Two-Photon Decays of π^0, η and η' ◇

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The two-photon decays $\pi^0, \eta, \eta' \to \gamma\gamma$ are phenomenological manifestations of the chiral anomaly of QCD and can provide important information on the chiral symmetry of the strong interactions. In order to study the phenomenological implications of the chiral anomaly, it is convenient to employ a chiral effective Lagrangian, since at low energies the effective degrees of freedom are colorless hadrons rather than quarks and gluons. The effective Lagrangian contains a piece which reproduces the anomalous behavior of the effective action under chiral transformations, the Wess-Zumino-Witten (WZW) Lagrangian.

In [1] the two-photon decays of π^0, η and η' with one, both or none of the photons being off-shell, $\pi^0, \eta, \eta' \to \gamma^{(*)}\gamma^{(*)}$ are investigated within a chiral unitary framework. To this end, we have supplemented the one-loop calculation of chiral perturbation theory by a Bethe-Salpeter approach which satisfies unitarity constraints and generates vector mesons from composed states of two pseudoscalar mesons.

The decays $P \to \gamma\gamma$ ($P = \pi^0, \eta, \eta'$) with both photons on-shell are dominated by the WZW Lagrangian. For the decays $P \to \gamma\gamma^*$, on the other hand, contributions from higher chiral orders will become increasingly more important for larger photon virtualities. In this case one-loop contributions turn out to be divergent and must be renormalized by appropriate counterterms. The remaining finite parts of the relevant counterterms can be estimated by vector meson exchange contributions. In previous investigations, vector mesons have been included explicitly and integrating them out from the effective theory produces contact interactions. An underlying assumption of this approach is that the masses of the vector mesons are much larger than the involved momenta.

Alternatively, the chiral Lagrangian for the Goldstone bosons is able to reproduce a number of meson resonances such as the $f_0(980)$ and the $\rho(770)$, when combined with non-perturbative Bethe-Salpeter approaches which are employed in such a way so that they ensure unitarity. Within these approaches effective coupled channel potentials are derived from the chiral meson Lagrangian and iterated in Bethe-Salpeter equations (BSEs). The BSE generates dynamically quasi-bound states of the mesons and accounts for the exchange of resonances without including them explicitly. The usefulness of this approach lies in the fact that from a small set of parameters a large variety of data can be explained and no additional assumptions need to be made on the couplings of the resonances. In [2] the approach has been extended to include the η' and successfully applied to the hadronic decays of η and η' in [3]. The main purpose of [1] was to embed the coupled channel approach in the two-photon decays $P \to \gamma^{(*)}\gamma^{(*)}$ and to investigate the importance of vector mesons for these decays from a different perspective.

While the one-loop result is sufficient to achieve agreement with the decay widths $P \to \gamma\gamma$ ($P = \pi^0, \eta, \eta'$), the vector meson exchange is crucial to reproduce the sharp increase of the transition form factor for time-like photons in the decays $P \to \gamma\gamma^*$. Our method reproduces also the resonance structure in the transition form factor of the decay $\eta' \to \gamma\gamma^*$ at photon virtualities around $k^2 \approx 0.6$ GeV^2, see Figure.

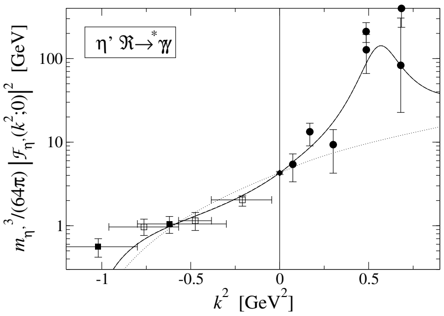

Figure: Results of the one-loop calculation (dotted) and the coupled channel approach (solid) for $\eta' \to \gamma\gamma^*$. The data are taken from different experiments.

Furthermore, our approach distinguishes between single and double vector meson exchange, the latter one being the only contribution in the complete Vector Meson Dominance picture. This study suggests that for the decays with off-shell photons the exchange of one vector meson is the dominant contribution, whereas the two vector meson exchange is almost negligible which is in contradistinction to complete Vector Meson Dominance. The available data on electromagnetic transition form factors is restricted to decays with exactly one off-shell photon. When coupling to an on-shell photon, the pertinent vector meson propagator reduces to a vertex so that no clear distinction can be made between the two approaches. However, an experiment with two off-shell photons should be able to clarify, whether one or two vector meson exchange occurs. The question whether double Vector Meson Dominance holds is also an important issue for kaon decays and the anomalous magnetic moment of the muon. We have presented predictions for the decays with two off-shell photons, and again the exchange of two vector mesons plays a minor role.

This approach has also been applied in a straightforward manner to the anomalous decays $\eta, \eta' \to \pi^+\pi^-\gamma$ [4].

References

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