Impact of squark generation mixing on the search for squarks decaying into fermions at LHC

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Abstract

We study the effect of squark generation mixing on squark production and decays at LHC in the Minimal Supersymmetric Standard Model (MSSM). We show that the effect can be very large despite the very strong constraints on quark flavour violation (QFV) from experimental data on B mesons. We find that the two lightest up-type squarks $\tilde{u}_{1,2}$ can have large branching ratios for the decays into $c\tilde{\chi}_1^0$ and $t\tilde{\chi}_1^0$ at the same time due to squark generation mixing, leading to QFV signals \( pp \rightarrow c\bar{t}(t\bar{c}) + \text{missing-}E_T + X \) with a significant rate. The observation of this remarkable signature would provide a powerful test of supersymmetric QFV at LHC. This could have a significant impact on the search for squarks and the determination of the underlying MSSM parameters.
1 Introduction

The exploration of the TeV scale has begun with the start up of the LHC run. Gluinos and squarks, the supersymmetric partners of gluons and quarks, will be produced copiously for masses up to $O(1 \text{ TeV})$ if supersymmetry (SUSY) is realized in nature. After the discovery of SUSY, the determination of SUSY parameters will be one of the main experimental programs. The determination of the soft-SUSY-breaking parameters will be particularly important to pin down the SUSY breaking mechanism. As the soft-SUSY-breaking terms are the source of flavour violation beyond the Standard Model (SM), the measurement of flavour violating observables is directly linked to the crucial question about the SUSY-breaking mechanism. It is usually assumed that production and decays of gluinos and squarks are quark-flavour conserving (QFC). However, additional flavour structures (i.e. squark generation mixings) would imply that squarks are not quark-flavour eigenstates, which could result in sizable quark-flavour violation (QFV) effects significantly larger than those due to the Cabibbo-Kobayashi-Maskawa (CKM) mixing.

The effect of QFV in the squark sector on reactions with external particles being SM particles [1, 2] (or SUSY Higgs bosons [3]) has been studied in several publications. In this case the effect of QFV in the squark sector is induced only by SUSY particle (sparticle) loops. However, in reactions with external SUSY particles, the QFV effect can already occur at tree-level and hence can be rather large. The QFV decay $\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$ [4] and QFV gluino decays [5] were studied in the scenario of minimal flavour violation (MFV), where the only source of QFV is the mixing due to the CKM matrix. Squark pair production and their decays at LHC have been analyzed in scenarios of non-minimal flavour violation (NMFV), where the effect of the squark generation mixing is also included [6, 7]. QFV gluino decays [8] and QFV squark decays [9] have been studied in the Minimal Supersymmetric Standard Model (MSSM) with squark generation mixing in its most general form.

In the present paper, we study the effect of QFV due to the mixing of charm-squarks and top-squarks both on production and subsequent decays of squarks in the general MSSM with R parity conservation. We show that the QFV squark decay branching ratios $B(\tilde{u}_i \rightarrow c \tilde{\chi}_1^0)$ and $B(\tilde{u}_i \rightarrow t \tilde{\chi}_1^0)$ ($i = 1, 2$) can be very large (up to $\sim 50\%$) simultaneously due to the squark generation mixing in a significant region of
the QFV parameters despite the very strong experimental constraints from B factories, Tevatron and LEP. Here $\tilde{u}_{1,2}$ are the two lightest up-type squarks and $\tilde{\chi}^0_1$ is the lightest neutralino. This leads to QFV signal events '$pp \rightarrow c \bar{t} \ (\bar{c}t) + E_T^{mis} + X'$ and '$pp \rightarrow tt \ (\bar{t}t) + E_T^{mis} + X'$ at LHC, which we also study in the present article, where $E_T^{mis}$ is the missing transverse energy.

2 Squark mixing with flavour violation

The most general up-type squark mass matrix including left-right mixing as well as quark-flavour mixing in the super-CKM basis of $\tilde{u}_0\gamma = (\tilde{u}_L, \tilde{c}_L, \tilde{t}_L, \tilde{u}_R, \tilde{c}_R, \tilde{t}_R)$, $\gamma = 1, \ldots, 6$, is [10]

$$M^2_u = \begin{pmatrix} M^2_{\tilde{u} LL} & (M^2_{\tilde{u} RL})^\dagger \\ M^2_{\tilde{u} RL} & M^2_{\tilde{u} RR} \end{pmatrix},$$

where the three $3 \times 3$ matrices read

$$(M^2_{\tilde{u} LL})_{\alpha\beta} = M^2_{Q_{u\alpha\beta}} + \left[\left(\frac{1}{2} - \frac{2}{3} \sin^2 \theta_W \right) \cos 2\beta \ m_Z^2 + m_{u_\alpha}^2\right] \delta_{\alpha\beta},$$

$$(M^2_{\tilde{u} RR})_{\alpha\beta} = M^2_{U_{\alpha\beta}} + \left[\frac{2}{3} \sin^2 \theta_W \cos 2\beta \ m_Z^2 + m_{u_\alpha}^2\right] \delta_{\alpha\beta},$$

$$(M^2_{\tilde{u} RL})_{\alpha\beta} = (v_2/\sqrt{2})T_{U_{\beta\alpha}} - m_{u_\alpha} \mu^* \cot \beta \ \delta_{\alpha\beta}. $$

The indices $\alpha, \beta = 1, 2, 3$ characterize the quark flavours $u, c, t$, respectively. $M^2_{Q_u}$ and $M^2_U$ are the hermitean soft-SUSY-breaking mass matrices for the left and right up-type squarks, respectively. Note that in the super-CKM basis one has $M^2_{Q_u} = K \cdot M^2_{Q} \cdot K^\dagger$ due to the SU(2) symmetry, where $M^2_{Q}$ is the hermitean soft-SUSY-breaking mass matrix for the left down-type squarks and $K$ is the CKM matrix. Note also that $M^2_{Q_u} \simeq M^2_{Q}$ as $K \simeq 1$. $T_{U}$ is the soft-SUSY-breaking trilinear coupling matrix of the up-type squarks: $L_{int} = -(T_{U_{\alpha\beta}} \tilde{u}^\dagger_{R\beta} \tilde{u}_{La} H^0_2 + h.c.) + \cdots$. $\mu$ is the higgsino mass parameter. $v_{1,2}$ are the vacuum expectation values of the Higgs fields with $v_{1,2}/\sqrt{2} \equiv \langle H^0_{1,2} \rangle$, and $\tan \beta \equiv v_2/v_1$. $m_{u_\alpha}$ ($u_\alpha = u, c, t$) are the quark masses.
The physical mass eigenstates \( \tilde{u}_i, i = 1, \ldots, 6 \), are given by \( \tilde{u}_i = R_{\alpha \alpha}^u \tilde{u}_{0 \alpha} \). The mixing matrix \( R^u \) and the mass eigenvalues are obtained by a unitary transformation \( R^u M_u^2 R^u \dagger = \text{diag}(m_{\tilde{u}_1}, \ldots, m_{\tilde{u}_6}) \), where \( m_{\tilde{u}_i} < m_{\tilde{u}_j} \) for \( i < j \).

Having in mind that \( M_{Q_u}^2 \simeq M_Q^2 \), we define the QFV parameters \( \delta_{\alpha \beta}^{uL}, \delta_{\alpha \beta}^{uR} \) and \( \delta_{\alpha \beta}^{R} \) (\( \alpha \neq \beta \)) as follows [11]:

\[
\begin{align*}
\delta_{\alpha \beta}^{uL} & \equiv \frac{M_{Q_{\alpha \beta}}^2}{\sqrt{M_{Q_{\alpha \alpha}}^2 M_{Q_{\beta \beta}}^2}} ,
\delta_{\alpha \beta}^{uR} & \equiv \frac{M_{U_{\alpha \beta}}^2}{\sqrt{M_{U_{\alpha \alpha}}^2 M_{U_{\beta \beta}}^2}} ,
\delta_{\alpha \beta}^{R} & \equiv \frac{(\nu_2/\sqrt{2})T_{U_{\beta \alpha}}}{\sqrt{M_{U_{\alpha \alpha}}^2 M_{Q_{\beta \beta}}^2}} .
\end{align*}
\]

The relevant QFV parameters in this study are \( \delta_{23}^{uL}, \delta_{23}^{uR}, \delta_{23}^{R} \) and \( \delta_{32}^{uR} \) which are the \( \tilde{c}_L - \tilde{t}_L, \tilde{c}_R - \tilde{t}_R, \tilde{c}_R - \tilde{t}_L \) and \( \tilde{c}_L - \tilde{t}_R \) mixing parameters, respectively. The down-type squark mass matrix can be parametrized analogously to the up-type squark mass matrix [10].

The properties of the charginos \( \tilde{\chi}_i^\pm (i = 1, 2, m_{\tilde{\chi}_1^\pm} < m_{\tilde{\chi}_2^\pm}) \) and neutralinos \( \tilde{\chi}_k^0 (k = 1, \ldots, 4, m_{\tilde{\chi}_1^0} < \ldots < m_{\tilde{\chi}_4^0}) \) are determined by the parameters \( M_2, M_1, \mu \) and \( \tan \beta \), where \( M_2 \) and \( M_1 \) are the SU(2) and U(1) gaugino mass parameters, respectively.

### 3 Constraints

In our analysis, we impose the following conditions on the MSSM parameter space in order to respect experimental and theoretical constraints as in [8]:

(i) Constraints from the B-physics experiments relevant mainly for the mixing between the second and third generations of squarks:

\[
B(b \to s \gamma) = (3.57 \pm ((0.24 \times 1.96)^2 + (0.23 \times 1.96)^2)^{1/2}) \times 10^{-4} = (3.57 \pm 0.65) \times 10^{-4} \quad (95\% \text{ CL}),
\]

where we have combined the experimental error of \( 0.24 \times 1.96 \times 10^{-4} \quad (95\% \text{ CL}) \) [12] quadratically with the theoretical uncertainty of \( 0.23 \times 1.96 \times 10^{-4} \quad (95\% \text{ CL}) \) [13], \( 0.60 \times 10^{-6} < B(b \to s l^+l^-) < 2.60 \times 10^{-6} \) with \( l = e \) or \( \mu \) (95% CL) [14], \( B(B_s \to \mu^+\mu^-) < 4.3 \times 10^{-8} \quad (95\% \text{ CL}) \) [12], \( |R_{Br}\rangle_{\text{ SUSY}} - 1.35| < 0.76 \quad (95\% \text{ CL}) \) with \( R_{Br}\rangle_{\text{ SUSY}} = B\rangle_{\text{ SUSY}}(B^\rightarrow_{u} \to \tau^-\nu_\tau)/B\rangle_{\text{ SM}}(B^\rightarrow_{u} \to \tau^-\nu_\tau) \simeq (1 - (m_{\tilde{\mu}^+} \tan \beta))/m_{\tilde{\mu}^+}^2 \rangle^2 \) [15]. Moreover we impose the following condition on the SUSY
prediction: $|\Delta M_{B_s}^{SUSY} - 17.77| < ((0.12 \times 1.96)^2 + 3.3^2)^{1/2} ps^{-1} = 3.31 \, ps^{-1}$ (95% CL), where we have combined the experimental error of 0.12 × 1.96 ps⁻¹ (95% CL) [16] quadratically with the theoretical uncertainty of 3.3 ps⁻¹ (95% CL) [17].

(ii) The experimental limit on SUSY contributions to the electroweak $\rho$ parameter [18]: $\Delta \rho(SUSY) < 0.0012$.

(iii) The LEP limits on the SUSY particle masses [19]: $m_{\tilde{\chi}_i^\pm} > 103$ GeV, $m_{\tilde{\chi}_i^0} > 50$ GeV, $m_{\tilde{u}_1,\tilde{d}_1} > 100$ GeV, $m_{\tilde{u}_1,\tilde{d}_1} > m_{\tilde{\chi}_1^0}$, $m_{A^0} > 93$ GeV, $m_{h^0} > 110$ GeV, where $A^0$ is the CP-odd Higgs boson and $h^0$ is the lighter CP-even Higgs boson.

(iv) The Tevatron limits on the gluino and squark masses [20].

(v) The vacuum stability conditions for the trilinear coupling matrix [21]:

\[
|T_{U_{\alpha\alpha}}|^2 < 3 Y^2_{U_{\alpha}} (M^2_{Q_{u\alpha\alpha}} + M^2_{U_{\alpha\alpha}} + m^2_2), \tag{8}
\]

\[
|T_{D_{\alpha\alpha}}|^2 < 3 Y^2_{D_{\alpha}} (M^2_{Q_{d\alpha\alpha}} + M^2_{D_{\alpha\alpha}} + m^2_1), \tag{9}
\]

\[
|T_{U_{\alpha\beta}}|^2 < Y^2_{U_{\gamma}} (M^2_{Q_{u\alpha\alpha}} + M^2_{U_{\beta\beta}} + m^2_2), \tag{10}
\]

\[
|T_{D_{\alpha\beta}}|^2 < Y^2_{D_{\gamma}} (M^2_{Q_{d\alpha\alpha}} + M^2_{D_{\beta\beta}} + m^2_1), \tag{11}
\]

with $(\alpha \neq \beta; \gamma = \text{Max}(\alpha, \beta); \alpha, \beta = 1, 2, 3)$ and $m^2_1 = (m^2_{H^\pm} + m^2_2 \sin^2 \theta_W) \sin^2 \beta - \frac{1}{2} m^2_Z$, $m^2_2 = (m^2_{H^\pm} + m^2_Z \sin^2 \theta_W) \cos^2 \beta - \frac{1}{2} m^2_Z$. The Yukawa couplings of the up-type and down-type quarks are $Y_{U_{\alpha}} = \sqrt{2} m_{u_{\alpha}} / v_2 = \frac{g}{\sqrt{2} m_{W} \sin \beta} (u_{\alpha} = u, c, t)$ and $Y_{D_{\alpha}} = \sqrt{2} m_{d_{\alpha}} / v_1 = \frac{g}{\sqrt{2} m_{W} \cos \beta} (d_{\alpha} = d, s, b)$, with $m_{u_{\alpha}}$ and $m_{d_{\alpha}}$ being the running quark masses at the weak scale and $g$ the SU(2) gauge coupling. All soft-SUSY-breaking parameters are assumed to be given at the weak scale. As SM parameters we take $m_W = 80.4$ GeV, $m_Z = 91.2$ GeV and the on-shell top-quark mass $m_t = 174.3$ GeV. We have found that our results shown in the following are fairly insensitive to the precise value of $m_t$.

We calculate the observables in (i)-(iv) by using the public code SPheno v3.0 [22]. Condition (i) except for $B(B_u^- \rightarrow \tau^- \bar{\nu}_\tau)$ strongly constrains the 2nd and 3rd generation squark mixing parameters $M^2_{Q_{23}}, M^2_{U_{23}}, M^2_{D_{23}}, T_{U_{23}}, T_{D_{23}}$ and $T_{D_{32}}$. The constraints from $B(b \rightarrow s\gamma)$ and $\Delta M_{B_s}$ are especially important [9]. $B(b \rightarrow s\gamma)$ is sensitive to $M^2_{Q_{23}}, T_{U_{23}}, T_{D_{23}}$ and $\Delta M_{B_s}$ is sensitive to $M^2_{Q_{23}} \cdot T_{U_{23}}, M^2_{Q_{23}} \cdot T_{D_{23}}$. 


Table 1: The basic MSSM parameters in our reference scenario with QFV. All of $T_{U_{\alpha\beta}}$ and $T_{D_{\alpha\beta}}$ are set to zero. All mass parameters are given in GeV.

4 Flavour violating fermionic squark decays

We study the effect of the mixing between the 2nd and 3rd generation of squarks on their decays. The branching ratios of the squark decays

$$\tilde{u}_{1,2} \rightarrow c \, \chi_1^0 \quad \text{and} \quad \tilde{u}_{1,2} \rightarrow t \, \chi_1^0$$  \hspace{1cm} (12)$$

are calculated by taking into account the following two–body decays:

$$\tilde{u}_i \rightarrow u_k \, \tilde{g}, \ u_k \, \chi_n^0, \ d_k \, \tilde{\chi}_m^+, \ \tilde{u}_j \, Z^0, \ \tilde{d}_j \, W^+, \ \tilde{u}_j \, h^0,$$  \hspace{1cm} (13)$$

where $u_k = (u, c, t)$ and $d_k = (d, s, b)$. The decays into the heavier Higgs bosons are kinematically forbidden in our scenarios studied below. The formulae for the widths of the two–body decays in (13) can be found in [6], except for the squark decays into the Higgs boson, for which we take the formulae of [23, 24].

We take $\tan \beta, m_{A^0}, M_1, M_2, M_3, \mu, M^2_{Q_{\alpha\beta}}, M^2_{U_{\alpha\beta}}, M^2_{D_{\alpha\beta}}, T_{U_{\alpha\beta}}$ and $T_{D_{\alpha\beta}}$ as the basic MSSM parameters at the weak scale and assume them to be real. Here $M_3$ is the SU(3) gaugino mass parameter. The QFV parameters are the squark generation mixing terms $M^2_{Q_{\alpha\beta}}, M^2_{U_{\alpha\beta}}, M^2_{D_{\alpha\beta}}, T_{U_{\alpha\beta}}$ and $T_{D_{\alpha\beta}}$ with $\alpha \neq \beta$. We study a specific scenario which is chosen so that QFV signals at LHC may be maximized and hence can serve as a benchmark scenario for further experimental investigations. As such a scenario, we
Table 2: Sparticles, Higgs bosons and corresponding masses (in GeV) in the scenario of Table 1. $H^0$ is the heavier CP-even Higgs boson.

| $\tilde{u}$ | $\tilde{d}$ | $\tilde{c}$ | $\tilde{t}$ |
|------------|------------|------------|------------|
| $\tilde{u}_1$ | 472 | 708 | 819 | 837 | 897 | 918 |
| $\tilde{u}_2$ | 800 | 820 | 830 | 835 | 897 | 922 |
| $\tilde{u}_3$ | $\tilde{d}_1$ | 1003 | 1007 |
| $\tilde{u}_4$ | $\tilde{d}_2$ | 261 | 1007 |
| $\tilde{u}_5$ | $\tilde{d}_3$ | 261 | 1007 |
| $\tilde{u}_6$ | $\tilde{d}_4$ | 122 | 800 |
| $\tilde{u}_7$ | $\tilde{d}_5$ | 800 | 800 |
| $\tilde{u}_8$ | $\tilde{d}_6$ | 804 |

Table 3: The up-type squark compositions in the flavour eigenstates, i.e. the absolute values of the mixing matrix elements $R_{\tilde{u}\alpha}^\tilde{u}$ for the scenario of Table 1.

| $|R_{\tilde{u}\alpha}^\tilde{u}|$ | $\tilde{u}_L$ | $\tilde{c}_L$ | $\tilde{t}_L$ | $\tilde{u}_R$ | $\tilde{c}_R$ | $\tilde{t}_R$ |
|-----------------|-----------|-----------|----------|-----------|-----------|----------|
| $\tilde{u}_1$   | 0.001     | 0.004     | 0.024    | 0         | 0.715     | 0.699    |
| $\tilde{u}_2$   | 0.003     | 0.014     | 0.055    | 0         | 0.699     | 0.713    |
| $\tilde{u}_3$   | 0         | 0         | 0.10     | 0         | 0         | 0        |
| $\tilde{u}_4$   | 0.128     | 0.584     | 0.800    | 0         | 0.021     | 0.053    |
| $\tilde{u}_5$   | 0.181     | 0.781     | 0.598    | 0         | 0.008     | 0.024    |
| $\tilde{u}_6$   | 0.975     | 0.221     | 0.005    | 0         | 0         | 0        |

For the most important decay branching ratios of the two lightest up-type squarks we get $B(\tilde{u}_1 \to c\tilde{\chi}^0_1) = 0.59$, $B(\tilde{u}_1 \to t\tilde{\chi}^0_1) = 0.39$, $B(\tilde{u}_2 \to c\tilde{\chi}^0_1) = 0.44$, $B(\tilde{u}_2 \to t\tilde{\chi}^0_1) = 0.40$. Note that the branching ratios of the decays of a squark into quarks of different generations are very large simultaneously, which could lead to large QFV effects. In our scenario this is a consequence of the facts that both squarks $\tilde{u}_{1,2}$ are mainly...
are very heavy in this scenario. The main decay branching ratios of the other up-type squarks are as follows: $B(\tilde{u}_3 \to u\tilde{\chi}_1^0) = 0.93$, $B(\tilde{u}_4 \to c\tilde{\chi}_2^0) = 0.09$, $B(\tilde{u}_4 \to t\tilde{\chi}_2^0) = 0.21$, $B(\tilde{u}_4 \to s\tilde{\chi}_1^+) = 0.21$, $B(\tilde{u}_3 \to b\tilde{\chi}_1^+) = 0.45$, $B(\tilde{u}_5 \to c\tilde{\chi}_2^0) = 0.19$, $B(\tilde{u}_5 \to t\tilde{\chi}_2^0) = 0.07$, $B(\tilde{u}_5 \to s\tilde{\chi}_1^+) = 0.37$, $B(\tilde{u}_6 \to b\tilde{\chi}_1^+) = 0.17$, $B(\tilde{u}_6 \to c\tilde{\chi}_2^0) = 0.17$, $B(\tilde{u}_6 \to u\tilde{\chi}_2^0) = 0.22$, $B(\tilde{u}_6 \to d\tilde{\chi}_1^+) = 0.47$, and $B(\tilde{u}_6 \to u\tilde{\chi}_2^0) = 0.28$.

We now study various parameter dependences of the QFV squark decay branching ratios for the reference scenario of Table 1. In all plots we mark the point corresponding to this scenario by an ”x”. In Figs.1-3 we show that both $B(\tilde{u}_i \to c\tilde{\chi}_1^0)$ and $B(\tilde{u}_i \to t\tilde{\chi}_1^0)$ (i=1,2) can be very large simultaneously in a sizable QFV parameter region satisfying all of the conditions (i)-(v), which can lead to large rates for QFV signal events at LHC as we will see in the next section.

Fig.1 shows the contours of $B(\tilde{u}_1 \to c\tilde{\chi}_1^0)$ and $B(\tilde{u}_1 \to t\tilde{\chi}_1^0)$ in the ($\Delta M_{\tilde{U}}^2, M_{\tilde{U}}^2$) plane with $\Delta M_{\tilde{U}}^2 \equiv M_{\tilde{U}_{22}}^2 - M_{\tilde{U}_{33}}^2$. The range of $M_{\tilde{U}}^2$ shown corresponds to the range $|\delta_{23}^{ll}| < 0.45$ for $\Delta M_{\tilde{U}}^2 = 0$. In the region shown all of the low energy constraints are fulfilled. We see that there are sizable regions where both decay modes are important at the same time. The observed behavior can be easily understood in the limit where the $\tilde{t}_L - \tilde{t}_R$ mixing is neglected since in this limit only the mixing between $\tilde{c}_R$ and $\tilde{t}_R$ is relevant for $\tilde{u}_{1,2}$ and the corresponding effective mixing angle is given by $\tan(2\theta_{cRtR}^{eff}) \equiv 2M_{\tilde{U}}^2/(\Delta M_{\tilde{U}}^2 - m_t^2)$. Note that for $\Delta M_{\tilde{U}}^2 - m_t^2 > 0$ [\Delta M_{\tilde{U}}^2 - m_t^2 < 0], we have $\tilde{u}_1 \sim \tilde{t}_R (+ \tilde{c}_R)$ [$\tilde{u}_1 \sim \tilde{c}_R (+ \tilde{t}_R)$]. We also find that the behavior of $B(\tilde{u}_2 \to c\tilde{\chi}_1^0)$ and $B(\tilde{u}_2 \to t\tilde{\chi}_1^0)$ is similar to that of $B(\tilde{u}_1 \to t\tilde{\chi}_1^0)$ and $B(\tilde{u}_1 \to c\tilde{\chi}_1^0)$, respectively, which is a consequence of the fact that mainly the mixing between $\tilde{c}_R$ and $\tilde{t}_R$ is important for the $\tilde{u}_{1,2}$ system.

Fig.2 presents contours of $B(\tilde{u}_2 \to c\tilde{\chi}_1^0)$ and $B(\tilde{u}_2 \to t\tilde{\chi}_1^0)$ in the $\delta_{23}^{uu} - \delta_{23}^{RR}$ plane where all of the conditions (i)-(v) are satisfied except the $b \to s\gamma$ constraint which we show by plotting the corresponding $B(b \to s\gamma)$ contours. All basic parameters other than $M_{\tilde{Q}_{24}}^2$ and $M_{\tilde{U}_{23}}^2$ are fixed as in the scenario of Table 1. For $B(\tilde{u}_1 \to c\tilde{\chi}_1^0)$ and $B(\tilde{u}_1 \to t\tilde{\chi}_1^0)$ we have obtained similar contours to Fig.2.(b) and Fig.2.(a), respectively, but they are almost flat. From Fig.2 we find that the possibility of the large QFV
Figure 1: Contours of the QFV decay branching ratios (a) \(B(\tilde{u}_1 \rightarrow c\tilde{\chi}_1^0)\) and (b) \(B(\tilde{u}_1 \rightarrow t\tilde{\chi}_1^0)\) in the \((\Delta M^2_U, M_{U23}^2)\) plane where all of the conditions (i)-(v) are satisfied.

effect can not be excluded by the \(b \rightarrow s\gamma\) constraint even if the experimental error of \(B(b \rightarrow s\gamma)\) becomes very small. We see also that \(B(\tilde{u}_2 \rightarrow c\tilde{\chi}_1^0)\) and \(B(\tilde{u}_2 \rightarrow t\tilde{\chi}_1^0)\) are sensitive [rather insensitive] to \(\delta_{23}^{uRR} [\delta_{23}^{uLL}]\). For large values of \(\delta_{23}^{uRR}\) we see that there is a mild dependence on \(\delta_{23}^{uLL}\). This is due the fact that for large \(\delta_{23}^{uRR}\) the mass squared difference between \(\tilde{u}_2\) (the heavier of the RR sector, i.e. the \(\bar{c}_R-\bar{t}_R\) sector) and \(\tilde{u}_4\) (the lighter of the LL sector, i.e. the \(\bar{c}_L-\bar{t}_L\) sector) becomes small and of the same size as the \(\tilde{t}_L-\tilde{t}_R\) mixing term \((= -m_t\mu \cot \beta)\) (see Eq.(4)) enhancing the mixing between the RR and LL sectors. For small values of \(\delta_{23}^{uRR}\) the RR sector decouples effectively from the LL sector and hence the \(\tilde{u}_2\) decay branching ratios are almost independent of \(\delta_{23}^{uLL}\).

In Fig.3 we show the \(\delta_{23}^{uRL}\) dependences of the \(\tilde{u}_{1,2}\) decay branching ratios, where all basic parameters other than \(T_{U32}\) are fixed as in the scenario of Table 1. The observed dependences are a consequence of the enhanced \(\tilde{t}_L\) component in \(\tilde{u}_{1,2}(\sim \bar{c}_R + \tilde{t}_R)\) for increased \(|\delta_{23}^{uRL}|\). The enhanced \(\tilde{t}_L\) content implies an enhancement of the \(b \tilde{\chi}_1^+(\sim \tilde{W}^+)\) mode. The enhancement of \(B(\tilde{u}_2 \rightarrow \tilde{u}_1 h^0)\) for increased \(|\delta_{23}^{uRL}|\) is partly also caused by the enhanced \(\tilde{t}_L\) component and, more importantly, by the increased coupling of \(\tilde{u}_2\tilde{u}_1 h^0\) which contains a term proportional to \(T_{U32}\). Note that in such scenarios squark decays could be additional sources of the Higgs boson. The asymmetry with respect to \(\delta_{23}^{uRL} = 0\) follows from the \(\tilde{t}_L-\tilde{t}_R\) mixing term \((= -m_t\mu \cot \beta \neq 0)\) (see Eq.(4)) which already induces some \(\tilde{t}_L\) component in \(\tilde{u}_{1,2}\) (see Table 3). As for the \(\delta_{32}^{uRL}\) dependence
Figure 2: Contours of (a) $B(\tilde{u}_2 \to c\tilde{\chi}_1^0)$ and (b) $B(\tilde{u}_2 \to t\tilde{\chi}_1^0)$ (solid lines) in the $\delta_{23}^{uLL} - \delta_{23}^{uRR}$ plane where all of the conditions (i)-(v) except the $b \to s\gamma$ constraint are satisfied. Contours of $10^4 \times B(b \to s\gamma)$ (dashed lines) are also shown. The condition (i) requires $2.92 < 10^4 \times B(b \to s\gamma) < 4.22$.

Figure 3: $\delta_{23}^{uRL}$ dependences of the (a) $\tilde{u}_1$ and (b) $\tilde{u}_2$ decay branching ratios. The shown range of $\delta_{23}^{uRL}$ is the whole range allowed by the conditions (i) to (v) given in the text; note that the range $|\delta_{23}^{uRL}| \gtrsim 0.3$ is excluded by the condition (v).
of the $\tilde{u}_{1,2}$ decay branching ratios, we have obtained results similar to those for the $\delta_{23}^{uRL}$ dependence in Fig.3.

5 Impact on collider signatures

We now study effects of the squark generation mixing on QFV signals at LHC. The large $B(\tilde{u}_i \rightarrow c\tilde{\chi}_1^0)$ and $B(\tilde{u}_i \rightarrow t\tilde{\chi}_1^0)$ ($i = 1, 2$) may result in a sizable rate for the following QFV signals:

$$p p \rightarrow \tilde{u}_{1,2} \tilde{u}_{1,2} X \rightarrow c \bar{t} \tilde{\chi}_1^0 \tilde{\chi}_1^0 X, \ t \bar{c} \tilde{\chi}_1^0 \tilde{\chi}_1^0 X,$$

where $X$ contains only beam jets and the $\tilde{\chi}_1^0$'s give rise to missing transverse energy $E_T^{mis}$. The corresponding cross sections are given by

$$\sigma_{ij}^{ct} \equiv \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X \rightarrow c\bar{t}(c\bar{t})\tilde{\chi}_1^0 \tilde{\chi}_1^0 X)$$

$$\equiv \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X \rightarrow c\bar{t}\tilde{\chi}_1^0 \tilde{\chi}_1^0 X) + \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X \rightarrow t\bar{c}\tilde{\chi}_1^0 \tilde{\chi}_1^0 X)$$

$$= \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X)[B(\tilde{u}_i \rightarrow c\tilde{\chi}_1^0) \cdot B(\tilde{u}_j \rightarrow t\tilde{\chi}_1^0) + B(\tilde{u}_i \rightarrow t\tilde{\chi}_1^0) \cdot B(\tilde{u}_j \rightarrow c\tilde{\chi}_1^0)]. \quad (15)$$

We calculate the relevant squark-squark and squark-antisquark pair production cross-sections at leading order using the WHIZARD/O’MEGA packages [25, 26] where we have implemented the model described in Section 2 with squark generation mixing in its most general form. We use the CTEQ6L global parton density fit [27] for the parton distribution functions and take $Q = m_{\tilde{u}_i} + m_{\tilde{u}_j}$ for the factorization scale, where $\tilde{u}_i$ and $\tilde{u}_j$ are the squark pair produced. The QCD coupling $\alpha_s(Q)$ is also evaluated (at the two-loop level) at this scale $Q$. We have cross-checked our implementation of QFV by comparing with the results obtained using the public packages FeynArts [28] and FormCalc [29].

Defining QFC production cross sections as

$$\sigma_{q\bar{q}}^{ij} \equiv \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X \rightarrow q\bar{q}\tilde{\chi}_1^0 \tilde{\chi}_1^0 X)$$

$$= \sigma(pp \rightarrow \tilde{u}_i \tilde{u}_j X) \cdot B(\tilde{u}_i \rightarrow q\tilde{\chi}_1^0) \cdot B(\tilde{u}_j \rightarrow \bar{q}\tilde{\chi}_1^0) \quad (q = c, t), \quad (16)$$

we obtain the following cross sections at the center-of-mass energy $E_{cm}=14$ TeV [7 TeV] in the scenario of Table 1: $\sigma_{1t}^{11} = 172.8 [11.8]$ fb, $\sigma_{1t}^{22} = 11.5 [0.41]$ fb, $\sigma_{1t}^{11} = 131.4$
[9.0] fb, $\sigma_{ct}^{22} = 6.3$ [0.23] fb, $\sigma_{ct}^{11} = 56.8$ [3.89] fb, $\sigma_{ct}^{22} = 5.2$ [0.19] fb. The expected number of the $c\bar{t}$ / $t\bar{c}$ production events of Eq. (14) is $\mathcal{L} \cdot \sum_{i,j=1,2} \sigma_{ij} \simeq 18400$ [10] events for an integrated luminosity of $\mathcal{L} = 100 fb^{-1}[1fb^{-1}]$ at LHC with $E_{cm} = 14$ TeV [7 TeV].

The main contribution to $\sigma(pp \to \tilde{u}_i \tilde{u}_i X)$ ($i = 1, 2$) comes from the subprocess $gg \to \tilde{u}_i \tilde{u}_i$. The gluon-$\tilde{u}_i$-$\tilde{u}_j$ coupling vanishes for $i \neq j$ due to the color SU(3) symmetry. Therefore, $\sigma(pp \to \tilde{u}_i \tilde{u}_j X)$ and hence $\sigma_{ij}^{zz}$, $\sigma_{cc}^{zz}$ and $\sigma_{tt}^{zz}$ are very small for $i \neq j$, e.g. O(0.01) fb [O(10$^{-4}$) fb] for $(i,j) = (1,2)$ at $E_{cm} = 14$ TeV [7 TeV]. We have found that the production cross sections of the quark pair ($c\bar{t}$, $t\bar{c}$, $c\bar{c}$, $t\bar{t}$) plus two $\tilde{\chi}_1^0$'s and $n$ $\nu$'s ($n = 0, 2, 4, \ldots$) via production of the heavier up-type squarks $\tilde{u}_i$ ($i \geq 3$) are very small in this scenario.

In Fig.4 we show the $\delta_{23}^{uRL}$ dependences of the QFV production cross sections $\sigma_{ct}^{ii}$ ($i = 1, 2$) at $E_{cm} = 7$ and 14 TeV, where all basic parameters other than $M_{23}^u$ are fixed as in the scenario of Table 1. The QFV cross sections at 14 TeV are about an order of magnitude larger than those at 7 TeV. We see that the QFV cross sections quickly increase with increase of the QFV parameter $|\delta_{23}^{uRL}|$ around $\delta_{23}^{uRL} \approx 0$ and that they can be quite sizable in a wide allowed range of $\delta_{23}^{uRL}$. The mass of $\tilde{u}_1$ ($\tilde{u}_2$) decreases (increases) with increase of $|\delta_{23}^{uRL}|$. This leads to the increase of $\sigma_{ct}^{11}$ and the decrease of $\sigma_{ct}^{22}$ with increase of $|\delta_{23}^{uRL}|$. $\sigma_{ct}^{11}$ vanishes for $|\delta_{23}^{uRL}| \gtrsim 0.76$, where the decay $\tilde{u}_1 \to t\tilde{\chi}_1^0$ is kinematically forbidden. We have $\tilde{u}_2 = \tilde{u}_R$ for $|\delta_{23}^{uRL}| \gtrsim 0.9$, which explains the enhancement of $\sigma(pp \to \tilde{u}_2 \tilde{u}_2 X)$ and the vanishing of $\sigma_{ct}^{22}$ for $|\delta_{23}^{uRL}| \gtrsim 0.9$. Note that in case $\tilde{u}_2 = \tilde{u}_R$, the subprocess $u\tilde{u} \to \tilde{u}_2(\tilde{u}_R)\tilde{\nu}_2(\tilde{\nu}_R)$ via t-channel gluino exchange also can contribute to $\sigma(pp \to \tilde{u}_2 \tilde{u}_2 X)$.

We have also studied the $\delta_{32}^{uRL}$ dependence of the QFV production cross sections $\sigma_{ct}^{ii}$ ($i = 1, 2$) at $E_{cm} = 7$ TeV and 14 TeV, where all basic parameters other than $T_{U23}$ are fixed as in the scenario of Table 1. We find that the QFV cross sections are rather insensitive to the QFV parameter $\delta_{32}^{uRL}$ and that they can be large in a wide allowed range $|\delta_{32}^{uRL}| \lesssim 0.3 : \sigma_{ct}^{11} \sim 170$ [10] fb, $\sigma_{ct}^{22} \sim 10$ [0.4] fb at $E_{cm} = 14$ TeV [7 TeV]. The masses of $\tilde{u}_{1,2}$ decrease (and hence the cross sections $\sigma^{ii}$ ($i = 1, 2$) increase) and the branching ratios $B(\tilde{u}_{1,2} \to c/t \tilde{\chi}_1^0)$ tend to decrease with increase of $|\delta_{32}^{uRL}|$. This implies that the QFV cross sections are rather insensitive to $\delta_{32}^{uRL}$. As for the $\delta_{23}^{uRL}$ dependence of $\sigma_{ct}^{ii}$ ($i = 1, 2$) we have obtained similar results to those for the $\delta_{32}^{uRL}$ dependence.
The large $\tilde{c}_R - \tilde{t}_R$ mixing could also give rise to the following QFV production cross sections:

$$
\sigma_{ij}^{tt} \equiv \sigma(pp \to \tilde{u}_i \tilde{u}_j X \to t t \tilde{\chi}^0_1 \tilde{\chi}^0_1 X) = \sigma(pp \to \tilde{u}_i \tilde{u}_j X) \cdot B(\tilde{u}_i \to t \tilde{\chi}^0_1) \cdot B(\tilde{u}_j \to t \tilde{\chi}^0_1) \quad (i, j = 1, 2),
$$

where $X$ contains only beam jets. Here the $\tilde{u}_i \tilde{u}_j$ pair (with $\tilde{u}_{i,j} \sim \tilde{c}_R + \tilde{t}_R$ in the scenario under consideration) is produced mainly via a t-channel gluino exchange subprocess $c c \to \tilde{u}_i \tilde{u}_j$ with $c$ being the charm-quark in the beam proton. Note that the signal event ”top-quark + top-quark + $E_{\text{T}}^{\text{mis}} + \text{beam-jets}”$ can practically not be produced in the MSSM with QFC (nor in the SM). It turns out however that in the scenario of Table 1 the corresponding cross section $\sigma_{tt} \equiv \sigma_{tt}^{11} + \sigma_{tt}^{12}$ is at most $O(0.1) \text{ fb}$ at $E_{\text{cm}}=14 \text{ TeV}$ and hence that it might be relevant for a very high luminosity [30]. Therefore this QFV process will not be discussed further.

In addition, we study QFV in production and decays of squarks at LHC for a QFV scenario based on the mSUGRA scenario SPS1a’ [31] which has served as input for several experimental studies. The high energy inputs at the GUT scale $M_{\text{GUT}} = 2.47 \times 10^{16} \text{ GeV}$ in the scenario SPS1a’ are taken as $m_0=70 \text{ GeV}$, $m_{1/2}=250 \text{ GeV}$, $A_0 = -300 \text{ GeV}$ and $\mu > 0$ together with $\tan \beta(m_Z)=10$. Here $m_0$, $m_{1/2}$ and $A_0$ are the common scalar mass, gaugino mass and trilinear coupling at the GUT scale,
respectively. We use SPheno v3.0 [22] to obtain the resulting MSSM parameters at the scale Q=1 TeV according to the SPA convention [31]. At this scale, we add the QFV parameters (i.e. the squark generation mixing parameters) and vary them around zero (i.e. around the MFV scenario). An example set of the MSSM parameters thus obtained is given in Table 4 and the resulting mass spectrum and the up-type squark compositions in the flavour eigenstates in Tables 5 and 6, respectively. In this scenario one has $\delta_{23}^{uLL} = 0$, $\delta_{23}^{uRR} = 0.4$ and $\delta_{23}^{uRL} = \delta_{32}^{uRL} = 0$ for the QFV parameters at the scale Q=1 TeV. Note that the resulting squark and gluino masses are smaller than those in the scenario of Table 1. We have checked that all of the constraints in section 3 are fulfilled in this scenario. For the important squark decay branching ratios we obtain $B(\tilde{u}_1 \to c\tilde{\chi}_1^0) = 0.100$, $B(\tilde{u}_1 \to t\tilde{\chi}_1^0) = 0.230, B(\tilde{u}_2 \to c\tilde{\chi}_1^0) = 0.146, B(\tilde{u}_2 \to t\tilde{\chi}_1^0) = 0.004$. In this scenario the squark mass eigenstate $\tilde{u}_1$ (\tilde{u}_2) is dominated by a strong mixture of the flavour eigenstates $\tilde{t}_R$, $\tilde{t}_L$ and $\tilde{c}_R$ ($\tilde{t}_L$ and $\tilde{c}_R$) and $\tilde{\chi}_1^0$ is nearly the U(1) gaugino $\tilde{B}$ which couples to the right up-type squarks sizably. This explains the sizable branching ratios of $B(\tilde{u}_1 \to c\tilde{\chi}_1^0)$, $B(\tilde{u}_1 \to t\tilde{\chi}_1^0)$ and $B(\tilde{u}_2 \to c\tilde{\chi}_1^0)$ and the very small $B(\tilde{u}_2 \to t\tilde{\chi}_1^0)$ in this scenario. In this scenario we obtain the following cross sections at the center-of-mass energy $E_{cm}=14$ TeV [7 TeV]: $\sigma_{el}^{11} = 119.7 [11.8]$ fb, $\sigma_{el}^{22} = 0.197 [0.01]$ fb.

Note that the QFV decay branching ratios $B(\tilde{u}_{1,2} \to c/t \tilde{\chi}_1^0)$ are significantly smaller than those in the scenario of Table 1, but that the QFV production cross section $\sigma_{el}^{11}$ is nevertheless large due to the lighter squarks in this scenario based on SPS1a’.

Table 4: The MSSM parameters at the scale Q=1 TeV in the QFV scenario based on the SPS1a’ scenario. $T_{U\alpha\beta}$ and $T_{D\alpha\beta}$ are set to zero for $\alpha \neq \beta$. All mass parameters are given in GeV. Note that $M_{23}^{2}=0$ in the original SPS1a’ scenario.
Table 5: Sparticles, Higgs bosons and corresponding physical masses (in GeV) in the scenario of Table 4.

| $\tilde{u}_i$ | $\tilde{u}_2$ | $\tilde{u}_3$ | $\tilde{u}_4$ | $\tilde{u}_5$ | $\tilde{u}_6$ | $\tilde{d}_1$ | $\tilde{d}_2$ | $\tilde{d}_3$ | $\tilde{d}_4$ | $\tilde{d}_5$ | $\tilde{d}_6$ |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 332      | 541      | 548      | 565      | 565      | 612      | 506      | 547      | 547      | 547      | 571      | 571      |

| $\tilde{g}$ | $\tilde{\chi}_1^0$ | $\tilde{\chi}_2^0$ | $\tilde{\chi}_3^0$ | $\tilde{\chi}_4^0$ | $\tilde{\chi}_1^\pm$ | $\tilde{\chi}_2^\pm$ | $h^0$ | $H^0$ | $A^0$ | $H^+$ |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 608      | 98       | 184      | 402      | 415      | 184      | 417      | 112     | 426     | 426     | 434      |

Table 6: The up-type squark compositions in the flavour eigenstates, i.e. the absolute values of the mixing matrix elements $R_{\tilde{u}i\alpha}$, at the scale $Q=1$ TeV for the scenario of Table 4.

| $|R_{\tilde{u}i\alpha}|$ | $\tilde{u}_L$ | $\tilde{c}_L$ | $\tilde{t}_L$ | $\tilde{u}_R$ | $\tilde{c}_R$ | $\tilde{t}_R$ |
|----------|----------|----------|----------|----------|----------|----------|
| $\tilde{u}_1$ | 0.010 | 0.032 | 0.457 | 0 | 0.369 | 0.809 |
| $\tilde{u}_2$ | 0.014 | 0.015 | 0.691 | 0 | 0.720 | 0.062 |
| $\tilde{u}_3$ | 0 | 0 | 0 | 1.0 | 0 | 0 |
| $\tilde{u}_4$ | 0.896 | 0.444 | 0.011 | 0 | 0.003 | 0.001 |
| $\tilde{u}_5$ | 0.443 | 0.893 | 0.036 | 0 | 0.062 | 0.008 |
| $\tilde{u}_6$ | 0.021 | 0.058 | 0.559 | 0 | 0.585 | 0.585 |

In Fig.5 we show the $\delta_{23}^{uRR}$ dependence of the QFV production cross section $\sigma_{ct}^{11}$ at $E_{cm} = 7$ TeV and 14 TeV, where all basic parameters other than $M_{U23}(Q = 1 TeV)$ are fixed as in the scenario of Table 4. $\sigma_{ct}^{22}$ is very small due to the very small $B(\tilde{u}_2 \rightarrow t\tilde{\chi}_1^0)$. We see that the QFV cross section increases with increase of the QFV parameter $|\delta_{23}^{uRR}|$ and that it can be quite sizable in a wide allowed range of $\delta_{23}^{uRR}$. The mass of $\tilde{u}_1$ decreases and $B(\tilde{u}_1 \rightarrow c\tilde{\chi}_1^0) \cdot B(\tilde{u}_1 \rightarrow t\tilde{\chi}_1^0)$ increases with increase of $|\delta_{23}^{uRR}|$. This leads to the increase of $\sigma_{ct}^{11}$ with increase of $|\delta_{23}^{uRR}|$. $\sigma_{ct}^{11}$ vanishes for $|\delta_{23}^{uRR}| \gtrsim 0.62$, where the decay $\tilde{u}_1 \rightarrow t\tilde{\chi}_1^0$ is kinematically forbidden.

Next, we briefly discuss the detectability of the signature of the QFV production processes $pp \rightarrow \tilde{u}_i\tilde{u}_i X \rightarrow \bar{c}t(\bar{t}c)\tilde{\chi}_1^0\tilde{\chi}_1^0 X$ (i=1,2) at LHC. It is important whether one can discriminate between these processes and the QFC process $pp \rightarrow \tilde{u}_i\tilde{u}_i X \rightarrow \bar{t}\tilde{t}\tilde{\chi}_1^0\tilde{\chi}_1^0 X$. The signature of the QFV processes would be 'charm-jet + (anti)top-quark + $E_{T}^{mis}$ + X', where X contains only beam jets. Therefore, identifying the top quarks in the final
Figure 5: $\delta_{23}^{uRR}$ dependences of $\sigma^{11} \equiv \sigma(pp \rightarrow \tilde{u}_1 \tilde{u}_1 X)$ and $\sigma^{11}_{ct}$ at $E_{cm} = 7$ TeV and 14 TeV. The point "x" of $\delta_{23}^{uRR} = 0.4$ corresponds to the QFV scenario of Table 4. The shown range of $\delta_{23}^{uRR}$ is allowed by the conditions (i) to (v) given in the text.

states is necessary and charm-tagging also would be very useful. If charm-tagging is not possible, one should search for the process $pp \rightarrow \tilde{u}_i \tilde{u}_i X \rightarrow q\bar{t}(t\bar{q})\tilde{\chi}_1^0 \tilde{\chi}_1^0 X$ ($q \neq t$), i.e. for the signature 'jet + (anti)top-quark + $E_T^{mis} + X$'. There could be another QFV signal process leading to the same final states, i.e. gluino production and its QFV decay [8] $pp \rightarrow \tilde{g}\tilde{\chi}_1^0 X \rightarrow c\bar{t}(t\bar{c})\tilde{\chi}_1^0 \tilde{\chi}_1^0 X$. The cross section of this process is found to be rather small (i.e. about a factor of 20-30 smaller than that of the QFV process via squark pair production discussed above) in the scenarios studied here due to the electroweak interactions involved. The most important SUSY background would be due to the QFC production $pp \rightarrow \tilde{u}_i \tilde{u}_i X \rightarrow t\bar{t}\tilde{\chi}_1^0 \tilde{\chi}_1^0 X$, where one W-boson stemming from a top-quark decays hadronically and the other one decays leptonically with the charged lepton being missed or mis-identified. The most important SM background would be top-quark pair production $pp \rightarrow t\bar{t}Z^0 X \rightarrow t\bar{t}\nu\bar{\nu}X$, where one of the W-bosons from the top-quarks decays leptonically with the charged lepton being not detected. Single top-quark production $pp \rightarrow W^+Z^0 X \rightarrow t\bar{b}\nu\bar{\nu}X$ also could be a SM background. However the cross sections of these SM background processes would be very small because they involve weak processes.

Detailed Monte Carlo studies including background processes and detector effects are necessary to identify the parameter region where the proposed QFV signal is observable.
with sufficient significance, e.g. the so-called "5σ discovery region". However, this is clearly beyond the scope of the present article.

6 Conclusion

To conclude, we have studied the effects of squark mixing of the second and third generation, especially $\tilde{c}_{L/R} - \tilde{t}_{L/R}$ mixing, on squark production and decays at LHC in the MSSM. We have shown that the effect can be very large in a significant region of the QFV parameters despite the very strong constraints on QFV from experimental data on B mesons. The QFV squark decay branching ratios $B(\tilde{u}_i \rightarrow c\tilde{\chi}_i^0)$ and $B(\tilde{u}_i \rightarrow t\tilde{\chi}_i^0)$ ($i = 1, 2$) can be very large (up to $\sim 50\%$) simultaneously. This can result in QFV signal events 'pp $\rightarrow c\bar{t}$ ($t\bar{c}$) + $E_T^{\text{mis}}$ + beam-jets' with a significant rate at LHC. The observation of these remarkable signatures would provide a powerful test of supersymmetric QFV at LHC. Therefore, in the squark search one should take into account the possibility of significant contributions from QFV squark decays. Moreover, one should also include the QFV squark parameters (i.e. the squark generation mixing parameters) in the determination of the basic SUSY parameters at LHC.

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