PHYSICAL REVIEW D **86,** 114009 (2012)

$b \to s$ decays in a model with Z-mediated flavor changing neutral current

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(Received 28 October 2012; published 5 December 2012)

In the scenario with Z-mediated flavor changing neutral current occurring at the tree level due to the addition of a vectorlike isosinglet down-type quark d' to the SM particle spectrum, we perform a χ^2 fit using the flavor physics data and obtain the best fit value along with errors of the tree level $Z\bar{b}s$ coupling, U_{sb}. The fit indicates that the new physics coupling is constrained to be small: we obtain $|U_{sb}| \le 3.40 \times 10^{-4}$ at 3σ. Still, this does allow for the possibility of new physics signals in some of the observables, such as semileptonic CP asymmetry in B_s decays.

DOI: 10.1103/PhysRevD.86.114009 PACS numbers: 12.60.−i, 12.15.Mm, 13.25.Hw

I. INTRODUCTION

The Standard Model (SM) of the electroweak interactions successfully explains most of the experimental data to date. However, in recent years, there have been quite a few measurements of quantities in B decays that differ from the predictions of the SM. For example, in $B \to \pi K$, the SM has some difficulty in accounting for all the experimental measurements [1]. The measured indirect (mixing-induced) CP asymmetry in some $b \to s$ penguin decays is found not to be identical to that in $\bar{B} \to J/\psi K_S$ [2–4], counter to the expectations of the SM. The measurement of indirect CP asymmetry in $\bar{B}_s \to J/\psi \phi$ by the CDF and D0 Collaborations shows a deviation from the SM prediction [5–7].[1] The observation of the anomalous dimuon charge asymmetry by the DØ Collaboration [9–11] also points toward some new physics in B_s mixing that affects the lifetime difference and mixing phase involved therein [12,13]. A further hint of new physics has been seen in the exclusive semileptonic decay $\bar{B} \to \bar{K}^* \mu^+ \mu^-$: the forward-backward asymmetry ($A_{\rm FB}$) has been found to deviate somewhat from the predictions of the SM [14–17].[2] Though the disagreements are only at the level of ~2–3σ, and hence not statistically significant, they are intriguing since they all appear in $b \to s$ transitions. Therefore, the study of new physics effects in various $b \to s$ observables is crucially important.

A minimal extension of SM can be obtained by adding a vectorlike isosinglet up-type or down-type quark to the SM particle spectrum [19–34]. Such exotic fermions can appear in E_6 grand unified theories as well as in models with large extra dimensions. Here we consider the extension of SM by adding a vectorlike down-type quark d'. The ordinary $Q_{\rm em} = -1/3$ quarks mix with the d'. Because the d'_L has a different I_{3L} from d_L, s_L and b_L, Z-mediated FCNCs (ZFCNC) appear at tree level in the left-hand sector. In particular, a $Z\bar{b}s$ coupling can be generated,

$$\mathcal{L}^Z_{\rm FCNC} = -\frac{g}{2\cos\theta_W} U_{sb} \bar{s}\gamma^\mu P_L b Z_\mu + \text{H.c.} \qquad (1)$$

This coupling leads to a new physics contribution to $b \to s$ transition (such as B_s-$\bar{B}_s$ mixing, $b \to s\mu^+\mu^-$ & $b \to s\nu\bar{\nu}$ decays, etc.) at the tree level. This tree-level coupling U_{sb} can be constrained by various measurements in the $b \to s$ sector.

In this paper we consider observables such as B_s-$\bar{B}_s$ mixing and branching ratios of $\bar{B} \to X_s \mu^+\mu^-$, $\bar{B}_s \to \mu^+\mu^-$ and $\bar{B} \to X_s \nu\bar{\nu}$ to constrain the new physics coupling U_{sb}. Instead of obtaining the usual scatter plot which shows the allowed ranges of the U_{sb} parameter space, we perform a χ^2 fit which provides us the best fit value of U_{sb} along with the errors. We then study the effect of tree-level $Z\bar{b}s$ coupling on the indirect CP asymmetry in $B_s \to \psi\phi$, anomalous dimuon charge asymmetry $a^s_{\rm sl}$, forward-backward (FB) asymmetry in $\bar{B} \to X_s \mu^+\mu^-$ and the branching ratio of $\bar{B}_s \to \tau^+\tau^-$. We show that the various measurements in the $b \to s$ sector put strong constraint on the allowed values of U_{sb}. However, it is still possible to have new physics signals in some $b \to s$ observables.

The paper is organized as follows. In Sec. II, we discuss the methodology for the fit. In Sec. III, we present the results of the fit. In Sec. IV, we obtain predictions for various $b \to s$ observables. Finally, in Sec. V, we present our conclusions.

II. METHOD

As U_{sb} denotes the $Z\bar{b}s$ coupling generated in the ZFCNC model, the parameters of the model are therefore the magnitude and the phase of this coupling, $|U_{sb}|$ and $\phi_{sb} \equiv \arg U_{sb}$.

In order to obtain constraints on the new physics coupling U_{sb}, we perform a χ^2 fit using the CERN minimization

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[1]The recent LHCb update does not confirm this result [8]. Their measurement is consistent with the SM prediction.
[2]The recent LHCb update does not confirm this result [18]. Their measurement of the $A_{\rm FB}$ distribution is consistent with the SM prediction, except in the high-q^2 region.

code MINUIT [35]. The fit includes observables that have relatively small hadronic uncertainties: (i) the branching ratio of $\bar{B} \to X_s \mu^+ \mu^-$ in the low- and high-q^2 regions, (ii) the branching ratio of $\bar{B}_s \to \mu^+\mu^-$, (iii) the ratio of the branching ratio of $\bar{B}_s \to \mu^+\mu^-$ and the mass difference in B_s system and (iv) the branching ratio of $\bar{B} \to X_s \nu\bar{\nu}$. We include both experimental errors and theoretical uncertainties in the fit. In the following subsections, we discuss various observables used as a constraint. The inputs used in our fit are given in Table I.

A. $\bar{B} \to X_s \mu^+ \mu^-$

The effective Hamiltonian for the quark-level transition $b \to s\mu^+\mu^-$ in the SM can be written as

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_{i=1}^{10} C_i(\mu) O_i(\mu), \tag{2}$$

where the form of the operators O_i and the expressions for calculating the coefficients C_i are given in Ref. [36]. The operator O_i, $i = 1, 6$ can contribute indirectly to $b \to s\mu^+\mu^-$, and their effects are included in the effective Wilson coefficients C_9 and C_7 [36,37].

The $Z\bar{b}s$ coupling generated in the ZFCNC model changes the values of the Wilson coefficients $C_{9,10}$. The Wilson coefficients $C_{9,10}^{\rm tot}$ in the ZFCNC model can be written as

$$C_9^{\rm tot} = C_9^{\rm eff} - \frac{\pi}{\alpha} \frac{U_{sb}}{V_{ts}^* V_{tb}} (4\sin^2\theta_W - 1) \tag{3}$$

$$C_{10}^{\rm tot} = C_{10} - \frac{\pi}{\alpha} \frac{U_{sb}}{V_{ts}^* V_{tb}}. \tag{4}$$

Here $V_{ts}^* V_{tb} \simeq -0.0403 e^{-i1^\circ}$. We use the SM Wilson coefficients as given in Ref. [37].

The calculation of branching ratio gives

$$\mathcal{BR}(\bar{B} \to X_s \mu^+\mu^-) = \frac{\alpha^2 \mathcal{BR}(B \to X_c e\bar{\nu})}{4\pi^2 f(\hat{m}_c)\kappa(\hat{m}_c)} \frac{|V_{ts}^* V_{tb}|^2}{|V_{cb}|^2} \times \int D(z) dz, \tag{5}$$

where

$$D(z) = (1-z)^2\Big[(1+2z)(|C_9^{\rm tot}|^2 + |C_{10}^{\rm tot}|^2) + 4\Big(1+\frac{2}{z}\Big)|C_7^{\rm eff}|^2 + 12\,{\rm Re}(C_7^{\rm eff} C_9^{\rm tot*})\Big]. \tag{6}$$

Here $z \equiv q^2/m_b^2 \equiv (p_{\mu^+} + p_{\mu^-})^2/m_b^2$ and $\hat{m}_q = m_q/m_b$ for all quarks q. The expressions for the phase-space factor $f(\hat{m}_c)$ and the one-loop QCD correction factor $\kappa(\hat{m}_c)$ are given in Ref. [38].

The theoretical prediction for the branching ratio of $\bar{B} \to X_s \mu^+\mu^-$ in the intermediate q^2 region (7 GeV$^2 \le q^2 \le 12$ GeV^2) is rather uncertain due to the nearby charmed resonances. The predictions are relatively cleaner in the low-q^2 (1 GeV$^2 \le q^2 \le 6$ GeV^2) and the high-q^2 (14.4 GeV$^2 \le q^2 \le m_b^2$) regions. We therefore consider both the low-q^2 and high-q^2 regions in the fit.

We define χ^2 as

$$\chi^2_{\bar{B}\to X_s\mu^+\mu^-:\ {\rm low}} = \left(\frac{D_{\rm low} - 5.69947}{1.82522}\right)^2, \tag{7}$$

$$\chi^2_{\bar{B}\to X_s\mu^+\mu^-:\ {\rm high}} = \left(\frac{D_{\rm high} - 1.56735}{0.635465}\right)^2, \tag{8}$$

where

$$D_{\rm low} = \int_{\frac{1}{m_b^2}}^{\frac{6}{m_b^2}} D(z)dz = \mathcal{BR}(\bar{B} \to X_s\mu^+\mu^-)_{\rm low} \times \frac{4\pi^2 f(\hat{m}_c)\kappa(\hat{m}_c)}{\alpha^2 \mathcal{BR}(B \to X_c e\bar{\nu})} \frac{|V_{cb}|^2}{|V_{ts}^* V_{tb}|^2} = 5.69947 \pm 1.82522, \tag{9}$$

$$D_{\rm high} = \int_{\frac{14.4}{m_b^2}}^{(1-\frac{m_s}{m_b})^2} D(z)dz = \mathcal{BR}(\bar{B} \to X_s\mu^+\mu^-)_{\rm high} \times \frac{4\pi^2 f(\hat{m}_c)\kappa(\hat{m}_c)}{\alpha^2 \mathcal{BR}(B \to X_c e\bar{\nu})} \frac{|V_{cb}|^2}{|V_{ts}^* V_{tb}|^2} = 1.56735 \pm 0.635465. \tag{10}$$

Here we have added an overall correction of 30% to the theoretical prediction of $\mathcal{BR}(B \to X_s\mu^+\mu^-)_{\rm high}$, which includes the nonperturbative corrections.

TABLE I. Inputs that we use in order to constrain $|U_{sb}|$-ϕ_{sb} parameter space. When not explicitly stated, we take the inputs from Particle Data Group [48].

$\eta_B = 0.5765 \pm 0.0065$ [49]	$\mathcal{BR}(\bar{B}_s \to \mu^+\mu^-) = (0.0 \pm 2.30) \times 10^{-9}$ [40]
$f_{bs} = 0.229 \pm 0.006$ GeV [50,51]	$\mathcal{BR}(\bar{B} \to X_s\mu^+\mu^-)_{\rm low} = (1.60 \pm 0.50) \times 10^{-6}$ [52,53]
$B_{bs} = 1.291 \pm 0.043$ [50,51]	$\mathcal{BR}(\bar{B} \to X_s\mu^+\mu^-)_{\rm high} = (0.44 \pm 0.12) \times 10^{-6}$ [52,53]
$\Delta M_s = (17.69 \pm 0.08)$ ps^{-1} [54]	$\mathcal{BR}(\bar{B} \to X_s\nu\nu) = (0.0 \pm 40) \times 10^{-5}$ [43]
$\frac{\lvert V_{ts}^* V_{tb}\rvert}{\lvert V_{cb}\rvert} = 0.967 \pm 0.009$ [50]	$m_t(m_t) = 163.5$ GeV
$\lvert V_{ts}^* V_{tb}\rvert = -(0.0403 \pm 0.0009)$	$m_c/m_b = 0.29 \pm 0.02$
$\mathcal{BR}(B \to X_c\ell\nu) = (10.61 \pm 0.17) \times 10^{-2}$	$\tau_{B_s} = (1.520 \pm 0.020)$ ps [8]

B. $\bar{B}_s \to \mu^+\mu^-$

The purely leptonic decay $\bar{B}_s \to \mu^+\mu^-$ is chirally suppressed within the SM. The SM prediction for the branching ratio is $(3.35 \pm 0.32) \times 10^{-9}$ [39]. Recently, LHCb Collaboration reported a very strong upper bound on the branching ratio of $\bar{B}_s \to \mu^+\mu^-$, which is 3.8×10^{-9} at 90% C.L. [40].

The branching ratio of $\bar{B}_s \to \mu^+\mu^-$ in the ZFCNC model is given by

$$\mathcal{BR}(\bar{B}_s \to \mu^+\mu^-) = \frac{G_F^2 \alpha^2 M_{B_s} m_\mu^2 f_{bs}^2 \tau_{B_s}}{16\pi^3} |V_{ts}^* V_{tb}|^2 \times \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}} |C_{10}^{\rm tot}|^2. \tag{11}$$

We define χ^2 as

$$\chi^2_{\bar{B}_s \to \mu^+\mu^-} = \left(\frac{|C_{10}^{\rm tot}|^2 - 0.0}{13.5408}\right)^2, \tag{12}$$

with

$$|C_{10}^{\rm tot}|^2 = \frac{16\pi^3 \mathcal{BR}(\bar{B}_s \to \mu^+\mu^-)}{G_F^2 \alpha^2 M_{B_s} m_\mu^2 f_{bs}^2 \tau_{B_s} |V_{ts}^* V_{tb}|^2 \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}}} = 0.0 \pm 13.5408. \tag{13}$$

C. Ratio of $\mathcal{BR}(\bar{B}_s \to \mu^+\mu^-)$ and the mass difference in the B_s system

The mass difference ΔM_s is given by

$$\Delta M_s = 2|M_{12}^{\rm SM}|. \tag{14}$$

The SM contribution to M_{12}^s is

$$M_{12}^{s,\rm SM} = \frac{G_F^2}{12\pi^2}(V_{ts}^* V_{tb})^2 M_W^2 M_{B_s} \eta_B f_{B_s}^2 B_{B_s} E(x_t), \tag{15}$$

where $x_t = m_t^2/M_W^2$ and η_B is the QCD correction. The loop function $E(x_t)$ is given by

$$E(x_t) = \frac{-4x_t + 11x_t^2 - x_t^3}{4(1-x_t)^2} + \frac{3x_t^3 \ln x_t}{2(1-x_t)^3}. \tag{16}$$

The mass difference ΔM_s in the ZFCNC model is given by [28]

$$\Delta M_s = \frac{G_F^2}{6\pi^2} |V_{ts}^* V_{tb}|^2 M_W^2 M_{B_s} \eta_B f_{bs}^2 B_{bs} |E(x_t)||\Delta_s|. \tag{17}$$

Δ_s is given by

$$\Delta_s = 1 + a\left(\frac{U_{sb}}{V_{ts}^* V_{tb}}\right) - b\left(\frac{U_{sb}}{V_{ts}^* V_{tb}}\right)^2, \tag{18}$$

where

$$a = 4\frac{C(x_t)}{E(x_t)}, \qquad b = \frac{2\sqrt{2}\pi^2}{G_F M_W^2 E(x_t)}. \tag{19}$$

The loop function $C(x_t)$ is given by [28]

$$C(x_t) = \frac{x_t}{4}\left[\frac{4 - x_t}{1 - x_t} + \frac{3x_t \ln x_t}{(1-x_t)^2}\right]. \tag{20}$$

The term in Eq. (17) proportional to a is obtained from a diagram with both SM and new physics Z vertices; that, proportional to b, corresponds to the diagram with two new physics Z vertices.

Dividing Eq. (11) by Eq. (17), we get

$$\frac{\mathcal{BR}(\bar{B}_s \to \mu^+\mu^-)}{\Delta M_s} = \frac{3\alpha^2 \tau_{B_s} m_\mu^2}{8\pi M_W^2 \eta_B B_{bs} |E(x_t)|} \times \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}} \frac{|C_{10}^{\rm tot}|^2}{|\Delta_s|}. \tag{21}$$

We define χ^2 as

$$\chi^2_{\text{BR-mix}} = \left(\frac{\frac{|C_{10}^{\rm tot}|^2}{|\Delta_s|} - 0.0}{13.6328}\right)^2, \tag{22}$$

with

$$\frac{|C_{10}^{\rm tot}|^2}{|\Delta_s|} = \frac{\mathcal{BR}(\bar{B}_s \to \mu^+\mu^-)}{\Delta M_s \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}}} \frac{8\pi M_W^2 \eta_B B_{bs} |E(x_t)|}{3\alpha^2 \tau_{B_s} m_\mu^2} = 0.0 \pm 13.6328. \tag{23}$$

D. $\bar{B} \to X_s \nu\bar{\nu}$

The effective Hamiltonian for the decay $\bar{B} \to X_s \nu\bar{\nu}$ is given by

$$H_{\rm eff} = \frac{G_F}{\sqrt{2}} \frac{\alpha}{2\pi \sin^2\theta_W} V_{ts}^* V_{tb} X_0(x_t) (\bar{s}b)_{V-A} (\bar{\nu}\nu)_{V-A} + \text{H.c.}, \tag{24}$$

with

$$X_0(x_t) = \frac{x_t}{8}\left[\frac{2 + x_t}{x_t - 1} + \frac{3x_t - 6}{(x_t - 1)^2} \ln x_t\right]. \tag{25}$$

The presence of tree-level $Z\bar{b}s$ coupling changes the value of the structure function $X_0(x_t)$. The structure function within the ZFCNC model can be written as

$$X_0'(x_t) = X_0(x_t) + \left(\frac{\pi \sin^2\theta_W}{\alpha V_{ts}^* V_{tb}}\right) U_{sb}. \tag{26}$$

The branching ratio of $\bar{B} \to X_s \nu\bar{\nu}$ is given by [41,42]

$$\mathcal{BR}(\bar{B} \to X_s \nu\bar{\nu}) = \mathcal{BR}(B \to X_c e\bar{\nu}) \frac{\tilde{C}^2 \bar{\eta}}{|V_{cb}|^2 f(\hat{m}_c) \kappa(\hat{m}_c)}, \tag{27}$$

where $\tilde{C}^2$ is given by

$$\tilde{C}^2 = \frac{\alpha^2}{2\pi^2 \sin^4\theta_W} |V_{ts}^* V_{tb} X_0'(x_t)|^2. \quad (28)$$

We define χ^2 as

$$\chi^2_{\bar{B}\to X_s \nu\bar{\nu}} = \left(\frac{|V_{ts}^* V_{tb} X_0'(x_t)|^2 - 0.0}{0.069157}\right)^2, \quad (29)$$

with

$$|V_{ts}^* V_{tb} X_0'(x_t)|^2 = \frac{\mathcal{BR}(\bar{B}\to X_s \nu\bar{\nu})}{\mathcal{BR}(B\to X_c e\bar{\nu})} \times \frac{2\pi^2 \sin^4\theta_W |V_{cb}|^2 f(\hat{m}_c)\kappa(\hat{m}_c)}{\bar{\eta}\alpha^2} = 0.0 \pm 0.069157. \quad (30)$$

Here we have used the present upper bound $\mathcal{BR}(\bar{B}\to X_s \nu\bar{\nu}) < 64\times 10^{-5}$ at 90% C.L. [43] which can be written as $(0.0 \pm 40)\times 10^{-5}$.

Therefore, the total χ^2 can be written as

$$\chi^2_{\rm total} = \chi^2_{\bar{B}\to X_s\mu^+\mu^-:\ {\rm low}} + \chi^2_{\bar{B}\to X_s\mu^+\mu^-:\ {\rm high}} + \chi^2_{\bar{B}_s\to\mu^+\mu^-} + \chi^2_{\text{BR-mix}} + \chi^2_{\bar{B}\to X_s\nu\bar{\nu}}. \quad (31)$$

III. RESULTS OF THE FIT

The results of these fits are presented in Table II. It may be observed that the χ^2 per degree of freedom is small, indicating that the fit is good. We observe that the present flavor data put strong constraint on $Z\bar{b}s$ coupling. At 3σ, we obtain $|U_{sb}| \le 3.40\times 10^{-4}$.

IV. PREDICTIONS

A. Semileptonic asymmetry $a_{\rm sl}^s$

The expression for the semileptonic asymmetry $a_{\rm sl}^s$ is given by

$$a_{\rm sl}^s = \frac{|\Gamma_{12}^s|}{|M_{12}^s|}\sin\phi_s = \frac{|\Gamma_{12}^s|}{|M_{12}^{s,\rm SM}|}\frac{\sin\phi_s}{|\Delta_s|}, \quad (32)$$

where the CP violating phase ϕ_s is defined by the following equation,

$$\phi_s \equiv {\rm Arg}\left[-\frac{M_{12}^s}{\Gamma_{12}^s}\right]. \quad (33)$$

The parameter Δ_s takes into account the new physics effects in mixing and is defined as

TABLE II. The results of the fit to the parameters of the ZFCNC model.

Parameter	Value
$\|U_{sb}\|$	$(0.90 \pm 0.83)\times 10^{-4}$
ϕ_{sb}	$(0.00 \pm 181.34)^\circ$
χ^2/d.o.f.	1.72/3

TABLE III. ZFCNC predictions for potential observables.

	Predictions	
Observables	SM	ZFCNC
ϕ_s^Δ (rad)	0	(0.00 ± 0.03)
$\|\Delta_s\|$	1	1.01 ± 0.01
$a_{\rm sl}^s \times 10^5$	(1.92 ± 0.67)	(1.98 ± 13.88)
${\rm Br}(B_s\to\tau^+\tau^+)\times 10^7$	5.74 ± 0.27	3.34 ± 1.92
$(q^2)_0^{\rm incl}$ GeV^2	3.33 ± 0.25	3.38 ± 0.26

$$M_{12}^s = M_{12}^{s,\rm SM}\left(1 + \frac{M_{12}^{s,\rm NP}}{M_{12}^{s,\rm SM}}\right) = M_{12}^{s,\rm SM}\Delta_s = M_{12}^{s,\rm SM}|\Delta_s|e^{\phi_s^\Delta}. \quad (34)$$

Thus ϕ_s can be written as

$$\phi_s = \phi_s^\Delta + \phi_s^{\rm SM}, \quad (35)$$

where $\phi_s^{\rm SM} = (3.84 \pm 1.05)\times 10^{-3}$ [44]. Also, one has [45,46]

$$\frac{|\Gamma_{12}^s|}{|M_{12}^{s,\rm SM}|} = (5.0 \pm 1.1)\times 10^{-3}. \quad (36)$$

The predictions for ϕ_s^Δ, $|\Delta_s|$ and $a_{\rm sl}^s$ in the ZFCNC model are given in Table III. We see that it is possible to have large deviations in ϕ_s (and hence $a_{\rm sl}^s$) from its SM predictions.

B. Zero of forward-backward asymmetry

The FB asymmetry of muons in $\bar{B}\to X_s\mu^+\mu^-$ is obtained by integrating the double differential branching ratio $(\frac{d^2\mathcal{BR}}{dz\,d\cos\theta})$ with respect to the angular variable $\cos\theta$ [47]

$$A_{\rm FB}(z) = \frac{\int_0^1 d\cos\theta \frac{d^2\mathcal{BR}}{dz\,d\cos\theta} - \int_{-1}^0 d\cos\theta \frac{d^2\mathcal{BR}}{dz\,d\cos\theta}}{\int_0^1 d\cos\theta \frac{d^2\mathcal{BR}}{dz\,d\cos\theta} + \int_{-1}^0 d\cos\theta \frac{d^2\mathcal{BR}}{dz\,d\cos\theta}}, \quad (37)$$

where θ is the angle between the momentum of the $\bar{B}$-meson and that of μ^+ in the dimuon center-of-mass frame.

Within the ZFCNC model, FB asymmetry in $\bar{B}\to X_s\mu^+\mu^-$ is given by

$$A_{\rm FB}(z) = \frac{-3E(z)}{D(z)}, \quad (38)$$

where $D(z)$ is given in Eq. (6) and $E(z)$ by

$$E(z) = {\rm Re}(C_9^{\rm tot}C_{10}^{\rm tot*})z + 2\,{\rm Re}(C_7^{\rm eff}C_{10}^{\rm tot*}). \quad (39)$$

Zero of $A_{\rm FB}(z)$ is determined by

$$E(z) = {\rm Re}(C_9^{\rm tot}C_{10}^{\rm tot*})z + 2\,{\rm Re}(C_7^{\rm eff}C_{10}^{\rm tot*}) = 0. \quad (40)$$

The prediction for $(q^2)_0^{\rm incl}$ in the ZFCNC model is given in Table III. One can see that large deviations from the SM prediction are not possible.

C. $\mathcal{BR}(\bar{B}_s \to \tau^+\tau^-)$

The branching ratio of $\bar{B}_s \to \tau^+\tau^-$ in the ZFCNC model is given by

$$\mathcal{BR}(\bar{B}_s \to \tau^+\tau^-) = \frac{3\alpha^2 \tau_{B_s} m_\tau^2}{8\pi M_W^2 \eta_B B_{bs} |E(x_t)|} \times \sqrt{1 - \frac{4m_\tau^2}{M_{B_s}^2}} \frac{|C_{10}^{\rm tot}|^2}{|\Delta_s|} \Delta M_s. \quad (41)$$

The prediction for $\mathcal{BR}(\bar{B}_s \to \tau^+\tau^-)$ in the ZFCNC model is given in Table III. We see that it is possible to have large suppression in $\mathcal{BR}(\bar{B}_s \to \tau^+\tau^-)$ as compared to its SM prediction.

V. CONCLUSION

In this paper, we consider a minimal extension of the SM by adding a vectorlike isosinglet down-type quark d' to the SM particle spectrum. As a consequence, Z-mediated FCNCs appear at tree level in the left-hand sector. In particular, we are interested in $Z\bar{b}s$ coupling which leads to a new physics contribution to $b \to s$ transition such as B_s-$\bar{B}_s$ mixing and $b \to s\mu^+\mu^-$, $b \to s\nu\bar{\nu}$ decays, etc. at the tree level. Using inputs from several observables in flavor physics, we perform a χ^2 fit to constrain the tree-level $Z\bar{b}s$ coupling, U_{sb}. The fit takes into account both the theoretical as well as the experimental uncertainties.

We conclude the following:

(i) χ^2 per degree of freedom is small, indicating that the fit is good. This is expected as the SM itself is in good agreement with the data.

(ii) The present data put strong constraint on the $Z\bar{b}s$ coupling. At 3σ, $|U_{sb}| \le 3.40 \times 10^{-4}$.

(iii) The predictions for various $b \to s$ observables such as semileptonic CP asymmetry in B_s decays, zero of FB asymmetry of muons in $\bar{B} \to X_s\mu^+\mu^-$ and branching ratio of $\bar{B}_s \to \tau^+\tau^-$ are consistent with their SM predictions. However, due to large errors, it is still possible to have new physics signals in some of the observables such as semileptonic CP asymmetry in B_s decays. Hence, the ZFCNC model neither predicts a significant deviation from the SM nor forbids such possibility of a large deviation due to large errors.

ACKNOWLEDGMENTS

We thank Soumitra Nandi for helpful collaboration on several parts of this analysis. The work of S. G. is supported by DFG Emmy Noether Grant No. TA 867/1-1.

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