a loop, to which the f_0 or a_0 and a photon are attached in a gauge invariant manner. In the present talk (based on ³ where more detail is given) we introduce a complementary approach which emphasises the “family” or symmetry aspects of the analysis, without making a commitment to a particular quark structure for the scalars.

Our framework is that of a standard non-linear chiral Lagrangian containing, in addition to the pseudoscalar nonet ϕ , the vector and scalar nonets ρ_μ and S . Details of the introduction of the vector and scalar mesons in a chiral invariant manner (which gives vector meson dominance naturally) can be found in ⁴ and ⁵ respectively. The new feature of the present work is the inclusion of strong trilinear scalar-vector-vector terms in the chiral effective Lagrangian:

$$L_{SVV} = \beta_A \epsilon_{abc} \epsilon^{a'b'c'} [F_{\mu\nu}(\rho)]_{a'}^a [F_{\mu\nu}(\rho)]_{b'}^b S_{c'}^c + \beta_B \text{Tr}[S] \text{Tr}[F_{\mu\nu}(\rho)F_{\mu\nu}(\rho)] \\ + \beta_C \text{Tr}[SF_{\mu\nu}(\rho)] \text{Tr}[F_{\mu\nu}(\rho)] + \beta_D \text{Tr}[S] \text{Tr}[F_{\mu\nu}(\rho)] \text{Tr}[F_{\mu\nu}(\rho)] .$$

We see that the rare radiative ϕ decays are examples of a class of decays which occur at tree-level, examples of which are shown in the Feynman diagrams in the figure. The decay amplitudes for processes $V \rightarrow S\gamma$, $S \rightarrow \gamma\gamma$ and $S \rightarrow V\gamma$ are described by the parameters β_A , β_B and β_C as well as the scalar isoscalar mixing angle. To illustrate the kinds of predictions we can obtain, we consider the case where we assume a single putative scalar nonet with a mixing angle ⁵ $\theta_S \simeq -20^\circ$ (characteristic of $qq\bar{q}\bar{q}$ type scalars).

The parameters β_A and β_B may be estimated from experimental branching ratios for $a_0 \rightarrow \gamma\gamma$ and $f_0 \rightarrow \gamma\gamma$. Next, assuming $\phi \rightarrow \eta\pi^0\gamma$ is domi-

nated by $\phi \rightarrow a_0\gamma$, $\Gamma_{\text{exp}}(\phi \rightarrow a_0\gamma)$ is extracted and determines β_C . Knowing β_A , β_B and β_C we can predict $\Gamma(\phi \rightarrow f_0\gamma)$. Unfortunately this prediction is smaller than the listed value¹. We also obtain predictions for $\Gamma(\sigma \rightarrow \gamma\gamma)$ and $\Gamma(a_0 \rightarrow \rho\gamma)$ for example.

We have presented so far a simple model in which vector-meson dominance, together with the assumptions of SU(3) flavor symmetry and a single nonet of scalar mesons, allows us to relate many radiative decay processes. There are many improvements that can be made to this simplest picture. We must also take into account interference for example between σ and f_0 as well as non-resonant backgrounds. We are also studying the three-body ϕ decays and kaon-loop corrections to this initial treatment. Another interesting possibility is that of mixing between $q\bar{q}\bar{q}$ and heavier $q\bar{q}$ scalar nonets.

References

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