Decay properties of heavy quarkonia employing Cornell potential

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Quarkonia are the mesonic states having both the quark of the same type and out of which heavy quarkonia refer to the bound state of charm and/or bottom quark. These flavorless mesons are one of the very important tool to understand the strongly interacting systems. First heavy quarkonium state J/ψ which is the bound state of charm and anticharm quarks ($c\bar{c}$) was discovered in Stanford Linear Accelerator and Brookhaven National Laboratory in 1974. First bottomonium state ($b\bar{b}$) discovered at Fermilab in 1977. In 1998, CDF collaboration reported the first mixed heavy quarkonium state $c\bar{b}$ (B_c meson) discovered. According to the Particle Data Group, there are more then 20 heavy quarkonium states were discovered experimentally. These states are not only identified in their ground state and also their excited states are well reported with sufficient significance [1].

On theoretical front, there are numerous ways in which these states are studied world wide. Out of which, the oldest and still applicable one is the potential model formalism, in which the interacting potential is considered to be of the type Coulomb plus linear confinement potential. This potential is also known as Cornell potential [2]. In the literature, other phenomenological approaches include relativistic and nonrelativistic potential models. It is important to note that Cornell potential is the most widely accepted potential model and it is also supported by lattice quantum chromodynamics simulations [3, 4]. These theoretical models have successfully computed the mass spectra of heavy quarkonia however many decay properties computations are still deviating from the experimental data [5, 6].

Recently, we have studied the mass spectra and weak decay properties of charmonia, bottomonia and B_c mesons [7, 8]. For computation of mass spectra, we consider the interacting potential between quark and antiquark of the form Cornell potential given by

$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + Ar,$$

where A is the confinement strength and α_s is the string running coupling constant. We compute the mass spectra by numerically solving the Schrödinger equation for Cornell potential. Here the potential parameters such as quark masses and confinement strengths are fine tuned to obtain the experimental ground state masses for charmonia and bottomonia. For computation of excited state spectra, we employ the spin dependent part of confined one gluon exchange potential nonperturbatively. We compare our findings with experimental data, lattice simulations and different other theoretical approaches such as relativistic potential models, nonrelativistic potential models and it is observed that our results are in good agreement with most of the literature. In Fig. 1, we present our mass spectra of charmonia and bottomonia along with the comparison with the Particle Data Group (PDG) [1]. PDG Quarkonium states are identified with various decay channels in world wide experimental facilities. These decay properties are reported mostly for the

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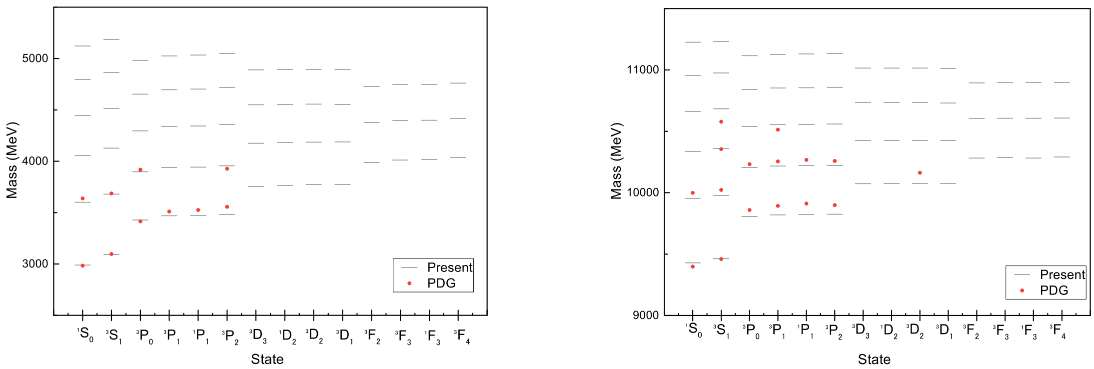

FIG. 1: Mass spectrum of charmonia (left) and bottomonia (right) [8].

ground states only. For excited states, the precise decay rates are still not available. We use these opportunity to compute the decay properties for ground states and predict for the higher excited states. Using the numerical wave function and other potential parameters, we compute various weak decay properties of charmonia and bottomonia employing nonrelativistic Van Royen Weiskopf formula. We compute several weak decay properties such as leptonic decay constants, digamma, digluon, dilepton, three gamma, three gluon, gamma-digluon, charge radii as well as electromagnetic transition rates. We also compare our findings with the experimental data and many other theoretical predictions and it is observed that our results are well agreement with the most of the literature. Using the spectator model [9], we also compute the weak decays of B_c mesons and determined the life time of the B_c meson to be 0.539 ps which is also in good resemblance with the PDG data. Detailed study regarding mass spectra and decay formalism, we suggest the readers to refer the ref. [7, 8]. We have also very recently studied the bottomonium spectroscopy using the potential nonrelativistic quantum chromodynamics (pNRQCD) formalism [10]. Here, we consider the interaction between the constituents of the form Cornell plus pNRQCD correcting term.

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