SUSY-induced FCNC top-quark processes at the Large Hadron Collider postprint

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Abstract

We systematically calculate various flavor-changing neutral-current top-quark processes induced by supersymmetry at the Large Hadron Collider, which include five decay modes and six production channels. To reveal the characteristics of these processes, we

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GeV, $\tan\beta = 5$, $\mu = m_A = 500$ GeV, $M_2 = 200$ GeV, and $\delta^d_{LL} = \delta^d_{LR} = \delta^d_{RL} = \delta^d_{RR} = 0$. From this figure, one can see that $b \to s\gamma$ and m_h are the most stringent constraints.

As a second example, we consider the case with non-universal squark masses. In Fig. 14 [Figure 14: see original paper] we show the allowed region in the δ_{LL}-δ_{LR} plane for $M_{Q3} = 500$ GeV, $M_{U3} = 400$ GeV, $M_{Q2} = 600$ GeV, $X_t = 1000$ GeV, $m_{\tilde{g}} = 250$ GeV, $\tan\beta = 5$, $\mu = m_A = 500$ GeV, $M_2 = 200$ GeV, and $\delta^d_{LL} = \delta^d_{LR} = \delta^d_{RL} = \delta^d_{RR} = 0$. In this case, the allowed region is much larger than that in Fig. 13.

B. Maximal rates for FCNC top quark processes

In this subsection, we perform a scan over the parameter space to find the maximal rates for various top quark FCNC processes. We consider two cases: Case A, where only the direct experimental constraints on sparticle and Higgs boson masses are imposed; and Case B, where all the direct and indirect constraints discussed in the previous subsection are imposed.

In our scan, we vary the SUSY parameters in the following ranges: 100 GeV $< M_{Q2,3}, M_{U3} <$ 1000 GeV, $|X_t| < 3\min(M_{Q3}, M_{U3})$, 200 GeV $< m_{\tilde{g}} <$ 1000 GeV, $2 < \tan\beta < 50$, $|\delta_{LL}|, |\delta_{LR}| < 1$.

For Case B, we also vary the parameters in the down-squark sector and the gaugino mass M_2: 100 GeV $< M_{D2,3} <$ 1000 GeV, 100 GeV $< M_2 <$ 1000 GeV, $|\delta^d_{LL}|, |\delta^d_{LR}|, |\delta^d_{RL}|, |\delta^d_{RR}| < 0.1$.

The maximal branching ratios for top quark FCNC decays and the maximal cross sections for top quark FCNC productions at the LHC ($\sqrt{s} = 14$ TeV) are summarized in Table I and Table II, respectively.

Table I: Maximal branching ratios for top quark FCNC decays. | Process | Case A | Case B | | :— | :— | :— | | $t \to cg$ | 1.2×10^{-4} | 1.8×10^{-6} | | $t \to cgg$ | 2.1×10^{-4} | 3.2×10^{-6} | | $t \to cZ$ | 1.5×10^{-6} | 2.4×10^{-8} | | $t \to c\gamma$ | 3.2×10^{-7} | 5.1×10^{-9} | | $t \to ch$ | 4.5×10^{-4} | 1.2×10^{-5} |

Table II: Maximal cross sections (in pb) for top quark FCNC productions at the LHC. | Process | Case A | Case B | | :— | :— | :— | | $cg \to t$ | 12.5 | 0.15 | | $gg \to t\bar{c}$ | 0.85 | 0.012 | | $cg \to tg$ | 1.12 | 0.015 | | $cg \to tZ$ | 0.012 | 1.8×10^{-4} | | $cg \to t\gamma$ | 0.003 | 4.2×10^{-5} | | $cg \to th$ | 0.045 | 1.1×10^{-3} |

From these tables, we can see that the indirect constraints (Case B) significantly reduce the maximal rates for all processes. Under these constraints, only a few channels may be observable at the LHC. Specifically, the decay $t \to ch$ and the production $cg \to t$ have the best prospects for discovery.

VI. Conclusion

In this paper, we have systematically studied various FCNC top-quark processes induced by supersymmetry at the LHC. We performed a comprehensive study of five decay modes and six production channels. We used the effective vertex method to simplify the calculations and investigated the dependence of the rates on the relevant SUSY parameters. We also considered all the direct and indirect current experimental constraints on the scharm-stop flavor mixings. Our results show that, under all these constraints, only a few channels, such as $cg \to t$ and $t \to ch$, may be observable at the LHC. These processes could serve as a good probe for new physics beyond the SM.

Appendix: Loop Functions and Effective Vertices

In this appendix, we provide the explicit expressions for the loop-induced FCNC interactions used in our calculations. The effective $\bar{t}cg$ vertex is given by:

$$\Gamma^{\mu}_{\bar{t}cg} = \frac{g_s^2}{16\pi^2} \sum_{\alpha,\beta} (\Gamma_U)_{3\alpha} (\Gamma_U)^*_{2\beta} \left[V_1 \gamma^\mu P_L + V_2 \frac{i\sigma^{\mu\nu} k_\nu}{m_t} P_R \right]$$

where V_1 and V_2 are form factors involving the three-point tensor loop functions C_{ij}. Similar expressions can be derived for the $\bar{t}cZ$, $\bar{t}c\gamma$, and $\bar{t}ch$ vertices. The box diagram contributions to $gg \to t\bar{c}$ involve the four-point tensor loop functions D_{ij}. All these functions are evaluated numerically in our code.