COMMENTS

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Comment on "Exact analytical form for the box diagram with one heavy external quark"

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(Received 14 October 1991)

Within the framework of the electroweak standard model, I recalculate an exact analytical form of the effective Hamiltonian for the box-diagram amplitude with one heavy external quark. For the absorptive part of the effective Hamiltonian, my result includes all possible thresholds, compared to the result of He, McKellar, and Pallaghy where only the lowest threshold was included. The analyses of mixing and CP violation in the neutral T_u^0- and T_c^0-meson systems are also discussed.

PACS number(s): 12.15.Mm, 11.30.Er, 12.15.Ff, 12.15.Ji

I. INTRODUCTION

A recent Collider Detector at Fermilab (CDF) experiment [1] shows that the t-quark mass should be larger than 89 GeV, and the recent analyses of the electroweak radiative correction to the masses of the Z and W show that $M_t \approx 150\pm50$ GeV (Ref. [2]). If the t quark is actually produced by future accelerators, many properties of the t quark will be investigated in detail in addition to its mass. Then the important properties that should be analyzed might be the mixing and CP violation of the neutral T^0-meson ($T_u^0 = t\bar{u}, T_c^0 = t\bar{c}$) systems.

When we analyze the mixing and CP violation of neutral-meson (P^0) systems in the electroweak standard model, we need the effective Hamiltonian for the box-diagram amplitude describing the $P^0 \leftrightarrow \bar{P}^0$ transition. In 1981 Inami and Lim [3] gave the exact analytical form of the effective Hamiltonian, which was very useful for analyzing the $K^0 \leftrightarrow \bar{K}^0$ and $D^0 \leftrightarrow \bar{D}^0$ transitions. They pointed out that in the light neutral-meson systems the dominant contribution to the box-diagram amplitude comes from internal quarks much heavier than external ones, and the external quark masses and momenta can be neglected. However, it is not obvious whether the Inami-Lim effective Hamiltonian can be applied to the $B^0 \leftrightarrow \bar{B}^0$ and $T^0 \leftrightarrow \bar{T}^0$ transitions because the external b- and t-quark masses are large, and may not be ignored. In 1982 Cheng [4] first gave the effective Hamiltonian for the heavy-neutral meson systems in integral form to analyze the $B^0 \leftrightarrow \bar{B}^0$ and $T^0 \leftrightarrow \bar{T}^0$ transitions. In 1984 Buras, Slominski, and Steger [5] (BSS) repeated Cheng's calculation carefully. They disagreed with Cheng on the calculation and gave the correct expression for the effective Hamiltonian in integral form. Then it turned out that the external b-quark mass hardly contributed to the $B^0 \leftrightarrow \bar{B}^0$ transition, but the external t-quark mass sizably contributed to the $T^0 \leftrightarrow \bar{T}^0$ transition. However, the integral form of the BSS effective Hamiltonian was too complex to analyze mixing and CP violation in the heavy neutral-meson systems. In 1990 He, McKellar, and Pallaghy [6] (HMP) tried to do the integration analytically and gave a closed form of the effective Hamiltonian.

I have repeated HMP's calculation very carefully and found that some of the kinematically allowed channels were ignored in their calculation for the absorptive part of the effective Hamiltonian. In this paper I will make an analysis by including all allowed decay channels and give a complete form for the absorptive part of the effective Hamiltonian. The result will be useful for heavy-neutral meson systems since a lot of thresholds appear when the external quark mass is larger than the W-boson mass. As mentioned above, the t quark might be heavier than the W boson, so the result is applied to analyze the $T^0 \leftrightarrow \bar{T}^0$ transition.

II. EXACT ANALYTICAL FORM OF THE BOX FUNCTION WITH ONE HEAVY EXTERNAL QUARK

The $P^0 \leftrightarrow \bar{P}^0$ transition diagrams in the electroweak standard model are depicted in Fig. 1. In this paper the loop integral is evaluated under the following assumptions.

(i) The pseudoscalar neutral meson P^0 is composed of one heavy quark h and one light quark l, $P^0 = \bar{h}l$. The mass and momentum of the heavy quark are much larger than those of the light quark.

(ii) The external quarks are on shell.

(iii) The 't Hooft–Feynman gauge is used.

(iv) The QCD correction and long-distance effects are ignored.

The matrix element of the effective Hamiltonian $H_{\rm eff}$ is given by

$$\langle P^0|H_{\text{eff}}|\bar{P}^0\rangle \equiv M_{12}-i\tfrac{1}{2}\Gamma_{12}\ , \tag{1}$$

$$M_{12}=\frac{G_F^2M_W^2B_Pf_P^2m_P}{12\pi^2}\sum_{i,j=1}^{N}S_{ij}^{(d)}\lambda_i\lambda_j\ , \tag{1a}$$

$$\Gamma_{12}=\frac{G_F^2M_W^2B_Pf_P^2m_P}{12\pi^2}\sum_{i,j=1}^{N}S_{ij}^{(a)}\lambda_i\lambda_j\ , \tag{1b}$$

where i and j represent the quark flavors, G_F is the Fermi coupling constant, M_W is the mass of the W boson, m_P is the mass of the neutral meson P^0, f_P is the decay constant, B_P is the bag parameter, and $\lambda_i=V_{ih}^*V_{il}$ [V_{ij} is the Kobayashi-Maskawa [7] (KM) matrix element]. M_{12} and $i\frac{1}{2}\Gamma_{12}$ represent the dispersive (d) and absorptive (a) parts of the amplitude (1), respectively. $S_{ij}^{(d)}$ and $S_{ij}^{(a)}$ are the real (d) and imaginary (a) parts, respectively, of the following loop integral S_{ij} (Refs. [5,6]) called the box function:

$$S_{ij}=B_{ij}-\tfrac{5}{8}C_{ij}\ ,$$

$$\begin{aligned}B_{ij}=&\frac{1}{(1-x_i)(1-x_j)}\\&\times\sum_k{}'\int_0^1 d\alpha\{(2+\tfrac{1}{2}x_ix_j)\Lambda_k(\alpha)-2x_ix_j\\&\qquad+x_h[\alpha x_i+(1-\alpha)x_j]\}\ln\Lambda_k(\alpha)\ ,\end{aligned} \tag{2}$$

$$\begin{aligned}C_{ij}=&\frac{1}{(1-x_i)(1-x_j)}x_h(4+x_ix_j)\\&\times\sum_k{}'\int_0^1 d\alpha(1-\alpha)\alpha\ \ln\Lambda_k(\alpha)\ ,\end{aligned} \tag{3}$$

where

$$x_i=\frac{m_i^2}{M_W^2}\ ,\quad \sum_k{}'=\sum_{k=1}^{2}-\sum_{k=3}^{4}\ ,$$

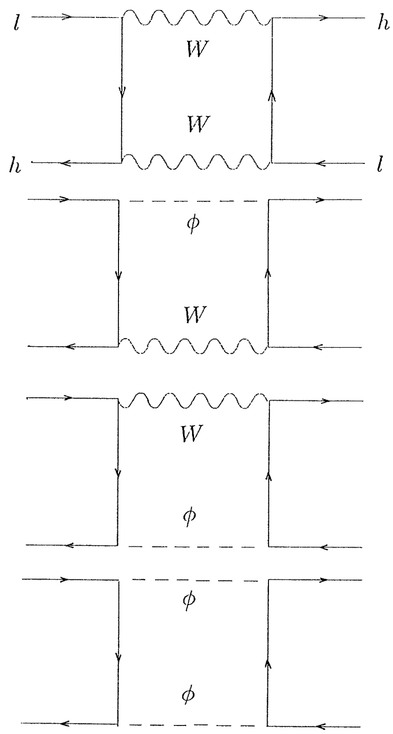

FIG. 1. Feynman diagrams for the $P^0\leftrightarrow\bar{P}^0$ transition. W represents the W boson and ϕ represents the unphysical scalar boson.

$$\Lambda_1(\alpha)=\alpha x_i+(1-\alpha)x_j-\alpha(1-\alpha)x_h\ ,$$
$$\Lambda_2(\alpha)=1-\alpha(1-\alpha)x_h\ ,$$
$$\Lambda_3(\alpha)=\alpha+(1-\alpha)x_j-\alpha(1-\alpha)x_h\ ,$$
$$\Lambda_4(\alpha)=\alpha x_i+1-\alpha-\alpha(1-\alpha)x_h\ .$$

Performing the integration in (2) and (3) I obtained the analytical form for $S_{ij}^{(d)}$ and $S_{ij}^{(a)}$:

$$\begin{aligned}S_{ij}^{(d)}=&\frac{1}{(1-x_i)(1-x_j)}\sum_k{}'D_k(x_i,x_j)\ ,\\
D_k(x_i,x_j)=&\left[x_j\left[\frac{(p_{ki}-q_{kj})^2}{4x_h}-\frac{q_{kj}}{2}\right]-x_i\left[\frac{(p_{ki}-q_{kj})^2}{4x_h}-\frac{p_{ki}}{2}\right]-\frac{x_ix_j}{x_h}(p_{ki}-q_{kj})\right.\\
&+\left[1+\frac{1}{4}x_ix_j\right]\left[\frac{1}{4}\frac{(p_{ki}-q_{kj})^3}{x_h^2}-\frac{p_{ki}^2-q_{kj}^2}{8x_h}\right]\left]\ln\frac{p_{ki}}{q_{kj}}\right.\\
&+\left[1+\frac{1}{4}x_ix_j\right]\left[\frac{p_{ki}+q_{kj}}{2}\right]\ln(p_{ki}q_{kj})+\left[1+\frac{1}{4}x_ix_j\right]\frac{p_{ki}q_{kj}}{x_h}\\
&+\left[\left[\frac{|\Delta_k|+\Delta_k}{2}\right]^{1/2}\ln|\Xi_k|+\left[\frac{|\Delta_k|-\Delta_k}{2}\right]^{1/2}\Theta_k\right]\\
&\times\left[\left[1+\frac{1}{4}x_ix_j\right]\left[\frac{(p_{ki}-q_{kj})^2}{2x_h}+\frac{1}{4}(p_{ki}+q_{kj})-\frac{3}{4}x_h\right]\right.\\
&\left.+\frac{x_j}{2}(p_{ki}-q_{kj}+x_h)-\frac{x_i}{2}(p_{ki}-q_{kj}+x_h)-2x_ix_j\right]\ ,\end{aligned} \tag{4a}$$

where

$$i,j=1-N\ ,\quad k=1,2,3,4\ ,\quad x_i=\frac{m_i^2}{M_W^2}\ ,$$

$$q_{1i}=q_{3i}=p_{1i}=p_{4i}=x_i\ ,$$

$$q_{2i}=q_{4i}=p_{2i}=p_{3i}=1\ ,$$

$$\Delta_k=\frac{1}{4x_h^2}[x_h^2-2x_h(p_{ki}+q_{kj})+(p_{ki}-q_{kj})^2]\ ,$$

$$\Xi_k=\frac{x_h-(p_{ki}+q_{kj})+\sqrt{|\Delta|_k}}{x_h-(p_{ki}+q_{kj})-\sqrt{|\Delta|_k}}\ ,$$

$$\Theta_k=2\left\{\arctan\frac{x_h-p_{ki}+q_{kj}}{\sqrt{|\Delta|_k}}-\arctan\frac{-x_h-p_{ki}+q_{kj}}{\sqrt{|\Delta|_k}}\right\}\ ,$$

$$S_{ij}^{(a)}=-\frac{\pi}{2x_h^2}\frac{1}{(1-x_i)(1-x_j)}\times[A(x_i,x_j)+A(1,1)-A(1,x_j)-A(x_i,1)]\ , \tag{4b}$$

where

$$A(x,y)=\theta(x_h-x-y-2\sqrt{xy})\times[x_h^2-2x_h(x+y)+(x-y)^2]^{1/2}\times\{[3x_h^2-x_h(x+y)-2(x-y)^2](1+\tfrac{1}{4}xy)+2x_h(x+y)(x+y-x_h)\}\ .$$

Substituting (4a) and (4b) into (1a) and (1b), we obtain the analytical form of the effective Hamiltonian for the $P^0\leftrightarrow\bar{P}^0$ transition. Though my result of $S_{ij}^{(d)}$ is expressed symmetrically for indices i and j, it is exactly the same as that of HMP. On the other hand, my result of $S_{ij}^{(a)}$ is not the same as that of HMP. The absorptive part of the amplitude (1) has four different thresholds depending on m_h. The corresponding diagrams are depicted in Fig. 2. Figures (2a)–(2d) represent the on-shell $P^0\leftrightarrow l\bar{q}_i\bar{l}q_j\leftrightarrow\bar{P}^0$, $P^0\leftrightarrow WW\leftrightarrow\bar{P}^0$, $P^0\leftrightarrow W\bar{l}q_j\leftrightarrow\bar{P}^0$, and $P^0\leftrightarrow l\bar{q}_i W\leftrightarrow\bar{P}^0$ transitions, respectively. HMP ignored some kinematically allowed decay channels [Figs. 2(b)–2(d)]. This difference in the absorptive part alters the phenomenological consequences sizably for large m_h. I will show this in the next section. It should be noted that we can easily get the Inami-Lim box function if we set $m_h=0$ in Eq. (2) before the integration, and if we use the unitarity condition of the KM matrix.

III. T^0-$\bar{T}^0$ MIXING AND CP VIOLATION

I apply the above effective Hamiltonian to the $T^0\leftrightarrow\bar{T}^0$ transition assuming the existence of three generations of quarks. Equations (1a) and (1b) can be rewritten in the following form with the help of the unitarity of the KM matrix ($\lambda_d+\lambda_s+\lambda_b=0$):

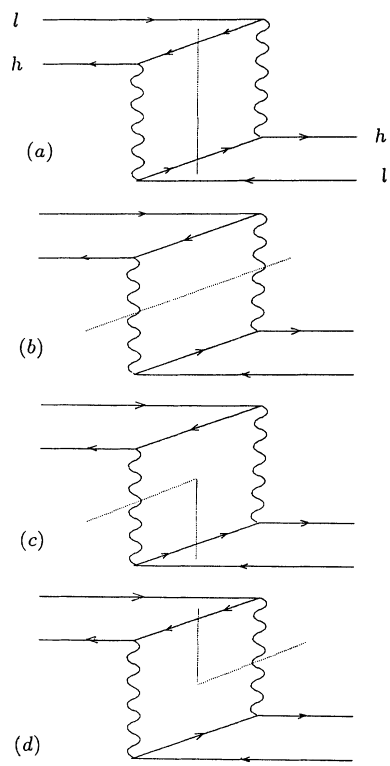

FIG. 2. Diagrams contributing to the absorptive part of the effective Hamiltonian. The dotted line denotes the presence of a real intermediate state.

$$M_{12}=\frac{G_F^2M_W^2B_Tf_T^2m_t}{12\pi^2}(D_{ss}\lambda_s^2+2D_{sb}\lambda_s\lambda_b+D_{bb}\lambda_b^2)\ ,$$
$$\Gamma_{12}=\frac{G_F^2M_W^2B_Tf_T^2m_t}{12\pi^2}(A_{ss}\lambda_s^2+2A_{sb}\lambda_s\lambda_b+A_{bb}\lambda_b^2)\ , \tag{5}$$

where

$$D_{ij}=S_{dd}^{(d)}+S_{ij}^{(d)}-S_{id}^{(d)}-S_{dj}^{(d)}\ , \tag{6a}$$

$$A_{ij}=S_{dd}^{(a)}+S_{ij}^{(a)}-S_{id}^{(a)}-S_{dj}^{(a)}\ . \tag{6b}$$

From the hierarchy of the KM matrix and the relation $m_d<m_s<m_b$ the following inequalities hold:

$$|D_{ss}\lambda_s^2|\ll|2D_{sb}\lambda_s\lambda_b|\ll|D_{bb}\lambda_b^2|\ ,$$
$$|A_{ss}\lambda_s^2|\ll|2A_{sb}\lambda_s\lambda_b|\ll A_{bb}\lambda_b^2|\ .$$

Therefore the dispersive and absorptive parts of the effective Hamiltonian (5) are represented approximately by

$$M_{12}=\frac{G_F^2M_W^2B_Tf_T^2m_t}{12\pi^2}D_{bb}\lambda_b^2\ , \tag{7a}$$

$$\Gamma_{12}=\frac{G_F^2M_W^2B_Tf_T^2m_t}{12\pi^2}A_{bb}\lambda_b^2\ . \tag{7b}$$

In Fig. 3 the t-quark mass dependence of D_{bb} and A_{bb} is shown. Both D_{bb} and A_{bb} have very small values. There are two reasons for their smallness. One reason is that all the d-type internal quark masses are almost degenerate compared with the external heavy-quark mass, and Glashow-Iliopoulos-Maiani (GIM) cancellation [8] is al-

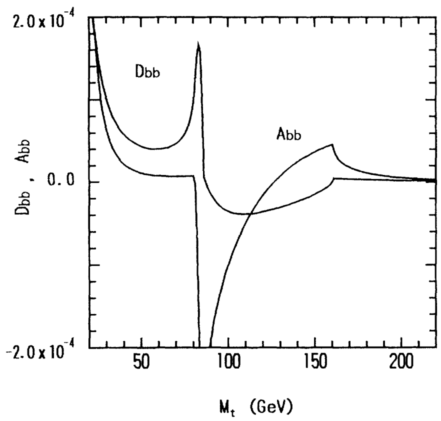

FIG. 3. t-quark mass dependence of the box functions D_{bb} and A_{bb}. Input parameters are $M_W=80.25$ GeV and $m_b=5.0$ GeV.

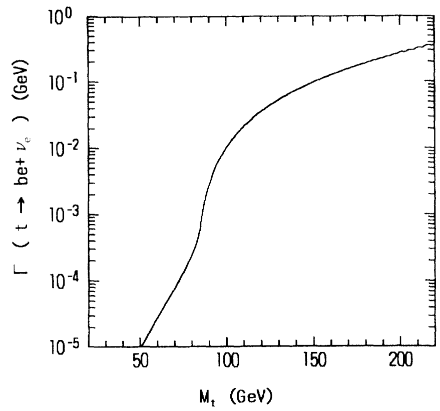

FIG. 4. Semileptonic decay width of the t quark as a function of m_t. Input parameters are $M_W=80.25$ GeV, $m_b=5.0$ GeV, $m_e=0.511$ MeV, and $m_\nu=0.0$ MeV.

most perfect. The other reason is that D_{bb} and A_{bb} are not proportional to the large constant x_t $(=m_t^2/M_W^2)$. Each box function $S_{ij}^{(x)}$ $(x=d,a)$ contains x_t and has a large value, but the x_t's are canceled in D_{bb} and A_{bb}, which are constructed of $S_{ij}^{(x)}$ through Eqs. (6a) and (6b).

The peak in D_{bb} around 80 GeV in Fig. 3 comes from the large contribution of the virtual W-boson exchange. Around 85 GeV D_{bb} decreases and A_{bb} has a large negative value. This is because the T^0-$\overline{T}^0$ transition occurs through the on-shell transition $t\to bW^+$. Since $|A_{bb}|>|D_{bb}|$ holds for $m_t>85$ GeV, the $T^0\leftrightarrow\overline{T}^0$ transition tends to occur through the on-shell transition. A small variation of D_{bb} and A_{bb} at 160 GeV comes from the occurrence of the on-shell $T^0\leftrightarrow W^+W^-\leftrightarrow\overline{T}^0$ transition. It should be noted that, by comparing Fig. 3 with Fig. 1 in HMP [6], we can see a big difference between them for A_{bb}. According to HMP, the absorptive part of the box function $S_{ij}^{(a)}$ would not play an important role in the T^0-$\overline{T}^0$ transition. On the contrary, according to our result, it has an important role in the transition if $m_t>m_W$.

Since I have shown the effective Hamiltonian for the T^0-$\overline{T}^0$ transition as a function of the t-quark mass, I will now estimate the T^0-$\overline{T}^0$ mixing and CP violation using (7). In the semileptonic decay $T^0\to\bar{l}\nu_l X$, the T^0-$\overline{T}^0$ mixing will be identified by observation of the subsequent decay of the $\Delta T=2$ transition $T^0\to\overline{T}^0\to l\bar{\nu}_l\overline{X}$. Let us define the mixing ratio between T^0 and $\overline{T}^0$ mesons as

$$r_T\equiv\frac{\Gamma(T^0\to l\bar{\nu}_l\overline{X})}{\Gamma(T^0\to\bar{l}\nu_l X)}=\frac{N^{++}+N^{--}}{N^{+-}}=\frac{\tilde{x}_T^2+\tilde{y}_T^2}{2+\tilde{x}_T^2+\tilde{y}_T^2},$$

where

$$\tilde{x}_T=\frac{G_F^2M_W^2B_Tf_T^2m_t}{6\pi^2\Gamma_T}|D_{bb}||\lambda_b|^2,$$

$$\tilde{y}_T=\frac{G_F^2M_W^2B_Tf_T^2m_t}{12\pi^2\Gamma_T}|A_{bb}||\lambda_b|^2,$$

and Γ_T is the total decay width of the t quark which varies with m_t. The total decay width was calculated at a tree level containing W-boson and unphysical scalar-boson contributions in the 't Hooft–Feynman gauge. The result fully agrees with what was calculated in the unitary gauge by Barger, Baer, Hagiwara, and Phillips [9]. In Fig. 4 a semileptonic decay width is shown. The total decay width Γ_t is given by $\Gamma_t\approx 9\Gamma(be^+\nu_e)$ since real W^+ can decay into $e^+\nu_e$, $\mu^+\nu_\mu$, $\tau^+\nu_\tau$, $u\bar{d}$, and $c\bar{s}$. The amount of the mixing ratio r_T is shown in Fig. 5, by taking account of the fact that Γ_T depends on m_t. The mixing ratios for T_u^0- and T_c^0-meson systems have extremely small values below $\sim 10^{-30}$ for $m_t>M_W$. This implies that it is impossible to observe the T^0-$\overline{T}^0$ mixing. This results from the fact that the main decay process $t\to bW^+$ is Cabibbo-allowed, and therefore the lifetime of the t quark is too short.

A good measurement for CP violation may be the charge asymmetry, which is defined as same-sign dilepton events in the final state. I shall denote the charge asymmetry parameter by $a\equiv(N_{++}-N_{--})/N_{+-}$. In the case of the $\Delta T=2$ transition, this parameter is represented by [6]

$$a_T=2\frac{\mathrm{Im}\lambda_b^*\lambda_s}{|\lambda_b|^2}\left[\frac{A_{bs}}{A_{bb}}-\frac{D_{bs}}{D_{bb}}\right]\frac{D_{bb}A_{bb}}{|D_{bb}|^2+|A_{bb}|^2/4}.$$

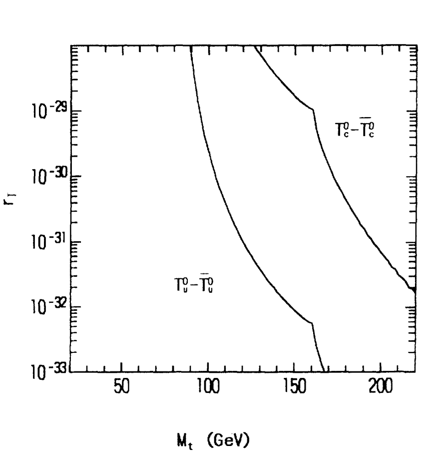

FIG. 5. Mixing ratio in the T_u^0 and T_c^0 systems as a function of m_t. Input parameters are $M_W=80.25$ GeV, $B_T=1$, $f_T=200$ MeV, $|V_{tb}|\cong 1.0$, $|V_{ub}|=0.007$, and $|V_{ub}|=0.046$.

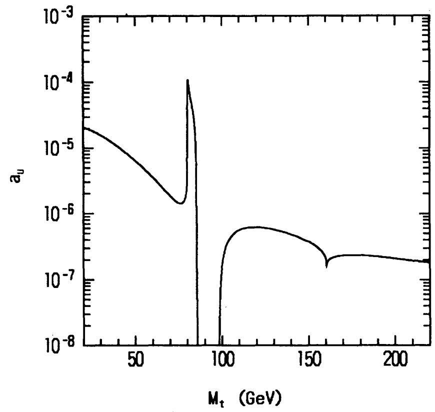

FIG. 6. Charge asymmetry in the T_u^0 system as a function of m_t. Input parameters are $\lambda=0.22$, $\eta=0.1$, and $A=1.1$ in Wolfenstein's notation.

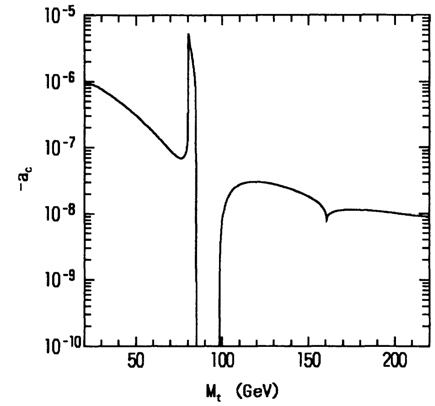

FIG. 7. Charge asymmetry in the T_c^0 system as a function of m_t. Input parameters are $\lambda=0.22$, $\eta=0.1$, and $A=1.1$ in Wolfenstein's notation.

The coefficient $\mathrm{Im}\lambda_b^*\lambda_s$ equals $-J_{CP}$ in the T_u^0-meson system and $+J_{CP}$ in the T_c^0-meson system, where J_{CP} is the so-called Jarlskog parameter [10] which is invariant under the phase transformation of quark fields. This parameter is represented by $J_{CP}=s_1^2s_2s_3c_1c_2c_3\sin\delta$ in KM notation [7] and $J_{CP}=A^2\lambda^6\eta(1-\frac{1}{2}\lambda^2)$ in Wolfenstein's [11] notation. The charge asymmetry parameters for the T_u^0- and T_c^0-meson systems are shown in Figs. 6 and 7, respectively. They have large values around $m_t \sim M_W$ at which the box functions D_{bb} and A_{bb} vary remarkably. They have almost constant values ($\sim 10^{-6}$ for the T_u^0-meson system and $\sim 10^{-7}$ for the T_c^0-meson system) for $m_t > 110$ GeV at which the box functions D_{bb} and A_{bb} vary slowly. Thus, it is also difficult to expect large CP asymmetry in the $T^0 \leftrightarrow \bar{T}^0$ transition. Although CP asymmetry in the nonleptonic decay of the T^0-meson will be parametrized in different ways, we cannot expect large CP asymmetry in this decay since the parameter is also proportional to the small parameter $\tilde{x}_T$.

IV. CONCLUSIONS

I conclude that, in the electroweak standard model with three generations of quarks, we will not be able to observe T^0-$\bar{T}^0$ mixing or to expect large CP violation in the $T^0 \leftrightarrow \bar{T}^0$ transition. This may be easily shown experimentally if the t-quark mass is greater than the W-boson mass, since precise information for the T^0-$\bar{T}^0$ mixing and CP violation will be obtained by investigating the leptonic decay of the W boson and associating b-quark jets produced in the decay process $t \to bW^+$. If the T^0-$\bar{T}^0$ mixing is experimentally observed, it will mean that we must go beyond the standard model. One of the major candidates would be the four-generation model. If a fourth-generation d-type quark that is heavier than the t quark exists, and if the KM matrix elements for the t quark and the fourth-generation d-type quark dominate those for the t and b quarks, then the t-quark decay width will be small. Therefore, the mixing ratio would be sufficiently larger than the case of three generations. The closed form of the effective Hamiltonian can be applied to the neutral-meson system, which is composed of a fourth-generation quark and a light quark, so the $B'^0 \leftrightarrow \bar{B}'^0$ transition, for example, can be easily analyzed. The mixing and CP violation are different from HMP's result. This will be discussed in a separate paper.

ACKNOWLEDGMENTS

I would like to thank Dr. Y. Kizukuri for a careful reading of the manuscript. I am also grateful to Dr. C. S. Lim for his encouragement.

[1] M. Contreras, in *Proceedings of the Joint International Lepton and Photon Symposium and Europhysics Conference on High Energy Physics,* Geneva, Switzerland, 1991, edited by S. Hegarty, K. Potter, and E. Quercigh (World Scientific, Singapore, 1992).

[2] Z. Hioki, Prog. Theor. Phys. **82**, 875 (1989); Phys. Rev. Lett. **65**, 683 (1990); Z. Phys. C **49**, 287 (1991); Mod. Phys. Lett. A **6**, 2129 (1991); A. Sirlin, Phys. Lett. B **232**, 123 (1989); J. Ellis and G. L. Fogli, *ibid.* **232**, 139 (1989); P. Langacker, Phys. Rev. Lett. **63**, 1920 (1989); S. Fanchiotti and A. Sirlin, Phys. Rev. D **41**, 319 (1990); V. Barger, J. L. Hewett, and T. G. Rizzo, Phys. Rev. Lett. **65**, 1313 (1990).

[3] T. Inami and C. S. Lim, Prog. Theor. Phys. **65**, 297 (1981); **65**, 1772(E) (1981).

[4] H.-Y. Cheng, Phys. Rev. D **26**, 143 (1982).

[5] A. J. Buras, W. Slominski, and H. Steger, Nucl. Phys. **B245**, 369 (1984).

[6] X.-G. He, B. H. J. McKellar, and P. K. Pallaghy, Phys. Rev. D **41**, 248 (1990). The following authors gave similar results independently, but their results are not as compact as those of He, McKellar, and Pallaghy; S. Nandi and L. Zhang, *ibid.* **41**, 240 (1990).

[7] M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).

[8] S. L. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D **2**, 1285 (1970); M. K. Gaillard and B. W. Lee, *ibid.* **10**, 897 (1974).

[9] V. Barger, H. Baer, K. Hagiwara, and R. J. N. Phillips, Phys. Rev. D **30**, 947 (1984).

[10] C. Jarlskog, Phys. Rev. Lett. **55**, 1039 (1985); Z. Phys. C **29**, 491 (1985).

[11] L. Wolfenstein, Phys. Rev. Lett. **51**, 1945 (1984).