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The golden modes $B^0 \to J/\psi K_{S,L}$ in the era of precision flavor physics

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CP violation is a major challenge of contemporary particle physics. It has been discovered in kaon decays and appears also in *B* decays, where the $B^0 \to J/\psi K_{S,L}$ channels are considered to be clean probes of this phenomenon. Recent *B*-factory data challenge the description of *CP* violation in the standard model of particle physics, showing some "tension" with theoretical predictions. We take a detailed look at certain standard-model contributions, which are usually neglected, and point out that they can be included unambiguously through measurements of the $B^0 \to J/\psi \pi^0$ observables. Using the most recent data, we show that the tension with the standard model is softened, and we constrain a possible new-physics phase in $B^0 - \bar{B}^0$ mixing. Our strategy is crucial to fully exploit the accuracy of the search for this kind of new physics at the LHC and future super-flavor factories.

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CP-violating effects in B^0 decays into *CP* eigenstates f are studied through time-dependent rate asymmetries:

$$A_{CP}(t;f) \equiv \frac{\Gamma(B^0(t)\to f) - \Gamma(\bar{B}^0(t)\to f)}{\Gamma(B^0(t)\to f) + \Gamma(\bar{B}^0(t)\to f)} = C(f)\cos(\Delta M_d t) - S(f)\sin(\Delta M_d t), \quad (1)$$

where $C(f)$ and $S(f)$ describe direct and mixing-induced *CP* violation, respectively. The key application is given by $B^0 \to J/\psi K_{S,L}$ decays, which arise from $\bar{b} \to \bar{c}c\bar{s}$ processes. If we assume the standard model (SM) and neglect doubly Cabibbo-suppressed contributions to the $B^0 \to J/\psi K^0$ amplitude, we obtain [1–4]

$$C(J/\psi K_{S,L}) \approx 0, \qquad S(J/\psi K_{S,L}) \approx -\eta_{S,L} \sin 2\beta, \quad (2)$$

where $\eta_S = -1$ and $\eta_L = +1$ are the *CP* eigenvalues of the final states, and β is an angle of the unitarity triangle (UT) of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. The usual experimental analyses assume that (2) is valid exactly; the most recent data then result in

$$(\sin 2\beta)_{J/\psi K^0} = 0.657 \pm 0.024, \quad (3)$$

which is obtained from the average of the measured $S(J/\psi K_{S,L})$ values [5,6]. It is the purpose of the present paper to critically review this assumption.

Using also data for *CP* violation in $B^0 \to J/\psi K^*$ decays [7], β can be fixed unambiguously, where the value in (3) corresponds to $\beta = (20.5 \pm 0.9)^\circ$. In Fig. 1, created with the CKMFITTER software [8], we show the resulting constraint for the apex of the UT in the $\bar{\rho} - \bar{\eta}$ plane of the generalized Wolfenstein parameters [9,10]. Moreover, we include the circle coming from the UT side $R_b \equiv (1 - \lambda^2/2)|V_{ub}/(\lambda V_{cb})|$, where $\lambda \equiv |V_{us}| = 0.225\,21 \pm 0.000\,83$ [11]; taking into account the most recent developments in the determination of $|V_{ub}|$ and $|V_{cb}|$ from semileptonic B decays [12], where inclusive and exclusive determinations of $|V_{ub}|$ are now consistent with each other, we find $R_b = 0.423^{+0.015}_{-0.022} \pm 0.029$. Here and in the following the first error comes from experiment and the second from theory. We show also the range corresponding to $\gamma = (65 \pm 10)^\circ$, which is well in accordance with the analyses of the UT in Refs. [11,13] and the information from $B_{d,s} \to \pi\pi$, πK, KK decays [14]. This angle will be determined with only a few degrees uncertainty thanks to *CP* violation measurements in pure tree decays at the LHCb (CERN). In analogy to R_b, the value of γ extracted in this way is expected to be very robust with respect to new-physics (NP) effects. In Fig. 1, we can see the tension that is also present in more refined fits of the UT for a couple of years [11,13].

Since $B^0 - \bar{B}^0$ mixing is a sensitive probe for NP (see, e.g., [15–17]), this effect could be a footprint of such contributions. Provided they are *CP* violating, we have

$$\phi_d = 2\beta + \phi_d^{\rm NP}, \quad (4)$$

where ϕ_d denotes the $B^0 - \bar{B}^0$ mixing phase and $\phi_d^{\rm NP}$ is its NP component. If we assume that NP has a minor impact on the $B^0 \to J/\psi K^0$ amplitude, the relations in (2) remain valid, with the replacement $2\beta \to \phi_d$.

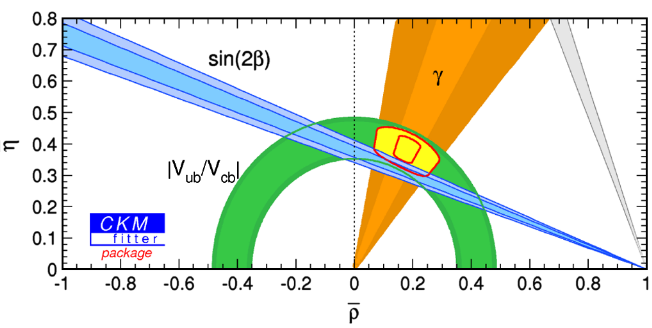

FIG. 1 (color online). Constraints in the $\bar{\rho} - \bar{\eta}$ plane (1σ and 2σ ranges).

Using Fig. 1, the "true" value of β can be determined through R_b and tree-level extractions of γ. We find $\beta_{\rm true} = (24.9^{+1.0}_{-1.5} \pm 1.9)^\circ$, which is essentially independent of the error on γ for a central value around 65° [and yields $(\sin 2\beta)_{\rm true} = 0.76^{+0.02+0.04}_{-0.04-0.05}$]. Consequently,

$$(\phi_d)_{J/\psi K^0} - 2\beta_{\rm true} = -(8.7^{+2.6}_{-3.6} \pm 3.8)^\circ. \qquad (5)$$

Let us now have a critical look at the hadronic SM uncertainties affecting the extraction of ϕ_d from $B^0 \to J/\psi K_{\rm S,L}$. In the SM, we may write [18]

$$A(B^0 \to J/\psi K^0) = (1 - \lambda^2/2)\mathcal{A}[1 + \epsilon a e^{i\theta} e^{i\gamma}], \qquad (6)$$

where

$$\mathcal{A} \equiv \lambda^2 A[A_{\rm T}^{(c)} + A_{\rm P}^{(c)} - A_{\rm P}^{(t)}] \qquad (7)$$

and

$$a e^{i\theta} \equiv R_b \left[\frac{A_{\rm P}^{(u)} - A_{\rm P}^{(t)}}{A_{\rm T}^{(c)} + A_{\rm P}^{(c)} - A_{\rm P}^{(t)}}\right] \qquad (8)$$

are CP-conserving parameters, with $A_{\rm T}^{(c)}$ and $A_{\rm P}^{(j)}$ denoting strong amplitudes that are related to tree-diagram-like and penguin topologies (with internal $j \in \{u, c, t\}$ quarks), respectively, while $A \equiv |V_{cb}|/\lambda^2 = 0.809 \pm 0.026$ and $\epsilon \equiv \lambda^2/(1 - \lambda^2) = 0.053$ are CKM factors.

Looking at (6), we observe that $ae^{i\theta}$ enters with the tiny parameter ϵ. Therefore, this term is usually neglected, which yields (2). However, $ae^{i\theta}$ suffers from large hadronic uncertainties, and may be enhanced through long-distance effects. As discussed in detail in Ref. [19], the generalization of these expressions, taking also the penguin-topology effects into account, reads as follows:

$$\frac{-\eta_{\rm S,L} S(J/\psi K_{\rm S,L})}{\sqrt{1 - C(J/\psi K_{\rm S,L})^2}} = \sin(\phi_d + \Delta\phi_d), \qquad (9)$$

where

$$\sin\Delta\phi_d = \frac{2\epsilon a \cos\theta \sin\gamma + \epsilon^2 a^2 \sin 2\gamma}{N\sqrt{1 - C(J/\psi K_{\rm S,L})^2}}, \qquad (10)$$

$$\cos\Delta\phi_d = \frac{1 + 2\epsilon a \cos\theta \cos\gamma + \epsilon^2 a^2 \cos 2\gamma}{N\sqrt{1 - C(J/\psi K_{\rm S,L})^2}}, \qquad (11)$$

with $N \equiv 1 + 2\epsilon a \cos\theta \cos\gamma + \epsilon^2 a^2$, so that

$$\tan\Delta\phi_d = \frac{2\epsilon a \cos\theta \sin\gamma + \epsilon^2 a^2 \sin 2\gamma}{1 + 2\epsilon a \cos\theta \cos\gamma + \epsilon^2 a^2 \cos 2\gamma}. \qquad (12)$$

Concerning direct CP violation, we have

$$C(J/\psi K^0) = -0.003 \pm 0.019, \qquad (13)$$

which is again an average over the $J/\psi K_{\rm S}$ and $J/\psi K_{\rm L}$ final states [5,6]. Consequently, the deviation of the terms $\sqrt{1 - C(J/\psi K_{\rm S,L})^2}$ from 1 is at most at the level of 0.0002, and is hence completely negligible.

In order to probe the importance of the penguin effects described by $ae^{i\theta}$, we may use a $\bar{b} \to \bar{d}c\bar{c}$ transition, as here this parameter is not doubly Cabibbo suppressed [18,20]. In the following, we will use the decay $B^0 \to J/\psi \pi^0$. In Ref. [21], a similar ansatz was used to constrain the penguin effects in the golden mode. However, the quality of the data has improved such that we go beyond this paper by allowing for $\phi_d^{\rm NP} \neq 0^\circ$. Moreover, as we will see below, the current B-factory data point already towards a *negative* value of $\Delta\phi_d$, where mixing-induced CP violation in $B^0 \to J/\psi \pi^0$ is the driving force, thereby reducing the tension (5) in the fit of the UT.

In the SM, we have

$$\sqrt{2} A(B^0 \to J/\psi \pi^0) = \lambda \mathcal{A}'[1 - a' e^{i\theta'} e^{i\gamma}], \qquad (14)$$

where the $\sqrt{2}$ factor is associated with the π^0 wave function, while $\mathcal{A}'$ and $a'e^{i\theta'}$ are the counterparts of (7) and (8), respectively. We see now explicitly that—in contrast to (6)—the latter quantity does not enter (14) with the ϵ. The CP asymmetry $A_{CP}(t; J/\psi\pi^0)$ [see (1)] was recently measured by the *BABAR* (SLAC) [22] and Belle (KEK) [23] collaborations, yielding the following averages [7]:

$$C(J/\psi \pi^0) = -0.10 \pm 0.13, \qquad (15)$$

$$S(J/\psi \pi^0) = -0.93 \pm 0.15. \qquad (16)$$

Note that the error of $S(J/\psi\pi^0)$ is that of the Heavy Flavour Averaging Group [7], which is not inflated due to the inconsistency of the data.

The values of these CP asymmetries allow us to calculate a' as functions of θ'. We obtain two relations from $C(J/\psi\pi^0)$ and $S(J/\psi\pi^0)$ ($\mathcal{O} = C$ and S, respectively),

$$a' = U_{\mathcal{O}} \pm \sqrt{U_{\mathcal{O}}^2 - V_{\mathcal{O}}}, \qquad (17)$$

where

$$U_C \equiv \cos\theta' \cos\gamma + \frac{\sin\theta' \sin\gamma}{C(J/\psi\pi^0)}, \qquad V_C \equiv 1, \qquad (18)$$

and

$$U_S \equiv \left[\frac{\sin(\phi_d + \gamma) + S(J/\psi\pi^0)\cos\gamma}{\sin(\phi_d + 2\gamma) + S(J/\psi\pi^0)}\right]\cos\theta', \qquad (19)$$

$$V_S \equiv \frac{\sin\phi_d + S(J/\psi\pi^0)}{\sin(\phi_d + 2\gamma) + S(J/\psi\pi^0)}. \qquad (20)$$

The intersection of the $C(J/\psi\pi^0)$ and $S(J/\psi\pi^0)$ contours then fixes the hadronic parameters a' and θ' in the SM; when allowing for an additional NP phase, one has to take into account $S(J/\psi K^0)$ together with $S(J/\psi\pi^0)$ in order to have a constraint in the $a' - \theta'$ plane. From $C(J/\psi K^0)$

comes another constraint, which is of the form (17) with the replacements $a' \to \epsilon a$ and $\theta' \to 180° + \theta$. It should be stressed that (17)–(20) are valid exactly, as these expressions follow from the SM structure of $B^0 \to J/\psi \pi^0$.

Neglecting penguin annihilation and exchange topologies, which contribute to $B^0 \to J/\psi \pi^0$ but have no counterpart in $B^0 \to J/\psi K^0$ and are expected to play a minor role (which can be probed through $B_s^0 \to J/\psi \pi^0$), we obtain in the $SU(3)$ limit

$$a' = a, \qquad \theta' = \theta. \tag{21}$$

Thanks to these relations, we can determine the shift $\Delta\phi_d$ by means of (9)–(13) from the data. We expect them to hold to a reasonable accuracy; however, one has to keep in mind that sizable nonfactorizable effects may induce $SU(3)$-breaking corrections. Their impact on the determination of $\Delta\phi_d$ can be easily inferred from (12). Neglecting terms of order ϵ^2, we have a linear dependence on $a\cos\theta$. Consequently, corrections to the left-hand side of (21) propagate linearly, while $SU(3)$-breaking effects in the strong phases will generally lead to an asymmetric uncertainty for $\Delta\phi_d$.

Before having a closer look at the picture emerging from the current B-factory data, let us discuss another constraint which follows from the CP-averaged branching ratios. To this end, we introduce

$$\begin{aligned} H &\equiv \frac{2}{\epsilon}\left[\frac{\mathrm{BR}(B_d \to J/\psi \pi^0)}{\mathrm{BR}(B_d \to J/\psi K^0)}\right]\left|\frac{\mathcal{A}}{\mathcal{A}'}\right|^2 \frac{\Phi_{J/\psi K^0}}{\Phi_{J/\psi \pi^0}} \\ &= \frac{1 - 2a'\cos\theta'\cos\gamma + a'^2}{1 + 2\epsilon a\cos\theta\cos\gamma + \epsilon^2 a^2}, \end{aligned} \tag{22}$$

where the $\Phi_{J/\psi P} \equiv \Phi(M_{J/\psi}/M_{B^0}, M_P/M_{B^0})$ are phase-space factors [18]. In order to extract H from the data, we have to analyze the $SU(3)$-breaking corrections to $|\mathcal{A}/\mathcal{A}'|$. We assume them to be factorizable, and thus given by the ratio of two form factors, evaluated at $q^2 = M_{J/\psi}^2$. This ratio has been studied in detail using QCD light-cone sum rules (LCSR) [24]. We shall use the latest result for the form-factor ratio at $q^2 = 0$ [25,26],

$$f^+_{B\to K}(0)/f^+_{B\to\pi}(0) = 1.38^{+0.11}_{-0.10}, \tag{23}$$

and perform the extrapolation to $q^2 = M_{J/\psi}^2$ by using a simple BK parametrization [27],

$$f^+(q^2) = f^+(0)\left[\frac{M_B^2 M_*^2}{(M_*^2 - q^2)(M_B^2 - \alpha q^2)}\right]. \tag{24}$$

Here M_* is the mass of the ground state vector meson in the relevant channel, and the pole at M^2/α models the contribution of the hadronic continuum for $q^2 > M_*^2$. The BK parameter α has been fitted to the $B \to \pi$ lattice data to be $\alpha_\pi = 0.53 \pm 0.06$. Nothing is known about the value of α for the $B \to K$ form factor, and we shall use the simple assumption that the main $SU(3)$-breaking effect is due to the shift of the continuous part of the spectral function from the $B\pi$ to the BK threshold. This leads to $\alpha_K = 0.49 \pm 0.05$, and—extrapolating in this way to $q^2 = M_{J/\psi}^2$—we get

$$f^+_{B\to K}(M_{J/\psi}^2)/f^+_{B\to\pi}(M_{J/\psi}^2) = 1.34 \pm 0.12. \tag{25}$$

Using $\mathrm{BR}(B^0 \to J/\psi K^0) = (8.63 \pm 0.35) \times 10^{-4}$ and $\mathrm{BR}(B^0 \to J/\psi \pi^0) = (0.20 \pm 0.02) \times 10^{-4}$ [7], we obtain $H = 1.53 \pm 0.16_{\mathrm{BR}} \pm 0.27_{\mathrm{FF}}$, where we give the errors induced by the branching ratios and the form-factor ratio.

Using (21), we obtain the following relation [18]:

$$C(J/\psi K^0) = -\epsilon H C(J/\psi \pi^0), \tag{26}$$

which would offer an interesting probe for $SU(3)$ breaking. However, the value of H given above yields $C(J/\psi K^0) = 0.01 \pm 0.01$, which is consistent with (13), but obviously too small for a powerful test.

If we apply once more (17) with

$$U_H = \left(\frac{1 + \epsilon H}{1 - \epsilon^2 H}\right)\cos\theta'\cos\gamma, \tag{27}$$

$$V_H = (1 - H)/(1 - \epsilon^2 H), \tag{28}$$

i.e. $\mathcal{O} = H$, we may again calculate a' as a function of θ'. In contrast to the CP asymmetries of $B^0 \to J/\psi \pi^0$, we have to deal here with $SU(3)$-breaking effects, which enter implicitly through the determination of H.

In Fig. 2, we show the fits in the $\theta' - a'$ plane for the current data with 1σ ranges. The major implication of $S(J/\psi \pi^0)$ is $\theta' \in [90°, 270°]$. Looking at (8), this is actually what we expect. $S(J/\psi K^0)$ fixes the NP phase essentially to $(\phi_d)_{J/\psi K^0} - 2\beta_{\mathrm{true}}$, as the NP phase is an

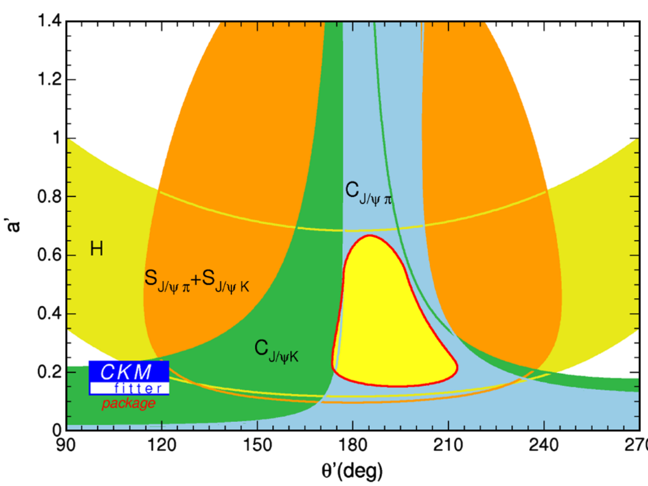

FIG. 2 (color online). The 1σ ranges in the $\theta' - a'$ plane with current data.

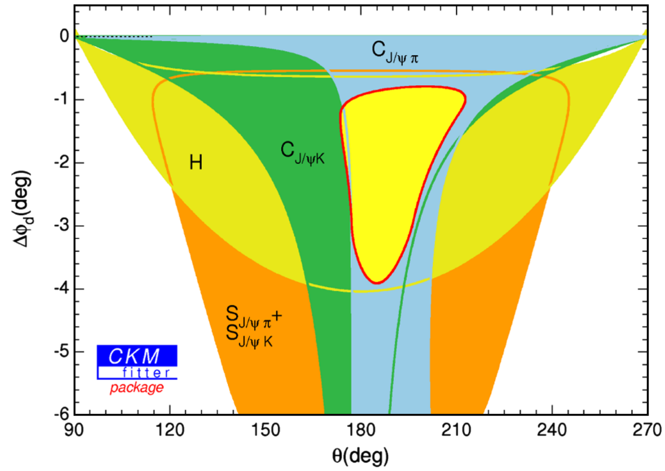

FIG. 3 (color online). $\Delta\phi_d$ for the constraints shown in Fig. 2.

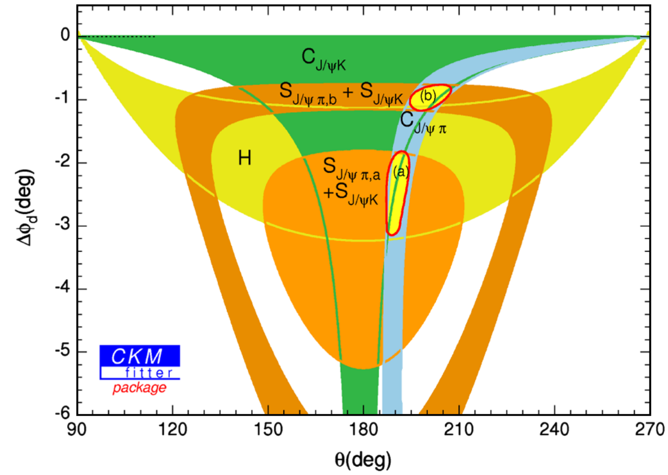

FIG. 4 (color online). Future benchmark scenarios, as discussed in the text.

$\mathcal{O}(1)$ effect in $S(J/\psi K^0)$, while the additional SM contribution is suppressed by ϵ. The negative central value of $C(J/\psi\pi^0)$ prefers $\theta' > 180°$. The intersection of the $C(J/\psi\pi^0)$ and H bands, which falls well into the $S(J/\psi\pi^0, J/\psi K^0)$ as well as the $C(J/\psi K^0)$ region, then gives $a' \in [0.15, 0.67]$ and $\theta' \in [174, 213]°$ at the 1σ level. Note that all three constraints give finally an unambiguous solution for these parameters.

In Fig. 3, we convert the curves in Fig. 2 into the $\theta - \Delta\phi_d$ plane with the help of (10)–(12) and (21). We see that a negative value of $\Delta\phi_d$ emerges; the global fit to all observables yields $\Delta\phi_d \in [-3.9, -0.8]°$, mainly due to the constraints from H and $C(J/\psi\pi^0)$, corresponding to $\phi_d = (42.4^{+3.4}_{-1.7})°$. Furthermore, the fit gives $\phi_d^{\rm NP} \in [-13.8, 1.1]°$, which includes the SM value $\phi_d^{\rm NP} = 0°$. Consequently, the negative sign of the SM correction $\Delta\phi_d$ softens the tension in the fit of the UT.

We have studied the impact of $SU(3)$-breaking corrections by setting $a = \xi a'$ in (21) and uncorrelating θ and θ'. Even when allowing for $\xi \in [0.5, 1.5]$ and $\theta, \theta' \in [90, 270]°$ in the fit, and using a 50% increased error for the form-factor ratio in view of nonfactorizable contributions to $|\mathcal{A}/\mathcal{A}'|$, the global fit yields $\Delta\phi_d \in [-6.7, 0.0]°$ and $\phi_d^{\rm NP} \in [-14.9, 4.0]°$, determined now mostly by $C(J/\psi K^0)$ and H. Consequently, these $SU(3)$-breaking effects do not alter our conclusions. It should be emphasized that the novel feature of this determination of $\phi_d^{\rm NP}$ in comparison with other analyses in the literature is that the doubly Cabibbo-suppressed SM contributions are included, which is crucial in order to eventually detect or exclude such a NP effect.

In view of the large experimental errors, we cannot yet draw final conclusions. However, the increasing experimental precision will further constrain the hadronic parameters. The final reach for a NP contribution to the $B_d^0 - \bar{B}_d^0$ mixing phase will strongly depend on the measured values of the CP asymmetries of $B^0 \to J/\psi\pi^0$, which are challenging for the LHCb because of the neutral pions (here a similar analysis could be performed with $B_s^0 \to J/\psi K_S$ [18]), but can be measured at future super-B factories.

We illustrate this through two benchmark scenarios, assuming a reduction of the experimental uncertainties of the CP asymmetries of $B^0 \to J/\psi K^0$ by a factor of 2, and errors of the branching ratios and γ that are five times smaller; the scenarios agree in $C(J/\psi\pi^0) = -0.10 \pm 0.03$, but differ in $S(J/\psi\pi^0)$. In the high-S scenario (a), we assume $S = -0.98 \pm 0.03$. As can be seen in Fig. 4, $\Delta\phi_d \in [-3.1, -1.8]°$ (with $a' \sim 0.42$, $\theta' \sim 191°$) will then come from the lower value of S and H, which we assume as $H = 1.53 \pm 0.03 \pm 0.27$. In the low-$S$ scenario (b), we assume $S = -0.85 \pm 0.03$. In this case, $\Delta\phi_d \in [-1.2, -0.8]°$ (with $a' \sim 0.18$, $\theta' \sim 201°$) would be determined by S and C alone, while H would only be used to rule out the second solution. By the time the accuracies of these benchmark scenarios can be achieved, we will also have a much better picture of $SU(3)$-breaking effects through data about $B_{s,d,u}$ decays.

Since the experimental uncertainty of $(\phi_d)_{J/\psi K^0}$ could be reduced to $\sim 0.3°$ at an upgrade of the LHCb and an e^+e^- super-B factory, these corrections will be essential. It is interesting to note that the quality of the data will soon reach a level in the era of precision flavor physics where subleading effects, i.e. doubly Cabibbo-suppressed penguin contributions, have to be taken into account. In particular, in the analyses of CP violation in the golden $B^0 \to J/\psi K_{\rm S,L}$ modes, this is mandatory in order to fully exploit the physics potential for NP searches.

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[1] A. B. Carter and A. I. Sanda, Phys. Rev. Lett. **45**, 952 (1980); Phys. Rev. D **23**, 1567 (1981); I. I. Y. Bigi and A. I. Sanda, Nucl. Phys. **B193**, 85 (1981).
[2] D. London and R. D. Peccei, Phys. Lett. B **223**, 257 (1989).
[3] B. Grinstein, Phys. Lett. B **229**, 280 (1989).
[4] M. Gronau, Phys. Rev. Lett. **63**, 1451 (1989).
[5] K.-F. Chen *et al.* (Belle Collaboration), Phys. Rev. Lett. **98**, 031802 (2007).
[6] B. Aubert *et al.* (*BABAR* Collaboration), arXiv:0808.1903.
[7] E. Barberio *et al.* (Heavy Flavour Averaging Group), arXiv:0704.3575; for the most recent updates, see http://www.slac.stanford.edu/xorg/hfag.
[8] A. Höcker, H. Lacker, S. Laplace, and F. Le Diberder, Eur. Phys. J. C **21**, 225 (2001).
[9] L. Wolfenstein, Phys. Rev. Lett. **51**, 1945 (1983).
[10] A. J. Buras, M. E. Lautenbacher, and G. Ostermaier, Phys. Rev. D **50**, 3433 (1994).
[11] J. Charles *et al.* (CKMfitter Group), Eur. Phys. J. C **41**, 1 (2005); for updates, see http://ckmfitter.in2p3.fr/.
[12] C. Amsler *et al.* (Particle Data Group), Phys. Lett. B **667**, 1 (2008).
[13] M. Bona *et al.* (UTfit Collaboration), J. High Energy Phys. 07 (2005) 028; for updates, see http://utfit.roma1.infn.it/.
[14] R. Fleischer, Eur. Phys. J. C **52**, 267 (2007).
[15] R. Fleischer and T. Mannel, Phys. Lett. B **506**, 311 (2001).
[16] M. Bona *et al.* (UTfit Collaboration), J. High Energy Phys. 03 (2006) 080.
[17] P. Ball and R. Fleischer, Eur. Phys. J. C **48**, 413 (2006).
[18] R. Fleischer, Eur. Phys. J. C **10**, 299 (1999).
[19] S. Faller, R. Fleischer, and T. Mannel, Phys. Rev. D **79**, 014005 (2009).
[20] R. Fleischer, Phys. Rev. D **60**, 073008 (1999).
[21] M. Ciuchini, M. Pierini, and L. Silvestrini, Phys. Rev. Lett. **95**, 221804 (2005).
[22] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **101**, 021801 (2008).
[23] S. E. Lee *et al.* (Belle Collaboration), Phys. Rev. D **77**, 071101 (2008).
[24] P. Ball and R. Zwicky, Phys. Rev. D **71**, 014015 (2005).
[25] G. Duplancic, A. Khodjamirian, T. Mannel, B. Melic, and N. Offen, J. High Energy Phys. 04 (2008) 014.
[26] G. Duplancic and B. Melic, Phys. Rev. D **78**, 054015 (2008).
[27] D. Becirevic and A. B. Kaidalov, Phys. Lett. B **478**, 417 (2000).