Top decays in extended models

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Abstract.
Top quark decays are interesting as a mean to test the Standard Model (SM) predictions. The Cabbibo-Kobayashi-Maskawa (CKM)-suppressed process $t \longrightarrow cWW$, and the rare decays $t \longrightarrow cZ$, $t \longrightarrow H^0 + c$, and $t \longrightarrow c\gamma$ an excellent window to probe the predictions of theories beyond the SM. We evaluate the flavor changing neutral currents (FCNC) decay $t \longrightarrow H^0 + c$ in the context of Alternative Left-Right symmetric Models (ALRM) with extra isosinglet heavy fermions; the FCNC decays may place at tree level and are only supressed by the mixing between ordinary top and charm quarks. We also comment on the decay process $t \longrightarrow c + \gamma$, which involves radiative corrections.

Rare top quark decays are interesting because they might source of possible new physics effects. In the Standard Model (SM), flavor-changing neutral currents (FCNC) are absent at the tree level due to Glashow-Iliopoulos-Maiani mechanism, and they are extremely small at loop level. If there is physics beyond the SM, new FCNC can appear in the top decays, which may be enhanced to reach detectable levels.

In the CERN Large Hadron Collider (LHC), about 10^7 top quark pairs will be produced per year [1]. An eventual signal of FCNC in the top quark decay will have to be ascribed to new physics. Furthermore, since the Higgs boson could also be produced at significant rates in future colliders, it is also important to search for all the relevant FCNC Higgs decays.

In this work we evaluate de flavor changing neutral currents (FCNC) decays $t \longrightarrow H^0 + c$ and $t \longrightarrow \gamma + c$ in the context of Alternative Left-Right Symmetry Models (ALRM) with extra isosinglet heavy fermions; in the first case FCNC decay may take place at tree level, and in the second one at one loop level.

The ALRM formulation is based on the gauge group $SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$. It has been formulated in order to solve different problems such as the hierarchy of quark and lepton masses or the strong CP problem, different authors have enlarged the fermion content [2] to be of the form

$$\begin{array}{rcl} l^0_{iL} = \begin{pmatrix} \nu^0_i \\ e^0_i \end{pmatrix}_L , \; e^0_{iR} & ; & \widehat{l}^0_{iR} = \begin{pmatrix} \widehat{\nu}^0_i \\ \widehat{e}^0_i \end{pmatrix}_R , \; \widehat{e}^0_{iL} \\ Q^0_{iL} = \begin{pmatrix} u^0_i \\ d^0_i \end{pmatrix}_L , \; u^0_{iR} \, , \; d^0_{iR}, & ; & \widehat{Q}^0_{iR} = \begin{pmatrix} \widehat{u}^0_i \\ \widehat{d}^0_i \end{pmatrix}_R , \; \widehat{u}^0_{iL} \, , \; \widehat{d}^0_{iL} \, , \end{array} \tag{1}$$

where the index i ranges over the three fermion families. The superscript 0 denote weak eigenstates. The quantum numbers of these fermions, under the gauge group $SU(3)_C \otimes SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$, are given by

$$\begin{array}{llllcllll} l^0_{iL} & (1,2,1)_{-1} & e^0_{iR} & (1,1,1)_{-2} & ; & \widehat{l}^0_{iR} & (1,1,2)_{-1} & \widehat{e}^0_{iL} & (1,1,1)_{-2} \\ u^0_{iR} & (3,1,1)_{\frac{4}{3}} & d^0_{iR} & (3,1,1)_{\frac{2}{3}} & ; & \widehat{u}^0_{iL} & (3,1,1)_{\frac{4}{3}} & \widehat{d}^0_{iL} & (3,1,1)_{\frac{2}{3}} \\ & & Q^0_{iL} & (3,2,1)_{\frac{1}{3}} & & \widehat{Q}^0_{iR} & (3,1,2)_{\frac{1}{3}} & & \end{array} \tag{2}$$

In order to break $SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$ down to $U(1)_{em}$ the ALRM introduces two Higgs doublets. The SM one (ϕ) and its partner ($\widehat{\phi}$). The symmetry breaking is done in such a way that the vacuum expectation values of the Higgs fields are

$$\langle \phi \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v \end{pmatrix} \quad ; \quad \langle \widehat{\phi} \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \widehat{v} \end{pmatrix} . \tag{3}$$

The partial width for the $t \rightarrow c + H$ can be present at tree-level in this model and it is given by [3]:

$$\begin{gathered} \Gamma(t \rightarrow H^0 + c) = \\ \frac{G_F \, \eta_{32}^2 \cos^2 \alpha}{16\sqrt{2}\pi m_t} \left(m_t^2 + m_c^2 - M_H^2 \right) \left[\left(m_t^2 - \left(M_H + m_c \right)^2 \right) \left(m_t^2 - \left(M_H - m_c \right)^2 \right) \right]^{\frac{1}{2}} \end{gathered} \tag{4}$$

where G_F is the Fermi constant, m_t denotes the top mass, m_c is the charm mass, and M_H is the mass of the neutral Higgs boson. We can see from this formula that the branching ratio will be proportional to the product $\eta_{32} \cos\alpha$, of the top-quark mixing with the charm-quark, η_{32} and the mixing of the SM Higgs boson mixing with the extra Higgs boson, $\cos\alpha$.

Thanks to the possible combined effect of a big $\cos\alpha$ (null mixing between the SM Higgs boson and the additional Higgs bosons) and a big value of η_{32} this branching ratio could be as high as 10^{-5} [3], for a Higgs mass of 117 GeV and a value $\eta_{32} = 0.009$, that could be considered as the most stringent constraint.

On the other hand, in the process $t \rightarrow \gamma + c$, the final state particles are on-shell and the photon has transverse polarization, therefore, the partial width can be written generality as

$$\Gamma(t \to c+\gamma) = \frac{1}{\pi}\left[\frac{m_t^2 - m_c^2}{2m_t}\right]\left(|A|^2 + |B|^2\right) . \tag{5}$$

with A and B are the vector and axial vector form factors.

In the limit $m_c = 0$ the vector and axial vector form factors are equal ($A = B$). For instance, the contribution of the diagram shown in Fig. (1) in this limit is:

$$\begin{aligned} A = B = \frac{eg\hat{U}_{tb}^{*}V_{c\hat{b}}^{R}}{192\pi^2 m_t^3}\Big\{ & m_t^2 + \left(m_b^2 - m_{\hat{b}}^2\right) B_0\left(0; m_b^2, m_{\hat{b}}^2\right) \\ & + \left(m_b^2 - M_{\hat{W}}^2\right) B_0\left(0; m_b^2, M_{\hat{W}}^2\right) - \left(2m_t^2 + 3m_{\hat{b}}^2 - 3M_{\hat{W}}^2\right) B_0\left(0; m_{\hat{b}}^2, M_{\hat{W}}^2\right) \\ & +4\left(m_{\hat{b}}^4 - m_b^2 m_{\hat{b}}^2 + m_t^2 m_{\hat{b}}^2 - M_{\hat{W}}^2 m_{\hat{b}}^2 - \frac{1}{2} m_b^2 m_t^2 + m_b^2 M_{\hat{W}}^2\right) C_0\left(0,0,m_t^2; m_b^2, m_{\hat{b}}^2, M_{\hat{W}}^2\right)\Big\} \end{aligned} \tag{6}$$

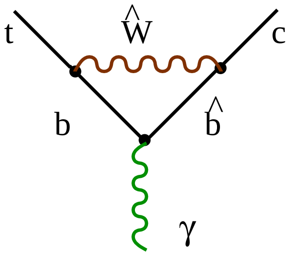

FIGURE 1. Example of Feynman diagram contributing to the $t \to c+\gamma$ decay amplitude in the ALRM

This is just and example of the kind of diagrams that contributes to this decay. The computation of all the diagrams in the ALRM is now under way and we expect to report final results on this process in the near future.

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