We analyze the singlet $P$–wave charmonium production at $e^+e^-$ colliders within the framework of unconstrained supersymmetry. We show that the CP–violating transitions, dominated by the gluino exchange, are typically four orders of magnitude larger than the CP–conserving ones, and former is generated by the electric dipole moment of the charm quark. Our results can be directly tested via the charmonium searches at the CLEO–c experiment.

I. INTRODUCTION

A permanent electric dipole moment (EDM) of an elementary particle is a clear signature for the CP violation. In the Standard Model (SM) of electroweak interactions CP-violation originates from the phase in the CKM matrix; but in this model the single fermion’s EDM vanishes up to two-loop order, and also three-loop contributions partially cancel. Therefore, the SM contribution is neither relevant phenomenologically nor numerically important. However, the Supersymmetric (SUSY) extension of SM contains many new sources of CP violation generated by soft SUSY breaking terms. Actually such a SUSY Model has many phases, but not all of them are physical. After using some symmetries such as R-symmetry and the Peccei-Quinn symmetry, only two of them remain physical: the trilinear coupling $A$ and the $\mu$ parameter.

The upper bounds for the neutron and electron EDMs imply that CP violation phases are duly small if the exchanged SUSY particles have masses close to their current experimental lower limits. There are several suggestions to find the electron and neutron EDMs below the experimental upper limits when CP phases $\sim O(1)$. Two possibilities have been commonly discussed in the literature which include (i) finding appropriate parameter domain where different contributions cancel or (ii) making the first two generations of scalar fermions heavy enough but keeping the soft masses of the third generation below the TeV scale.

As the analysis of Ref. [1] shows clearly, the electric dipole moments (EDM) of the heavy quarks play an important role in the direct production of singlet $P$–wave mesons at $e^+e^-$ colliders. Indeed, it is possible to observe $^1P_1$ bottomonium in $B$ factories like BaBaR, KEK or BEPC with sufficiently high statistics provided that the $b$ quark possesses a large enough EDM. Since the single fermion EDMs are exceedingly small in the standard electroweak theory [2] the SUSY contribution remains as the only viable option. Indeed, in SUSY the EDMs exist already at the one-loop level and typically exceed the existing 1.5$\sigma$ upper bounds.

However, not only the bottom quark but also the charm quark EDM offers an important arena in searching for the singlet $P$–wave charmonia. Indeed, in near future with increasing data at CLEO-c experiment [3], it might be possible to produce the $^1P_1$ charmonium state, $h_c$, directly. Therefore, a direct estimate of the charm quark EDM $D_c$ in SUSY will help in predicting how large the effect could be at CLEO-c.

In our analysis we will concentrate on unconstrained low-energy SUSY model as in Ref. [1] in that portion of the parameter space where large SUSY contributions to electron and neutron EDMs are naturally suppressed. Such a region of the SUSY parameter space is characterized by a small phase for the $\mu$ parameter: $-\pi/(5 \tan \beta) \leq \varphi_\mu \leq \pi/(5 \tan \beta)$ [4].

Assuming universality of the gaugino masses at some ultra high scale, it is known that the only physical soft phases are those of the $A$ parameters, $\varphi_{A_i}$ $(i = u,c,\cdots b)$ and the $\mu$ parameter. Therefore, in what follows we will scan the SUSY parameter space by varying (i) all soft masses from $m_t$ to 1 TeV, (ii) the phases of the $A$ parameters from 0 to $\pi$, and finally, (iii) the phase of the $\mu$ parameter in bounds noted above suggested by the cancellation mechanism.

In the second section, we calculate the chargino and gluino contributions to the c-quark EDM in effective SUSY at one-loop level and show that the gluino contribution dominates.

Section 3 is devoted to the analysis of our numerical calculations.

In section 4, we discuss the possible signatures of the c-quark EDM in the $e^+e^-$ annihilation. After examining the formation of $^1P_1$ charmonium state in $e^+e^-$ channel, we show that the CP-violating part, generated by the c-quark EDM dominates over the CP-conserving ones. In the case of observing the CP-odd resonance in the data accumulating at CLEO-c experiment, this would be a direct evidence for the charm quark’s EDM and also for the CP-violation in SUSY.
2. THE CHARM QUARK EDM in SUSY

The EDM of a spin 1/2 particle is defined as follows

$$\mathcal{L} = -\frac{i}{2} \mathcal{D}_f \overline{\psi} \sigma_{\mu\nu} \gamma_5 \psi F^{\mu\nu}$$

(1)

which obviously appears as a quantum loop-effects. In the SM, $\mathcal{D}_f$ vanishes up to two-loop order [5], whereas in SUSY it exists already at one-loop level.

As shown in Fig. 1 the c EDM is generated by the gluino, chargino and neutralino diagrams at one loop level. The general expressions for the quark EDMs in SUSY can be found in [6]. Large $\tan \beta$ the individual contributions to the c quark EDM take the following compact forms. The gluino contribution is given by

$$\left( \frac{D_g}{\ell} \right)^\pm \equiv \left( \frac{\alpha_g(M_{\text{SUSY}})}{\alpha_s(m_t)} \right)^{16/21} \left( \frac{\alpha_s(m_t)}{\alpha_s(m_b)} \right)^{16/23} \left( \frac{\alpha_s(m_b)}{\alpha_s(m_c)} \right)^{\frac{4\pi}{3} \frac{2\alpha_s}{m_\tilde{g} m_\tilde{b} \text{Im}[A_c^*]}} \frac{M_{\tilde{g}}}{M_{\tilde{c}_1}^2 - M_{\tilde{c}_2}^2}$$

(2)

where the loop function $B(x)$ can be found in [6]. Here $M_{\tilde{c}_{1,2}}$ are the masses of the charm squark. It is clear that at large $\tan \beta$ the (dominant) gluino–scharm contribution to c–quark EDM is almost independent of the phase of the $\mu$ parameter.

The chargino contribution, which proceeds via the exchange of charged gauginos and Higgsinos together with the scalar $s$–quark does have a direct dependence on the phase of the $\mu$ parameter via chargino mass matrix [1]. The exact expression reads as

$$\left( \frac{D_c}{\ell} \right)^\pm \equiv \left( \frac{\alpha_s(M_{\text{SUSY}})}{\alpha_s(m_t)} \right)^{16/21} \left( \frac{\alpha_s(m_t)}{\alpha_s(m_b)} \right)^{16/23} \left( \frac{\alpha_s(m_b)}{\alpha_s(m_c)} \right)^{\frac{4\pi}{3} \frac{2\alpha_s}{m_\tilde{g} m_\tilde{b} \text{Im}[A_c^*]}} \frac{m_c}{M_W^2} \sum_{j=1} \left| C_j^\pm (M_W) \right|$$

(3)

where the first line results from the direct computation, and depends on the vertex factors $\Gamma_{\chi^{\pm}}^{k_j j}$ and the loop function $F_{\pm}$ both defined in Ref. [1]. The second line, however, is the dipole coefficient arising in $c \rightarrow u \gamma$ decay as was pointed out in Ref. [1] for $b \rightarrow s \gamma$. (This relation to rare radiative decays is particularly important as $C_7^\pm (M_W)$ is particularly sensitive to large $\tan \beta$ effects [7] which introduces large enhancements compared to the SM.) A precise determination of the branching ratio and the CP–asymmetry in $c \rightarrow u \gamma$ (or the hadronic mode $D \rightarrow \pi \gamma$) [8] decay will help in fixing the chargino contribution to the c–quark EDM. Presently, the experimental data is not precise enough to bound this contribution so that we will analyze the result of the direct calculation in (3) in the numerical studies below.

The neutralino contribution is at least 20 times smaller numerically than the gluino contribution. So we do not include it in our numerical analysis below.

3. NUMERICAL ANALYSIS

We now discuss numerically the gluino and chargino contributions to the EDM of the c-quark. As mentioned before, in our analysis we take the SUSY parameters in the following ranges:

- Soft masses: $m_t^2 \leq M_{\tilde{t}_1}^2, M_{\tilde{t}_2}^2, |A_{c,s}|^2 \leq (1 \text{ TeV})^2$
- Gaugino Masses: $m_t \leq M_2 \leq 1 \text{ TeV}$ with $m_\tilde{g} = \frac{\alpha_s}{\alpha_2} M_2$
• Phase of the μ parameter: \(-\frac{\pi}{2 \tan \beta} \leq \varphi_\mu \leq \frac{\pi}{2 \tan \beta}\)

• Phase of the A parameters: \(0 \leq \varphi_{A_{\pm}} \leq \pi\)

• \(\tan \beta: 10 \leq \tan \beta \leq 50\)

where the modulus of \(\mu\) is determined via the relation

\[
|A_c - \mu \cot \beta| = \frac{1}{4m_c^2} \left[ (M_{\tilde{c}_1}^2 - M_{\tilde{c}_2}^2)^2 - r M_W^4 (\cos 2\beta)^2 \right]
\]

(4)

with \(r = (g_2^2 - (5/3)g_1^2)/(2g_2^2)\).

In Fig.2 we plot the gluino contribution, \(D_G^c\), in units of 10\(^{-26}\) e.cm, as a function of the \(A_c\) phase (Fig.2(a)), \(\mu\) parameter phase (Fig.2(c)) and \(\tan \beta\) (Fig.2(b)). We have to emphasize that here we use the exact formula instead of Eq.(2). In all these plots, we scan the other parameters in their allowed ranges. It is clear from Fig. 2(a) that for most of the \(\varphi_A\) space (i.e. from 0 to \(\pi\)) the value of the EDM is around 10\(^{-21}\) e.cm, showing a slight maximum at \(\pi/2\). At \(\varphi_A=0\), the 10\(^{-24}\) times smaller value of \(D_G^c\) comes from the \(\varphi_\mu\) phase in the large \(\tan \beta\) limit. As we have already mentioned, Fig.2(b) shows the almost independent behavior of the EDM on \(\varphi_\mu\) phase for large \(\tan \beta\). In Fig.2(c) we see a slight dependence on \(\tan \beta\), as we expected for the c-quark contrary to the case of the b-quark [1].

We conclude that for a reasonable portion of the parameter space the c-quark EDM gets a gluino contribution to the order of 10\(^{-21}\) e.cm.

Fig.3(a-c) show the dependence of the chargino contribution on the parameters \(\varphi_A, \varphi_\mu\) and \(\tan \beta\), respectively. All the plots give a very small contribution, smaller than 10\(^{-24}\) e.cm which is at least two orders of magnitude smaller than the gluino contribution. Although its numerical value is far below of the gluino contribution, it would be worth mentioning the rather slight increase of the chargino contribution with \(\varphi_\mu\) and \(\tan \beta\). In these plots we used exact expression for \(D_C^{\pm}\) which depends on the phase of \(\mu\) parameter and \(\tan \beta\) in a very complicated way. In order to explain the origin of these behaviours, one needs an analytical dependence of \(\sum_{k=1}^2 \sum_{j=1}^2 \Im \left[ \Gamma_{kj}^{\pm} \right]\) factor on \(\varphi_\mu\) and \(\tan \beta\) which could be achieved only by using some approximations.

4. CHARM QUARK EDM and \(^1P_1\) CHARMONIUM

Recently the E760 collaboration [9] at Fermilab have announced the first possible observation of the \(^1P_1\) CP-odd charmonium state in pp annihilations and the mass value of \(h_c(1P)\) is given \((3525.20\pm 0.15 \pm 0.20)\) MeV. However the production of the \(^1P_1\) charmonium state in the \(e^+e^-\) annihilation is very interesting from the point of view of the experimental evidence of the c-quark EDM, since the coupling of photon to the \(h_c(1P_1(1^{++}))\) charmonium is identical to the effective Lagrangian (1). The quantum numbers of this CP-odd resonance coincide with those of the current density [10]

\[
J^a(\bar{c}c)^{1P_1} = \bar{c}(x) \gamma_5 c(x)
\]

(5)

In the \(e^+e^-\) annihilation the \(^1P_1\) state can be produced via the \(\gamma Z\) and \(ZZ\) box diagrams in the framework of the SM. After using the same consideration in Ref. [1] one can reach the following effective CP invariant Hamiltonian

\[
H_{SM} = \frac{\alpha}{3\pi \sqrt{2}} G_F m_e m_e \mathfrak{B} J^a(\bar{c}c)^{1P_1} \cdot J^a(e^+e^-)^{1P_1}
\]

(6)

where the current is defined in Eq.(6), and the box function \(\mathfrak{B}\) comes from standard loop integrals [11] and it behaves as

\[
\mathfrak{B} \sim \frac{1}{M_Z^2 m_e^2} \ln \left( \frac{m_e}{m_c} \right)
\]

(7)

In minimal SUSY with two Higgs doublets, in addition to \(\gamma Z\) box diagram there is another CP-odd Higgs scalar, \(A^0\) which also contributes to the formation of \(^1P_1\) resonance in \(e^+e^-\) annihilation. Replacing the Z boson by \(A^0\) in Fig 4, the SUSY contributions to the CP-conserving effective Hamiltonian can be written
which is typically smaller than the SM amplitude for $M_{A^0} > M_Z$. In this sense size of the CP-conserving transitions is fixed by the SM not by the SUSY contribution. This is an important difference between the charm and bottom $P_1$ production in $e^+e^-$ collisions.

In addition to the CP-conserving decay modes, the $P_1$ state can also be produced via the c-EDM in $e^+e^-$ channel which is a CP-violating mode. Grey blob in Fig.4(b) represents the effective Lagrangian (1). In this CP-violating mode, $e^+e^-$ system is in the most probable state $^3S_1$. Therefore the effective Hamiltonian violating CP from the Fig. 4(b) is

$$H_{SUSY} = \frac{4\pi\alpha}{M_{h_c}^2}(\frac{D_c}{e})J_\alpha(c\bar{c}|^1P_1). (e^+(x) \gamma_\alpha e^-(x))$$

which is a pure SUSY effect. The comparison between the sizes of this CP-violating transition with the CP-conserving one is a comparison between the SUSY and SM contributions. In fact, the CP-violating production amplitude dominates the CP-conserving one provided that the EDM of charm quark exceeds the critical value

$$\frac{|D_c^{crit}|}{e} \sim \frac{G_F m_c M_{h_c}^2}{12\sqrt{2}\pi^2 M_Z^2} \ln m_c/m_e \sim 10^{-26} \text{ cm},$$

which is one order of magnitude smaller than the one for the $b$ quark EDM. If $D_c$ is large enough compared to $D_c^{crit}$ then the CP-violating transition Eq. (9) can be suited to generate the $h_c$ meson. In the preceding section we performed a scanning of the SUSY parameter space within the bounds mentioned before, and found that $D_c$ is well above the critical value Eq.(10).

Now we discuss our estimates with possible $h_c$ signatures at charm factories. The bottomonia and charmonia production in lepton and hadron colliders have been the primary step for experimental investigation of $B$ and $D$ mesons. Indeed, several experiments like the $B$ factories (BABAR, CLEO and KEK-B $e^-e^+$ colliders running at $\Upsilon(4S)$, the $D$ factories (CLEO-C and BES $e^-e^+$ colliders running at $J/\psi$, $\psi'$, $\psi''$ and $\psi(4140)$ resonances) as well as $p\bar{p}$ (FNAL E789 at $\sqrt{s} = 800$ GeV, and CERN WA102 at $\sqrt{s} = 450$ GeV) and $p\bar{p}$ (FNAL E771 at $\sqrt{s} = 800$ GeV) colliders form an arena where different bottomonia and charmonia can be produced in intermediate and final states.

Among all $b\bar{b}$ and $c\bar{c}$ resonances we are particularly interested in the singlet P–wave states, $h_b(nP)$ and $h_c(nP)$, as these are CP–odd states their production and decays are highly sensitive to sources of CP violation in the underlying theory. Presently, there is no experimental evidence for such resonances except for the discovery of $h_c(1P)$ at FNAL E760 experiment [9]. However, as the recent work [1] suggests, the production of the singlet P–wave mesons (of $b\bar{b}$ type) at $e^+e^-$ colliders are particularly interesting in that there are spectacular enhancements in CP–violating transitions if the underlying theory admits large enough electric dipole moments (EDM) for heavy quarks. In this sense production is directly tied up to the smallness of its production size of the CP–conserving transitions within the bounds mentioned before, and found that $D_c$ is well above the critical value Eq.(10).

Considering CLEO-C for definiteness and its variable center–of–mass energy, it is possible to estimate to what extent it can observe $h_c$ meson. Let us suppose that CLEO-C observed resonance at or in close vicinity of the E760 value of $M_{h_c}$ then the cross section for this event will be

$$\sigma(e^+e^- \rightarrow h_c) = 27\left| \frac{D_c}{e} \right|^2 \left| \frac{R'_P(0)}{R_S(0)} \right|^2 \sigma(e^+e^- \rightarrow ^3S_1) \sim 27 \left| \frac{M_{h_c} D_c}{e} \right|^2 \sigma(e^+e^- \rightarrow ^3S_1)$$

where $R_P$ and $R_S$ are the wavefunctions of $h_c$ and $^3S_1$ states, respectively. Clearly, when $D_c/e \sim M_{h_c}^{-1}$ the two cross sections will be of similar size making $h_c$ highly observable. However, except for FNAL E760, no experiment has been able to detect such a CP–odd meson so far. Therefore, its production cross section must be rather small compared to $\sigma(e^+e^- \rightarrow ^3S_1)$. This rareness of $h_c$ production is directly tied up to the smallness of its production.
cross section. Indeed, for the face value of $D_c/e \sim 10^{-21}$ cm as follows from the dominant gluino production, one expects $\sigma(e^+e^- \rightarrow h_c) \sim 10^{-12} \sigma(e^+e^- \rightarrow S_1)$. If CLEO-c observes this resonance with a much larger rate then one will need other sources of CP violation to enhance the charm quark EDM. On the other hand, if the observed cross section turns out to be this size then it will clearly be an indication for SUSY CP violation.

5. LIGHT GLUINO CASE

It is useful to look for regions of the SUSY parameter space where $h_c$ production cross section in other words the EDM of charm quark is substantially enhanced. This would be useful, at least, for excluding certain portions of the SUSY parameter space depending on the size of the signal in near-future experiments like CLEO-c. It is straightforward to observe that the charm quark EDM, especially the gluino contribution, is grossly enhanced in regions of the SUSY parameter space where the gluino and lighter scharm are nearly degenerate and close to the hadronic scale (See [14] for analogous discussion of the scalar bottom quarks). To prevent any conflict with the LEP results, we must suppress $Z$ boson couplings to scharms [15] hence we take

$$\sin \theta_c = \sqrt{\frac{4}{3}} \sin \theta_W,$$

(12)

and $M_{c_1} \gg M_{c_2}$. Here $\theta_c$ is the mixing angle of scalar charm quarks, and its is fixed by requiring that $Z$ boson does not couple to light scharm, $c_2$. On the other hand, the two scalar charms must be well splitted in mass to suppress $e^+e^- \rightarrow Z^* \rightarrow c_2\bar{c}_2$ and $c_2\bar{c}_1$ signals at LEP. Under these conditions, the gluino contribution to the charm quark EDM becomes,

$$\left( \frac{D_c}{e} \right)^g \sim \frac{\alpha_s(m_{\tilde{g}})}{2\pi} \frac{\sin \varphi_{A_c}}{m_{\tilde{g}}}$$

(13)

when $m_{\tilde{g}} \sim M_{c_2}$. Therefore, when $m_{\tilde{g}}$ value lies between $m_b$ and $2m_b$ the charm quark EDM is around $10^{-17}$ cm, $\sin \varphi_{A_c}$ which is nine orders of magnitude larger than the critical value computed in Sec. 4. It is clear that, with such an enhancement the $h_c$ production cross section obeys roughly $\sigma(e^+e^- \rightarrow h_c) \approx 10^{-4} \sigma(e^+e^- \rightarrow S_1)$ which must be in the experimentally detectable range. With a heavy SUSY spectrum, as investigated in previous sections, the $h_c$ production cross section is rather small, and unless the detector has a good energy resolution it is difficult to observe an $h_c$ resonance in $s$ channel. However, a SUSY spectrum with light gluinos and scalar charm quark (with no conflict with the existing experiments) it is possible to enhance the $h_c$ production cross section significantly making it easier to search for such resonances at, for instance, the CLEO experiment.

For making our results more transparent to experimental investigation, it is useful to discuss the quantity

$$R = L\sigma(e^+e^- \rightarrow h_c) \sim 27 \times N_{J/\psi} \left| \frac{M_{h_c} D_c}{e} \right|^2$$

where $N_{J/\psi} \approx 10^9$ is the expected number of events at CLEO-c. For a heavy particle spectrum, $R \sim 10^{-2}$ whereas for a scenario with light gluinos and scharms one has $R \sim 10^5$ which is well inside the observable range provided that $10^9$ $J/\psi$ mesons are produced.

6. DISCUSSIONS AND CONCLUSION

We have discussed the production of singlet $P$–wave charmonia at $e^+e^-$ colliders. This process is determined mainly by the CP–violating transitions shown in Fig. 4 (b). It is clear that the EDM of the charm quark is the basic machinery to generate $h_c$, and it is only via SUSY with explicit CP violation that the CP–violating transition dominates the CP–conserving channel.

The channel we discuss here, which can be directly tested at the CESR–c collider, suggests a direct access to the SUSY phases. The amount of CP violation provided by SUSY is large, and hard to realize in other extensions $e.g$ two–doublet models. Therefore, any evidence for $h_c$ at the CESR–c experiment will form a direct evidence for SUSY in general, and SUSY CP violation in particular.

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[1] D. A. Demir and M. B. Voloshin, Phys. Rev. D 63, 115011 (2001) [arXiv:hep-ph/0012123].
[2] S. Dar, arXiv:hep-ph/0008248.
[3] See the URL: http://www.lns.cornell.edu/public/CLEO/spoke/CLEOc/.
[4] M. Brhlik, G. J. Good and G. L. Kane, Phys. Rev. D 59, 115004 (1999) [arXiv:hep-ph/9810457]; V. D. Barger, T. Falk, T. Han, J. Jiang, T. Li and T. Plehn, Phys. Rev. D 64, 056007 (2001) [arXiv:hep-ph/0101106].
[5] E. P. Shabalin, Phys. Lett. B109, 490(1982); Sov. J. Nucl. Phys. 32, 228(1980); N. G. Deshpande, G. Eilam and W. L. Spence, Phys. Lett. B109, 42(1982); J. O. Eeg and I. Picek, Nucl. Phys. B244, 77(1984).
[6] T. Ibrahim and P. Nath, Phys. Rev. D 58, 111301 (1998) [Erratum-ibid. D 60, 099902 (1998)] [arXiv:hep-ph/9807501].
[7] D. A. Demir and K. A. Olive, Phys. Rev. D 65, 034007 (2002) [arXiv:hep-ph/0107329].
[8] M. Boz and Z. Kirca, Mod. Phys. Lett. A 15, 2345 (2000); S. Prelovsek and D. Wyler, Phys. Lett. B 500, 304 (2001) [arXiv:hep-ph/0012116].
[9] T. A. Armstrong et al. [E760 Collaboration], Phys. Rev. Lett. 69, 2337(1992).
[10] V. A. Novikov, L. B. Okun, M. A. Shifman, A. I. Vainshtein, M. B. Voloshin and V. I. Zakharov, Phys. Rept. 41, 1(1978)
[11] G. ’t Hooft and M. Veltman, Nucl. Phys. B153, 365(1979); G. Passarino and M. Veltman, Nucl. Phys. B160, 203(1979).
[12] B. Aubert et al. [BABAR Collaboration], arXiv:hep-ex/0105044.
[13] F. A. Harris [BES Collaboration], arXiv:hep-ex/9910027; arXiv:hep-ex/9903036.
[14] E.L. Berger, B.W. Harris, D.E. Kaplan, Z. Sullivan, T.M.P. Tait, C.E.M. Wagner Phys.Rev.Lett. 86, 4231(2001) [arXiv:hep-ph/0012001]
[15] M. Carena, S. Heinemeyer, C. E. Wagner and G. Weiglein, Phys. Rev. Lett. 86, 4463 (2001) [arXiv:hep-ph/0008023].
FIG. 1. The Feynman one-loop diagrams of the SUSY contributions to the EDM of c-quark.
FIG. 2. The gluino contribution to c-quark EDM in units of $10^{-26} \text{e.cm}$ as a function of (a) trilinear couplings $A_c$ phase, (b) $\mu$ parameter phase and (c) $\tan\beta$. 
FIG. 3. The chargino contribution to c-quark EDM in units of $10^{-26}\, e\, cm$ as a function of (a) trilinear couplings $A_s$ phase, (b) $\mu$ parameter phase and (c) $\tan\beta$. 
FIG. 4. The Feynman diagrams of the $^1P_1$ charmonium resonance in $e^+e^-$ scattering: (a) The CP-conserving decay mode and (b) is the CP-violating decay mode where the grey blob stands for the insertion of the effective Lagrangian (1).