Searching for possible large *CP*-violation effects in neutral-charm-meson decays

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Possible large *CP*-violation effects in the partial-decay-rate asymmetries for the D^0-$\bar{D}^0$ system are discussed. All possible nonleptonic two-body final states are studied. It turns out that $D^0 \to \pi^- K^+$, $\pi^0 K^0$, $\pi^0\eta$, $\pi^0\omega$, K^+K^-, ϕK^0 are the most promising channels. If the D^0-$\bar{D}^0$ mixing is on $\sim 1\%$ level, 10^4–10^6 $D^0\bar{D}^0$ pairs would be enough for testing these channels.

I. INTRODUCTION

There was a common belief in the literature that the *CP*-violation effects in D^0-$\bar{D}^0$ decays were very small because of the small mixing. But some recent data from the Mark III group seem to show the possibility[1] that the D^0-$\bar{D}^0$ mixing might be on 1% level (this corresponds to $\Delta m_D/\Gamma_D \sim 0.1$). Although more recent analysis has failed to support this possibility, it is not excluded. This inspired a hope for larger *CP*-violation effects in the neutral-charm-meson decays.[2]

Theoretically, some authors advocated that the long-distance effect dominates the D^0-$\bar{D}^0$ mixing.[3,4] They estimated, within the framework of the standard model with three generations of quarks and leptons, that

$$\frac{\Delta m_D}{\Gamma_D} \sim 10^{-3} \text{ (Ref. 4)},$$

$$\frac{\Delta m_D}{\Gamma_D} \sim 10^{-2} \text{ (Ref. 3)},$$

respectively. They even estimated the upper limit for $\Delta m_D/\Gamma_D$:

$$\frac{\Delta m_D}{\Gamma_D} \leq 0.1 \text{ (Ref. 3)}.$$

Obviously, in the extreme case of $\Delta m_D/\Gamma_D \sim 0.1$, the mixing should be $\sim 1\%$ level. Thus, if the Mark III data are confirmed, this would bring us to the border of new physics.

Keeping the large D^0-$\bar{D}^0$ mixing in mind, there would be a hope of large *CP*-violation effects in D^0-$\bar{D}^0$ decays owing to the interplay of mixing and amplitude interference just as in the B^0-$\bar{B}^0$ case.[5,6] The observation of *CP*-violation effects in D^0-$\bar{D}^0$ decays will provide another sign of new physics in addition to the large mixing itself. In this short paper we shall discuss possible large *CP*-violation effects in the neutral-*D*-meson decays in detail.

II. PARTIAL-DECAY-RATE ASYMMETRIES

Take the phase convention as

$$CP\,|D^0\rangle = |\bar{D}^0\rangle . \tag{1}$$

Define

$$|D_S\rangle = p\,|D^0\rangle + q\,|\bar{D}^0\rangle , \qquad |D_L\rangle = p\,|D^0\rangle - q\,|\bar{D}^0\rangle . \tag{2}$$

Assume the corresponding eigenvalues of D_S, D_L are

$$\lambda_S = m_S - i\frac{\gamma_S}{2} , \qquad \lambda_L = m_L - i\frac{\gamma_L}{2} , \tag{3}$$

respectively. Then the time-evolved states are (*CPT* invariance is assumed throughout this paper)

$$|D_P^0(t)\rangle = g_+(t)\,|D^0\rangle + \frac{q}{p} g_-(t)\,|\bar{D}^0\rangle , \qquad |\bar{D}_P^0(t)\rangle = \frac{p}{q} g_-(t)\,|D^0\rangle + g_+(t)\,|\bar{D}^0\rangle , \tag{4}$$

where

$$g_\pm(t) = \tfrac{1}{2}(e^{-i\lambda_S t} \pm e^{-i\lambda_L t}) . \tag{5}$$

We consider only those hadronic final states f which both D^0 and $\bar{D}^0$ can decay into:

$$\begin{matrix} D^0 \searrow & \\ & f . \\ \bar{D}^0 \nearrow & \end{matrix}$$

In these cases, we have amplitude interference which will enhance the asymmetry.

Denote the *CP*-conjugate state of f by $\bar{f}$

$$|\bar{f}\rangle = CP\,|f\rangle . \tag{6}$$

Here we do not restrict ourselves to the cases $\bar{f} = f$. Instead, we consider all possible final states. This is different from Bigi and Sanda.[2]

Because the very small lifetime difference of D_S, D_L, we have to consider time-integrated effects. So, we define the time-integrated partial-decay-rate asymmetry

$$C_f = \frac{\Gamma(D_P^0 \to f) - \Gamma(\bar{D}_P^0 \to \bar{f})}{\Gamma(D_P^0 \to f) + \Gamma(\bar{D}_P^0 \to \bar{f})} , \tag{7}$$

where

$$\Gamma(D_P^0 \to f) = \int_0^\infty dt\, |\langle f\,|D_P^0(t)\rangle|^2 , \tag{8}$$

$$\Gamma(\bar{D}^0_P \to \bar{f}) = \int_0^\infty dt\, |\langle \bar{f} | \bar{D}^0_P(t)\rangle|^2 . \tag{9}$$

We only discuss the following cases where there is no direct *CP* violation in the magnitude of the amplitude in pure $D^0,\bar{D}^0$ decays, i.e.,

$$|A(D^0 \to f)| = |\bar{A}(\bar{D}^0 \to \bar{f})| . \tag{10}$$

In order to guarantee the equality of Eq. (10), some conditions should be satisfied. Assume that there are two different strong-interaction channels,

$$A(D^0 \to f) \equiv A(f) = G_1 e^{i\alpha} + G_2 e^{i\beta} , \tag{11}$$

$$\bar{A}(\bar{D}^0 \to \bar{f}) \equiv \bar{A}(\bar{f}) = G_1^* e^{i\alpha} + G_2^* e^{i\beta} , \tag{12}$$

where G_1,G_2 are Kobayashi-Maskawa factors, and α,β are the strong-interaction phases. Obviously, if

$$G_1 = G_2 \tag{13}$$

or

$$\alpha = \beta , \tag{14}$$

Eq. (10) will be satisfied. We shall see later, Eq. (13) is usually satisfied.

Under the condition of Eq. (10), all the amplitudes cancel out in the calculation of the asymmetry C_f.

Define

$$x = \frac{\bar{A}(f)}{A(f)} ; \tag{15}$$

$$\bar{x} = \frac{A(\bar{f})}{\bar{A}(\bar{f})} ; \tag{16}$$

$$G_+ \equiv \int_0^\infty dt\, |g_+(t)|^2 = \frac{2+z^2-y^2}{2\gamma(1+z^2)(1-y^2)} ,$$
$$G_- \equiv \int_0^\infty dt\, |g_-(t)|^2 = \frac{z^2+y^2}{2\gamma(1+z^2)(1-y^2)} , \tag{17}$$
$$G_{+-} \equiv \int_0^\infty dt\, g_+^*(t) g_-(t) = \frac{(1+z^2)y + i(1-y^2)z}{2\gamma(1+z^2)(1-y^2)} ;$$

$$\Delta m = m_S - m_L ,$$
$$\Delta\gamma = \gamma_S - \gamma_L > 0 , \tag{18}$$
$$\gamma = \frac{\gamma_S + \gamma_L}{2} .$$

In Eq. (17),

$$z = \frac{\Delta m}{\gamma} \tag{19}$$

is the mixing parameter, while

$$y = \frac{\Delta\gamma}{2\gamma} . \tag{20}$$

Because y is the same order as z (Ref. 3), even in the extreme case of $z \sim 0.1$, we still have

$$z^2, y^2 \ll 1 . \tag{21}$$

In that case

$$G_+ \approx \frac{1}{\gamma} ,$$
$$G_- \approx \frac{z^2+y^2}{2\gamma} , \tag{22}$$
$$G_{+-} \approx \frac{y+iz}{2\gamma} .$$

After a lengthy but straightforward calculation, we arrive at

$$C_f = \frac{(z^2+y^2)\left[\left|\frac{q}{p}x\right|^2 - \left|\frac{p}{q}\bar{x}\right|^2\right] + 2y\,\mathrm{Re}\left[\frac{q}{p}x - \frac{p}{q}\bar{x}\right] - 2z\,\mathrm{Im}\left[\frac{q}{p}x - \frac{p}{q}\bar{x}\right]}{4 + (z^2+y^2)\left[\left|\frac{q}{p}x\right|^2 + \left|\frac{p}{q}\bar{x}\right|^2\right] + 2y\,\mathrm{Re}\left[\frac{q}{p}x + \frac{p}{q}\bar{x}\right] - 2z\,\mathrm{Im}\left[\frac{q}{p}x + \frac{p}{q}\bar{x}\right]} . \tag{23}$$

This expression is rephasing invariant because $(q/p)x$ and $(p/q)\bar{x}$ are phase-convention independent (see Ref. 6).

If we assume

$$\bar{x} = x^* , \tag{24}$$

then

$$\frac{q}{p}x = \left|\frac{q}{p}x\right| e^{i\phi}, \quad \frac{p}{q}x^* = \left|\frac{p}{q}x^*\right| e^{-i\phi} , \tag{25}$$

that is, $(q/p)x$ and $(p/q)x^*$ just have opposite phase.

Substituting Eqs. (24) and (25) into (23), we have

$$C_f = \frac{(z^2+y^2)|x|^2\left[\left|\frac{q}{p}\right|^2 - \left|\frac{p}{q}\right|^2\right] + 2y|x|\left[\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right|\right]\cos\phi - 2z|x|\left[\left|\frac{q}{p}\right| + \left|\frac{p}{q}\right|\right]\sin\phi}{4 + (z^2+y^2)|x|^2\left[\left|\frac{q}{p}\right|^2 + \left|\frac{p}{q}\right|^2\right] + 2y|x|\left[\left|\frac{q}{p}\right| + \left|\frac{p}{q}\right|\right]\cos\phi - 2z|x|\left[\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right|\right]\sin\phi} . \tag{26}$$

TABLE I. Final results. In the third column, spec and ex denote spectator and exchange diagrams, respectively.

Quark decay	$D^0 \to f$	Diagram	$x = \frac{\overline{A}(f)}{A(f)}$	$\lvert x \rvert^2$	C_f	$C_{fl}(C,l=\text{even})$	B (%)	$N_{D\overline{D}}(\sin\phi=1)$	$N_{D\overline{D}}(\sin\phi=0.1)$
$c \to s\,\bar{s}u$	K^+K^-	spec,ex$_u$					0.68	1.5×10^4	1.5×10^6
	$\phi\pi^0$	spec	$\frac{V_{cs}V_{us}^*}{V_{cs}^*V_{us}}$	1	$-0.1\sin\phi$	$-0.2\sin\phi$			
	$\phi\eta$	spec							
$c \to d\,\bar{d}u$	$\pi^+\pi^-$	spec,ex$_u$					0.18	5.5×10^4	5.5×10^6
	$\pi^0\pi^0$	ex$_d$	$\frac{V_{cd}V_{ud}^*}{V_{cd}^*V_{ud}}$	1	$-0.1\sin\phi$	$-0.2\sin\phi$	0.09[a]	1.1×10^5	1.1×10^7
	$\eta\eta$	ex$_d$							
	$\omega\omega$	ex$_d$							
$c \to d\bar{s}u$	π^-K^+	spec,ex$_u$					1.6×10^{-2}[a]	1.3×10^4	1.3×10^6
	π^0K^0	ex$_d$					1.6×10^{-2}[a]	1.3×10^4	1.3×10^6
	ηK^0	ex$_d$	$\frac{V_{cs}V_{ud}^*}{V_{cd}^*V_{us}}$	351	$-0.7\sin\phi$	$-0.6\sin\phi$			
	ωK^0	ex$_d$							
	ϕK^0	ex$_d$					3.4×10^{-3}[a]	6.0×10^4	6.0×10^6
$c \to s\bar{d}u$	$\phi\overline{K}^0$	ex$_s$					1.18	3.0×10^6	3.0×10^8
	$\pi^0\overline{K}^0$	spec,ex$_d$					2.2	1.6×10^6	1.6×10^8
	$\eta\overline{K}^0$	spec,ex$_d$					1.8	2.0×10^6	2.0×10^8
	$\omega\overline{K}^0$	spec,ex$_d$					3.8	9.4×10^5	9.4×10^7
	$\pi^0\overline{K}^{0*}$	spec,ex$_d$	$\frac{V_{cd}V_{us}^*}{V_{cs}^*V_{ud}}$	2.85×10^{-3}	$-5.3\times10^{-3}\sin\phi$	$-1.1\times10^{-2}\sin\phi$	2.1	1.7×10^6	1.7×10^8
	$\rho^0\overline{K}^0$	spec,ex$_d$					1.3	2.7×10^6	2.7×10^8
	π^+K^-	spec,ex$_u$					5.6	6.4×10^5	6.4×10^7
	ρ^+K^-	spec,ex$_u$					13.7	2.6×10^5	2.6×10^7
	π^+K^{-*}	spec,ex$_u$					7.3	4.9×10^5	4.9×10^7

[a]Theoretically estimated branching ratio from the known data.

In the case of the B^0-$\bar{B}^0$ system, the short-distance effect dominates $\Delta m, \Delta\gamma$. There we can calculate $q/p, p/q$ by means of the box diagram. It turns out that $|q/p| \sim |p/q| \sim 1$ is a very good approximation. In the D^0-$\bar{D}^0$ case, the long-distance effect dominates $\Delta m, \Delta\gamma$, and we do not know how to calculate q/p and p/q. In order to estimate the order of magnitude of C_f in Eq. (26), we here, as in Ref. 2, assume

$$\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right| \ll 1, \quad \left|\frac{q}{p}\right|^2 - \left|\frac{p}{q}\right|^2 \ll 1 . \tag{27}$$

Substituting Eq. (27) into (26), we have

$$C_f = \begin{cases} -z\,|x|\sin\phi \quad \text{for } |x| \le 1 , \\ \dfrac{-4z\,|x|\sin\phi}{4+2(z^2+y^2)|x|^2} \quad \text{for } |x| \gg 1 . \end{cases} \tag{28}$$

We have searched for all possible two-body final states of D^0-$\bar{D}^0$ decays. Only $D^0,\bar{D}^0 \to K^0\bar{K}^0$ do not satisfy the condition of Eq. (10). All other decay modes satisfy Eq. (10) and are listed in Table I. They have only three different values of $|x|^2$, namely, 1, 2.85×10^{-3}, and 351. Here we have taken $c_1 \sim c_2 \sim c_3 \sim 1$, $s_1 \sim 0.231$, $s_2 \sim s_1^2$, $s_3 \sim 0.5 s_2$. If we take the mixing parameter $z \sim 0.1$, we have

$$C_f = \begin{cases} -0.1\sin\phi \quad \text{for } |x|^2 = 1 , \\ -5.3\times10^{-3}\sin\phi \quad \text{for } |x|^2 = 2.85\times10^{-3} , \\ -0.7\sin\phi \quad \text{for } |x|^2 = 351 . \end{cases} \tag{29}$$

For the branching ratios, there are already experimental data for most of the two-body decays.[7] For the processes for which there are no data we can estimate the corresponding branching ratios through the known data. For example,

$$\frac{B(\pi^-K^+)}{B(\pi^+K^-)} \simeq \frac{|V_{us}V_{cd}^*|^2}{|V_{ud}V_{cs}^*|^2} \sim 2.85\times10^{-3} \tag{30}$$

so we can deduce

$$B(\pi^-K^+) \sim 2.85\times10^{-3} B(\pi^+K^-) \sim 1.6\times10^{-2}\% . \tag{31}$$

We use a superscript a to denote the theoretically estimated branching ratios in the Table I.

For the number of D^0-$\bar{D}^0$ pairs needed for testing the asymmetries, we use

$$N_{D\bar{D}} \sim \frac{1}{B}\frac{1}{C_f^2} \tag{32}$$

for one-standard-deviation (1σ) signature, and

$$N_{D\bar{D}} \sim \frac{9}{B}\frac{1}{C_f^2} \tag{33}$$

for 3σ signature. In Table I we present only $N_{D\bar{D}}$ for the 1σ signature, but for different values of $\sin\phi$ ($\sin\phi = 1$ and $\sin\phi = 0.1$).

Because the leptonic tagging asymmetries C_{fl} are the same order as C_f (see the next section), we estimate $N_{D\bar{D}}$ only by use of C_f. In addition, in Table I we also give the quark diagrams responsible for the decays. Here, spec means spectator diagram and ex_q means exchange diagram with a $q\bar{q}$ pair created from the vacuum.

III. LEPTONIC TAGGING AND CHARGED-CHARM TAGGING

In most cases $D^0\bar{D}^0$ are produced in pair. So we have to consider[2] whether the $D^0\bar{D}^0$ pair is produced in the charge-conjugation-even or -odd or orbital-angular-momentum-even or -odd states. We use η_c, η_l to denote charge-conjugation parity and angular-momentum parity of the $D\bar{D}$ pair, respectively. Then

$$\eta_c = \begin{cases} +1 \quad \text{for } C \text{ even} , \\ -1 \quad \text{for } C \text{ odd} ; \end{cases}$$

$$\eta_l = \begin{cases} +1 \quad \text{for } l \text{ even} , \\ -1 \quad \text{for } l \text{ odd} . \end{cases}$$

In most cases, $\eta_c = \eta_l$. In some cases, $\eta_c = -\eta_l$. For instance, in the processes

$$\begin{aligned} &e^+e^- \to \gamma^* \to D\bar{D} , \\ &e^+e^- \to \gamma^* \to D^*\bar{D} + D\bar{D}^* \to D\bar{D}\pi , \end{aligned} \tag{34}$$

$\eta_c = \eta_l = -1$ because $D\bar{D}$ is in a P-wave state. In the processes

$$e^+e^- \to \gamma^* \to D^*\bar{D} + D\bar{D}^* \to D\bar{D}\gamma, e^+e^- \to \gamma^* \to D^*\bar{D}^* \to D\bar{D} + \pi\gamma, e^+e^- \to 2\gamma^* \to D\bar{D} , \tag{35}$$

$\eta_c = \eta_l = 1$ because $D\bar{D}$ is in a S wave. For the processes

$$e^+e^- \to \gamma^* \to D^*\bar{D}^* \to D\bar{D} + \pi\pi, \gamma\gamma , \tag{36}$$

$\eta_c = -1$, $\eta_l = +1$, i.e., $\eta_c = -\eta_l$ if $D\bar{D}$ is in a S wave. In all the above cases, we can always write the time evoluted state as

$$|i\rangle = |D^0(k_1,t_1)\bar{D}^0(k_2,t_2)\rangle + \eta\,|D^0(k_2,t_2)\bar{D}^0(k_1,t_1)\rangle , \tag{37}$$

where $\eta = \eta_c$ or η_l.

Assume that $D^0 \to l^+X, \bar{D}^0 \to l^-X$ only. Then we can use semileptonic decay to tag on one of the two time-evolved states $D_P^0(t)$ or $\bar{D}_P^0(t)$. So we define the leptonic tagging asymmetry C_{fl} as

$$C_{fl} = \frac{N(l^-,f) - N(l^+,\bar{f})}{N(l^-,f) + N(l^+,\bar{f})} , \tag{38}$$

where

$$N(l^-,f)=\int_0^\infty dt_1dt_2\,|\langle l^-,f\,|\,i\rangle|^2,\quad N(l^+,\bar f)=\int_0^\infty dt_1dt_2\,|\langle l^+,\bar f\,|\,i\rangle|^2\,. \tag{39}$$

Using

$$|(D^0\to l^+X)|=|\bar A(\bar D^0\to l^-X)|\,,\quad |A(f)|=|\bar A(\bar f)|\,, \tag{40}$$

and

$$z^2,y^2\ll 1$$

we have

$$C_{fl}=\frac{N}{D}\,, \tag{41}$$

where

$$N=(2+\eta)(z^2+y^2)|x|^2\left[\left|\frac{q}{p}\right|^2-\left|\frac{p}{q}\right|^2\right]+2(1+\eta)|x|\left[y\left[\left|\frac{q}{p}\right|-\left|\frac{p}{q}\right|\right]\cos\phi-z\left[\left|\frac{q}{p}\right|+\left|\frac{p}{q}\right|\right]\sin\phi\right]$$

$$\approx -4(1+\eta)|x|z\sin\phi\,, \tag{42}$$

$$D=4+(2+\eta)(z^2+y^2)|x|^2\left[\left|\frac{q}{p}\right|^2+\left|\frac{p}{q}\right|^2\right]+2(1+\eta)|x|\left[y\left[\left|\frac{q}{p}\right|+\left|\frac{p}{q}\right|\right]\cos\phi-z\left[\left|\frac{q}{p}\right|-\left|\frac{p}{q}\right|\right]\sin\phi\right]$$

$$\approx 4+2(2+\eta)(z^2+y^2)|x|^2+4(1+\eta)y|x|\cos\phi\,. \tag{43}$$

Thus

$$C_{fl}=\begin{cases}\dfrac{-8|x|z\sin\phi}{4+6|x|^2(z^2+y^2)+8|x|y\cos\phi} & \text{for } C(l) \text{ even}\,,\\ 0 \text{ for } C(l) \text{ odd}\,.\end{cases} \tag{44}$$

The corresponding values of C_{fl} for different decay modes are given in the Table I. They are in the same order of magnitude as C_f.

Sometimes, a charged-charm meson D^+ (D^-) is produced along with a neutral one, $\bar D^0$ (D^0):

$$e^+e^-\to D^0D^-X,\quad e^+e^-\to\bar D^0D^+X\,. \tag{45}$$

Tagging on D^+ (D^-) we can know the other partner to be $\bar D^0$ (D^0) at $t=0$. In that case we can still use the asymmetry defined by Eq. (7).

IV. THE PENGUIN-DIAGRAM CONTRIBUTION

The penguin diagram can only cause $c\to u$ and $\bar c\to\bar u$ decays. The effective Hamiltonian is[8]

$$H^{c\to u}_{\text{penguin}}=C_p\frac{G_F}{\sqrt2}V_{ub}V^*_{cb}\bar u\gamma_\mu(1-\gamma_5)\lambda_a c(\bar u\gamma^\mu\lambda_a u+\bar d\gamma^\mu\lambda_a d+\bar s\gamma^\mu\lambda_a s)+\text{H.c.}\,, \tag{46}$$

where

$$C_p=\frac{\alpha_s(m_c{}^2)}{12\pi}\ln\left[\frac{m_b{}^2}{m_c{}^2}\right]\approx 0.013\,. \tag{47}$$

In view of Eq. (46), for the two-body final states, the penguin diagram can only contribute to

$$D^0\to\pi^0\pi^0,\eta\eta,\omega\omega,\pi^+\pi^-,K^+K^-\,.$$

But the ratios between the penguin and the spectator or exchange diagram contributions are very small, namely,

$$\frac{\Gamma_{\text{penguin}}(D^0\to\pi^0\pi^0)}{\Gamma_{\text{exchange}}(D^0\to\pi^0\pi^0)}\approx C_p{}^2\frac{|V_{ud}V^*_{cb}|^2}{|V^*_{cd}V_{ud}|^2}$$

$$\sim C_p{}^2s_2{}^2\sim C_p{}^2s_1{}^4$$

$$\sim 4.8\times10^{-7}\,, \tag{48a}$$

$$\frac{\Gamma_{\text{penguin}}(D^0\to\pi^+\pi^-)}{\Gamma_{\text{spectator}}(D^0\to\pi^+\pi^-)}\approx C_p{}^2\frac{|V_{ub}V_{cb}^*|^2}{|V_{cd}^*V_{ud}|^2}$$

$$\sim C_p{}^2 s_2{}^2 \sim 4.8\times10^{-7}\,, \quad (48\text{b})$$

$$\frac{\Gamma_{\text{penguin}}(D^0\to K^+K^-)}{\Gamma_{\text{spectator}}(D^0\to K^+K^-)}\approx C_p{}^2\frac{|V_{ub}V_{cb}^*|^2}{|V_{us}V_{cs}^*|^2}$$

$$\sim C_p{}^2 s_2{}^2 \sim 4.8\times10^{-7}\,. \quad (48\text{c})$$

So, the penguin contributions can be completely neglected.

V. DISCUSSION

In our estimations, we have used two conditions: Eqs. (10) and (24). Equation (10) is always satisfied, but Eq. (24) is not because of the final-state interactions. The detailed discussion can be found in Ref. 6. Here we only want to emphasize that $\bar{x}=x^*$ is just a qualitative approximation. The only decay channel where $\bar{x}=x^*$ might be exact is $D^0\to\phi\bar{K}^0$ or ϕK^0. These two modes have only one isospin final state so that $\bar{x}=x^*$ might be true. Unfortunately, the rescattering of $D^0\to\bar{K}^{0*}\eta\to\bar{K}^0\phi$, $D^0\to K^{0*}\eta\to K^0\phi$ also contribute to these decays,[9] and the rescattering involves different isospin states, that makes $\bar{x}=x^*$ even for $D^0\to\phi\bar{K}^0,\phi K^0$, approximate. In addition to $\phi\bar{K}^0,\phi K^0$, the rescatterings of $D^0\to\bar{K}^{0*}\eta\to\bar{K}^0\pi^0$ and $D^0\to K^{0*}\eta\to\pi^0K^0$ also contribute to the decays of $D^0\to\pi^0\bar{K}^0$ and $D^0\to\pi^0K^0$, respectively.

Now we turn to the final results given in Table I. From the table we can see that the most promising decay channels to observe CP violation in D^0-$\bar{D}^0$ decays might be

$$D^0\to\pi^-K^+,\pi^0K^0,\pi^0\eta,\pi^0\omega,K^+K^-,\phi K^0\,.$$

They would need only $\sim10^4$ $D^0\bar{D}^0$ pairs if $\sin\phi$ is the order of unity. At the SLAC e^+e^- storage ring SPEAR the Mark III group has collected 3762 ± 42 $D^0\bar{D}^0$ pairs within the integrated luminosity of 9.2 pb^{-1} (Ref. 10). It seems not difficult to collect $\sim10^4$ $D^0\bar{D}^0$ pairs at the $\psi(3700)$ resonance for longer running time. So we hope our experimental colleagues will undertake these efforts.

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