

Tests of CPT symmetry in $B^0\text{-}\bar{B}^0$ mixing and in $B^0 \rightarrow c\bar{c}K^0$ decays

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(Received 16 May 2016; published 18 July 2016)

Using the eight time dependences $e^{-\Gamma t}(1 + C_i \cos \Delta m t + S_i \sin \Delta m t)$ for the decays $\Upsilon(4S) \rightarrow B^0 \bar{B}^0 \rightarrow f_j f_k$, with the decay into a flavor-specific state $f_j = \ell^\pm X$ before or after the decay into a CP eigenstate $f_k = c\bar{c}K_{S,L}$, as measured by the *BABAR* experiment, we determine the three CPT -sensitive parameters $\text{Re}(\mathbf{z})$ and $\text{Im}(\mathbf{z})$ in $B^0\text{-}\bar{B}^0$ mixing and $|\bar{A}/A|$ in $B^0 \rightarrow c\bar{c}K^0$ decays. We find $\text{Im}(\mathbf{z}) = 0.010 \pm 0.030 \pm 0.013$, $\text{Re}(\mathbf{z}) = -0.065 \pm 0.028 \pm 0.014$, and $|\bar{A}/A| = 0.999 \pm 0.023 \pm 0.017$, in agreement with CPT symmetry.

DOI: 10.1103/PhysRevD.94.011101

I. INTRODUCTION

The discovery of CP violation in 1964 [1] motivated searches for T and CPT violation. Since $CPT = CP \times T$, violation of CP means that T or CPT or both are also violated. For the K^0 system, the two contributions were first determined [2] in 1970, by using the Bell-Steinberger unitarity relation [3] for CP violation in $K^0\text{-}\bar{K}^0$ mixing: T was violated with about 5σ significance and no CPT violation was observed. Large CP violation in the B^0 system was discovered in 2001 [4,5] in the interplay of $B^0\text{-}\bar{B}^0$ mixing and $B^0 \rightarrow c\bar{c}K^0$ decays, but an explicit demonstration of T violation was given only recently [6]. In the present analysis, we test CPT symmetry quantitatively in $B^0\text{-}\bar{B}^0$ mixing and in $B^0 \rightarrow c\bar{c}K^0$ decays.

Transitions in the $B^0\text{-}\bar{B}^0$ system are well described by the quantum-mechanical evolution of a two-state wave function

$$\Psi = \psi_1|B^0\rangle + \psi_2|\bar{B}^0\rangle, \quad (1)$$

using the Schrödinger equation

$$\dot{\Psi} = -i\mathcal{H}\Psi, \quad (2)$$

where the Hamiltonian \mathcal{H} is given by two constant Hermitian matrices, $\mathcal{H}_{ij} = m_{ij} + i\Gamma_{ij}/2$. In this evolution, CP violation is described by three parameters, $|q/p|$, $\text{Re}(\mathbf{z})$, and $\text{Im}(\mathbf{z})$, defined by

$$|q/p| = 1 - \frac{2\text{Im}(m_{12}^*\Gamma_{12})}{4|m_{12}|^2 + |\Gamma_{12}|^2}, \quad (3)$$

$$\mathbf{z} = \frac{(m_{11} - m_{22}) - i(\Gamma_{11} - \Gamma_{22})/2}{\Delta m - i\Delta\Gamma/2},$$

where $\Delta m = m(B_H) - m(B_L) \approx 2|m_{12}|$ and $\Delta\Gamma = \Gamma(B_H) - \Gamma(B_L) \approx +2|\Gamma_{12}|$ or $-2|\Gamma_{12}|$ are the mass and the width differences of the two mass eigenstates (H = heavy, L = light) of the Hamiltonian,

$$B_H = (p\sqrt{1 + \mathbf{z}B^0} - q\sqrt{1 - \mathbf{z}\bar{B}^0})/\sqrt{2},$$

$$B_L = (p\sqrt{1 - \mathbf{z}B^0} + q\sqrt{1 + \mathbf{z}\bar{B}^0})/\sqrt{2}. \quad (4)$$

Note that we use the convention with $+q$ for the light and $-q$ for the heavy eigenstate. If $|q/p| \neq 1$, the evolution violates the discrete symmetries CP and T . If $\mathbf{z} \neq 0$, it violates CP and CPT . The normalizations of the two eigenstates, as given in Eq. (4), are precise in the lowest order of r and \mathbf{z} , where $r = |q/p| - 1$. Throughout the following, we neglect contributions of orders r^2 , \mathbf{z}^2 , $r\mathbf{z}$, and higher.

The T -sensitive mixing parameter $|q/p|$ has been determined in several experiments, the present world average [7] being $|q/p| = 1 + (0.8 \pm 0.8) \times 10^{-3}$. The CPT -sensitive parameter $\text{Im}(\mathbf{z})$ has been determined by analyzing the time dependence of dilepton events in the decay $\Upsilon(4S) \rightarrow B^0 \bar{B}^0 \rightarrow (\ell^+ \nu X)(\ell^- \bar{\nu} X)$; the *BABAR* result [8] is $\text{Im}(\mathbf{z}) = (-13.9 \pm 7.3 \pm 3.2) \times 10^{-3}$. Since $\Delta\Gamma$ is very small, dilepton events are only sensitive to the product $\text{Re}(\mathbf{z})\Delta\Gamma$. Therefore, $\text{Re}(\mathbf{z})$ has so far only been determined by analyzing the time dependence of the decays $\Upsilon(4S) \rightarrow B^0 \bar{B}^0$ with one B meson decaying into $\ell \nu X$ and the other one into $c\bar{c}K$. With $88 \times 10^6 B\bar{B}$ events, *BABAR* measured $\text{Re}(\mathbf{z}) = (19 \pm 48 \pm 47) \times 10^{-3}$ in 2004 [9], while Belle used $535 \times 10^6 B\bar{B}$ events to measure $\text{Re}(\mathbf{z}) = (19 \pm 37 \pm 33) \times 10^{-3}$ in 2012 [10].

In our present analysis, we use the final data set of the *BABAR* experiment [11,12] with $470 \times 10^6 B\bar{B}$ events for a new determination of $\text{Re}(\mathbf{z})$ and $\text{Im}(\mathbf{z})$. As in Refs. [9,10], this is based on $c\bar{c}K$ decays with amplitudes A for $B^0 \rightarrow c\bar{c}K^0$ and \bar{A} for $\bar{B}^0 \rightarrow c\bar{c}\bar{K}^0$, using the following two assumptions:

- (1) $c\bar{c}K$ decays obey the $\Delta S = \Delta B$ rule, i.e., B^0 states do not decay into $c\bar{c}\bar{K}^0$, and \bar{B}^0 states do not decay into $c\bar{c}K^0$;

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(2) CP violation in K^0 - \bar{K}^0 mixing is negligible, i.e.,
 $K_S^0 = (K^0 + \bar{K}^0)/\sqrt{2}$, $K_L^0 = (K^0 - \bar{K}^0)/\sqrt{2}$.

The CPT -sensitive parameters are determined from the measured time dependences of the four decay rates $B^0, \bar{B}^0 \rightarrow c\bar{c}K_S^0, K_L^0$. In $Y(4S)$ decays, B^0 and \bar{B}^0 mesons are produced in the entangled state $(B^0\bar{B}^0 - \bar{B}^0B^0)/\sqrt{2}$. When the first meson decays into $f = f_1$ at time t_1 , the state collapses into the two states f_1 and B_2 . The later decay $B_2 \rightarrow f_2$ at time t_2 depends on the state B_2 and, because of B^0 - \bar{B}^0 mixing, on the decay-time difference

$$t = t_2 - t_1 \geq 0. \quad (5)$$

Note that t is the only relevant time here; it is the evolution time of the single-meson state B_2 in its rest frame.

The present analysis does not start from raw data but uses intermediate results from Ref. [6] where, as mentioned above, we used our final data set for the demonstration of large T violation. This was shown in four time-dependent transition-rate differences

$$R(B_j \rightarrow B_i) - R(B_i \rightarrow B_j), \quad (6)$$

where $B_i = B^0$ or \bar{B}^0 , and $B_j = B_+$ or B_- . The two states B_i were defined by flavor-specific decays [13] denoted as $B^0 \rightarrow \ell^+ X$, $\bar{B}^0 \rightarrow \ell^- X$. The state B_+ was defined as the remaining state B_2 after a $c\bar{c}K_S^0$ decay, and B_- as B_2 after a $c\bar{c}K_L^0$ decay. In order to use the two states for testing T symmetry in Eq. (6), they must be orthogonal; $\langle B_+ | B_- \rangle = 0$, which requires the additional assumption

$$(3) |\bar{A}/A| = 1.$$

In the same 2012 analysis, we demonstrated that CPT symmetry is unbroken within uncertainties by measuring the four rate differences

$$R(B_j \rightarrow B_i) - R(\bar{B}_i \rightarrow B_j). \quad (7)$$

For both measurements in Eqs. (6) and (7), expressions

$$R_i(t) = N_i e^{-\Gamma t} (1 + C_i \cos \Delta m t + S_i \sin \Delta m t), \quad (8)$$

$i = 1 \dots 8$, were fitted to the four time-dependent rates where the ℓX decay precedes the $c\bar{c}K$ decay, and to the four rates where the order of the decays is inverted. The rate ansatz in Eq. (8) requires $\Delta\Gamma = 0$. The time $t \geq 0$ in these expressions is the time between the first and the second decay of the entangled $B^0\bar{B}^0$ pair as defined in Eq. (5). In our 2012 analysis, we named it $\Delta\tau$, equal to $t_{c\bar{c}K} - t_{\ell X}$ if the ℓX decay occurred first, and equal to $t_{\ell X} - t_{c\bar{c}K}$ with $c\bar{c}K$ as the first decay. After the fits, the T -violating and CPT -testing rate differences were evaluated from the obtained S_i and C_i results. The CPT test showed no CPT violation, i.e., it was compatible with $\mathbf{z} = 0$, but no results for $\text{Re}(\mathbf{z})$ and $\text{Im}(\mathbf{z})$ were given in 2012.

Our present analysis uses the eight measured time dependences in the 2012 analysis, i.e., the 16 results C_i and S_i , for determining \mathbf{z} . This is possible without assumption (3) since we do not need to use the concept of states B_+ and B_- . We are therefore able to determine the decay parameter $|\bar{A}/A|$ in addition to the mixing parameters $\text{Re}(\mathbf{z})$ and $\text{Im}(\mathbf{z})$. As in 2012, we use $\Delta\Gamma = 0$, but we show at the end of this analysis that the final results are independent of this constraint. Accepting assumptions (1) and (2), and in addition

(4) that the amplitudes A and \bar{A} have a single weak phase,

only two more parameters $|\bar{A}/A|$ and $\text{Im}(q\bar{A}/pA)$ are required in addition to $|q/p|$ and \mathbf{z} for a full description of CP violation in time-dependent $B^0 \rightarrow c\bar{c}K^0$ decays. In this framework, T symmetry requires $\text{Im}(q\bar{A}/pA) = 0$ [14], and CPT symmetry requires $|\bar{A}/A| = 1$ [15].

II. B-MESON DECAY RATES

The time-dependent rates of the decays $B^0, \bar{B}^0 \rightarrow c\bar{c}K$ are sensitive to both symmetries CPT and T in B^0 - \bar{B}^0 mixing and in B^0 decays. For decays into final states f with amplitudes $A_f = A(B^0 \rightarrow f)$ and $\bar{A}_f = A(\bar{B}^0 \rightarrow f)$, using $\lambda_f = q\bar{A}_f/(pA_f)$ and approximating $\sqrt{1 - \mathbf{z}^2} = 1$, the rates are given by

$$\begin{aligned} R(B^0 \rightarrow f) &= \frac{|A_f|^2 e^{-\Gamma t}}{4} |(1 - \mathbf{z} + \lambda_f) e^{i\Delta m t} e^{\Delta\Gamma t/4} + (1 + \mathbf{z} - \lambda_f) e^{-\Delta\Gamma t/4}|^2, \\ R(\bar{B}^0 \rightarrow f) &= \frac{|\bar{A}_f|^2 e^{-\Gamma t}}{4} |(1 + \mathbf{z} + 1/\lambda_f) e^{i\Delta m t} e^{\Delta\Gamma t/4} + (1 - \mathbf{z} - 1/\lambda_f) e^{-\Delta\Gamma t/4}|^2. \end{aligned} \quad (9)$$

For the CP eigenstates $c\bar{c}K_L^0$ ($CP = +1$) and $c\bar{c}K_S^0$ ($CP = -1$) with $A_{S(L)} = A[B^0 \rightarrow c\bar{c}K_{S(L)}^0]$ and $\bar{A}_{S(L)} = A[\bar{B}^0 \rightarrow c\bar{c}K_{S(L)}^0]$, assumptions (1) and (2) give $A_S = A_L = A/\sqrt{2}$ and $\bar{A}_S = -\bar{A}_L = \bar{A}/\sqrt{2}$. In the

following, we only need to use $\lambda_S = -\lambda_L = \lambda$. Setting $\Delta\Gamma = 0$ and keeping only first-order terms in the small quantities $|\lambda| - 1$, \mathbf{z} , and $r = |q/p| - 1$, this leads to rate expressions as given in Eq. (8) with coefficients

$$\begin{aligned}
S_1 &= S(\ell^- X, c\bar{c}K_L) \\
&= \frac{2\text{Im}(\lambda)}{1 + |\lambda|^2} - \text{Re}(z)\text{Re}(\lambda)\text{Im}(\lambda) + \text{Im}(z)[\text{Re}(\lambda)]^2, \\
C_1 &= +\frac{1 - |\lambda|^2}{2} - \text{Re}(\lambda)\text{Re}(z) - \text{Im}(\lambda)\text{Im}(z), \\
S_2 &= S(\ell^+ X, c\bar{c}K_L) \\
&= -\frac{2\text{Im}(\lambda)}{1 + |\lambda|^2} - \text{Re}(z)\text{Re}(\lambda)\text{Im}(\lambda) - \text{Im}(z)[\text{Re}(\lambda)]^2, \\
C_2 &= -\frac{1 - |\lambda|^2}{2} + \text{Re}(\lambda)\text{Re}(z) - \text{Im}(\lambda)\text{Im}(z), \\
S_3 &= S(\ell^- X, c\bar{c}K_S) \\
&= -\frac{2\text{Im}(\lambda)}{1 + |\lambda|^2} - \text{Re}(z)\text{Re}(\lambda)\text{Im}(\lambda) + \text{Im}(z)[\text{Re}(\lambda)]^2, \\
C_3 &= +\frac{1 - |\lambda|^2}{2} + \text{Re}(\lambda)\text{Re}(z) + \text{Im}(\lambda)\text{Im}(z), \\
S_4 &= S(\ell^+ X, c\bar{c}K_S) \\
&= \frac{2\text{Im}(\lambda)}{1 + |\lambda|^2} - \text{Re}(z)\text{Re}(\lambda)\text{Im}(\lambda) - \text{Im}(z)[\text{Re}(\lambda)]^2, \\
C_4 &= -\frac{1 - |\lambda|^2}{2} - \text{Re}(\lambda)\text{Re}(z) + \text{Im}(\lambda)\text{Im}(z). \quad (10)
\end{aligned}$$

The four other rates $R_5(t) \cdots R_8(t)$ with $c\bar{c}K$ as the first decay and $t_{\ell X} - t_{c\bar{c}K} = t$ follow from the same two-decay-time expression [16,17] as the rates $R_1 \cdots R_4$ with $t_{c\bar{c}K} - t_{\ell X} = t$. Therefore, the rates $R_5(c\bar{c}K_L, \ell^- X)$, $R_6(c\bar{c}K_L, \ell^+ X)$, $R_7(c\bar{c}K_S, \ell^- X)$, and $R_8(c\bar{c}K_S, \ell^+ X)$ are given by Eq. (8) with the coefficients

$$S_i = -S_{i-4}, C_i = +C_{i-4} \quad \text{for } i = 5, 6, 7, \text{ and } 8. \quad (11)$$

The S_i and C_i results from our 2012 analysis, including uncertainties and correlation matrices, have been published as Supplemental Material [18] of Ref. [6] in Tables II–IV. For completeness, we include in Table I the results and the uncertainties.

TABLE I. Input values from the Supplemental Material [18] of Ref. [6]. The second column gives the two decays with their sequence in decay time.

i	decay pairs	S_i	σ_{stat}	σ_{sys}	C_i	σ_{stat}	σ_{sys}
1	$\ell^- X, c\bar{c}K_L$	0.51	0.17	0.11	-0.01	0.13	0.08
2	$\ell^+ X, c\bar{c}K_L$	-0.69	0.11	0.04	-0.02	0.11	0.08
3	$\ell^- X, c\bar{c}K_S$	-0.76	0.06	0.04	0.08	0.06	0.06
4	$\ell^+ X, c\bar{c}K_S$	0.55	0.09	0.06	0.01	0.07	0.05
5	$c\bar{c}K_L, \ell^- X$	-0.83	0.11	0.06	0.11	0.12	0.08
6	$c\bar{c}K_L, \ell^+ X$	0.70	0.19	0.12	0.16	0.13	0.06
7	$c\bar{c}K_S, \ell^- X$	0.67	0.10	0.08	0.03	0.07	0.04
8	$c\bar{c}K_S, \ell^+ X$	-0.66	0.06	0.04	-0.05	0.06	0.03

III. FIT RESULTS

The relations between the 16 observables $y_i = S_1 \cdots C_8$ in Eqs. (10) and (11) and the four parameters $p_1 = (1 - |\lambda|^2)/2$, $p_2 = 2\text{Im}(\lambda)/(1 + |\lambda|^2)$, $p_3 = \text{Im}(z)$, and $p_4 = \text{Re}(z)$ are approximately linear. Therefore, the four parameters can be determined in a two-step linear χ^2 fit using matrix algebra. The first-step fit determines p_1 and p_2 by fixing $\text{Re}(\lambda)$ and $\text{Im}(\lambda)$ in the products $\text{Re}(z)\text{Re}(\lambda)$, $\text{Im}(z)\text{Im}(\lambda)$, $\text{Im}(z)[\text{Re}(\lambda)]^2$, and $\text{Re}(z)\text{Re}(\lambda)\text{Im}(\lambda)$. After fixing these terms, the relation between the vectors y and p is strictly linear,

$$y = M_1 p, \quad (12)$$

where M_1 uses $\text{Im}(\lambda) = 0.67$ and $\text{Re}(\lambda) = -0.74$, motivated by the results of analyses assuming CPT symmetry [7]. With this ansatz, χ^2 is given by

$$\chi^2 = (M_1 p - \hat{y})^T G (M_1 p - \hat{y}), \quad (13)$$

where \hat{y} is the measured vector of observables, and the weight matrix G is taken to be

$$G = [C_{\text{stat}}(y) + C_{\text{sys}}(y)]^{-1}, \quad (14)$$

where $C_{\text{stat}}(y)$ and $C_{\text{sys}}(y)$ are the statistical and systematic covariance matrices, respectively. The minimum of χ^2 is reached for

$$\hat{p} = \mathcal{M}_1 \hat{y} \quad \text{with} \quad \mathcal{M}_1 = (M_1^T G M_1)^{-1} M_1^T G, \quad (15)$$

and the uncertainties of \hat{p} are given by the covariance matrices

$$\begin{aligned}
C_{\text{stat}}(p) &= \mathcal{M}_1 C_{\text{stat}}(y) \mathcal{M}_1^T, \\
C_{\text{sys}}(p) &= \mathcal{M}_1 C_{\text{sys}}(y) \mathcal{M}_1^T, \quad (16)
\end{aligned}$$

with the property

$$C_{\text{stat}}(p) + C_{\text{sys}}(p) = (M_1^T G M_1)^{-1}. \quad (17)$$

This first-step fit yields

$$\begin{aligned}
p_1 &= 0.001 \pm 0.023 \pm 0.017, \\
p_2 &= 0.689 \pm 0.030 \pm 0.015. \quad (18)
\end{aligned}$$

This leads to

$$\begin{aligned}
|\lambda| &= 1 - p_1 = 0.999 \pm 0.023 \pm 0.017, \\
\text{Im}(\lambda) &= (1 - p_1)p_2 = 0.689 \pm 0.034 \pm 0.019, \\
\text{Re}(\lambda) &= -(1 - p_1)\sqrt{1 - p_2^2} \\
&= -0.723 \pm 0.043 \pm 0.028, \quad (19)
\end{aligned}$$

where the negative sign of $\text{Re}(\lambda)$ is motivated by four measurements [19–22]. The results of all four favor $\cos 2\beta > 0$, and in Ref. [22] $\cos 2\beta < 0$ is excluded with 4.5σ significance.

In the second step, we fix the two λ values according to the p_1 and p_2 results of the first step, i.e. to the central values in Eqs. (19). Equations (12) to (17) are then applied again, replacing M_1 with the new relations matrix M_2 . This gives the same results for p_1 and p_2 as in Eq. (18), and

$$\begin{aligned} p_3 = \text{Im}(\mathbf{z}) &= 0.010 \pm 0.030 \pm 0.013, \\ p_4 = \text{Re}(\mathbf{z}) &= -0.065 \pm 0.028 \pm 0.014, \end{aligned} \quad (20)$$

with a χ^2 value of 6.9 for 12 degrees of freedom.

The $\text{Re}(\mathbf{z})$ result deviates from 0 by 2.1σ . The result for $|\lambda|$ can be easily converted into $|\bar{A}/A|$ by using the world average of measurements for $|q/p|$. With $|q/p| = 1.0008 \pm 0.0008$ [7], we obtain

$$|\bar{A}/A| = 0.999 \pm 0.023 \pm 0.017, \quad (21)$$

in agreement with *CPT* symmetry. Using the matrix algebra in Eqs. (12) to (17) allows us to determine the separate statistical and systematic covariance matrices of the final results, in agreement with the condition $C_{\text{stat}}(p) + C_{\text{sys}}(p) = (M^T G M)^{-1}$, where M relates y and p after convergence of the fit. The statistical correlation coefficients are $\rho[|\bar{A}/A|, \text{Im}(\mathbf{z})] = 0.03$, $\rho[|\bar{A}/A|, \text{Re}(\mathbf{z})] = 0.44$, and $\rho[\text{Re}(\mathbf{z}), \text{Im}(\mathbf{z})] = 0.03$. The systematic correlation coefficients are $\rho[|\bar{A}/A|, \text{Im}(\mathbf{z})] = 0.03$, $\rho[|\bar{A}/A|, \text{Re}(\mathbf{z})] = 0.48$, and $\rho[\text{Re}(\mathbf{z}), \text{Im}(\mathbf{z})] = -0.15$.

IV. ESTIMATING THE INFLUENCE OF $\Delta\Gamma$

Using an accept/reject algorithm, we have performed two “toy simulations,” each with $\sim 2 \times 10^6$ events, i.e. t values sampled from the distributions

$$e^{-\Gamma t} [1 + \text{Re}(\lambda) \sinh(\Delta\Gamma t/2) + \text{Im}(\lambda) \sin(\Delta m t)], \quad (22)$$

with $\Delta\Gamma = 0$ for one simulation and $\Delta\Gamma = 0.01\Gamma$ for the other one, corresponding to one standard deviation from the present world average [7]. For both simulations we use $\text{Im}(\lambda) = 0.67$ and $\text{Re}(\lambda) = -0.74$ and sample t values between 0 and $+5/\Gamma$. We then fit the two samples, binned in intervals of $\Delta t = 0.25/\Gamma$, to the expressions

$$N e^{-\Gamma t} [1 + C \cos(\Delta m t) + S \sin(\Delta m t)], \quad (23)$$

with three free parameters N , C and S . The fit results agree between the two simulations within 0.002 for C and 0.008 for S . We, therefore, conclude that omission of the sinh term in Ref. [6] has a negligible influence on the three final results of this analysis.

V. CONCLUSION

Using $470 \times 10^6 B\bar{B}$ events from *BABAR*, we determine

$$\begin{aligned} \text{Im}(\mathbf{z}) &= 0.010 \pm 0.030 \pm 0.013, \\ \text{Re}(\mathbf{z}) &= -0.065 \pm 0.028 \pm 0.014, \\ |\bar{A}/A| &= 0.999 \pm 0.023 \pm 0.017, \end{aligned}$$

where the first uncertainties are statistical and the second uncertainties are systematic. All three results are compatible with *CPT* symmetry in B^0 - \bar{B}^0 mixing and in $B \rightarrow c\bar{c}K$ decays. The uncertainties on $\text{Re}(\mathbf{z})$ are comparable with those obtained by Belle in 2012 [10] with $535 \times 10^6 B\bar{B}$ events, $\text{Re}(\mathbf{z}) = -0.019 \pm 0.037 \pm 0.033$. The uncertainties on $\text{Im}(\mathbf{z})$ are considerably larger, as expected, than those obtained by *BABAR* in 2006 [8] with dilepton decays from $232 \times 10^6 B\bar{B}$ events, $\text{Im}(\mathbf{z}) = -0.014 \pm 0.007 \pm 0.003$. The result of the present analysis for $\text{Re}(\mathbf{z})$, $-0.065 \pm 0.028 \pm 0.014$, supersedes the *BABAR* result of 2004 [9].

ACKNOWLEDGMENTS

We thank H.-J. Gerber (ETH Zurich) and T. Ruf (CERN) for very useful discussions on *T* and *CPT* symmetry. We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support *BABAR*. The collaborating institutions thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (Netherlands), NFR (Norway), MES (Russia), MINECO (Spain), STFC (United Kingdom), and BSF (USA-Israel). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation (USA).

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