Rare decays of B and B_s mesons

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Introduction

There has been great amount of interest in recent times for the study of rare decay processes such as $B_s \to \mu^+\mu^-$ as they offer opportunities to probe physics beyond the standard model [1]. Though the present experimental data for these rare leptonic decays are available with lesser precision [2], future experimental efforts are expected to provide high precision data [3].

Theory

Flavor-changing neutral currents (FCNCs) in leptonic and semileptonic decays of charmed mesons are of higher order, very suppressed modes in the standard model (SM) of particle interactions. The rare leptonic decays, $B_q \to \ell^+\ell^-$ where $q \in d, s$ and $\ell = e, \mu, \tau$ are fully dominated by internal top-quark contributions proceed through loop diagrams (see Fig.1) and is of fourth order in the weak coupling[4].

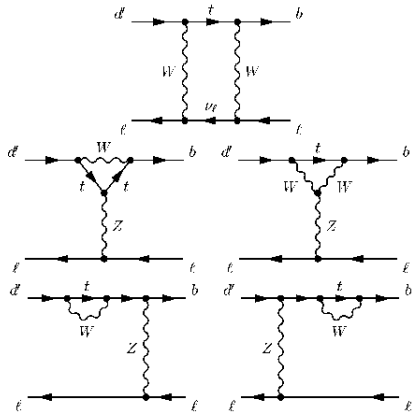

FIG. 1: Dominant SM diagrams for $B_{s,d} \to \ell^+\ell^-$

Evaluating the hadronic matrix elements, the rare leptonic branching ratio is given by [5]

$$B(B_q \to \ell^+\ell^-) = \frac{G_F^2\alpha^2 m_{B_q}^3 \tau_{B_q} f_{B_q}^2}{64\pi^3}|V_{tb}^* V_{tq}|^2 \times \sqrt{1-\frac{4m_\ell^2}{m_{B_q}^2}}\left[\left(1-\frac{4m_\ell^2}{m_{B_q}^2}\right)\left|\frac{m_{B_q}}{m_b+m_q}C_s\right|^2 + \left|\frac{2m_\ell}{m_{B_q}}C_{10} - \frac{m_{B_q}}{m_b+m_q}C_P\right|^2\right] \quad (1)$$

Where all the notations have their usual meanings. Here, C_{10}, C_S and C_P are the Wilson coefficients. In the case $C_S = C_P = 0$ the theory is limited to the standard model.

Methodology

To obtain the spectroscopic related input parameters such as masses and the wave functions, we employ the potential model with $V(x) = -\alpha_c/r + Ar^\nu$ [6]. Where A and ν are the potential strength and potential index respectively. For the present study we have adopted the numerical method to solve the non relativistic Schrödinger equation.

The decay constants (f_{B_q}) are calculated using the respective wave function and the meson mass. All other parameters are taken from PDG [2]. The computed leptonic widths with different choices of the inter quark potential index ν are tabulated.

Results and Conclusion

Our results for $B \to \ell^+\ell^-$ with the potential index in the range $0.1 < \nu < 1.0$ are in accordance with the theoretical predictions of [5] within their estimated uncertainties. And that for $B_s \to \ell^+\ell^-$ lie in the narrow range

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TABLE I: $B_q \to \ell^+\ell^-$ decay widths in GeV

	B decays			B_s decays		
ν	e^+e^-	$\mu^+\mu^-$	$\tau^+\tau^-$	e^+e^-	$\mu^+\mu^-$	$\tau^+\tau^-$
0.1	1.86×10^{-15}	0.79×10^{-10}	1.67×10^{-8}	0.93×10^{-14}	0.40×10^{-9}	0.85×10^{-7}
0.3	3.40×10^{-15}	1.45×10^{-10}	3.04×10^{-8}	2.35×10^{-14}	1.00×10^{-9}	2.13×10^{-7}
0.5	4.70×10^{-15}	2.01×10^{-10}	4.19×10^{-8}	3.97×10^{-14}	1.70×10^{-9}	3.60×10^{-7}
0.7	5.77×10^{-15}	2.47×10^{-10}	5.14×10^{-8}	5.70×10^{-14}	2.44×10^{-9}	5.16×10^{-7}
0.8	6.27×10^{-15}	2.68×10^{-10}	5.58×10^{-8}	6.56×10^{-14}	2.80×10^{-9}	5.93×10^{-7}
0.9	6.72×10^{-15}	2.87×10^{-10}	5.98×10^{-8}	7.48×10^{-14}	3.20×10^{-9}	6.76×10^{-7}
1.0	7.13×10^{-15}	3.05×10^{-10}	6.34×10^{-8}	8.37×10^{-14}	3.58×10^{-9}	7.56×10^{-7}
1.1	7.50×10^{-15}	3.20×10^{-10}	6.66×10^{-8}	9.31×10^{-14}	3.98×10^{-9}	8.41×10^{-7}
1.3	8.12×10^{-15}	3.47×10^{-10}	7.21×10^{-8}	11.13×10^{-14}	4.76×10^{-9}	10.04×10^{-7}
1.5	8.71×10^{-15}	3.72×10^{-10}	7.72×10^{-8}	12.88×10^{-14}	5.50×10^{-9}	11.62×10^{-7}
[5]	$3.8^{+3.0}_{-2.2} \times 10^{-15}$	$1.6^{+1.3}_{-0.9} \times 10^{-10}$	$3.4^{+2.7}_{-2.0} \times 10^{-8}$	$10^{+0.2}_{-0.2} \times 10^{-14}$	$4.3^{+0.9}_{-0.8} \times 10^{-9}$	$9.2^{+1.9}_{-1.8} \times 10^{-7}$
[7]	4.2×10^{-15}	1.8×10^{-10}		$6.1 \times 10{-}14$	2.6×10^{-9}	
[2]	$< 8.3 \times 10^{-8}$	$< 1.5 \times 10^{-8}$	$< 4.1 \times 10^{-3}$	$< 2.8 \times 10^{-7}$	$< 4.7 \times 10^{-8}$	

of the potential index $1.1 < \nu < 1.3$ for all the three cases of leptonic pairs. While, the present results agree with that of [7] with a very narrow range of the potential index $0.3 < \nu < 0.5$ in the case of $B \to \ell^+\ell^-$ and $0.7 < \nu < 0.8$ in the case of $B_s \to \ell^+\ell^-$. All the results lie within the limit given by the PDG [2]. Thus we conclude that the rare decays of B meson occur relatively at weaker interquark interaction compared to that of the rare decays of B_s meson.

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