Analysis of $B \rightarrow K\pi$ decays with small elastic final state interactions

Claudia Isola and T. N. Pham

Centre de Physique Thorique,
Centre National de la Recherche Scientifique, UMR 7644,
Ecole Polytechnique, 91128 Palaiseau Cedex, France

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Abstract

An analysis of $B \rightarrow K\pi$ decays is given, assuming a small elastic $\pi K$ rescattering phase difference. Using factorization model elastic $\pi K$ rescattering phase difference. Using factorization model only for the tree-level and electroweak penguin amplitudes, we show that the strong penguin amplitude, its absorptive part and the CP-violation weak phase $\gamma$ can be obtained from the measured $B \rightarrow K\pi$ branching ratios. The strength of the strong penguin and its absorptive part thus obtained from the CLEO data, are found to be very close to factorization model values and suggests a current $s$ quark mass around $m_s = 106$ MeV. The central value of $\gamma$ is found to be around 76.10°, with a possible value in the range $50^\circ - 100^\circ$.
The recent CLEO data [1] on charmless two-body nonleptonic $B$ decays indicates that non-leptonic interactions enhanced by short-distance QCD radiative corrections combined with factorization model seems to describe qualitatively the $B \to K\pi$ decays. In particular, the penguin interactions contribute a major part to the decay rates and provide an interference between the Cabibbo-suppressed tree and penguin contribution resulting in a CP-asymmetry between the $B \to K\pi$ decay and its charge conjugate mode. Though the data are not yet sufficiently accurate to allow a determination of the weak CP-violating phase $\gamma$, they seem to favor a large $\gamma$ in the range of $(90^\circ - 120^\circ)$, as shown in a previous analysis of $B \to K\pi$ using the factorization model with elastic rescattering phase included [2]. This large value of $\gamma$ is also found by the CLEO Collaboration in an analysis of all measured charmless two-body $B$ decays with the factorization model [3]. A large $\gamma$ would also help to explain the suppression of the $\bar{B}^0 \to \pi^+\pi^-$ decays as the interference between the tree-level and penguin terms which increases the $B \to K\pi$ decay rates, becomes destructive in $B \to \pi\pi$ decays. However, as shown in our previous analysis, a large $\gamma$ would require a large $\pi K \to \pi K$ rescattering phase difference in the range $(50^\circ - 100^\circ)$ to account for the near-equality of the two largest $\bar{B}^0 \to K^-\pi^+$ and $B^- \to \bar{K}^0\pi^-$ branching ratios. Although a large elastic rescattering phase is not excluded by experiments, it is not expected in high energy elastic $\pi K$ scattering which is dominated by the isospin-independent Pomeron exchange amplitude so that the rescattering phase difference $\delta = \delta_{3/2} - \delta_{1/2}$ would be small in $B$ decays. Indeed, a recent analysis of $\pi K$ elastic scattering at the $B$ mass [4] finds $\delta = (17 \pm 3)^\circ$. For $B \to K\pi$, from the factorization model, if $\gamma < 110^\circ$, with some adjustment of form factors, the current $s$ quark mass and CKM parameters it might be possible to accommodate the two largest branching ratios with a small $\delta$. It is thus useful to study the consequence of a small $\delta$ in $B \to K\pi$ decays. Infact, as shown in Fig.1 in [2], for $\delta < 50^\circ$, the CP-averaged $B \to K\pi$ branching ratios are practically independent of $\delta$ in this range, as the $\delta$-dependent terms which come from the small $\cos\delta - 1$ and the $\sin\delta$ term which is also very small. Since the strong penguin amplitude with its small inelastic absorptive part found in perturbative QCD [5,6] produce sufficiently the $B \to K\pi$ decay rates, it is likely
that, in general, the inelastic absorptive part should not be too large in $B \to K\pi$ decays. In this case, for $\delta < 50^\circ$, the $\delta$-dependent terms in the $B \to K\pi$ decay rates would be small and could be therefore neglected in the CP-averaged $B \to K\pi$ decay rates. In particular, for $\delta$ in this range, the $B^- \to \bar{K}^0\pi^-$ decay rate, is essentially given by the $\gamma$-independent strong penguin contribution. Now, if we assume factorization for the small tree-level and electroweak terms, the strong penguin and its absorptive part and $\gamma$ could then be obtained from the measured CP-averaged $B \to K\pi$ decay rates. With the dominant strong penguin contribution obtained from experiments, the value of $\gamma$ thus obtained is subjected to very little theoretical uncertainties in contrast with the result from the factorization model for the whole amplitude as the penguin matrix elements are sensitive to the $s$ quark mass which is not known to a good accuracy. This is the main purpose of this paper. In the following, we shall obtain the strong penguin contribution and $\gamma$ from the measured $B \to K\pi$ decay rates, assuming factorization for the tree-level and electroweak penguin terms and a small $\pi K$ rescattering phase difference $\delta$. We find agreement with factorization model for the strong penguin contribution and its absorptive part. The value of $\gamma$ is found to be in the range $(50^\circ - 100^\circ)$, with a central value of $70^\circ$. To proceed, we begin by writing down the $B \to K\pi$ decay amplitudes in terms of the decay amplitudes into $I = 1/2$ and $I = 3/2$ final states [2,7],

$$A_{K^-\pi^0} = \frac{2}{3}B_3e^{i\delta_3} + \sqrt{\frac{1}{3}}(A_1 + B_1)e^{i\delta_1},$$

$$A_{\bar{K}^0\pi^-} = \frac{\sqrt{2}}{3}B_3e^{i\delta_3} - \frac{2}{3}(A_1 + B_1)e^{i\delta_1},$$

$$A_{K^-\pi^+} = \frac{\sqrt{2}}{3}B_3e^{i\delta_3} + \sqrt{\frac{2}{3}}(A_1 - B_1)e^{i\delta_1},$$

$$A_{\bar{K}^0\pi^0} = \frac{2}{3}B_3e^{i\delta_3} - \sqrt{\frac{1}{3}}(A_1 - B_1)e^{i\delta_1},$$

(1)

$A_1$ is the sum of the strong penguin $A_1^S$ and the $I = 0$ tree-level $A_1^T$ as well as the $I = 0$ electroweak penguin $A_1^W$ contributions to the $B \to K\pi I = 1/2$ amplitude; similarly $B_1$ is the sum of the $I = 1$ tree-level $B_1^T$ and electroweak penguin $B_1^W$ contribution to the $I = 1/2$ amplitude, and $B_3$ is the sum of the $I = 1$ tree-level $B_3^T$ and electroweak penguin
$B_3^W$ contribution to the $I = 3/2$ amplitude. Using the following effective Hamiltonian for $B \to K \pi$ decays\textsuperscript{38} \textsuperscript{10,11}

$$H_{\text{eff}} = \frac{G_F}{\sqrt{2}} [V_{ub} V_{us}^* (c_1 O_1^u + c_2 O_2^u) + V_{cb} V_{cs}^* (c_1 O_1^c + c_2 O_2^c)$$

$$- \sum_{i=3}^{10} (V_{tb} V_{ts}^* c_i) O_i] + \text{h.c.}, \quad (2)$$

where the $c_i$, at the next-to-leading logarithms, take the form of an effective Wilson coefficients $c_i^{\text{eff}}$ which contain also the penguin contribution from the $c$ quark loop\textsuperscript{38} \textsuperscript{10,11}, we obtain in the factorization model,

$$A_1^T = i \frac{\sqrt{3}}{4} V_{ub} V_{us}^* r a_2,$$

$$B_1^T = i \frac{1}{2 \sqrt{3}} V_{ub} V_{us}^* r \left[ - \frac{1}{2} a_2 + a_1 X \right],$$

$$B_3^T = i \frac{1}{2} V_{ub} V_{us}^* r [a_2 + a_1 X],$$

$$A_1^S = - i \frac{\sqrt{3}}{2} V_{ub} V_{us}^* r [a_4 + a_6 Y], \quad B_1^S = B_3^S = 0$$

$$A_1^W = - i \frac{\sqrt{3}}{8} V_{ub} V_{us}^* r [a_8 Y + a_{10}],$$

$$B_1^W = i \frac{\sqrt{3}}{4} V_{ub} V_{us}^* r \left[ \frac{1}{2} a_8 Y + \frac{1}{2} a_{10} + (a_7 - a_9) X \right],$$

$$B_3^W = - i \frac{3}{4} V_{ub} V_{us}^* r [(a_8 Y + a_{10}) - (a_7 - a_9) X], \quad (3)$$

where $r = G_F f_K F_0^{B \pi} (m_K^2 - m_B^2) / (m_B^2 - m_{B^*}^2)$, $X = (f_\pi / f_K) (F_0^{B \pi} (m_\pi^2) / F_0^{B \pi} (m_K^2)) (m_B^2 - m_{B^*}^2) / (m_B^2 - m_{B^*}^2)$, $Y = 2 m_{K^*}^2 / [(m_s + m_q) (m_b - m_q)]$ with $q = u, d$ for $\pi^{\pm,0}$ final states, respectively. In this analysis, $f_\pi = 133$ MeV, $f_K = 158$ MeV, $F_0^{B \pi} (0) = 0.33$, $F_0^{B K} (0) = 0.38$ \textsuperscript{12} \textsuperscript{14} ; $|V_{cb}| = 0.0395, |V_{cd}| = 0.224$ and $|V_{ub}| / |V_{cb}| = 0.08$ \textsuperscript{13}. We take $m_s = 120$ MeV. The value of $m_s$ is not known to a good accuracy, but a value around $(100 - 120)$ MeV inferred from $m_{K^*} - m_\rho$, $m_{D^+_s} - m_{D^+_s}$ and $m_{B^0_s} - m_{B^0_s}$ mass differences\textsuperscript{16} seems not unreasonable. $a_j$ are given in terms of the effective Wilson coefficients $c_j^{\text{eff}}$ ($N_c$ is the number of effective colors) by

$$a_j = c_j^{\text{eff}} + c_{j+1}^{\text{eff}} / N_c \quad \text{for } j = 1, 3, 5, 7, 9$$

$$a_j = c_j^{\text{eff}} + c_{j-1}^{\text{eff}} / N_c \quad \text{for } j = 2, 4, 6, 8, 10. \quad (4)$$
For $N_c = 3$ and $m_b = 5.0 \text{ GeV}$, $a_j$ take the following numerical values

\[a_1 = 0.07, \quad a_2 = 1.05, \]
\[a_4 = -0.043 - 0.016i, \quad a_6 = -0.054 - 0.016i, \]
\[a_7 = 0.00004 - 0.00009i, \quad a_8 = 0.00033 - 0.00003i, \]
\[a_9 = 0.00907 - 0.00009i, \quad a_{10} = -0.0013 - 0.00003i. \quad (5)\]

As pointed out in Ref. [2], $a_1$ is sensitive to $N_c$ and is rather small for $N_c = 3$. As there is no evidence for a large positive $a_1$ in $B \to K\pi$ decays which are penguin-dominated and are not sensitive to $a_1$, we use $a_1$ evaluated with $N_c = 3$ given in Eq.(5). Indeed, the predicted branching ratios remain essentially unchanged with $a_1 = 0.20$ taken from the Cabibbo-favored $B$ decays [13]. We note that the coefficients $c_{3}^{\text{eff}}, c_{4}^{\text{eff}}, c_{5}^{\text{eff}}$ and $c_{6}^{\text{eff}}$, are enhanced by the internal charm quark loop due to the large time-like virtual gluon momentum $q^2 = m_b^2/2$ as pointed out in [5,6] (the other electroweak penguin coefficients like $c_{7}^{\text{eff}}$ and $c_{9}^{\text{eff}}$ are not affected by the charm quark loop contribution in any significant amount). This enhancement of the strong penguin term increases the decay rates and bring the theoretical $B \to K\pi$ decay rates closer to the latest CLEO measurements. The tree-level amplitudes are suppressed relative to the penguin terms by the CKM factor $V_{ub}V_{us}^{\ast}/V_{tb}V_{ts}^{\ast}$ which can be approximated by $-(|V_{ub}|/|V_{cb}|) \times (|V_{cd}|/|V_{ud}|) \exp(-i \gamma)$ after neglecting terms of the order $O(\lambda^5)$ in the (bs) unitarity triangle. The $B \to K\pi$ decay rates then depend on the FSI rescattering phase difference $\delta = \delta_3 - \delta_1$ and the weak phase $\gamma$. The factorization model prediction for $B \to K\pi$ decays is shown in Fig.1 and Fig.4 of [2], where the $B \to K\pi$ branching ratios are plotted against $\delta$ for $\gamma = 70^\circ$ and $\gamma = 110^\circ$ respectively. As can be seen, factorization with the short-distance Wilson coefficients obtained by perturbative QCD reproduces qualitatively the CLEO data, which gives [1]

\[B(B^+ \to K^+\pi^0) = (11.6^{+3.0+1.4}_{-2.7-1.3}) \times 10^{-6}, \]
\[B(B^+ \to K^0\pi^+) = (18.2^{+4.6}_{-4.0} \pm 1.6) \times 10^{-6}, \]
\[B(B^0 \to K^+\pi^-) = (17.2^{+2.5}_{-2.4} \pm 1.2) \times 10^{-6}, \]
We remark that for $\delta < 50^\circ$, the $B \to K\pi$ branching ratios show practically no variation with $\delta$ which, as explained earlier, come from the small $\cos(\delta) - 1$ and the $\sin(\delta)$ term. Also the computed branching ratios for $\gamma = 110^\circ$ are somewhat larger than the values with $\gamma = 70^\circ$. Factorisation also shows that $B^- \to \bar K^0\pi^-$ and $\bar B^0 \to K^-\pi^+$ are the two largest modes, in qualitative agreement with the CLEO data which give near-equality of these two largest branching ratios. Fig.1 of [2] shows that the two largest branching ratios are quite apart, except for $\delta < 50^\circ$ where the difference of these two branching ratios becomes smaller, about $2.0 \times 10^{-6}$. For larger $\gamma$, as in Fig.4 of [2], this difference reverses the sign and become large for $\gamma = 110^\circ$, even for $\delta < 50^\circ$, except in a small region around $\delta = 50^\circ$. As mentioned earlier, this value of $\delta$ seems too large compared with a theoretical value of $(17 \pm 3)^\circ$ [4]. We thus have to accommodate the $B \to K\pi$ data with $\delta < 50^\circ$ and $\gamma < 110^\circ$. We now assume that $\delta < 50^\circ$ and proceed to the determination of the strong penguin contribution and the weak phase $\gamma$ from the CP-averaged $B \to K\pi$ branching ratios assuming factorization for the tree-level and electroweak penguin contributions. A test of factorization for the strong penguin contribution could then be made by comparing the value obtained from experiments with the factorization prediction. The value for $\gamma$ thus obtained will not suffer from the uncertainties in the computation of the strong penguin matrix elements. For this purpose we need the $B^- \to \bar K^0\pi^-$ branching ratio for which the $\delta$-dependent terms are neglected and two other $\delta$-independent quantities obtained from the $B^- \to \bar K^0\pi^-$, $B^- \to K^-\pi^0$ and $\bar B^0 \to K^-\pi^+$ decay rates given by [2]

\[
Q_{12} = r_b \left[ B(B^- \to K^-\pi^0) + B(B^- \to \bar K^0\pi^-) \right]
\]

\[
Q_{23} = r_b B(B^- \to \bar K^0\pi^-) + B(\bar B^0 \to K^-\pi^+)
\]

\[
Q_2 = r_b B(B^- \to \bar K^0\pi^-)_{\delta=0}
\]

where $r_b = \tau_{B^0}/\tau_{B^-}$. Similarly,

\[
Q_{34} = B(\bar B^0 \to K^-\pi^+) + B(\bar B^0 \to \bar K^0\pi^0)
\]
\[ Q_{14} = r_b B(B^+ \rightarrow K^-\pi^0) + B(B^0 \rightarrow K^0\pi^0) \].

The strong penguin amplitude \( A^S_1 \), in the factorization model, is proportional to \( a_4 + a_6 Y \).

We now consider the quantity \( a_4 + a_6 Y \) as a parameter and write \( P \exp(ih) = -10\sqrt{3}(a_4 + a_6 Y)/2 \). \( P \sin h \) is then the absorptive part of the strong penguin amplitude. \( A^S_1 \) is now given by

\[
A^S_1 = i \frac{1}{10} V_{tb} V_{ts}^* r P \exp(ih),
\]

where we have parametrised the strong penguin amplitude in terms of the quantity \( r \) as in the factorization model. With factorization for the tree-level and electroweak penguin amplitude, the \( B \rightarrow K\pi \) decays branching ratios can now be obtained in terms of 3 parameters, \( P \), the inelastic strong phase \( h \) and \( \gamma \) which can now be determined from experiments. In Eq. (9), \( Q_2 \) is the \( B^- \rightarrow \bar{K}^0\pi^- \) branching ratio (CP-averaged) evaluated for \( \delta = 0 \), at which the tree-level term vanished. \( Q_2 \) gives us the strength of the penguin contribution \( P \). \( Q_{12} \) and \( Q_{23} \), can then determine \( P \cos h \) and \( \cos \gamma \). As the experimental errors is larger in \( B(B^0 \rightarrow \bar{K}^0\pi^0) \), we have used \( Q_{23} \) which is also \( \delta \)-independent to a good approximation, instead of the quantity \( Q_{34} \) which is the sum of \( B(B^0 \rightarrow K^-\pi^+) \) and \( B(B^0 \rightarrow \bar{K}^0\pi^0) \). With the numerical values for the effective Wilson coefficients of the tree-level and electroweak operators and the BWS value for the form factors [14], we find, for the CP-averaged branching ratios,

\[
Q_{12} = (3.984 P^2 + 0.301 P \cos h - 0.459 P \cos h \cos \gamma \\
-0.057 \cos \gamma + 0.060) \times 10^{-5}
\]

\[
Q_{23} = (5.312 P^2 + 0.030 P \cos h - 0.862 P \cos h \cos \gamma \\
-0.010 \cos \gamma + 0.070) \times 10^{-5}
\]

\[
Q_2 = (2.656 P^2 - 0.030 P \cos h) \times 10^{-5}.
\]

Similarly, we obtain,

\[
Q_{34} = (3.984 P^2 - 0.256 P \cos h - 0.834 P \cos h \cos \gamma \\
-0.013 \cos \gamma + 0.089) \times 10^{-5}
\]
\begin{align*}
Q_{14} &= (2.656 P^2 + 0.015 P \cos h - 0.431 P \cos h \cos \gamma \\
&\quad - 0.060 \cos \gamma + 0.079) \times 10^{-5}.
\end{align*}

(11)

In the expressions for \(Q_{23}\) and \(Q_{14}\) shown above, a negligible \(\cos \delta \cos \gamma\) term of the order \(10^{-7}\) has been included for completeness. Comparing \(Q_{23}\) and \(Q_{14}\) in Eq.\((10)\) and Eq.\((11)\), we find,

\[
rbB_{\bar{K}^0\pi^-} + B_{K^-\pi^+} = 2 [B_{\bar{K}^0\pi^0} + rbB_{K^-\pi^0}]
\]

valid up to a small \(\delta\)-dependent term \(\Delta\) (\(C\) being the usual phase space factor)

\[
\Delta = \left\{ \Gamma(B^- \to \bar{K}^0\pi^-) + \Gamma(B^0 \to K^-\pi^+) \\
- 2 \left[ \Gamma(B^- \to K^-\pi^0) + \Gamma(B^0 \to \bar{K}^0\pi^0) \right] \right\} \tau_{B^0} \\
= \left[ -\frac{4}{3} |B_3|^2 - \frac{8}{\sqrt{3}} \text{Re}(B_3^*B_1e^{i\delta}) \right] (C\tau_{B^0})
\]

(13)

which is of the order \(O(10^{-6})\). Eq.\((12)\) then gives, to a good approximation

\[
B_{\bar{K}^0\pi^0} = (1/2)(rbB_{\bar{K}^0\pi^-} + B_{K^-\pi^+}) - rbB_{K^-\pi^0}.
\]

(14)

The CLEO data [1] then gives,

\[
B_{\bar{K}^0\pi^0} = (0.60^{+0.7}_{-0.6}) \times 10^{-5}.
\]

(15)

The above predicted central value is smaller than the CLEO value, but a more precise test of this relation must await further measurements of the \(B \to K\pi\) decays, when a more accurate value for the \(B^0 \to \bar{K}^0\pi^0\) branching ratio. For this reason, we shall not use the measured value for \(B_{\bar{K}^0\pi^0}\) and use only the 3 quantities \(Q_2\), \(Q_{12}\) and \(Q_{23}\) given in Eq.\((10)\) in our determination of \(P\), \(h\) and \(\gamma\) in this analysis. We note that \(Q_2\), which is almost independent of \(\gamma\) and \(P \cos h\), allows a determination of the strength of the strong penguin interactions \(P\). Infact, by neglecting terms of the order \(10^{-6}\) or smaller in \(Q^2\), we find, using the measured value for \(B(B^+ \to \bar{K}^0\pi^+),\)
\[ P = 0.81 \pm 0.12 \]  
(16)
to be compared with
\[ P_0 = 0.77 \]  
(17)

obtained from perturbative QCD and factorization model with \( m_s = 120 \text{ MeV} \) and normalised with the BSW form factor \[ \text{[2]} \]. This suggests that factorization model could accommodate the \( B^+ \rightarrow K^0 \pi^+ \) branching ratio with \( m_s = 106 \text{ MeV} \). It is more difficult to obtain \( P \cos h \) and \( P \cos h \cos \gamma \) as these terms are present in the decay rates with small coefficients and the large experimental errors in the current measured branching ratios. However, if we consider the quantity \( D_{23} = Q_{23} - 2Q_2 \) and \( D_{12} = Q_{12} - 1.5Q_2 \) obtained from Eq.(10), as given by,

\[
D_{23} = (-0.86 P \cos h \cos \gamma + 0.09 P \cos h + 0.07) \times 10^{-5}
\]

\[
D_{12} = (-0.459 P \cos h \cos \gamma + 0.345 P \cos h + 0.057 \cos \gamma + 0.060) \times 10^{-5}
\]

(18)

we can infer from the data which show the near-equality of the two largest branching ratios \( B_{K^0\pi^-} \) and \( B_{K^-\pi^+} \) that \( P \cos h \) is \( O(1) \) and \( \cos \gamma \) is smaller, of the order \( O(10^{-1}) \). This shows that the absorptive part of the strong penguin contribution is not large and the weak phase angle \( \gamma \) should be around \( 90^\circ \). Indeed, by solving Eq.(10) for \( P^2, P \cos h \) and \( P \cos h \cos \gamma \) with the central values for the measured quantities \( Q_2, Q_{12} \) and \( Q_{23} \), we find,

\[
P^2 = 0.668, \quad P \cos h = 0.826, \quad \cos \gamma = 0.240
\]

(19)

which gives,

\[
P = 0.817, \quad \cos h = 1.01, \quad \gamma = 76.10^\circ .
\]

(20)
The value for \( P \), as mentioned, is quite closer to value of 0.77 obtained from perturbative QCD and factorization model with \( m_s = 120 \text{ MeV} \). It is not surprising to obtain a value for
cos h slightly unphysical, because of large errors in the measured branching ratios. This value indicates that sin h should be small and hence a small absorptive part for the strong penguin contribution. This is consistent with the theoretical value obtained with perturbative QCD and factorization which gives cos h = 0.95. As the current measured values for the branching ratios have large experimental uncertainties, of the order few times 10^{-6}, it is not very meaningful to quote the experimental errors in the determination of γ. The value of P is better determined, with an errors of about 10%. Taking account of large experimental errors, we can say that h should be around 17° as suggested by QCD and γ should be in the range (50 − 100)°. Infact, as shown in Fig.1, where D_{12} and D_{23} obtained with cos h = 0.95 is plotted against γ, the very small CLEO measured values for D_{23} and D_{12} would suggest a possible value of γ in the range (50 − 100)°.

Taking the central value P = 0.817 and γ = 76.10° obtained above and cos h = 0.95 as suggested by QCD, we give in Fig.2 the CP-averaged B → Kπ branching ratios plotted against the rescattering phase difference δ. As can be seen, for δ below 50°, as assumed in this analysis, the CP-averaged branching ratios show no visible variation with δ, consistent with our assumption that we can put δ = 0 in the computation of the CP-averaged branching ratios.

The CP-asymmetries in B → Kπ decays can now be obtained by including the δ-dependent terms in the branching ratios. As shown in Fig.3, we find that the asymmetries can be appreciable, in the range 10 − 15% for the absolute CP-asymmetries, except for the \Bar{B}^{0} \rightarrow \Bar{K}^{0} \pi^{0} mode, for which the asymmetries could amount to 20 − 25%.

In conclusion, we have shown that, as long as the elastic πK rescattering phase difference is less than 50°, a determination of the strong penguin contribution as well as its absorptive part could be done with the measured CP-averaged B → Kπ branching ratios using only factorization for the tree-level and electroweak penguin amplitudes as theoretical input. We have found that the strength of the strong penguin amplitude and its absorptive part are very close to perturbative QCD and factorization and suggests a value of m_s = 106 MeV. The value for γ is found to be in the range 50° − 100°. With small rescattering phase
difference, we found that the CP-asymmetries are in the range $10 - 15\%$. More precise data is needed for a precise determination of $\gamma$ without the use of factorization model for the strong penguin matrix elements, as done in this analysis.
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FIG. 1. The curves (a) for $D_{23}$ and (b) for $D_{12}$ versus $\gamma$
FIG. 2. $B(B \to K\pi)$ vs. $\delta$ for $\gamma = 76^\circ$. The curves (a), (b), (c), (d) are for the CP-averaged branching ratios $B^- \to K^-\pi^0$, $\bar{K}^0\pi^-$ and $\bar{B}^0 \to K^-\pi^+$, $\bar{K}^0\pi^0$, respectively.

FIG. 3. The asymmetries vs.$\delta$ for $\gamma = 76^\circ$. The curves (a), (b), (c), (d) are for $A_{sB^-\to K^-\pi^0}$, $A_{sB^-\to \bar{K}^0\pi^-}$, $A_{s\bar{B}^0\to K^-\pi^+}$, $A_{s\bar{B}^0\to \bar{K}^0\pi^0}$,