Eur. Phys. J. C 40, 193–197 (2005)
Digital Object Identifier (DOI) 10.1140/epjc/s2005-02143-y

THE EUROPEAN PHYSICAL JOURNAL C

$B \to D^{(*)}$ transitions in a quark model

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Received: 29 December 2004 /
Published online: 21 February 2005 –

Abstract. We propose a constituent quark model to evaluate heavy decay constants and form factors relevant for $B \to D^{(*)}$ semileptonic transitions. We show that the model reproduces the scaling laws dictated by the spin-flavor symmetry in the heavy quark limit and describes quite well the experimental data.

1 Introduction

The study of exclusive charmed semileptonic decays of B mesons is of primary importance to extract [1] one of the free parameters of the standard model: the absolute value of the Cabibbo–Kobayashi–Maskawa matrix element, $|V_{cb}|$ [2]. The extraction is based on the prediction of the heavy quark effective theory (HQET) [3] which fixes an absolute normalization, at zero recoil point, of the form factor which survives in the limit of infinite quark masses. Moreover, it is possible to show that differently from the $B \to D\ell\nu$ process the $B \to D^*\ell\nu$ decay does not receive $1/m_Q$ corrections at zero recoil point [4]. This facts allow us to extract $|V_{cb}|$ from the differential partial decay width for the $B \to D^*\ell\nu$ process in a nearly model independent way [5,6].

In this paper we will study the $B \to D^{(*)}\ell\nu$ processes from a different point of view. We propose a very simple constituent quark model to evaluate heavy decay constants and heavy-to-heavy form factors. They exhibit the scaling laws dictated by the HQET at leading order and describe in a satisfactory way the experimental data. To study the semileptonic transitions between the heavy mesons B and $D^{(*)}$ and to compute the relevant hadronic matrix elements we use the ideas presented in the papers in [7] devoted to a study of heavy-to-light semileptonic and rare B transitions. In these papers, the heavy meson B is described as a $b\bar{q}$ ($q \in \{u, d\}$) bound state and the corresponding wave function, $\psi(k)$, is obtained by solving a QCD relativistic potential model. Here, we adopt a different point of view. As in [7], we describe the involved (heavy) mesons as a bound state of a heavy quark and a light anti-quark but for the wave functions we assume their mathematical form and we fix the free parameters by comparing model predictions and experimental data, when available (see below).

This paper is organized as follows. In the next section we introduce our constituent quark model; heavy decay constants and heavy-to-heavy form factors are evaluated in Sect. 3. Section 4 is devoted to a discussion of the heavy quark limit for decay constants and form factors. Numerical results and conclusions are collected in Sect. 5.

2 The model

We describe any heavy meson $H(Q\bar{q})$, with $Q \in \{b, c\}$, by introducing the matrix

$$H = \frac{1}{\sqrt{3}} \psi_H(k) \sqrt{\frac{m_Q m_q}{m_q m_Q + q_1 \cdot q_2}} \; \frac{\not{q}_1 + m_Q}{2m_Q} \, \Gamma \, \frac{-\not{q}_2 + m_q}{2m_q} \, , \tag{1}$$

where m_Q (m_q) stands for the heavy (light) quark mass; q_1^μ, q_2^μ their corresponding 4-momenta (cf. Fig. 1). With $\psi_H(k)$ we indicate the meson's wave function and the factors are chosen to satisfy the following relations:

$$\langle H|H\rangle \equiv \mathrm{Tr}\{(-\gamma_0 H^\dagger \gamma_0)\, H\} \;=\; 2\, m_H \, ,$$
$$\int \frac{\mathrm{d}^3 k}{(2\pi)^3} |\psi_H(k)|^2 = 2\, m_H \, . \tag{2}$$

The meson–constituent quarks vertex, Γ, is given by

$$\Gamma = -\mathrm{i}\gamma_5 \equiv \Gamma_P$$

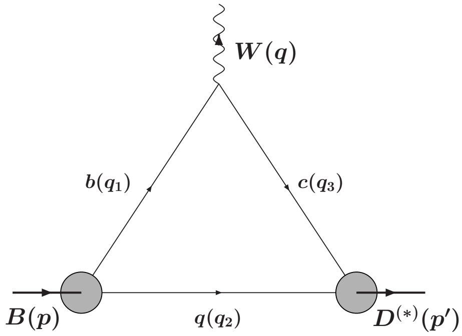

Fig. 1. Quark model diagram for the semileptonic B decays involving $b \to c$ transition. The thin lines represent quarks, the thick ones mesons. The gray disks represent the quark–quark–meson vertices

for pseudoscalar mesons, (3)

$$\Gamma = \varepsilon_\mu \left[\gamma^\mu - \frac{q_1^\mu - q_2^\mu}{m_H + m_Q + m_q}\right] \equiv \Gamma_V(\varepsilon, q_1, q_2)$$

for vector mesons, (4)

where ε is the polarization 4-vector of the (vector) meson H. In any $HQ\bar{q}$ vertex we assume 4-momentum conservation, i.e. $q_1^\mu + q_2^\mu = p^\mu$, the H meson 4-momentum. Therefore, if we choose $q_1^\mu = (E_Q, \boldsymbol{k})$, and $q_2^\mu = (E_q, -\boldsymbol{k})$, i.e. the H rest frame, we have ($k \equiv |\boldsymbol{k}|$)

$$E_Q + E_q = \sqrt{m_Q^2 + k^2} + \sqrt{m_q^2 + k^2} = m_H \ , \quad (5)$$

which can be read as the definition of a running heavy quark mass, as was done in [7]. In fact, (5) with the constraint $m_Q(k) \geq 0$ gives the relation

$$0 \leq k \leq K_M \equiv \frac{m_H^2 - m_q^2}{2m_H} \quad (6)$$

on the loop momentum k

$$\int \frac{\mathrm{d}^3k}{(2\pi)^3} \ . \quad (7)$$

Let us now write down the remaining rules for the computation of the hadronic matrix elements in the framework of this model.

(a) For the weak hadronic current, $\overline{q}_2\ \Gamma^\mu\ q_1$, one puts the factor

$$\sqrt{\frac{m_{q_1}}{E_{q_1}}}\ \sqrt{\frac{m_{q_2}}{E_{q_2}}}\ \Gamma^\mu \ , \quad (8)$$

where Γ^μ is some combination of Dirac matrices;

(b) for each quark loop, in addition to the integration in (7), one puts a color factor of 3 and performs a trace over Dirac matrices.

3 Leptonic decay constants and $B \to D^{(*)}$ semileptonic transitions

In this section we introduce heavy decay constants and semileptonic form factors for heavy-to-heavy transitions and we give their expressions in the framework of our model. Using the rules introduced in the previous section we immediately get the expressions for the heavy meson decay constants. The pseudoscalar case was obtained and discussed in [7]; for future convenience, we report the resulting expression for the B meson:

$$f_B = \frac{\sqrt{3}}{2\pi^2 m_B^2}\int_0^{K_M} \mathrm{d}k k^2 \times \psi_B(k)\frac{(m_b + m_q)(m_b m_q + q_1\cdot q_2)}{\sqrt{E_b E_q (m_b m_q + q_1 \cdot q_2)}} \ . \quad (9)$$

Moreover, we have evaluated the vector heavy meson decay constant, which is defined by

$$\langle 0|V_\mu|H^*(p,\varepsilon)\rangle = m_{H^*}\ f_{H^*}\ \varepsilon_\mu \ . \quad (10)$$

In particular, if we consider the B^* meson, we obtain

$$f_{B^*} = \frac{\sqrt{3}}{2\pi^2 m_{B^*}}\int_0^{K_M} \mathrm{d}k \frac{k^2\psi_{B^*}(k)}{\sqrt{E_b E_q (m_b m_q + q_1\cdot q_2)}} \times \left[(m_b m_q + q_1\cdot q_2) - \frac{2}{3}\frac{k^2 m_{B^*}}{m_{B^*} + m_b + m_q}\right] . \quad (11)$$

3.1 $B \to D$ and $B \to D^*$ form factors

The same rules allow us to evaluate the matrix element $\langle D(p')|\bar{c}\gamma_\mu b|B(p)\rangle$ relevant to the weak semileptonic transition of B to D mesons. With reference to the graph in Fig. 1 and choosing the 4-momenta q_1 and q_2 as in the previous section and $q_3^\mu = (E_c, \boldsymbol{k} - \boldsymbol{q}\,)$, we get

$$\begin{aligned}&\langle D(p')|\bar{c}\gamma_\mu b|B(p)\rangle \\ &= \int_{\mathcal{D}} \frac{\mathrm{d}^3k}{(2\pi)^3}\psi_D(k)\psi_B(k) \\ &\times\sqrt{\frac{m_q m_b}{m_q m_b + q_1\cdot q_2}}\sqrt{\frac{m_q m_c}{m_q m_c + q_3\cdot q_2}} \\ &\times\sqrt{\frac{m_b m_c}{E_b E_c}}\,\mathrm{Tr}\left[\frac{-\not{q}_2 + m_q}{2m_q}(\Gamma_P^\dagger)\frac{\not{q}_3 + m_c}{2m_c}\gamma_\mu\right. \\ &\left.\times\frac{\not{q}_1 + m_b}{2m_b}(\Gamma_P)\frac{-\not{q}_2 + m_q}{2m_q}\right] . \quad (12)\end{aligned}$$

In the previous equation the integration domain $\mathcal{D}$ is fixed enforcing the energy conservation both in the initial and final quarks–meson vertices. This can be done introducing, in addition to the beauty running mass (cf. (5)), the charm running mass $m_c(k)$ for which $m_c(k) \geq 0$. After some algebra the physical domain $\mathcal{D}$ is found to be given by

$$\begin{aligned}\mathrm{Max}(0, k_-) \leq &\quad k \quad \leq \mathrm{Min}(K_M, k_+), \\ \mathrm{Max}(-1, f(k, |\boldsymbol{q}\,|)) \leq &\cos(\theta) \leq +1, \quad (13) \\ 0 \leq &\quad \phi \quad \leq 2\pi,\end{aligned}$$

with

$$k_\pm = \frac{|\boldsymbol{q}|\,(m_D^2 + m_q^2) \pm (m_D^2 - m_q^2)\sqrt{m_D^2 + \boldsymbol{q}^{\,2}}}{2m_D^2} \ , \quad (14)$$

$$f(k, |\boldsymbol{q}|) = \frac{2\sqrt{m_D^2 + \boldsymbol{q}^{\,2}}\sqrt{k^2 + m_q^2} - (m_D^2 + m_q^2)}{2k\,|\boldsymbol{q}|} \ . \quad (15)$$

ϕ and θ are the azimuthal and the polar angles, respectively. Note that we have chosen the z-axis along the direction of $\boldsymbol{q}$, the (tri-)momentum of the W boson (cf. Fig. 1).

Equation (12) allows us to immediately extract the form factors $f_\pm(q^2)$ defined by

$$\begin{aligned}&\langle D(p')|\bar{c}\gamma_\mu b|B(p)\rangle \\ &= f_+(q^2)(p_\mu + p'_\mu) + f_-(q^2)(p_\mu - p'_\mu) \ . \quad (16)\end{aligned}$$

The last matrix element relevant to charmed semileptonic decay of B mesons is usually written in terms of the following form factors:

$$\begin{aligned}
&\langle D^*(p',\varepsilon)|\bar{c}\gamma_\mu(1-\gamma_5)b|B(p)\rangle \\
&= 2g(q^2)\epsilon^{\mu\nu\alpha\beta}\varepsilon^*_\nu\, p_\alpha\, p'_\beta \qquad (17)\\
&\quad -\mathrm{i}\left\{f(q^2)\,\varepsilon^*_\mu\right.\\
&\quad \left. +(\varepsilon^*\cdot p)\,\left[a_+(q^2)\,(p_\mu+p'_\mu)+a_-(q^2)\,(p_\mu-p'_\mu)\right]\right\},
\end{aligned}$$

they are connected in our model to

$$\begin{aligned}
&\langle D^*(p',\varepsilon)|\bar{c}\gamma_\mu(1-\gamma_5)b|B(p)\rangle \\
&= \int_{\mathcal{D}}\frac{\mathrm{d}^3k}{(2\pi)^3}\psi_{D^*}(k)\psi_B(k)\\
&\quad\times\sqrt{\frac{m_q m_b}{m_q m_b+q_1\cdot q_2}}\sqrt{\frac{m_q m_c}{m_q m_c+q_3\cdot q_2}}\sqrt{\frac{m_b m_c}{E_b E_c}}\\
&\quad\times\mathrm{Tr}\left[\frac{-\not{q}_2+m_q}{2m_q}(\Gamma_V(\varepsilon,q_3,q_2)^\dagger)\frac{\not{q}_3+m_c}{2m_c}\gamma_\mu\right.\\
&\qquad\left.\times(1-\gamma_5)\frac{\not{q}_1+m_b}{2m_b}(\Gamma_P)\frac{-\not{q}_2+m_q}{2m_q}\right]. \qquad (18)
\end{aligned}$$

Also in this case the extraction of the form factors in (17) can be done using the same frame we adopt for the extraction of $f_\pm(q^2)$. For the polarization vectors we use

$$\varepsilon^\mu(\lambda)=\begin{cases}(0,-1,0,0) & \lambda=1,\\ (0,0,1,0) & \lambda=2,\\ (|\boldsymbol{q}|,0,0,-E_{D^*})/m_{D^*} & \lambda=\mathrm{L},\end{cases} \qquad (19)$$

where $E_{D^*}(=\sqrt{\boldsymbol{q}^{\,2}+m^2_{D^*}})$ represents the energy of the D^* meson.

4 Heavy quark limit

In this section we discuss the heavy quark limit for decay constants and form factors. We show that decay constants and heavy-to-heavy form factors satisfy the scaling laws predicted by HQET at leading order [3].

To show how the results of our model depend on the heavy quark mass, we need to specify the shape of the wave functions $\psi_H(k)$. We choose two possible forms, the gaussian-type, extensively used in literature (see for example [8,9]),

$$\psi_H(k)=4\pi^{3/4}\sqrt{\frac{m_H}{\omega_H^3}}\,\exp\left\{\frac{-k^2}{2\,\omega_H^2}\right\}, \qquad (20)$$

and the exponential one,

$$\psi_H(k)=4\pi\sqrt{\frac{m_H}{\omega_H^3}}\,\exp\left\{\frac{-k}{\omega_H}\right\}, \qquad (21)$$

which is able to fit the results of relativistic quark model [10]. In our approach ω_H is a free parameter which should be fixed (cf. next section for details).

4.1 Heavy decay constants

To extract the heavy mass dependence from the decay constant, it is useful to define $x=(2\alpha k)/m_B$ in such a way that the expressions in (9) and (11) can be formally written as

$$f_{B^{(*)}}=\int_0^\alpha \mathrm{d}x\;\psi_B(k(x))\;F_{B^{(*)}}(x,z)\,, \qquad (22)$$

where $F_{B^{(*)}}(x,z)$ have very simple expressions for $z=0$ ($z\equiv m_q/m_B$):

$$F_B(x,0)=\sqrt{\frac{3}{2}}\,\frac{m_B^2}{8\pi^2\alpha^3}\,\frac{x^2(\alpha-x)}{\sqrt{(\alpha-x)(2\alpha-x)}}\,, \qquad (23)$$

$$F_{B^*}(x,0)=\frac{m_B^2\,x^2}{8\sqrt{6}\,\pi^2\,\alpha^3}\,\frac{3\left(\alpha+\sqrt{\alpha(\alpha-x)}\right)-x}{\sqrt{2\alpha-x}\left(\sqrt{\alpha}+\sqrt{\alpha-x}\right)}. \qquad (24)$$

The integral in (22), for $0<\alpha\ll 1$ can be evaluated analytically, obtaining for the leading behavior the following result:

$$f_{B^{(*)}}\simeq\begin{cases}\dfrac{1}{\sqrt{m_B}}\,\dfrac{\sqrt{6\,\omega_B^3}}{\pi^{3/4}} & \text{gaussian-type,}\\[2ex] \dfrac{1}{\sqrt{m_B}}\,\dfrac{4\sqrt{3\,\omega_B^3}}{\pi} & \text{exponential-type,}\end{cases} \qquad (25)$$

in both cases in agreement with the scaling law predicted by the HQET.

4.2 $B \to D$ form factors

The same procedure applied to the heavy-to-heavy ($B\to D$) transitions allows us to find the scaling laws of the form factors $f_\pm$ defined in (16). As for the decay constants, we can formally write

$$f_\pm(q^2)=\int_0^\alpha \mathrm{d}x\;\psi_B(k(x))\;\psi_D(k(x))\;F_\pm(x,z,q^2)\,, \qquad (26)$$

where, for $z=0$, $x\ll 1$ and near the zero recoil point ($q^2=q^2_{\mathrm{max}}$)

$$\begin{aligned}
&F_\pm(x,0,q^2)|_{q^2\simeq q^2_{\mathrm{max}}} \qquad (27)\\
&\simeq\frac{x^2}{64\pi^2\alpha^3}\,m_D^2(m_D\pm m_B)\left(1-\frac{11}{12}(w-1)\right).
\end{aligned}$$

Here $w=v\cdot v'$ with v and v' the four-velocities of the B and D mesons, respectively. Also in this case we can extract the dependence of the form factors from the heavy masses performing the integration in (26)

$$f_\pm(q^2)|_{q^2\simeq q^2_{\mathrm{max}}}\simeq\frac{m_D\pm m_B}{2\sqrt{m_D m_B}}$$

$$\times \begin{cases} \left[2\sqrt{2} \left(\frac{\omega_B\,\omega_D}{\omega_B^2 + \omega_D^2} \right)^{3/2} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{gaussian-type,} \\ \left[8\frac{\sqrt{\omega_B^3 \omega_D^3}}{(\omega_B + \omega_D)^3} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{exponential-type.} \end{cases} \tag{28}$$

It should be observed that the terms in square brackets should be interpreted as the Isgur–Wise function, $\xi(w)$, near $w = 1$. Moreover, in the heavy quark limit we should have $\omega_B = \omega_D$ which implies the correct normalization, $\xi(1) = 1$, for both wave functions.

4.3 $B \to D^*$ form factors

The same analysis can be carried out for the $B \to D^*$ form factors. Let us start to consider the form factors $a_\pm(q^2)$. As for the $f_\pm$, we can write

$$a_\pm(q^2) = \int_0^\alpha \mathrm{d}x\ \psi_B(k(x))\ \psi_{D^*}(k(x))\ A_\pm(x,z,q^2)\,, \tag{29}$$

where, for $z = 0$, $x \ll 1$ and near the zero recoil point

$$A_\pm(x,0,q^2)|_{q^2\simeq q^2_{\max}} \simeq -\frac{x^2}{64\pi^2\alpha^3}\,\frac{m^2_{D^*}}{m_B}\left(1 - \frac{11}{12}(w-1)\right). \tag{30}$$

Analogously to the $B \to D$ case, the heavy mass dependence can be obtained performing the integration in (29),

$$a_\pm(q^2)|_{q^2\simeq q^2_{\max}} \simeq \mp\frac{1}{2\sqrt{m_D m_B}} \times \begin{cases} \left[2\sqrt{2} \left(\frac{\omega_B\,\omega_D}{\omega_B^2 + \omega_D^2} \right)^{3/2} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{gaussian-type,} \\ \left[8\frac{\sqrt{\omega_B^3 \omega_D^3}}{(\omega_B + \omega_D)^3} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{exponential-type.} \end{cases} \tag{31}$$

The behavior with heavy masses of the vectorial form factor, $g(q^2)$, is the same of $a_-(q^2)$ in agreement with the prediction of heavy quark symmetry. For the last axial form factor, $f(q^2)$, our model predicts

$$f(q^2)|_{q^2\simeq q^2_{\max}} \simeq \sqrt{m_{D^*} m_B}\,(1+w) \times \begin{cases} \left[2\sqrt{2} \left(\frac{\omega_B\,\omega_D}{\omega_B^2 + \omega_D^2} \right)^{3/2} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{gaussian-type,} \\ \left[8\frac{\sqrt{\omega_B^3 \omega_D^3}}{(\omega_B + \omega_D)^3} \left(1 - \frac{11}{12}(w-1) \right) \right] \\ \quad \text{exponential-type.} \end{cases} \tag{32}$$

Thus all the form factors satisfy the scaling laws dictated by the HQET. Moreover, the model predicts the following Isgur–Wise function:

$$\xi(w) = 1 - \frac{11}{12}(w-1) + \frac{77}{96}(w-1)^2 + o((w-1)^3)\,, \tag{33}$$

where the quadratic term, neglected in (28), (31) and (32), is shown. The resulting Isgur–Wise function satisfies both the Bjorken sum rule [11]

$$\rho^2 \equiv -\xi'(1) = \frac{11}{12} \geq \frac{3}{4}\,, \tag{34}$$

and the lower bound on the curvature [12]:

$$\sigma^2 \equiv \xi''(1) = \frac{77}{48} \geq \frac{4}{5}\rho^2\left(1 + \frac{3}{4}\rho^2\right) = \frac{99}{80}\,. \tag{35}$$

5 Numerical results and discussion

As we have seen in Sect. 3, the heavy-to-heavy form factors can be easily extracted with the help of the (12), (16), (17) and (18). Nevertheless, unlike for the decay constants, their analytical expressions are quite long, and, for the sake of brevity, we do not report them here.

As already discussed in the previous section, to evaluate numerically form factors and decay constants, we must fix the meson wave functions, $\psi_H(k)$. For the wave function we considered two possibilities: the gaussian and the exponential form. In both cases, for any heavy meson, H, we have one more free parameter, ω_H. In order to determine the free parameters of the model we proceed as follows. We neglect differences between pseudoscalar and vector mesons in the vertex function, in other words we put $\omega_D = \omega_{D^*}$. Moreover, we neglect differences between u and d quark masses. In such a way the free parameters of the model are ω_B, ω_D and m_q. They are adjusted by fitting the experimental values of f_D, $\mathrm{BR}(B \to D\ell\nu)$ and the results of lattice simulation on the ratio f_D/f_B. The numerical results are collected in Tables 1 and 2.

Comments about the results in Table 1 are in order. Let us start with decay constants. The model predicts large $1/m_c$ corrections for f_D in such a way the predicted ratio f_D/f_B violates strongly the heavy quark mass limit. However, in the allowed region for the parameters there

Table 1. The experimental values [1] and lattice result [13] for the decay constants used in the fit of the free parameters of the model. For the free parameter we assume $\omega_D = \omega_{D^*}$. Moreover, we use $|V_{cb}| = (41.3 \pm 1.5) \times 10^{-3}$ [1]

	Exp. or lattice	our fit (exp.)	our fit (gauss.)
f_D/f_B	1.23 ± 0.22 [13]	1.03	1.05
f_D	$300^{+180+80}_{-150-40}$ MeV [1]	145 MeV	145 MeV
$\mathrm{BR}(B \to D\ell\nu)$	$(2.14 \pm 0.15)\%$ [1]	2.04%	1.75%
f_B		140 MeV	139 MeV

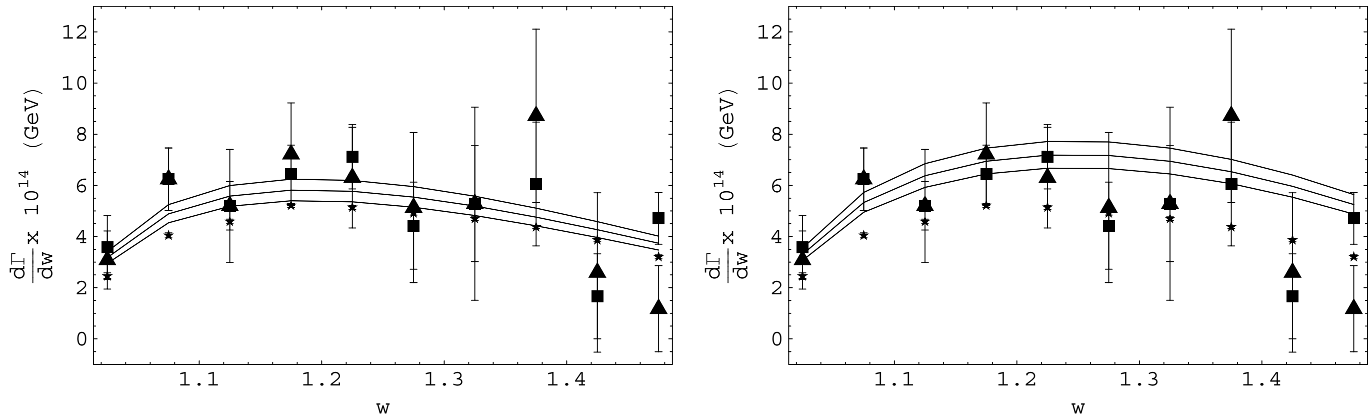

Fig. 2. Predicted ranges for $\mathrm{d}\Gamma(B \to D^*\ell\nu)/\mathrm{d}w$ compared to data. Solid boxes (triangles) refer to $\bar{B}^0 \to D^{+*}\ell^-\bar{\nu}$ ($B^- \to D^{0*}\ell^-\bar{\nu}$) process [5]. Data points from BABAR [6] are displayed with stars. Solid lines refer to model predictions for exponential (left) and gaussian (right) in correspondence of $|V_{cb}| = (39.8, 41.3, 42.8) \times 10^{-3}$ [1]

Table 2. The values for the free parameters of the model in correspondence of the best fit for both wave functions. The two sets of values are obtained for the exponential (exp.) and gaussian vertex (gauss.)

Parameter	fitted values (exp.)	fitted values (gauss.)
m_q	311 MeV	269 MeV
ω_B	258 MeV	421 MeV
ω_D	255 MeV	347 MeV

is the possibility to fulfill both the heavy quark limit and the lattice result but the values of the decay constants ($f_D \sim f_B \sim 140\,\mathrm{MeV}$) are predicted smaller than the ones obtained by lattice simulations [13]. Regarding the $B \to D$ form factors, it should be observed that the experimental value for the $\mathrm{BR}(B \to D\ell\nu)$ can be reproduced with $|V_{cb}| = (41.3 \pm 1.5) \times 10^{-3}$ [1]. However, when the exponential function is considered, the agreement becomes better as a consequence of the larger value predicted for $f_+(0)$ ($f_+(0) = 0.57\,(0.51)$ for exponential (gaussian) vertex function). The same situation occurs if the differential partial decay width for the $B \to D^*\ell\nu$ is considered. In Fig. 2, assuming the values in Table 2, we plot $\mathrm{d}\Gamma(B \to D^*\ell\nu)/\mathrm{d}w$ in comparison with experimental data [5,6]. In particular, the left (right) panel allows one to compare model predictions and experimental data for the exponential (gaussian) vertex function. Both panels contain three curves corresponding to the predicted $\mathrm{d}\Gamma(B \to D^*\ell\nu)/\mathrm{d}w$ for the central, upper and lower $1-\sigma$ values of $|V_{cb}|$ [1]. The agreement between model predictions and experimental data is quite good, a better agreement requires a smaller value of $|V_{cb}|$. In this respect, using exponential vertex function and a value of $|V_{cb}| = 38.7 \times 10^{-3}$ [6], the predicted $\mathrm{d}\Gamma(B \to D^*\ell\nu)/\mathrm{d}w$ is in very good agreement with experimental data from Babar [6].

In conclusion we have proposed a constituent quark model to describe heavy mesons. We showed that the model predictions on decay constants and form factors reproduce the scaling laws dictated by HQET at leading order in the heavy quark mass limit. For finite heavy quark masses the agreement with experimental data is quite good.

Acknowledgements. One of us (P.S.) thanks Giuseppe Nardulli for useful discussions.

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