Annihilation of S-wave charmonium state into $\gamma\gamma\gamma$, γgg and ggg in CPP_ν model

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Introduction

The simplest three body decay of vector quarkonia are to $\gamma\gamma\gamma$, γgg and ggg. Experimental study of $\gamma\gamma\gamma$, γgg and ggg quarkonium decays has progressed substantially, but has not entered the realm of precision [1]. This motivates theorists to study these decay in a great detail. For the present study we focus on $\gamma\gamma\gamma$, γgg and ggg decays of charmonium states.

Theory

The decays ${}^3S_1 \to 3\gamma$ have very small rates proprtional to α^3. However, a measurement of such decay for the J/ψ resonance does not appear to be unrealistic. The rate of the decay in the potential approach is given by,

$$\Gamma(J/\psi \to 3\gamma) = \frac{16(\pi^2-9)e_c^6\alpha^3}{3\pi M^2}|R(0)|^2 \quad (1)$$

The mixed electromagnetic and strong annihilation into a photon and two gluons is quite interesting on its own [3]. The rate of decay in the given channel can be written as,

$$\Gamma(n^3S_1 \to \gamma gg) = \frac{32(\pi^2-9)e_c^2\alpha\alpha_s^2}{9\pi M^2}|R(0)|^2 \quad (2)$$

The minimal number of gluons into which a ${}^3S_1$ state of a heavy quark pair can annihilate is three, since the process through one virtual gluon is forbidden by colour and a two-gluon final state is excluded by the negative C parity of the initial state. The decay rate is the lowest order in QCD can be found by decorating the orthopositronium decay formula with the appropriate colour factor, while the first QCD radiative correction is known by numerically, and being expressed in terms of α_s normalized at the scale m_c in the $\bar{M}S$ scheme reads as [2],

$$\Gamma(n^3S_1 \to 3g) = \frac{40}{81}\frac{\pi^2-9}{\pi}\frac{\alpha_s^3(m_c)}{M^2}|R(0)|^2 \quad (3)$$

Phenomenology

For the description of mass spectra and form of wave function of charmonium state we adopt here the potential model with the potential as $V(r) = -\alpha_s/r + Ar^\nu$. Here A and ν are the potential strength and potential exponent respectively. For the present study we vary range of potential exponent as $0.1 \le \nu \le 2.0$. For different choices of potential exponent ν radial wave functions are obtained by solving the nonrelativistic schrodinger equation numerically. Computed values of the branching ratios from Eqn. 1, 2 and 3 are drawn as function of potential exponent, ν in Fig. 1, 2 and 3.

Results and Discussion

As seen from Fig. 1, 2 and 3 our predicted branching ratios agrees with the experimental data within their respective error bar [4] in the range of potential exponent $0.5 \le \nu \le 0.8$ which is lower than the ν ($\nu \approx 1.1$) as observed for the charmonium spectroscopy [5]. So we conclude here that the decay of charmonium states occur at quark-antiquark interaction comparatively weaker than that correspond to their bound state formation.

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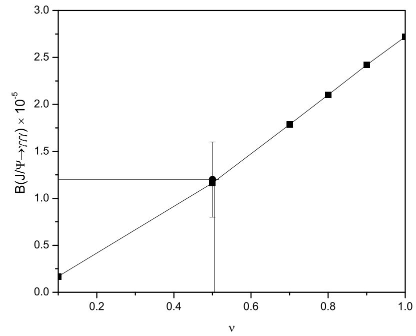

FIG. 1: Branching ratio for $\gamma\gamma\gamma$ charmonium decay

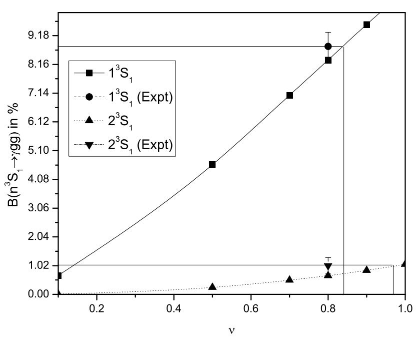

FIG. 2: Branching ratio for γgg charmonium decay

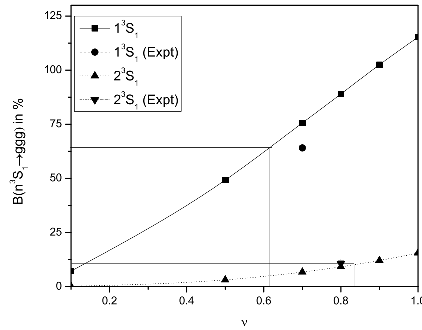

FIG. 3: Branching ratio for ggg charmonium decay

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