Contributions from different Dirac structures in BS wave functions of vector mesons to calculations of their decay widths

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Introduction: In this work we have studied electromagnetic decays of vector mesons in the framework of Bethe-Salpeter Equation (BSE) under Covariant Instantaneous Ansatz (CIA), which is a Lorentz-invariant generalization of Instantaneous Ansatz (IA). In these studies, the main ingredient is the 4D hadron-quark vertex function Γ which plays the role of an exact effective coupling vertex of the hadron with all its constituents (quarks). This hadron-quark vertex Γ is considered to sum up all the non-perturbative QCD effects in the hadron. Now one of the main ingredients in Γ is its Dirac structure. Recent studies have revealed that various mesons have many different Dirac structures in their BS wave function (written as $\psi = S_{F1}\Gamma S_{F2}$), whose inclusion is necessary to obtain quantitatively accurate observables. Towards this end, to ensure a systematic procedure of incorporating various Dirac structures from their complete set in the BSWs of various hadrons (pseudoscalar, vector etc.), we developed a naive power counting rule in [1,2], by which we incorporate various Dirac structures in BSW, order-by-order in powers of inverse of meson mass. This framework had earlier given good predictions for a number of processes that were studied at the quark level of compositeness such as: $V \to \gamma P$, $V \to PP$, $P \to l\overline{\nu_l}$, $V \to e^+e^-$, $P \to \gamma\gamma$ etc. (see[1] and references therein). However they were studied using only the leading Dirac structures.

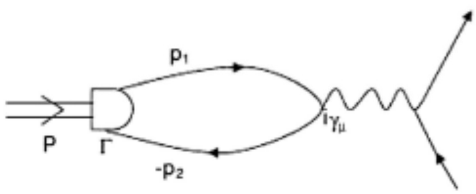

Fig.1: Quark-loop diagram for $V \to \gamma \to e^+ + e^-$ showing the coupling of electromagnetic current to quark loop.

In this work we study electromagnetic decays of ground state equal mass vector mesons: $\rho, \omega, \varphi, \psi$ and Υ through the process $V \to \gamma \to e^- + e^+$. We employ the generalized structure of hadron-quark vertex function Γ which incorporates all Dirac structures from their complete set. In [1], we have explicitly shown the derivation of this general form of this Hadron-quark vertex function Γ (in terms of unknown coefficients) for a vector meson with incorporation of all the Dirac structures (ie. those dependent on external hadron momentum, P, as well those dependent on internal hadron momentum q) as the solution of the full 4×4 Bethe-Salpeter Equation. However the unknown coefficients multiplying the various Dirac structures are calculated by reducing the 4×4 BSE to a determinantal form [1]. To obtain these coefficients, A_i, we calculated the difference $\hat{q}^2$(LHS - RHS)] for determinantal form of BSE at several chosen values of $\hat{q}$, together with differences between f_V and $f_V^{Exp.}$ and then we found values of coefficients A_i that minimize those differences for all the 5 vector mesons studied. Our approach gives no unique solution, but we chose the best set of values of A_i that not only gave a reasonable agreement with the experimental f_V values, but also a good agreement between the numerical values of LHS and RHS of the BSE, as well as the agreement between the plots of their integrands for all the 5 vector mesons studied.

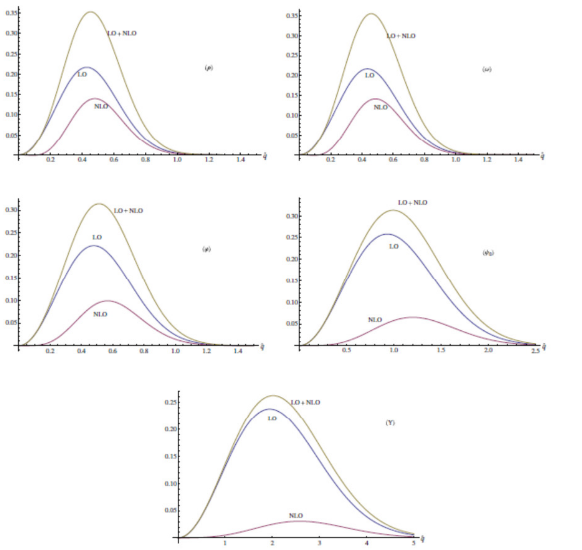

Fig.2: Plots of integrand functions that give rise to LO, NLO and LO+NLO contributions to f_V as functions of $\hat{q}$ for five vector mesons, $\rho, \omega, \varphi, \psi$ and Y for set of coefficients $A_0 = 1, A_1 = .0064, A_2 = .0048, A_3 = -.453, A_4 = -.79, A_5 = -2.08474$.

Only this would ensure that the hadron-quark vertex Γ given by (with unknown coefficients A_i) is indeed a solution of the BSE, though the general form of Γ has been shown to be derivable from BSE. Using this criterion we selected the best set of coefficients should respectively be [1]: $A_0 = 1, A_1 = .0064, A_2 = .0048, A_3 = -.453, A_4 = -.79, A_5 = -2.084$ to give decay constant values: f_ρ=0.192GeV, f_ω=0.194 GeV, f_φ=0.220 GeV, f_ψ=0.406GeV, and f_Y=0.7097GeV. These decay constant values have an average error with respect to the experimental data of 3.58%. This is in contrast to an earlier approach [3], where we had fixed these coefficients to experiment.

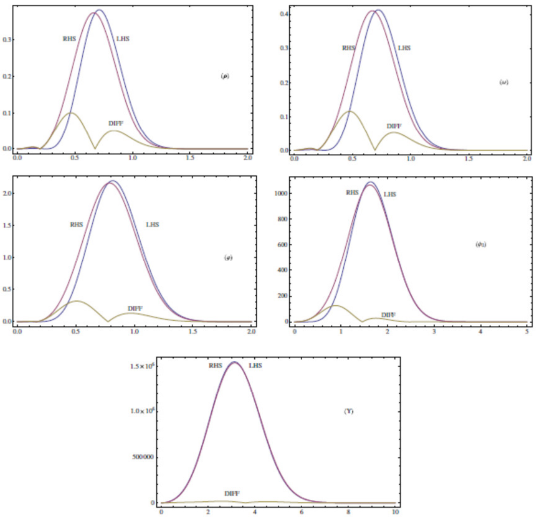

Fig.3: Plots of integrand functions of LHS and RHS of BSE and absolute value of their difference as function of $\hat{q}$ for five vector mesons, $\rho, \omega, \varphi, \psi$ and Y for the above set of coefficients.

In Fig.2 (see [1]) above we have shown the relative importance of LO and NLO Dirac structures identified from our power counting rule for calculation of f_V values for five vector mesons, which shows LO as the leading Dirac structures. And Fig.3 shows the plots of LHS and RHS of BSE for the set of coefficients A_i derived as solutions of BSE (see [1] for details).

References:

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