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New physics in penguin dominated $B \to \pi K$ decays

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Abstract

Measurements of the combined branching ratios for $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$ allow interesting constraints on the CKM angle γ, the ratio $r \equiv |T'|/|P'|$ of the current-current and penguin operator contributions to $B_d \to \pi^\mp K^\pm$, and the CP asymmetry in that decay. Present CLEO results for these branching ratios indicate where problems with consistency of the Standard Model may arise in the future. In this paper we discuss scenarios of new physics in these decays and investigate their implications for the above constraints.

1 Introduction

Using flavor symmetries of strong interactions, decays of B mesons into πK and $\pi\pi$ final states play an important role to determine the angles of the unitarity triangle [1] of the CKM matrix [2], in particular for the angle γ which is notoriously difficult to measure at B factories (see e.g. [3] for a recent review). An experimentally promising approach to determine γ with the help of the branching ratios for $B^+ \to \pi^+ K^0$, $B_d^0 \to \pi^- K^+$ and their charge-conjugates was proposed in [4]. Recently the CLEO collaboration has reported a first measurement of these decays [5]. Since at present only results for the combined branching ratios

$$\mathrm{BR}(B^\pm \to \pi^\pm K) \equiv \frac{1}{2}\left[\mathrm{BR}(B^+ \to \pi^+ K^0) + \mathrm{BR}(B^- \to \pi^- \overline{K^0})\right] \tag{1}$$

$$\mathrm{BR}(B_d \to \pi^\mp K^\pm) \equiv \frac{1}{2}\left[\mathrm{BR}(B_d^0 \to \pi^- K^+) + \mathrm{BR}(\overline{B_d^0} \to \pi^+ K^-)\right] \tag{2}$$

are available, it is unfortunately not yet possible to fix γ using that approach.

However, as we have pointed out in a recent paper [6], even the *combined* branching ratios (1) and (2) allow to derive stringent constraints on γ. So far information about that angle could only be obtained in an indirect way by using experimental data on $|V_{cb}|$,

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$|V_{ub}|/|V_{cb}|$, B_d^0–$\overline{B_d^0}$ mixing and CP violation in the neutral K-meson system. Following these lines and using present data, one typically finds in the SM framework (see e.g. [7, 8])

$$40^\circ \lesssim \gamma \lesssim 140^\circ. \tag{3}$$

Using on the other hand our approach [6], one gets an allowed range for γ that is complementary to (3) and is given by

$$0^\circ \leq \gamma \leq \gamma_0 \quad \vee \quad 180^\circ - \gamma_0 \leq \gamma \leq 180^\circ\,, \tag{4}$$

where γ_0 is related both to

$$R = \frac{\mathrm{BR}(B_d \to \pi^\mp K^\pm)}{\mathrm{BR}(B^\pm \to \pi^\pm K)} \tag{5}$$

and to the amplitude ratio

$$r \equiv \frac{|T'|}{|P'|} \tag{6}$$

of the current-current and penguin operator contributions to $B_d \to \pi^\mp K^\pm$. The consistent description of $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$ within the Standard Model (SM) implies furthermore the allowed range

$$\left|1 - \sqrt{R}\right| \leq r \leq 1 + \sqrt{R} \tag{7}$$

and upper limits for the CP asymmetry arising in $B_d \to \pi^\mp K^\pm$. It is interesting to note that commonly accepted means to estimate r yield rather small values that are at the edge of compatibility with the present CLEO results due to the lower bound in (7).

Concerning the constraints (4) on γ, an important difference arises between $R < 1$ and $R > 1$. In the former case – the central values of the present CLEO results [5]

$$\mathrm{BR}(B^\pm \to \pi^\pm K) = \left(2.3^{+1.1+0.2}_{-1.0-0.2} \pm 0.2\right) \cdot 10^{-5} \tag{8}$$

$$\mathrm{BR}(B_d \to \pi^\mp K^\pm) = \left(1.5^{+0.5+0.1}_{-0.4-0.1} \pm 0.1\right) \cdot 10^{-5} \tag{9}$$

give $R = 0.65 < 1$ – the bound γ_0 takes a maximal value

$$\gamma_0^{\mathrm{max}} = \arccos\left(\sqrt{1-R}\right) \tag{10}$$

independent of the amplitude ratio r. To be specific, for $R = 0.65$ we have $\gamma_0^{\mathrm{max}} = 54^\circ$. The CKM angle γ can even be constrained in a more restrictive way if one uses additional knowledge on r. In contrast to $R < 1$, if R is found to be larger than 1, such information on r is required to constrain γ.

Consequently, once more data come in confirming $R < 1$, the SM can be put to a decisive test and our approach [6] could give hints for "New Physics". Therefore it is an interesting issue to analyze new physics effects in $B \to \pi K$ decays and in particular their implications for the bounds derived in [6]. Such considerations are the topic of the present paper. In Section 2 we parametrize contributions of physics beyond the SM to the modes $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$. Using some specific scenarios of new physics, we investigate the corresponding modifications of the constraints arising from these decays in Section 3. The main results are summarized briefly in Section 4.

2 Parametrization of new physics in $B \to \pi K$

Before we turn to effects of new physics, let us recall the general structure of the SM transition amplitudes for $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$. Using $SU(2)$ isospin symmetry of strong interactions to relate the hadronic matrix elements of the relevant four-quark operators, we may write these amplitudes as [4, 6]

$$A(B^+ \to \pi^+ K^0) = P' - \frac{1}{3} P'^{\rm C}_{\rm EW} \tag{11}$$

$$A(B^0_d \to \pi^- K^+) = -\left[\left(P' + \frac{2}{3} P'^{\rm C}_{\rm EW}\right) + T'\right], \tag{12}$$

where P' and $P'^{\rm C}_{\rm EW}$ denote the QCD and color-suppressed electroweak (EW) penguin amplitudes, respectively, and T' is the color-allowed $\bar{b} \to \bar{u} u \bar{s}$ current-current amplitude. Estimates within the SM yield [3, 6]

$$\rho_{\rm EWP} \equiv \frac{|P'^{\rm C}_{\rm EW}|}{|P'|} = \mathcal{O}(10^{-2}), \tag{13}$$

so that the EW penguin amplitudes in (11) and (12) are expected to play a very minor role [3]. Consequently we will neglect these contributions in the following discussion as we have done in [6]. In Subsection 3.3 we shall come back to this issue, assuming a large enhancement of the EW penguins.

Since we are considering only $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$ decays, new physics can be incorporated very generally by modifying the two amplitudes (11) and (12). To this end we write in a completely general way

$$A(B^+ \to \pi^+ K^0) = P' + P_d^{\rm new} \tag{14}$$

$$A(B^0_d \to \pi^- K^+) = -\left(P' + T' + P_u^{\rm new}\right), \tag{15}$$

where $P_d^{\rm new}$ and $P_u^{\rm new}$ are the new physics contributions to $\bar{b} \to \bar{s} d \bar{d}$ and $\bar{b} \to \bar{s} u \bar{u}$ quark-level transitions, respectively.

We are obviously not in a position to fix the two complex amplitudes from present data. This means that additional assumptions have to be made in order to reduce the number of unknown parameters. In principle one could refer now to commonly used models for physics beyond the SM to estimate the new physics contributions [9, 10]. Here we shall simply use some generic assumptions related to the behaviour of the new physics under isospin. Although these additional assumptions may appear ad hoc, we think that they are of at least comparable use as the model estimates performed before.

Our first assumption is that no direct CP violation shows up in the new physics contributions to the decays under consideration, i.e.

$$|\overline{P_q^{\rm new}}| = |P_q^{\rm new}|, \tag{16}$$

where $q \in \{d, u\}$ and the overlined amplitudes correspond to the charge-conjugate processes. In that particular case the $P_q^{\rm new}$ amplitudes can be expressed as

$$P_q^{\rm new} = e^{i\phi_q} e^{i\delta_q^{\rm new}} |P_q^{\rm new}|, \tag{17}$$

where $\delta_q^{\rm new}$ is a CP-conserving strong phase and ϕ_q a CP-violating weak phase so that we have

$$\overline{P_q^{\rm new}} = e^{-i\phi_q} e^{i\delta_q^{\rm new}} |P_q^{\rm new}| . \tag{18}$$

Taking into account (see e.g. [3, 6])

$$P' = -e^{i\delta_{P'}}|P'| = \overline{P'}, \quad T' = e^{i\gamma}e^{i\delta_{T'}}|T'|, \quad \overline{T'} = e^{-i\gamma}e^{i\delta_{T'}}|T'| \tag{19}$$

and using (17), we get

$$\left\langle |A(B^\pm \to \pi^\pm K)|^2 \right\rangle = |P'|^2 \left(1 - 2\,\rho_d \cos\Delta_d \cos\phi_d + \rho_d^2\right) \tag{20}$$

$$\begin{aligned}\left\langle |A(B_d \to \pi^\mp K^\pm)|^2 \right\rangle = |P'|^2 \Big[&1 - 2\,r\cos\delta\cos\gamma - 2\,\rho_u \cos\Delta_u \cos\phi_u \\ &+2\,\rho_u\, r\,\cos(\Delta_u - \delta)\cos(\phi_u - \gamma) + \rho_u^2 + r^2\Big] ,\end{aligned} \tag{21}$$

where the "averages" are defined by $\langle |A|^2\rangle \equiv (|A|^2 + |\overline{A}|^2)/2$, $\delta \equiv \delta_{T'} - \delta_{P'}$ and $\Delta_q \equiv \delta_q^{\rm new} - \delta_{P'}$ denote differences of CP-conserving strong phases, and the parameters $\rho_q \equiv |P_q^{\rm new}|/|P'|$ measure the strengths of the new physics contributions relative to the QCD penguin amplitude.

We do not expect the quantities ρ_q to be small of the order M_W^2/Λ^2, where Λ^2 is the scale of new physics. While such a suppression is active for CKM allowed tree level processes, in our case $\rho_q = \mathcal{O}(0.5)$ is not unreasonable due to the loop suppression of the QCD penguins in the SM.

A striking effect of new physics in $B^\pm \to \pi^\pm K$ would be a large CP asymmetry

$$\mathcal{A}_{\rm CP}^{\rm dir}(B^+ \to \pi^+ K^0) \equiv \frac{{\rm BR}(B^+ \to \pi^+ K^0) - {\rm BR}(B^- \to \pi^- \overline{K^0})}{{\rm BR}(B^+ \to \pi^+ K^0) + {\rm BR}(B^- \to \pi^- \overline{K^0})} . \tag{22}$$

Within the SM only very small values of that asymmetry, at most of $\mathcal{O}(1\%)$ [11], can be accommodated[3], whereas interference between the QCD penguin and new physics contributions may lead to potentially large CP-violating effects in that decay which are described by

$$\mathcal{A}_{\rm CP}^{\rm dir}(B^+ \to \pi^+ K^0) = \frac{2\,\rho_d \sin\Delta_d\,\sin\phi_d}{1 - 2\,\rho_d\cos\Delta_d\,\cos\phi_d + \rho_d^2} \tag{23}$$

and require that both Δ_d and ϕ_d take values different from 0 or π.

One of the central ingredients of our approach [6] to constrain γ is the quantity

$$R \equiv \frac{\langle |A(B_d \to \pi^\mp K^\pm)|^2 \rangle}{|P'|^2} , \tag{24}$$

which is given within the SM, neglecting small phase-space and B lifetime differences, by the ratio (5). That is, however, not the case in the presence of new physics. In order to distinguish (5) from (24), we refer to the former ratio in the following discussion as $R_{\rm exp}$ since it can be obtained directly from the combined branching ratios that have been specified in (1) and (2). Another important quantity is the amplitude ratio (6). In [6]

[3]These tiny effects are neglected in our formulae.

we were using the combined branching ratio for $B^\pm \to \pi^\pm K$ to fix the magnitude of the QCD penguin amplitude P' yielding

$$r = \frac{|T'|}{\sqrt{\langle |A(B^\pm \to \pi^\pm K)|^2\rangle}}\,. \tag{25}$$

In the presence of new physics, the right-hand side of that equation does not measure (6). Since that ratio will nevertheless play an important role for our considerations, we refer to (25) in the following as $r_{\rm exp}$. Strategies to fix $|T'|$ are discussed in [6].

In order to derive constraints from the combined $B \to \pi K$ branching ratios (1) and (2), the combination

$$C \equiv \frac{1-R}{2\,r} + \frac{1}{2}\,r \tag{26}$$

of R and r plays a central role as we have pointed out in [6]. Within the SM, this quantity is simply given by the product of $\cos\delta$ and $\cos\gamma$. Taking into account possible contributions from new physics, we get

$$C_{\rm new} \equiv \frac{1-(R_{\rm exp}+R_{\rm new})}{2\,r_{\rm exp}} + \frac{1}{2}\,r_{\rm exp} = \frac{\cos\delta\cos\gamma - \rho_u\cos(\Delta_u-\delta)\cos(\phi_u-\gamma)}{\sqrt{1-2\,\rho_d\cos\Delta_d\cos\phi_d+\rho_d^2}}\,, \tag{27}$$

where

$$R_{\rm new} \equiv \frac{2\,(\rho_u\cos\Delta_u\cos\phi_u - \rho_d\cos\Delta_d\cos\phi_d)+\rho_d^2-\rho_u^2}{1-2\,\rho_d\cos\Delta_d\cos\phi_d+\rho_d^2}\,. \tag{28}$$

Consequently new physics manifests itself in two ways: first the relevant value of R is shifted from its measured value $R_{\rm exp}$ by $R_{\rm new}$, and second $C_{\rm new}$ is no longer related in a simple way to $\cos\gamma$, i.e. to the weak CP-violating phase of the T' amplitude. Let us note that our expressions are still very general since we have so far only used (16) to simplify our analysis.

3 Scenarios of new physics in $B \to \pi K$ decays

In order to proceed further, we have to make additional assumptions to reduce the number of unknown parameters. To this end we will focus on some scenarios of new physics. A very transparent one is discussed in the following subsection.

3.1 New physics I: $SU(2)$ isospin-symmetric case

One of the basic assumptions in this subsection is that the new physics contributions are equal for $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$, i.e. couple equally to d- and u-quarks, so that we have

$$\begin{aligned} \phi_d &= \phi_u = \phi \\ \rho_d &= \rho_u = \rho \\ \Delta_d &= \Delta_u = \Delta \end{aligned} \tag{29}$$

implying $R_{\rm new} = 0$. In fact, isospin is conserved in many new physics scenarios, such as models with enhanced chromomagnetic dipole operators [12].

In addition we assume that the strong phase difference between the QCD penguin and the new physics contributions vanishes, i.e. $\Delta = 0$. Consequently the CP asymmetry (23) for $B^+ \to \pi^+ K^0$ is zero in that case as in the SM. Combining all these assumptions we get

$$C_{\rm new} = \frac{1 - R_{\rm exp}}{2\, r_{\rm exp}} + \frac{1}{2}\, r_{\rm exp} = \cos\delta\, \cos\gamma_{\rm exp} \tag{30}$$

and

$$\mathcal{A}_{\rm CP}^{\rm dir}(B_d^0 \to \pi^- K^+) = 2\, \frac{r_{\rm exp}}{R_{\rm exp}}\, \sin\delta\, \sin\gamma_{\rm exp}\,, \tag{31}$$

where

$$\gamma_{\rm exp} = \gamma + \Gamma \tag{32}$$

with

$$\cos\Gamma = \frac{1 - \rho\, \cos\phi}{\sqrt{1 - 2\,\rho\, \cos\phi + \rho^2}}\,, \quad \sin\Gamma = \frac{\rho\, \sin\phi}{\sqrt{1 - 2\,\rho\, \cos\phi + \rho^2}}\,. \tag{33}$$

Therefore the experimentally determined angle $\gamma_{\rm exp}$ is not equal to the weak phase γ of the T' amplitude, but is shifted by Γ.

There are several strategies for experimental determinations of γ on the market [3]. Within the SM, these methods would all yield the same value of γ. Once new physics shows up, differences may appear between these results since one type of strategies refers to charged B decays originating from $b \to c\bar{u}s$ ($\bar{b} \to \bar{u}c\bar{s}$) transitions that receive only current-current and no penguin contributions [13], while another type uses $B_s^0 - \overline{B_s^0}$ mixing [14]. Since new physics is expected to affect these mixing processes significantly – in particular the corresponding mixing phase – as they are suppressed FCNC loop processes [9], the latter methods are sensitive to physics beyond the SM similarly as our penguin dominated $B \to \pi K$ modes. In the case of the former strategies, only small effects of new physics are expected since they are using essentially pure "tree" decays and no FCNC processes.

In Fig. 1 we show the dependence of Γ on ϕ for various values of ρ. Since (30) and (31) have exactly the same form as the corresponding SM expressions, the formalism developed in [6] can be applied by making only the simple replacements $R \to R_{\rm exp}$, $r \to r_{\rm exp}$, $\gamma \to \gamma_{\rm exp}$. In particular, since $C_{\rm new}$ is still constrained between -1 and $+1$, the bounds on $r_{\rm exp}$ given in [6] still remain valid. Consequently, whereas the overlap between (3) and (4) can be increased, the possible problem related to the constraints on $r_{\rm exp}$ that we have pointed out in [6], namely that any reasonable estimate of this amplitude ratio is only marginally compatible with the present CLEO measurements, cannot be solved using this simple scenario.

3.2 New physics II: $SU(2)$ isospin symmetry violation

A scenario of new physics which potentially cures the problem with the value of $r_{\rm exp}$ is one in which the new physics contributions couple differently to d- and u-quarks and hence violate isospin as is e.g. the case in models where a heavy boson is mediating additional $b \to s$ FCNC contributions. In order to implement this in a managable "toy" model, we

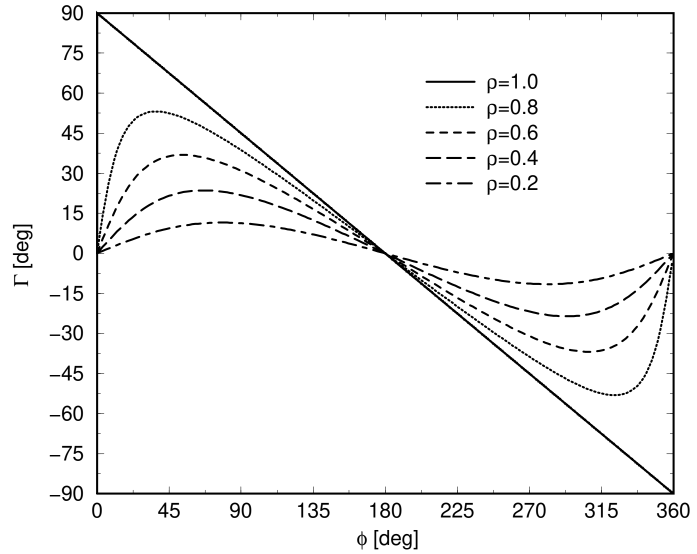

Figure 1: The dependence of Γ on ϕ for various values of ρ.

assume

$$\begin{aligned} \phi_d &= \phi_u = 0 \\ \Delta_d &= \Delta_u = 0\,. \end{aligned} \tag{34}$$

The vanishing of these phases is certainly a restrictive assumption. It is only meant to demonstrate that (27) and (28) incorporate a possible solution to the potential consistency problem with γ and $r_{\rm exp}$. In the case of our specific $SU(2)$-violating scenario of new physics, these expressions simplify considerably to

$$C_{\rm new} = \left(\frac{1-\rho_u}{1-\rho_d}\right) \cos\delta\,\cos\gamma \tag{35}$$

$$R_{\rm new} = \frac{(\rho_u-\rho_d)\,(2-\rho_u-\rho_d)}{(1-\rho_d)^2}\,, \tag{36}$$

so that the bound γ_0 is given by

$$\gamma_0 = \arccos\left[\left(\frac{1-\rho_d}{1-\rho_u}\right)\,C_{\rm new}\right]. \tag{37}$$

Analogously to our recent paper [6], we show in Fig. 2 the dependence of γ_0 on $r_{\rm exp}$ for fixed $R_{\rm exp}=0.65$ corresponding to the central values of the recent CLEO measurements and various values of (ρ_u,ρ_d). The new physics affects also the direct CP-violating asymmetry of the decay $B_d\to\pi^\mp K^\pm$ as can be seen in Fig. 3, where we plot the maximal value

$$\left|\mathcal{A}_{\rm CP}^{\rm dir}(B_d^0\to\pi^-K^+)\right|_{\rm max} = 2\,\frac{r_{\rm exp}}{R_{\rm exp}}\left[\left(\frac{1-\rho_u}{1-\rho_d}\right)-|C_{\rm new}|\right] \tag{38}$$

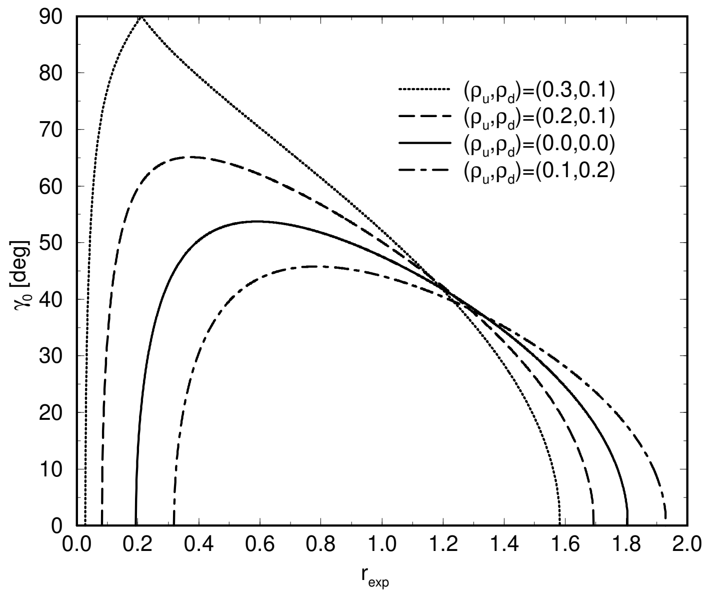

Figure 2: The dependence of γ_0 constraining the CKM angle γ through (4) on $r_{\rm exp}$ for a specific scenario of new physics discussed in the text and $R_{\rm exp} = 0.65$ corresponding to the central values of the present CLEO measurements.

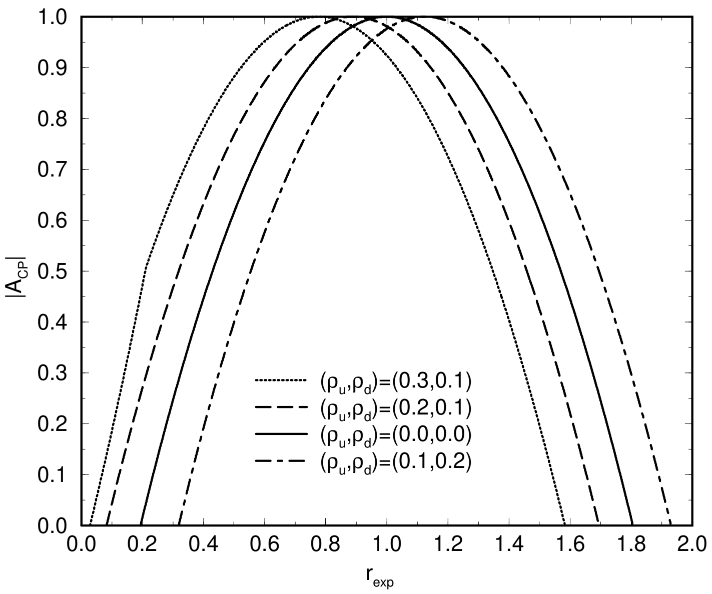

Figure 3: The dependence of the maximal value (38) of $|A_{\rm CP}^{\rm dir}(B_d^0 \to \pi^- K^+)|$ on $r_{\rm exp}$ for $R_{\rm exp} = 0.65$ and a specific scenario of new physics.

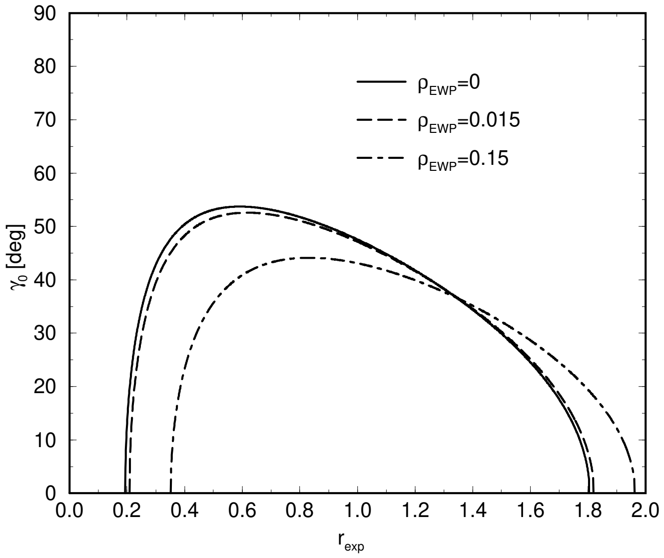

Figure 4: The dependence of γ_0 constraining the CKM angle γ through (4) on $r_{\rm exp}$ for $R_{\rm exp} = 0.65$ in the presence of enhanced EW penguins. The dashed line corresponds to the SM expectation for these operators.

of that asymmetry on $r_{\rm exp}$ for $R_{\rm exp} = 0.65$ and various values of (ρ_u, ρ_d). Looking at these figures, we observe that one can indeed incorporate smaller values of $r_{\rm exp}$ and larger values of $\gamma_0^{\rm max}$ in our simple isospin-breaking toy model if ρ_u is larger than ρ_d. As far as the CP asymmetry is concerned, the curves for $\rho_u > \rho_d$ are shifted towards smaller $r_{\rm exp}$ compared to the SM case so that larger CP asymmetries can be accommodated.

Also the SM has, however, an interesting source of isospin breaking, namely EW penguins. Since their contributions to the decays discussed in our paper are expected to be negligibly small within the SM, the corresponding amplitudes have been neglected so far. In the next paragraph we will discuss their impact on our analysis in slightly more detail by assuming a dramatic enhancement.

3.3 New physics III: enhanced EW penguin contributions

The EW penguin contributions can easily be incorporated into our formulae by using

$$
\begin{aligned}
\rho_d &= \frac{1}{3}\rho_{\rm EWP}, \quad \phi_d = 0 \\
\rho_u &= \frac{2}{3}\rho_{\rm EWP}, \quad \phi_u = \pi. \qquad (39)
\end{aligned}
$$

Moreover we assume $\Delta_d = \Delta_u = 0$. The quantity $\rho_{\rm EWP}$ has been introduced already in (13) and measures the strength of the color-suppressed EW penguin contributions with respect to the QCD penguin amplitude. Based on the estimates in [6] one finds $\rho_{\rm EWP}$ in the range of one to two percent.

Let us assume that non-perturbative effects in the hadronic matrix elements of the corresponding EW penguin operators or new physics effects give an enhancement of $\rho_{\rm EWP}$ by a factor of $\mathcal{O}(10)$ with respect to our simple estimates. This is shown in Fig. 4, where we have again used the central values of the CLEO measurements to fix $R_{\rm exp}$. From this figure we conclude that the SM contribution of the EW penguins is indeed negligible, and that a QCD enhancement tends to shift the bound γ_0 towards higher values of $r_{\rm exp}$. Hence it will probably not be able to cure the potential problem with the amplitude ratio $r_{\rm exp}$. Moreover, an artificially enhanced EW penguin contribution will lower γ_0 leaving thus less overlap with the conventional bounds (3). For these considerations we have assumed that the strong interaction effects enhancing the EW penguins will not drastically change the CP-conserving strong phases of the EW penguin amplitudes. This assumption is questionable and for a large phase shift, as e.g. $\Delta_d \approx \Delta_u \approx \pi$, the situation could as well reverse.

4 Conclusions

It is generally accepted that penguin dominated decays of B mesons may be sensitive to new physics effects at a level which makes them interesting probes for non-SM effects. While this type of decays clearly will not be able to discriminate between different high energy scenarios, it still may turn out to be the first hint on physics beyond the SM. In [6] we have pointed out that already combined branching ratios for $B^\pm \to \pi^\pm K$ and $B_d \to \pi^\mp K^\pm$ decays may lead to potential problems for the SM if the CLEO measurements should stabilize at their present central values. Firstly, the amplitude ratio $r_{\rm exp}$ of the current-current and the QCD penguin amplitudes is at the edge of compatibility with the SM, secondly the allowed range for γ obtained from the combined $B \to \pi K$ branching ratios has only a small overlap with the conventional determination of this angle, and thirdly a future measurement of the CP asymmetry in $B_d \to \pi^\mp K^\pm$ may lead to a surprise.

The most general ansatz introducing new physics into these decays turns out to have too many parameters to be useful. Hence some additional theoretical assumptions have to enter the game. A first restriction we have applied is to assume that the new physics contributions do not exhibit direct CP violation in the decays under consideration. We have given the expressions for the relevant observables in that particular case. They still involve six parameters related to new physics so that a general analysis becomes too clumsy.

In order to proceed further, we have discussed three cases which we consider interesting, but which are of course quite restrictive. The first example assumes that the new physics contributions to the decays at hand are symmetric under $SU(2)$ isospin. In that case the experimentally determined value $\gamma_{\rm exp}$ of γ is simply shifted by some angle Γ depending on the new physics. Interestingly, while this scenario offers a solution of the potential problem with γ, it cannot solve the one related to $r_{\rm exp}$. The second example was taylored to tackle that problem. Here we assume that new physics breaks isospin. Making certain assumptions concerning strong and weak phases of the new physics, we have shown that appropriate isospin-breaking could indeed cure the potential problem with $r_{\rm exp}$ as well as the one with γ.

Finally we reconsider the isospin-breaking due to EW penguin operators which are already present in the SM. Estimates suffering from large hadronic uncertainties indicate that EW penguins should play a negligible role in the decays under consideration within the SM. An interesting observation is that the EW penguin contributions tend to shift the results such that the potential problems with consistency of the SM become worse. Even if for some reason the EW penguins become dramatically enhanced, they will not cure these potential problems unless rescattering effects yield large CP-conserving strong phase shifts as e.g. $\Delta_d \approx \Delta_u \approx \pi$.

Although the hadronic uncertainties in $B \to \pi K$ modes, which are exclusive non-leptonic B decays, are very large, these transitions may play an important role concerning the search for new physics. At first sight, this statement seems to be contradictory. However, the SM predicts the general phase structure of the corresponding decay amplitudes on solid ground. Moreover isospin symmetry of strong interactions – working very well within the SM – allows to derive relations among these decay amplitudes. Consequently, combining experimental data for $B \to \pi K$ in a clever way, the consistency of that description can be tested. Since experimental data on these decays is now starting to become available, certainly an exciting time is ahead of us and a future reduction of the presently large experimental uncertainties may shed light on physics beyond the SM.

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