Di-gamma Branching Ratio of $\chi_{c0,2}$ states

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Introduction

Study of the di-gamma, the di-lepton and di-gluon decay widths are important properties of quarkonia that provide better understanding of the quark-antiquark dynamics within the meson [1–4]. As these decay rates are sensitive to the quarkonium wave function, the successful predictions along with the spectroscopic predictions become an important measure of the success of any phenomenological model employed for the study of quarkonia. The spectroscopic parameters such as the masses and the resultant radial wave functions obtained using the Coulomb plus power potential CPP$_\nu$ for the different choices of the potential index, ν are being used here to compute the di-gamma decay rates of $\chi_{c0,2}$ states [4].

Theory

The di-gamma (Two-photon) annihilation rates of few P-wave states are estimated in the non-relativistic approach. It is well known that two-photon annihilation rate of charmonia $c\bar{c}$ is related to the wave function, so this process will be helpful to understand the formalism of inter-quark interactions, and can be a sensitive test of the potential models [5]. In the traditional non-relativistic bound state calculation, the two-photon widths for the scalar quarkonium state depend on the behavior of the radial wave function at the origin $|R^{\ell}_{n\ell}(0)|$ extracted from the potential models [6].

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The two-photon decay of the spin one state χ_{c1} is forbidden by the Landau-Yang theorem [7, 8]. With the one-loop QCD radiative corrections to the decays of $^3P_0$ and $^3P_2$ states into two photons are given by [9, 10]

$$\Gamma^{\gamma\gamma}_{\chi_{Q0}} = \frac{27 e_Q^4 \alpha^2}{m_Q^4} |R'_{\chi_{Q0}}(0)|^2 \left[1 + \frac{\alpha_s}{\pi}\left(\frac{\pi^2}{3} - \frac{28}{9}\right)\right] \quad (1)$$

$$\Gamma^{\gamma\gamma}_{\chi_{Q2}} = \frac{36 e_Q^4 \alpha^2}{5 m_Q^4} |R'_{\chi_2}(0)|^2 \left[1 - \frac{\alpha_s}{\pi}\frac{16}{3}\right] \quad (2)$$

It is obvious to note that the computations of the decay widths and the radiative correction terms described here require the right description of the meson state by its radial wave functions at the origin ($R^{\ell}_{n\ell}(0)$) and its mass ($M_{n\ell}$). Generally, due to lack of exact solutions for colour dynamics and with the uncertainties over the exact nature of interquark potential, the wave function and the mass of the states are also been considered as free parameters for the computations of decay widths [11]. However, it would be more appropriate to employ the spectroscopic quantities of the mesons such as the mass and the corresponding wave function predicted by the models for the estimation of the decay properties of the mesons. These spectroscopic quantities are further related to the model parameters like α_s, confinement strength (A) and model quark masses ($m_{Q/\bar{Q}}$). Within the potential confinement scheme, we consider the constituent quark mass m_Q appeared in Eqns (1) and (2) as effective mass of the quark within the bound state of the $Q\bar{Q}$ systems defined by

$$m_Q^{eff} \ = \ m_Q\left(1 + \frac{\langle E_{bind}\rangle_{n\ell}}{m_Q + m_{\bar{Q}}}\right) \quad (3)$$

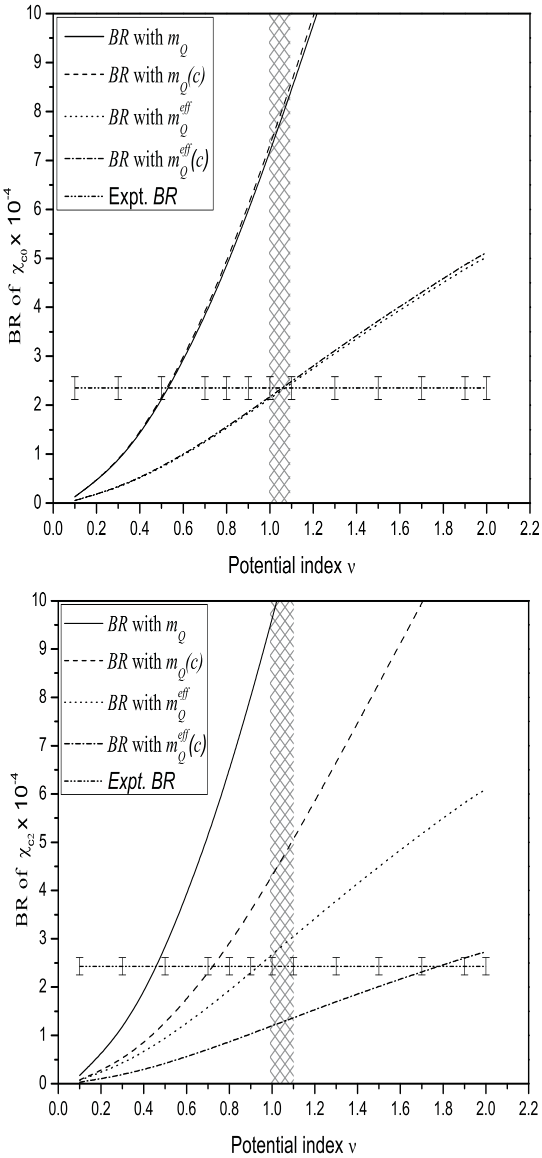

FIG. 1: Branching Ratio of χ_{c0} and χ_{c2} of $c\bar{c}$ meson with using total width of 10.2 MeV and 2.03 MeV of PDG 2008 respectively.

where, $\langle E_{bind} \rangle_{n\ell} = M_{Q\bar{Q}} - (m_Q + m_{\bar{Q}})$ and the $m_{Q/\bar{Q}}$ corresponds to the respective quark/antiquark mass parameter employed in the phenomenological model and $M_{Q/\bar{Q}}$ is the respective mass of the $Q\bar{Q}$ meson state.

Results and Discussion

The Branching ratio of the $\Gamma^{\gamma\gamma}_{\chi_{Q0}}$ and $\Gamma^{\gamma\gamma}_{\chi_{Q2}}$ are obtained using the computed di-gamma decay widths and using the total widths of $\Gamma_{\chi_{c0/2}}$ states from PDG [12]. Our results are shown graphically in Fig.1 against the potential index ν. The experimental branching ratio are drawn with error bar. Masses of P-wave agree with experimental mass within the potential index range $1.0 \leq \nu \leq 1.1$ which are drawn by vertical net in Fig.1. Our prediction for the branching ratio of the $\Gamma^{\gamma\gamma}_{\chi_{Q0}}$ and $\Gamma^{\gamma\gamma}_{\chi_{Q2}}$ with effective quark masses and the masses of $P-$wave are agree with experimental results [12] within the potential index range $1.0 \leq \nu \leq 1.1$.

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