Mass Spectra of B_c Meson with with Instanton Potential

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Introduction

The bottom-charm (B_c) mesons are consisting of heavy quarks with different flavours (b and c), they provides an opportunity to study the non-relativistic limit of quantum chromodynamics. The difference of quark flavours forbids annhilation into gluons. Thus B_c mesons are stable than bottomonium and charmonium states. The ground state of the meson is intermediate between bottomonium and charmonium systems [3–5].

Theoretical Background

In the approach to the potential model, all quark dynamics in meson is governed by a Hamiltonian which is composed of a kinetic energy term K and a potential energy term V. The potential energy V is the sum of heavy-quark potential $V_{Q\bar{Q}}(\vec{r})$, confining potential $V_{conf}(\vec{r})$ and coulomb potential $V_{coul}(\vec{r})$, that is,

$$V(\vec{r}) = V_{Q\bar{Q}}(\vec{r}) + V_{coul}(\vec{r}) + V_{conf}(\vec{r}) \quad (1)$$

The heavy quark potential $V_{Q\bar{Q}}(\vec{r})$ is,

$$V_{Q\bar{Q}}(\vec{r}) = V_C(\vec{r}) + V_{SD}(\vec{r}) \quad (2)$$

Here, $V_C(\vec{r})$ and $V_{SD}(\vec{r})$ are central and spin dependent potentials due to instant-on vacuum respectively $V_C(\vec{r})$ is given by the following expression

$$V_C(\vec{r}) \simeq \frac{4\pi\bar{\rho}^3}{\bar{R}^4 N_c}\left(1.345\frac{r^2}{\bar{\rho}^2} - 0.501\frac{r^4}{\bar{\rho}^4}\right) \quad (3)$$

Here, $\rho = \frac{1}{3}$ fm is the average size of the instant on, $\bar{R} = 1$ fm is the average separation between instantaneous and number of colors N_C is 3. The spin-spin interaction, $V_{SS}(\vec{r})$, the spin orbit coupling term $V_{LS}(\vec{r})$ and the tensor part $V_T(\vec{r})$ contribute to the spin dependent potential $V_{SD}(\vec{r})$:

$$V_{SD}(\vec{r}) = V_{SS}(\vec{r}) + V_{LS}(\vec{r}) + V_T(\vec{r})$$

$$V_{SS}(\vec{r}) = \frac{1}{3m_Q{}^2}\nabla^2 V_C(\vec{r}); \;\; V_{LS}(\vec{r}) = \frac{1}{2m_Q{}^2}\frac{1}{r}\frac{dV_C(\vec{r})}{dr};$$

$$V_T(\vec{r}) = \frac{1}{3m_Q{}^2}\left(\frac{1}{r}\frac{dV_C(\vec{r})}{dr} - \frac{d^2V_C(\vec{r})}{dr^2}\right).$$

The coulomb-like (Perturbation)one gluon exchange part of potential is given by,

$$V_{coul}(\vec{r}) = \frac{-4\alpha_s}{3r} \quad (4)$$

With the strong coupling constant α_s and inter quark distance r. The confinement term represents the non perturbation effect of QCD which includes the spin independent linear confinement term[8]

$$V_{conf}(\vec{r}) = -\left[\frac{3}{4}V_O + \frac{3}{4}cr\right]F_1 \cdot F_2 \quad (5)$$

where c and V_O are constants. F is related to Gell-Mann matrix, $F_1 = \frac{\lambda_1}{2}$ and $F_2 = \frac{\lambda_2^*}{2}$ and $F_1 \cdot F_2 = \frac{-4}{3}$ for the mesons.

Results and Discussions

In our work, we have used the three-dimensional harmonic oscillator wave function which has been extensively used in atomic and nuclear physics is used as the trial wave function for obtaining the $Q\bar{Q}$ mass spectrum.

TABLE I: B_c meson mass spectrum (in MeV)

State	This Work	[3]	[7]	[9]	[10]	[11]
1^1S_0	6268	6275	6278	6272	6275	6274.47±0.32
1^3S_1	6349	6357	6331	6333	6331	
1^3P_0	6705	6638	6748	6699	6770	
$1P$	6725	6686	6767	6743	6781	
$1P'$	6748	6734	6769	6750	6793	
1^3P_2	6717	6737	6775	6761	6804	
1^3D_1	6952	6973	7030	7021	7142	
$1D$	6952	6974	7025	7025	7148	
$1D'$	7063	7003	7035	7026	7155	
1^3D_3	7022	7004	7026	7029	7146	
2^1S_0	6856	6862	6863	6842	6852	6871.2±1.0
2^3S_1	6895	6897	6873	6882	6890	
2^3P_0	7099	7084	7139	7094	7166	
$2P$	7135	7137	7155	7134	7176	
$2P'$	7167	7173	7156	7147	7185	
2^3P_2	7157	7175	7162	7157	7194	
$2D$	7370	7385	7361	7399		
$2D'$	7407	7408	7370	7400		
2^3D_3	7402	7410	7363	7405		
3^1S_0	7212	7308	7244	7226	7236	
3^3S_1	7261	7333	7249	7258	7268	

$$\psi_{nlm}(r,\theta,\phi) = N\left(\frac{r}{b}\right)^l L_n^{l+1/2}(\frac{r}{b}) exp\left(-\frac{r^2}{2b^2}\right) Y_{lm}(\theta,\phi)$$

where $|N|$ is the normalizing constant given by

$$|N|^2 = \frac{2\alpha^3 n!}{\sqrt{\pi}} \frac{2^{(2(n+l)+1)}}{(2n+2l+1)!}(n+l)! \qquad (6)$$

and $L_n^{l+1/2}(x)$ are the asst. Laguerre polynomials.

We use the following set of parameter values: $m_c = 1480.0$ MeV, $m_b = 4750.0$ MeV, $b = 0.350$ fm, $\alpha_s = 0.300$, $a_c = 145 MeV$ fm^{-1}

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