B → ρK and B → πK* decays in SCET

Gaber Faisal
Department of Physics and Center for Mathematics and Theoretical Physics, National Central University, Chung-li, TAIWAN 32054, and Egyptian Center for Theoretical Physics, Modern University for Information and Technology, Cairo, Egypt (Dated: October 31, 2011)

Exploring hints of New Physics in the decay modes B → πK* and B → ρK can shed light on the B → Kπ puzzle. In this talk, we discuss supersymmetric contributions to the direct CP asymmetries of the decays B → πK* and B → ρK within Soft Collinear Effective Theory. We consider non-minimal flavor SUSY contributions mediated by gluino exchange and apply the Mass Insertion Approximation (MIA) in the analysis. We show that gluino contributions can enhance the CP asymmetries and accommodate the experimental results.

PACS numbers: 13.25.Hw,12.60.Jv,11.30.Hv

I. INTRODUCTION

Soft Collinear Effective Theory (SCET) is an effective field theory describing the dynamics of highly energetic particles moving close to the light-cone interacting with a background field of soft quanta[1–10]. It provides a systematic and rigorous way to deal with the decays of the heavy hadrons that involve different energy scales. Moreover, the power counting in SCET helps to reduce the complexity of the calculations and the factorization formula provided by SCET is perturbative to all powers in αs expansion.

We can classify two different effective theories: SCETI and SCETII according to the momenta modes in the process under consideration. SCETI is applicable in the processes in which the momenta modes are the collinear and the ultra soft as in the inclusive decays of a heavy meson such as B → Xsγ at the end point region and e−p → e−X at the threshold region in which there are only collinear and ultra soft momenta modes. SCETII is applicable to the semi-inclusive or exclusive decays of a heavy meson such as B → Dπ, B → Kπ, B → πνe,....etc in which there are only collinear and soft momenta modes.

The amplitude of B → M1M2 where M1 and M2 are light mesons in SCET can be written as follows

\[ A_{B→M_1M_2}^{SCET} = A_{B→M_1M_2}^{LO} + A_{B→M_1M_2}^{Y} + A_{B→M_1M_2}^{ann} + A_{B→M_1M_2}^{c.c} \] (1)

Here \( A_{B→M_1M_2}^{LO} \) denotes the leading order amplitude in the expansion 1/m_b, \( A_{B→M_1M_2}^{Y} \) denotes the chirally enhanced penguin amplitude, \( A_{B→M_1M_2}^{ann} \) denotes the annihilation amplitude and \( A_{B→M_1M_2}^{c.c} \) denotes the long distance charm penguin contributions. In the following we give a brief account for each amplitude.

At leading power in (1/m_b) expansion, the full QCD effective weak Hamiltonian of the ΔB = 1 decays is matched into the corresponding weak Hamiltonian in SCETI by integrating out the hard scale m_b. Then, the SCETI weak Hamiltonian is matched into the weak Hamiltonian SCETII by integrating out the hard collinear modes with \( p^2 \sim \Lambda m_b \) and the amplitude of the ΔB = 1 decays at leading order in αs expansion can be obtained via [3]:
\begin{align*}
A_{B \to M_1 M_2}^0 &= -i(M_1 M_2 | H_W^{SCETII} | B) \\
&= \frac{G_F m_B^2}{\sqrt{2}} \left( f_{M_1} \int_0^1 du z T_{M_1}(u, z) \phi_{M_2}(z) \phi_{M_1}(u) \\
&+ \zeta^{BM_2} \int_0^1 du T_{M_1 Z}(u) \phi_{M_2}(u) \right) + (M_1 \leftrightarrow M_2). \tag{2}
\end{align*}

At leading order in $\alpha_s$ expansion, the parameters $\zeta^{BM_1 M_2}$, $\zeta_j^{BM_1 M_2}$ are treated as hadronic parameters and can be determined through the $\chi^2$ fit method using the non leptonic decay experimental data of the branching fractions and CP asymmetries. The hard kernels $T_{(M_1, M_2)z}$ and $T_{(M_1, M_2)j}$ can be expressed in terms of $c_i^{(f)}$ and $b_i^{(f)}$ which are functions of the Wilson coefficients as follows [6]

\begin{align*}
T_{1z}(u) &= c_{uL}^{BM_2} c_{fL u}^{M_1} c_1^{(f)}(u) + c_{fL}^{BM_2} c_{uL u}^{M_1} c_2^{(f)}(u) \\
&+ c_{fL}^{BM_2} c_{uL u}^{M_1} c_3^{(f)}(u) + c_{qL}^{BM_2} c_{fL q}^{M_1} c_4^{(f)}(u), \\
T_{1j}(u, z) &= c_{uL}^{BM_2} c_{fL u}^{M_1} b_1^{(f)}(u, z) + c_{fL}^{BM_2} c_{uL u}^{M_1} b_2^{(f)}(u, z) \\
&+ c_{fL}^{BM_2} c_{uL u}^{M_1} b_3^{(f)}(u, z) + c_{qL}^{BM_2} c_{fL q}^{M_1} b_4^{(f)}(u, z). \tag{3}
\end{align*}

Here $f$ stands for $d$ or $s$ and $c_i^{BM}$ and $c_i^M$ are Clebsch-Gordan coefficients that depend on the flavor content of the final state mesons. $c_i^{(f)}$ and $b_i^{(f)}$ are given by [7]

\begin{align*}
c_{1,2}^{(f)} &= \lambda_u^{(f)} \left[ C_{1,2} + \frac{1}{N} C_{2,1} \right] - \lambda_t^{(f)} \frac{3}{2} \left[ \frac{1}{N} C_{9,10} + C_{10,9} \right] + \Delta c_{1,2}^{(f)}, \\
c_3^{(f)} &= -\frac{3}{2} \lambda_t^{(f)} \left[ C_7 + \frac{1}{N} C_8 \right] + \Delta c_3^{(f)}, \\
c_4^{(f)} &= -\lambda_t^{(f)} \left[ \frac{1}{N} C_3 + C_4 - \frac{1}{2N} C_9 - \frac{1}{2} C_1 \right] + \Delta c_4^{(f)}, \tag{4}
\end{align*}

and

\begin{align*}
b_{1,2}^{(f)} &= \lambda_u^{(f)} \left[ C_{1,2} + \frac{1}{N} \left( 1 - \frac{m_b}{\omega_2} \right) C_{2,1} \right] - \lambda_t^{(f)} \frac{3}{2} \left[ C_{10,9} + \frac{1}{N} \left( 1 - \frac{m_b}{\omega_3} \right) C_{9,10} \right] + \Delta b_{1,2}^{(f)}, \\
b_3^{(f)} &= -\lambda_t^{(f)} \frac{3}{2} \left[ C_7 + \left( 1 - \frac{m_b}{\omega_2} \right) \frac{1}{N} C_8 \right] + \Delta b_3^{(f)}, \\
b_4^{(f)} &= -\lambda_t^{(f)} \left[ C_4 + \frac{1}{N} \left( 1 - \frac{m_b}{\omega_3} \right) C_5 \right] + \lambda_t^{(f)} \frac{1}{2} \left[ C_{10} + \frac{1}{N} \left( 1 - \frac{m_b}{\omega_3} \right) C_9 \right] + \Delta b_4^{(f)}, \tag{5}
\end{align*}

where $\omega_2 = m_b u$ and $\omega_3 = -m_b \bar{u}$. $u$ and $\bar{u} = 1 - u$ are momentum fractions for the quark and antiquark $\bar{u}$ collinear fields. The $\Delta c_i^{(f)}$ and $\Delta b_i^{(f)}$ denote terms depending on $\alpha_s$ generated by matching from $H_W$. The $O(\alpha_s)$ contribution to $\Delta c_i^{(f)}$ has been calculated in Refs. [11, 12] and later in Ref. [6] while the $O(\alpha_s)$ contribution to $\Delta b_i^{(f)}$ has been calculated in Refs. [6, 13, 14].

Corrections of order $\alpha_s(\mu_b)(\mu_M/\Lambda^2)$ where $\mu_M$ is the chiral scale parameter generate the so called Chirally enhanced penguins amplitude $A_{B \to M_1 M_2}^0$ $\mu_M$ for kaons and pions can be of order $(2GeV)$ and therefore chirally enhanced terms can compete with the order $\alpha_s(\mu_b)(\Lambda/m_b)$ terms. The chirally enhanced amplitude for $B \to M_1 M_2$ decays is given by [6].
Moreover, the predicted CP asymmetry of $\bar{B}$ is in agreement with the experimental measurements due to the large errors in these measurements [32].

Withen SCET, the predicted branching ratios of the decay modes $B \to \pi K^*$ and $B \to \rho K$ are in agreements with their corresponding experimental values in most of the decay modes [8]. On the other hand, the SM predictions for the CP asymmetries of $B^+ \to \pi^0 K^{*+}$ has different sign in comparison with the experimental measurement and the predicted CP asymmetries in many of the decay modes are in agreement with the experimental measurements due to the large errors in these measurements [32]. Moreover, the predicted CP asymmetry of $\bar{B} \to \pi^0 K^{*0}$ and $B^+ \to \rho^0 K^+$ disagree with the experimental

$$ A^\chi(\bar{B} \to M_1 M_2) = \frac{G_{FM_B}^2}{\sqrt{2}} \left\{ -\frac{\mu_M f_{M_1}}{3 m_B} c_{BM_2} \int_0^1 du R_1(u) \phi_{pp}^M(u) + (1 \leftrightarrow 2) \right. $$

$$ \left. - \frac{\mu_M f_{M_1}}{3 m_B} \int_0^1 dudz R_1'(u, z) \zeta_{BM_2}(z) \phi_{pp}^M(u) + (1 \leftrightarrow 2) \right. $$

$$ \left. - \frac{\mu_M f_{M_1}}{6 m_B} \int_0^1 dudz R_1^\chi(u, z) \zeta_{BM_2}(z) \phi_{BM_2}^M(u) + (1 \leftrightarrow 2) \right\} \quad (6) $$

The factors $\mu_M$ are generated by pseudoscalars and so they vanish for vector mesons [6]. The pseudoscalar light cone amplitude $\phi_{pp}^M(u)$ is defined as [15, 16]

$$ \phi_{pp}^M(u) = 3u[\phi_p^M(u) + \phi_e^M(u)]/6 + 2f_{3P}/(f_P f_P) \int dy' / y' \phi_{3P}(y - y', y). \quad (7) $$

The hard kernels $R_K, R_\pi, R_K^l, R_\pi^l, R_K^\chi$ and $R_\pi^\chi$ can be expressed in terms of Clebsch-Gordan coefficients for the different final states as [6]

$$ R_1(u) = C_{q}\delta_{q} C_{q} \left[ c_{q(2q)} \right], \quad (8) $$

$$ R_1'(u, z) = C_{q}\delta_{q} C_{q} \left[ b_{q(2q)} \right], \quad (9) $$

$$ R_1^\chi(u, z) = C_{q}\delta_{q} C_{q} \left[ b_{1(2q)} \right] + C_{q}\delta_{q} C_{q} \left[ b_{1(2q)} \right] $$

$$ + C_{q}\delta_{q} C_{q} \left[ b_{1(2q)} \right] + C_{q}\delta_{q} C_{q} \left[ b_{1(2q)} \right]. $$

Summation over $q = u, d, s$ is implicit and $c_{q}^u$ and $b_{q}^u$ are expressed in terms of the short-distance Wilson coefficients and can be found in Ref. [6].

Annihilation amplitudes $A_{B \to M_1 M_2}^{\pi\pi}$ have been studied in PQCD and QCD factorization in Refs. [17-20]. Within SCET, the annihilation contribution becomes factorizable and real at leading order, $O(\alpha_s(m_6)A/m_b)$ [21]. Their size are small and contains large uncertainty compared to the other contributions [6, 15].

In SCET, charm penguins are treated as non perturbative and its amplitude is parameterized as

$$ A_{B \to M_1 M_2}^{\pi\pi} = |A_{B \to M_1 M_2}| e^{i \delta_{cc}} \quad (9) $$

where $\delta_{cc}$ is the strong phase of the charm penguin. The modulus and the phase of the charm penguin are fixed through the fitting with non leptonic decays in a similar way to the hadronic parameters $\zeta_{BM_1 M_2}$, $\zeta_{BM_1 M_2}$

II. SM CONTRIBUTION TO THE CP ASYMMETRIES OF $B \to \pi K^*$ AND $B \to \rho K$ DECAYS
results within $1\sigma$ error of the experimental data. Note, SCET provides large strong phases and thus with new sources of weak CP violation one can expect enhancement of these asymmetries. This possibility will be discussed in the next section considering supersymmetry (SUSY) as a possible candidate of physics beyond SM that has new sources of weak phases.

III. SUSY CONTRIBUTIONS TO THE CP ASYMMETRIES OF $B \to \rho K$ AND $B \to \pi K^*$

Supersymmetry has new sources for CP violation which can account for the baryon number asymmetry and affect other CP violating observables in the B and K decays. The effects of these phases on the CP asymmetries in semi-leptonic $\tau$ decays has been studied in Refs. ([22–24]). In SUSY, Flavor Changing Neutral Current (FCNC) and CP quantities are sensitive to particular entries in the mass matrices of the scalar fermions. Thus it is useful to adopt a model independent- parametrization, the so-called Mass Insertion Approximation (MIA) where all the couplings of fermions and sfermions to neutral gauginos are flavor diagonal [25]. The Flavor Changing structure of the $A - B$ sfermion propagator is exhibited by its non-diagonality and it can be expanded as

$$\langle \tilde{f}_A \tilde{f}^*_B \rangle \simeq \frac{i\delta_{ab}}{k^2 - \tilde{m}^2} + \frac{i(\Delta_{AB})_{ab}}{(k^2 - \tilde{m}^2)^2} + O(\Delta^2), \quad (10)$$

where $a, b = (1, 2, 3)$ are flavor indices, $\Delta$ are the off-diagonal terms in the $(M^2)_{AB}$ and $I$ is the unit matrix. It is convenient to define a dimensionless quantity $(\delta_{AB})_{ab} \equiv (\Delta_{AB})_{ab}/\tilde{m}^2$. As long as $(\Delta_{AB})_{ab}$ is smaller than $\tilde{m}^2$ we can consider only the first order term in $(\delta_{AB})_{ab}$ of the sfermion propagator expansion.

The parameters $(\delta_{AB})_{ab}$ can be constrained through vacuum stability argument [26], experimental measurements concerning FCNC and CP violating phenomena [27]. Recent studies about other possible constraints can be found in Refs. ([28–30]).

The mass insertions $(\delta_{RL})_{32}$ and $(\delta_{LR})_{32}$ are not constrained by $b \to s\gamma$ and so we can set them as $(\delta_{RL})_{32} = (\delta_{LR})_{32} = e^{i\delta_u}$ where $\delta_u$ is the phase that can vary from $-\pi$ to $\pi$. It should be noted that in order to have a well defined Mass Insertion Approximation scheme, it is necessary to have $|(|\delta_{AB})_{ab}| < 1$ but here in order to maximize the SUSY CP-violating contributions we take it of order one. Applying $b \to s\gamma$ constraints leads to the following parametrization [31]

$$(\delta_{LL})_{23} = e^{i\delta_d} \quad (\delta_{LR})_{23} = (\delta_{RL})_{23} = 0.01e^{i\delta} \quad (11)$$

We consider two scenarios, the first one with a single mass insertion where we keep only one mass insertion per time and take the other mass insertions to be zero and the second scenario with two mass insertions will be considered only in the cases when one single mass insertion is not sufficient to accommodate the experimental measurement. After setting the different mass insertions as mentioned above, we find that, the terms that contain the mass insertions $(\delta_{RL})_{32}$ and $(\delta_{LR})_{32}$ will be small in comparison with the other terms and thus we expect that their contributions to the asymmetries will be small. These terms are obtained from diagrams mediated by the chargino exchange and thus we see that gluino contributions give the dominant contributions. The results are presented in Figures [32–34].
In Figure 1 we show the CP asymmetries, $A_{CP}(B^+ \rightarrow \pi^+ K^{*0})$ and $A_{CP}(B^+ \rightarrow \pi^0 K^{*+})$ versus the phase of the $(\delta_{AB})_{32}$ where A and B denote the chirality i.e. L, R. for 3 different mass insertions. The left diagram corresponds to $A_{CP}(B^+ \rightarrow \pi^+ K^{*0})$ while the right diagram corresponds to $A_{CP}(B^+ \rightarrow \pi^0 K^{*+})$. In both diagrams we take only one mass insertion per time and vary the phase of from $-\pi$ to $\pi$. The horizontal lines in both diagrams represent the experimental measurement to 1$\sigma$.

In Figure 2 we show the two asymmetries, $A_{CP}(B^0 \rightarrow \pi^0 K^{*0})$ and $A_{CP}(B^0 \rightarrow \pi^- K^{*+})$ versus the phase of the $(\delta_{AB})_{32}$ as before. Clearly from Figure 2 left, $A_{CP}(B^0 \rightarrow \pi^0 K^{*0})$ lies within 1$\sigma$ range of its experimental value for many values of the phase of the mass insertion $(\delta_{AB})_{32}$ only. The reason is that the two mass insertions $(\delta^d_{L1})_{23}$ and $(\delta^d_{RL})_{23}$ have equal contributions to the CP asymmetries which will be smaller than the case of using $(\delta^d_{LR})_{23}$. On the other hand, Figure 2 right, one sees that $A_{CP}(B^0 \rightarrow \pi^- K^{*+})$ can be accommodated within 1$\sigma$ for many values of the phase of the three gluino mass insertions.

Finally we present the CP asymmetries of the decay modes $B^+ \rightarrow \rho^+ K^0$ and $B^+ \rightarrow \rho^0 K^+$ in Figure 3. In Figure 3 we do not show the horizontal lines representing the 1$\sigma$ range of the experimental measurement as the three curves of the $A_{CP}(B^+ \rightarrow \rho^+ K^0)$ corresponding to the three gluino mass insertions totally lie in this 1$\sigma$ range for all values of the phase of the mass insertions. On the other hand, Figure 3 right, we see that $A_{CP}(B^+ \rightarrow \rho^0 K^+)$ can not be accommodated within 1$\sigma$ for any value of the phase of all gluino mass insertions. This motivates us to consider the second scenario with two mass insertions which is shown in Figure 4.

The left diagram correspond to gluino contributions where we keep the two mass insertions $(\delta^d_{LR})_{23}$
FIG. 2: CP asymmetries versus the phase of the \((\delta_{AB}^d)_{23}\) where A and B denote the chirality i.e. L, R, for 3 different mass insertions. The left diagram corresponds to \(A_{CP}(B^0 \rightarrow \pi^0 \bar{K}^0)\) while the right diagram corresponds to \(A_{CP}(B^0 \rightarrow \pi^- K^+\bar{K}^0)\). In both diagrams we take only one mass insertion per time and vary the phase of from \(-\pi\) to \(\pi\). The horizontal lines in both diagrams represent the experimental measurement to 1\(\sigma\)\(^{[32]}\).

FIG. 3: CP asymmetries versus the phase of the \((\delta_{AB}^d)_{23}\) where A and B denote the chirality i.e. L, R, for 3 different mass insertions. The left diagram corresponds to \(A_{CP}(B^+ \rightarrow \rho^+ K^0)\) while the right diagram corresponds to \(A_{CP}(B^+ \rightarrow \rho^0 K^+)\). In both diagrams we take only one mass insertion per time and vary the phase of from \(-\pi\) to \(\pi\). As can be seen from Fig. 4 left, two gluino mass insertions can not accommodate the experimental measurement for any value of the phase of the mass insertion. On the other hand from \((\delta_{RL}^d)_{23}\) and set the other mass insertions to zero. The right diagram correspond to both gluino and chargino contributions where we keep the two mass insertions \((\delta_{LR}^d)_{23}\) and \((\delta_{RL}^u)_{32}\) and set the other mass insertions to zero. In both diagrams we assume that the two mass insertion have equal phases and we vary the phase from \(-\pi\) to \(\pi\). As can be seen from Fig. 1, left, two gluino mass insertions can not accommodate the experimental measurement for any value of the phase of the mass insertion. On the other hand from
Fig. 4 right, two mass insertions one corresponding to chargino contribution and the other corresponding to gluino contribution can not accommodate the experimental measurements. We find that in order to accommodate the CP symmetry in this case the Wilson coefficient $C_9 \tilde{g}$ should be increased at least by a factor $-6\pi/\alpha$ without violating any constraints on the SUSY parameter space which is shown in Fig. 5.

FIG. 4: CP asymmetry of $A_{CP}(B^+ \rightarrow \rho^0 K^+)$ versus the phase of the mass insertion for 2 different mass insertions. The left diagram correspond to gluino contributions where we keep the two mass insertions $(\delta^{d}_{LR})_{23}$ and $(\delta^{d}_{LL})_{23}$ and set the other mass insertions to zero. The right diagram correspond to both gluino and chargino contributions where we keep the two mass insertions $(\delta^{d}_{LR})_{23}$ and $(\delta^{u}_{RL})_{32}$ and set the other mass insertions to zero. The horizontal lines in both diagrams represent the experimental measurements to $1\sigma$[32].

FIG. 5: CP asymmetry of $A_{CP}(B^+ \rightarrow \rho^0 K^+)$ versus the phase of the mass insertion for 2 different mass insertions correspond to gluino contributions where we keep the two mass insertions $(\delta^{d}_{LR})_{23}$ and $(\delta^{d}_{LL})_{23}$ and set the other mass insertions to zero. We assume that the two mass insertion have equal phases and we vary the phase from $-\pi$ to $\pi$. The horizontal lines in the diagram represent the experimental measurements to $1\sigma$[32].
IV. CONCLUSION

In this talk we discussed SUSY contributions to the direct CP asymmetries of $B \to \pi K^*$ and $B \to \rho K$ decays within Soft Collinear Effective Theory. We considered non minimal flavor SUSY models and applied the mass insertion approximation to analyze SUSY contributions to the CP asymmetries of $B \to \pi K^*$ and $B \to \rho K$ decays. We show that in most decay channels, direct CP asymmetries can be significantly enhanced by the SUSY contributions mediated by gluino exchange and thus accommodate the experimental results. For the decay mode $B^+ \to \rho^+ K^0$, we find that the enhancement is not enough to accommodate the CP asymmetry. To accommodate the CP asymmetry of $B^+ \to \rho^+ K^0$, the Wilson coefficient $C_9^\rho$ should be increased at least by a factor $-6\pi/\alpha$.

Acknowledgement

Gaber Faisel would like to thank David Delepine and Mostafa Shalaby for their collaborations in the realization of this work. Gaber Faisel’s work is supported by the National Science Council of R.O.C. under grants NSC 99-2112-M-008-003-MY3 and NSC 99-2811-M-008-085.

[1] C. W. Bauer, S. Fleming and M. E. Luke, Phys. Rev. D 63, 014006 (2000) arXiv:hep-ph/0005275.
[2] C. W. Bauer, S. Fleming, D. Pirjol and I. W. Stewart, Phys. Rev. D 63, 114020 (2001) arXiv:hep-ph/001336.
[3] J. Chay and C. Kim, Phys. Rev. D 68, 071502 (2003) arXiv:hep-ph/0301055.
[4] J. Chay and C. Kim, Nucl. Phys. B 680, 302 (2004) arXiv:hep-ph/0301262.
[5] C. W. Bauer, D. Pirjol and I. W. Stewart, Phys. Rev. D 67, 071502 (2003) arXiv:hep-ph/0211069.
[6] A. Jain, I. Z. Rothstein and I. W. Stewart, arXiv:0706.3399 [hep-ph].
[7] C. W. Bauer, D. Pirjol, I. Z. Rothstein and I. W. Stewart, Phys. Rev. D 70, 054015 (2004) arXiv:hep-ph/0401188.
[8] W. Wang, Y. M. Wang, D. S. Yang and C. D. Lu, Phys. Rev. D 78, 034011 (2008) arXiv:0801.3123 [hep-ph].
[9] S. Fleming, PoS EFT09, 002 (2009) arXiv:0907.3897 [hep-ph].
[10] G. Faisel, arXiv:1106.4651 [hep-ph].
[11] M. Beneke, G. Buchalla, M. Neubert and C. T. Sachrajda, Nucl. Phys. B 591, 313 (2000) arXiv:hep-ph/0006124.
[12] M. Beneke, G. Buchalla, M. Neubert and C. T. Sachrajda, Phys. Rev. Lett. 83, 1914 (1999) arXiv:hep-ph/9905312.
[13] M. Beneke and S. Jager, Nucl. Phys. B 751, 160 (2006) arXiv:hep-ph/0512351.
[14] M. Beneke and S. Jager, Nucl. Phys. B 768, 51 (2007) arXiv:hep-ph/0610322.
[15] C. M. Arnesen, Z. Ligeti, I. Z. Rothstein and I. W. Stewart, arXiv:hep-ph/0607001.
[16] A. Hardmeier, E. Lunghi, D. Pirjol and D. Wyler, Nucl. Phys. B 682, 150 (2004) arXiv:hep-ph/0307171.
[17] Y. Y. Keum, H. n. Li and A. I. Sanda, Phys. Lett. B 504, 6 (2001) arXiv:hep-ph/0004004.
[18] C. D. Lu, K. Ukai and M. Z. Yang, Phys. Rev. D 63, 074009 (2001) arXiv:hep-ph/0004213.
[19] M. Beneke, G. Buchalla, M. Neubert and C. T. Sachrajda, Nucl. Phys. B 606, 245 (2001) arXiv:hep-ph/00104110.
[20] A. L. Kagan, Phys. Lett. B 601, 151 (2004) arXiv:hep-ph/0405134.
[21] A. V. Manohar and I. W. Stewart, Phys. Rev. D 76, 074002 (2007) arXiv:hep-ph/0605001.
[22] D. Delepine, G. Faisel, S. Khalil and M. Shalaby, Int. J. Mod. Phys. A 22, 6011 (2007).
[23] D. Delepine, G. Faisel and S. Khalil, Phys. Rev. D 77, 016003 (2008) arXiv:0710.1441 [hep-ph].
[24] D. Delepine, G. Faisel, S. Khalil and G. L. Castro, Phys. Rev. D 74, 056004 (2006) arXiv:hep-ph/0608008.
[25] L. J. Hall, V. A. Kostelecky and S. Raby, Nucl. Phys. B 267, 415 (1986).
[26] J. A. Casas and S. Dimopoulos, Phys. Lett. B 387, 107 (1996) arXiv:hep-ph/9606237.
[27] F. Gabbiani, E. Gabrielli, A. Masiero and L. Silvestrini, Nucl. Phys. B 477, 321 (1996) arXiv:hep-ph/9604387.
[28] A. Crivellin and U. Nierste, Phys. Rev. D 79, 035018 (2009) [arXiv:0810.1613 [hep-ph]].
[29] A. Crivellin and U. Nierste, Phys. Rev. D 81, 095007 (2010) [arXiv:0908.4404 [hep-ph]].
[30] A. Crivellin and J. Girrbach, Phys. Rev. D 81, 076001 (2010) [arXiv:1002.0227 [hep-ph]].
[31] K. Huitu and S. Khalil, Phys. Rev. D 81, 095008 (2010) [arXiv:0911.1868 [hep-ph]].
[32] G. Faisel, D. Delepine and M. Shalaby, [arXiv:1101.2710 [hep-ph]].