PHYSICAL REVIEW D **72,** 037901 (2005)

T violation in $\bar{B}^0 \to \Lambda \bar{p} \pi^+$

C. Q. Geng and Y. K. Hsiao
Department of Physics, National Tsing Hua University, Hsinchu, Taiwan 300
(Received 29 March 2005; published 25 August 2005)

We study T violation in the three-body charmless baryonic decay of $\bar{B}^0 \to \Lambda \bar{p} \pi^+$ through the T-odd triple product correlation in the standard model. We discuss the difference between T violating triple product correlation and direct CP violating rate asymmetries by showing the explicit strong and weak phase dependences. We find that the T violating asymmetry is 10%, which is accessible to the current B factories at KEK and SLAC, while the CP violating one 1.1%. We emphasize that this triple product correlation would be the first measurable direct T violating effect predicted in the standard model, which provides a reliable test of the Cabbibo-Kobayashi-Maskawa mechanism of T violation.

DOI: 10.1103/PhysRevD.72.037901 PACS numbers: 11.30.Er, 13.25.Hw

CP violating effects are sought after as to get the idea on the origin of CP violation. In that pursuit, most of interests are now focussed on in B decays which are expected to exhibit CP violation "visibly". A component of CP violation induced by the $B - \bar{B}$ mixing in the Cabbibo-Kobayashi-Maskawa (CKM) framework [1] of the standard model, namely $\sin 2\beta$, has already been measured by Belle and *BABAR* collaborations at KEK and SLAC respectively [2,3]. In these studies, both theory and experiment, the objective now turns out to be three folded: to test the CKM paradigm of CP violation, to fix its limitations and to unfold the physics beyond it.

Characteristic observables of CP violation are rate asymmetries and momentum correlations. The direct CP asymmetries arise if both the weak (γ) and strong (δ) phases are nonvanishing

$$A_{CP} \propto \sin\gamma \sin\delta. \tag{1}$$

Whereas the correlations among spin and momenta of the initial and final state particles constitute a measure of T-violating observables. The correlations known as triple product correlations (TPC's), of the T-odd form $\vec{v}_1 \cdot (\vec{v}_2 \times \vec{v}_3)$, where $\vec{v}_i$'s are spin ($\vec{s}_i$) or momentum ($\vec{p}_i$), are used to probe T-violation, for early works see Refs. [4–13]. In the framework of local quantum field theories, T-violation implies CP-violation (and vice versa), because of the CPT invariance of such theories. Experimentally, T violation has been only observed in the neutral kaon system [14] so far. Moreover, no violation of CPT symmetry has been found [11]. Still, it will be worthwhile to remember that outside this framework of local quantum field theories, there is no reason for the two symmetries to be linked [16]. Therefore, it would be interesting to directly investigate T violation in B decays, rather than infering it as a consequence of CP-violation.

Existence of a nonzero TPC is given by

$$A_T = \frac{\Gamma(\vec{v}_1 \cdot (\vec{v}_2 \times \vec{v}_3) > 0) - \Gamma(\vec{v}_1 \cdot (\vec{v}_2 \times \vec{v}_3) < 0)}{\Gamma(\vec{v}_1 \cdot (\vec{v}_2 \times \vec{v}_3) > 0) + \Gamma(\vec{v}_1 \cdot (\vec{v}_2 \times \vec{v}_3) < 0)}, \tag{2}$$

where Γ is the decay rate of the process in question. In comparison with the conjugate process, TPC asymmetry (TPA), $\mathcal{A}_T$ is expressed as

$$\mathcal{A}_T = \frac{1}{2}(A_T - \bar{A}_T). \tag{3}$$

By expressing so, we reaffirm the TPC is indeed due to weak phase. Otherwise, the nonzero TPC in Eq. (2) can occur due to only strong phase. Then TPA turns out to be:

$$\mathcal{A}_T \propto \sin\gamma \cos\delta. \tag{4}$$

This is in contrast with the CP asymmetry in Eq. (1). TPA is *protected* from strong interaction effects encoded in the phase, δ. In the vanishing limit of the strong phase, the TPA is maximal, see Refs. [11,12]. We note that there is no contribution to $\mathcal{A}_T$ in Eq. (3) from final state interaction due to electromagnetic interaction.

In this letter, we consider the three-body charmless baryonic process of $\bar{B}^0 \to \Lambda \bar{p} \pi^+$ looking for TPC of the type $\vec{s}_\Lambda \cdot (\vec{p}_{\bar{p}} \times \vec{p}_\Lambda)$. It has been emphasized in Ref. [17] that the Λ polarization can be detected from its decaying to $p\pi^-$. It is interesting on its own to note that the branching ratio of three-body baryonic decay is much larger than that of the two-body one with the same baryon pair as observed [18,19]:

$$\begin{aligned} Br(B^0 \to \bar{\Lambda} p \pi^-) &= (3.27^{+0.62}_{-0.51} \pm 0.39) \times 10^{-6}, \\ Br(B^- \to \Lambda \bar{p}) &< 4.9 \times 10^{-7}. \end{aligned} \tag{5}$$

The enhancement of three-body decay over the two-body one is due to the reduced energy release in B to π transition by the fastly recoiling π meson that favors the dibaryon production [20]. Theoretical estimations on the modes in Eq. (5) and other baryonic B decays are made [21–26], in consistent with the experimental observations.

In the factorization method, the decay amplitude of $\bar{B}^0 \to \Lambda \bar{p} \pi^+$ contains the $\bar{B}^0 \to \pi^+$ transition and $\Lambda \bar{p}$ baryon-pair inducing from the vacuum. The contributions to the decay at the quark level are mainly from O_1, O_4 and O_6 operators defined in Refs. [27,28]. From those operators

1550-7998/2005/72(3)/037901(4)$23.00

and the factorization approximation, the decay amplitude is given by [22]

$$\begin{aligned} M &= M_1 + M_4 + M_6, \\ M_i &= \frac{G_f}{\sqrt{2}} \lambda_i a_i \langle \pi^+ | \bar{u} \gamma^\mu (1-\gamma_5) b | \bar{B}^0 \rangle \langle \Lambda \bar{p} | \bar{s} \gamma_\mu (1-\gamma_5) u | 0 \rangle, \quad (i = 1, 4), \\ M_6 &= \frac{G_f}{\sqrt{2}} V_{tb} V_{ts}^* 2a_6 \langle \pi^+ | \bar{u} \gamma^\mu (1-\gamma_5) b | \bar{B}^0 \rangle \frac{(p_\Lambda + p_{\bar{p}})_\mu}{m_b - m_u} \langle \Lambda \bar{p} | \bar{s}(1+\gamma_5) u | 0 \rangle, \end{aligned} \tag{6}$$

where $\lambda_1 = V_{ub} V_{us}^*$, $\lambda_4 = -V_{tb} V_{ts}^*$ and $a_1 = c_1^{\text{eff}} + c_2^{\text{eff}}/N_c$, $a_4 = c_4^{\text{eff}} + c_3^{\text{eff}}/N_c$, $a_6 = c_6^{\text{eff}} + c_5^{\text{eff}}/N_c$ with $c_i^{\text{eff}}(i = 1, 2, \ldots, 6)$ being effective Wilson coefficients (WC's) given in Refs. [27–30] and N_c color number. We note that c_i^{eff}/N_c are included to express the color-octet terms. The $\bar{B}^0 \to \pi^+$ transition matrix is given by

$$\langle \pi^+ | \bar{u} \gamma^\mu (1-\gamma_5) b | \bar{B}^0 \rangle = \left[(p_B + p_\pi)^\mu - \frac{m_B^2 - m_\pi^2}{(p_B - p_\pi)^2} (p_B - p_\pi)^\mu \right] F_1^{B\to\pi}(t) + \frac{m_B^2 - m_\pi^2}{(p_B - p_\pi)^2} (p_B - p_\pi)^\mu F_0^{B\to\pi}(t), \tag{7}$$

where $t \equiv (p_\Lambda + p_{\bar{p}})^2$ and $F_{1,0}^{B\to\pi}(t)$ can be found in Ref. [31]. As for the baryon pair form factors involving the vector, axial vector, scalar and pseudoscalar currents in Eq. (6), we have

$$\begin{aligned} \langle \Lambda \bar{p} | \bar{s} \gamma_\mu u | 0 \rangle &= \bar{u}(p_\Lambda) \left\{ [F_1(t) + F_2(t)] \gamma_\mu + \frac{F_2(t)}{m_\Lambda + m_{\bar{p}}} (p_{\bar{p}} - p_\Lambda)_\mu \right\} v(p_{\bar{p}}), \\ \langle \Lambda \bar{p} | \bar{s} \gamma_\mu \gamma_5 u | 0 \rangle &= \bar{u}(p_\Lambda) \left\{ g_A(t) \gamma_\mu + \frac{h_A(t)}{m_\Lambda + m_{\bar{p}}} (p_{\bar{p}} + p_\Lambda)_\mu \right\} \gamma_5 v(p_{\bar{p}}) \\ \langle \Lambda \bar{p} | \bar{s} u | 0 \rangle &= f_S(t) \bar{u}(p_\Lambda) v(p_{\bar{p}}), \qquad \langle \Lambda \bar{p} | \bar{s} \gamma_5 u | 0 \rangle = g_P(t) \bar{u}(p_\Lambda) \gamma_5 v(p_{\bar{p}}). \end{aligned} \tag{8}$$

In Eq. (8), the baryonic form factors are defined b [17]

$$\begin{aligned} &F_1(t) + F_2(t) = -\sqrt{\frac{3}{2}} G_M^p(t), \qquad g_A(t) = -\frac{1}{\sqrt{6}} [D_A(t) + 3F_A(t)], \qquad h_A(t) = -g_A(t) \frac{(m_\Lambda + m_{\bar{p}})^2}{t} \\ &f_S(t) = -\sqrt{\frac{3}{2}} n_q G_M^p(t), \qquad g_P(t) = -\frac{1}{\sqrt{6}} [D_P(t) + 3F_P(t)], . \end{aligned} \tag{9}$$

It is noted that $G_M^p(t)$ is the nucleon magnetic (Sachs) form factor, while $D_{A(P)}(t)$ and $F_{A(P)}(t)$ are the similar parametrized functions in the QCD counting rules. n_q is defined by $n_q \equiv (m_\Lambda - m_{\bar{p}})/(m_s - m_u)$, and we fix it to be 1.3 to account for the SU(3) breaking effect.The functions of $G_M^p(t)$, $D_A(t)$, $F_A(t)$, $D_P(t)$ and $F_P(t)$ have been expanded in terms of t and their fitting results can be found in Ref. [21–23].

We now study the TPC involving the Λ spin from Eq. (6), and we get

$$\begin{aligned} |M|^2 = |M_1|^2 + |M_4|^2 + |M_6|^2 + 2Re(M_1 M_4^\dagger) \\ + 2Re(M_1 M_6^\dagger) + 2Re(M_4 M_6^\dagger). \end{aligned} \tag{10}$$

In our calculation, we will sum over the proton spin. We note that TPC can only arise from the interference terms, i.e., $Re(M_1 M_4^\dagger)$, $Re(M_1 M_6^\dagger)$ and $Re(M_4 M_6^\dagger)$. However, as we will show next, the T-odd term in $Re(M_1 M_4^\dagger)$ disappears since M_1 and M_4 have the same current structures as seen from Eq. (6).

To describe the triple momentum correlations explicitly, we write the four components of the Λ spin as $(s_0, \vec{s}) = (\vec{p}_\Lambda \cdot \vec{\xi}/m_\Lambda, s_0 \vec{p}_\Lambda/(E_\Lambda + m_\Lambda) + \vec{\xi})$, where the $\vec{\xi}$ is an unit vector along the Λ spin in its rest frame. By defining the unit vectors along the longitudinal, normal, and transverse components of the Λ polarization to be $\vec{e}_L = \vec{p}_\Lambda/|\vec{p}_\Lambda|$, $\vec{e}_N = \vec{p}_\Lambda \times (\vec{p}_\Lambda \times \vec{p}_{\bar{p}})/|\vec{p}_\Lambda \times (\vec{p}_\Lambda \times \vec{p}_{\bar{p}})|$, $\vec{e}_T = \vec{p}_{\bar{p}} \times \vec{p}_\Lambda/|\vec{p}_{\bar{p}} \times \vec{p}_\Lambda|$, the partial decay width with the polarized Λ for $\bar{B}^0 \to \Lambda \bar{p} \pi^+$ is given by

$$d\Gamma = \frac{1}{(2\pi)^3} \frac{|M|^2}{32 M_B^3} dm_{\Lambda\bar{p}}^2 dm_{\bar{p}\pi}^2, \tag{11}$$

with the squared amplitude

$$|M|^2 = \rho_0 [1 + (P_L \vec{e}_L + P_N \vec{e}_L + P_T \vec{e}_T) \cdot \vec{\xi}], \tag{12}$$

where $m_{\Lambda\bar{p}}(m_{\bar{p}\pi}) \equiv p_\Lambda + p_{\bar{p}}(p_{\bar{p}} + p_\pi)$, ρ_0 is the distribution density which is free of the Λ spin and its integrated value is equal to $\Gamma/2$, and three components of P_i are defined by

$$P_i = \frac{d\Gamma(\vec{e}_i \cdot \vec{\xi} = 1) - d\Gamma(\vec{e}_i \cdot \vec{\xi} = -1)}{d\Gamma(\vec{e}_i \cdot \vec{\xi} = 1) + d\Gamma(\vec{e}_i \cdot \vec{\xi} = -1)} (\text{i} = \text{L}, \text{N}, \text{T}), \tag{13}$$

respectively. Explicitly, the transverse polarization asymmetry P_T, which is related to TPC, is found to be

$$P_T = \frac{8G_F^2 m_B |\vec{p}_{\bar{p}} \times \vec{p}_\Lambda|}{\rho_0} \{(V \cdot S + A \cdot P) \times [Im(V_{ub}V_{us}^* V_{tb}V_{ts}^* a_1 a_6^* - V_{tb}V_{ts}^* V_{tb}V_{ts}^* a_4 a_6^*)]\}, \quad (14)$$

where

$$V = F_1^{B\to\pi}(t)[F_1(t) + F_2(t)], A = F_1^{B\to\pi}(t) g_A(t), \quad S = \chi_c F_0^{B\to\pi}(t) f_S(t), P = \chi_c F_0^{B\to\pi}(t) g_P(t). \quad (15)$$

with $\chi_c \equiv (m_B^2 - m_\pi^2)/(m_b - m_u)$. It is obvious that $V \cdot S$ ($A \cdot P$) term is from vector-scalar (axial-vector-pseudoscalar) interference and there is no T-odd term from $Re(M_1 M_4^\dagger)$ due to the same current structures. From Eq. (13), we may also define the integrated transverse Λ polarization asymmetry by

$$A_T = \frac{\int d\Gamma(\vec{e}_T \cdot \vec{\xi} = 1) - \int d\Gamma(\vec{e}_T \cdot \vec{\xi} = -1)}{\int d\Gamma(\vec{e}_T \cdot \vec{\xi} = 1) + \int d\Gamma(\vec{e}_T \cdot \vec{\xi} = -1)}. \quad (16)$$

In our numerical calculations, the CKM parameters are taken to be [15] $V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ and $V_{tb}V_{ts}^* = -A\lambda^2$ with $A = 0.853$, $\lambda = 0.2200$, and ρ and η are expressed as functions of the weak phase γ by $\rho = R_b \cos\gamma$ and $\eta = R_b \sin\gamma$ with $R_b \equiv \frac{|V_{ub}|}{|V_{cb}|}/\lambda = 0.403$ [15]. We note that the current allowed values of (ρ, η) are $(0.20 \pm 0.09, 0.33 \pm 0.05)$ [15]. To distinguish the origin of CP violation, we use the weak phases $\gamma = 60°$ and $0°$ corresponding to $(\rho, \eta) = (0.20, 0.35)$ and $(0.40, 0)$, respectively. We remark that a_1, a_4 and a_6 [27,28,30] contain both weak and strong phases, induced by η and quark-loop rescatterings, respectively. Explicitly, at the scale m_b and $N_c = 3$, we obtain a set of $(a_1, a_4, a_6) = (1.05, [(-388 \mp 8.5\eta - 3.7\rho) + i(-115 \pm 3.7\eta - 8.5\rho)] \times 10^{-4}, [(-556 \mp 8.5\eta - 3.7\rho) + i(-115 \pm 3.7\eta - 8.5\rho)] \times 10^{-4})$ for $b \to s$ ($\bar{b} \to \bar{s}$) transition. As an illustration, we would also like to turn off the strong phase ($\delta = 0$), by taking the imaginary parts of the quark-loop rescattering effects to be zero. It is noted that from Eq. (11), when summing over all spins, the decay branching ratio of $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ is found to be 3.26×10^{-6}, which reconfirms the result in Ref. [22] and agrees well with the experimental data in Eq. (5). This result also confirms that the factorization approximation is valid in this mode.

Using Eq. (16), the numerical values for TPAs of A_T ($\bar{A}_T$) and $\mathcal{A}_T = (A_T - \bar{A}_T)/2$ are shown in Table I.

TABLE I. Triple product correlation asymmetries (in percent) of A_T ($\bar{A}_T$) for $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ ($B^0 \to \bar{\Lambda}p\pi^-$) and $\mathcal{A}_T = (A_T - \bar{A}_T)/2$.

$A_T, \bar{A}_T, \mathcal{A}_T$	$\gamma = 60°$	$\gamma = 0°$
$\delta \neq 0$	9.9, −5.2, 7.6	3.4, 3.4, 0
$\delta = 0$	10.4, −10.4, 10.4	0, 0, 0

From the table, we see explicitly that TPAs are indeed nonzero and maximal in the absence of the strong phase. We note that in our calculations we have neglected the final state interactions due to electromagnetic and strong interactions, which are believed to be small in three-body charmless baryonic decays [22]. It is interesting to point out that in order to observe the TPAs in $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ and $B^0 \to \bar{\Lambda}p\pi^-$ being at $10 - 7\%$, we need to have about $(1 - 2) \times 10^8$ $B\bar{B}$ pairs at 2σ level. This is within the reach of the present day B factories at KEK and SLAC and others that would come up. It is clear that an experimental measurement of $\mathcal{A}_T$ is a reliable test of the CKM mechanism of CP violation and, moreover, it could be the first evidence of the direct T violation in B decays.

We now illustrate the difference between the TPAs and the rate CP asymmetry defined by

$$A_{CP} = \frac{\Gamma(\bar{B}^0 \to \Lambda\bar{p}\pi^+) - \Gamma(B^0 \to \bar{\Lambda}p\pi^-)}{\Gamma(\bar{B}^0 \to \Lambda\bar{p}\pi^+) + \Gamma(B^0 \to \bar{\Lambda}p\pi^-)}. \quad (17)$$

The decay width can be obtained from the Eq. (16) by integrating and summing over the spins of the final state particles. Nonzero contributions on A_{CP} can be induced from the interferences among M_1, M_4 and M_6. Explicitly, we find that A_{CP} for $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ is 1.1%, which is about 1 order of magnitude smaller than that of $\mathcal{A}_T$. It is clear that without strong or weak phase there is no direct CP violating asymmetry as seen in Eq. (1).

To conclude, we have shown that the T violating triple product correlation asymmetries in $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ and $B^0 \to \bar{\Lambda}p\pi^-$ are $O(10\%)$ in the standard model, which are large enough so that they can be interesting measurements. In fact, they would be the first measurable direct T violating effects in B physics.

Finally, several remarks are given as follows: (i) We have also explored T violating effects in a large class of interesting charmless baryonic decays such as $B \to \Lambda\bar{\Lambda}K$ [26] and we have found that they are small [32]. (ii) Many three-body charmless baryonic B decays [21–26] such as $p\bar{p}K(\pi)$, $\Lambda\bar{\Lambda}K(\pi)$, $\Lambda(\Sigma^0)\bar{p}\gamma$ and $\Lambda\bar{p}\pi$ have been studied with QCD counting rules based on the factorization approximation and all results are agree well with the experimental data. This clearly assures the validity of the factorization in these three-body decays. In particular, for the considered mode of $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ in this study, we have used the generalized factorization hypothesis (GFH) [33] in which N_c is taken to be as an effective color number to incorporate nonfactorizable effects. We have checked our results with $N_c = 2$ and ∞ and we have found that they are insensitive to the value of N_c. Note that other factorization methods beyond the GFH such as QCD factorization (QCDF) [34] and perturbative QCD (PQCD) [35] have not been extended to three-body baryonic B decays. (iii) The errors in our numerical results due to the CKM parameters and QCD uncertainties are expected to be less than 10%. (iv) In this letter, we have considered only the possible standard model contributions to TPAs. The implications of alternative models on the sizes of the asymmetries in various three-body baryonic B decays will be presented elsewhere [32].

This work is financially supported by the National Science Council of Republic of China under the contract numbers NSC-91-2112-M-007-043, NSC-92-2112-M-007-025 and NSC-93-2112-M-007-014.

[1] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and K. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).

[2] A. Abashian *et al.*, (Belle Collaboration), Phys. Rev. Lett. **86**, 2509 (2001); B. Aubert *et al.*, (*BABAR* Collaboration), Phys. Rev. Lett. **86**, 2515 (2001).

[3] B. Aubert *et al.*, *BABAR* Collaboration, Phys. Rev. Lett.**93**, 131801 (2004); Y. Chao *et al.*, (Belle Collaboration), Phys. Rev. Lett. **93**, 191802 (2004).

[4] L. B. Okun and Khriplovich, Sov. J. Nucl. Phys.**6**, 598 (1968); E. S. Ginsberg and J. Smith, Phys. Rev. D **8**, 3887 (1973); S. W. MacDowell, Nuovo Cimento **9**, 258 (1958); N. Cabibbo and A. Maksymowicz, Phys. Lett. **9**, 352 (1964); Phys. Lett. **11**, 360 (1964); Phys. Lett. **14**, 72 (1986).

[5] G. Valencia, Phys. Rev. D **39**, 3339 (1989); B. Kayser, Nucl. Phys. B Proc. Suppl. **13**, 487 (1990).

[6] R. Garisto and G.L. Kane, Phys. Rev. D **44**, 2038 (1991).

[7] G. Belanger and C. Q. Geng, Phys. Rev. D **44**, 2789 (1991); P. Agrawal *et al.*, Phys. Rev. Lett. **67**, 537 (1991); Phys. Rev. **45**, 2383 (1992).

[8] D. Atwood and A. Soni, Phys. Rev. Lett. **74**, 220 (1995); Phys. Rev. Lett. **81**, 3324 (1998).

[9] C. H. Chen, C. Q. Geng, and J. N. Ng, Phys. Rev. D **65**, 091502 (2002); Nucl. Phys. B Proc. Suppl. **115**, 263 (2003).

[10] C. H. Chen and C. Q. Geng, Phys. Lett. B **607**, 115 (2005).

[11] W. Bensalem and D. London, Phys. Rev. D **64**, 116003(2001).

[12] W. Bansalem, A. Datta, and D. London, Phys. Lett. B **538**, 309 (2002); W. Bensalem, London, N. Sinha, and R. Sinha, Phys. Rev. D **67**, 034007 (2003); A. Datta and D. London, Int. J. Mod. Phys. A **19**, 2505 (2004).

[13] S. Arunagiri and C. Q. Geng, Phys. Rev. D **69**, 017901 (2004).

[14] A. Angelopoulos *et al.* (CPLEAR Collaboration), Phys. Lett. B **444**, 43 (1998).

[15] S. Eidelman *et al.* (Particle Data Group), Phys. Lett. B **592**, 1 (2004).

[16] C. Q. Geng and L. Geng, hep-ph/0504215.

[17] M. Suzuki, J. Phys. G **29**, B15 (2003).

[18] M. Z. Wang *et al.*, (Belle Collaboration), Phys. Rev. Lett. **90**, 201802 (2003); J. Schümann, hep-ex/0505098.

[19] K. Abe *et al.* (BELLE Collaboration), Phys. Rev. D **71**, 072007 (2005).

[20] W. S. Hou and A. Soni, Phys. Rev. Lett. **86**, 4247 (2001).

[21] C. K. Chua, W. S. Hou, and S. Y. Tsai, Phys. Rev. D **66**, 054004 (2002).

[22] C. K. Chua and W. S. Hou, Eur. Phys. J. C **29**, 27 (2003).

[23] C. K. Chua, W. S. Hou, and S. Y. Tsai, Phys. Lett. B **528**, 233 (2002).

[24] F. Piccinini and A. D. Polosa, Phys. Rev. D **65**, 097508 (2002); H. Y. Cheng and K. C. Yang, Phys. Lett. B**533**, 271 (2002); Phys. Rev. D **66**, 014020 (2002).

[25] C. Q. Geng and Y. K. Hsiao, Phys. Lett. B **610**, 67 (2005).

[26] C. Q. Geng and Y. K. Hsiao, hep-ph/0503264.

[27] A. Ali, G. Kramer, and C-D. Lu, Phys. Rev. D **58**, 094009 (1998).

[28] Y. H. Chen, *et al.*, Phys. Rev. D **60**, 094014 (1999).

[29] G. Buchalla, A. J. Buras, and M. E. Lautenbacher, Rev. Mod. Phys. **68**, 1125 (1996).

[30] H. Y. Cheng and K. C. Yang, Phys. Rev. D **62**, 054029 (2000).

[31] D. Melikhov and B. Stech, Phys. Rev. D **62**, 014006 (2000).

[32] C. Q. Geng and Y. K. Hsiao (to be published).

[33] A. Ali and C. Greub, Phys. Rev. D **57**, 2996 (1998); H. Y. Cheng and B. Tseng, Phys. Rev. D **58**, 094005 (1998).

[34] M. Beneke, *et al.*, Phys. Rev. Lett. **83**, 1914 (1999); Nucl. Phys. **B591**, 313 (2000).

[35] H. n. Li, Phys. Rev. D **64**, 014019 (2001).