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Física

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THE CHARGED HIGGS BOSON DECAYS IN THE 2HDM-III

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RESUMEN

Consideramos el modelo THDM-III el cual genera cambios de sabor a nivel árbol. Calculamos todos los modos de decaimiento del Higgs cargado en dos cuerpos.

Palabras claves: Higgs, Dos dobletes

ABSTRACT

We consider the Two Higgs Doublet Model (2HDM) of type III which leads to Flavour Changing Neutral Currents (FCNC) at tree level. We calculate the possible channel decays of the chargued Higgs boson into two body.

Keywords: Higgs, Two Higgs doublets

The two doublets of complex scalars correspond to 8 degrees of freedom, 3 of which are absorbed as Goldstone bosons to give mass and longitudinal components to the $W^{\pm}$ and Z bosons. This leaves 5 physical states: two neutral scalars h^0 and H^0, a pseudoscalar A^0, and a pair of charged Higgs bosons $H^{\pm}$. While it may be hard to distinguish any one of these neutral Higgs bosons from that of the Standard Model, the $H^{\pm}$ pair carry a distinctive hall-mark of the MSSM. Hence the charged Higgs boson plays a very important role in the search of the SUSY Higgs sector. Therefore the direct or indirect evidence of a charged Higgs boson would play an important role in the discovery of an extended Higgs sector. Direct searches have carried out by LEP collaborations and they reported a combined lower limit on $M_{H^{\pm}}$ of 78.6 GeV assuming $H^+ \to \tau^+\nu_\tau(c\bar{s})$. At the Tevatron,the direct searches for charged Higgs boson are based on $p\bar{p} \to t\bar{t}$ with at least one top quark using $t \to H^+b$. The CDF collaboration has reported a direct search for charged Higgs boson, setting an upper limit on $B(t \to H^+b)$ around 0.36 at 95% C.L. for masses in the range 60-160 GeV . Other experimental bounds on the charged Higgs boson mass come from processes where the charged Higgs boson is a virtual particle that is the case of the process $B \to X_s\gamma$. Finally, the search for the charged Higgs boson will continue above the top quark mass at LHC. The main production mechanisms would be the processes $gg \to tbH^+$ and $gb \to tH^+$ which have been studied using simulations of the LHC detectors.

The 2HDM includes a second Higgs doublet, and both doublets acquire vacuum expectation value (VEV) different from zero. We will consider a general 2HDM-III where the Higgs doublets can couple with the up and down quark sector at the same time because there is not any discrete symmetry. Then the Yukawa Lagrangian for the quarks in this model [1, 2, 3]

$$-\mathcal{L}_Y^{(III)} = \eta_{ij}^{U,0}\bar{Q}_{iL}^0\widetilde{\Phi}_1U_{jR}^0 + \eta_{ij}^{D,0}\bar{Q}_{iL}^0\Phi_1D_{jR}^0 + \xi_{ij}^{U,0}\bar{Q}_{iL}^0\widetilde{\Phi}_2U_{jR}^0 + \xi_{ij}^{D,0}\bar{Q}_{iL}^0\Phi_2D_{jR}^0 + \text{h.c}, \quad (1)$$

where Φ_i are the Higgs doublets, η_{ij}^0 and ξ_{ij}^0 are non-diagonal 3×3 matrices and the suffix "0"means that these fermion states are not mass eigenstates. In the present work we take into account the Cheng-Sher-Yuan (CSY) parameterization which is the geometric mean of the Yukawa couplings of the quark fields [2], $\xi_{ij} \equiv \frac{\sqrt{m_i m_j}}{v}\lambda_{ij}$. Bounds and restrictions on the λ_{ij} for the quark sector and ξ_{ij} for the leptonic sector can be found in literature [1, 7].

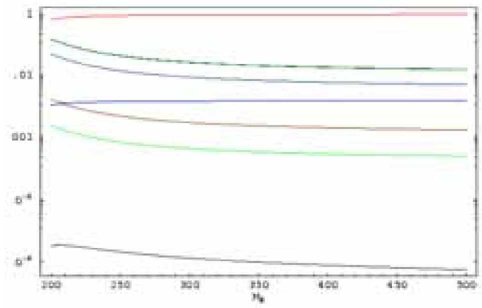

Figura 1: Branching ratios in the 2HDM-III for $\lambda_{tc} = 2$, $\lambda_{tt} = 1{,}5$, $\lambda_{bb} = 10$, $\lambda_{\mu\mu} = 0{,}12$,$\lambda_{\tau\tau} = 2{,}2 \times 10^{-2}$, $\lambda^2_{\mu\tau} = 4{,}44 \times 10^{-2}$.

In 2HDM-III there is a global symmetry which can make a rotation of the Higgs doublets and fix one VEV equal to zero [1]. In such a way, $v_1 = v$ and $v_2 = 0$, and the mixing parameter $\tan\beta = v_2/v_1$ can be eliminated from the Lagrangian. In this way we have the usual 2HDM type III [1], where the Lagrangian of the charged sector is given by

$$-L^{III}_{H^{\pm}ud} = H^{+}\bar{U}[K\xi^{D}P_R - \xi^{U}KP_L]D + h.c. \qquad (2)$$

where K is the Cabbibo-Kobayashi-Maskawa (CKM) matrix and $\xi^{U,D}$ the flavour changing matrices. In the framework of the 2HDM type III is useful the parameterization proposed by Cheng and Sher [2] for the couplings $\xi_{ii} = \lambda_{ii} g m_i/(2m_W)$.

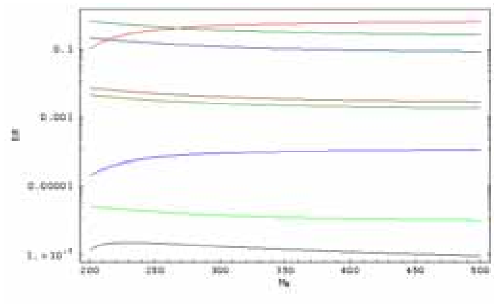

Figura 2: Branching ratios in the 2HDM-III for $\lambda_{tc} = 0{,}1$, $\lambda_{tt} = 0{,}1$, $\lambda_{bb} = 10$, $\lambda_{\mu\mu} = 0{,}12$,$\lambda_{\tau\tau} = 2{,}2 \times 10^{-2}$, $\lambda^2_{\mu\tau} = 4{,}44 \times 10^{-2}$.

Using the above Lagrangian and some aproximations for the λ_{ij} we get the following decay widths

$$
\begin{aligned}
\Gamma(H^+ \to t\bar{b}) &= \frac{3m_H K_{tb}^2}{16\pi\nu^2}\left[\left(1-(\frac{m_t^2+m_b^2}{m_H^2})\right)(m_b^2\lambda_{bb}^2+m_t^2\lambda_{tt}^2)-4\frac{m_t^2 m_b^2}{m_H^2}\lambda_{tt}\lambda_{bb}\right]|\vec{p}_H(m_t,m_b)| \\
\Gamma(H^+ \to c\bar{s}) &= \frac{3m_H K_{ts}^2}{16\pi\nu^2}\left[\left(1-(\frac{m_c^2+m_s^2}{m_H^2})\right)\lambda_{tc}^2 m_t m_c\right]|\vec{p}_H(m_c,m_s)| \\
\Gamma(H^+ \to t\bar{s}) &= \frac{3m_H K_{ts}^2}{16\pi\nu^2}\left[\left(1-(\frac{m_t^2+m_s^2}{m_H^2})\right)\lambda_{tt}^2 m_t^2\right]|\vec{p}_H(m_t,m_s)| \\
\Gamma(H^+ \to c\bar{b}) &= \frac{3m_H}{16\pi\nu^2}\left[\left(1-(\frac{m_c^2+m_b^2}{m_H^2})\right)(m_b^2 K_{cb}^2\lambda_{bb}^2+m_t m_c K_{bt}^2\lambda_{tc}^2)\right. \\
&- \left. 4\frac{m_b^2 m_c\sqrt{m_t m_c}}{m_H^2}V_{tb}\lambda_{tc}V_{cb}\lambda_{bb}\right]|\vec{p}_H| \qquad (3) \\
\Gamma(H^+ \to \tau\nu_\tau) &= \frac{m_H}{16\pi}\left(1-\frac{m_\tau^2}{m_H^2}\right)\xi_{\tau\tau}^2 \\
\Gamma(H^+ \to \tau\nu_\mu) &= \frac{m_H}{16\pi}\left(1-\frac{m_\tau^2}{m_H^2}\right)\xi_{\tau\mu}^2 \\
\Gamma(H^+ \to \mu\nu_\mu) &= \frac{m_H}{16\pi}\left(1-\frac{m_\mu^2}{m_H^2}\right)\xi_{\mu\mu}^2
\end{aligned}
$$

$$
\Gamma(H^+ \to W^+h^0) = \frac{\cos^2\alpha}{16\pi\nu^2}\left(1-(\frac{m_h+m_W}{m_H})^2\right)^{\frac{1}{2}}\left(1-(\frac{m_h-m_W}{m_H})^2\right)^{\frac{1}{2}} \qquad (4)
$$

where ν is the vacuum expectacion value and $|\vec{p}_H(m_i,m_j)| = (1-(\frac{m_i-m_j}{m_H})^2)^{1/2}(1-(\frac{m_i+m_j}{m_H})^2)^{1/2}$

In order to proceed with the numerical evaluations, bounds and restrictions on the λ_{ij} for the quark sector and ξ_{ij} for the leptonic sector can be found in literature [1, 4, 3, 7]. We present the possible branching fractions in two different scenarios of the parameter space of our framework. They are shown in figues 1 and 2.

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