# The masses and decay constant of $B_c$ meson

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## Introduction

The $B_c$ meson are made up of two heavy quarks with differing flavour $B$ and $C$, according to conventional quark-model assignments. The experimental information of the $B_c$ meson is still extremely limited today. Recently the collaboration of LHCb and CMS provided us ground state as well excited state of $B_c$ mesons [2, 4]. [$B_c^+ = 6.274 \pm 0.027 \pm 0.017$ GeV and $B_c^+(2S) = 6.871 \pm 0.001 \pm 0.008$ GeV ]. The recent result from lattice QCD calculation $m_{B_c^*} = 6331 \pm 7$ MeV [5]. Because $B_c$ is the only heavy flavour meson with different charge and flavour, its decay properties are expected to differ from those of flavour neutral mesons. Due to $m_{B_c^*} - m_{B_c} \simeq 57$ MeV , the isospin violating decay $B_c^* \to B_c\pi$ is expressly forbidden by the law of energy conservation. Because of $m_{B_c^*} - m_{B_c} \simeq 57$ MeV , the isospin violating decay $B_c^* \to B_c\pi$ is expressly forbidden by the law of energy conservation. As a result, the dominant decay mode should be the electromagnetic radiative transition $B_c^* \to B_c\gamma$ [6]. There will be more than $3 \times 10^{10}$ $B_c^*$ events corresponding to a dataset of 300 $fb^1$ at LHCb for pp collisions. Hence, the $B_c^{*-} \to \tau^-\nu_\tau, \mu^-\nu_\mu, e^-\nu_e$ decays are expected to be carefully measured at LHCb experiments in the future

## Mass spectrum of bottom-charm

Inspired from experimental observation as well theoretical prediction, we measured the $q\bar{Q}$ mass spectra and decay properties within commonly used coulomb plus linear potential [Cornell potential $\mathcal{O}(\frac{1}{m})$][17, 18]. The Cornell potential well working in heavy-light and heavy-heavy flavours, hence for bound states study of $B_c$ meson we apply non-relativistic Hamiltonian [11, 12].

The following Hamiltonian has been employed to study the heavy-light bound state system[13],

$$H = \sqrt{p^2 + m_1^2} + \sqrt{p^2 + m_{\bar{2}}^2} + V(\mathbf{r}); \quad (1)$$

Here, $p$ is the relative momentum of the quark anti-quark, $m_1$ and $m_{\bar{2}}$ are heavy(charm) and light(up/down) quark masses. The kinetic energy part of the Hamiltonian has been expanded up to $\mathcal{O}(p^{10})$ to accompany the relativistic effects. The quark anti-quark potential $V(\mathbf{r})$ is of the form [16]

$$V(r) = V^{(0)}(r) + \left(\frac{1}{m_1} + \frac{1}{m_{\bar{2}}}\right) V^{(1)}(r) + \mathcal{O}\left(\frac{1}{m^2}\right); \quad (2)$$

TABLE I: Mass spectra of $B_c$ meson . (in GeV).

| State $n^{2S+1}L_J$ | $J^P$ | Present study | PDG [1] | [8] | [9] | [10] | [15] |
|---|---|---|---|---|---|---|---|
| $1^1S_0$ | $0^-$ | 6.275 | $6.274 \pm 0.8$ | 6.278 | 6.269 | 6.349 | 6.270 |
| $1^3S_1$ | $1^-$ | 6.332 | | 6.331 | 6.337 | 6.373 | 6.332 |
| $2^1S_0$ | $0^-$ | 6.858 | 6.842± 4 [3]<br>6.871[3]<br>6.872[3] | 6.853 | 6.743 | 6.821 | 6.835 |
| $2^3S_1$ | $1^-$ | 6.868 | | 6.873 | 6.767 | 6.855 | 7.072 |

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## Decay Constant ($f_{p/v}$) of $B_c$

The decay properties of $B_c^+$ meson is interest of as it decays only through weak interactions [10, 14]. Incorporating a first order QCD correction factor in the Van-Royan-Weisskopf Formulla [7]. We compute decay constants using this relation,

$$f_{p/v}^2 = \frac{12|\Psi_{p/v}(0)|^2}{M_{p/v}}\bar{C^2}(\alpha_s) \qquad (3)$$

Where $\bar{C^2}(\alpha_s)$ is the QCD correction factor given by [7]. The computed $f_{p/v}$ for $B_c$ meson using Eq.(1) are tabulated in Table II. Results of the vector decay constant without and with QCD correction compare with other phenomenological model.[8, 9, 15].

TABLE II: Decay constant ($f_{p/v}$) (in GeV).

| Meson | State | 1S | 2S | 3S |
|---|---|---|---|---|
| $B_c$ | $f_{Pcor}$ | 0.410 | 0.165 | 0.112 |
| | $f_p$ | 0.479 | 0.192 | 0.131 |
| | [8] | 0.469 | 0.289 | 0.256 |
| | [9] | 0.525 | | |
| | [15] | 0.433 | | |

## Results and Discussion

We were able to successfully estimate the 1S and 2S - wave masses and decay constant $B_c$ meson using a non relativistic screening coulomb potential system using a variational approach in Tables I and II. Mass spectrum and decay constants are computed for the potential index $\nu$ is 1.0. The ground state $1^1S_0$ is exactly matched with experimental results [1] and other theoretical model[8–10, 15]. The decay constant with QCD correction for $B_c$ meson is 0.410 GeV, which is underestimated and without QCD correction is 0.479 GeV, agreement with Ref.[8, 9, 15]. A simple non relativistic variational method with Screening potential employed in the present study is found to be quite successful in predicting various properties of $B_c^+$ meson. The method can be useful to study various hadronic and radiative transitions of the charm-beauty system.

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