Spectroscopic of Heavy (c, b) Flavoured Mesons in Screening Potential

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Summary

Many experimental facilities (LHCb, ATLAS, CERN, BELLE, BABER etc.) continuous provided us information regarding spectroscopy of Charm and Bottom meson [1]. At large or short distance potential model provided quantitative and qualitative analysis of C and B mesons. The success of various of theoretical (phenomenological) model like relativistic quark model[2], Non- relativistic quark model [3, 4, 6, 7] are help us for more calculation of Quarkonia ($Q\bar{Q}$) and heavy-light ($Q\bar{q}$) mesons spectroscopy. Quarkonia are solved by nonperturbative approches like NRQCD in ground states aspects for QCD demand extension [4, 5]. For short distance running coupling constant (α_s) is important parameter in heavy quark (m_Q) while for long distant non relativistic function ($\mathcal{O}$ ($\frac{1}{m}$)) or its derivative. Among all potential we have chosen screening potential $V_s(r) = \frac{A}{\mu}(1 - e^{-\mu r})$ for better improvisation. Using screening potential we calculated : Mass spectra of mesons, Decay constants, Leptonic branching fractions, Electromagnetic transitions, Rgge-trajectories, Mixing Oscillations and Decay widths in present thesis
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The phenomenological potential well working in light-heavy ($q\bar{Q}$) and heavy-heavy ($Q\bar{Q}$) flavour mesons. Hence, for the study of the bound states of mesons, we apply semi-relativistic Hamiltonian [3, 7].

$$H = \sqrt{p^2 + m_Q^2} + \sqrt{p^2 + m_{\bar{q}}^2} + V(\tilde{r}); \quad (1)$$

here, p is the relative momentum of the quark anti-quark, m_q and $m_{\bar{Q}}$ are light (up/down) and heavy (charm/beauty) quark masses. The kinetic energy part of the Hamiltonian has been expanded up to $\mathcal{O}(\vec{p}^{10})$ to accompany the relativistic effects.

$$\begin{aligned} K.E \ = \ & \frac{\mathbf{p}^2}{2}\left(\frac{1}{m_Q} + \frac{1}{m_{\bar{q}}}\right) - \frac{\mathbf{p}^4}{8}\left(\frac{1}{m_Q^3} + \frac{1}{m_{\bar{q}}^3}\right) \\ & + \frac{\mathbf{p}^6}{16}\left(\frac{1}{m_Q^5} + \frac{1}{m_{\bar{q}}^5}\right) - \frac{5\mathbf{p}^8}{128}\left(\frac{1}{m_Q^7} + \frac{1}{m_{\bar{q}}^7}\right) \\ & + \frac{7\mathbf{p}^{10}}{256}\left(\frac{1}{m_Q^9} + \frac{1}{m_{\bar{q}}^9}\right) \end{aligned} \quad (2)$$

For spin-independent port, we have chosen below potential for calculations[12–14]

$$V(\vec{r}) = -\frac{4}{3}\frac{\alpha_s}{r} + \frac{A}{\mu}(1 - e^{-\mu r}) + V_0 \quad (3)$$

Incorporating a first order QCD correction factor in the Van-Royan-Weisskopf Formulla [8]. We compute decay constants using this relation,

$$f_{p/v}^2 = \frac{12|\Psi_{p/v}(0)|^2}{M_{p/v}}\bar{C}^2(\alpha_s) \quad (4)$$

Where $\bar{C}^2(\alpha_s)$ is the QCD correction factor given by [8].

$$\bar{C}^2(\alpha_s) = 1 - \frac{\alpha_s}{\pi}\left[2 - \frac{m_Q - m_{\bar{q}}}{m_Q + m_{\bar{q}}} ln\frac{m_Q}{m_{\bar{q}}}\right] \quad (5)$$

The leptonic branching fraction for mesons are obtained using the formula

$$BR = \Gamma \times \tau \quad (6)$$

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here, τ is life time and Γ is the leptonic, semi-leptonic, weak, radiactive-leptonic and rare-leptonic decay width,[9]

$$\Gamma(p \to l\nu_l) = \frac{G_F^2}{8\pi} f_p^2 \left|V_{cq/bq}\right|^2 m_l^2 \left(1 - \frac{m_l^2}{m_p^2}\right)^2 m_p \quad (7)$$

The study of the radiative transition, in addition to the study of the mass spectrum is essential to understand the theory of strong interaction in the nonperturbative regime of QCD. Such transitions have a distance from the begging state ($n^{2S+1}L_J$) to the last state, ($n^{'2S+1}L^{'}_{J'}$)[10, 11]. Regge-trajectories are the combination of two Quantities: One total angular momentum quantum number (J) and two square of mass (M^2). RT is an important parameter to identify the quantum number for the phenomenological model. RT plays a major role in determining the theoretical state and confirming the quantum number for the specific state is given. We use our predicted masses to investigate RT in (J, M^2) and (n_r, M^2) planes. M is mass of meson state, n_r is a radial quantum number and J is total angular momentum quantum number. The VRW formula and the NRQCD technique can be used to compute the annihilation decay width. Using the spectroscopic parameters from the present study we discuss the mass oscillations of neutral open charm/beauty mesons and integrated oscillation rate.

Results and Discussion

The Gaussian wave function is used to determine the properties of light-heavy ($q\bar{Q}$) and heavy-heavy ($Q\bar{Q}$) flavoured mesons. The screened potential shrinks the masses of higher excited states. For D mesons, $D_J(3000)^0$, $D_J^*(3000)^0$, $D_2^*(3000)$, $D_2^*(2460)^0$, $D_2^*(2460)^+$, $D(2750)^0$ as a 3^3S_1, 3^3P_2, 1^3P_2, 3^1S_0, 1^1D_2 respectively. For D_s mesons, $D_{s2}(2573)^{\pm}$, $D_{s1}^*(2860)^{\pm}$, $D_{sJ}(3044)^{\pm}$, $D_{s1}^*(2700)^{\pm}$ as a 1^3P_2, 1^3D_1, 1^3P_2, 2^3S_1 respectively. For B mesons, $B_J^*(5732)^+$, $B_J(5970)^+$ and $B_J(5970)^0$ as a 1^3P_0, 2^3S_1 respectively. For B_s mesons $B_{sJ}(6064)$ is fitted for 1^1D_2. For $c\bar{c}$ mesons $\chi_{c1}(3511)$, $\chi_{c2}(3556)$, $\chi_{c2}(3930)$ as a 1^3P_1, 1^3P_2, 2^3P_2 respectively. For $b\bar{b}$ mesons $\chi_{b1}(1P)$, $h_b(1P)$, $\chi_{b2}(1P)$, $\eta_b(9999)$, $\Upsilon(1D)$ as a 1^3P_1, 1^1P_1, 1^3P_2, 2^1S_0, 1^3D_2. In bottom meson magnitude dipole (M1) transition $B(1^3S_1) \to B(1^3S_0)$ is exactly matched with experimental result[1]. Many states of E1 and M1 transitions in $c\bar{c}$ and $b\bar{b}$ mesons are closely matched with experimental states of S and P waves. Above all ($q\bar{Q}$) and ($Q\bar{Q}$) flavoured mesons states, the Regge-trajectories are constructed in (n_r, M^2) and (J, M^2) planes. The various decay properties experimentally unknown for Heavy (c, b) flavoured mesons are calculated which are provided valuable information for future research.

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