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Forward-backward asymmetries of $B \rightarrow \phi\ell^+\ell^-$ decay in the SM4

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Abstract

In this paper, we investigate the effects of fourth generation quarks in the unpolarized and polarized forward-backward asymmetries of $B \rightarrow \phi\ell^+\ell^-$ decay. The fourth generation quarks change the values of Wilson coefficients in effective Hamiltonian which is the main part of differential decay rate. Taking the $|V_{t'b}V^*_{t's}| \sim \{0.02\}$ with phase $\{90^o\}$, we conclude that the forward-backward asymmetries of $B \rightarrow \phi l^+ l^-$decay is very sensitive to existing of new parameters of fourth generation quarks for both (μ, τ) leptons. In the end, It seems that the study of the forward-backward asymmetries can be a very useful tool for establishing new physics beyond Standard model as well as B-physics experiments.

Keywords: Fourth generation quarks, Forward-backward asymmetries, Effective Hamiltonian, Wilson coefficients.

1 Introduction

Fourth generation standard model (denoted SM4) is an attractive and new version of Standard Model (SM) with three generation of fermions (i.e. quarks and leptons) [1,2]. Although the LHC (Large Hadron Corridor) researches have not discovered directly the heavy fourth generation t' and b' quarks so far. One of the efficient ways to establish the existence of the 4th generation is via their indirect manifestations in loop diagrams. There are many works in various field that approve the existence of fourth generation quarks for instance Higgs and neutrino physics, Cosmology and dark matter [3-8].

In this paper we investigate the possibility of new physics in the heavy baryon decays $B \rightarrow \phi\ell^+\ell^-$ using the Standard Model with fourth generation t' and b' quarks. The fourth quark (t′), like u, c, t quarks, contributes in the b → s(d) transition at loop level. It would, Clearly, change the branching ratio and asymmetries such as forward-backward, CP-violation and polarizations. The sensitivity of the CP asymmetry, double lepton polarization and single lepton polarization asymmetries to the existence of fourth generation quarks in $B \to \phi\ell^+\ell^-$ decay is investigated in [9-11] and it is obtained that these asymmetries are very sensitive to the fourth generation parameters $(m_{t'}, r_{sb}, \phi_{sb})$.

One of the most important experimental quantity for searching the new physics (NP) and new signs about particles is forward-backward asymmetry. In this work, we study the forward-backward asymmetries for $B \to \phi\ell^+\ell^-$ decay with four generation of quarks.

This paper is organized as follows. In Section II, we drive the differential decay rate using effective Hamiltonian in the presence of fourth generation quarks (t', b'). Section III devoted to calculation of the analytic expressions for the forward-backward asymmetries. Finally, the numerical analysis of forward-backward asymmetries for $B \to \phi\ell^+\ell^-$ decay with our consequences have been presented in section IV.

2 Differential decay rate

For investigation of any physical quantity in particle physics such as CP violation, Polarization asymmetry and other experimental quantities, we need to calculate the differential decay rate. The differential decay rate of $B \to \phi\ell^+ \ell^-$ decay will be determine via effective Hamiltonian at level quark for $b \to s\ell^+\ell^-$ transition as

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

Where $\mathcal{O}_i$ and $\mathcal{C}_i$ are the full set operators and the corresponding Wilson coefficients respectively which are given in [12]. Considering above items, matrix element for the $b \to s\ell^+\ell^-$ transition can be writing in the following form

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

Where effective Wilson coefficients $\tilde{C}_7^{eff}$, $\tilde{C}_9^{eff}$ and $\tilde{C}_{10}^{eff}$ at μ scale with details are given in [9].

The fourth generation changes the values of the Wilson coefficients $\tilde{C}_7^{eff}$, $\tilde{C}_9^{eff}$ and $\tilde{C}_{10}^{eff}$, via virtual exchange of the fourth generation up type quark t'. The above mentioned Wilson coefficients will explicitly change as

$$\begin{aligned} C_i^{\text{eff new}}(\mu) &= C_i^{\text{eff}}(\mu) + \frac{\lambda_{t'}}{\lambda_t} C_i^{\text{eff SM4}}(\mu), \qquad i = 7, \\ \tilde{C}_i^{\text{eff new}}(\mu) &= \tilde{C}_i^{\text{eff}}(\mu) + \frac{\lambda_{t'}}{\lambda_t} \tilde{C}_i^{\text{eff SM4}}(\mu), \qquad i = 9, 10. \end{aligned} \quad (3)$$

In the above equation, $\lambda_f = V_{fb}^* V_{fs}$ and $\lambda_{t'}$ can be parameterized as:

$$\lambda_{t'} = V_{t'b} V_{t's}^* = r_{sb} e^{i\phi_{sb}}. \quad (4)$$

The unitary of the 4×4 CKM matrix lead to

$$\lambda_u + \lambda_c + \lambda_t + \lambda_{t'} = 0. \quad (5)$$

Consequently, as required by GIM mechanism, the factor $\lambda_t C_i^{new}$ should be modified to $\lambda_t C_i$ when $m_{t'} \to m$ or $\lambda_{t'} \to 0$ (see [12, 13]). We can easily check the validity of this condition by using Eq.(5):

$$\begin{aligned} \lambda_t C_i^{\text{new}} = \lambda_t C_i + \lambda_{t'} C_i^{\text{SM4}} &= -(\lambda_u + \lambda_c) C_i + \lambda_{t'} (C_i^{\text{SM4}} - C_i) \\ &= -(\lambda_u + \lambda_c) C_i \\ &= \lambda_t C_i. \end{aligned} \quad (6)$$

Now, in order to obtaining differential decay rate width for this decay, we must calculate the matrix element at hadron level as

$$\mathcal{M}(B_s \to \phi\ell^+\ell^-) = \frac{G\alpha}{4\sqrt{2}\pi} V_{tb}V_{ts}^* \times \Bigg\{ \bar{\ell}\gamma^\mu(1-\gamma_5)\ell \Big[-2B_0\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\phi^\lambda q^\sigma - iB_1\varepsilon_\mu^* + iB_2(\varepsilon^* q)(p_{B_s}+p_\phi)_\mu + iB_3(\varepsilon^* q)q_\mu \Big] + \bar{\ell}\gamma^\mu(1+\gamma_5)\ell \Big[-2C_1\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\phi^\lambda q^\sigma - iD_1\varepsilon_\mu^* + iD_2(\varepsilon^* q)(p_{B_s}+p_\phi)_\mu + iD_3(\varepsilon^* q)q_\mu \Big] \Bigg\}, \quad (7)$$

Where

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

Above coefficients parametrized in term of form factor as

$$F(q^2) \in \{V(q^2), A_0(q^2), A_1(q^2), A_2(q^2), A_3(q^2), T_1(q^2), T_2(q^2), T_3(q^2)\}\ , \quad (8)$$

are fitted to the following function [14,15]:

$$F(q^2) = \frac{F(0)}{1 - a_F\frac{q^2}{m_{B_s}^2} + b_F(\frac{q^2}{m_{B_s}^2})^2}, \quad (9)$$

where the parameters $F(0), a_F$ and $b_F$are shown in the table1.

Table 1: The form factors for $B \to \phi\ell^+\ \ell^-$ in a three–parameter fit [14].

	$A_0^{B_s\to\phi}$	$A_1^{B_s\to\phi}$	$A_2^{B_s\to\phi}$	$V^{B_s\to\phi}$	$T_1^{B_s\to\phi}$	$T_2^{B_s\to\phi}$	$T_3^{B_s\to\phi}$
$F(0)$	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

From the above expression for matrix element, we can get the following result for the differential decay rate width

$$\frac{d\Gamma^{\phi}}{d\hat{s}}(B_s \to \phi \ell^+ \ell^-) = \frac{G^2 \alpha^2 m_{B_s}}{2^{14}\pi^5} \left|V_{tb}V_{ts}^*\right|^2 \lambda^{1/2}(1,\hat{r},\hat{s}) v \Delta(\hat{s}) \ , \tag{10}$$

With

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

Where $\hat{r}_\phi = m_\phi^2/m_{B_s}^2$, $\hat{s} = q^2/m_{B_s}^2$, $\lambda(a,b,c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc$,

$\hat{m}_\ell = m_\ell/m_{B_s}$ and $v = \sqrt{1 - 4\hat{m}_\ell^2/\hat{s}}$ is the final lepton velocity. For more detail about calculating above relations for $B \to \phi l^+ \, l^-$ decay see [9-11].

3 Forward-Backward Asymmetry of $B \to \phi l^+ \, l^-$ Decay

The definition of the unpolarized and normalized differential forward–backward asymmetry is [16-18]

$$\mathcal{A}_{FB} = \frac{\displaystyle\int_0^1 \frac{d^2\Gamma}{d\hat{s}dz} - \int_{-1}^0 \frac{d^2\Gamma}{d\hat{s}dz}}{\displaystyle\int_0^1 \frac{d^2\Gamma}{d\hat{s}dz} + \int_{-1}^0 \frac{d^2\Gamma}{d\hat{s}dz}} \ , \tag{11}$$

where $z = cos\theta$ is the angle between B meson and ℓ^- in the center of mass frame of leptons. For the spins of both leptons, the A_{FB}^{ij} will be a function of the spins of the final leptons as

$$\mathcal{A}_{FB}^{ij}(\hat{s}) = \left(\frac{d\Gamma(\hat{s})}{d\hat{s}}\right)^{-1}\left\{\int_0^1 dz - \int_{-1}^0 dz\right\}\left\{\left[\frac{d^2\Gamma(\hat{s},\vec{s}^- = \vec{i},\vec{s}^+ = \vec{j})}{d\hat{s}dz} - \frac{d^2\Gamma(\hat{s},\vec{s}^- = \vec{i},\vec{s}^+ = -\vec{j})}{d\hat{s}dz}\right] - \left[\frac{d^2\Gamma(\hat{s},\vec{s}^- = -\vec{i},\vec{s}^+ = \vec{j})}{d\hat{s}dz} - \frac{d^2\Gamma(\hat{s},\vec{s}^- = -\vec{i},\vec{s}^+ = -\vec{j})}{d\hat{s}dz}\right]\right\},$$
$$= \mathcal{A}_{FB}(\vec{s}^- = \vec{i},\vec{s}^+ = \vec{j}) - \mathcal{A}_{FB}(\vec{s}^- = \vec{i},\vec{s}^+ = -\vec{j}) - \mathcal{A}_{FB}(\vec{s}^- = -\vec{i},\vec{s}^+ = \vec{j}) + \mathcal{A}_{FB}(\vec{s}^- = -\vec{i},\vec{s}^+ = -\vec{j}) \,. \quad (12)$$

Where $i, j = L, N\ and\ T$ refer to the longitudinal, normal and transversal polarization. Using these definition for the double lepton forward-backward asymmetries after calculating we get the following results:

$$A_{FB}^{NN} = 0$$
$$A_{FB}^{TT} = 0 \quad (13)$$

$$\begin{aligned} A_{FB}^{TN} &= \frac{2}{\hat{r}_\phi \Delta\hat{s}} m_B^2 \sqrt{\lambda} Im[-2m_B^4 \hat{m_l}^2 \hat{s}\lambda(B_2 + D_2)(B_3^* - D_3^*) \\ &+ 4m_B^4 \hat{m_l}^2 \lambda(1 - \hat{r}_\phi) B_2 D_2^* \\ &+ 2m_B^2 \hat{m_l}^2 \hat{s}(1 + 3\hat{r}_\phi - \hat{s})(B_1 B_2^* - D_1 D_2^*) \\ &+ \hat{m}_l(1 - \hat{r}_\phi - \hat{s})\{-2\hat{s}m_B^2 \hat{m}_l(B_1 + D_1)(B_3^* - D_3^*) \\ &+ 4\hat{m}_l B_1 D_1^*\} \\ &+ 2m_B^2 \hat{m_l}^2[\lambda + (1 - \hat{r}_\phi - \hat{s})(1 - \hat{r}_\phi)](B_1^* D_2 + B_2^* D_1)] \end{aligned} \quad (14)$$

$$\begin{aligned} A_{FB}^{NT} &= \frac{2}{\hat{r}_\phi \Delta\hat{s}} m_B^2 \sqrt{\lambda} Im[-2m_B^4 \hat{m_l}^2 \hat{s}\lambda(B_2 + D_2)(B_3^* - D_3^*) \\ &+ 4m_B^4 \hat{m_l}^2 \lambda(1 - \hat{r}_\phi) B_2 D_2^* \\ &+ 2m_B^2 \hat{m_l}^2 \hat{s}(1 + 3\hat{r}_\phi - \hat{s})(B_1 B_2^* - D_1 D_2^*) \\ &+ \hat{m}_l(1 - \hat{r}_\phi - \hat{s})\{+2\hat{s}m_B^2 \hat{m}_l(B_1 + D_1)(B_3^* - D_3^*) \\ &+ 4\hat{m}_l B_1 D_1^*\} \\ &+ 2m_B^2 \hat{m_l}^2[\lambda + (1 - \hat{r}_\phi - \hat{s})(1 - \hat{r}_\phi)](B_1^* D_2 + B_2^* D_1)] \end{aligned} \quad (15)$$

$$\begin{aligned} A_{FB}^{TL} &= \frac{4}{3\hat{r}_\phi \Delta\hat{s}} m_B^2 \sqrt{\hat{s}}\lambda Re[\hat{m}_l\{|B_1 + D_1|^2 + m_B^4 \lambda |B_2 + D_2|^2\} \\ &- 4m_B^4 \hat{m}_l \hat{s}\hat{r}_\phi\{|B_0 + C_1|^2\} \\ &- 2m_B^2 \hat{m}_l(1 - \hat{r}_\phi - \hat{s})(B_1 + D_1)(B_2^* + D_2^*)] \end{aligned} \quad (16)$$

$$\begin{aligned} A_{FB}^{LT} &= \frac{4}{3\hat{r}_\phi \Delta\hat{s}} m_B^2 \sqrt{\hat{s}}\lambda Re[-\hat{m}_l\{|B_1 + D_1|^2 + m_B^4 \lambda |B_2 + D_2|^2\} \\ &+ 4m_B^4 \hat{m}_l \hat{s}\hat{r}_\phi\{|B_0 + C_1|^2\} \\ &+ 2m_B^2 \hat{m}_l(1 - \hat{r}_\phi - \hat{s})(B_1 + D_1)(B_2^* + D_2^*)] \end{aligned} \quad (17)$$

$$A_{FB}^{NL} = \frac{8}{3\hat{r}_\phi \Delta \hat{s}} m_B^2 \sqrt{\hat{s}} \lambda v Im[-\hat{m}_l(B_1 D_1^* + m_B^4 \lambda B_2 D_2^*) + 4 m_B^4 \hat{m}_l \hat{r}_\phi \sqrt{\hat{s}} B_0 C_1^* + m_B^2 \hat{m}_l (1 - \hat{r}_\phi - \hat{s})(B_1 D_2^* + B_2 D_1^*)] \quad (18)$$

$$A_{FB}^{LN} = \frac{8}{3\hat{r}_\phi \Delta \hat{s}} m_B^2 \sqrt{\hat{s}} \lambda v Im[-\hat{m}_l(B_1 D_1^* + m_B^4 \lambda B_2 D_2^*) + 4 m_B^4 \hat{m}_l \hat{r}_\phi \sqrt{\hat{s}} B_0 C_1^* + m_B^2 \hat{m}_l (1 - \hat{r}_\phi - \hat{s})(B_1 D_2^* + B_2 D_1^*)] \quad (19)$$

$$A_{FB}^{LL} = \frac{2}{\hat{r}_{\phi^*} \Delta} m_B^3 \sqrt{\lambda} v Re[8 m_B \hat{r}_\phi \hat{s}(B_0 B_1^* - C_1 D_1^*)] \quad (20)$$

4 Numerical Analysis

In this section, we examine the dependence the polarized forward-backward asymmetry to the fourth quark parameters ($m_{t'}, r_{sb} e^{i\phi_{sb}}$). The main input parameters we use in our numerical calculation as follow as:

$$m_{B_s} = 5.37\,\text{GeV}\,,\; m_b = 4.8\,\text{GeV}\,,\; m_c = 1.5\,\text{GeV}\,,\; m_\tau = 1.77\,\text{GeV}\,,$$
$$m_\mu = 0.105\,\text{GeV},\; m_\phi = 1.020\,\text{GeV}\;,\; |V_{tb}V_{ts}^*| = 0.0385\,,\; \alpha^{-1} = 129\,,$$
$$G_f = 1.166 \times 10^{-5}\,\text{GeV}^{-2}\,,\; \tau_{B_s} = 1.46 \times 10^{-12}\,s\,.$$

For quantitative analysis of the forward-backward asymmetry of $\rightarrow \phi \ell^+ \ell^-$, the values of fourth-generation parameters ($m_{t'}, r_{sb}, \phi_{sb}$) are needed. Using the experimental values of $B \rightarrow X_s \gamma$ and $B \rightarrow X_s \ell^+ \ell^-$decays [19,20], we insert bounds on r_{sb}~{0.01-0.03} for $\phi_{sb} \sim \{0^0 - 360^0\}$ and $m_{t'} \sim \{200 - 600\}$ GeV. Accordingly, we took this new parameters taking into account all the above constraints as:

$$r_{sb} = 0.02,\; \phi_{sb} = 90^0, m_{t'} = 200 \le m_{t'} \le 600$$

Now before performing numerical analysis, we should solve a problem about dependencies of the Forward-Backward asymmetry formula (A_{FB}^{ij}) 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 Forward-Backward asymmetry. The total branching ratio (B_r) and average A_{FB}^{ij}over $q^2$are defined as:

$$B_r = \int_{4\hat{m}_\ell^2}^{(1-\sqrt{\hat{r}_\phi})^2} \frac{d\mathcal{B}}{d\hat{s}} d\hat{s}\;, \quad (21)$$

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

Figure 1-6 show the dependence of forward-backward asymmetris on r_{sb} =0.02, $\phi_{sb} = 90^0$ in term of $m_{t'}$ for μ and τ leptons. All figures dedicate that values $< A_{FB}^{ij} >$ strongly sensitive to fourth generation quark mass for both τ and μ channels. Moreover, the maximum deviation from SM in τ case is much more than that in μ case for $< A_{FB}^{LL} >$, $< A_{FB}^{LT} >$, $< A_{FB}^{TL} >$, $< A_{FB}^{TN} >$, and $< A_{FB}^{NT} >$. These results can be interesting since the maximum deviation from SM happens for $m_{t'} \sim \{300 - 400\}$ GeV. Therefore, the measurement of forward-backward asymmetry of $B \to \phi \ell^+ \ell^-$ decay in this range can used as a good tool when looking for the fourth generation quark and new physics.

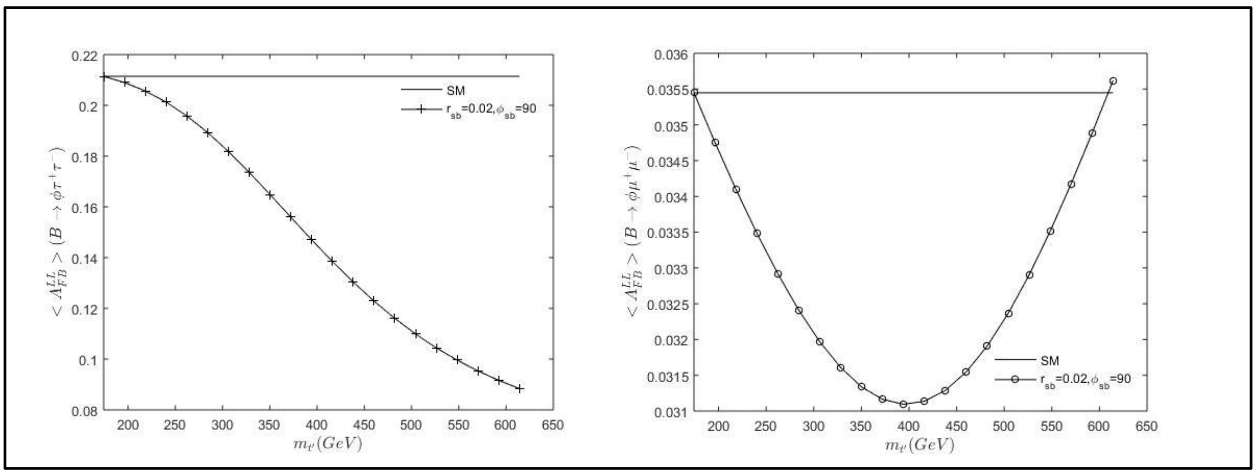

Figure 1: The dependence of the $< A_{FB}^{LL} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

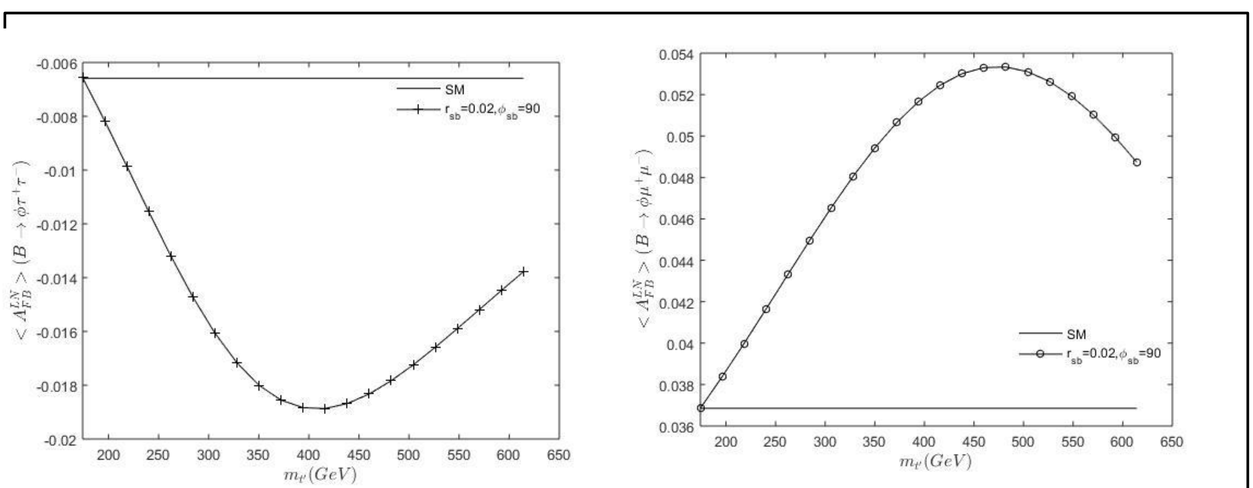

Figure 2: The dependence of the $< A_{FB}^{LN} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

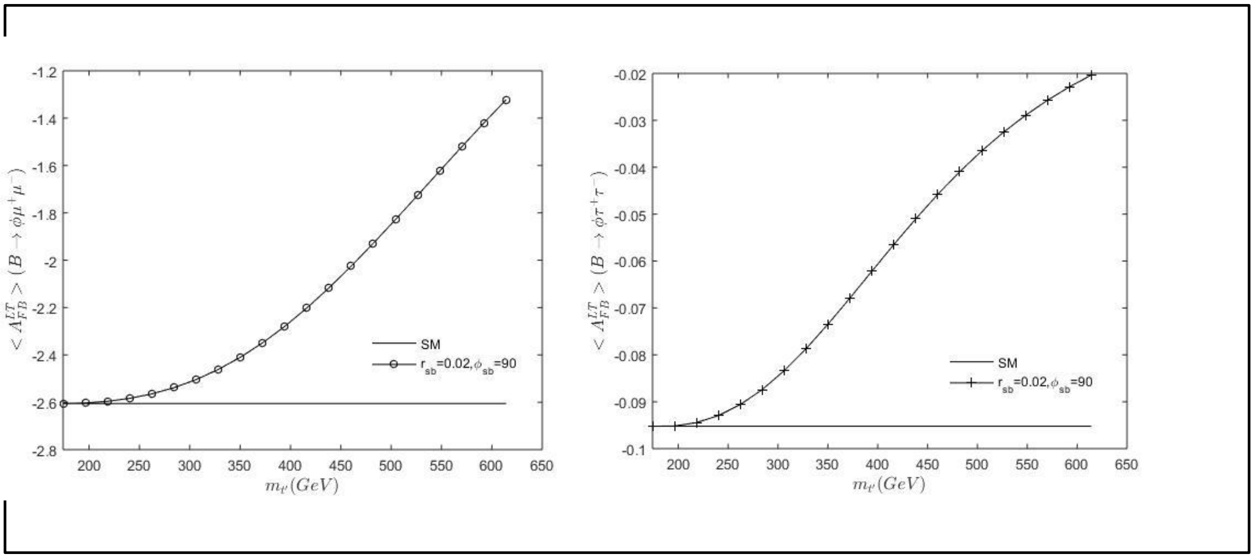

Figure 3: The dependence of the $< A_{FB}^{LT} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

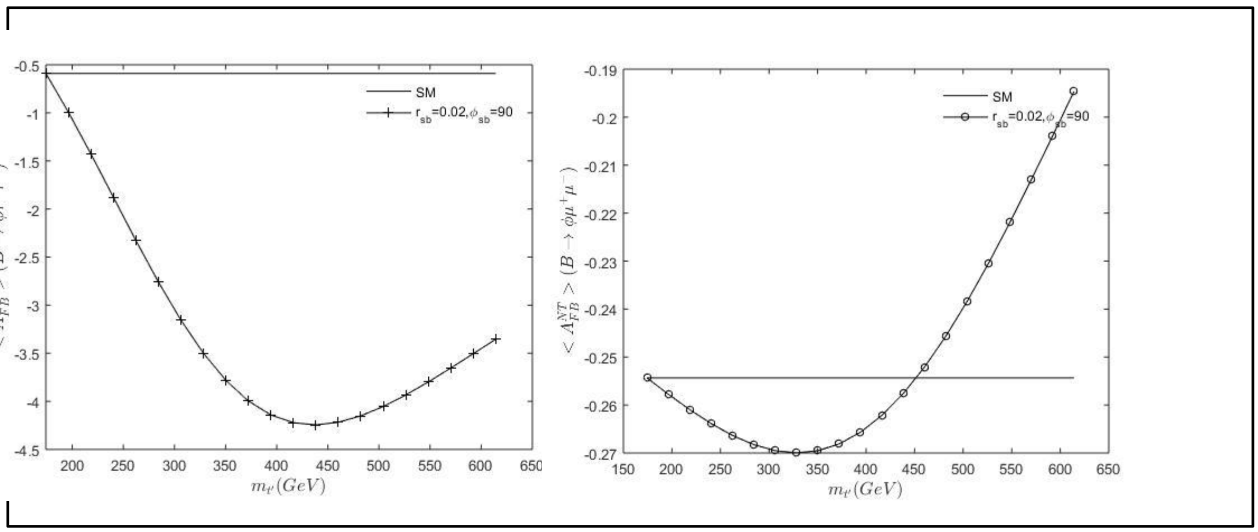

Figure 4: The dependence of the $< A_{FB}^{NT} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

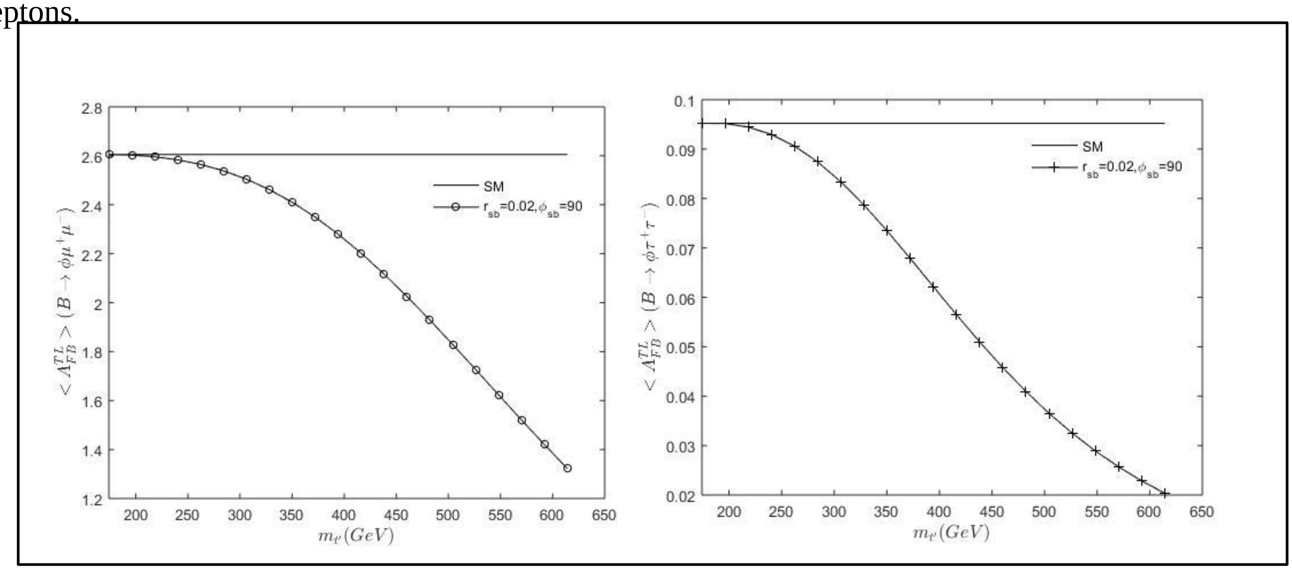

Figure 5: The dependence of the $< A_{FB}^{TL} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

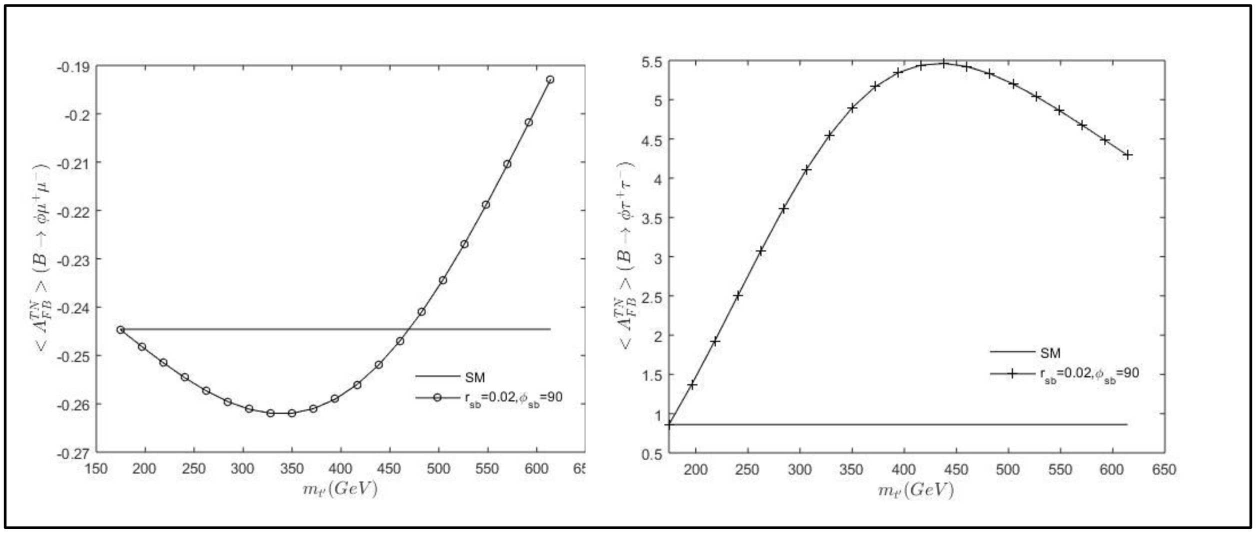

Figure 6: The dependence of the $< A_{FB}^{TN} >$ on the fourth generation quark mass $m_{t'}$ for the μ and τ leptons.

Conclusion

To conclude, we investigate effects of fourth generation quark on the forward-backward asymmetries for $B \to \phi\ell^+\ell^-$ decay. All $< A_{FB}^{ij} >$ showed intensive dependency on the fourth generation parameters. In the other hand, we found that this dependency in τ lepton is greater than μ lepton and probability of finding this new generation for $m_{t'} \sim \{300 - 400\}$ GeV in high energy physics laboratories is more expectant.

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