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EXPLORING NEW PHYSICS WITH *CP* ASYMMETRIES IN B^0 DECAYS*

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CP asymmetries in B^0 decays into *CP* eigenstates are shown to be very useful in probing effects of new physics. Although there are many possible sources for inconsistencies with the Standard Model predictions, we find that various relations among the asymmetries test different aspects of new physics. We suggest a new way to test the assumption that the direct decays are dominated by a single combination of mixing parameters. We argue that new physics in $K-\bar{K}$ mixing is unlikely to affect the results. New physics in the mixing of $B_d-\bar{B}_d$ and $B_s-\bar{B}_s$ can be probed separately and independently of the unitarity of the CKM matrix.

1. Introduction

The main goal of future B factories is to measure *CP* asymmetries in B^0 decays into *CP* eigenstates [1]. Within the Standard Model (SM), these asymmetries are fully determined by the Cabibbo–Kobayashi–Maskawa (CKM) parameters. Consequently, their measurement provides a very clean test of the CKM model for the quark sector.

If such *CP* asymmetries are measured and found to be consistent with the SM, they will be useful to drastically reduce the allowed ranges for the CKM parameters. If, on the other hand, we find inconsistencies with the SM constraints, there are two (related) questions to be posed: (i) Which ingredients of the SM have to be superseded? (ii) What kind of physics is signalled beyond the SM?

In this work we explain how one can use various relations among *CP* asymmetries as a guide in answering the above questions. When the rich structure of assumptions within the SM is unfolded, one may be discouraged: so many of the SM ingredients are involved in the predictions that it seems very difficult, if not

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TABLE 1
Classes of *CP* asymmetries

Class	Quark sub-process	Decaying meson	S	Final state (example)
1d	$\bar{b} \to \bar{c}c\bar{s}$	B_d	+1	ψK_S
2d	$\bar{b} \to \bar{c}c\bar{d}$	B_d	0	D^+D^-
3d	$\bar{b} \to \bar{u}u\bar{d}$	B_d	0	$\pi^+\pi^-$
1s	$\bar{b} \to \bar{c}c\bar{s}$	B_s	0	$D_s^+D_s^-$
2s	$\bar{b} \to \bar{c}c\bar{d}$	B_s	−1	ψK_S
3s	$\bar{b} \to \bar{u}u\bar{d}$	B_s	−1	ρK_S

impossible, to extract any precise information on new physics if these predictions fail. We show, however, that *CP* asymmetries provide an equally rich structure of experimental results, allowing one to disentangle various aspects of new physics.

Previous studies on *CP* asymmetries in B^0 decays beyond the SM have demonstrated that inconsistencies with the SM predictions may occur in specific models [2]. A way to find whether interference between two direct amplitudes contributes to a *CP* asymmetry has been suggested in ref. [3]. Our emphasis is on the insight into the nature of new physics that may be provided to us by *CP* asymmetries.

We choose to concentrate on six classes of processes, given in table 1. Each class is defined by the quark sub-process ($\bar{b} \to \bar{c}c\bar{s}$, $\bar{b} \to \bar{c}c\bar{d}$ or $\bar{b} \to \bar{u}u\bar{d}$) and by the decaying B-meson (B_d or B_s). For our purposes, the net strangeness (S) of the final state (before possible K^0–$\bar{K}^0$ mixing occurs) is also important. We emphasize that the list of hadronic final states in table 1 is given as an example. We did not try to evaluate which final states are best from the experimental point of view. We always quote the *CP* asymmetry for *CP*-even states, regardless of the specific hadronic states.

2. The Standard Model

Within the SM, the decay rate of a time-evolved initially pure $B^0(\bar{B}^0)$ into a *CP* eigenstate f is (see ref. [4] and references therein)

$$\Gamma\left(B^0_{\rm phys}(t) \to f\right) \propto e^{-\Gamma t}[1 - \mathrm{Im}\,\lambda \sin(\Delta m t)],$$

$$\Gamma\left(\bar{B}^0_{\rm phys}(t) \to f\right) \propto e^{-\Gamma t}[1 + \mathrm{Im}\,\lambda \sin(\Delta m t)]. \quad (1)$$

The main assumptions in the derivation of eq. (1) are that for the neutral B system $\Gamma_{12} \ll M_{12}$, and that the direct decay is dominated by a single combination of CKM parameters. The interference term, Im λ, responsible for *CP* violation, is determined by three factors,

$$\lambda = \left(\frac{X}{X^*}\right)\left(\frac{Y}{Y^*}\right)\left(\frac{Z}{Z^*}\right). \tag{2}$$

The X-factor depends on the quark sub-process amplitude. If it is dominated by the W-mediated tree-level diagram then

$$X(\bar{b} \to \bar{c}c\bar{s}) = V_{cb}V_{cs}^*,$$

$$X(\bar{b} \to \bar{c}c\bar{d}) = V_{cb}V_{cd}^*,$$

$$X(\bar{b} \to \bar{u}u\bar{d}) = V_{ub}V_{ud}^*. \tag{3}$$

The Y-factor depends on the mixing amplitude of the decaying meson. If it is dominated by the SM box-diagrams with virtual t-quarks then

$$Y(B_d) = V_{tb}^*V_{td}, \qquad Y(B_s) = V_{tb}^*V_{ts}. \tag{4}$$

The Z-factor depends on whether a K^0 ($S = +1$) or $\bar{K}^0$ ($S = -1$) is produced in the direct decay. As the decay that follows B–$\bar{B}$ mixing produces a neutral K of opposite S, interference between the two amplitudes is possible only due to K–$\bar{K}$ mixing which gives the final K_S (or K_L), namely a *CP* eigenstate. If K–$\bar{K}$ mixing is dominated by the SM box-diagram with virtual c-quarks then

$$Z(S = +1) = V_{cd}^*V_{cs} = [Z(S = -1)]^*. \tag{5}$$

Independent of the model, $Z(S = 0) = 1$ and $Z(S = +1) = [Z(S = -1)]^*$. To find the SM prediction for the various asymmetries, Im λ_{iq} ($i = 1,2,3$; $q = d, s$), one puts the appropriate factors from eqs. (3)–(5) in eq. (2). In addition, one makes use of the constraints that follow from unitarity of the 3×3 CKM matrix,

$$\mathcal{U}_{ds} \equiv V_{us}V_{ud}^* + V_{cs}V_{cd}^* + V_{ts}V_{td}^* = 0,$$

$$\mathcal{U}_{db} \equiv V_{ub}V_{ud}^* + V_{cb}V_{cd}^* + V_{tb}V_{td}^* = 0,$$

$$\mathcal{U}_{sb} \equiv V_{ub}V_{us}^* + V_{cb}V_{cs}^* + V_{tb}V_{ts}^* = 0. \tag{6}$$

(We define the quantities $\mathcal{U}_{ij}$ for later convenience.) The best-known prediction of the SM (for recent studies see ref. [5] and references therein) is that *CP* asymmetries measure angles of the unitarity triangle (see fig. 1),

$$\text{Im}\,\lambda_{2d} = -\sin 2\beta, \qquad \text{Im}\,\lambda_{3d} = \sin 2\alpha, \tag{7}$$

$$\text{Im}\,\lambda_{3s} = -\sin 2\gamma. \tag{8}$$

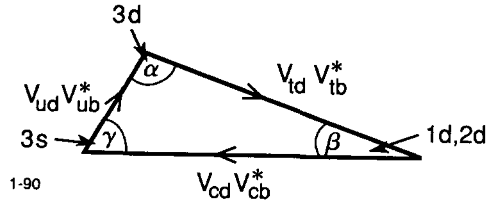

Fig. 1. The unitarity triangle. Relevant classes of *CP* asymmetries are indicated for each angle [see eqs. (7)–(9)].

The angles α, β and γ are defined as the three angles of a triangle, whose sides are calculated within the SM. More specifically, the sides of the triangle are determined from e.g. hadron decays ($|V_{ud}V_{ub}|$ and $|V_{cd}V_{cb}|$) and B_d–$\overline{B}_d$ mixing ($|V_{td}V_{tb}|$), assuming that these processes proceed via SM diagrams. The angles are then calculated assuming that the three sides indeed form a triangle. We emphasize that while $\mathrm{Im}\,\lambda_{iq}$ are experimentally measured quantities and, therefore, defined in a model-independent way, the angles α, β and γ are defined throughout this work by the procedure described above, namely within the SM.

Other important predictions are

$$\mathrm{Im}\,\lambda_{1d} = \mathrm{Im}\,\lambda_{2d}\,, \qquad \mathrm{Im}\,\lambda_{1s} = \mathrm{Im}\,\lambda_{2s} \tag{9}$$

and, to a good approximation,

$$\mathrm{Im}\,\lambda_{1s} = 0\,. \tag{10}$$

3. Beyond the Standard Model

We now proceed to study the situation in the presence of new physics beyond the SM. At first stage, we retain only two of the assumptions that underlie the SM analysis, and examine the consequences,

(i) For the neutral B system $\Gamma_{12} \ll M_{12}$.

(ii) The asymmetries arise dominantly from interference of amplitudes corresponding to two paths to the same final state, one of which involves B^0–$\overline{B}^0$ mixing.

The first assumption is very mild and holds on rather general grounds [6]. The second one is less solid but still likely to be valid. Implicit in this assumption is the condition that in B^0 decays, each quark sub-process is dominated by a single amplitude or, more generally, by a single combination of mixing parameters. We emphasize that even within the SM, each of the relevant processes gets contributions from both a tree-level diagram and a penguin diagram. The CKM suppression is similar for both amplitudes. (For $\bar{b} \to \bar{u}u\bar{s}$ processes, the CKM suppression is stronger for tree-level diagrams, which is the reason we did not consider them in the first place.) However, the penguin diagram is further suppressed by a factor of order $(\alpha_s/12\pi)\ln(m_t^2/m_b^2)$. If the hadronic matrix elements are of the same order of magnitude (which is uncertain), the effects of penguin diagrams are no more than a few percent [7]. Finally, the phase difference between the two amplitudes is almost zero for $\bar{b} \to \bar{c}c\bar{s}$, smaller than $\pi/4$ for $\bar{b} \to \bar{c}c\bar{d}$ and could be maximal (namely $\pi/2$) only for $\bar{b} \to \bar{u}u\bar{d}$ [7]. Consequently, the assumption that a single combination of CKM elements is dominant is likely to be safe for classes $1q$, a good approximation for classes $2q$ and a reasonable approximation for classes $3q$. We later explain why it is likely to hold beyond the SM.

Under the above two assumptions, eq. (1) for the decay rate and eq. (2) for the interference term hold. In particular, $|\lambda| = 1$. However, the actual expressions for the X, Y and Z factors may be very different from those predicted by the SM. Moreover, we do not insist that the 3×3 CKM matrix is unitary. In other words, some or all of eqs. (3)–(6) may not hold.

We find that, even though we may be completely ignorant of the physics that dominates B decays (the X-factor) and, more likely, of the physics behind B–$\bar{\text{B}}$ mixing (the Y-factor) and K–$\bar{\text{K}}$ mixing (the Z-factor), or even of the full picture of quark mixing (the unitarity constraints), we still may extract valuable information from eq. (2) by itself. This information is given by the following relations:

$$\begin{aligned} &\arg \lambda_{1d} - \arg \lambda_{2d} - \arg \lambda_{1s} + \arg \lambda_{2s} = 0, \\ &\arg \lambda_{1d} - \arg \lambda_{3d} - \arg \lambda_{1s} + \arg \lambda_{3s} = 0, \\ &\arg \lambda_{2d} - \arg \lambda_{3d} - \arg \lambda_{2s} + \arg \lambda_{3s} = 0. \end{aligned} \qquad (11)$$

The derivation of eq. (11) is straightforward. For example, as classes 1d and 1s share the same quark sub-process (namely, the same X-factor), whatever phase it carries cancels out in the difference between their arguments.

Once CP asymmetries are measured, they should be tested against the constraints in eq. (11). [As we actually measure (Im λ), there is a twofold ambiguity: $\arg \lambda \leftrightarrow \pi - \arg \lambda$.] If we cannot find any consistent solution then, most likely, assumption (ii) does not hold. Although only two of the relations in eq. (11) are independent, all three tests are important, as each of them is independent of a different quark sub-process. As explained above, significant contributions from penguin diagrams are unlikely in $\bar{b} \to \bar{c}c\bar{s}$ and $\bar{b} \to \bar{c}c\bar{d}$ processes. This highlights the first relation of eq. (11) as a probe to physics beyond the SM. If the measurements are inconsistent with this relation, it may signal processes from new physics which compete with SM tree-level processes, a most intriguing possibility.

If the constraints in eq. (11) are fulfilled, assumptions (i) and (ii) are very likely to hold. In such a case, it seems most natural to add a third assumption:

(iii) Direct decays are dominated by the tree-level W-mediated amplitudes.

However, we allow for arbitrary mechanisms to account for mixing in the neutral meson systems. Our line of reasoning goes as follows: within the SM, B^0 decays proceed via tree-level diagrams, while neutral meson mixings proceed via box-diagrams, which are suppressed by being of higher order in the weak coupling and by the GIM mechanism. Thus, SM loop processes are much more sensitive to new physics. For example, new physics may contribute to mixing of neutral mesons at tree level. While these contributions are likely to be suppressed by the high-energy scale, they are lower order in the couplings and free of GIM suppression.

With assumptions (i)–(iii), eqs. (1)–(3) hold, but some or all of eqs. (4)–(6) may not be valid. Under these conditions, we will now examine whether the presence of new physics in each of the mixings, $K-\bar{K}$, $B_s-\bar{B}_s$ and $B_d-\bar{B}_d$ can be discovered.

4. $K-\bar{K}$ mixing

If $K-\bar{K}$ is accounted for by new physics, the Z-factor may be different from the one given in eq. (5). In principle, if eq. (5) were a sufficient condition for some relation among *CP* asymmetries to hold, then violation of this relation would invalidate the SM description of $K-\bar{K}$ mixing. We will now show that (a) it is true that if the prediction given in eq. (9),

$$\begin{aligned} \mathrm{Im}\,\lambda(B_d \to D^+D^-) &= \mathrm{Im}\,\lambda(B_d \to \psi K_S)\,, \\ \mathrm{Im}\,\lambda(B_s \to D_s^+D_s^-) &= \mathrm{Im}\,\lambda(B_s \to \psi K_S)\,, \end{aligned} \tag{12}$$

fails, a new mechanism for $K-\bar{K}$ mixing is implied but that (b) in practice, it is very unlikely to be violated.

The general condition for eq. (12) is

$$\arg[Z(S=+1)] = \arg[X(\bar{b} \to \bar{c}c\bar{d})/X(\bar{b} \to \bar{c}c\bar{s})] \pmod{\pi} = \arg[V_{cd}^* V_{cs}] \pmod{\pi}\,, \tag{13}$$

where we used eq. (3). If eq. (5) holds, so does eq. (13), independently of whether eqs. (4) and (6) hold. Thus, indeed, a failure of the predictions in eq. (12) will indicate new physics in $K-\bar{K}$ mixing, as claimed in (a).

To prove (b) we show that, although $Z(S=+1)$ may be modified with new physics, $\arg[Z(S=+1)]$ may not. Consider the condition on mixing in the K system from the measurement of the ϵ-parameter,

$$\arg(M_{12}/\Gamma_{12}) \pmod{\pi} = 6.6 \times 10^{-3}\,. \tag{14}$$

To an excellent approximation, M_{12} and Γ_{12} carry the same phase (mod π). Assuming that the $K \to 2\pi$ amplitude is proportional to $V_{ud}^* V_{us}$, we may use

$$\arg[Z(S = +1)] = \arg[V_{ud}^* V_{us}], \tag{15}$$

independent of the model. The predictions of eq. (12) hold as long as

$$\arg[V_{ud}^* V_{us}] = \arg[V_{cd}^* V_{cs}] \pmod{\pi}. \tag{16}$$

Within any three generation model, eq. (16) holds to a very good approximation due to unitarity constraints, and in particular the $\mathscr{U}_{ds}$ constraint of eq. (6). Even with an extended quark sector, eq. (16) is likely to be valid, and could be circumvented only within very contrived models. We conclude that the small value of ϵ guarantees, in an almost model-independent way, the validity of eq. (9).

An important lesson from this analysis is the following: *CP* asymmetries in B^0 decays are able to explore only the phase structure of neutral meson mixing. Therefore, a new mechanism for mixing which, for some reason, has the same phase structure as the SM one, will not be signalled.

5. B–$\overline{\text{B}}$ mixing

Before we proceed to show how the SM description of B–$\overline{\text{B}}$ mixing can be tested, we would like to argue that there is a connection between the three generation unitarity constraints and mixing in the B system. More specifically, if $\mathscr{U}_{sb} \neq 0$ [$\mathscr{U}_{db} \neq 0$], it is very likely that there will be contributions from beyond the SM to B_s–$\overline{B}_s$ [B_d–$\overline{B}_d$] mixing [see eq. (6) for the definition of $\mathscr{U}_{qb}$].

If the full spectrum of colored fermions consists of the three known generations of quarks, the 3×3 CKM matrix is unitary, and all the constraints in eq. (6) hold. There are two basic ways to extend the quark sector, thus allowing a violation of the unitarity constraints:

(i) Adding sequential quarks, namely left-handed doublets and right-handed singlets. With n generations, the CKM matrix is a sub-matrix of an $n \times n$ unitary mixing matrix. The relevant unitarity constraints of eq. (6) are replaced by

$$\mathscr{U}_{qb} = -\sum_{k=4}^{n} V_{kb} V_{kq}^*. \tag{17}$$

At the same time, the u_k-quark contributes to B_q–$\overline{B}_q$ mixing through box-diagrams proportionally to $V_{kb} V_{kq}^*$ [or $(V_{kb} V_{kq}^*)^2$].

(ii) Adding non-sequential quarks. The charged current mixing matrix is non-unitary, and consequently there are flavor-changing neutral currents. The best-known example is [8] the model with an $SU(2)_L$ singlet of charge $-1/3$ quark. In this case, the unitarity constraints are modified to

$$\mathcal{U}_{q\mathrm{b}} = U_{q\mathrm{b}}, \tag{18}$$

where $U_{q\mathrm{b}}$ is a flavor-changing coupling of the Z^0 gauge boson. At the same time, there is a contribution to B_q–$\overline{B}_q$ mixing from tree-level Z-mediated diagrams, proportional to $(U_{q\mathrm{b}})^2$.

We conclude that if the expression for $Y(B_s)$ [$Y(B_d)$] in eq. (4) and the constraint on $\mathcal{U}_{\mathrm{sb}}$ [$\mathcal{U}_{\mathrm{db}}$] in eq. (6) were a sufficient condition for some relation among *CP* asymmetries to hold, then violation of this relation would invalidate the SM description of B_s–$\overline{B}_s$ [B_d–$\overline{B}_d$] mixing. We will now show that this is indeed the case for eq. (10) with regard to B_s and for eq. (7) with regard to B_d.

The SM prediction given in eq. (10) is

$$\mathrm{Im}\,\lambda(B_s \to D_s^+ D_s^-) = 0. \tag{19}$$

The general condition for eq. (19) is

$$\arg[Y(B_s)] = -\arg[X(\bar{b} \to \bar{c}c\bar{s})] \pmod{\pi} = \arg[V_{cb}^* V_{cs}] \pmod{\pi}. \tag{20}$$

Combining the unitarity constraint on $\mathcal{U}_{\mathrm{sb}}$ [eq. (6)] and the experimental information, $|V_{ub}V_{us}^*| \ll |V_{cb}V_{cs}^*|$, one gets $V_{cb}V_{cs}^* + V_{tb}V_{ts}^* \approx 0$. Therefore, if $Y(B_s)$ is given by eq. (4) and $\mathcal{U}_{\mathrm{sb}}$ by eq. (6), eq. (20) holds independently of the other relations in eqs. (4)–(6). [The prediction given in eq. (19) holds in the limit $V_{ub}V_{us}^* = 0$. The exact prediction is $|\mathrm{Im}\,\lambda_{1s}| = 2|(\sin\gamma)V_{us}^* V_{ub}/V_{cb}| \leqslant 0.07$.] Thus, if the prediction of eq. (19) fails, it will indicate new physics in B_s–$\overline{B}_s$ mixing.

The SM prediction given in eq. (7) is

$$\mathrm{Im}\,\lambda(B_d \to D^+ D^-) = -\sin 2\beta,$$

$$\mathrm{Im}\,\lambda(B_d \to \pi^+ \pi^-) = \sin 2\alpha. \tag{21}$$

The general conditions for eq. (21) are

$$\arg[Y(B_d)] = \{-\arg[X(\bar{b} \to \bar{c}c\bar{d})] - \beta\} \pmod{\pi} = [\arg(V_{cb}^* V_{cd}) - \beta] \pmod{\pi},$$

$$\arg[Y(B_d)] = \{-\arg[X(\bar{b} \to \bar{u}u\bar{d})] + \alpha\} \pmod{\pi} = [\arg(V_{ub}^* V_{ud}) + \alpha] \pmod{\pi}. \tag{22}$$

If $Y(B_d)$ is given by eq. (4) and $\mathcal{U}_{\mathrm{db}}$ by eq. (6), eq. (22) holds independently of the other relations in eqs. (4)–(6). Thus, if the prediction of eq. (21) fails, it will indicate new physics in B_d–$\overline{B}_d$ mixing.

6. The angles of the unitarity triangle

The angles α and β are calculated within the SM, as explained above. If we use only SM tree-level processes and the x_d-parameter, we do not add to the assumptions that underlie the prediction of eq. (21) [namely, that $Y(B_d)$ and $\mathcal{U}_{db}$ are as given by the SM]. Consequently, we still have a clean test of the B_d–$\overline{B}_d$ mixing mechanism. It would be erroneous, for the purpose of this test, to use, for example, information from x_s. Although that may give a narrower range for α and β, inconsistencies cannot be cleanly interpreted, as additional assumptions [namely, that $Y(B_s)$ and $\mathcal{U}_{sb}$ are as given by the SM] are introduced.

The reader may wonder why we left the prediction of eq. (8) out of our discussion. The reason is that all six relations given in eqs. (4)–(6) are incorporated in this prediction and the calculation of γ. Consequently, a failure of this prediction by itself is not very useful from the theoretical point of view. When analyzing within the SM (see e.g. ref. [5]), class 3s processes are pointed out as useful for measuring γ, while class 1s processes are overlooked because they are predicted to give zero asymmetry. From our point of view, the situation should be the opposite: while inconsistencies with the SM predictions for class 3s asymmetries are difficult to interpret, those of class 1s are a clean test of the B_s–$\overline{B}_s$ mixing mechanism. Moreover, new physics in B_s–$\overline{B}_s$ mixing may have dramatic effects, e.g. maximal asymmetry instead of the (almost) zero asymmetry predicted by the SM.

Another demonstration of the significance of our results is the following. In ref. [5] it was noted that "whether the independently measured three angles will sum up to π is a stringent test for the CKM model of *CP*-violation". In the language of the present study, the suggested test is

$$\arg \lambda_{1d} - \arg \lambda_{3d} + \arg \lambda_{3s} = 0 \ (\mathrm{mod}\ \pi) . \tag{23}$$

Eq. (11) shows that this is equivalent to $\arg \lambda_{1s} = 0$. From our discussion it follows that if the prediction of eq. (23) fails, it will strongly indicate new physics in B_s–$\overline{B}_s$ mixing. Conversely, if the mechanism of B_s–$\overline{B}_s$ mixing has the same phase as that predicted for the SM box diagram, eq. (23) will hold independently of the nature of this mechanism and, more surprisingly, of whether the measured asymmetries correspond to the angles of the unitarity triangle.

7. Conclusions

Our study serves two purposes: it clarifies which of the SM properties are tested when *CP* asymmetries in B^0 decays are measured, and it suggests specific tests that will guide us to understand the nature of the new physics which may account for inconsistencies with the SM predictions. We intend to give an explicit example of the applications of this study within a specific model with an $SU(2)_L$-singlet quark [9].

The following assumptions underlie the prediction that *CP* asymmetries will measure the angles of the unitarity triangle: (i) For the neutral B system $\Gamma_{12} \ll M_{12}$. (ii) Asymmetries arise dominantly from interference of amplitudes corresponding to two paths to the same final state, one of which involves B^0–$\overline{B}^0$ mixing. (iii) Direct decays are dominated by SM tree-level W-mediated diagrams. (iv) B^0 mixings proceed via SM box-diagrams. (v) The 3×3 CKM matrix is unitary.

The variety of possible measurements is rich enough to find certain predictions for *CP* asymmetries which depend on only few of these assumptions, thus allowing separate tests for various aspects of new physics.

(i) The first two assumptions together may be tested via e.g.

$$\arg \lambda(B_d \to \psi K_S) - \arg \lambda(B_d \to D^+D^-) = \arg \lambda(B_s \to D_s^+D_s^-) - \arg \lambda(B_s \to \psi K_S) .$$

(A different way to test whether the interference between two direct amplitudes contributes to a *CP* asymmetry has been suggested in ref. [3].) If these assumptions hold then

(ii) The SM description of K–$\overline{K}$ mixing may be tested via e.g.

$$\operatorname{Im} \lambda(B_d \to D^+D^-) = \operatorname{Im} \lambda(B_d \to \psi K_S) .$$

However, it is unlikely that this prediction will fail, as the small measured value of ϵ constrains the phase structure of the K–$\overline{K}$ mixing mechanism to be similar to that of the SM.

(iii) The SM description of B_s–$\overline{B}_s$ mixing may be tested via e.g.

$$\operatorname{Im} \lambda(B_s \to D_s^+D_s^-) = 0 .$$

(iv) The SM description of B_d–$\overline{B}_d$ mixing may be tested via e.g.

$$\operatorname{Im} \lambda(B_d \to D^+D^-) = -\sin 2\beta .$$

We conclude that the measurement of *CP* asymmetries in B^0 decays is a powerful tool in probing new physics. An asymmetric B factory operating at the $\Upsilon(4S)$ region (or a polarized Z factory) has the potential of seriously exploring physics at energy scales which are hundreds of times higher.

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