Single photon radiative decays of ρ and ω mesons

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Introduction: Meson decays provide an important tool for exploring the structures of these simplest bound states in QCD, and for studies on non-perturbative behavior of strong interactions. These decays has been studied in the framework of Bethe-Salpeter Equation (BSE) under Covariant Instantaneous Ansatz (CIA), which has earlier given good predictions for electromagnetic decay constants of vector mesons through the process, $V \rightarrow e^{+} + e^{-}$ [1,2], weak decay constants of unequal mass pseudoscalar mesons through the process, $P \rightarrow l + \nu_l$ [3], two photon electromagnetic decays of equal mass pseudoscalar mesons through the process $P \rightarrow \gamma + \gamma$ [3], as well as the recent high energy tests of the model in the study of double charmonium production in electron-positron annihilation at energies $\sqrt{s}$= 10.6 GeV., through the process, $e^{-} + e^{+} \rightarrow J/\psi + \eta_c$.

In this work using the framework of BSE, we study radiative decays of vector mesons through the process: $h \rightarrow h' + \gamma$ taking h and h' as equal mass vector and pseudoscalar mesons respectively. We calculate the decay widths for the processes: $\omega \rightarrow \pi^0 + \gamma$, $\rho^0 \rightarrow \pi^0 + \gamma$, and $\rho^{\pm} \rightarrow \pi^{\pm} + \gamma$, which are in reasonable agreement with data. Here we wish to mention that the Bethe-Salpeter Equation (BSE) is a conventional non-perturbative approach in dealing with relativistic bound state problems in QCD. It is firmly established in the framework of Field Theory and from the solutions we obtain useful information about the inner structure of hadrons. These studies have become an interesting topic in recent years since calculations have shown that BSE framework using phenomenological potentials can give satisfactory results as more and more data is being accumulated. We get useful insight about the treatment of various processes using BSE due to the unambiguous definition of the 4D BS wave function which provides exact effective coupling vertex (Hadron-quark vertex) of the hadron with all its constituents (quarks). This Hadron-quark vertex is considered to sum up all the non-perturbative QCD effects in the hadron. It has been shown that the CIA leads to exact interconnection between the 3D and the 4D form of BSE with all the Dirac covariants incorporated [1].

Radiative decays of vector mesons: We first obtain the hadron-quark vertex functions for the individual hadrons h and h' in the process: $h \rightarrow h' + \gamma$ studied here. We start with a BSE for a $q\bar{q}$ system with BS amplitude, ψ(P,q) of a hadron with external momentum P and internal momentum q, and with interaction kernel K(q,q'). We decompose the internal momentum of the hadron q_μ as the sum of two parts, the transverse component, $\hat{q}_\mu = q_\mu - \frac{q.P}{P^2} P_\mu$, which is orthogonal to total hadron momentum P_μ, and the longitudinal component, $\sigma P_\mu = \frac{q.P}{P^2} P_\mu$, which is parallel to P_μ(for details see Ref.[1]). Using a sequence of steps, we express the full 4D BS amplitude, ψ(P,q) as, $\psi(P,q) = S_F(p_1)\Gamma(\hat{q})S_F(-p_2)$, where the hadron-quark vertex $\Gamma(\hat{q})$ is sandwiched between two quark propagators constituting a meson. For a vector meson, h, and for pseudoscalar meson, h', the hadron-quark vertex functions with only the leading Dirac covariants included are: $\Gamma_h(\hat{q}) = (i\gamma.\varepsilon^h)D(\hat{q})\varphi(\hat{q})/2\pi i$, and $\Gamma_{h'}(\widehat{q'}) = \gamma_5 D(\widehat{q'})\varphi(\widehat{q'})/2\pi i$, respectively, where ε^h is the polarization vector for V-meson, while D is the denominator function, and φ is the 3D BS wave function for a given meson. The lowest order quark-loop diagrams that contribute to the process, $h \to h' + \gamma$ are given in Fig.1 below:

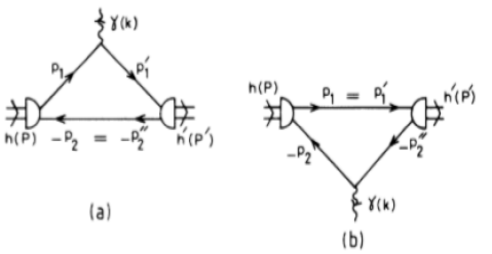

Fig.1: Leading order quark triangle diagrams for the process, $h \to h' + \gamma$, where h is vector meson in initial state, while h' is pseudoscalar meson in final state.

The total amplitude for the above process is given by $M_{tot} = M_a + M_b$. For ρ and ω mesons which involve the lightest u and d quarks, the total amplitude can be conveniently expressed as [4]:

$$M_{tot} = \frac{4meN_PN_V}{\sqrt{8\pi^2\omega_k V}}\epsilon_{\mu\nu\lambda\beta}P'_\mu\varepsilon_\nu^{\gamma*}P_\lambda\varepsilon_\beta^h[X];$$

$$[X] = \int d^4q \frac{D_V(\hat{q})D_P(\hat{q}')\varphi_V(\hat{q})\varphi_P(\hat{q}')}{\Delta_1\Delta_2\Delta'_1}$$

where we have taken the electric charges of uand d quarks as $2e/3$, and $e/3$ respectively. In the expression for M_{tot}, N_V and N_P are the 4D BS normalizers for vector and pseudoscalar mesons respectively, while $\varepsilon^{\gamma*}$ and ε^h are the polarization vectors of the emitted photon and the vector meson respectively. And [X] is the 4D integral over the poles of the quark propagators involved in the process. The decay width for the process is given as,

$$\Gamma_{h\to h'\gamma} = \frac{\alpha_{em}N_V^2N_P^2m^2M^3}{24\pi^2}(1-\frac{M'^2}{M^2})^3|X|^2,$$

where m is the constituent mass of u and d quarks (taken as .265GeV.), M and M' are the masses of vector meson and pseudoscalar meson respectively. With input quark masses, $m_{u,d} = .265GeV.$, and experimental values of meson masses, $M_{\pi^0} = .135GeV.$, $M_{\pi^\pm} = .140GeV.$, $M_{\rho^{0,\pm}} = .770GeV.$, $M_\omega = .782GeV.$, we obtain the decay widths given below which are in reasonable agreement with the central values of data [5] (in brackets) as: $(\rho^\pm \to \gamma\pi^\pm = .959 \times 10^{-4}GeV.$ (Exp.=.671× $10^{-4}GeV.$[5]), $\Gamma(\rho^0 \to \gamma\pi^0 = 1.110 \times 10^{-4}GeV.$(Exp. =.894 $\times 10^{-4}GeV.$[5]), and $\Gamma(\omega^0 \to \gamma\pi^0) = 5.810 \times 10^{-4}GeV.$ (Exp.=7.029× $10^{-4}GeV.$) .

References:

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