# Bc Meson : Decay modes and Life-time

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## Introduction

Decays of beauty quark are crucial in understanding the violation of the standard model [1]. And the understanding of the simplest bound systems of a quark are necessary in order to understand the quark dynamics. Here we focus on the decays of bound system of beauty and charm quark.

## Consideration of the Potential

The success of Martin potential eqn.(1) in explaining the spectroscopic properties of quarkonium like $c\bar{c}$ and $b\bar{b}$ [2] draws our attention towards explaining the similiar system which is the charmed beauty meson ($c\bar{b}$)

$$V(r) = \lambda r^{\nu} + V_0. \tag{1}$$

where $\nu = 0.1$

## 1. Decay constants

We calculated pseudoscalar and vector decay constants using the modified Van-Royen-Weisskopf formula [3]

$$f_{B_c} = \sqrt{\frac{3}{\pi M_{B_c}}}|R_{10}|^2 \tag{2}$$

where $R_{10}$ is the value of radial wavefunction of the ground state of the meson at origin [4].

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## Pure-Leptonic Decay

The decay width for pure leptonic decay of $B_c$ meson ($B_c \to l^- \nu_l$) can be written as [7]

$$\Gamma = \frac{G_F^2}{8\pi^2}|V_{cb}|^2 f_{B_c}^2 m_{B_c}^3 \frac{m_l^2}{m_{B_c}^2}\left(1 - \frac{m_l^2}{m_{B_c}^2}\right)^2, \tag{3}$$

where,
$G_F = 1.6638 \times 10^{-5} GeV^{-2}$[10],
$V_{cb} = 41 \times 10^{-3}$[10],
$f_{B_c}$ = Pseudoscalar Decay Constant, and
$m$ = maases of corresponding subscript

## Radiative-Leptonic Decay

The pure Leptonic Decays are helicity suppresed [7], so we calculate the Radiative-leptonic decay width using the results of [7]

$$\Gamma[B_c \to \gamma l^- \nu_l] = \frac{\alpha G_F^2 |V_{cb}|^2}{2592\pi^2} f_{B_c}^2 m_{B_c}^3 \times \left[\left(3 - \frac{m_{B_c}}{m_b}\right)^2 + \left(3 - 2\frac{m_{B_c}}{m_c}\right)^2\right] \tag{4}$$

## 2. Life-time

We have also predicted the lifetime of the $B_c$ meson using the spectator model [9],which gives the total decay width of the $B_c$ meson as

$$\Gamma(B_c \to X) = \Gamma(b \to X) + \Gamma(c \to X) + \Gamma(Ann.) \tag{5}$$

where,

$$\Gamma(b \to X) = 9\frac{G_F^2 |V_{cb}|^2 m_b^5}{192\pi^3}, \tag{6}$$

$$\Gamma(c \to X) = 5\frac{G_F^2 |V_{cs}|^2 m_c^5}{192\pi^3} \quad (7)$$

and

$$\Gamma(Ann.) = \frac{G_F^2}{8\pi}|V_{bc}|^2 f_{B_c}^2 M_{B_c} \sum m_i^2 \left(1 - \frac{m_i^2}{m_{B_c}^2}\right)^2 C_i \quad (8)$$

where, the summation is for two values of $m_i$ and $C_i$ (i.e., $m_i = m_c$ & $C_i = 3|V_{cs}|^2$ for $\bar{c}s$ channel and $m_i = m_\tau$ & $C_i = 1$ for $\tau\nu_\tau$ channel).

## Result and Discussion

### A. Decay Constants

The values that we predict using eqn. (2) are
$f_p = 0.4674 GeV$, and
$f_v = 0.4652 GeV$
which are comparable with other theoretical predictions [5],[6].

### B. Pure-Leptonic Decay

In the **TABLE I** & **II**, we have mentioned the decay widths (DW) and the branching ratios (BR) that we have found for the pure leptonic decays and the orders are comparable with Ref. [8]

**TABLE I :** Pure Leptonic decay widths(DW)

| Lepton | [our] DW($GeV$) | [8] DW($GeV$) |
|---|---|---|
| $e$ | $2.82909 \times 10^{-21}$ | $1.827 \times 10^{-21}$ |
| $\mu$ | $1.20956 \times 10^{-16}$ | $0.7841 \times 10^{-21}$ |
| $\tau$ | $2.73207 \times 10^{-14}$ | $1.862 \times 10^{-21}$ |

**TABLE II :** Pure Leptonic branching ratios(BR)

| Lepton | [our] BR | [8] BR |
|---|---|---|
| $e$ | $2.19205 \times 10^{-9}$ | $1.44 \times 10^{-9}$ |
| $\mu$ | $0.937201 \times 10^{-4}$ | $0.62 \times 10^{-4}$ |
| $\tau$ | $2.11688 \times 10^{-2}$ | $1.47 \times 10^{-2}$ |

### C. Radiative-Leptonic Decay

we found the radiative-leptonic decay width using eqn.(4) to be $7.85417 \times 10^{-17} GeV$ which gives the branching ratio for the radiative leptonic decay width of the $B_c$ meson to be $6.08561 \times 10^{-5}$. Here the results are comparable with $4.9 \times 10^{-5}$ Ref. [7].

### D. Life-Time

We found the Life-time of the $B_c$ to be $3.66787 \times 10^{-13} s$ ($0.366787 ps$) which is nearly comparable with the experimental $0.510 \pm 0.009 ps$[10].

As expected from the Martin potential, it can also explain some of the decay properties of the charmed beauty meson

## References


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