http://garmian.edu.krd https://doi.org/10.24271/garmian.171

The Effect of Fourth Generation Standard Model on the CP Asymmetry in $B_s \to \phi\ell^+\ell^-$ Decay

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Abstract

This work investigate the influence of the fourth generation of quarks on the CP asymmetry in $B_s \to \phi\ell^+\ell^-$ Decay. This new quarks changes the values of the Wilson coefficients $C_7(\mu)$, $C_9(\mu)$ and $C_{10}(\mu)$ via virtual exchange of the fourth generation up type quark t'. Taking the $|V_{tb}V_{ts}^*| \sim \{0.01 - 0.03\}$ with phase $\{60, 90, 120\}$, which is consistent with the $b \to s\ell^+\ell^-$ rate and the B_s mixing parameter $\Delta_{m_{B_s}}$, We obtain that for both (μ, τ) channels the CP-asymmetries are quite sensitive to the 4th generation quarks mass and mixing parameters. Hence, studying CP-asymmetry for $B \to \phi\ell^+\ell^-$ decay with new Wilson coefficients can serve as an effective way to identify the new generation quarks (t', b') in high energy physics laboratories.

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1 Introduction

Although the Standard Model (SM) is very successful for describing the particle physics phenomena, but there are many interesting open questions, such as CP violation that it no explanation for them. Therefore, intensive search for new physics beyond the SM is very necessary. One possible extension is SM with more than three generations.

From experimental data, the existence of a fourth generation of fermions has not been excluded, although it is strongly confined by precision measurements of electroweak observables. The restrictions on the new generation of fermions come from the experimental data on the ρ and S Parameters[1]. Therefore, the mass of fourth generation quark (m_t') considering this data and other constraints lies between 175 GeV and 600 GeV [2, 3].

The pervious works that support the existence of fourth-generation quarks apply this new physics in different fields, for instance Higgs and neutrino physics, cosmology and dark matter [4]–[9]. The fourth quark (t'), like u, c, t quarks, contributes in the $b \to s$ transition at loop level. Clearly, it would change the branching ratio, CP-asymmetry and polarization asymmetries which have been widely studied in baryonic and semileptonic $b \to s$ transition [10]-[15].

In our previous paper[16], we have studied the influences the fourth generation quarks on the Double lepton polarization asymmetry in $B_s \to \phi\ell^+\ell^-$ decay. In this paper, we investigate the effects of fourth generation of quarks (b', t') on the B-meson leptonic rare decay $B_s \to \phi\ell^+\ell^-$ for CP asymmetry which is one of the most important physical observable in establishing new physics beyond the SM.

This paper is organized as follows. In Section II, we drive the matrix element and the differential decay width for $B_s \to \phi\ell^+\ell^-$ in the SM using effective Hamiltonian. The effect of the fourth generation of quarks on the effective Hamiltonian have been presented in section III. Section IV devoted to the numerical analysis of the CP asymmetries with our conclusion in section V.

2 The differential decay width in the Standard Model

For calculating Differential decay rate, it's necessary to obtain effective Hamiltonian. At quark level, the rare decay $B_s \to \phi\ell^+\ell^-$ demonstrate by $b \to s\ell^+\ell^-$ and effective Hamiltonian relevant for this transition cab be written as

$$\mathcal{H}_{\text{eff}}(b \to s\ell^+\ell^-) = -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} C_i(\mu)\mathcal{O}_i(\mu)\,, \tag{1}$$

where $\mathcal{O}_i(\mu)$ the full set operators and the corresponding Wilson coefficients $C_i(\mu)$ are given in [17]. Matrix element for the $b \to s\ell^+\ell^-$ transition by using above effective Hamiltonian as

$$\begin{aligned}
\mathcal{M}(b \to s\ell^+\ell^-) &= < s\ell^+\ell^-|\mathcal{H}_{\text{eff}}|b> \\
&= -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i C_i^{\text{eff}}(\mu) < s\ell^+\ell^-|\mathcal{O}_i|b>^{tree} . \\
&= -\frac{G_F \alpha}{2\pi\sqrt{2}} V_{tb} V_{ts}^* \Bigg[\tilde{C}_9^{\text{eff}} \bar{s}\gamma_\mu(1-\gamma_5)b\,\bar{\ell}\gamma_\mu\ell \\
&\quad + \tilde{C}_{10}^{\text{eff}} \bar{s}\gamma_\mu(1-\gamma_5)b\,\bar{\ell}\gamma_\mu\gamma_5\ell \\
&\quad - 2C_7^{\text{eff}} \frac{m_b}{q^2} \bar{s}\sigma_{\mu\nu}q^\nu(1+\gamma_5)b\,\bar{\ell}\gamma_\mu\ell \Bigg],
\end{aligned} \tag{2}$$

where effective Wilson coefficients C_7^{eff}, $\tilde{C}_9^{\text{eff}}$ and $\tilde{C}_{10}^{\text{eff}}$ at μ scale, can be written in the following form [17, 18]:

$$\begin{aligned}
C_7^{\text{eff}} &= C_7 - \frac{1}{3}C_5 - C_6 \\
C_{10}^{\text{eff}} &= \frac{\alpha}{2\pi}\tilde{C}_{10}^{\text{eff}} = C_{10} \\
C_9^{\text{eff}} &= \frac{\alpha}{2\pi}\tilde{C}_9^{\text{eff}} = C_9 + \frac{\alpha}{2\pi}Y(s).
\end{aligned} \tag{3}$$

where $s = q^2/m_b^2$ and the function $Y(s)$ dedicates the perturbative part due to the one loop matrix elements of four quark operators as [17],

$$\begin{aligned}
Y(s) &= Y_{per}(s) + \frac{3\pi}{\alpha^2}(3C_1 + C_2 + 3C_3 + C_4 + 3C_5 + C_6) \\
&\times \sum_{V_i=\psi_i} \kappa_i \frac{m_{V_i}\Gamma(V_i \to \ell^+\ell^-)}{m_{V_i}^2 - s m_b^2 - i m_{V_i}\Gamma_{V_i}},
\end{aligned} \tag{4}$$

where the second term is Breit-Wigner form of the resonance propagator and $Y_{per}(s)$ is long distance contributions which have provenance to the real $c\bar{c}$ intermediate states, i.e., J/ψ, ψ', $\cdots$ that can be written as [19]-[21]

$$\begin{aligned} Y_{per}(s) &= h(\frac{m_c}{m_b}, s)(3C_1 + C_2 + 3C_3 + C_4 + 3C_5 + C_6) \\ &- \frac{1}{2}h(1, s)(4C_3 + 4C_4 + 3C_5 + C_6) \\ &- \frac{1}{2}h(0, s)(C_3 + 3C_4) + \frac{2}{9}(3C_3 + C_4 + 3C_5 + C_6). \end{aligned} \quad (5)$$

the values of C_i and The explicit expressions for h functions can be found in [17] as well as the phenomenological parameters κ_i in Eq.(4) can be determined from experimental measurements of semileptonic B decays

$$\mathcal{B}(B \to K^* V_i \to K^* \ell^+ \ell^-) = \mathcal{B}(B \to K^* V_i)\, \mathcal{B}(V_i \to \ell^+ \ell^-), \quad (6)$$

where the data for the right hand side is given in [22]. For the lowest resonances, J/ψ and ψ' one can use $\kappa = 1.65$ and $\kappa = 2.36$, respectively (see [23]).

Now, By using effective Hamiltonian and relevant Wilson coefficients, we can calculate the transition matrix elements which is vital for computing the decay width and other physical observables of $B_s \to \phi \ell^+ \ell^-$ decay. For this purpose, we need to sandwich effective Hamiltonian between initial hadron state $B(p_{B_s})$ and final hadron state $\phi(p_\phi)$ that can be parameterized in terms of form factors as

$$\begin{aligned} < \phi(p_\phi, \epsilon) \mid \bar{s}\gamma_\mu(1 - \gamma_5)b \mid B(p_{B_s}) >= -\frac{2V(q^2)}{m_{B_s} + m_\phi}\epsilon_{\mu\nu\rho\sigma} p_\phi^\rho q^\sigma \epsilon^{*\nu} \\ -i \left[\epsilon_\mu^*(m_{B_s} + m_\phi)A_1(q^2) - (\epsilon^* q)(p_{B_s} + p_\phi)_\mu \frac{A_2(q^2)}{m_{B_s} + m_\phi} \right. \\ \left. - q_\mu(\epsilon^* q)\frac{2m_\phi}{q^2}(A_3(q^2) - A_0(q^2)) \right], \end{aligned} \quad (7)$$

$$\begin{aligned} &\langle \phi(p_\phi, \varepsilon) \left| \bar{s} i \sigma_{\mu\nu} q^\nu (1 + \gamma_5) b \right| B(p_{B_s}) \rangle = \\ &\quad 4\epsilon_{\mu\nu\rho\sigma}\varepsilon^{*\nu} p^\rho q^\sigma T_1(q^2) + 2i \left[\varepsilon_\mu^*(m_{B_s}^2 - m_\phi^2) - (p_{B_s} + p_\phi)_\mu (\varepsilon^* q) \right] T_2(q^2) \\ &\quad +2i(\varepsilon^* q) \left[q_\mu - (p_{B_s} + p_\phi)_\mu \frac{q^2}{m_{B_s}^2 - m_\phi^2} \right] T_3(q^2) \, . \end{aligned} \quad (8)$$

where ε_μ is the polarization vector of meson ϕ and $q = p_{B_s} - p_\phi$ is the momentum transfer as well as $A_3(q^2)$ can be written as a linear combination of the form factors A_1 and A_2 :

$$A_3(q^2) = \frac{1}{2m_\phi} \left[(m_{B_s} + m_\phi)A_1(q^2) - (m_{B_s} - m_\phi)A_2(q^2) \right] . \quad (9)$$

where $A_3(q^2=0)=A_0(q^2=0)$ (this condition ensures that there is no kinematical singularity in the matrix element at $q^2=0$). The other form factors

$$F(q^2)\in\{V(q^2),A_0(q^2),A_1(q^2),A_2(q^2),A_3(q^2),T_1(q^2),T_2(q^2),T_3(q^2)\}\ ,$$

are fitted to the the following functions [24, 25]:

$$F(q^2)=\frac{F(0)}{1-a_F\frac{q^2}{m_{B_s}^2}+b_F(\frac{q^2}{m_{B_s}^2})^2}, \tag{10}$$

where the parameters $F(0)$, a_F and b_F are shown in the TableI.

	$A_0^{B_s\to\phi}$	$A_1^{B_s\to\phi}$	$A_2^{B_s\to\phi}$	$V^{B_s\to\phi}$	$T_1^{B_s\to\phi}$	$T_2^{B_s\to\phi}$	$T_3^{B_s\to\phi}$
$F(0)$	0.382	0.296	0.255	0.433	0.174	0.174	0.125
a_F	1.77	0.87	1.55	1.75	1.82	0.70	1.52
b_F	0.856	−0.061	0.513	0.736	0.825	−0.315	0.377

Table 1: The form factors for $B_s\to\phi\,\ell^+\ell^-$ in a three–parameter fit [24].

The matrix element of the $B_s\to\phi\,\ell^+\ell^-$ decay using above equation can be written as:

$$\begin{aligned}\mathcal{M}(B_s\to\phi\ell^+\ell^-)=&\frac{G\alpha}{4\sqrt{2}\pi}V_{tb}V_{ts}^* \qquad (11)\\ \times\Bigg\{&\bar\ell\gamma^\mu(1-\gamma_5)\ell\Big[-2B_0\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\phi^\lambda q^\sigma-iB_1\varepsilon_\mu^*\\ &+iB_2(\varepsilon^*q)(p_{B_s}+p_\phi)_\mu+iB_3(\varepsilon^*q)q_\mu\Big]\\ &+\bar\ell\gamma^\mu(1+\gamma_5)\ell\Big[-2C_1\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\phi^\lambda q^\sigma-iD_1\varepsilon_\mu^*\\ &+iD_2(\varepsilon^*q)(p_{B_s}+p_\phi)_\mu+iD_3(\varepsilon^*q)q_\mu\Big]\Bigg\}\ ,\end{aligned}$$

where

$$
\begin{aligned}
B_0 &= (\tilde{C}_9^{\rm eff} - \tilde{C}_{10}^{\rm eff})\frac{V}{m_{B_s}+m_\phi} + 4(m_{B_s}+m_s)C_7^{\rm eff}\frac{T_1}{q^2}\ , \\
B_1 &= (\tilde{C}_9^{\rm eff} - \tilde{C}_{10}^{\rm eff})(m_{B_s}+m_\phi)A_1 + 4(m_{B_s}-m_s)C_7^{\rm eff}(m_{B_s}^2-m_\phi^2)\frac{T_2}{q^2}\ , \\
B_2 &= \frac{\tilde{C}_9^{\rm eff} - \tilde{C}_{10}^{\rm eff}}{m_{B_s}+m_\phi}A_2 + 4(m_{B_s}-m_s)C_7^{\rm eff}\frac{1}{q^2}\left[T_2 + \frac{q^2}{m_{B_s}^2-m_\phi^2}T_3\right]\ , \\
B_3 &= 2(\tilde{C}_9^{\rm eff} - \tilde{C}_{10}^{\rm eff})m_\phi\frac{A_3-A_0}{q^2} - 4(m_{B_s}-m_s)C_7^{\rm eff}\frac{T_3}{q^2}\ , \\
C_1 &= B_0(\tilde{C}_{10}^{\rm eff} \to -\tilde{C}_{10}^{\rm eff})\ , \\
D_i &= B_i(\tilde{C}_{10}^{\rm eff} \to -\tilde{C}_{10}^{\rm eff})\ , \quad (i=1,\ 2,\ 3).
\end{aligned}
$$

From the expression of the matrix element given in Eq. (11), we get the following result for the differential decay width

$$
\frac{d\Gamma^\phi}{d\hat{s}}(B_s \to \phi\ell^+\ell^-) = \frac{G^2\alpha^2 m_{B_s}}{2^{14}\pi^5}\,|V_{tb}V_{ts}^*|^2\,\lambda^{1/2}(1,\hat{r},\hat{s})v\Delta(\hat{s})\ , \qquad (12)
$$

with

$$
\begin{aligned}
\Delta \;=\;& \frac{2}{3\hat{r}_\phi\hat{s}}m_{B_s}^2 Re[-12m_{B_s}^2\hat{m_l}^2\lambda\hat{s}\{(B_3-D_2-D_3)B_1^* - (B_3+B_2-D_3)D_1^*\} \\
&+12m_{B_s}^4\hat{m_l}^2\lambda\hat{s}(1-\hat{r}_\phi)(B_2-D_2)(B_3^*-D_3^*) \\
&+48\hat{m_l}^2\hat{r}_\phi\hat{s}(3B_1D_1^* + 2m_{B_s}^4\lambda B_0C_1^*) \\
&-16m_{B_s}^4\hat{r}_\phi\hat{s}\lambda(\hat{m_l}^2-\hat{s})\{|B_0|^2+|C_1|^2\} \\
&-6m_{B_s}^4\hat{m_l}^2\lambda\hat{s}\{2(2+2\hat{r}_\phi-\hat{s})B_2D_2^* - \hat{s}|(B_3-D_3)|^2\} \\
&-4m_{B_s}^2\lambda\{\hat{m_l}^2(2-2\hat{r}_\phi+\hat{s}) + \hat{s}(1-\hat{r}_\phi-\hat{s})\}(B_1B_2^*+D_1D_2^*) \\
&+\hat{s}\{6\hat{r}_\phi\hat{s}(3+v^2)+\lambda(3-v^2)\}\{|B_1|^2+|D_1|^2\} \\
&-2m_{B_s}^4\lambda\{\hat{m_l}^2[\lambda-3(1-\hat{r}_\phi)^2]-\lambda\hat{s}\}\{|B_2|^2+|D_2|^2\}],
\end{aligned}
$$

where $\hat{s}=q^2/m_{B_s}^2$, $\hat{r}_\phi = m_\phi^2/m_{B_s}^2$ and $\lambda(a,b,c)=a^2+b^2+c^2-2ab-2ac-2bc$, $\hat{m}_\ell = m_\ell/m_{B_s}$, $v=\sqrt{1-4\hat{m}_\ell^2/\hat{s}}$ is the final lepton velocity.

3 The Effects of the Fourth-Generation

The new effective hamiltonian with existence of fourth generation quarks as:

$$\mathcal{H}_{\text{eff}} = -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} C_i^{\text{new}}(\mu) \mathcal{O}_i(\mu), \tag{13}$$

Where $C_i^{\text{new}}(\mu)$ are

$$C_i^{\text{new}}(\mu) \;=\; C_i(\mu) + \frac{\lambda_{t'}}{\lambda_t} C_i^{\text{SM4}}(\mu), \qquad i = 1 \ldots 10. \tag{14}$$

Where $\lambda_f = V_{fb}^* V_{fs} = r_{sb} e^{i\phi_{sb}}$ and $\lambda_{t'}$ can be parameterized as:

$$\lambda_{t'} = V_{t'b} V_{t's}^* = r_{sb} e^{i\phi_{sb}}. \tag{15}$$

In the above equation, it is clear that the insertion of fourth generation in the $\mathcal{H}_{\text{eff}}$ not lead to new operators and all Wilson coefficients receive additional terms as$\frac{\lambda_{t'}}{\lambda_t} C_i^{\text{SM4}}(\mu)$ either via virtual exchange of the fourth-generation up type quark $t'(C_3, ..., C_{10})$ or via using the unitarity of CKM matrix (C_1, C_2). The unitary quark mixing matrix is now 4×4 satisfy the relation

$$\lambda_u + \lambda_c + \lambda_t + \lambda_{t'} = 0. \tag{16}$$

As a result, for the $m_{t'} \to m_t$ or $\lambda_{t'} \to 0$ the factor $\lambda_t C_i^{\text{new}}$ should be modified to $\lambda_t C_i$ as required by the GIM mechanism as Eq.(29):

$$\begin{aligned} \lambda_t C_i^{\text{new}} = \lambda_t C_i + \lambda_{t'} C_i^{\text{SM4}} &= -(\lambda_u + \lambda_c) C_i + \lambda_{t'} (C_i^{\text{SM4}} - C_i) \\ &= -(\lambda_u + \lambda_c) C_i \\ &= \lambda_t C_i. \end{aligned} \tag{17}$$

Now by using the above effective Hamiltonian, we can recalculate the one-loop matrix elements of $b \to s\ell^+\ell^-$ by replacing $C_i^{\text{eff}}(\tilde{C}_i^{\text{eff}})$ with $C_i^{\text{eff new}}(\tilde{C}_i^{\text{eff new}})$ in Eq.(2), where $C_i^{\text{eff new}}$ and $\tilde{C}_i^{\text{eff new}}$ are given as:

$$\begin{aligned} C_i^{\text{eff new}}(\mu) &= C_i^{\text{eff}}(\mu) + \frac{\lambda_{t'}}{\lambda_t} C_i^{\text{eff SM4}}(\mu), \qquad i = 7, \\ \tilde{C}_i^{\text{eff new}}(\mu) &= \tilde{C}_i^{\text{eff}}(\mu) + \frac{\lambda_{t'}}{\lambda_t} \tilde{C}_i^{\text{eff SM4}}(\mu), \qquad i = 9, 10. \end{aligned} \tag{18}$$

Here the effective Wilson coefficients $C_i^{\text{eff SM4}}$ and $\tilde{C}_i^{\text{eff SM4}}$ are defined in the same way as Eqs.(3) by substituting C_i with C_i^{SM4}. It is worth nothing that the explicit forms of $C_i^{\text{eff SM4}}$ and $\tilde{C}_i^{\text{eff SM4}}$ can also be found from the corresponding

Wilson coefficients in SM by replacing $m_{t'} \to m_t$ [17]. Consequently, we can reobtain the differential decay width for $B_s \to \phi\ell^+\ell^-$ decay in the presence of the fourth-generation and use it in next section for calculating of the CP-violating asymmetry.

4 Numerical analysis

In this section, we will analyze the dependence of the CP-violating asymmetry to the mass of fourth quark (mt') and the product of quark mixing matrix elements $(V_{t'b}V^*_{t's} = r_{sb}e^{i\phi_{sb}})$, which is defined as

$$A^{\phi}_{CP}(\hat{s}) = \frac{\left(\frac{d\Gamma^{\phi}}{d\hat{s}}\right)_0 - \left(\frac{d\bar{\Gamma}^{\phi}}{d\hat{s}}\right)_0}{\left(\frac{d\Gamma^{\phi}}{d\hat{s}}\right)_0 + \left(\frac{d\bar{\Gamma}^{\phi}}{d\hat{s}}\right)_0} \tag{19}$$

where $(\frac{d\Gamma^{\phi}}{d\hat{s}})_0$ is the unpolarized differential decay rate given by Eq. (12) $(\frac{d\bar{\Gamma}^{\phi}}{d\hat{s}})_0$ and is the unpolarized differential decay rate for the antiparticle channel.
The main input parameters in the calculations are the form factors, which are the predictions of light cone QCD sum rule method [24, 25],as pointed out in section II. The other input parameters we use in our numerical calculations as follow:

$$\begin{aligned} &m_{B_s} = 5.37\,\text{GeV}\,,\; m_b = 4.8\,\text{GeV}\,,\; m_c = 1.5\,\text{GeV}\,,\; m_\tau = 1.77\,\text{GeV}\,,\\ &m_\mu = 0.105\,\text{GeV},\; m_\phi = 1.020\,\text{GeV}\;,\; |V_{tb}V^*_{ts}| = 0.0385\,,\; \alpha^{-1} = 129\,,\\ &G_f = 1.166\times10^{-5}\,\text{GeV}^{-2}\,,\; \tau_{B_s} = 1.46\times10^{-12}\,s\,. \end{aligned} \tag{20}$$

In order to present a quantitative analysis of the CP asymmetry, the values of fourth-generation parameters $(m_{t'}, r_{sb}, \phi_{sb})$ are needed. We include the bound on $r_{sb} \sim \{0.01 - 0.03\}$ for $\phi_{sb} \sim \{0^\circ - 360^\circ\}$ and $m_{t'} \sim \{200 - 600\}$ GeV using the experimental values of $B \to X_s\gamma$ and $B \to X_s\ell^+\ell^-$ decays [15, 26]. In the other hand, considering the B_s mixing, which is in terms of the Δm_{B_s} a sharp restriction on ϕ_{sb} has been obtained $(\phi_{sb} \sim 90^\circ)$[27]. Accordingly, this new parameters taking into account all the above constraints can be determine as:
$r_{sb} = \{0.01, 0.02, 0.03\}$, $\phi_{sb} = \{60^\circ, 90^\circ, 120^\circ\}$, $m_{t'} = 175 \leq m_{t'} \leq 600$.
Now before performing numerical analysis, we should solve a problem about dependencies of the CP asymmetry formula (A^{ϕ}_{CP}) on both $\hat{s}$ and new parameters $(m_{t'}, r_{sb}, \phi_{sb})$, because it may be experimentally difficult to investigate these dependencies at the same time. One way to deal with this problem is to integrate over

q^2 and study the averaged CP asymmetry. The total branching ratio and average of A_{CP}^{ϕ} over q^2 are defined as:

$$B_r = \int_{4\hat{m}_\ell^2}^{(1-\sqrt{\hat{r_\phi}})^2} \frac{d\mathcal{B}}{d\hat{s}} d\hat{s} \ . \tag{21}$$

$$\langle A_{CP}^{\phi} \rangle = \frac{\displaystyle\int_{4\hat{m}_\ell^2}^{(1-\sqrt{\hat{r_\phi}})^2} A_{CP}^{\phi} \frac{d\mathcal{B}}{d\hat{s}} d\hat{s}}{B_r} \ . \tag{22}$$

Figure 1 shows the dependence of CP asymmetry on various r_{sb} in terms of m_t' for μ and τ leptons. For μ channel, the values of $\langle A_{CP}^{\phi} \rangle$ sensitive to the fourth generation quark mass $(m_t{}')$ and the product of quark mixing matrix elements (r_{sb}). Furthermore, $\langle A_{CP}^{\phi} \rangle$ is decreasing function of r_{sb} and increasing function of ϕ_{sb} for μ channel while it is increasing and decreasing function of $(m_t{}')$.

Numerical calculations in figure 1 show that the $\langle A_{CP}^{\phi} \rangle$ strongly dependents on the fourth-generation parameters for τ channel. But this dependency in τ case is greater than μ case. Similar to the $|mu$ case the maximum deviation from SM happens for $r_{sb} \sim \{0.02 - 0.03\}$ and $m_{t'} \sim \{300 - 400\}$GeV. Therefor The measurement $\langle A_{CP}^{\phi} \rangle$,especially, for τ case can used as a good tool when looking for the fourth generation of quarks.

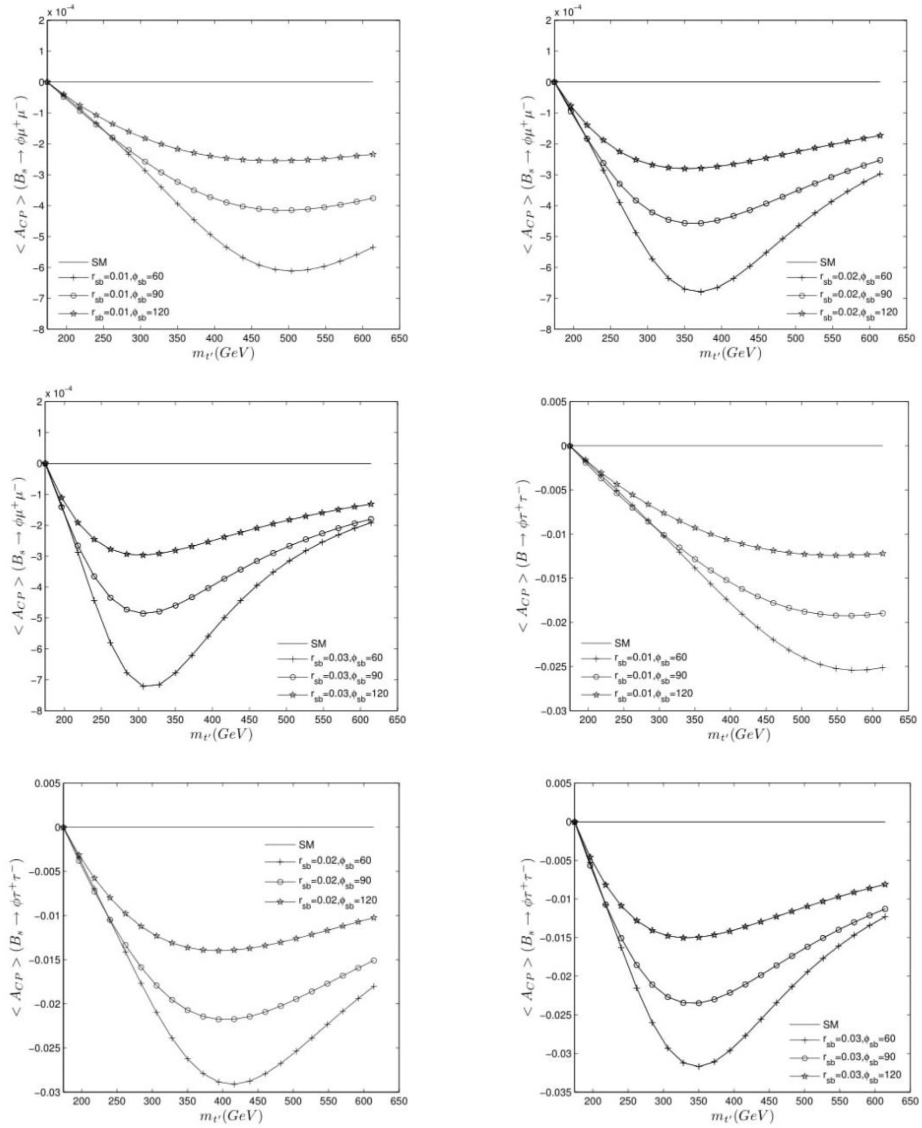

Figure 1: The dependence of the $\langle A^{\phi}_{CP} \rangle$ on the fourth-generation quark mass $m_{t'}$ at three different values of $\phi_{sb} = \{60^\circ,\ 90^\circ,\ 120^\circ\}$ and $r_{sb} = \{0.01,\ 0.02,\ 0.03\}$ for the μ and τ channels.

5 Conclusion

As the concluding remark we can state that, we study the effects of fourth generation quarks on semileptonic rare $B_s \to \phi\ell^+\ell^-$ decay. The CP asymmetry of the relevant decay for $\ell = \mu, \tau$ leptons are analysed. We found out that CP asymmetry depict a strong dependence on the fourth quark (m'_t) and on the product of quark mixing matrix elements $(V_{t'b}V^*_{t's} = r_{sb}e^{i\phi_{sb}})$. We found that this dependency in τ case is greater than μ case. In particular, the results can be used for an indirect search to look for the fourth generation of quarks at experimental particle physics laboratories.

6 Acknowledgment

Support of Research center of university of Garmian is gratefully acknowledged.

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