Signals from Flavor Changing Scalar Currents at the Future Colliders*

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ABSTRACT

We present a general phenomenological analysis of a class of Two Higgs Doublet Models with Flavor Changing Neutral Currents arising at the tree level. The existing constraints mainly affect the couplings of the first two generations of quarks, leaving the possibility for non negligible Flavor Changing couplings of the top quark open. The next generation of lepton and hadron colliders will offer the right environment to study the physics of the top quark and to unravel the presence of new physics beyond the Standar Model. In this context we discuss some interesting signals from Flavor Changing Scalar Neutral Currents.

I. GENERAL FRAMEWORK

The next generation of lepton and hadron colliders will play a fundamental role in the study of new physics beyond the Standar Model (SM). Higher energies will allow a careful study of the physics of the top quark (its couplings in particular) and of the scalar and gauge sector of the fundamental theory of elementary particles.

In this context, we have analyzed the possibility of having a Two Higgs Doublet Model (2HDM) with Flavor Changing Neutral Currents (FCNC's) allowed at the tree level [1]-[3]. This Model constitutes a simple extension of the scalar sector of the Standard Model and closely mimics the Higgs sector of a SuperSymmetric Theory (SUSY). However, the possibility of having flavor changing (FC) tree level couplings in the neutral scalar sector definitely distinguishes it from both the SM and SUSY. Moreover, the discovery and study of extra scalar or pseudoscalar, neutral and charged particles with not too heavy masses will be in the reach of the future machines. From here our interest.

Although there is no *a priori* veto to the existence of FCNC at the tree level, the low energy phenomenology of the K- and of the B-meson as well as the existing precision measurements of the SM impose strong constraints on the possibility of having sizable effects from FCNC. However, under suitable assumptions, the FC couplings of the top quark partially escape these constraints and can be predicted to give non negligible signals as we will illustrate in the following.

A. The Model

A mild extension of the SM with one additional scalar SU(2) doublet opens up the possibility of flavor changing scalar currents (FCSC's) at the tree level. In fact, when the up-type quarks and the down-type quarks are allowed simultaneously to couple to more than one scalar doublet, the diagonalization of the up-type and down-type mass matrices does not automatically ensure the diagonalization of the couplings with each single scalar doublet. For this reason, the 2HDM scalar potential and Yukawa Lagrangian are usually constrained by an *ad hoc* discrete symmetry [4], whose only role is to protect the model from FCSC's at the tree level. Let us consider a Yukawa Lagrangian of the form

$$\begin{aligned}\mathcal{L}_Y &= \eta^U_{ij}\bar{Q}_{i,L}\tilde{\phi}_1 U_{j,R} + \eta^D_{ij}\bar{Q}_{i,L}\phi_1 D_{j,R} + \\ &\quad \xi^U_{ij}\bar{Q}_{i,L}\tilde{\phi}_2 U_{j,R} + \xi^D_{ij}\bar{Q}_{i,L}\phi_2 D_{j,R} + h.c.\end{aligned} \tag{1}$$

where ϕ_i, for $i = 1, 2$, are the two scalar doublets of a 2HDM, while $\eta^{U,D}_{ij}$ and $\xi^{U,D}_{ij}$ are the non diagonal matrices of the Yukawa couplings. Imposing the following *ad hoc* discrete symmetry

$$\begin{aligned}\phi_1 \to -\phi_1 \quad &\text{and} \quad \phi_2 \to \phi_2 \\ D_i \to -D_i \quad &\text{and} \quad U_i \to \mp U_i\end{aligned} \tag{2}$$

some of the terms in $\mathcal{L}_Y$ have to be dropped and one obtains the so called Model I and Model II, depending on whether the up-type and down-type quarks are coupled to the same or to two different scalar doublets respectively [5].

In contrast we will consider the case in which no discrete symmetry is imposed and both up-type and down-type quarks then have FC couplings. For this type of 2HDM, which we will call Model III, the Yukawa Lagrangian for the quark fields is as in Eq. (1) and no term can be dropped *a priori*, see also refs. [6, 7] .

For convenience we can choose to express ϕ_1 and ϕ_2 in a suitable basis such that only the $\eta^{U,D}_{ij}$ couplings generate the fermion masses, i.e. such that

$$\langle\phi_1\rangle = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix} \quad , \quad \langle\phi_2\rangle = 0 \ . \tag{3}$$

The two doublets are in this case of the form

$$\begin{aligned}\phi_1 &= \frac{1}{\sqrt{2}}\left[\begin{pmatrix} 0 \\ v + H^0 \end{pmatrix} + \begin{pmatrix} \sqrt{2}\,\chi^+ \\ i\chi^0 \end{pmatrix}\right] \\ \phi_2 &= \frac{1}{\sqrt{2}}\begin{pmatrix} \sqrt{2}\,H^+ \\ H^1 + iH^2 \end{pmatrix} \ .\end{aligned} \tag{4}$$

The scalar Lagrangian in the (H^0, H^1, H^2, $H^\pm$) basis is such that [8, 5] : the doublet ϕ_1 corresponds to the scalar doublet of the SM and H^0 to the SM Higgs field (same couplings and no interactions with H^1 and H^2); all the new scalar fields belong

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to the ϕ_2 doublet; both H^1 and H^2 do not have couplings to the gauge bosons of the form $H^{1,2}ZZ$ or $H^{1,2}W^+W^-$.
$H^\pm$ is the charged scalar mass eigenstate, while the two scalar plus one pseudoscalar neutral mass eigenstates are obtained from (H^0, H^1, H^2) as follows

$$\begin{aligned} \bar{H}^0 &= \left[(H^0-v)\cos\alpha + H^1\sin\alpha\right] \\ h^0 &= \left[-(H^0-v)\sin\alpha + H^1\cos\alpha\right] \\ A^0 &= H^2 \end{aligned} \tag{5}$$

where α is a mixing angle, such that for $\alpha=0$, (H^0, H^1, H^2) coincide with the mass eigenstates.

Furthermore, to the extent that the definition of the $\xi_{ij}^{U,D}$ couplings is arbitrary, we will denote by $\xi_{ij}^{U,D}$ the new rotated couplings, such that the charged couplings look like $\xi^U \cdot V_{\rm CKM}$ and $V_{\rm CKM}\cdot\xi^D$. This form of the charged couplings is indeed peculiar to Model III compared to Models I and II and can have important phenomenological repercussions [9, 10].

In order to apply to specific processes we have to make some definite ansatz on the $\xi_{ij}^{U,D}$ couplings. Many different suggestions can be found in the literature [1, 2, 3, 7]. In addition to symmetry arguments, there are also arguments based on the widespread perception that these new FC couplings are likely to mainly affect the physics of the third generation of quarks only, in order to be consistent with the constraints coming from $K^0-\bar{K}^0$ and $B_d^0-\bar{B}_d^0$. A natural hierarchy among the different quarks is provided by their mass parameters, and that has led to the assumption that the new FC couplings are proportional to the mass of the quarks involved in the coupling. Most of these proposals are well described by the following ansatz

$$\xi_{ij}^{U,D} = \lambda_{ij}\,\frac{\sqrt{m_i m_j}}{v} \tag{6}$$

which basically coincides with what was proposed by Cheng and Sher [1]. In this ansatz the residual degree of arbitrariness of the FC couplings is expressed through the λ_{ij} parameters, which need to be constrained by the available phenomenology. In particular we will see how K^0–$\bar{K}^0$ and B_d^0–$\bar{B}_d^0$ mixings (and to a less extent $D^0-\bar{D}^0$ mixing) put severe constraints on the FC couplings involving the first family of quarks. Additional constraints are given by the combined analysis of the $Br(B\rightarrow X_s\gamma)$, the ρ parameter, and R_b, the ratio of the $Z\rightarrow b\bar{b}$ rate to the Z hadronic rate. We will analyze all these constraints in the following section

B. Discussion of the Constraints

The existence of FC couplings is very much constrained by the experimental results on $F^0-\bar{F}^0$ flavor mixings (for $F=K,B$ and to a less extent D)

$$\begin{aligned} \Delta M_K &\simeq 3.51\cdot 10^{-15}\ \text{GeV} \\ \Delta M_{B_d} &\simeq 3.26\cdot 10^{-13}\ \text{GeV} \\ \Delta M_D &< 1.32\cdot 10^{-13}\ \text{GeV} \end{aligned} \tag{7}$$

due to the presence of new tree level contributions to each of the previous mixings. We have analyzed the problem in detail [10], taking into account both tree level and loop contributions. Indeed the two classes of contributions can affect different FC couplings, due to the peculiar structure of the charged scalar couplings (see previous section).

We find that, unless for scalar masses in the multi-TeV range, the tree level contributions need to be strongly suppressed, requiring that the corresponding FC couplings are much less than one. Enforcing the ansatz made in Eq. (6), this amounts to demand that

$$\lambda_{ds}^D \ll 1 \quad , \quad \lambda_{db}^D \ll 1 \ \ \text{and} \ \ \lambda_{ud}^U \ll 1\ . \tag{8}$$

More generally, we can assume that the FC couplings involving the first generation are negligible. Particular 2HDM's have been proposed in the literature in which this pattern can be realized [11]. The remaining FC couplings, namely ξ_{ct}^U and ξ_{sb}^D are not so drastically affected by the $F^0-\bar{F}^0$ mixing phenomenology. From the analysis of the loop contributions to the $F^0-\bar{F}^0$ mixings (box and penguin diagrams involving the new scalar fields) we verify that many regions of the parameter space are compatible with the results in Eq. (7) [10]. Therefore we may want to look at other constraints in order to single out the most interesting scenarios.

Three are in particular the physical observables that impose strong bounds on the masses and couplings of Model III [9, 10]

- The inclusive branching ratio for $B\rightarrow X_s\gamma$, which is measured to be [12]

$$Br(B\rightarrow X_s\gamma) = (2.32\pm0.51\pm0.29\pm0.32)\times 10^{-4} \tag{9}$$

- The ratio

$$R_b = \frac{\Gamma(Z\rightarrow b\bar{b})}{\Gamma(Z\rightarrow \text{hadrons})} \tag{10}$$

  whose present measurement [13] is such that $R_b^{\rm expt} > R_b^{\rm SM}$ $(\sim 1.8\sigma)$[1]

$$\begin{aligned} R_b^{\rm expt} &= 0.2178\pm0.0011 \\ R_b^{\rm SM} &= 0.2156\pm0.0002 \end{aligned} \tag{11}$$

  The value of $R_b^{\rm expt}$ seems to challenge many extensions of the SM [14, 9]. However, several issues on the measurement of this observable are still unclear and require further scrutiny [9].

- The corrections to the ρ parameter. In fact, the relation between M_W and M_Z is modified by the presence of new physics and the deviation from the SM prediction is usually

[1] The value of $R_b^{\rm expt}$ reported in Eq. (11) corresponds to the experimental measurement obtained for $R_c=R_c^{\rm SM}=0.1724$.

described by introducing the parameter ρ_0 [15, 16], defined as

$$\rho_0 = \frac{M_W^2}{\rho M_Z^2 \cos^2\theta_W} \tag{12}$$

where the ρ parameter absorbs all the SM corrections to the gauge boson self energies. In the presence of new physics

$$\rho_0 = 1 + \Delta\rho_0^{\mathrm{NEW}} \tag{13}$$

From the recent global fits of the electroweak data, which include the input for m_t from Ref. [17] and the new experimental results on R_b, ρ_0 turns out to be very close to unity [16, 9, 10]. This impose severe constraints on many extension of the SM, especially on the mass range of the new particles.

As is the case in 2HDM's with no FCNC's, it is very difficult to reconcile the measured values of the previous three observables in the presence of an extended scalar sector. Taking into account also the constraints from the F^0–$\bar{F}^0$ mixings, two main scenarios emerge depending on the choice of enforcing or not $R_b^{\exp}$ [10].

1. If we **enforce the constraint from** R_b^{expt} (see Eq. (11)), then we can accommodate the present measurement of the $Br(B \to X_s\gamma)$ (see Eq. (9)) and of the $\Delta F = 2$ mixings (see Eq. (7)) and at the same time satisfy the global fit result for the ρ parameter [16] provided the following conditions are satisfied.

   i) The neutral scalar h^0 and the pseudoscalar A^0 are very light, i.e.

   $$50\,\mathrm{GeV} \leq M_h \sim M_A < 70\,\mathrm{GeV}\ . \tag{14}$$

   ii) The charged scalar H^+ is heavier than h^0 and A^0, but not too heavy to be in conflict with the constraints from the ρ parameter. Thus

   $$150\,\mathrm{GeV} \leq m_c \leq 200\,\mathrm{GeV}\ . \tag{15}$$

   iii) The ξ_{ij}^D couplings are enhanced with respect to the ξ_{ij}^U ones

   $$\begin{aligned} \lambda_{bb} &\gg 1 \ \text{ and } \ \lambda_{tt} \ll 1 \\ \lambda_{sb} &\gg 1 \ \text{ and } \ \lambda_{ct} \ll 1\ . \end{aligned} \tag{16}$$

   The choice of the phase α is not as crucial as the above conditions and therefore we do not make any assumption on it.

2. If we **disregard the constraint from** R_b^{expt} there is no need to impose the bounds of Eqs. (14)-(16) and we can safely work in the scenario in which only the first generation FC couplings are suppressed

   $$\lambda_{ui}, \lambda_{dj} \ll 1 \quad \text{for} \quad i,j = 1,2,3 \tag{17}$$

   in order to satisfy the experimental constraints on the $F^0 - \bar{F}^0$ mixings. We will assume the FC couplings of the second an third generations to be given by Eq. (6) with

   $$\lambda_{ct} \simeq O(1) \ \text{ and } \ \lambda_{sb} \simeq O(1)\ . \tag{18}$$

   The value of the mixing angle α is not relevant, while the masses are mainly dictated by the fit to $Br(B \to X_s\gamma)$ and $\Delta\rho_0$ [9]

   $$M_H, M_h \leq M_c \leq M_A \ \text{ and } \ M_A \leq M_c \leq M_H, M_h\ . \tag{19}$$

We can see that, except in a very narrow window of the parameter space, it is in general very difficult to accomodate the present value of $R_b^{\exp}$ in Model III. Due to the present unclear experimental situation for R_b, we will mainly concentrate on the second scenario[2]. This scenario has the very interesting characteristics of providing sizable FC couplings for the top quark, in a way that will certainly be testable at the next generation of lepton and hadron colliders. We will discuss some of these phenomenological issues in the next section.

II. SIGNALS OF TOP-CHARM PRODUCTION

If we assume $\lambda_{sb} \simeq O(1)$ and $\lambda_{ct} \simeq O(1)$ as in Eq. (18), ξ_{ct}^U becomes the most relevant FC coupling. The presence of a ξ_{ct}^U flavor changing coupling can be tested by looking at both top decays and top production (see ref. [10] and references therein). We want to concentrate here on top-charm production at lepton colliders, both e^+e^- and $\mu^+\mu^-$, because, as we have emphasized before [7, 18], in this environment the top-charm production has a particularly clean and distinctive signature. The SM prediction for this process is extremely suppressed and any signal would be a clear evidence of new physics with large FC couplings in the third family. Moreover it has a very distinctive signature, with a very massive jet recoiling against an almost massless one (very different from a bs signal, for instance). This characteristic is enhanced even more in the experimental environment of a lepton collider.

In principle, the production of top-charm pairs arises both at the tree level, via the s channel exchange of a scalar field with FC couplings, and at the one loop level, via corrections to the Ztc and γtc vertices. The s channel top-charm production is one of the new interesting possibilities offered by a $\mu^+\mu^-$ collider in studying the physics of standard and non standard scalar fields. However, it is not relevant for an e^+e^- collider, because the coupling of the scalar fields to the electron is likely to be very suppressed (see Eq. (6)). Therefore we will consider these two cases separately.

[2] See ref. [10] for a discussion of the scenario which accomodates $R_b^{\exp}$.

In the case of an e^+e^- collider, top-charm production arises via γ and Z boson exchange, i.e. the process $e^+e^- \rightarrow \gamma^*, Z^* \rightarrow \bar{t}c + \bar{c}t$, where the effective one loop γtc or Ztc vertices are induced by scalars with FC couplings. We will consider the total cross section normalized to the cross section for producing $\mu^+\mu^-$ pairs via one photon exchange, i.e.

$$R^{tc} \equiv \frac{\sigma(e^+e^- \rightarrow t\bar{c} + \bar{t}c)}{\sigma(e^+e^- \rightarrow \gamma^* \rightarrow \mu^+\mu^-)} \tag{20}$$

and normalized to $\lambda_{ij} \simeq \lambda = 1$ (see Eq. (6)), consistently with our Eq. (18). For the moment, we want to simplify our discussion by taking the same λ for all of the $\xi_{ij}^{U,D}$ couplings. Moreover, we want to factor out this parameter, because it summarizes the degree of arbitrariness we have on these new couplings and it will be useful for further discussion.

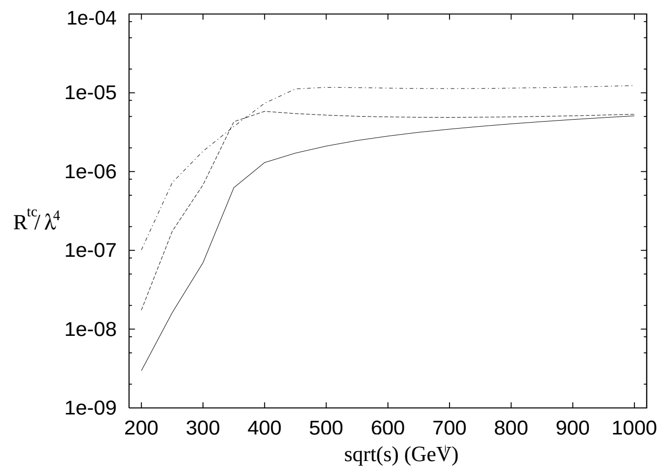

Figure 1: R_{tc}/λ^4 vs. $\sqrt{s}$ when $M_h = 200$ GeV and $M_A \simeq M_c = 1$ TeV (solid), $M_A = 200$ GeV and $M_h \simeq M_c = 1$ TeV (dashed), $M_c = 200$ GeV and $M_h \simeq M_A = 1$ TeV (dot-dashed).

As already discussed in Ref. [7], we take $m_t \simeq 180$ GeV and vary the masses of the scalar and pseudoscalar fields in a range between 200 GeV and 1 TeV. Larger values of the scalar masses are excluded by the requirement of a weak coupled scalar sector. The phase α does not play a relevant role and in our qualitative analysis we will set $\alpha = 0$. In Fig. 1 we plot R^{tc}/λ^4 as a function of $\sqrt{s}$ for a sample of relevant cases, in which one of the scalar particles is taken to be light ($M_l \simeq 200$ GeV) compared to the other two ($M_h \simeq 1$ TeV). We find that even with different choices of M_h, M_A and M_c it is difficult to push R^{tc}/λ^4 much higher than 10^{-5}. Therefore the three cases illustrated in Fig. 1 appear to be a good sample to illustrate the type of predictions we can obtain for the rate for top-charm production in model III.

From Fig. 1, we also see that going to energies much larger than ~ 400–500 GeV (i.e. $\sim 2M_l$) does not gain much in the rate and in this case R^{tc}/λ^4 can be as much as 10^{-5}. Since it is reasonable to expect 10^4–10^5 $\mu^+\mu^-$ events in a year of running for the next generation of e^+e^- colliders ($\int \mathcal{L} \simeq 5 \times 10^{33}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$) at $\sqrt{s} = 500$ GeV, this signal could be at the detectable level only for not too small values of the arbitrary parameter λ. Thus we can expect experiments to be able to constrain $\lambda \leq 1$, for scalar masses of a few hundred GeVs.

Another interesting possibility to study top-charm production is offered by Muon Colliders [18]. Although very much in the notion stage at present, $\mu^+\mu^-$ colliders has been suggested as a possible lepton collider for energies in the TeV range [19, 20]. Most of the applications of Muon Colliders would be very similar to electron colliders. One advantage, however, is that they may be able to produce neutral Higgs bosons ($\mathcal{H}$) in the s channel in sufficient quantity to study their properties directly (remember that $m_\mu \simeq 200\, m_e$). The crucial point is also that in spite of the fact that the $\mu^+\mu^-\mathcal{H}$ coupling, being proportional to m_μ, is still small, if the Muon Collider is run on the Higgs resonance, $\sqrt{s} = m_\mathcal{H}$, Higgs bosons may be produced at an appreciable rate.

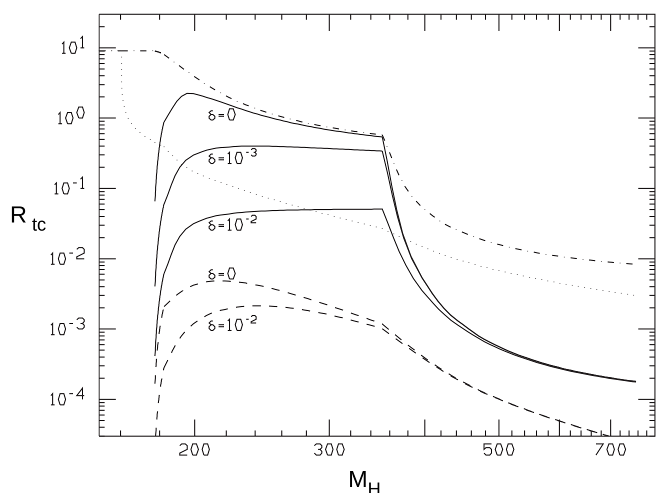

Figure 2: R_{tc} for $\delta = 0$, 10^{-3} and 10^{-2} in case 1 (set of solid curves) and case 2 (set of dashed curves). We also plot $\tilde{R}(\mathcal{H})$ in case 1 (dot-dashed) and case 2 (dotted).

We have considered [18] the simple but fascinating possibility that such a Higgs, $\mathcal{H}$, has a flavor-changing $\mathcal{H}t\bar{c}$ coupling, as is the case in Model III or in any other 2HDM with FCNC. As we did for the e^+e^- case, also in the $\mu^+\mu^-$ case we can define the analogous of R_{tc} in eq.(20) to be

$$R_{tc} = \tilde{R}(\mathcal{H})\,(B^{\mathcal{H}}_{t\bar{c}} + B^{\mathcal{H}}_{c\bar{t}}) \tag{21}$$

where $\tilde{R}(\mathcal{H})$ is the effective rate of Higgs production at a Muon Collider with beam energy spread described by δ (i.e., $m^2_\mathcal{H}(1-\delta) < s < m^2_\mathcal{H}(1+\delta)$)

$$\tilde{R}(\mathcal{H}) = \left[\frac{\Gamma_\mathcal{H}}{m_\mathcal{H}\delta}\arctan\frac{m_\mathcal{H}\delta}{\Gamma_\mathcal{H}}\right] R(\mathcal{H}) \tag{22}$$

$R(\mathcal{H})$ is here the rate of Higgs production, $\Gamma_\mathcal{H}$ the width of the considered Higgs and $B^{\mathcal{H}}_{t\bar{c}}$ or $B^{\mathcal{H}}_{c\bar{t}}$ denotes the branching ratio for $\mathcal{H} \rightarrow t\bar{c}$ and $\mathcal{H} \rightarrow c\bar{t}$ respectively. Assuming that the background will be under reasonable control by the time they will start operate a Muon Collider, our extimate is that

$10^{-3} < \tilde{R}_{tc} \leq 1$, depending on possible different choices of the parameters. In Fig. 2 we have illustrated in particular the case in which $\mathcal{H}=h^0$, and $\alpha=0$ (case 1) or $\alpha=\pi/4$ (case 2). We extimate that for a Higgs particle of $m_{\mathcal{H}} = 300$ GeV, a luminosity of $10^{34} cm^{-2} s^{-1}$ and a year of $10^7 s$ (1/3 efficiency), a sample of tc events ranging from almost one hundred to few thousands can be produced [18]. Given the distinctive nature of the final state and the lack of a Standard Model background, the predicted luminosity should allow the observation of such events. Therefore many properties of the Higgs-tc coupling could be studied in detail.

Finally we want to consider the impact that a tree level ξ^U_{ct} coupling could have on the present scenario of the Higgs discovery. As was already pointed out in the literature [21], if $M_{\mathcal{H}} > m_t$ (for $\mathcal{H} = \bar{H}^0, h^0$ or A^0) Model III allows the new decay channel

$$\mathcal{H} \to c\bar{t} + \bar{c}t \tag{23}$$

which should also be considered in the search for a non standard Higgs particle. In the mass range $m_t < M_{\mathcal{H}} < 2m_t$, this single top production is of particular interest because its rate can be greater than the rate for $\mathcal{H} \to b\bar{b}$ while the decay $\mathcal{H} \to t\bar{t}$ is not yet possible. Assuming Eq. (6), the rate for $\mathcal{H} \to c\bar{t} + \bar{c}t$ is given by

$$\begin{aligned} \Gamma(\mathcal{H} \to c\bar{t} + \bar{c}t) &= N_c \frac{G_F}{4\sqrt{2}\pi} M_{\mathcal{H}} \lambda_{ct}^2 m_c m_t \cdot \\ & \left[1 - \frac{(m_t + m_c)^2}{M_{\mathcal{H}}^2}\right]^{3/2} \left[1 - \frac{(m_t - m_c)^2}{M_{\mathcal{H}}^2}\right]^{1/2} \end{aligned} \tag{24}$$

to be compared with the rate for $\mathcal{H} \to q\bar{q}$, i.e.

$$\Gamma(\mathcal{H} \to q\bar{q}) = N_c \frac{G_F}{4\sqrt{2}\pi} M_{\mathcal{H}} m_q^2 \left[1 - 4\frac{m_q^2}{M_{\mathcal{H}}^2}\right]^{3/2} \tag{25}$$

We see for instance that for $M_{\mathcal{H}} \simeq 300$ GeV, $\Gamma(\mathcal{H} \to c\bar{t}+\bar{c}t) \sim 6\lambda_{ct}^2 \Gamma(\mathcal{H} \to b\bar{b})$. Therefore, depending on λ_{ct}, there are cases in which in the range $m_t < M_{\mathcal{H}} < 2m_t$ we could predict a distinctive signal, both with rispect to the SM and to SUSY. When $\mathcal{H} = h^0, \bar{H}^0$ then $\mathcal{H} \to c\bar{t} + t\bar{c}$ competes only with the decays $\mathcal{H} \to ZZ$ or WW, depending on the value of the phase α. In the case $\mathcal{H} = A^0$ the decays into gauge boson pairs are absent.

When the phase α is chosen in such a way that the couplings $\mathcal{H}ZZ$ and $\mathcal{H}WW$ (for $\mathcal{H} = h^0, \bar{H}^0$) are suppressed, the decay we are interested in can be produced for instance via $e^+e^- \to h^0A^0, h^0\bar{H}^0 \to (t\bar{c} + c\bar{t})\, q\bar{q}$ (lepton collider) or $gg \to \mathcal{H} \to t\bar{c} + c\bar{t}$ (hadron collider). Therefore both NLC and LHC should be able to look for it: the first one would offer the possibility of a much cleaner signal while the second one would provide a much higher statistics. As is the case of many other decays, a good b-tagging is clearly necessary. However the kinematic constraints of the $\mathcal{H} \to t\bar{c} + c\bar{t}$ decay should be so distinctive to limit the size of the background. We think that dedicated simulations and sistematic studies of the background will be useful in understanding the real potentiality of this decay channel.

In conclusion, we think that Model III offers a simple but interesting example in which some important topics of the physics at the future colliders can be investigated. With a few assumptions we are able to propose some distinctive processes, the existence of which would be clear evidence of some very new physics beyond the Standard Model.

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