B → ππ, New Physics in B → πK and Implications for Rare K and B Decays

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Abstract

The measured B → ππ, πK branching ratios exhibit puzzling patterns. We point out that the B → ππ hierarchy can be nicely accommodated in the Standard Model (SM) through non-factorizable hadronic interference effects, whereas the B → πK system may indicate new physics (NP) in the electroweak (EW) penguin sector. Using the B → ππ data and the SU(3) flavour symmetry, we may fix the hadronic B → πK parameters, which allows us to show that any currently observed feature of the B → πK system can be easily explained through enhanced EW penguins with a large CP-violating NP phase. Restricting ourselves to a specific scenario, where NP enters only through Z0 penguins, we derive links to rare K and B decays, where an enhancement of the KL → π0ν̅ν rate by one order of magnitude, with BR(KL → π0ν̅ν) > BR(K+ → π+ν̅ν), BR(KL → π0e+e−) = O(10−10), (sin 2β)πν̅ν < 0, and a large forward–backward CP asymmetry in Bd → K+μ+μ−, are the most spectacular effects. We address also other rare K and B decays, ε′/ε and Bd → φKs.
**B → ππ**, New Physics in $B → πK$ and Implications for Rare $K$ and $B$ Decays

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The measured $B → ππ, πK$ branching ratios exhibit puzzling patterns. We point out that the $B → ππ$ hierarchy can be nicely accommodated in the Standard Model (SM) through non-factorizable hadronic interference effects, whereas the $B → πK$ system may indicate new physics (NP) in the electroweak (EW) penguin sector. Using the $B → ππ$ data and the SU(3) flavour symmetry, we may fix the hadronic $B → πK$ parameters, which allows us to show that any currently observed feature of the $B → πK$ system can be easily explained through enhanced EW penguins with a large CP-violating NP phase. Restricting ourselves to a specific scenario, where NP enters only through $Z^0$ penguins, we derive links to rare $K$ and $B$ decays, where an enhancement of the $K_L → π^0ν¯ν$ rate by one order of magnitude, with $BR(K_L → π^0ν¯ν) > BR(K^+ → π^+ν¯ν)$, $BR(K_L → π^0e^+e^−) = O(10^{-10})$, $(sin 2β)_{ν¯ν} < 0$, and a large forward–backward CP asymmetry in $B_d → K^+μ^+μ^−$, are the most spectacular effects. We address also other rare $K$ and $B$ decays, $ε'/ε$ and $B_d → φKS$.

Keywords: Non-leptonic $B$ decays, CP violation, rare $K$ and $B$ decays

1. In this letter, we consider simultaneously the decays $B → ππ, B → πK$ and prominent rare $K$ and $B$ decays within the SM and its simple extension in which NP enters dominantly through enhanced EW penguins with new weak phases. Our analysis consists of three interrelated parts, and has the following logical structure:

i) Since $B → ππ$ decays and the usual analysis of the unitarity triangle (UT) are only insignificantly affected by EW penguins, the $B → ππ$ system can be described as in the SM and allows the extraction of the relevant hadronic parameters by assuming only the isospin symmetry. The values of these parameters imply important non-factorizable contributions, and allow us to predict the CP-violating $B_d → π^0π^0$ observables.

ii) Using the SU(3) flavour symmetry and plausible dynamical assumptions, we may determine the hadronic $B → πK$ parameters through their $B → ππ$ counterparts, and may analyse the $B → πK$ system in the SM. Interestingly, those observables where EW penguins play a minor rôle are found to agree with the pattern of the $B$-factory data. On the other hand, the observables that are significantly affected by EW penguins are found to disagree with the experimental picture, thereby suggesting NP in the EW penguin sector. Indeed, we may describe all the currently available data through sizeably enhanced EW penguins with a large CP-violating NP phase around $−90°$, and may then predict the CP-violating $B_d → π^0K_S$ observables. Moreover, we may obtain insights into SU(3)-breaking effects, which support our working assumptions, and may determine the UT angle $γ$, in accordance with the well-known UT fits.

iii) In turn, the enhanced EW penguins, with their large CP-violating NP phases, have important implications for rare $K$ and $B$ decays, with several predictions that are significantly different from the SM expectations.

This letter summarizes the most interesting results of each step. The details behind the findings presented here are described in [1], where the arguments for the assumptions made in our analysis are spelled out, other results are presented, and a detailed list of references is given.

2. The BaBar and Belle collaborations have very recently reported the observation of $B_d → π^0π^0$ decays with CP-averaged branching ratios of $(2.1±0.6±0.3) × 10^{-6}$ and $(1.7±0.6±0.2) × 10^{-6}$, respectively [2, 3]. These measurements represent quite a challenge for theory. For example, in a recent state-of-the-art calculation within QCD factorization [4], a branching ratio that is about six times smaller is favoured, whereas the calculation of $B_d → π^+π^−$ points towards a branching ratio about two times larger than the current experimental average. On the other hand, the calculation of $B^+ → π^+π^0$ reproduces the data rather well. This “$B → ππ$ puzzle” is reflected by the following quantities:

\[ R_{ππ}^{T⁻} = 2 \left( \frac{BR(B^± → π^±π^0)}{BR(B_d → π^±π^−)} \right) \frac{τ_{B^0}}{τ_{B^+}} = 2.12 ± 0.37 \]  
\[ R_{ππ}^{T₀₀} = 2 \left( \frac{BR(B_d → π^0π^0)}{BR(B_d → π^±π^−)} \right) = 0.83 ± 0.23 \]

where we have used $τ_{B^+/τ_{B^0}} = 1.086 ± 0.017$ and the most recent compilation of the Heavy Flavour Averaging Group (HFAG) [5], the central values calculated within QCD factorization [4] give $R_{ππ}^{T⁻} = 1.24$ and $R_{ππ}^{T₀₀} = 0.07$. In order to simplify our $B → ππ$ analysis, we neglect EW penguins, which play a minor rôle in these transitions and can be straightforwardly included through the isospin symmetry [4, 6, 7]. We then have

\[ \sqrt{2}A(B^+ → π^+π^0) = -[T + \bar{C}] \] 
\[ A(B^0_d → π^0π^−) = -[T + P] \] 
\[ \sqrt{2}A(B^0_d → π^0π^0) = -[\bar{C} - P], \]
where

\[ P = \lambda^3 A(\mathcal{P}_q - \mathcal{P}_c) \equiv \lambda^3 A P_{tc} \]  
(6)  
\[ \tilde{T} = \lambda^3 A R_0 e^{i\gamma} \left[ T - (\mathcal{P}_{tu} - \mathcal{E}) \right] \]  
(7)  
\[ \tilde{C} = \lambda^3 A R_0 e^{i\gamma} \left[ C + (\mathcal{P}_{tu} - \mathcal{E}) \right] \]  
(8)

Here \( \lambda, A \) and \( R_0 \propto |V_{ub}/V_{cb}| \) parametrize the Cabibbo-Kobayashi-Maskawa (CKM) matrix, the \( \mathcal{P}_q \) are the strong amplitudes of QCD penguins with internal \( q \)-quark exchanges (\( q \in \{ t, c, u \} \)), including annihilation and exchange penguins, while \( \mathcal{T} \) and \( \mathcal{C} \) are the strong amplitudes of colour-allowed and colour-suppressed tree-diagram-like topologies, respectively, and \( \mathcal{E} \) denotes exchange topologies. Introducing the hadronic parameters

\[ de^{i\theta} \equiv -e^{\delta_{tu}e^{i\gamma}} P/\bar{T} = -|P/\bar{T}| e^{(\delta_{tu} - \delta_{pu})} \]  
(9)  
\[ xe^{i\Delta} \equiv \tilde{C}/\bar{T} = |\tilde{C}/\bar{T}| e^{(\delta_{tu} - \delta_{pu})} \]  
(10)

with the strong phases \( \delta_{tu}, \delta_{pu} \) and \( \delta_{tu} \), we obtain

\[ R_{\pi \pi}^{+} \equiv \frac{1 + 2x \cos \Delta + x^2}{1 - 2d \cos \theta \cos \gamma + d^2} \]  
(11)  
\[ R_{\pi \pi}^{00} \equiv \frac{d^2 + 2dx \cos(\Delta - \theta) \cos \gamma + x^2}{1 - 2d \cos \theta \cos \gamma + d^2} \]  
(12)  
\[ \mathcal{A}_{\text{CP}}^{\text{dir}} = -\left[ \frac{2d \sin \theta \sin \gamma}{1 - 2d \cos \theta \cos \gamma + d^2} \right] \]  
(13)  
\[ \mathcal{A}_{\text{CP}}^{\text{mix}} = \frac{\sin(\phi_d + 2\gamma) - 2d \cos \theta \sin(\phi_d + \gamma) + d^2 \sin \phi_d}{1 - 2d \cos \theta \cos \gamma + d^2} \]  
(14)

where \( \phi_d \) denotes the \( B_d^0 - \bar{B}_d^0 \) mixing phase and \( \mathcal{A}_{\text{CP}}^{\text{dir}} \) and \( \mathcal{A}_{\text{CP}}^{\text{mix}} \) are the direct and mixing-induced \( B_d \rightarrow \pi^+\pi^- \) CP asymmetries. \( \delta_{tu} \). The currently available BaBar and Belle results for \( \mathcal{A}_{\text{CP}}^{\text{dir}}(\pi^+\pi^-) \) and \( \mathcal{A}_{\text{CP}}^{\text{mix}}(\pi^+\pi^-) \) are not fully consistent with each other. If one calculates, nevertheless, the weighted averages, one finds \( \delta_{tu} \).

\[ \mathcal{A}_{\text{CP}}^{\text{dir}}(\pi^+\pi^-) = -0.38 \pm 0.16, \quad \mathcal{A}_{\text{CP}}^{\text{mix}}(\pi^+\pi^-) = 0.58 \pm 0.20. \]  
(15)

As pointed out in \( \delta_{tu} \), in the case of \( \phi_d \sim 47^\circ \), the CP asymmetries in \( \delta_{tu} \) point towards \( \gamma \sim 60^\circ \), in accordance with the SM. In the following, our main focus is on the hadronic parameters. If we assume that \( \gamma = (65 \pm 7)^\circ \) and \( \phi_d = 2\beta = (47 \pm 4)^\circ \), as in the SM \( \delta_{tu} \), \( \delta_{tu} \), \( \delta_{tu} \), the data in \( \delta_{tu} \), \( \delta_{tu} \), \( \delta_{tu} \) imply

\[ d = 0.49 \pm 0.33, \quad \theta = +1(137 \pm 23)^\circ, \]  
\[ x = 1.22 \pm 0.25, \quad \Delta = -1(71 \pm 25)^\circ, \]  
(16)

where we have suppressed a second solution for \( \delta_{tu} \), which does not allow us to accommodate the \( B \rightarrow \pi K \) data \( \delta_{tu} \). This determination is essentially theoretically clean, and the experimental picture will improve significantly in the future. We observe that \( x = O(1) \), which implies \( \tilde{C} \sim |\bar{T}| \). In view of the anticipated colour suppression of \( \mathcal{C} \) with respect to \( \mathcal{T} \), this can only be satisfied if the usually neglected contributions \( (\mathcal{P}_{tu} - \mathcal{E}) \) in \( \delta_{tu} \) and \( \delta_{tu} \) are significant \( \delta_{tu} \). Indeed, because of the different signs in \( \delta_{tu} \) and \( \delta_{tu} \), we may explain the surprisingly small \( B_d \rightarrow \pi^+\pi^- \) branching ratio naturally, through destructive interference between the \( \mathcal{T} \) and \( \mathcal{P}_{tu} - \mathcal{E} \) amplitudes, whereas the puzzling large \( B_d \rightarrow \pi^+\pi^- \) branching ratio originates from constructive interference between the \( \mathcal{C} \) and \( \mathcal{P}_{tu} - \mathcal{E} \) amplitudes. Within factorization, \( B_d \rightarrow \pi^+\pi^- \) would favour \( \gamma > 90^\circ \), in contrast to the SM expectation, thereby reducing \( \text{BR}(B_d \rightarrow \pi^+\pi^-) \) through destructive interference between trees and penguins.

Now we arrive at a picture that is very different from factorization and exhibits certain interference effects at the hadronic level; this allows us to accommodate straightforwardly any currently observed feature of the \( B \rightarrow \pi \pi \) system within the SM. Moreover, we may predict the CP-violating \( B_d \rightarrow \pi^+\pi^- \) observables \( \delta_{tu} \):

\[ \mathcal{A}_{\text{CP}}^{\text{dir}}(\pi^+\pi^-) = -0.40 \pm 0.35, \quad \mathcal{A}_{\text{CP}}^{\text{mix}}(\pi^+\pi^-) = -0.56 \pm 0.44. \]  
(17)

3. In the \( B \rightarrow \pi K \) system, the following ratios of CP-averaged branching ratios are of central interest \( \delta_{tu} \):

\[ R_c \equiv \sqrt{\frac{\text{BR}(B^\pm \rightarrow \pi^0 K^\pm)}{\text{BR}(B^\pm \rightarrow \pi^\pm K^0)}} = 1.17 \pm 0.12 \]  
(18)  
\[ R_n \equiv \sqrt{\frac{\text{BR}(B_d \rightarrow \pi^+ K^-)}{\text{BR}(B_d \rightarrow \pi^0 K^0)}} = 0.76 \pm 0.10, \]  
(19)

with numerical values following from \( \delta_{tu} \). As noted in \( \delta_{tu} \), the pattern of \( R_c \) and \( R_n \) < 1 is actually very puzzling. On the other hand,

\[ R \equiv \frac{\text{BR}(B_d \rightarrow \pi^+ K^-)}{\text{BR}(B^\pm \rightarrow \pi^\pm K)} \frac{\tau_{B^\pm}}{\tau_{B_d}} = 0.91 \pm 0.07 \]  
(20)

does not show any anomalous behaviour. Since \( R_c \) and \( R_n \) are affected significantly by colour-allowed EW penguins, whereas these topologies may only contribute in colour-suppressed form to \( R \), this “\( B \rightarrow \pi K \) puzzle” may be a manifestation of NP in the EW penguin sector \( \delta_{tu} \), offering an attractive avenue for physics beyond the SM to enter the \( B \rightarrow \pi K \) system \( \delta_{tu} \).

In this letter, we neglect colour-suppressed EW penguins, employ \( SU(3) \) flavour-symmetry arguments, and assume that penguin annihilation and exchange topologies are small. The latter topologies can be probed through \( B_d \rightarrow K^+ K^- \), where the current experimental bound of \( \text{BR}(B_d \rightarrow K^+ K^-) < 0.6 \times 10^{-6} \) (90% C.L.) \( \delta_{tu} \) does not indicate any anomalous behaviour \( \delta_{tu} \). We then go beyond \( \delta_{tu} \) in two respects. First, we employ the \( B \rightarrow \pi \pi \) data to fix the hadronic parameters of the \( B \rightarrow \pi K \) system. Second, we consider CP-violating NP contributions to the EW penguin sector, so that these topologies are described by a parameter \( q \) with a CP-violating weak phase \( \phi \), which vanishes in the SM. We
may then write
\[ A(B_d^0 \rightarrow \pi^- K^+) = P' \left[ 1 - re^{i\delta} e^{i\gamma} \right] \] (21)
\[ \sqrt{2} A(B_d^0 \rightarrow \pi^0 K^0) = -P' \left[ 1 + \rho_n e^{i\theta_n} e^{i\gamma} - q e^{i\phi} r e^{i\delta} \right], \] (22)
where \( P' \equiv (1 - \lambda^2/2) A \lambda^2 (P_L - P_R) \) is the counterpart of \( A \), and the \( B \rightarrow \pi\pi \) analysis described above allows us to fix the hadronic \( B \rightarrow K \) parameters through \( A \).

\[ re^{i\delta} \equiv \left( \frac{\lambda^2 R_b}{1 - \lambda^2} \right) \left[ \frac{T - (P_L - P_R)}{P_L - P_R} \right] = -\frac{\epsilon}{de^{i\delta}} \] (23)
\[ \rho_n e^{i\theta_n} \equiv \left( \frac{\lambda^2 R_b}{1 - \lambda^2} \right) \left[ C + (P_L - P_R) \right] = x e^{i\Delta} re^{i\delta} \] (24)
\[ r_c e^{i\delta_c} \equiv \left( \frac{\lambda^2 R_b}{1 - \lambda^2} \right) \left[ T + C \right] = r e^{i\delta} + \rho_n e^{i\theta_n}, \] (25)
where \( \epsilon \equiv \lambda^2/(1 - \lambda^2) = 0.05 \). Consequently, \( r e^{i\delta} \) and \( \rho_n e^{i\theta_n} \) differ strongly from factorization.

However, the small value of \( r \) implies generally small CP violation in \( B_d \rightarrow \pi^+ K^- \) at the 10% level \( A \), in accordance with the data \( A \). Interestingly, the value of \( r_c \) agrees well with the one of an alternative determination through \( B^- \rightarrow \pi^+ \pi^0 \), \( \pi^+ K^- \) decays \( A \), 0.196 ± 0.016, thereby pointing towards moderate non-factorizable \( SU(3) \)-breaking corrections. The charged \( B \rightarrow \pi K \) modes involve an additional parameter \( \rho_n e^{i\theta_n} \propto \lambda^2 R_b A \), which is estimated to contribute at the few-per cent level, and is neglected, as in \( A \). This assumption is also supported by the searches for direct CP violation in \( B^\pm \rightarrow \pi^\pm K^\mp \) and the experimental upper bounds for \( BR(B^\pm \rightarrow \pi K) \). We may then write
\[ A(B^+ \rightarrow \pi^+ K^0) = -P' \] (27)
\[ \sqrt{2} A(B^+ \rightarrow \pi^0 K^+ \rightarrow \pi^+ K^-) = P' \left[ 1 - (e^{i\gamma} - q e^{i\phi} r e^{i\delta}) \right], \] (28)
allowing us to study the \( R_{c,n} \) and the relevant \( B \rightarrow \pi K \) CP asymmetries as functions of \( q \) and \( \phi \). We find – in accordance with \( A \) – that the data in \( A \) and \( A \) cannot be described properly for the SM values \( q = 0.69 \) \( A \) and \( \phi = 0 \); in particular, \( R_c \sim 1.14 \) and \( R_n \sim 1.11 \). However, treating \( q \) and \( \phi \) as free parameters, we obtain
\[ q = 1.78^{+1.24}_{-0.97}, \quad \phi = -(85^{+11}_{-13})^\circ, \] (29)
and a generically small CP asymmetry in \( B^\pm \rightarrow \pi^0 K^\pm \), in accordance with the data \( A \). If we allow for a strong phase \( \omega \) in the EW penguin sector, which may be induced by non-factorizable \( SU(3) \)-breaking effects \( A \), the data for this CP asymmetry and the \( R_{c,n} \) allow us to determine \( \omega \) as well. We find a phase at the few-degree level and essentially unchanged values of \( q \) and \( \phi \), thereby giving us additional support for the use of the \( SU(3) \) flavour symmetry \( A \). In contrast to \( A \), where larger direct CP asymmetries in the \( B \rightarrow \pi K \) modes were favoured, the determination of the hadronic parameters through the \( B \rightarrow \pi \) system and the introduction of the weak EW penguin phase \( \phi \) now allow us to describe any currently observed feature of the \( B \rightarrow \pi K \) modes. Moreover, we predict the \( B_d \rightarrow \pi^0 K^0 \) CP asymmetries as follows \( A \): \[
A_{\text{CP}}(\pi^0 K^0) = +0.05^{+0.24}_{-0.20}, \quad A_{\text{CP}}(\pi^0 K^0) = -0.99^{+0.04}_{-0.01}. \] (30)

Recently, the BaBar collaboration reported the results of \( 0.40^{+0.28}_{-0.10} \pm 0.10 \) and \( -0.48^{+0.47}_{-0.38} \pm 0.11 \) for these direct and mixing-induced CP asymmetries, respectively \( A \).

Let us finally note that we may complement the \( B \rightarrow \pi \pi \) data in a variety of ways with the experimental information provided by the \( B_d \rightarrow \pi^\pm K^\mp \) modes, allowing us to determine \( \gamma \) as well. If we take also the constraints from the whole \( B \rightarrow \pi K \) system into account, we find results for \( \gamma \) in remarkable agreement with the UT fits, i.e. we arrive at a very consistent overall picture \( A \). In the future, \( B_s \rightarrow K^+ K^- \) will provide a powerful tool for the simultaneous determination of \( \gamma \) and \( (d, \theta) \).
This should be compared with the SM values $C = 0.79$, $X = 1.53$ and $Y = 0.98$ for $m_t(m_t) = 167$ GeV.

The enhanced function $|C|$ and its large complex phase may affect the usual analysis of the UT through double $Z^0$-penguin contributions to $\varepsilon_K$ and $\Delta M_{s,d}$, but as demonstrated in [1], these effects can be neglected. Inserting then the values of $|X|e^{i\phi_X}$ and $|Y|e^{i\theta_Y}$ listed in (33) into the known formulae for rare $K$- and $B$-decay branching ratios [24], we obtain the following results:

a) For the very clear $K \to \pi^0\nu\bar{\nu}$ decays, we find

\[
\begin{align*}
BR(K^+ \to \pi^+\nu\bar{\nu}) &= (7.5 \pm 2.1) \times 10^{-11} \\
BR(K_L \to \pi^0\nu\bar{\nu}) &= (3.1 \pm 1.0) \times 10^{-10},
\end{align*}
\]

(34)
to be compared with the SM estimates $(7.7 \pm 1.1) \times 10^{-11}$ and $(2.6 \pm 0.5) \times 10^{-11}$ [27], respectively, and the AGS E787 result $BR(K^+ \to \pi^+\nu\bar{\nu}) = (15.7^{+17.5}_{-8.2}) \times 10^{-11}$ [28]. The enhancement of $BR(K_L \to \pi^0\nu\bar{\nu})$ by one order of magnitude and the pattern in (34) are dominantly the consequences of $\beta_X = \beta - \theta_X \approx 110^\circ$, as

\[
\frac{BR(K_L \to \pi^0\nu\bar{\nu})}{BR(K^+ \to \pi^+\nu\bar{\nu})} \approx 4.4 \times (\sin \beta_X)^2 \approx (4.2 \pm 0.2).
\]

(36)

Interestingly, the above ratio turns out to be very close to its absolute upper bound in [24]. A spectacular implication of these findings is a strong violation of $(\sin 2\beta)_{\pi^0\nu\bar{\nu}} = (\sin 2\beta)_{\psi K_S}$ [31], which is valid in the SM and any model with minimal flavour violation. Indeed, we find

\[
(\sin 2\beta)_{\pi^0\nu\bar{\nu}} = (\sin 2\beta)_X = -(0.69^{+0.23}_{-0.41})
\]

(37)
in striking disagreement with $(\sin 2\beta)_{\psi K_S} = 0.74 \pm 0.05$.

b) Another implication is the large branching ratio

\[
BR(K_L \to \pi^0\epsilon^+\epsilon^-) = (7.8 \pm 1.6) \times 10^{-11},
\]

(38)

which is governed by direct CP violation. On the other hand, the SM result $(3.2^{+0.8}_{-0.5}) \times 10^{-11}$ [31] is dominated by indirect CP violation. Moreover, the integrated forward–backward CP asymmetry for $B_d \to K^*\mu^+\mu^-$ [24], which is given by

\[
A_{FB}^{CP} = (0.03 \pm 0.01) \times \tan \theta_Y,
\]

(39)
can be very large in view of $\theta_Y \approx -100^\circ$.

c) Next, $BR(B \to X_{s,d}\nu\bar{\nu})$ and $BR(B_{s,d} \to \mu^+\mu^-)$ are enhanced by factors of 2 and 5, respectively, whereas the impact on $K_L \to \mu^+\mu^-$ is rather moderate.

d) As emphasized in [21], enhanced $Z^0$ penguins may play an important role in $\varepsilon'/\varepsilon$. The enhanced value of $|C|$ and its large negative phase suggested by the $B \to \pi K$ analysis require a significant enhancement of the relevant hadronic matrix element of the QCD penguin operator $Q_8$, with respect to the one of the EW penguin operator $Q_6$, to be consistent with the $\varepsilon'/\varepsilon$ data [11].

e) We have also explored the implications for the decay $B_d \to \phi K_S$ [1]. Large hadronic uncertainties preclude a precise prediction, but assuming that the sign of the cosine of a strong phase agrees with factorization, we find that $(\sin 2\beta)_{\phi K_S} > (\sin 2\beta)_{\psi K_S}$, where $(\sin 2\beta)_{\phi K_S} \approx 1$ may well be possible. This pattern is qualitatively different from the present B-factory data [20], which are, however, not yet conclusive. On the other hand, a future confirmation of this pattern would be another signal of enhanced CP-violating $Z^0$ penguins at work.

In the next couple of years, it will be very exciting to follow the development of the values of the observables considered in this letter and to monitor them by using the strategies presented here and in [11].

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