Comment on "New Physics Contributions to the Lifetime Difference in D^0-$\bar{D}^0$ Mixing"

The precision measurement on the oscillation of a neutral particle and its antiparticle is very important to probe the footprints of new physics (NP). Although so far no clear signal tells us the existence of NP, Golowich, Pakvasa, and Petrov [1] have recently shown that the NP effects could have significant contributions to the lifetime difference in the D^0-$\bar{D}^0$ mixing, with the resultant form

$$y \simeq \sum_n \frac{\rho_n}{\Gamma_D} A_n^{(\mathrm{SM})} \bar{A}_n^{(\mathrm{SM})} + 2\sum_n \frac{\rho_n}{\Gamma_D} A_n^{\mathrm{NP}} \bar{A}_n^{(\mathrm{SM})}, \tag{1}$$

where $y \equiv \Delta\Gamma_D/2\Gamma_D$, $\Gamma_D(\Delta\Gamma_D)$ is the decay rate (rate difference), ρ_n corresponds to the phase space of the charmless intermediate state n, and $A^{(\mathrm{SM})}[A^{(\mathrm{NP})}]$ denotes the decay amplitude for $D^0 \to n$ dictated by the standard model (SM) [NP] contributions. In their Letter, various NP models, including vectorlike, supersymmetry (SUSY) without (with) R parity, left-right (LR) and multi-Higgs models, on the Eq. (1) are analyzed. Their results display that except the SUSY models without R parity, y is typically less than 10^{-4}. However, we find that in the nonmanifest LR model, an important LR mixing effect, illustrated in Fig. 1, was not considered in Ref. [1].

Two charged gauge bosons $W_{L,R}$ in the LR model are mixed and described by $W_1 = \cos\zeta W_L + \sin\zeta W_R$ and $W_2 = -\sin\zeta W_L + \cos\zeta W_R$ [2], where W_1 is the observed boson and ζ is the mixing angle between W_L and W_R. Interestingly, ζ of $O(10^{-2})$ is still allowed by current experimental data [2,3]. Using the small mixing angle, the charged current interaction associated with LR mixing is given by

$$\mathcal{L}_{\mathrm{LR}} = \frac{g_R}{\sqrt{2}} V_{ab}^{(R)} \zeta \bar{u}_b \gamma_\mu P_R d_a W_1^\mu, \tag{2}$$

where $a(b)$ is the flavor index. g_R and $V^{(R)}$ are the right-handed gauge coupling and flavor mixing matrix, respectively. In the nonmanifest LR model, since the pattern for $V^{(R)}$ could be $V_{\mathrm{cs}}^{(R)} \sim V_{\mathrm{ud}}^{(R)} \sim 0$ and $V_{\mathrm{us}}^{(R)} \approx V_{\mathrm{cd}}^{(R)} \approx O(1)$ [4], it is clear that Fig. 1 gives the dominant contribution. In terms of the leading results of the operator product expansion, only $\mathcal{O}_4^{ijk\ell} = \bar{u}_k \Gamma_\mu p_c \bar{\Gamma}_2 c_j \bar{u}_\ell \bar{\Gamma}_1 \Gamma^\mu c_i$ in Eq. (7) of Ref. [1] has the contribution, where i, j, k, ℓ denote the color indices, $\Gamma_\mu = \gamma_\mu P_L$, $\bar{\Gamma}_2 = \gamma_\nu P_L$, and $\bar{\Gamma}_1 = \gamma^\nu P_R$. Consequently, the effect for the lifetime difference is found to be

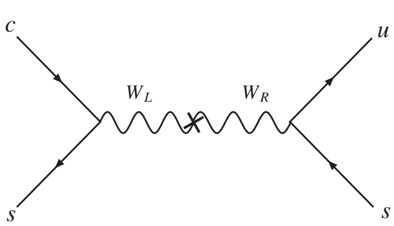

FIG. 1. Feynman diagram for the left-right mixing.

$$y_{\mathrm{LR}} = \mathcal{C}_{\mathrm{LR}} V_{\mathrm{cs}}^{(L)} V_{\mathrm{us}}^{(R)*} [K_2\langle Q' \rangle + K_1 \langle \tilde{Q}' \rangle], \tag{3}$$

where $K_1 = C_1\bar{C}_1 N_c + C_1\bar{C}_2 + \bar{C}_1 C_2$ with $N_c = 3$, $K_2 = C_2\bar{C}_2$, $\langle Q' \rangle = \langle \bar{D}^0 | \bar{u}_i \gamma_\mu P_L c_i \bar{u}_j \gamma^\mu P_R c_j | D^0 \rangle$, $\langle \tilde{Q}' \rangle = \langle \bar{D}^0 | \bar{u}_i \gamma_\mu P_L c_j \bar{u}_j \gamma^\mu P_R c_i | D^0 \rangle$, and

$$\mathcal{C}_{\mathrm{LR}} = \frac{G_F^2}{2\pi m_D \Gamma_D} \xi_g \lambda m_c^2 \sqrt{x_s}, \tag{4}$$

with $x_s = m_s^2/m_c^2$, $\xi_g = \zeta g_R/g_L$, and λ being the Wolfenstein's parameter. Here, $\bar{C}_{1(2)} = C_{1(2)}$. From Eq. (4), we see clearly that the LR mixing contribution is at least $1/\sqrt{x_s} = m_c/m_s$ larger than that presented in Ref. [1].

With $G_F = 1.166 \times 10^{-5}\ \mathrm{GeV}^{-2}$, $m_s = 0.12$ GeV, $m_c = 1.4$ GeV, $m_D = 1.86$ GeV, $f_D = 0.23$ GeV, $\xi_g < 0.033$, $C_1 \approx -0.55$, and $C_2 \approx 1.3$, we get the maximum value of

$$y_{\mathrm{LR}} \approx 1.4 \times 10^{-3}. \tag{5}$$

Recently, *BABAR* [5] and BELLE [6] Collaborations have reported the evidence for the D-$\bar{D}$ mixing with the combined 68% C.L. results of

$$x \equiv \frac{\Delta m_D}{\Gamma_D} = (5.5 \pm 2.2) \times 10^{-3}, \quad y = (5.4 \pm 2.0) \times 10^{-3}. \tag{6}$$

Clearly, our result in Eq. (5) based on the LR mixing mechanism in the nonmanifest LR model fits well with the data in Eq. (6).

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