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Heavy to Light Baryon Transition Form Factors

Xin-Heng Guo[1,3], *Tao Huang*[1,2] *and Zuo-Hong Li*[3]

[1]Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brasil,
[2]CCAST(World Laboratory)P.O.Box 8730, Beijing 100080, P. R. China,
[3]Institute of High Energy Physics, Academia Sinica, Beijing 100039, P. R. China.

ABSTRACT

Recently, Stech found form factor relations for heavy to light transitions based on two simple dynamical assumptions for spectator partical. In this work we generalize his approach to the case of baryons and find that for $\Lambda_Q \to \Lambda$ (Q=b or c) only one independent form factor remains in limit $m_Q \to \infty$. Furthermore, combining with the model of Guo and Kroll we determine both of the two form factors for $\Lambda_Q \to \Lambda$ in the heavy quark limit. The results are applied to $\Lambda_b \to \Lambda + J/\psi$ which is not clarified both theoretically and experimentally. It is found that the branching ratio of $\Lambda_b \to \Lambda + J/\psi$ is of order 10^{-5}.

Key-words: Heavy baryon; Light baryon; Heavy quark effective theory.

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1 Introduction

The heavy quark effective theory (HQET)[1] has been proven to be a powerful tool dealing with the physics of hadrons containing a heavy quark, and based on it there have been a lot of developments in the study of the heavy flavor weak decay. The advantage of HQET in dealing with the weak decays of heavy hadrons is that the number of the form factors describing hadronic matrix elements is reduced. For example, in $\Lambda_b \to \Lambda_c$ transition all the form factors can be expressed in terms of the Isgur-Wise function and a unknown parameter $\bar{\Lambda}$ to order $1/m_Q$ where m_Q is c or b quark mass, and in the heavy-to-light processes such as $\Lambda_b \to \Lambda$, the use of HQET in the limit $m_Q \to \infty$ allows one to express this transition in terms of two independent form factors[2]. In order to find the relations for the remaining form factors for the heavy to light transitions, recently, Stech[3] proposed a new approach dealing with heavy-to-light transitions in the case of mesons where two simple dynamical assumptions for spectator particle in the decay process are made. In the present work, we will try to generalize Stech's work to the baryon cases, i.e., $\Lambda_{b,c} \to \Lambda$ transitions. It will be found that this can provide an additional relation between the form factors F_1 and F_2 in the limit $m_Q \to \infty$.

The decrease of the form factor number can simplify calculations. However, these form factors contain all soft QCD effects, which are difficult to be calculated from the fist principle. Therefore, one must resort to some phenomenological models to calculate them. A very interesting process is $\Lambda_b \to \Lambda + J/\psi$. UA1[4] reported the measurement result $F(\Lambda_b)BR(\Lambda_b \to \Lambda + J/\psi) = (1.8 \times \pm 0.6 \pm 0.9) \times 10^{-3}$ where $F(\Lambda_b)$ is the fraction of b quark transition into Λ_b, while CDF[5] and OPAL[6] only observed the upper limit 0.5×10^{-3} and 1.1×10^{-3} respectively. On the other hand, theoretically, in refs. [7] and [8] the authors discussed the process $\Lambda_b \to \Lambda + J/\psi$ on the basis of HQET and some phenomenal considerations. Their results for the branching ratios of $\Lambda_b \to \Lambda + J/\psi$ are different: in [7] $BR(\Lambda_b \to \Lambda + J/\psi)$ is of order 10^{-4} from quark model calculations, while in [8] it is found that $BR(\Lambda_b \to \Lambda + J/\psi)$=$4 \times 10^{-5}$ by extracting form factors at $\omega = 1$ from experiments. The up-down asymmetry parameter α which in fact depends on the ratio between two form factors in the amplitude of $\Lambda_b \to \Lambda$ in heavy quark limit, is -0.11 in [7] and 0.25 in [8]. Hence, both theoretically and experimentally, the branching ratio of $\Lambda_b \to \Lambda + J/\psi$ is very equivocal and to clarify this issue is necessary.

This paper is organized as the following: In sect.2 we recapitulate the Stech's approach and then generalize it to the case of baryons and find a relation between F_1 and F_2. To determine F_1 and F_2 absolutely, another relation between F_1 and F_2 obtained in the model of Guo and Kroll[9] is applied to our case in sect.3. In sec.4 the branching ratio of $\Lambda_b \to \Lambda + J/\psi$ in heavy quark limit is obtained. The last section is devoted to conclusion.

2 Stech's approach and its generalization to the case of baryons

In this section, we briefly review Stech's approach[3] to deal with the heavy-to-light transitions in the meson case. The key point of the Stech's method is the following two dynamical assumptions:

i). In the rest frame of a meson the off-shell energy of a constituent quark is close to its constituent mass independent or little dependent of its space momentum.

ii). In the first stage of the weak transition, i.e., before final hadronization, the spectator quark retains its original momentum and spin.

From assumption i), one can think that the off-shell energy of the spectator quark ϵ_{sp} in the rest frame of a meson is remarkably smaller than b-quark mass m_b. Using these two assumptions and some Lorentz transition relations between the initial and final state rest frames, Stech arrives at three conclusions: (a), In the first stage of the weak transition, the energy carried by the spectator quark is approximately equal to that of the spectator in the rest frame of the final state particle even for energetic transition, i.e., the spectator doesn't pick up a large energy fraction; (b), In the process of weak transition, even with large energy release, the relevant b-quark space momenta are much smaller than b-quark mass and of the order of confinement scale. (c), In the first stage of the weak decay the generated u or c-quark carries energy and longitudinal momentum of the final particle, apart from correction of order ϵ^F_{sp}/E_F where ϵ^F_{sp} and E_F are the energy of spectator quark in final state rest frame and the energy of final particle in the initial meson rest frame, respectively.

Making use of these conclusions and taking a reasonable assumption into account that the average of the transverse momentum squared of the b-quark $(\vec{q}_{b\perp})^2$ is very small compared to E_F^2, one can find that the transition matrix element of the weak current corresponding to $b \to c$ or u is proportional to the c-number matrix element T^μ

$$T^\mu = [\bar{U}^{s'}_{u,c}(\vec{p}_F, m_{u,c})\gamma^\mu(1-\gamma_5)U^s_b(\vec{0}, m_b)]L_{s',s}, \tag{1}$$

where m_i $(i = u, c, b)$ is the corresponding current mass of quark, the b-quark space momentum in the Dirac spinor of the b-quark has been neglected due to the conclusion (b). The $L_{s',s}$ are the elements of a 2×2 spin unit matrix. $L = I$ if B decays to a pseudoscalar meson and $L = \vec{\sigma} \cdot \vec{e}$ if B decays to a vector particle polarized in $\vec{e}$ direction. A comparison of (1) with the conventional form factor decomposition[10] gives some form factor relations[3] in the heavy-to-light transitions. For example, for B to pseudoscalar meson via transition $b \to u$ one can take m_u=0 and find

$$F_1(q^2, m_F) = R^B_{u,c}(q^2, m_F), \tag{2}$$

$$F_0(q^2, m_F) = (1 - \frac{q^2}{m_B^2 - m_F^2})R^B_{u,c}(q^2, m_F), \tag{3}$$

where $R^B_{u,c}(q^2, m_F)$ is an unknown universal function depending not only on q^2 but also on m_F and the flavor of outgoing quarks (and on m_B).

Making a comparison between the heavy-to-light and the heavy-to-heavy form factors, we can see that the main difference between them is that the heavy-to-light transition form factors depend on m_F due to the lack of heavy quark symmetry, while the heavy-to-heavy form factors have nothing to do with the final state particle.

Generally the theoretical predictions[3] from Stech's approach are in good agreement with experimental data.

In the following, we try to generalize it to the case of baryons. It is well known that a baryon containing a heavy quark, for example, Λ_b, can be effectively considered as a bound state of a b-quark and a scalar diquark $S[ud]$ with $[ud]$ quantum numbers. In the transition $\Lambda_{b,c} \to \Lambda$, b (or c)quark decays into s quark and the other part $[ud]$ behaves as spectator. This decay picture is almost same as that of meson case. The only difference is that the spectator quark in meson case is replaced by a diquark. The mass of the $S[ud]$ diquark is about several hundred Mev. In the light of this picture, the two basic dynamical assumptions made by Stech can be generalized to the baryon case. It is straightforward to see that the three conclusions mentioned before are still valid now.

Λ_b and Λ can be represented by Dirac spinor $U(v)$ and $U(P_\Lambda)$ respectively where $m_b v$ and P_Λ are four momentum of Λ_b and Λ. In the limit $m_b \to \infty$, the matrix element of $\Lambda_b \to \Lambda$ can be written as[2]

$$< \Lambda(P_\Lambda) \mid \bar{s}\gamma_\mu(1-\gamma_5)b \mid \Lambda_b(v) >= \bar{U}_\Lambda(P_\Lambda)[F_1(v\cdot P_\Lambda)+\not{v}F_2(v\cdot P_\Lambda)]\gamma_\mu(1-\gamma_5)U_{\Lambda_b}(v). \quad (4)$$

According the generalized Stech's approach in the baryon case, this matrix element should be proportional to the following C-number matrix element

$$T^\mu_{\Lambda_b\to\Lambda} = \bar{U}_s(\vec{P}_\Lambda, m_s)\gamma_\mu(1-\gamma_5)U_b(\vec{0}, m_b) \quad (5)$$

A comparison of (4) and (5) gives

$$F_1 \sim \sqrt{\frac{(E_\Lambda+m_s)m_\Lambda}{(E_\Lambda+m_\Lambda)m_s}}\frac{2E_\Lambda+m_\Lambda+m_s}{2(E_\Lambda+m_s)}, \quad (6)$$

$$F_2 \sim \sqrt{\frac{(E_\Lambda+m_s)m_\Lambda}{(E_\Lambda+m_\Lambda)m_s}}\frac{m_s-m_\Lambda}{2(E_\Lambda+m_s)}, \quad (7)$$

where m_s is current mass of the s-quark and E_Λ is energy of Λ in the rest frame of Λ_b. For the heavy-to-heavy transition, for instance, $\Lambda_b \to \Lambda_c$, $m_c \simeq m_{\Lambda_c}$ in heavy quark limit, hence F_2=0 and F_1 is the only form factor, which is in fact the Isgur-Wise function. This is consistent with HQET. From (6) and (7), we arrive at the form factor ratio

$$\frac{F_2}{F_1} = \frac{m_S - m_\Lambda}{2(E_\Lambda + m_S + m_\Lambda)}. \quad (8)$$

In the rest frame of Λ_b, E_Λ can be represented by the invariant momentum transfer $q^2 (= (P_{\Lambda_b} - P_\Lambda)^2)$

$$E_\Lambda = \frac{1}{2m_{\Lambda_b}}(m^2_{\Lambda_b} + m^2_\Lambda - q^2). \quad (9)$$

Taking m_s=0.15 GeV, m_Λ=1.116GeV and m_{Λ_b}=5.64GeV, one finds that E_Λ ranges from 1.116GeV to 2.93GeV and F_2/F_1 varies from -0.28 to -0.14, with the q^2 from $q^2_{max} = (m_{\Lambda_b} - m_\Lambda)^2$ to $q^2 = 0$. Similarly , F_2/F_1 for $\Lambda_c \to \Lambda$ changes from -0.28 to -0.24. This is in good agreement with experimental value ($-0.25\pm0.14\pm0.08$) measured recently by CLEO[11].

3 Overlap Integral for $\Lambda_{b,c} \to \Lambda$ Form Factors

In last section eq. (8) provides a relation between F_1 and F_2. To determine them absolutely , we prepare to use model adopted by Guo and Kroll[8] where they worked in the infinite momentum frame (IFM) which is arrived at by boosting along the 3-direction (with $P \to \infty$) from a frame with opposite velocities: $P^{\mu}_{\Lambda_b} = m_{\Lambda_b}(\sqrt{1+v^2/4}, -v/2, 0, 0)$; $P^{\mu}_{\Lambda} = m_{\Lambda}(\sqrt{1+v^2/4}, v/2, 0, 0)$, the IFM momenta of Λ_b and Λ read, respectively,

$$P^{\mu}_{\Lambda_b} = P(1 + (1+v^2/4)m^2_{\Lambda_b}/(2P^2), -m_{\Lambda_b}v/(2P), 0, 1), \tag{10}$$

$$P^{\mu}_{\Lambda} = Pm_{\Lambda}/m_{\Lambda_b}(1 + (1+v^2/4)m^2_{\Lambda_b}/(2P^2), m_{\Lambda_b} \cdot v/(2P), 0, 1). \tag{11}$$

A heavy baryon (Λ_b or Λ_c) is regarded as a relativistic bound state of a heavy Q (b or c) of mass m_Q and a scalar diquark $S[ud]$,

$$\mid \Lambda_Q(\vec{P}, \lambda >= \sqrt{\frac{m_Q}{2m_{\Lambda_Q}}} \int \frac{d^3K}{\sqrt{E_Q E_S}} \Psi_{\Lambda_Q}(\vec{K}) \mid q(\vec{P}-\vec{K}), \lambda; S(\vec{K}) >, \tag{12}$$

where color indices have been omitted, E_Q and E_S are the IMF energies of the heavy quark and scalar-particle, respectively, λ represses the helicity of the baryon. State normalization is taken as

$$< \Lambda_Q(\vec{P'}), \lambda' \mid \Lambda_Q, (\vec{P}), \lambda >= \frac{E_{\Lambda_Q}}{m_{\Lambda_Q}} \delta(\vec{P} - \vec{P'}) \delta_{\lambda'\lambda}, \tag{13}$$

which results in the following normalization of the baryon wave function $\Psi_{\Lambda_Q}(x_1, \vec{K}_\perp)$

$$\int dx_1 d^2K_\perp \mid \Psi_{\Lambda_Q}(x_1, \vec{K}_\perp) \mid^2 = 1. \tag{14}$$

Here, the longitudinal momentum fraction x_1 carried by the heavy quark and the heavy quark's transverse momentum corresponding to its parent baryon $\vec{K}_\perp$ are introduced. Obviously, the scalar-particle[ud] carries $x_2 = 1 - x_1$ and -$\vec{K}_\perp$. The baryon wave function $\Psi_{\Lambda_Q}(x_1, \vec{K}_\perp)$ is a generalization of the BSW[10] meson wave function to the quark-diquark case

$$\Psi_{\Lambda_Q}(x_1, \vec{K}_\perp) = N_{\Lambda_Q} x_1 x_2^3 exp[-b^2(\vec{K}^2_\perp + m^2_{\Lambda_Q}(x_1 - x_0)^2)]. \tag{15}$$

The peak position of the wave function is at $x_0 = 1 - \varepsilon/m_{\Lambda_Q}$, where the parameter ε is the difference between the hadron and the heavy-quark (constituent) mass and has a value of about 0.6 GeV. This is almost the constituent mass of the diquark. Another parameter b in the wave function is related to the mean $K_\perp$ or the radius of the baryon and its precise value is not known. However, we expect the radius of a heavy baryon to be smaller than that of proton. In the following calculations, as in ref. [8], we use b=1.77GeV and b=1.18 GeV, corresponding to $< K^2_\perp >^{\frac{1}{2}} > = 400$ MeV and $< K^2_\perp >^{\frac{1}{2}} > = 600$MeV respectively. The wave function overlap integral for F_1 and F_2 can be easily obtained by the matrix elements of the so-call good current components ($\mu = 0, 3$)

$$F_1 + F_2 = C_s I(v), \tag{16}$$

where $I(v)$ is the overlap integral

$$I(v) = \sqrt{\frac{m_{\Lambda_b}}{m_\Lambda}} \int_{1-\frac{m_\Lambda}{m_{\Lambda_b}}}^{1} dx \int_{-\infty}^{\infty} d^2k_\perp \Psi_\Lambda(1 - \frac{m_{\Lambda_b}}{m_\Lambda}(1-x), \vec{K}_\perp + (1-x) m_{\Lambda_b} v \vec{e}_1) \Psi_{\Lambda_b}(x, \vec{K}_\perp). \tag{17}$$

Here $\vec{e}_1$ represents the unit vector in x direction, the occurrence of the parameter C_s is because that Λ has to be considered as a superposition of various quark-diquark configuration[12] but can not be regarded as being made just of a strang quark and a quasi-particle$[ud]$. However, in our case, only the $sS[ud]$ state can contribute to $\Lambda_b \to \Lambda$ decay and thus the overlap integral is suppressed by an appropriate Clebsch-Gordan coefficient C_s which is $1/\sqrt{3}$ in the model of [12]. Replacing the argument v in I by the invariant momentum transfer $q^2 = (P_{\Lambda_b} - P_\Lambda)^2$, from (8) and (16), we get

$$F_1 = \frac{2E_\Lambda + m_\Lambda + m_s}{2(E_\Lambda + m_s)} C_s I(q^2), \tag{18}$$

$$F_2 = \frac{m_s - m_\Lambda}{2(E_\Lambda + m_s)} C_s I(q^2). \tag{19}$$

The form factors F_1 and F_2 are plotted in Fig.1 as functions of $\omega (= v_{\Lambda_b} \cdot P_\Lambda / m_\Lambda)$.

4 Branching Ratio for $\Lambda_b \to \Lambda + J/\psi$

In this section, we will discuss the process $\Lambda_b \to \Lambda + J/\psi$ and calculate its branching ratio. This process proceeds only through the internal W-emission diagram and under factorization assumption its weak decay amplitude reads

$$A(\Lambda_b \to \Lambda + J/\psi) = \frac{G_F}{\sqrt{2}} V_{cb} V_{cs}^* a_2 < J/\psi \mid \bar{c}\gamma_\mu(1-\gamma_5)c \mid 0 >< \Lambda \mid \bar{s}\gamma_\mu(1-\gamma_5)b \mid \Lambda_b >, \tag{20}$$

where a_2 is a free parameter necessary to be determined experimentally, V_{cb} and V_{cs} are CKM matrix elements and G_F is Fermi coupling constant. The matrix element of $\Lambda_b \to \Lambda$ can be generally defined as the following on the ground of Lorentz decomposition

$$\begin{aligned} < \Lambda(P_\Lambda) \mid \bar{s}\gamma_\mu(1-\gamma_5)b \mid \Lambda_b(P_{\Lambda_b}) > \; &= \; \bar{U}_\Lambda[f_1(q^2)\gamma_\mu + i f_2(q^2)\sigma_{\mu\nu}q^\nu + f_3(q^2)q_\mu - (g_1(q^2)\gamma_\mu \\ &\quad + i g_2(q^2)\sigma_{\mu\nu}q^\nu + g_3(q^2)q_\mu)\gamma_5] U_{\Lambda_b}, \end{aligned} \tag{21}$$

where f_i and g_i are related to F_1 and F_2 by

$$f_1(q^2) = g_1(q^2) = F_1(q^2) + \frac{m_\Lambda}{m_{\Lambda_b}} F_2(q^2), \tag{22}$$

$$f_2(q^2) = g_2(q^2) = f_3(q^2) = g_3(q^2) = \frac{1}{m_{\Lambda_b}} F_2(q^2). \tag{23}$$

Comparing with the general amplitude of $\Lambda_b \to \Lambda + J/\psi$

$$A(\Lambda_b \to \Lambda + J/\psi) = i\bar{U}_\Lambda(P_\Lambda)\varepsilon^{*\mu}[A_1\gamma_\mu\gamma_5 + A_2(P_\Lambda)_\mu\gamma_5 + B_1\gamma_\mu + B_2(P_\Lambda)_\mu]U_{\Lambda_b}(P_{\Lambda_b}), \quad (24)$$

and using (21), (22) and (23) lead to

$$A_1 = -\eta[F_1(m^2_{J/\psi}) + F_2(m^2_{J/\psi})], \quad (25)$$

$$A_2 = -2\eta\frac{1}{m_{\Lambda_b}}F_2(m^2_{J/\psi}), \quad (26)$$

$$B_1 = \eta[F_1(m^2_{J/\psi}) - F_2(m^2_{J/\psi})], \quad (27)$$

$$B_2 = 2\eta\frac{1}{m_{\Lambda_b}}F_2(m^2_{J\psi}), \quad (28)$$

with $\eta = \frac{G_F}{\sqrt{2}}V_{cb}V^*_{cs}a_2 f_{J/\psi}m_{J/\psi}$, where $f_{J/\psi}$ is the J/ψ decay constant and $m_{J/\psi}$ expresses the mass of J/ψ. The decay width is given by [13]

$$\Gamma(\Lambda_b \to \Lambda + J/\psi) = \frac{1}{8\pi}\frac{E_\Lambda + m_\Lambda}{m_{\Lambda_b}}P_{J/\psi}[2(|S|^2 + |P_2|^2) + \frac{E^2_{J/\psi}}{m^2_{J/\psi}}(|S+D|^2 + |P_1|^2)]. \quad (29)$$

Here, $P_{J/\psi}$ and $E_{J/\psi}$ are the momentum and energy of J/ψ in the rest frame of Λ_b respectively and

$$S = -A_1, \quad (30)$$

$$D = -\frac{P^2_{J/\psi}}{E_{J/\psi}(E_\Lambda + m_\Lambda)}(A_1 - m_{\Lambda_b}A_2), \quad (31)$$

$$P_1 = -\frac{P_{J/\psi}}{E_{J/\psi}}(\frac{m_{\Lambda_b} + m_\Lambda}{E_\Lambda + m_\Lambda}B_1 + m_{\Lambda_b}B_2), \quad (32)$$

$$P_2 = \frac{P_{J/\psi}}{E_\Lambda + m_\Lambda}B_1. \quad (33)$$

Using the numerical values of F_1 and F_2 at $m_{J\psi}$ in the limit $m_b \to \infty$, we obtain the width and branching ratio of $\Lambda_b \to \Lambda + J/\psi$

$$\Gamma(\Lambda_b \to \Lambda + J/\psi) = \begin{cases} 1.83 \times 10^{-17} GeV & \text{when } b = 1.18 GeV^{-1}, \\ 1.19 \times 10^{-18} GeV & \text{when } b = 1.77 GeV^{-1}. \end{cases} \quad (34)$$

$$BR(\Lambda_b \to \Lambda + J/\psi) = \begin{cases} 2.97 \times 10^{-5} & \text{when } b = 1.18 GeV^{-1}, \\ 1.94 \times 10^{-5} & \text{when } b = 1.77 GeV^{-1}. \end{cases} \quad (35)$$

The up-down asymmetry parameter α given by[10]

$$\alpha = \frac{4m^2_{J/\psi}Re(S^*P_2) + 2E^2_{J/\psi}Re(S+D)^*P_1}{2(\mid S\mid^2 + \mid P_2\mid^2)m^2_{J/\psi} + (\mid S+D\mid^2 + \mid P_1\mid^2)E^2_{J/\psi}}, \tag{36}$$

is numerically found to be

$$\alpha(\Lambda_b \to \Lambda + J/\psi) = -0.19. \tag{37}$$

Some of parameters used in calculations are chosen as: $V_{cb} = 0.04$, $V_{cs} = 0.97$, $f_{J/\psi} = 0.395GeV$, $m_{\Lambda_b} = 5.64GeV$, $m_\Lambda = 1.116GeV$, $m_s = 0.15GeV$, $\varepsilon = 0.6GeV$, $\tau(\Lambda_b) = 1.07 \times 10^{-12}s$.

a_2 in eq. (20) has some uncertainty. In principle it is related to hadronization and at present it can only be determined by experiment. There are some discussions on it [14]. In the above calculation we choose $a_2 = 0.23$ [7].

5 Conclusion

To sum up, to study the transition $\Lambda_b \to \Lambda$, the two dynamical assumptions suggested by Stech in the meson case are generalized to the baryon case. This leads to a relation between the two form factors F_1 and F_2 in heavy quark limit. Further more, to determine F_1 and F_2 absolutely, we apply the model of Guo and Kroll to our case. Making use of the form factors F_1 and F_2 obtained, the width of decay and branching ratio of $\Lambda_b \to \Lambda + J/\psi$ are calculated. In spite of the sensitivities of the width of decay and branching ratio for $\Lambda_b \to \Lambda + J/\psi$ to the parameter b, which reflects the soft dynamics in the weak transition, we conclude that BR($\Lambda_b \to \Lambda + J/\psi$) is of the order of 10^{-5}, which is the same as that obtained by Datta but smaller than that in ref. [7]. This one order difference may arise from the assumption of the flavor independence of hadronic wave functions in ref. [7]. The up-down asymmetry parameter α is equal to -0.19 and basically in accordance with that arrived at in [7]. It is noted that the parameter α in our approach has nothing to do with the overlap integral of wave function and depends only on the Stech's dynamical assumptions generalized to baryon case. In other words, if the spectator's spin and momentum remain unchanged at the first stage of interaction and if its off-shell energy is almost a constant in the rest frame of its parent baryon this parameter is determined. In the present work , we proceeded only in the heavy quark limit and thus a correction of $1/m_b$ is necessary to improve our results. However, because of large mass of b-quark the results including $1/m_b$ corrections will not improve much over the present results.

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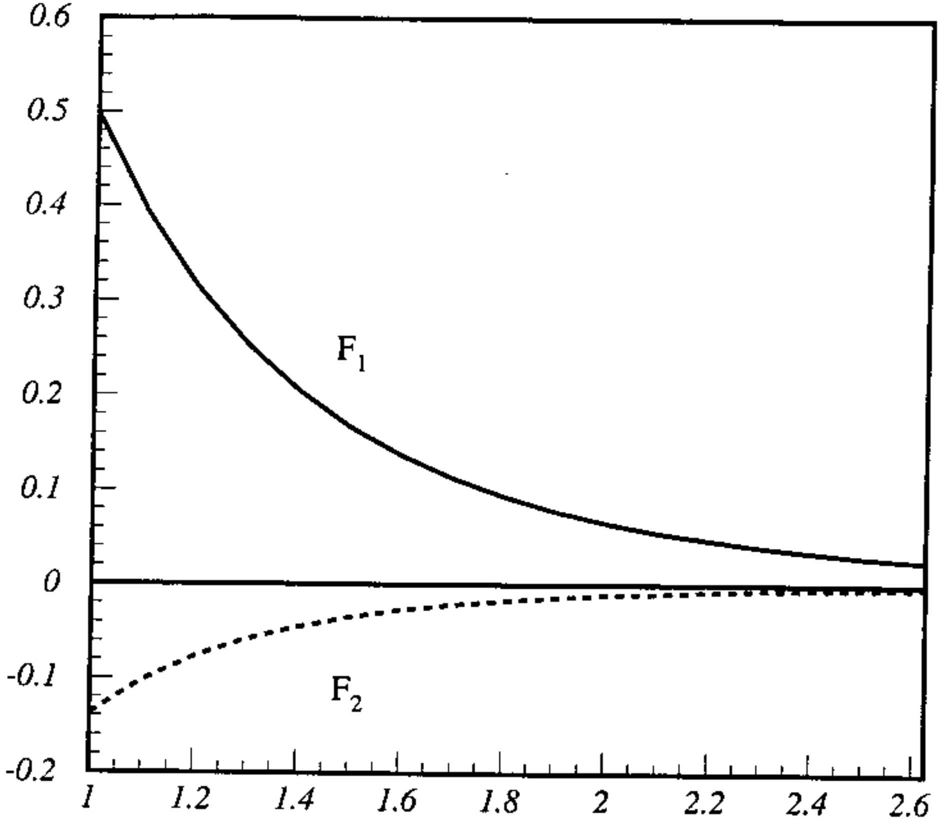

Fig. 1 $\Lambda_b \to \Lambda$ form factors F_1 and F_2 corresponding to argument ω (Here parameter b=1.77 GeV^{-1}).

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