Heavy Quarks and LCSRs

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1 de diciembre de 2016

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Lepton mass effects in semileptonics B meson decays provide an excellent environment for the study of the fundamental parameters of the Standard Model (SM). Taking into account that incoming years the production of B mesons in the PEP-II, KEKII[1] and LHCb factories will increase (and respective experiments Belle an BaBar[2]), it might be expected that some of these processes will be available for experiment.

Physics BSM is expected to be discovered at the LHC. Currently in the literature there ares studies of the fractions $R = \frac{\mathcal{B}(B \to D\tau\nu_\tau)}{\mathcal{B}(B \to D\ell\nu_\ell)}$ and $R^* = \frac{\mathcal{B}(B \to D^*\tau\nu_\tau)}{\mathcal{B}(B \to D^*\ell\nu_\ell)}$

We do the calculation of the decays fractions R and R^* using Heavy Quarks and LCSRs models.

Commonly in the literature we find two different parametrizations for the hadronic matrix element $\langle D|j_\mu|B\rangle$, and are given by

$$\langle D|j_u|B\rangle_1 = (P_B + P_D - \frac{m_D^2 - m_D^2}{q^2} q)_\mu F_1(q^2) + \frac{P_B + P_D}{q^2} q_\mu F_0(q^2) \quad (1)$$

$$\langle D(p_D)|V_\mu|\bar{B}(p_B)\rangle_2 \equiv f_+(p_B + p_D)_\mu + f_-(p_B - p_D)_\mu \quad (2)$$

The relation between form factors given by these two parametrizations is,

$$F_0(q^2) = f_+(q^2) + (q^2/(m_B^2 - m_D^2)) \times f_-(q^2) \tag{3}$$

,

$$F_1(q^2) = f_+(q^2) \tag{4}$$

and for the hadronic matrix element $\langle D^*|j_u|B\rangle$, and are given by

$$\langle D^*|J|B\rangle_1 = \frac{2}{m_B + m_{D^*}}\epsilon_{\mu\nu\rho\sigma}\epsilon^{*\nu}P_B^{\rho}P_{D^*}^{\sigma}V(q^2)$$
$$+i[\epsilon_{\mu}^{*}(m_B + m_{D^*})A_1(q^2) - \frac{\epsilon^* q}{m_B + m_{D^*}}(P_B + A_{D^*})_{\mu}$$
$$A_2(q^2) - \frac{\epsilon^* q}{q^2}2m_{D^*}q_{\mu}A_3(q^2) + \frac{\epsilon^* q}{q^2}2m_{D^*}q_{\mu}A_0(q^2)] \quad (5)$$

$$\langle D^*|J|B\rangle_2 = ig\epsilon_{\mu\nu\rho\sigma}\epsilon^{*\nu}(P_B + P_{D^*})^{\rho}(P_B - P_{D^*})^{\sigma}$$
$$-[f\epsilon_{\mu}^{*} + \epsilon^* P_B[a_+(P_B + P_{D^*})_{\mu} + a_-(P_B - P_{D^*})_{\mu}]] \quad (6)$$

The relation between form factors given by these two parametrizations is

$$A_0(q^2) = \frac{i}{2m_{D*}}[f(q^2) + a_-(q^2) + (m_B^2 - m_{D*}^2)a_+(q^2)] \tag{7}$$

$$A_1(q^2) = \frac{if(q^2)}{(m_B^2 + m_{D*}^2)} \tag{8}$$

$$A_2(q^2) = -i(m_B^2 + m_{D*}^2)a_+(q^2) \tag{9}$$

$$V(q^2) = (m_B^2 + m_{D*}^2)g(q^2). \tag{10}$$

To compare the parametrizaciÃșn given in of the WSB, HQ, LCSS models, we perform a similar process as above. The differential decay width of $B \to D\ell\nu_\ell$ over q^2 can be written as.

$$\frac{d}{dq^2}\Gamma(B \to D\ell\nu_\ell) = \frac{G_F^2|V_{bq_i}|^2}{192\pi^3 m_B^3}(1-\frac{m_\ell^2}{q^2})^2[(1+\frac{m_\ell^2}{q^2})^2$$

$$\lambda^{\frac{3}{2}}|f_+(q^2)|^2 + \frac{3m_\ell^2(m_B^2-m_D^2)\lambda^{\frac{1}{2}}(q^2|f_0(q^2)|^2}{2q^2}] \quad (11)$$

where $G_F = 1{,}66 \times 10^{-5} GeV^{-2}$ is the Fermi constant and $\lambda(q^2) = (m_B^2 + m_D^2 - q^2)^2 - 4m_B^2 m_D^2$ is the Kallen fuction

The hevavy quark effective theory (HQET) is constructed to provide a simplified description of processes where a heavy quark interacts with light degrees of freedom by the exchange of soft gluons.

Considering the Cornell potential $V(r) = \frac{-4*\alpha_s}{r} + br + c$, we have revisited the *Dalgarno*ı*s* method of perturbation by incorporating two scales r^{short} and r^{long} as integration limit so that the perturbative procedure can be improved in a potential model. With the improved version of the wave function the ground state masses of the heavy-light mesons D,D_s,B,B_s and B_s are computed. The slopes and curvatures of the form factors of semi-leptonic decays of heavy-light mesons in both HQET limit and ïňĄnite mass limit are calculated and compared with the available data [13].

Technically, the LCSR approach presents a marriage of QCD sum rules with the theory of hard exclusive processes. As a bonus, SVZ [10] vacuum condensates are substituted by light-cone hadron distribution functions of increasing twist which have a direct physical significance.

we present the analysis of the results obtained for $B_{(s,c)} \to D_{(s,c)}\ell\nu_\ell$ decays and R and R^* fractions.

Cuadro: Branching ratios (in units of 10^{-2}) for $B \to P\ell\nu_\ell(\ell = e, \mu)$ decays in HQ and LCSR models.

Process	Model		
	PDF (2016)	HQ	LCSRs
$B^0 \to D^+\ell\nu_\ell$	2.19	2.08	2.00
$B^0 \to D^+\tau\nu_\tau$	1.03	0.57	0.73
$B^+ \to D^0\ell\nu_\ell$	2.27	2.26	2.15
$B^+ \to D^0\tau\nu_\tau$	0.77	0.62	0.79
$B_s \to D_s\ell\nu_\ell$		2.14	2.21
$B_s \to D_s\tau\nu_\tau$		0.57	0.75
$B_c \to \eta_c\ell\nu_\ell$		1.28	1.55
$B_c \to \eta_c\tau\nu_\tau$		0.56	0.51

Cuadro: Branching ratios (in units of 10^{-2}) for $B \to D^* \ell \nu_\ell$ decays, in the HQ and LCSRs models

Process	Model		
	PDG (2016)	HQ	LCSRs
$B^0 \to D^{*+} \ell \nu_\ell$	4.93	2.29	2.4
$B^0 \to D^{*+} \tau \nu_\tau$	1.78	0.65	0.55
$B^+ \to D^{*0} \ell \nu_\ell$	5.69	2.25	2.6
$B^+ \to D^{*0} \tau \nu_\tau$	1.88	0.83	0.60
$B_s \to D_{*s} \ell \nu_\ell$		2.56	2.5
$B_s \to D_{*s} \tau \nu_\tau$		0.81	0.58
$B_c \to \eta_{*c} \ell \nu_\ell$		4.1	5.4
$B_c \to \eta_{*c} \ell \nu_\tau$		0.87	0.9

Process	Quarks Models			
	HQ	LCSRs	[12]	[16]
$\frac{B^0 \to D^+ \tau \nu_\tau}{B^0 \to D^+ \ell \nu_\ell}$	0.28	0.36	0.46	0.30
$\frac{B^+ \to D^0 \tau \nu_\tau}{B^+ \to D^0 \ell \nu_\ell}$	0.28	0.36	0.42	0.30
$\frac{B_s \to D_s \tau \nu_\tau}{B_s \to D_s \ell \nu_\ell}$	0.27	0.32		
$\frac{B_c \to \eta_c \ell \nu_\tau}{B_c \to \eta_c \ell \nu_\ell}$	0.43	0.32		

Usually is found that the standard deviation from experimental to theoretical models are $3{,}2 - 3{,}5\sigma$ [3,4] but in this study is found that the standard deviation was 3σ, using the LCSR model.

Process	Models Quarks			
	HQ	LCSRs	[12]	[16]
$\frac{B^0 \to D^+ \tau \nu_\tau}{B^0 \to D^+ \ell \nu_\ell}$	0.28	0.22	0.32	0.25
$\frac{B^+ \to D^0 \tau \nu_\tau}{B^+ \to D^0 \ell \nu_\ell}$	0.32	0.23	0.35	0.25
$\frac{B_s \to D_s \tau \nu_\tau}{B_s \to D_s \ell \nu_\ell}$	0.31	0.23		
$\frac{B_c \to J/\psi \ell \nu_\tau}{B_c \to J/\psi \ell \nu_\ell}$	0.21	0.16		

Usually is found that the standard deviation from experimental to theoretical models are $3{,}2 - 3{,}5\sigma$ Ref. [3,4] but in this study is found that the standard deviation was $2{,}7 - 3{,}1\sigma$, using the HQ model.

1. We found that the branching ratios (in units of 10^{-2}) for charmless $B \to P(V)\ell\nu_\ell$ decays are consistent with the Ref. [11], HQ [8] and LCSRs [9] models. In concordance they have the values of $B^+ \longrightarrow D^0\ell\nu_\ell = (2{,}1 \pm 0{,}09) \times 10^{-2}$, $B^0 \longrightarrow D^+\ell\nu_\ell = (2{,}07 \pm 0{,}09) \times 10^{-2}$,$B^+ \longrightarrow D^0\tau\nu_\ell = (0{,}69 \pm 0{,}09) \times 10^{-2}$.
2. With the BaBar experiment are compatible $B^+ \longrightarrow D^*\tau\nu_\ell = 1{,}5 \times 10^{-2}$, $B^0 \longrightarrow D^*\tau\nu_\ell = (1{,}1 \pm 0{,}09) \times 10^{-2}$, using the WSB model.
3. Between the more possible results to be measured experimentally they are $B_s \longrightarrow D_s\ell\nu_\ell = 1{,}9 \pm 0{,}09 \times 10^{-2}$,$B^+ \longrightarrow D^*\ell\nu_\ell = (6{,}07 \pm 0{,}09) \times 10^{-2}$, $B_s \longrightarrow D_s^*\ell\nu_\ell = (2{,}07 \pm 0{,}09 \pm 0{,}09) \times 10^{-2}$.

1. The fractions R for charmless $B \to P\ell\nu_\ell$ decays , the corresponding experimental value from Ref. [12].
2. In general the Branching ratios for charmless $B \to P\ell\nu_\ell(\ell = e, \nu)$ decays, they present an orden of magnitude in relation to $B \to P\tau\nu_\tau$.
3. The Branching ratios for charmless $B \to D\tau\nu_\tau$ decays, they present an orden of magnitude in relation to $B \to D^*\tau\nu_\tau$.

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