

The Search for New Physics in $D^0 \rightarrow \gamma\gamma$ Decay¹

S. Fajfer^{a,b}, P. Singer^c, J. Zupan^a

a) J. Stefan Institute, Jamova 39, P. O. Box 3000, 1001 Ljubljana, Slovenia

b) Department of Physics, University of Ljubljana, Jadranska 19, 1000 Ljubljana, Slovenia

c) Department of Physics, Technion - Israel Institute of Technology, Haifa 32000, Israel

ABSTRACT

We present main results of the investigation of the rare decay mode $D^0 \rightarrow \gamma\gamma$, in which the long distance contributions are expected to be dominant. Using the Heavy Quark Chiral Lagrangian we have considered the anomaly contribution which relates to the annihilation part of the weak Lagrangian and the one - loop π , K diagrams. The loop contributions which are proportional to g and contain the a_1 Wilson coefficient are found to dominate the decay amplitude. The branching ratio is then calculated to be $(1.0 \pm 0.5) \times 10^{-8}$. Observation of an order of magnitude larger branching ratio could signal new physics.

arXiv:hep-ph/0106131 v1 13 Jun 2001

¹Contributed Paper for LPO1

In the past years the rare decays of B mesons came under the spotlights as *the* source of possible signals of new physics. In the meanwhile studies of rare D decays have received much less attention. Partially this is because theoretical investigations of D weak decays are rather difficult, also due to the presence of many resonances close to this energy region. The penguin effects on the other hand, which are very important in B and also in K decays, are usually suppressed in the case of charm mesons due to the presence of d , s , b quarks in the loop with the respective values of CKM elements.

Nevertheless, D meson physics has produced some interesting results in the past year. Experimental results on time dependent decay rates of $D^0 \rightarrow K^+\pi^-$ by CLEO [1] and $D^0 \rightarrow K^+K^-$ and $D^0 \rightarrow K^-\pi^+$ by FOCUS [2] have stimulated several studies on the $D^0 - \bar{D}^0$ oscillations [3]. The recently measured D^* decay width by CLEO [4] has provided the long expected information on the value of $D^*D\pi$ coupling. Among the rare D decays, the decays $D \rightarrow V\gamma$ and $D \rightarrow V(P)l^+l^-$ are subjects of CLEO and FERMILAB searches [5]. On the theoretical side, these rare decays of charm mesons into light vector meson and photon or lepton pair have been considered lately by several authors (see, e.g., [6]- [11], for radiative leptonic D meson decay see [12]). The investigations of $D \rightarrow V\gamma$ showed that certain branching ratios can be as large as 10^{-5} , like for $D^0 \rightarrow \bar{K}^{*0}\gamma$, $D_s^+ \rightarrow \rho^+\gamma$ [6, 11]. However, the decays which are of some relevance to the $D^0 \rightarrow 2\gamma$ mode studied here, like $D^0 \rightarrow \rho^0\gamma$, $D^0 \rightarrow \omega\gamma$, are expected with branching ratios in the 10^{-6} range [13]. Thus, it is hard to believe that the branching ratio of the $D^0 \rightarrow 2\gamma$ decay mode can be as high as 10^{-5} in the Standard Model (SM), as found by [14]. Apart from this estimation, there has been no other detailed work on $D^0 \rightarrow 2\gamma$ prior to our analysis [15]. In addition to these theoretical studies there are experimental attempts to observe this decay rate done by CLEO and FOCUS [16].

On the other hand, in the B and K meson systems there are numerous studies of their decays to two photons. For example, the $B_s \rightarrow \gamma\gamma$ decay has been studied with various approaches within SM and beyond. In SM, the short distance (SD) contribution [17] leads to a branching ratio $B(B_s \rightarrow \gamma\gamma) \simeq 3.8 \times 10^{-7}$. The QCD corrections enhance this rate to 5×10^{-7} [18]. On the other hand, in some of the SM extensions the branching ratio can be considerably larger. The two Higgs doublet scenario, for example, could enhance this branching ratio by an order of magnitude [19]. Such "new physics" effects could at least in principle be dwarfed by long distance (LD) effects. However, existing calculations show that these are not larger than the SD contribution [20], which is typical of the situation in radiative B decays [21]. In the K^0 system the situation is rather different. Here, the SD contribution is too small to account for the observed rates of $K_S \rightarrow 2\gamma$, $K_L \rightarrow 2\gamma$ by factors of $\sim 3 - 5$ [22], although it could be of relevance in the mechanism of CP-violation. Many detailed calculations of these processes have been performed over the years (see recent refs. [22]-[25] and refs. therein), especially using the chiral approach to account for the pole diagrams and the loops. These LD contributions lead to rates which are compatible with existing measurements.

Motivated by the experimental efforts to observe rare D meson decays [16], and noticing that $B_s \rightarrow \gamma\gamma$ offers possibility to observe physics beyond the SM, we undertook an investigation of the $D^0 \rightarrow \gamma\gamma$ decay [15]. Here we present only the main results of our analyses, while the details of our work are presented in [15].

The short distance contribution is expected to be rather small, as already encountered in the one photon decays [6, 7], hence the main contribution would come from long distance interactions. In order to treat the long distance contributions, we use the heavy quark effective theory combined with chiral perturbation theory (HQ χ PT) [26]. This approach was used before for treating D^* strong and electromagnetic decays [27]-[29]. The leptonic and semileptonic decays of D meson were also treated within the same framework (see [27] and references therein).

The approach of HQ χ PT introduces several coupling constants that have to be determined from

experiment. The recent measurement of the D^* decay width [4] has determined the $D^*D\pi$ coupling, which is related to g , the basic strong coupling of the Lagrangian. There is more ambiguity, however, concerning the value of the anomalous electromagnetic coupling, which is responsible for the $D^*D\gamma$ decays [28, 29] (for further discussion on this point see [15]).

Let us address now some issues concerning the theoretical framework used in our treatment. For the weak vertex we used the factorization of weak currents with nonfactorizable contributions coming from chiral loops. The typical energy of intermediate pseudoscalar mesons is of order $m_D/2$, so that the chiral expansion p/Λ_χ (for $\Lambda_\chi \simeq 1$ GeV) is rather close to unity. Thus, for the decay under study we extend the possible range of applicability of the chiral expansion of HQ χ PT, compared to previous treatments like $D^* \rightarrow D\pi$, $D^* \rightarrow D\gamma$ [28] or $D^* \rightarrow D\gamma\gamma$ [29], in which a heavy meson appears in the final state, making the use of chiral perturbation theory rather natural. The suitability of our undertaking here must be confronted with experiment, and possibly other theoretical approaches.

At this point we also remark that the contribution of the order $\mathcal{O}(p)$ does not exist in the $D^0 \rightarrow \gamma\gamma$ decay, and the amplitude starts with contribution of the order $\mathcal{O}(p^3)$. At this order the amplitude receives an annihilation type contribution proportional to the a_2 Wilson coefficient, with the Wess-Zumino anomalous term coupling light pseudoscalars to two photons. However, the total amplitude is dominated by terms proportional to a_1 that contribute only through loops with Goldstone bosons. Loop contributions proportional to a_2 vanish at this order. We point out that any other model which does not involve intermediate charged states cannot give this kind of contribution. Therefore, the chiral loops naturally include effects of intermediate meson exchange.

The chiral loops of order $\mathcal{O}(p^3)$ are finite, as they are in the similar case of $K \rightarrow \gamma\gamma$ decays [22]-[25]. The next to leading terms might be almost of the same order of magnitude compared to the leading $\mathcal{O}(p^3)$ term, the expected suppression being approximately p^2/Λ_χ^2 . The inclusion of next order terms in the chiral expansion is not straightforward in the present approach. We include, however, terms which contain the anomalous electromagnetic coupling, and appear as next to leading order terms in the chiral expansion, in view of their potentially large contribution (as in $B^*(D^*) \rightarrow B(D)\gamma\gamma$ decays considered in [29]). As it turns out, these terms are suppressed compared to the leading loop effects, which at least partially justifies the use of HQ χ PT for the decay under consideration. Contributions of the same order could arise from light resonances like ρ , K^* , $a_0(980)$, $f_0(975)$. Such resonances are sometimes treated with hidden gauge symmetry (see, e.g., [27]), which is not compatible with chiral perturbation symmetry. Therefore, a consistent calculation of these terms is beyond our scheme and we disregard their possible effect.

The invariant amplitude for $D^0 \rightarrow \gamma\gamma$ decay can be written using gauge and Lorentz invariance in the following form:

$$M = \left[iM^{(-)} \left(g^{\mu\nu} - \frac{k_2^\mu k_1^\nu}{k_1 \cdot k_2} \right) + M^{(+)} \epsilon^{\mu\nu\alpha\beta} k_{1\alpha} k_{2\beta} \right] \epsilon_{1\mu} \epsilon_{2\nu}, \quad (1)$$

where $M^{(-)}$ is a parity violating and $M^{(+)}$ a parity conserving part of the amplitude, while $k_{1(2)}$, $\epsilon_{1(2)}$ are respectively the four momenta and the polarization vectors of the outgoing photons.

In the discussion of weak radiative decays $q' \rightarrow q\gamma\gamma$ or $q' \rightarrow q\gamma$ decays, usually the short (SD) and long distance (LD) contribution are separated. The SD contribution in these transitions is a result of the penguin-like transition, while the long distance contribution arises in particular pseudoscalar meson decay as a result of the nonleptonic four quark weak Lagrangian, when the photon is emitted from the quark legs. Here we follow this classification. In the case of $b \rightarrow s\gamma\gamma$ decay [30] it was noticed that without QCD corrections the rate $\Gamma(b \rightarrow s\gamma\gamma)/\Gamma(b \rightarrow s\gamma)$ is about 10^{-3} . One expects that a similar effect will show up in the case of $c \rightarrow u\gamma\gamma$ decays. Namely,

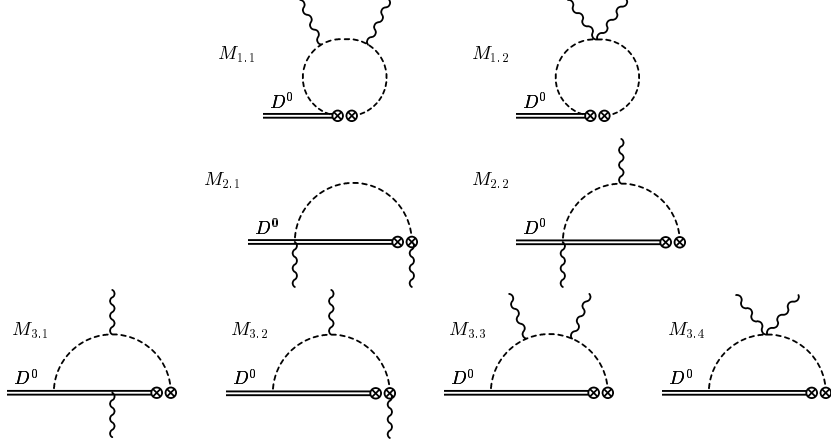


Figure 1: One loop diagrams, not containing beta-like terms, that give nonvanishing contributions to the $D^0 \rightarrow \gamma\gamma$ decay amplitude. Each sum of the amplitudes on diagrams in one row $M_i = \sum_j M_{i,j}$ is gauge invariant and finite. Numerical values are listed in Table 1.

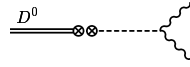


Figure 2: Anomalous contributions to $D^0 \rightarrow \gamma\gamma$ decay. The intermediate pseudoscalar mesons propagating from the weak vertex are π^0, η, η' .

according to the result of [30] the largest contribution to $c \rightarrow u\gamma\gamma$ amplitude would arise from the photon emitted either from c or u quark legs in the case of the penguin-like transition $c \rightarrow u\gamma$. Without QCD corrections the branching ratio for $c \rightarrow u\gamma$ is rather suppressed, being of the order 10^{-17} [7, 8]. The QCD corrections [31] enhance it up to order of 10^{-8} .

In our approach we include the $c \rightarrow u\gamma$ short distance contribution by using the Lagrangian

$$\mathcal{L} = -\frac{G_f}{\sqrt{2}} V_{us} V_{cs}^* C_{7\gamma}^{eff} \frac{e}{4\pi^2} F_{\mu\nu} m_c (\bar{u}\sigma^{\mu\nu}\frac{1}{2}(1 + \gamma_5)c), \quad (2)$$

where m_c is a charm quark mass. In our analysis we follow [31, 32] and we take $C_{7\gamma}^{eff} = (-0.7 + 2i) \times 10^{-2}$.

The main LD contribution will arise from the effective four quark nonleptonic $\Delta C = 1$ weak Lagrangian given by

$$\mathcal{L} = -\frac{G_f}{\sqrt{2}} \sum_{q=d,s} V_{uq} V_{cq}^* [a_1 (\bar{q}\Gamma^\mu c)(\bar{u}\Gamma_\mu q) + a_2 (\bar{u}\Gamma^\mu c)(\bar{q}\Gamma_\mu q)], \quad (3)$$

where $\Gamma^\mu = \gamma^\mu(1 - \gamma_5)$, a_i are effective Wilson coefficients [33], and $V_{q_i q_j}$ are CKM matrix elements. At this point it is worth pointing out that long distance interactions will contribute only if the $SU(3)$ flavor symmetry is broken, i.e. if $m_s \neq m_d$. Namely, due to $V_{ud} V_{cd}^* \simeq -V_{us} V_{cs}^*$ and $m_d = m_s$ the contribution arising from the weak Lagrangian (3) disappears in the case of exact $SU(3)$ flavor symmetry.

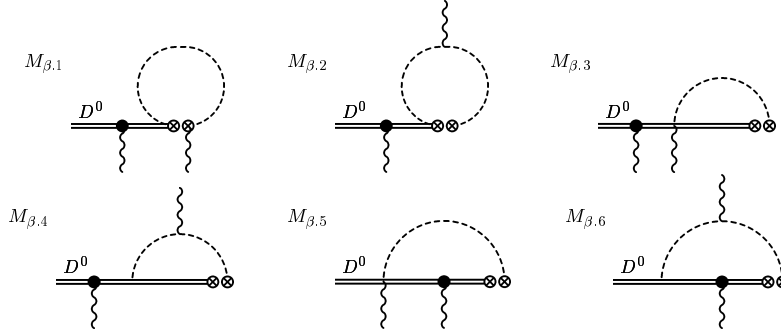


Figure 3: The diagrams which give nonzero amplitudes with one β -like coupling (denoted by \bullet).

Going from quark to meson level effective Lagrangian one uses heavy quark symmetry for c -quark and chiral symmetry of light quarks to construct HQ χ PT Lagrangian [15]. This is then used to calculate the $D^0 \rightarrow \gamma\gamma$ decay width to one loop order. Leaving out the details of our calculation (see [15]), we discuss the final results.

The decay width for the $D^0 \rightarrow \gamma\gamma$ decay can be obtained using the amplitude decomposition in (1)

$$\Gamma_{D^0 \rightarrow \gamma\gamma} = \frac{1}{16\pi m_D} (|M^{(-)}|^2 + \frac{1}{4}|M^{(+)}|^2 m_D^4). \quad (4)$$

The main contribution to the decay width arises from the diagrams presented on Figs. 1, 2. The calculated amplitudes depend on the number of input parameters, as mentioned in [15]. The coupling g is extracted from existing experimental data on $D^* \rightarrow D\pi$. Recently CLEO Collaboration has obtained the first measurement of D^{*+} decay width $\Gamma(D^{*+}) = 96 \pm 4 \pm 22$ keV [4] by studying the $D^{*+} \rightarrow D^0\pi^+$. Using the value of decay width together with branching ratio $Br(D^{*+} \rightarrow D^0\pi^+) = (67.7 \pm 0.5)\%$ one immediately finds at tree level that $g = 0.59 \pm 0.08$. The chiral corrections to this coupling were found to contribute about 10% [27, 28]. In order to obtain the α coupling, we use present experimental data on D_s leptonic decays ($f_D \simeq f_{D_s} = \alpha/\sqrt{m_D}$). In our calculation we take $\alpha = 0.31$ GeV $^{3/2}$ [15]. For the Wilson coefficients a_1 we take 1.26 and $a_2 = -0.47$ [33]. We give here the numerical results for the one-loop amplitudes in Table 1.

| | $M_i^{(-)}$ [$\times 10^{-10}$ GeV] | $M_i^{(+)}$ [$\times 10^{-10}$ GeV $^{-1}$] |
|----------------------|--------------------------------------|---|
| Anom. | 0 | -0.53 |
| SD | -0.27 -0.81 <i>i</i> | -0.16 -0.47 <i>i</i> |
| 1 | 3.55 +9.36 <i>i</i> | 0 |
| 2 | 1.67 | 0 |
| 3 | -0.54 +2.84 <i>i</i> | 0 |
| $\sum_i M_i^{(\pm)}$ | 4.41 +11.39 <i>i</i> | -0.69 -0.47 <i>i</i> |

Table 1: Table of the nonvanishing finite amplitudes. The amplitudes coming from the anomalous and short distance ($C_{\gamma\gamma}^{eff}$) Lagrangians are presented. The finite and gauge invariant sums of one-loop amplitudes are listed in the next three lines ($M_i^{(\pm)} = \sum_j M_{i,j}^{(\pm)}$). The numbers 1, 2, 3 denote the row of diagrams on the Fig.1. In the last line the sum of all amplitudes is given.

In the determination of $D^* \rightarrow D\gamma\gamma$ and $B^* \rightarrow B\gamma\gamma$ a sizable contribution from β -like electromagnetic terms [15] has been found [29]. Therefore, we have to investigate their effect in the $D^0 \rightarrow \gamma\gamma$ decay amplitude. The nonzero parity violating parts of the one loop diagrams containing β coupling are given on Fig. 3, while numerical results are presented in Table 2.

| Diag. | $M_i^{(-)}[\times 10^{-10} \text{ GeV}]$ | $M_i^{(+)}[\times 10^{-10} \text{ GeV}^{-1}]$ |
|----------------------|--|---|
| $\beta.1$ | 0 | -2.69 |
| $\beta.2$ | 0 | 2.69 |
| $\beta.3$ | 0 | 2.11 |
| $\beta.4$ | 0.88 | -0.007 |
| $\beta.5$ | 0 | 0.51 |
| $\beta.6$ | -2.88 | -0.52 |
| $\sum_i M_i^{(\pm)}$ | -2.00 | 2.09 |

Table 2: Table of nonzero contributions of the amplitudes coming from the diagrams with β coupling. In the last line the sums of the contributions are presented. We use $\beta = 2.3 \text{ GeV}^{-1}$, $m_c = 1.4 \text{ GeV}$.

Using short distance contributions, the finite one loop diagrams and the anomaly parts of the amplitudes and with numerical values of the amplitudes as listed in Table 1, one obtains

$$Br(D^0 \rightarrow \gamma\gamma) = 1.0 \times 10^{-8}. \quad (5)$$

This result is slightly changed when one takes into account the terms dependent on β . The branching ratio obtained when we sum all contributions is

$$Br(D^0 \rightarrow \gamma\gamma) = 0.95 \times 10^{-8}. \quad (6)$$

By varying β within $1 \text{ GeV}^{-1} \leq \beta \leq 5 \text{ GeV}^{-1}$ and keeping $g = 0.59 \pm 0.08$, the branching ratio is changed by at most 10%. On the other hand, one has to keep in mind that the loop contributions involving β are not finite and have to be regulated. We have used $\overline{\text{MS}}$ scheme, with the divergent parts being absorbed by counterterms. The size of these is not known, so they might influence the error in our prediction of the branching ratio. Note also that changing α would affect the predicted branching ratio. For instance, if the chiral corrections do decrease the value of α by 30% this would decrease the predicted branching ratio down to 0.5×10^{-8} .

We have presented here the results of the detailed calculation of the decay amplitude $D^0 \rightarrow \gamma\gamma$, which includes short distance and long distance contributions, by making use of the theoretical tool of Heavy Quark Chiral Perturbation Theory Lagrangian. Within this framework, the leading contributions are found to arise from the charged π and K mesons running in the chiral loops, and are of order $\mathcal{O}(p^3)$. These terms are finite and contribute only to the parity violating part of the amplitude. The inclusion of terms of higher order in the chiral expansion is unfortunately plagued with the uncertainty caused by the lack of knowledge of the counterterms. As to the parity conserving part of the decay, it is given by terms coming from the short distance contribution, the anomaly and from loop terms containing the beta coupling, the latter giving most of the amplitude. The size of this part of the amplitude is approximately one order of magnitude smaller than the parity violating amplitude, thus contributing less than 20% to the decay rate. Therefore, our calculation predicts that the $D \rightarrow 2\gamma$ decay is mostly a parity violating transition.

In addition to the uncertainties we have mentioned, there is the question of the suitability of the chiral expansion for the energy involved in this process; the size of the uncertainty related to

this is difficult to estimate. Altogether, our estimate is that the total uncertainty is not larger than 50%. Accordingly, we conclude that the predicted branching ratio is

$$Br(D^0 \rightarrow \gamma\gamma) = (1.0 \pm 0.5) \times 10^{-8}. \quad (7)$$

The reasonability of this result can be deduced also from a comparison with the calculated decay rates for the $D^0 \rightarrow \rho(\omega)\gamma$, which are found to be expected with a branching ratio of approximately 10^{-6} [6, 7, 13].

We look forward to experimental attempts of detecting this decay. Our result suggests that the observation of $D \rightarrow 2\gamma$ at a rate which is an order of magnitude larger than (7), could be a signal for the type of "new physics", which leads to sizable enhancement [32] of the short-distance $c \rightarrow u\gamma$ transition.

References

- [1] R. Godang et al. (CLEO Collaboration), Phys. Rev. Lett. **84**, 5038 (2000).
- [2] J. M. Link et al. (FOCUS Collaboration), Phys. Lett. B **485**, 62 (2000).
- [3] S. Bergmann, Y. Grossman, Z. Ligeti, Y. Nir and A. A. Petrov, Phys. Lett. B **486**, 418 (2000); I. I. Bigi and N. G. Uraltsev, Nucl. Phys. B **592**, 92 (2001).
- [4] T. E. Coan et al. (CLEO Collaboration), hep-ex/0102007, M. Dubrovin (for CLEO Collaboration), hep-ex/0105030.
- [5] A. Freyberger et al. (CLEO Collaboration), Phys. Rev. Lett. **76**, 3065 (1996); D. M. Asner et al. (CLEO Collaboration), Phys. Rev. D **58**, 092001 (1998); E. M. Aitala et al. (E791 Collaboration), hep-ex/0011077; D. A. Sanders, Mod. Phys. Lett. A **15**, 1399 (2000); A. J. Schwartz, hep-ex/0101050; D. J. Summers, hep-ex/0011079.
- [6] S. Fajfer, S. Prelovšek, P. Singer, Eur. Phys. J. C **6**, 471, 751(E) (1999).
- [7] G. Burdman, E. Golowich, J. L. Hewett and S. Pakvasa, Phys. Rev. D **52**, 6383 (1995).
- [8] Q. Ho-Kim, X. Y. Pham, Phys. Rev. D **61**, 013008 (2000).
- [9] A. Khodjamirian, G. Stoll and D. Wyler, Phys. Lett. B **358**, 129 (1995).
- [10] S. Fajfer, S. Prelovšek and P. Singer, Phys. Rev. D **58**, 094038 (1998).
- [11] R. F. Lebed, Phys. Rev. D **61**, 033004 (2000).
- [12] C. Q. Geng, C. C. Lih, W-M. Zhang, Mod. Phys. Lett. A **15**, 2087 (2000).
- [13] S. Fajfer, S. Prelovšek, P. Singer and D. Wyler, Phys. Lett. B **487**, 81 (2000).
- [14] H. Routh, V. P. Gautam, Phys. Rev. D **54**, 1218 (1996); H. Routh, H. Roy, A. K. Maity and V. P. Gautam, Acta Phys. Pol. B **30**, 2687 (1999).
- [15] S. Fajfer, P. Singer, J. Zupan., hep-ph/0104236.
- [16] M. Selen, Workshop on *Prospects for CLEO/CESR with $3 < E_{cm} < 5$ GeV*, Cornell University, May 5-7, 2001; I. Bediaga, private communication.

- [17] G.-L. Lin, J. Liu, Y.-P. Yao, Phys. Rev. Lett. **64**, 1498 (1990); *ibid.*, Phys. Rev. D **42**, 2314 (1990); *ibid.*, Mod. Phys. Lett. A **6**, 1333 (1991); H. Simma, D. Wyler, Nucl. Phys. B **344**, 283 (1990); E. Vanem and J. O. Eeg, Phys. Rev. D **58**, 114010 (1998).
- [18] L. Reina, G. Riccardi, A. Soni, Phys. Rev. D **56**, 5805 (1997); G. Hiller and E. O. Iltan, Phys. Lett. B **409**, 425 (1997).
- [19] M. Boz, E. O. Iltan, Phys. Rev. D **62**, 054010 (2000).
- [20] D. Choudhury, J. Ellis, Phys. Lett. B **433**, 102 (1998); W. Liu, B. Zhang and H. Zheng, Phys. Lett. B **461**, 295 (1999).
- [21] G. Eilam, A. Ioannissian, R. R. Mendel and P. Singer, Phys. Rev. D **53**, 3629 (1996); A. Ali, DESY-97-192, hep-ph/9709507.
- [22] M. K. Gaillard and B. W. Lee, Phys. Rev. D **10**, 897 (1974); E. Ma and A. Pramudita, Phys. Rev. D **24**, 2476 (1981); J. O. Eeg, B. Nizic and I. Picek, Phys. Lett. B **244**, 513 (1990).
- [23] J. L. Goity, Z. Phys. C **34**, 341 (1987).
- [24] G. D'Ambrosio and D. Espiriu, Phys. Lett. B **175**, 237 (1986).
- [25] J. Kambor and B. R. Holstein, Phys. Rev. D **49**, 2346 (1994).
- [26] M. B. Wise, Phys. Rev. D **45**, 2188 (1992); G. Burdman and J. Donoghue, Phys. Lett. B **280**, 287 (1992).
- [27] R. Casalbuoni, A. Deandrea, N. Di Bartolomeo, R. Gatto, F. Feruglio, and G. Nardulli, Phys. Rep. **281**, 145 (1997). This review provides many references on the use of HQCT in different processes.
- [28] I. W. Stewart, Nucl. Phys. B **529**, 62 (1998).
- [29] D. Guetta, P. Singer, Phys. Rev. D **61**, 054014 (2000).
- [30] S. Herrlich, J. Kalinowski, Nucl. Phys. B **381**, 502 (1992).
- [31] C. Greub, T. Hurth, M. Misiak and D. Wyler, Phys. Lett. B **382**, 415 (1996).
- [32] S. Prelovšek, D. Wyler, Phys. Lett. B **500**, 304 (2001); S. Prelovšek, hep-ph/0010106.
- [33] A. J. Buras, Nucl. Phys. B **434**, 606 (1995).