Looking for forward backward asymmetries in $B \to K\mu^+\mu^-$ and $K^+ \to \pi^+\mu^+\mu^-$

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Abstract

We investigate the possibility of scalar interaction affecting the forward backward asymmetry in the decay mode $B \to K\mu^+\mu^-$. Using the scalar contribution and advocating Cheng-Sher type ansatz we obtain sizable forward backward asymmetry. Furthermore, we study the effect of the scalar interaction in $K^+ \to \pi^+\mu^+\mu^-$. It is pointed out that non-zero forward backward asymmetry in $B \to Kl^+l^-$, if found in future B-factories, may indicate the new physics in the scalar sector.

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Standard model is very successful, as verified by the data, but it is still believed that physics beyond the standard model (SM) might be around the corner. Experimental searches are on for the same while we look into some avenue where we expect it to be observable. In this context we would like to study the forward backward asymmetries \((A_{FB})\) in \(B \to K \mu^+ \mu^-\) and \(K^+ \to \mu^+ \mu^-\), with a hope that they might be observed in future. The basic idea behind this study is that of the possible new physics in the scalar sector, i.e., through the neutral Higgs boson contribution leading to flavor changing neutral current (FCNC) at the tree level. We are therefore interested to study the forward backward (FB) asymmetries in the decay modes and some related processes which are governed by the quark level processes \(d_i \to d_j l^+ l^-\) \((d_i = b, s, d)\). To begin with, we point out that there exist many works in the literature involving these processes in the standard model framework and also in many beyond the standard model extensions [1-12]. So, we will not attempt to repeat this here but mention the salient features and use basic formulae needed, wherever necessary, to illustrate the idea.

It should be reminded here that forward backward asymmetries are identically zero in the framework of the standard model for the decay modes under consideration, i.e., in \(B \to K \mu^+ \mu^-\) and \(K^+ \to \pi^+ \mu^+ \mu^-\), since scalar interactions are absent in them and the forward backward asymmetry involves (see (8)) the scalar term. So in order to have nonzero forward backward asymmetry we must have a scalar term, whose presence (that is nonzero FB asymmetry in \(B \to K \mu^+ \mu^-\)) will give an unambiguous signal of new physics in the scalar sector. We note that in the most elegant extension of the standard model, i.e., in MSSM one requires the extension of the Higgs sector and of course the same in many extensions of the SM.

The standard model Higgs is the most sought after particle in the upcoming collider experiments, which is the missing part in the SM so far and is expected to be discovered very soon. Then Higgs sector will be subjected to more stringent tests and possible existence of the extension of Higgs sector may be confirmed thereafter. On the other hand observation of nonzero FB asymmetry in \(B \to K \mu^+ \mu^-\) or \(K^+ \to \pi^+ \mu^+ \mu^-\) will provide an invaluable clue to the existence of neutral Higgs boson contribution in this decay mode and make inroads necessary for the extension of the Higgs sector.

Unfortunately, we have not observed any \(A_{FB}\) so far [13, 14] but in the future B experiments FB asymmetry will be investigated thoroughly and therefore we give another close look at the possibility of tree level contribution to \(b \to s l^+ l^-\) process, keeping in mind the
renewed interests concerning the Z-induced FCNC in the literature and also the very recent split supersymmetry idea, where one can have tree level contributions. In order to implement the idea we use the idea of Cheng and Sher for the FCNC. FCNC suppression is naturally taken care of by the power form of the quark masses involved in the process concerned (for details see [15]). It might be possible that we have not been able to see this kind of interaction because of the lower masses involves in the light hadron sector but in the decays involving second and third generation quarks, i.e., in $b \rightarrow s$ decays the masses being larger so there is a possibility that it might be observable in these decays, which is being subjected to tests in the currently running B factories and so will continue in the future B-experiments. Whether or not we will be able to see any existence of tree level FCNC contribution will be verified in the future B related experiments but at least from theoretical point of view we would like to see whether it does make any sense or not, i.e., whether we can really have any indication of new physics, at least with this kind of idea. We take the ansatz as $(m_i m_j)^{1/2}/v$, where $m_{i,j}$ are the masses of the quarks involved and $v$ is the vev.

Here we present the relevant formulae used and provide some details, which are necessary. The most general effective lagrangian for the decay mode $B \rightarrow K \mu^+ \mu^-$ can be written as [16]

$$\mathcal{M} = \frac{G_F \alpha}{\sqrt{2} \pi} V_{tb} V_{ts}^* \left[ F_S \bar{l}l + F_P \bar{l} \gamma_5 l + F_V p^\mu \bar{l} \gamma_\mu l + F_A p^\mu \bar{l} \gamma_\mu \gamma_5 l \right],$$

(1)

where $p^\mu$ is the four-momentum of the initial $B$ meson and the $F_i$’s are functions of Lorentz-invariant quantities. $F_{S,P}$ are absent in the SM but since our objective is to study the effect of scalar interactions we deliberately keep them in our calculation and would like to see the possible effects, if any. It should be noted here that the tensor type interaction is not independent since it can be reduced to a combination of scalar and vector terms.

In this work our objective is to study the effect of scalar interaction in the $A_{FB}$ in rare semileptonic B decays. Therefore, we start with the effective lagrangian for $b \rightarrow s l^+ l^-$ including the new physics effect due to scalar type interaction:

$$\mathcal{H}_{eff} = -4 G_F \frac{V_{tb} V_{ts}^*}{\sqrt{2}} \left\{ \sum_{i=1}^{10} c_i(\mu) \mathcal{O}_i(\mu) + c_S(\mu) \mathcal{O}_S(\mu) + c_P(\mu) \mathcal{O}_P(\mu) \\
+ c'_S(\mu) \mathcal{O}'_S(\mu) + c'_P(\mu) \mathcal{O}'_P(\mu) \right\},$$

(2)

where, $c_i^{(\ell)}(\mu)$ and $\mathcal{O}_i^{(\ell)}(\mu)$ are the Wilson coefficients and local operators respectively. One can recover the effective Hamiltonian of the standard model taking the limit the new physics coefficients $c_i^{(\ell)}_{(S,P)} \rightarrow 0$. The detailed expressions of the operators can be found in the literature (see for example [6]).
We use the following hadronic matrix elements responsible for the exclusive decay $B \to Kl^+l^-$ as

\[< K(k)|\bar{s}\gamma_\mu b|B(p) > = (2p - q)_\mu f_+(q^2) + \frac{M_B^2 - M_K^2}{q^2} q_\mu [f_0(q^2) - f_+(q^2)], \tag{3}\]

\[< K(k)|\bar{s}i\sigma_{\mu\nu}q^\nu b|B(p) > = -[(2p - q)_\mu q^2 - (M_B^2 - M_K^2)q_\mu] \frac{f_T(q^2)}{M_B + M_K}, \tag{4}\]

where, \( q^\mu = (p - k)^\mu \) is the four-momentum transferred to the dilepton system. Further, employing equation of motion for \( s \) and \( b \) quarks, we obtain

\[< K(k)|\bar{s}b|B(p) > = \frac{M_B^2 - M_K^2}{m_b - m_s} f_0(q^2). \tag{5}\]

The form factors defined above \((f_0, f_+ \text{ and } f_T)\) are functions of the invariant mass of the dileptons. The two dimensional spectrum is then given by

\[\frac{1}{\Gamma_0} \frac{d\Gamma(B \to Kl^+l^-)}{ds \, dcos\theta} = \lambda^{1/2}(M_B^2, M_K^2, s) \beta_1 \{s(\beta_1^2 |F_s|^2 + |F_F|^2) \]

\[+ \frac{1}{4} \lambda(M_B^2, M_K^2, s)[1 - \beta_1^2 \cos^2\theta](|F_A|^2 + |F_V|^2) + 4m_t^2 M_F^2 |F_A|^2 \]

\[+ 2m_t \lambda M_B^2, M_K^2, s) \beta_1 Re(F_F F_\alpha^*) \cos\theta \]

\[+ (M_B^2 - M_K^2 + s) Re(F_F F_\alpha^*)\}, \tag{6}\]

where, \( s = q^2 = (p_{l^+} + p_{l^-})^2 \). \( \Gamma_0 = \frac{G_F^2 a^2}{2\pi s M_B^2} |V_{ts} V_{cb}^*|^2 \), \( \lambda(a, b, c) = a^2 + b^2 + c^2 - 2(ab + bc + ac) \) and \( \beta_i = \sqrt{1 - 4m_t^2/s} \). Furthermore, we have defined \( \theta \) as the angle between three momentum vectors \( \vec{p}_{l^-} \) and \( \vec{p}_s \) in the dilepton center of mass system. Also note that the values \( s \) and \( \theta \) are bounded by \( 4m_t^2 \leq s \leq (M_B^2 - M_K^2)^2 \) and \(-1 \leq \cos \theta \leq 1\), respectively.

The forward backward asymmetry [1] is defined as

\[A_{FB}(s) = \frac{\int_0^1 dcos\theta \frac{dt}{ds dcos\theta} - \int_0^1 dcos\theta \frac{dt}{ds dcos\theta}}{\int_0^1 dcos\theta \frac{dt}{ds dcos\theta} + \int_{-1}^0 dcos\theta \frac{dt}{ds dcos\theta}}, \tag{7}\]

which for the process under consideration is given by

\[A_{FB}(s) = \frac{2m_t \lambda(M_B^2, M_K^2, s) \beta_1^2 Re(F_F F_\alpha^*) \Gamma_0}{d\Gamma/ds}. \tag{8}\]

The dilepton invariant mass spectrum, \( d\Gamma/ds \) can be obtained by integrating the distribution \((6)\) with respect to \( \cos \theta \), which can be read as

\[\frac{1}{\Gamma_0} \frac{d\Gamma(B \to Kl^+l^-)}{ds} = 2\lambda^{1/2}(M_B^2, M_K^2, s) \beta_1 \{s(\beta_1^2 |F_s|^2 + |F_F|^2) \]

\[+ \frac{1}{6} \lambda(M_B^2, M_K^2, s)(1 + 2m_t^2/s)(|F_A|^2 + |F_V|^2) \]

\[+ 4m_t^2 M_B^2 |F_A|^2 + 2m_t (M_B^2 - M_K^2 + s) Re(F_F F_\alpha^*)\}, \tag{9}\]
$F_i$’s used in the above formulae are combination of Wilson coefficients and s-dependent functions ($f_i$’s), which are

\begin{align*}
F_S &= \frac{1}{2}(M_B^2 - M_K^2) f_0(s) \left[ \frac{c_S m_b + c'_S m_s}{m_b - m_s} \right], \\
F_P &= -m_t c_{10} \left\{ f_+(s) - \frac{M_B^2 - M_K^2}{s} (f_0(s) - f_+(s)) \right\} \\
&\quad + \frac{1}{2}(M_B^2 - M_K^2) f_0(s) \left[ \frac{c_P m_b + c'_P m_s}{m_b - m_s} \right], \\
F_A &= c_{10} f_+(s), \\
F_V &= [c_9^{eff} f_+(s) + 2c_7^{eff} m_b \frac{f_T(s)}{M_B + M_K}].
\end{align*}

In the above we have used the Wilson coefficients as

\begin{align*}
c_7^{eff} &= -0.308, c_9 = 4.154, \quad c_9^{eff} = c_9 + Y(s) + C^{res}, \\
c_{10} &= -4.261,
\end{align*}

with

\begin{align*}
Y(s) &= g(m_c, s)(3c_1 + c_2 + 3c_3 + c_4 + 3c_5 + c_6) - \frac{1}{2} g(m_s, s)(c_3 + 3c_4) \\
&\quad - \frac{1}{2} g(m_b, s)(4c_3 + 4c_4 + 3c_5 + c_6) + \frac{2}{9} (3c_3 + c_4 + 3c_5 + c_6), \\
C^{res} &= \frac{3\pi}{\alpha^2} (3c_1 + c_2 + 3c_3 + c_4 + 3c_5 + c_6) \sum_{V_i=\psi(1),\psi(2)} \kappa(V_i \rightarrow l^+ l^-) m_{V_i} \frac{\Gamma(V_i \rightarrow l^+ l^-) m_{V_i}}{m_{V_i}^2 - s - i m_{V_i} \Gamma(V_i)},
\end{align*}

where use has been made of $y_i = 4m_i^2/s$ and we have kept only two dominant resonances. The functions $g(m_i, s)$ are as defined in [17].

The s-dependent form factors ($f_i$’s) used above are obtained from the recent LCSR fit [18] as

\begin{align*}
f_0(s) &= \frac{0.1903}{1 - s/39.38}, \\
f_+(s) &= \frac{0.3338}{1 - s/29.3} + \frac{0.1478}{(1 - s/29.3)^2}, \\
f_T(s) &= \frac{0.1851}{1 - s/29.3} + \frac{0.1905}{(1 - s/29.3)^2}.
\end{align*}

Using the formalism presented above, we would like to see the possibility of observing nonzero FB asymmetry, and if found then it will indicate clearly the presence of new physics in the scalar sector. In order to visualize that we use the NNLO Wilson coefficients and use the Cheng-Sher formalism to calculate the appropriate scalar coefficient ($c_S$). Yukawa
interaction between scalar and fermion can naturally exist (see for example [19]) and can be
taken in the form
\[ \mathcal{L} = \xi_{ij} \bar{Q}_i \phi_2 D_{j,R} + ( \ldots ) + h.c. , \]
(14)
where the ... denotes the contribution from the up quark sector. In the above the scalar
doublet \( \phi_2 \) mediates the FCNC \( d_i \leftrightarrow d_j \) at the tree level, with nonzero \( \xi_{ij} \). In order to
compute the FB asymmetry we have incorporated the idea of Cheng and Sher [15] and
define
\[ \xi_{ij} = \lambda_{ij} (m_i m_j)^{1/2} / v , \]
(15)
where, \( \xi \) is a dimensionless parameter, and \( \lambda \)'s are expected to be order one. In fact the
values of \( \lambda \)'s can be taken in the range \( \lambda_{bs} \sim 1 - 10 \) and \( \lambda_{\mu\mu} \sim 1 \). \( B_s - \bar{B}_s \) mixing can provide dominant contribution to the \( \lambda_{bs} \) and thus it could be bounded from that but with
the available lower limit of \( \Delta M_{B_s} > 9.5 \times 10^{-12} \) GeV gives no constraint on \( \lambda_{bs} \), since the
SM contribution exceeds this value. When there will be a measurement then we will be able
to constrain \( \lambda_{bs} \) more meaningfully. In the absence of that let us try to explore other options
at hand. In the literature \( Z \rightarrow bs \) interaction vertex has been used to constrain the \( \lambda_{bs} \) coupling and in Ref. [20] it has been obtained that \( \lambda_{bs} < 10 \), while for \( \lambda_{\mu\mu} \) we will use the
value \( \lambda_{\mu\mu} \approx 1 \). On the other hand in Ref. [6] using model independent analysis it has been
inferred (using the upper limit of \( B \rightarrow K^* \mu^+ \mu^- \) ) that the scalar/pseudoscalar coefficient
can be at most \( R_{S,P} = 4 \) (in fact the set of \( R_S = 4 \) (maximum) and \( R_P = 0 \) was obtained
to be the most preferable option), where \( R_S \equiv c_i / c_{i,SM} \), and \( R_{S,P} \equiv m_b c_{S,P} \). \( c_{i,SM} \) are the
standard model Wilson coefficients and \( c_{S,P} \)'s are as defined before. Recently, a new upper
limit has been provided by Tevatron/CDF for the \( B_s \rightarrow \mu^+ \mu^- \) \( (B_s \rightarrow \mu^+ \mu^- < 5.8 \times 10^{-7} \)
[21]) and we use the same to constrain \( \lambda_{bs} \), which is found to be \( \lambda_{bs} \approx 3.5 \). Furthermore, we
recheck that this is well within the maximum limit obtained in [6]. In this analysis we have
used the value of the scalar Higgs mass to be 150 GeV.

It should be noted that in [6] the authors have studied the effect of Higgs boson contribution on the \( A_{FB} \) in two Higgs doublet model (THDM)-type-II and MSSM with minimal
flavor violation and large \( \tan\beta \), with \( 40 \leq \tan\beta \leq 60 \). Moreover, the \( \tan\beta \) dependence is
strong which appears as \( \tan^2\beta \) and the effect of the neutral Higgs boson is taken at the loop
level. In contrast, here we have considered the tree level scalar contribution \( (\xi_{bs} \xi_{\mu\mu} / m_H^2) \) for
the \( A_{FB} \) with the Cheng-Sher type ansatz. Our calculation is based on tree level contribution
instead of loop effects as in [6] and also we have not used any strong dependence like \( \tan^2\beta \)
(with \( 40 \leq \tan\beta \leq 60 \)). Although we have not considered any specific model but the tree
level contribution is similar to THDM (type-III). In order to constrain the FCNC coupling we have used the latest result on $B_s \to \mu^+\mu^-$ and also checked that it does not contradict any existing bound. Before proceeding further, we would like mention here that if nonzero $A_{FB}$ is found then it may not be immediately possible to infer whether it corresponds to tree level contribution or a loop effect and hence more careful studies are required to distinguish the same. But given the simplicity of our model and no strong dependence on any model dependent parameter (apart from the FCNC, which is ensured to be very small with the use of Cheng-Sher type ansatz) our explanation will be preferred over the other explanations. In a sense it may be meaningful to say that it may indicate to the one like THDM-(type-III), but not necessarily.

Using the parameters mentioned above and using the relevant input parameters (like, $m_B=5.28$, $m_K=0.5$, $m_\pi=0.14$, $m_b=4.6$, $m_s=0.15$, $m_\tau=1.78$ and $m_\mu=0.105$ in units of GeV [22], $\alpha=1/128$) we plot the forward backward asymmetry as a function of the invariant mass of the dileptons, which is presented below. The branching ratio for $B \to K\mu^+\mu^-$ is obtained to be $6.8 \times 10^{-7}$, including scalar interaction (as compared to the experimental value $5.6^{+2.9}_{-2.4} \times 10^{-7}$ [22]).

![Figure 1](image.png)

Figure 1: The forward backward asymmetry ($A_{FB}$) in $B \to K\mu^+\mu^-$, where s is in GeV$^2$

From the above figure, it becomes evident that we can expect to have some nonzero FB asymmetry in $B \to K\mu^+\mu^-$, which is a consequence of the fact that there might be tree level scalar interactions present in $b \to s$ transition. It can be seen from the figure that $A_{FB}$ can arise at the level of few percent due to the scalar type interaction and the integrated FB asymmetry over the whole dilepton invariant mass is found to be around a percent level. We have also studied the affect of scalar type of interactions in the forward backward asymmetry in $B \to K\tau^+\tau^-$, which is shown below. It can be seen that here too one can have sizable FB
asymmetry and it can be tested in future. The branching ratio obtained for $B \rightarrow K\tau^+\tau^-$ is $30 \times 10^{-7}$. Finally, we note that there are no significant deviations for the $FB$ asymmetries

$$A_{FB}$$

in $B \rightarrow K^*\mu^+\mu^-$ and $B \rightarrow X_s l^+l^-$ from that of the SM expectations.

With the above findings keeping in mind in the $b \rightarrow s$ transitions we thereafter looked into another similar possibility in $s \rightarrow d$ type transition. Here, we studied to see the effect of this type of scalar interaction in $K^+ \rightarrow \pi^+\mu^+\mu^-$. Since this process is also well studied in the literature, we do not mention here the details explicitly. Following [3] and using the same idea, as above, we plotted the forward backward asymmetry in the decay $K^+ \rightarrow \pi^+\mu^+\mu^-$ as a function of the lepton invariant mass. Using scalar interactions and Cheng-Sher ansatz we found $(f_S \sim 1 \times 10^{-6})$ and used $f_V = a_+ + b_+ \frac{m_K}{s} + \omega(s)$, where $a_+$, $b_+$ and $\omega$ are parameters as used in [3], which are extracted from the experimental data. Here we have used the value of $\lambda_{ds} \sim 0.08$, which is extracted from the $K^0 - \bar{K}^0$ mixing and $\lambda_{\mu\mu} \sim 1$. From the figure it can be seen that nonzero $A_{FB}$ can be obtained with scalar type interaction. It should be noted here that $A_{FB}(K^+ \rightarrow \pi^+\mu^+\mu^-) = O(10^{-3})$ is accessible to future experiments such as the CKM experiment at Fermilab [23]. The branching ratio obtained for $K^+ \rightarrow \pi^+\mu^+\mu^-$ is $8.3 \times 10^{-8}$ (whereas the experimental value is $(8.1 \pm 1.4) \times 10^{-8}$ [22]).

To summarize, in this brief note we have reanalyzed the possibility of observing the new physics with scalar type interactions in $B$ decays. Forward backward asymmetry in $B \rightarrow K\mu^+\mu^-$ is identically zero in the standard model. In order to have non-zero $FB$ asymmetry in $B \rightarrow K\mu^+\mu^-$ one must have scalar type of interaction, which is absent in standard model framework. Using Cheng-Sher type ansatz we have shown that one can obtain non-zero $FB$ asymmetry and thus if observed then it may establish the presence
Figure 3: The forward backward asymmetry \((A_{FB})\) in \(K^+ \rightarrow \pi^+ \mu^+ \mu^-\), where \(s\) is in GeV\(^2\) of new physics, which unfortunately we have not been able to observe so far. We obtain non-zero \(A_{FB}\) in \(B \rightarrow K \mu^+ \mu^-\) and in fact it is very significant in \(B \rightarrow K \tau^+ \tau^-\).

The \(A_{FB}\) in \(K^+ \rightarrow \pi^+ \mu^+ \mu^-\) like in the case of \(B \rightarrow K \mu^+ \mu^-\) and \(B \rightarrow K \tau^+ \tau^-\) seems to be also sizable and could be detectable. In fact, the non-zero \(A_{FB}\) in \(B \rightarrow K \tau^+ \tau^-\) will be one of the best tools, in near future, to establish the new physics. It should be pointed out that in order to detect 2% forward backward asymmetry, say in \(B \rightarrow K \mu^+ \mu^-\) with branching ratio at the level of \(\sim 6 \times 10^{-7}\) and at 3\(\sigma\) level, around \(10^{10}\) \(B's\) are needed. To conclude, we note the fact that forward backward asymmetry in \(B \rightarrow Kl^+l^-\) \((l = \mu, \tau)\) and \(K^+ \rightarrow \pi^+ \mu^+ \mu^-\) is a powerful tool to observe new physics. We hope, in the coming years, it will be possible to observe the non-zero \(A_{FB}\) and in that case it may establish the existence of scalar interaction, otherwise, the scalar interaction will be severely constrained as a source of new physics, at least for the rare \(B\) and \(K\) decays.

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References

[1] A. Ali, T. Mannel and T. Morozumi, Phys. Lett. B 273, 505 (1991).

[2] F. Kruger and L. M Seghal, Phys. Lett. B 380, 199 (1996); J. L. Hewett, Phys. Rev. D 53, 4964 (1996); P. Colangelo et al., Phys. Rev. D 53, 3672 (1996); C. Q. Geng and C.
P. Kao, Phys. Rev D 54, 5636 (1996); C. Q. Geng and C. P. Kao, Phys. Rev. D 57, 4479 (1998); A. Ali et al., Phys. Rev. D 61, 074024 (2000); T. Aliev et al., Phys. Rev. D 64, 055007 (2001); W. Bensalem et al., Phys. Rev. D 67, 034007 (2003); S. R. Choudhury et al., Phys. Rev D 68, 054016 (2003).

[3] C. H. Chen, C. Q. Geng and I. L. Ho, Phys. Rev. D 67, 074029 (2003).

[4] T. M. Aliev et al., J. Phys. G 24, 49 (1998); T. M. Aliev and M. Savci, Phys. Lett. B 452, 318 (1999); Phys. Rev. D 60, 014005; C. H. Chen and C. Q. Geng, Phys. Rev. D 66, 034006 (2002); C. H. Chen and C. Q. Geng, Phys. Rev. D 66, 014007 (2002); C. Hamzaoui, M. Pospelov and M. Toharia, Phys. Rev. D 59, 095005 (1999); A. Dedes, H. K. Dreiner and U. Nierste, Phys. Rev. Lett. 87, 251804 (2001); R. Arnowitt et al., Phys. Lett. B 538, 121 (2002); D. A. Demir, K. A. Olive and M. B. Voloshin, Phys. Rev. D 66, 034015 (2002); C. H. Chen and C. Q. Geng, Phys. Rev. D 66, 094018 (2002).

[5] Q. S. Yan, C. S. Huang, W. Liao and S. H. Zhu, Phys. Rev. D 62, 094023 (2000).

[6] C. Bobeth, T. Ewerth, F. Kruger and J. Urban, Phys. Rev. D 64, 074014 (2001).

[7] T. M. Aliev and E. O. Iltan, Phys. Lett B 410, 216 (1997).

[8] S. Fukae, C. S. Kim, T. Morozumi and T. Yoshikawa, Phys. Rev. D 59, 074013 (1999).

[9] T. M. Aliev, C. S. Kim and Y. G. Kim, Phys. Rev. D 62, 014026 (2000); A. Arda and M. Boz, Phys. Rev. D 66, 075012 (2002).

[10] S. Fukae, C. S Kim and T. Yoshikawa, Phys. Rev. D 61, 074015 (2000); T. M. Aliev, A. Ozpineci and M. Savci, Phys. Lett. B 511, 49 (2001).

[11] M Beneke, T. Feldmann and D. Siedel, Nucl. Phys. B 612, 25 (2001); A. Ali and A. S. Safir, Euro. Phys. J. C 25, 583 (2002).

[12] C. Greub, A, Ioannissian and D. Wyler, Phys. Lett. B 346, 149 (1995); W. Jaus and D. Wyler, Phys. rev. D 41, 3405 (1990); N. G. Deshpande, G. Eilam, A. Soni and G. L. Kane, Phys. Rev. Lett. 57, 1106 (1988); N. G. Deshpande and J. Trampetic, ibid, 60, 2583 (1988); D. Liu, Phys. Lett. B 346, 255 (1995); G. Burdman, Phys. Rev D 52, 6400 (1995).

[13] B. Aubert et al. [Babar Collaboration], Phys. Rev. Lett. 91, 221802 (2003).
[14] K. Abe et al. [Belle Collaboration], hep-ex/0410006.

[15] T. P. Cheng and M. Sher, Phys. Rev. D 35, 3484 (1987); M. Sher and Y. Yuan, Phys. Rev. D 44, 1461 (1991); M. Sher, Phys. Lett. B 487, 151 (2000); M. Sher, arxiv: hep-ph/9809590.

[16] G. Belanger and C. Q. Geng, Phys. Rev. D 44, 2789 (1991); P. Agrawal, J. N. Ng, G. Belanger and C. Q. Geng, Phys. Rev. Lett. 67, 537 (1991); Phys. Rev. D 45, 2383 (1992); G. Belanger, C. Q. Geng and P. Turcotte, Nucl. Phys. B 390, 253 (1993).

[17] A. J. Buras and M. Muenz, Phys. Rev. D 52, 186 (1995).

[18] P. Ball and R. Zwicky, Phys. Rev. D 71, 014015 (2005); Phys. Rev. D 71, 014029 (2005).

[19] A. J. Davis, and X-G He, Phys. Rev. D 43, 225 (1991).

[20] D. Atwood, L. Reina and A. Soni, Phys. Rev. D 55, 3156 (1997).

[21] D. Acosta et al [CDF Collaboration], Phys. Rev. Lett. 93, 032001 (2004).

[22] S. Eidelman et al., Phys. Lett. B 592, 1 (2004).

[23] E.C. Dukes et al. [HyperCP Collaboration], hep-ex/0205063.