Implications of the Yukawa's textures of the neutral Higgs bosons in the context of the THDM III1

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Resume

In this work we studied the neutral Higgs bosons decays in the two Higgs doblet model type III (THDM-III) taking acount the implications of Yukawa's textures. We calculate the decay widths (Γ) and the corresponding branching ratios (BR) of the main decay modes of such neutral Higgs bosons. We realized numerical analysis considering the analitic results in the permitted parameter space considering also different cases of the model. In addition, we bound the cases in concordance with the corresponding theoretical restrictions. Finally we present the expected event number, which it give the posibility of detection in current colliders.

Introduction

1. The Higgs boson: hypothetical elementary particle, his existence is given by the SSB. It gives the mass of the particles of the SM.
2. It was theorized in 1964 by Peter Higgs, Francois Englert y Robert Brout (in base to ideas of Philip Anderson), and independently by G. S. Guralnik, C. R. Hagen and T. W. B. Kibble [1].
3. The Higgs field has a vacuum expectation value ($VEV \neq 0$, $VEV = 246$ GeV).
4. SM doesn't predict the mass value of the Higgs boson[2].
5. If $115 < m_h < 180$ GeV, so SM is valid through the Planck scale(10^{16} TeV).
6. An extention of the SM is the Two Higgs Doblet Model (THDMIII).

THDM:
This model is introduced by three types:

1. Type I. One Higgs doublet couples to fermions.[1]
2. Type II. One of the Higgs doublets couples just to the up quarks, while the other one couples to down quarks.[2]
3. Type III. Higgs-fermions couplings are indistinc to anyone of the two doublets[3].

Standar Model

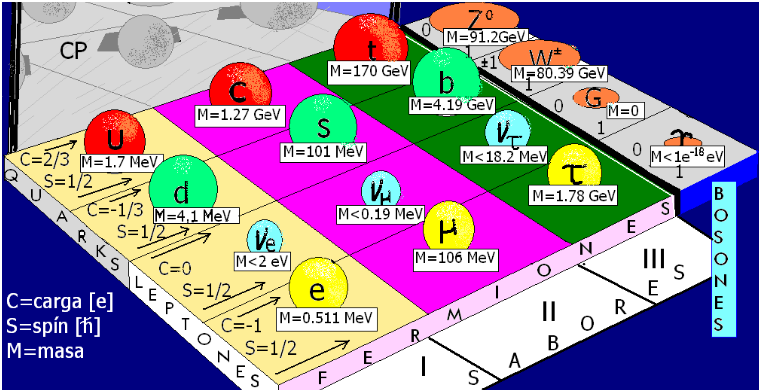


Figure 1:

The SM Lagrangian density, is gauge simmetry invariant is:

$$\mathcal{L}_{SM} \;=\; \mathcal{L}_F + \mathcal{L}_B + \mathcal{L}_{SBS} + \mathcal{L}_{YW} + \mathcal{L}_C, \qquad (1)$$

$\mathcal{L}_F$ is the fermionic Lagrangian, $\mathcal{L}_B$ is the bosonic Lagrangian ($\mathcal{L}_B = \mathcal{L}_{YM} + \mathcal{L}_{GF} + \mathcal{L}_{FP}$), $\mathcal{L}_{SBS}$ is the SSB Lagrangian, $\mathcal{L}_{YW}$ is the Yukawa Lagrangian and $\mathcal{L}_C$ is the current Lagrangian.
This includes **5 sectors: fermionic, Yang Mills, Higgs, Yukawa, and currents sectors.**

Yukawa's sector (important)

Yukawa's Lagrangian **give mass to fermions after SSB**. We introduce a covariant object under $SU_L(2)$, defined by:

$$\phi^c \sim i\tau_2\phi^* = \begin{pmatrix} \phi^{0*} \\ -\phi^- \end{pmatrix}, \tag{2}$$

where τ_2 is the second Pauli's matrix, ϕ^* is the complex conjugate of Higgs field; the isodoblet ϕ^c ($\widetilde{\phi}$) hypercharge is $Y = 1$.

General Yukawa's Lagrangian is:

$$\mathcal{L}_{YW} = -\sum_{a,k} Y_a^k \overline{\psi}_L^k \phi_a^r \psi_R^k + h.c., \tag{3}$$

$k = l, u, d$ is the fermion type, $a = 1, 2, 3, ...n$ where n is the number of Higgs fields in the model (THDM, $n = 2$) and r is the isodoublet Higgs field ϕ^c or the Higgs field ϕ, if fermions are type up or down, ψ_L are left doublet fermions of $SU(2)_L$:

1. $l_L^i = \begin{pmatrix} \nu_{l_i} \\ l_i \end{pmatrix}_L$, with l_i leptons (e^-, μ^-, τ^-), and
2. $Q_L^i = \begin{pmatrix} u^i \\ d^i \end{pmatrix}_L$, with u^i up quarks (u, c, t), and d^i down quarks (d, s, b).

The SSB Lagrangian density is:

$$\mathcal{L}_{SSB} = \frac{1}{2}\left|D_\mu \phi\right|^2 - V(\phi) - \frac{1}{4}(F_{\mu\nu})^2. \tag{4}$$

$$\begin{aligned} V(\phi) &= \frac{m^2}{2}\left|\phi\right|^2 + \frac{\lambda}{4}\left(\left|\phi\right|^2\right)^2 \\ &= -\frac{\mu^2}{2}\left|\phi\right|^2 + \frac{\lambda}{4}\left(\left|\phi\right|^2\right)^2, \end{aligned} \tag{5}$$

where $\mu = -m^2$ and $\lambda > 0$.

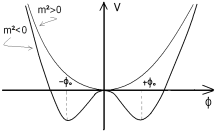


Figure 2: Higgs potential for real and imaginary mass.

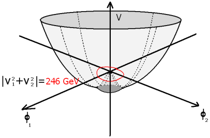


Figure 3: Higgs potential for $n = 2$, note that red region is given by 246 Gev's.

THDM

Some motivations:

1. **New phenomenology** (appear charged Higgs bosons,FCNC.),
2. **It allows to introduce ECPV**.
3. **It naturally solves the hierarchy** from the Yukawa's couplings in the third generation of quarks ($m_t/m_b \approx 173.1/4.67 \approx 37$), this is making by letting the bottom quark mass given by one doublet and the top one's for the other.

The **Higgs potential of THDM**. We introduce two $SU(2)_Y$ doublets ϕ_1, ϕ_2, with hypercharge $Y = \pm 1$. This is a renormalizable potential, compatible with gauge invariance, is obtained introducing the hermitian gauge invariants operators:

$$\hat{A} = \phi_1^\dagger \phi_1, \tag{6}$$

$$\hat{B} = \phi_2^\dagger \phi_2,$$

$$\hat{C} = \frac{1}{2}\left(\phi_1^\dagger \phi_2 + \phi_2^\dagger \phi_1\right) = Re(\phi_1^\dagger \phi_2), \tag{8}$$

$$\hat{D} = -\frac{i}{2}\left(\phi_1^\dagger \phi_2 - \phi_2^\dagger \phi_1\right) = Im(\phi_1^\dagger \phi_2). \tag{9}$$

The renormalizable and reparameterized Higgs potential for the THDM is:

$$\begin{aligned} V(\phi_1,\phi_2) &= m_{11}^2\left(\phi_1^\dagger\phi_1\right)+m_{22}^2\left(\phi_2^\dagger\phi_2\right)-\left[m_{12}^2\left(\phi_1^\dagger\phi_2\right)+h.c.\right] \\ &\quad +\frac{\lambda_1}{2}\left(\phi_1^\dagger\phi_1\right)^2+\frac{\lambda_2}{2}\left(\phi_2^\dagger\phi_2\right)^2+\lambda_3\left(\phi_1^\dagger\phi_1\right)\left(\phi_2^\dagger\phi_2\right) \\ &\quad +\lambda_4\left(\phi_1^\dagger\phi_2\right)\left(\phi_2^\dagger\phi_1\right)+\left\{\frac{\lambda_5}{2}\left(\phi_1^\dagger\phi_2\right)^2+\left[\lambda_6\left(\phi_1^\dagger\phi_1\right)\right.\right. \\ &\quad \left.\left. +\lambda_7\left(\phi_2^\dagger\phi_2\right)\right]\left(\phi_1^\dagger\phi_2\right)+h.c.\right\}, \end{aligned} \tag{10}$$

14 new, 6 real $(m_{11}^2, m_{22}^2, \lambda_1, \lambda_2, \lambda_3, \lambda_4)$ and 4 complex $(m_{12}^2, (m_{12}^2)^*, \lambda_5, \lambda_5^*, \lambda_6, \lambda_6^*, \lambda_7, \lambda_7^*)$ parameters.

PROPERTIES OF THE POTENTIAL:

1. It's renormalizable and hermitic $V^\dagger = V$.
2. It allows (**ECPV**), and just CPC[4], when $m_{12}, \lambda_5, \lambda_6, \lambda_7$ are reals.
3. If $\lambda_6 = \lambda_7 = m_{12}^2 = 0$ then V is symmetric under Z_2.

Then:

$$\phi_1 = \begin{pmatrix} \phi_1^+ \\ \frac{\phi_{1R}^0 + i\phi_{1I}^0}{\sqrt{2}} \end{pmatrix}, \qquad \phi_2 = \begin{pmatrix} \phi_2^+ \\ \frac{\phi_{2R}^0 + i\phi_{2I}^0}{\sqrt{2}} \end{pmatrix}, \tag{11}$$

Now we can calculate the mass matrix given by:

$$M_{ij}^2 = \frac{1}{2}\frac{\partial^2 V}{\partial\phi_i \partial\phi_j} = \begin{pmatrix} M_C^2 & 0 \\ 0 & M_N^2 \end{pmatrix}_{8\times 8}, \qquad (12)$$

with M_C^2, M_N^2 the 4×4 charged and neutral matrices, where:

$$M_N^2 = \begin{pmatrix}
\begin{matrix} (m_{12}^2 + (m_{12}^2)^*)\frac{v_2 e^{i\xi}}{4v_1} \\ +\lambda_1 \frac{v_1^2}{2} \\ +(\lambda_6 + \lambda_6^*)\frac{3v_1 v_2 e^{i\xi}}{8} - (\lambda_7 + \lambda_7^*)\frac{v_2^3 e^{i3\xi}}{8v_1} \end{matrix} &
\begin{matrix} -\left(m_{12}^2 + (m_{12}^2)^*\right)\frac{1}{4} \\ +\left(\lambda_3 + \lambda_4 + \frac{\lambda_5 + \lambda_5^*}{2}\right)\frac{v_1 v_2 e^{i\xi}}{2} \\ +(\lambda_6 + \lambda_6^*)\frac{3v_1^2}{8} + (\lambda_7 + \lambda_7^*)\frac{3v_2^2 e^{i2\xi}}{8} \end{matrix} &
\begin{matrix} (\lambda_5^* - \lambda_5)\frac{iv_2^2 e^{i2\xi}}{8} \\ +(\lambda_6^* - \lambda_6)\frac{iv_1 v_2 e^{i\xi}}{4} \end{matrix} &
(\lambda_5 - \lambda_5^*)\frac{iv_1 v_2 e^{i\xi}}{8} \\
\begin{matrix} -\left(m_{12}^2 + (m_{12}^2)^*\right)\frac{1}{4} \\ +\left(\lambda_3 + \lambda_4 + \frac{\lambda_5 + \lambda_5^*}{2}\right)\frac{v_1 v_2 e^{i\xi}}{2} \\ +(\lambda_6 + \lambda_6^*)\frac{3v_1^2}{8} + (\lambda_7 + \lambda_7^*)\frac{3v_2^2 e^{i2\xi}}{8} \end{matrix} &
\begin{matrix} (m_{12}^2 + (m_{12}^2)^*)\frac{v_1 e^{-i\xi}}{4v_2} \\ -\lambda_2 \frac{v_2^2 e^{i2\xi}}{2} - (\lambda_6 + \lambda_6^*)\frac{v_1^3 e^{-i\xi}}{8v_2} \\ +(\lambda_7 + \lambda_7^*)\frac{3v_1 v_2 e^{i\xi}}{8} \end{matrix} &
\begin{matrix} -(\lambda_5 - \lambda_5^*)\frac{(iv_1 v_2 e^{i\xi})}{8} \\ -(\lambda_7 - \lambda_7^*)\frac{iv_2^2 e^{i2\xi}}{4} \end{matrix} &
\begin{matrix} (\lambda_5 - \lambda_5^*)\frac{iv_1^2}{8} \\ +(\lambda_7 - \lambda_7^*)\frac{iv_1 v_2 e^{i\xi}}{4} \end{matrix} \\
\begin{matrix} (\lambda_5^* - \lambda_5)\frac{iv_2^2 e^{i2\xi}}{8} \\ +(\lambda_6^* - \lambda_6)\frac{iv_1 v_2 e^{i\xi}}{4} \end{matrix} &
\begin{matrix} -(\lambda_5 - \lambda_5^*)\frac{(iv_1 v_2 e^{i\xi})}{8} \\ -(\lambda_7 - \lambda_7^*)\frac{iv_2^2 e^{i2\xi}}{4} \end{matrix} &
\begin{matrix} (m_{12}^2 + (m_{12}^2)^*)\frac{v_2 e^{i\xi}}{4v_1} \\ -(\lambda_6 + \lambda_6^*)\frac{v_1 v_2 e^{i\xi}}{8} \\ -(\lambda_7 + \lambda_7^*)\frac{v_2^3 e^{i3\xi}}{8v_1} \end{matrix} &
\begin{matrix} -\frac{m_{12}^2 + (m_{12}^2)^*}{4} \\ +(\lambda_5 + \lambda_5^*)\frac{v_1 v_2 e^{i\xi}}{4} \\ +(\lambda_6 + \lambda_6^*)\frac{v_1^2}{8} + (\lambda_7 + \lambda_7^*)\frac{v_2^2 e^{i2\xi}}{8} \end{matrix} \\
(\lambda_5 - \lambda_5^*)\frac{iv_1 v_2 e^{i\xi}}{8} &
\begin{matrix} (\lambda_5 - \lambda_5^*)\frac{iv_1^2}{8} \\ +(\lambda_7 - \lambda_7^*)\frac{iv_1 v_2 e^{i\xi}}{4} \end{matrix} &
\begin{matrix} -\frac{m_{12}^2 + (m_{12}^2)^*}{4} + (\lambda_5 + \lambda_5^*)\frac{v_1 v_2 e^{i\xi}}{4} \\ +(\lambda_6 + \lambda_6^*)\frac{v_1^2}{8} \\ +(\lambda_7 + \lambda_7^*)\frac{v_2^2 e^{i2\xi}}{8} \end{matrix} &
\begin{matrix} (m_{12}^2 + (m_{12}^2)^*)\frac{v_1 e^{-i\xi}}{4v_2} \\ -(\lambda_7 + \lambda_7^*)\frac{v_1 v_2 e^{i\xi}}{8} \end{matrix}
\end{pmatrix}.$$

$$
\begin{aligned}
m^2_{H^0,h^0} &= \left(\lambda_1^* + \frac{1}{2}\lambda_+\right) v_1^2 - \frac{1}{2}\mu_2^2 \\
&\pm \sqrt{\left[\left(\lambda_1^* - \frac{1}{2}\lambda_+\right) v_1^2 + \frac{1}{2}\mu_2^2\right]^2 + \left(\frac{1}{2}\lambda_6^* v_1^2\right)^2}. \quad (13)
\end{aligned}
$$

$$
\begin{pmatrix} \cos\alpha \\ sen\alpha \end{pmatrix} \leftrightarrow m^2_{H^0}, \qquad \begin{pmatrix} -sen\alpha \\ \cos\alpha \end{pmatrix} \leftrightarrow m^2_{h^0}, \qquad (14)
$$

where:

$$\tan 2\alpha = \frac{\lambda_6^* v_1^2}{(2\lambda_1^* - \lambda_+)v_1^2 + \mu_2^2}, \qquad \lambda_+ \equiv \frac{1}{2}(\lambda_3 + \lambda_5), \tag{15}$$

and λ_i^*, μ_2 are given as the reparametrization. Thus, the diagonalization process makes the rotation:

$$\left(\begin{array}{cc} \cos\alpha & sen\alpha \\ -sen\alpha & \cos\alpha \end{array} \right) \left(\begin{array}{c} \sqrt{2}\phi_{1R}^0 - v_1 \\ \sqrt{2}\phi_{2R}^0 - v_2 \end{array} \right) = \left(\begin{array}{c} H^0 \\ h^0 \end{array} \right) \tag{16}$$

Yukawa's Lagrangian in THDM

Three diferent models according to the Yukawa's Lagrangian coupling.

1. **THDM-I** One doublet couples to all fermions.
2. **THDM-II** Each doublet couples to one type of fermions.
3. **THDM-III** All doublets couples to all fermions ($\exists$ **FCNSI**).

Yukawa's Lagrangian for the quark fields is:

$$\begin{aligned}\mathcal{L}_Y^q &= \bar{q}_L^0 Y_1^D \phi_1 d_R^0 + \bar{q}_L^0 Y_2^D \phi_2 d_R^0 + \bar{q}_L^0 Y_1^U \widetilde{\phi}_1 u_R^0 \\ &+ \bar{q}_L^0 Y_2^U \widetilde{\phi}_2 u_R^0 + h.c., \end{aligned} \tag{17}$$

with $Y_{1,2}^{U,D}$ the 3×3 Yukawa's matrices, q_L left quark doublets, u_R, d_R right singlets.

Before a correct SSB

The Higgs doublets are descomposed as:

$$\phi_1 = \begin{pmatrix} \phi_1^+ \\ \frac{v_1+\phi_1+i\chi_1}{\sqrt{2}} \end{pmatrix}, \qquad \phi_2 = \begin{pmatrix} \phi_2^+ \\ \frac{e^{i\xi} v_2+\phi_2+i\chi_2}{\sqrt{2}} \end{pmatrix}, \tag{18}$$

where v_1, v_2 $\epsilon\mathbb{R}^+$.
By expresing $\bar{q}_L^0$ using (18), and transforming the quark fields to the mass eigenstate basis through $u_{L,R} = U_{L,R} u_{L,R}^0$ and $d_{L,R} = D_{L,R} d_{L,R}^0$,

using quirality operators of the matrix:

$$M^{Q} = Q_L Y_1^Q Q_R^{\dagger} \frac{v_1}{\sqrt{2}} + Q_L Y_2^Q Q_R^{\dagger} \frac{e^{-i\xi} v_2}{\sqrt{2}}, \tag{19}$$

with $Q = U, D$, and

$$\begin{aligned} \phi_1 + i\chi_1 &= \sum_r (q_{r1} cos\beta - q_{r2} e^{-i(\theta_{23}+\xi)} sen\beta) H_r, \\ \phi_2 + i\chi_2 &= \sum_r (q_{r1} e^{i\xi} sen\beta + q_{r2} e^{-i\theta_{23}} cos\beta) H_r, \end{aligned} \tag{20}$$

where q_{ra} are written as combination of θ_{ij},these are given by:

r	q_{r1}	q_{r2}
1	$\cos\theta_{12}\cos\theta_{13}$	$-sen\theta_{12} - i\cos\theta_{12} sen\theta_{13}$
2	$sen\theta_{12}\cos\theta_{13}$	$\cos\theta_{12} - i sen\theta_{12} sen\theta_{13}$
3	$sen\theta_{13}$	$i\cos\theta_{13}$
4	i	0

Table 1: Values of q_{ra} in terms of the mixing angles of the rotation matrix.

We can rewrite the Lagrangian for neutral Higgs couplings to up and down quarks:

$$\mathcal{L}^{neutral}_{up,down} \;=\; \overline{(u,d)}_i \left[S^{u,d}_{ijr} + \gamma^5 P^{u,d}_{ijr} \right] (u,d)_j H_r + \overline{(u,d)}_i M^{u,D}_{ij} (u,d)_j . \tag{21}$$

$S^{u,d}_{ijr}$ and $P^{u,d}_{ijr}$ are given by:

$$\begin{aligned} S^{u,d}_{ijr} &= \frac{M^{u,D}}{2v}\left(q^*_{r1} + q_{r1} - tan\beta\left(q^*_{r2}e^{i(\theta+\xi)} + q_{r2}e^{-i(\theta+\xi)}\right)\right) \\ &+ \frac{1}{2\sqrt{2}cos\beta}\left(q^*_{r2}e^{i\theta}\widetilde{Y}_2^{u,D\dagger} + q_{r2}e^{-i\theta}\widetilde{Y}_2^{u\dagger,D}\right), \end{aligned} \tag{22}$$

$$\begin{aligned} P^{u,d}_{ijr} &= -^*\frac{M^{u,D}}{2v}\left(q^*_{r1} - q_{r1} - tan\beta\left(q^*_{r2}e^{i(\theta+\xi)} - q_{r2}e^{-i(\theta+\xi)}\right)\right) \\ &+ \frac{1}{2\sqrt{2}cos\beta}\left(q^*_{r2}e^{i\theta}\widetilde{Y}_2^{u,D\dagger} - q_{r2}e^{-i\theta}\widetilde{Y}_2^{u\dagger,D}\right). \end{aligned} \tag{23}$$

In THDM III we considere up y down sector **the values of S y P** for each of the H_i $(i = 1, 2, 3)$ as follows:

1. For $H_1 = h^0$: $S \neq 0$ and $P = 0$.
2. For $H_2 = H^0$: $S \neq 0$ and $P = 0$.
3. For $H_3 = A^0$: $S = 0$ and $P \neq 0$.

The texture formalism started by Bjorken proposing:

$$\begin{pmatrix} M_f + \Delta M_f & m_f & 0 \\ m_f^* & M_f + \Delta M_f & m_f \\ 0 & m_f^* & M_f + \Delta M_f \end{pmatrix}, \tag{24}$$

which reproduce the quarks mass and the elements of V_{CKM} with good aproximation.

1. It reproduces fermionic mass and mixing angles.
2. It supress FCNC.

The 4 textures Yukawa's hermitic matrix fulfill:

1. Hierarchy $|A_q| \gg |\widetilde{B}_q|, |B_q|, |C_q|$, A_q and $\widetilde{B}_q \, \epsilon \mathbb{R}$.
2. Phases of C_q and B_q (Φ_{B_q} and Φ_{C_q}) removed by $M_q = P_q^{\dagger} \widetilde{M}_q P_q$, with $P_q = diag(1, e^{i\Phi_{C_q}}, e^{i(\Phi_{C_q}+\Phi_{B_q})})$,
3. $\overline{M}_q = O_q^T \widetilde{M}_q O_q$, where M is:

$$M_q = \begin{pmatrix} 0 & C_q & 0 \\ C_q^* & \widetilde{B}_q & B_q \\ 0 & B_q^* & A_q \end{pmatrix} . \qquad (25)$$

The corrections to FC and FV depend of the diagonal matrix $\widetilde{Y}_2^q = O_q^T P_q Y_2^q P_q^\dagger O_q$. For $\widetilde{Y}_2^q$, we asumme that Y_2^q has the form of 4 textures. So with Cheng-Sher anzats:

$$(\widetilde{Y}_2^q)_{ij} = \frac{\sqrt{m_i^q m_j^q}}{v}\widetilde{\chi}_{ij}^q = \frac{\sqrt{m_i^q m_j^q}}{v}\chi_{ij}^q e^{i\vartheta_{ij}^q}, \qquad (26)$$

considering the ansatz $\overline{Y}_{2ij}^{u,d} = \chi_{ij}\frac{\sqrt{m_i m_j}}{v}$ and taking no CPV and using $e^{-i\theta_{23}} = 1$, $\cos\theta_{12} = sen(\beta-\alpha)$ y $sen\theta_{12} = \cos(\beta-\alpha)$:

$$\begin{aligned}
\mathcal{L}_{upint}^{neutral} &= \frac{g}{2m_w}\bar{u}_i\left[m_{u_i}\frac{\cos\alpha}{sen\beta}\delta_{ij} - \frac{\cos(\alpha-\beta)}{\sqrt{2}sen\beta}\sqrt{m_{u_i}m_{u_j}}\widetilde{\chi}_{ij}^{u}\right]u_j h^0 \\
&+\frac{g}{2m_w}\bar{u}_i\left[m_{u_i}\frac{sen\alpha}{sen\beta}\delta_{ij} - \frac{sen(\alpha-\beta)}{\sqrt{2}sen\beta}\sqrt{m_{u_i}m_{u_j}}\widetilde{\chi}_{ij}^{u}\right]u_j H^0 \\
&-\frac{ig}{2m_w}\bar{u}_i\left[-m_{u_i}\cot\beta\delta_{ij} + \frac{\sqrt{m_{u_i}m_{u_j}}}{\sqrt{2}sen\beta}\widetilde{\chi}_{ij}^{u}\right]\gamma^5 u_j A^0,
\end{aligned} \tag{27}$$

$$
\begin{aligned}
\mathcal{L}^{neutral}_{downint} \;=\;& \frac{g}{2m_w}\bar{d}_i\left[-m_{d_i}\frac{sen\alpha}{\cos\beta}\delta_{ij}+\frac{\cos(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{d_i}m_{d_j}}\widetilde{\chi}^{d}_{ij}\right]d_j h^0 \\
&+\frac{g}{2m_w}\bar{d}_i\left[m_{d_i}\frac{\cos\alpha}{\cos\beta}\delta_{ij}+\frac{sen(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{d_i}m_{d_j}}\widetilde{\chi}^{d}_{ij}\right]d_j H^0 \\
&+\frac{ig}{2m_w}\bar{d}_i\left[-m_{d_i}\tan\beta\delta_{ij}+\frac{\sqrt{m_{d_i}m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^{d}_{ij}\right]\gamma^5 d_j A^0,
\end{aligned}
$$

$$\begin{aligned}\mathcal{L}^{neutral}_{leptonesint} &= \frac{g}{2m_w}\bar{l}_i\left[-m_{l_i}\frac{sen\alpha}{\cos\beta}\delta_{ij}+\frac{\cos(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{l_i}m_{l_j}}\widetilde{\chi}^{l}_{ij}\right]l_j h^0\\ &+\frac{g}{2m_w}\bar{u}_i\left[m_{l_i}\frac{\cos\alpha}{\cos\beta}\delta_{ij}+\frac{sen(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{l_i}m_{l_j}}\widetilde{\chi}^{l}_{ij}\right]u_j H^0\\ &+\frac{ig}{2m_w}\bar{u}_i\left[-m_{d_i}\tan\beta\delta_{ij}+\frac{\sqrt{m_{d_i}m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^{d}_{ij}\right]\gamma^5 u_j A^0,\end{aligned} \tag{28}$$

From this, **we have the vertex for Feynman diagrams!**

Production and posible Decays of neutral Higgs. Neutral Higgs bosons can be produced by:

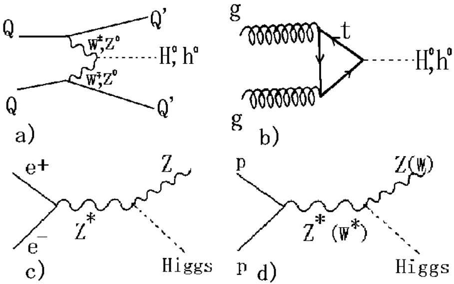


Figure 4: *a*) Gluon fusion, *b*) vectorial bosons fusion, *c*) e-p collisions, *d*) p-p collisions.

Neutral Higgs Decays in THDM III

We considered fermionic (with FCNC) and bosonic decays,

1. **two fermions**: $(\phi^0 \to \bar{f}_i f_j)$, $\phi^0 = h^0, H^0, A^0$ and $f_i = l_i, q_i$.
2. **two bosons**: $(H^0 \to \bar{V}_i V_j)$, $V_i = Z^0, W^\pm$.
3. **two bosons with one virtual**: $H^0, h^0 \to V^* V$, allowed for $m_V < m_h < 2m_V$.
4. **two Higgs bosons**: $H^0 \to h^0 h^0, H^0 \to A^0 A^0$.
5. **one gauge boson and a light Higgs** (just allowed $A^0 \to Zh^0$).

We calculate to tree level

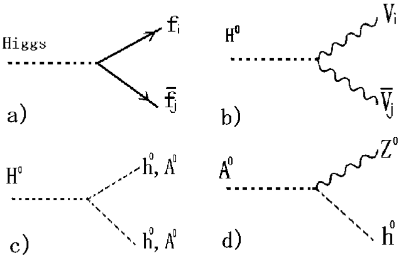


Figure 5: Feynman diagrams of neutral Higgs decaying to: *a*) 2 fermions with FCNC, *b*) 2 gauge bosons, *c*) 2 neutral Higgs, *d*) a vectorial gauge boson and a neutral Higgs.

Higgs decaying to two fermions

In THDMIII: 18 posible decays (twice that in SM).

$$\begin{aligned}&\Gamma_{f_i\bar{f}_j}\left(m_i, m_j, m\phi^0, Nc, n, \xi_{ij}\right) = \\ &\left(\frac{Nc}{8\pi(m\phi^0)^3}\right)\left(\frac{g}{2m_w}\right)^2 \xi_{ij}^2\left((m\phi^0)^2 - (m_i + m_j(-1)^n)^2\right) \\ &\cdot\left((m_i^2 - m_j^2 - (m\phi^0)^2)^2 - 4m_j^2(m\phi^0)^2\right)^{1/2}. \end{aligned} \tag{29}$$

where $Nc = 1(3)$ for leptons (quarks), n even for h^0, H^0; n odd for A^0 and $\phi^0 = h^0, H^0, A^0$.

And ξ_{ij} are given by:

Process	THDMIII	THDMII	SM
$h^0 \to u_i\bar{u}_j$	$m_{u_i}\frac{\cos\alpha}{sen\beta}\delta_{ij} - \frac{\cos(\alpha-\beta)}{\sqrt{2}sen\beta}\sqrt{m_{u_i}m_{u_j}}\widetilde{\chi}^u_{ij}$	$m_{u_i}\frac{\cos\alpha}{sen\beta}\delta_{ij}$	$m_{u_i}\delta_{ij}$
$h^0 \to d_i\bar{d}_j$	$-m_{d_i}\frac{sen\alpha}{\cos\beta}\delta_{ij} + \frac{\cos(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{d_i}m_{d_j}}\widetilde{\chi}^d_{ij}$	$-m_{d_i}\frac{sen\alpha}{\cos\beta}\delta_{ij}$	$m_{d_i}\delta_{ij}$
$H^0 \to u_i\bar{u}_j$	$m_{u_i}\frac{sen\alpha}{sen\beta}\delta_{ij} - \frac{sen(\alpha-\beta)}{\sqrt{2}sen\beta}\sqrt{m_{u_i}m_{u_j}}\widetilde{\chi}^u_{ij}$	$m_{u_i}\frac{sen\alpha}{sen\beta}\delta_{ij}$	$-$
$H^0 \to d_i\bar{d}_j$	$m_{d_i}\frac{\cos\alpha}{\cos\beta}\delta_{ij} + \frac{sen(\alpha-\beta)}{\sqrt{2}\cos\beta}\sqrt{m_{d_i}m_{d_j}}\widetilde{\chi}^d_{ij}$	$m_{d_i}\frac{\cos\alpha}{\cos\beta}\delta_{ij}$	$-$
$A^0 \to u_i\bar{u}_j$	$-m_{u_i}\cot\beta\delta_{ij} + \frac{\sqrt{m_{u_i}m_{u_j}}}{\sqrt{2}sen\beta}\widetilde{\chi}^u_{ij}$	$-m_{u_i}\cot\beta\delta_{ij}$	$-$
$A^0 \to d_i\bar{d}_j$	$-m_{d_i}\tan\beta\delta_{ij} + \frac{\sqrt{m_{d_i}m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^d_{ij}$	$-m_{d_i}\tan\beta\delta_{ij}$	$-$

Table 2: Values of ξ_{ij} according to decay and model.

Higgs decaying to two gauge bosons

In THDM III: 11 decays to gauge bosons (7 more than in SM).

$$\begin{aligned}\Gamma(h^0 \to VV) &= \frac{g^2 m_{h^0}^3}{k_V 64\pi m_W^2} sen^2(\beta-\alpha)\sqrt{1-x(V)} \\ &\times(1-x(V)+\frac{3}{4}x^2(V)), \end{aligned} \tag{30}$$

$$\begin{aligned}\Gamma(H^0 \to VV) &= \frac{g^2 m_{h^0}^3}{k_V 64\pi m_W^2} \cos^2(\beta-\alpha)\sqrt{1-x(V)} \\ &\times(1-x(V)+\frac{3}{4}x^2(V)), \end{aligned} \tag{31}$$

where $k_V = 1$ for $V = W$, $k_V = 2$ for $V = Z$ and $x(V) = 4\frac{m_v^2}{m_h^2}$.
Constrain: $m_{higgs} > 2m_V$.

Higgs decaying to two gauge boson and one virtual

$$\Gamma(h^0 \to WW^*) = 4\frac{g^4 m_{h^0}}{512\pi^3} sen^2(\alpha-\beta) F(m_W/m_{h^0}), \tag{32}$$

$$\begin{aligned}\Gamma(h^0 \to ZZ^*) \quad = \quad & 4\frac{g^4 m_{h^0}}{2048\pi^3} sen^2(\alpha-\beta) F(m_Z/m_{h^0}) \times \\ & \left[\frac{7-(40/3)sen^2\theta_W+(160/9)sen^4\theta_W}{\cos^4\theta_W}\right], \end{aligned} \tag{33}$$

where $F(x) = -(1-x^2)\left(\frac{47}{x}^2 - \frac{13}{2} + \frac{1}{x^2}\right) - 3(1-6x^2+4x^4)ln(x) + 3\left(\frac{1-8x^2+20x^4}{\sqrt{4x^2-1}}\right)\arccos\left(\frac{3x^2-1}{2x^3}\right)$. And for H^0:

$$\Gamma(H^0 \to WW^*, ZZ^*) = \Gamma(h^0 \to WW^*, ZZ^*)\cot^2(\alpha-\beta). \quad (34)$$

Note that

$$\sqrt{\frac{4m_W^2}{m_{h^0}^2} - 1} \quad \epsilon \quad \mathbb{R}, \quad (35)$$

then $\frac{4m_W^2}{m_{h^0}^2} - 1 > 0$ and so $m_{h^0} < \sqrt{4m_W^2}$, ($m_{h^0} < 160.78$ GeV's for $m_W = 80.39$ GeV).

$A^0 \to Z^0 h^0$ decay

The only way that A^0 decays to two bosons.

$$\Gamma(A^0 \to Z^0 h^0) = \frac{g^2 \lambda^{1/2} cos^2(\beta - \alpha)}{64\pi m_{A^0}^3 cos^2\theta_W} \left(m_Z^2 - 2(m_{A^0}^2 + 2m_{h^0}^2) + \frac{(m_{A^0}^2 - m_{h^0}^2)^2}{m_Z^2} \right), \quad (36)$$

with $\lambda^{1/2} = \left((m_{Z^0}^2 + m_{h^0}^2 - m_{A^0}^2)^2 - 4m_{Z^0}^2 m_{h^0}^2\right)^{1/2}$. No tree level coupling to a pair of vectorial bosons because CPC.

Higgs decaying to 2 Higgs

$H^0 \to h\ (h = h^0, A^0)$.

$$\Gamma(H^0 \to hh) = \frac{g^2 m_Z^2 f_h^2}{128\pi m_{H^0} \cos^2\theta_W} \left(1 - \frac{4m_h^2}{m_{H^0}^2}\right)^{1/2}, \qquad (37)$$

where

$$f_h = \begin{cases} \cos 2\alpha \cos(\beta+\alpha) - 2sen(2\alpha)sen(\beta+\alpha)\text{if}h = h^0, \\ \cos 2\alpha \cos(\beta+\alpha)\text{if}h = A^0. \end{cases}$$

Constrain: $m_{H^0} > 2m_h$.

Branching Ratios

To calculate Neutral Higgs bosons BR, we need to calculate the total width decay:

$$\Gamma_{tot} = \sum_{X,Y} \Gamma(\phi \to XY). \tag{38}$$

So the BR for the decay $\phi \to ab$ is:

$$BR(\phi \to ab) = \frac{\Gamma(\phi \to ab)}{\Gamma_{tot}}. \tag{39}$$

Constraints

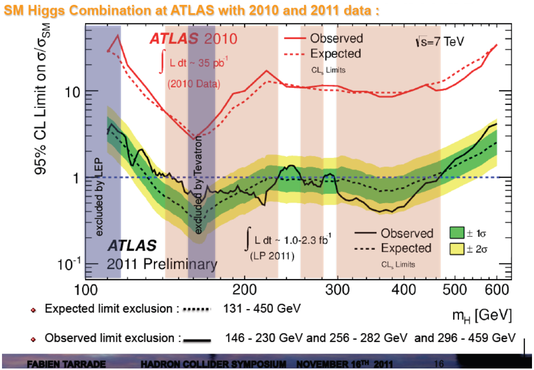
We have several constraints:

- **CUSTODIAL SIMMETRY $SU(2)_c$.**

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = \frac{\sum_k 2(T_k(T_k+1) - Y_k^2/4)\nu_k^2 + \sum_i 2T_i(T_i+1)\nu_i^2}{\sum_k \nu_k^2 Y^2},$$

- **TRIVIALITY COSTRAINTS.**
  $\lambda \neq 0$ and finite.
- **STABILITY CONSTRAINT OF THE VACUUM. Stable** vacuum **requires** $\lambda > 0$ so $(M_h \gtrsim 130$ GeV) but **vacuum must be metastable** so $M_h \gtrsim 115 GeV$.

Bounds of SM Higgs boson mass in november of 2011.



SM Higgs Combination at ATLAS with 2010 and 2011 data :

- Expected limit exclusion : ...... 131 - 450 GeV
- Observed limit exclusion : ▬ 146 - 230 GeV and 256 - 282 GeV and 296 - 459 GeV

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Figure 6: Combination of ATLAS data [4].

Results

We build a program in Mathematica® which we compute the next decay widths:

1. 18 to pair of fermions.
2. 11 to pair of bosons.
3. 4 to boson-virtual boson.
4. 3 to pair of Higgs bosons ($A^0 \to Z^0 h^0$, $H^0 \to hh, AA$)
5. **Total: 36 width decays** (possibles BR).

In 3 scenarios:

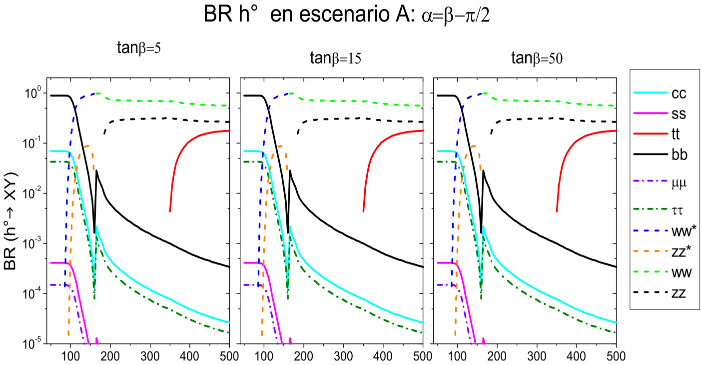
1. scenario A: $\alpha - \beta = -\frac{\pi}{2}$ (for h^0 this is SM scenario).
2. scenario B: $\alpha - \beta = 0$.
3. scenario C: $\alpha - \beta = -\frac{\pi}{3}$.

With:
$\tan\beta = 5, 10, 15, 20, 30, 50$; thus also values of $\chi_{ij} = 1, 0.5, 0, -0.2, -0.5,$
in the 4 Yukawa's textures context, $(\chi_{11} = \chi_{13} = \chi_{31} = 0)$.

Imput parameters:
$m_u = 0.0017$ GeV, $m_d = 0.004$ GeV, $m_s = 0.1$ GeV, $m_c = 1.3$ GeV, $m_b = 4.67$ GeV, $m_e = 0.0005$ GeV, $m_\mu = 0.105$ GeV, $m_\tau = 1.776$ GeV, $m_{Afijo} = 250$ GeV, $g = \sqrt{4\pi\alpha}$ GeV, $m_t = 173.1$ GeV, $m_w = 80.39$ GeV, $m_z = 91.1876$ GeV, $s_w = \sqrt{0.2254}$, $c_w = \sqrt{1 - s_w^2}$.

Branching Ratios of h^0

For the h^0 decays (SM Higgs boson), we considered for numerical analysis in range for the Higgs boson mass $500 \geq m_{h^0} \geq 50$ GeV, and we obtained the next graphics for BR.
$\chi_{ij} = 1, 0, -1$ ($\chi_{ij} = 0$ THDM type II and $\chi_{ij} = 1, -1$; allow FCNC, this is THDM-III), thus we considered the values $\tan\beta = 5, 15, 50$.


BR h° en escenario A: α=β−π/2
tanβ=5
tanβ=15
tanβ=50
BR (h°→ XY)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
100
200
300
400
500
cc
ss
tt
bb
μμ
ττ
ww*
zz*
ww
zz

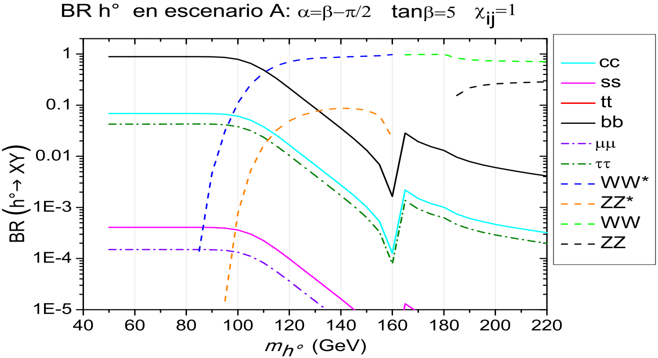
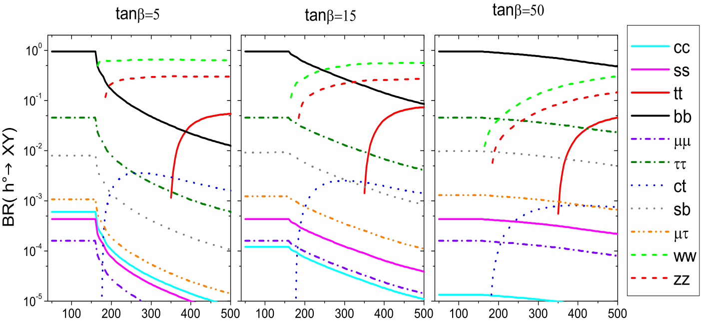
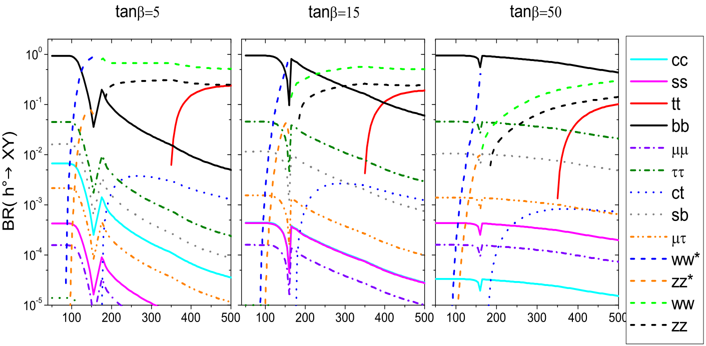


Figure 8: $BR(h^0)$ with $\mathcal{O} > 10^{-5}$ in SM.

BR h° en escenario B: $\alpha=\beta$





BR h° en escenario C: α=β−π/3

Branching Ratios of H^0

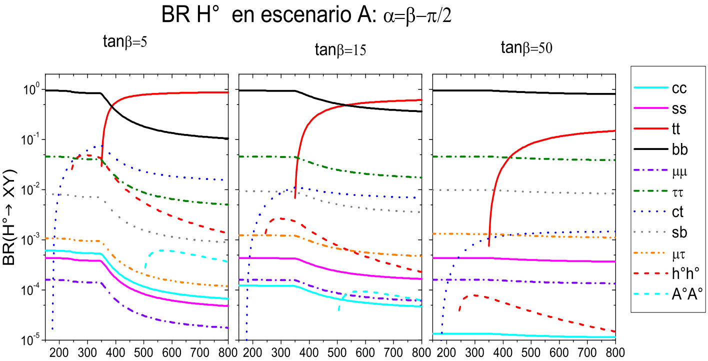
For H^0 decays (the neutral Higgs boson heavier than SM ones), we considered for the numerical analisis we considered a range for Higgs mass $800 \geq m_{H^0} \geq 150$ GeV. We considered 2 regions:

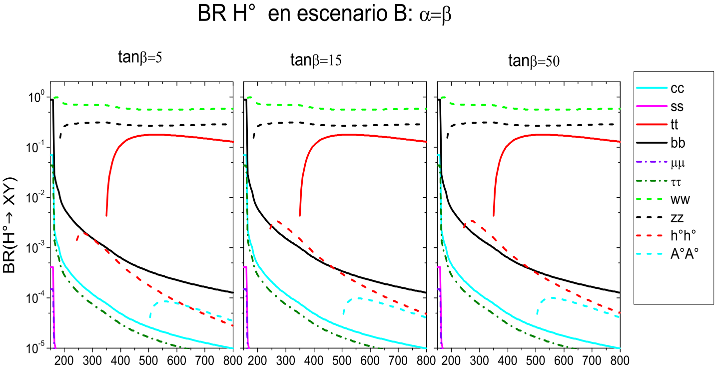
- $150 < m_{H^0} < 350$ GeV,
- $350 < m_{H^0} < 800$ GeV.

For the second the dominant decays depend on scenario. $\tan\beta$ and χ_{ij} values, for first region dominant decays is to pair of b-quarks ($b\bar{b}$) and WW pairs.

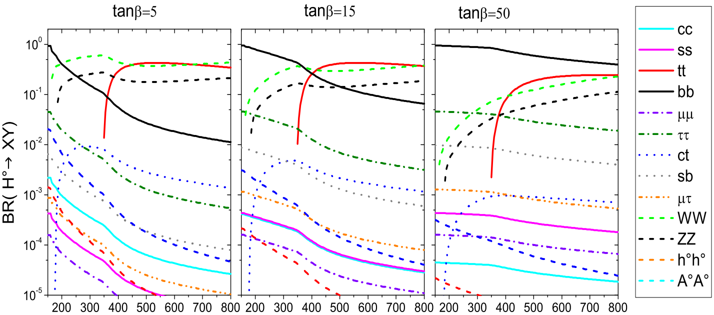
Proceso	ξ_{ij} en escenario A	ξ_{ij} en escenario B
$h^0 \to u_i \bar{u}_j$	$m_{u_i}\delta_{ij}$	$m_{u_i} \cot\beta\delta_{ij} - \frac{\sqrt{m_{u_i} m_{u_j}}}{\sqrt{2} sen\beta}\widetilde{\chi}^u_{ij}$
$h^0 \to d_i \bar{d}_j$	$-m_{d_i}\delta_{ij}$	$-m_{d_i} \tan\beta\delta_{ij} + \frac{\sqrt{m_{d_i} m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^d_{ij}$
$H^0 \to u_i \bar{u}_j$	$-m_{u_i} \cot\beta\delta_{ij} + \frac{\sqrt{m_{u_i} m_{u_j}}}{\sqrt{2} sen\beta}\widetilde{\chi}^u_{ij}$	$m_{u_i}\delta_{ij}$
$H^0 \to d_i \bar{d}_j$	$m_{d_i} \tan\beta\delta_{ij} - \frac{\sqrt{m_{d_i} m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^d_{ij}$	$m_{d_i}\delta_{ij}$
$A^0 \to u_i \bar{u}_j$	$-m_{u_i} \cot\beta\delta_{ij} + \frac{\sqrt{m_{u_i} m_{u_j}}}{\sqrt{2} sen\beta}\widetilde{\chi}^u_{ij}$	$-m_{u_i} \cot\beta\delta_{ij} + \frac{\sqrt{m_{u_i} m_{u_j}}}{\sqrt{2} sen\beta}\widetilde{\chi}^u_{ij}$
$A^0 \to d_i \bar{d}_j$	$-m_{d_i} \tan\beta\delta_{ij} + \frac{\sqrt{m_{d_i} m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^d_{ij}$	$-m_{d_i} \tan\beta\delta_{ij} + \frac{\sqrt{m_{d_i} m_{d_j}}}{\sqrt{2}\cos\beta}\widetilde{\chi}^d_{ij}$

Table 3: ξ_{ij} values according to decays and scenario[3].


BR H° en escenario A: α=β−π/2
tanβ=5
tanβ=15
tanβ=50
BR(H°→ XY)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
200 300 400 500 600 700 800
cc
ss
tt
bb
μμ
ττ
ct
sb
μτ
h°h°
A°A°


BR H° en escenario B: α=β
tanβ=5
tanβ=15
tanβ=50
BR(H°→ XY)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
200 300 400 500 600 700 800
cc
ss
tt
bb
μμ
ττ
ww
zz
h°h°
A°A°

BR H° en escenario C: α=β−π/3

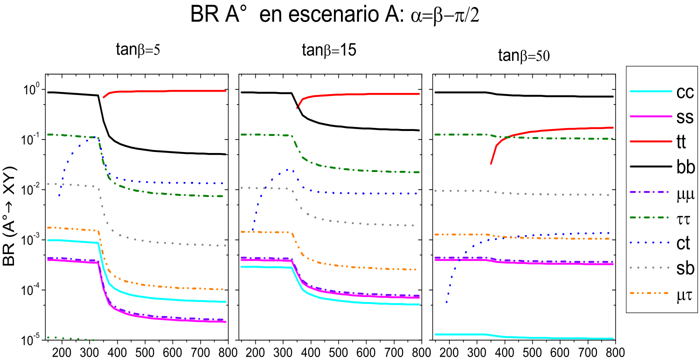


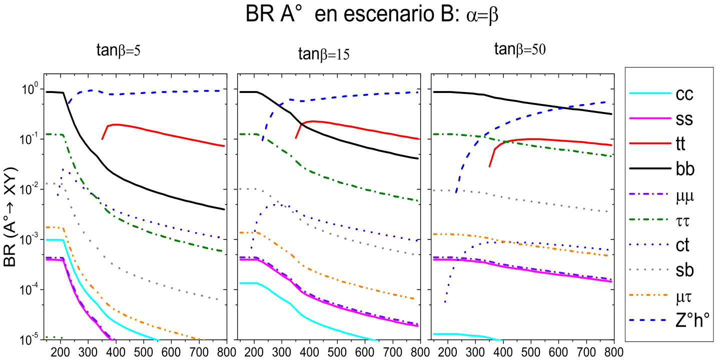
Branching Ratios of A^0

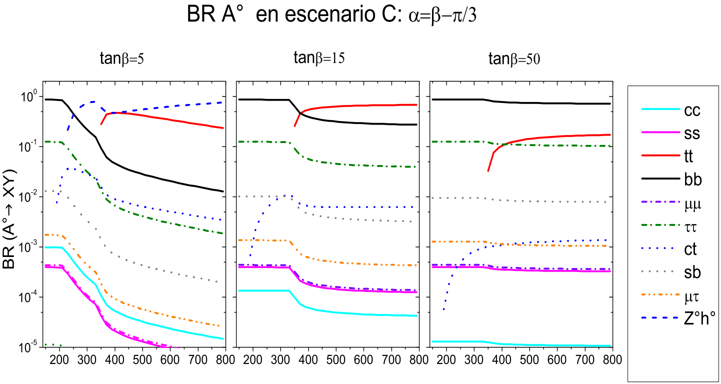
For A^0 decays we considered $800 \geq m_{A^0} \geq 150$ GeV. In 3 regions:

- $150 < m_{A^0} < m_z + m_{h^0} \approx 215$ GeV (para $m_{h^0} = 120$)
- $215 \lesssim m_{A^0} < m_z + m_{h^0} < 2m_t \approx 350$ GeV,
- $350 < m_{A^0} < 800$.

For the second and third region, dominant decays depend on $\tan\beta$ and χ_{ij}. For the first, the dominant decay is to $b\bar{b}$, this become dominant in second region for $\tan\beta \approx 50$. It is important to say that variations in BR are given the variation of $BR(h^0 \to Z^0 h^0)$ as well as the fermionic decays don't depend on α.


BR A° en escenario A: α=β−π/2
tanβ=5
tanβ=15
tanβ=50
BR (A°→ XY)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
200 300 400 500 600 700 800
cc
ss
tt
bb
μμ
ττ
ct
sb
μτ


BR A° en escenario B: α=β
tanβ=5
tanβ=15
tanβ=50
BR (A°→ XY)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
200 300 400 500 600 700 800
cc
ss
tt
bb
μμ
ττ
ct
sb
μτ
Z°h°


BR A° en escenario C: $\alpha=\beta-\pi/3$
tanβ=5
tanβ=15
tanβ=50
BR (A°→ XY)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
200 300 400 500 600 700 800
cc
ss
tt
bb
μμ
ττ
ct
sb
μτ
Z°h°

Events Number

Finally, to calculate the (ideal) events number that can occur in these decays, we have:

$$N_{eventos} = \mathcal{L} \times \sigma \times BR, \tag{40}$$

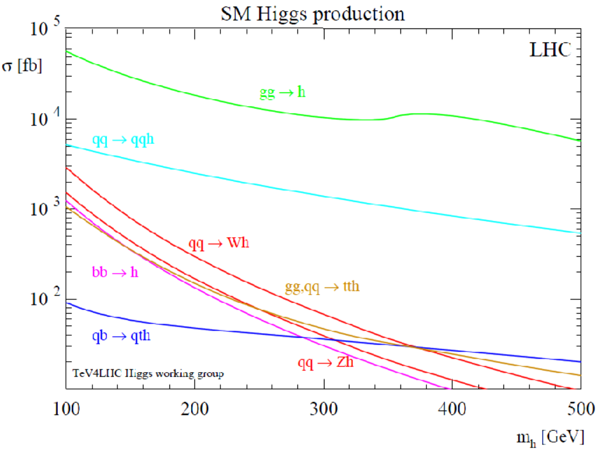


Figure 17: Cross sections in SM [5].

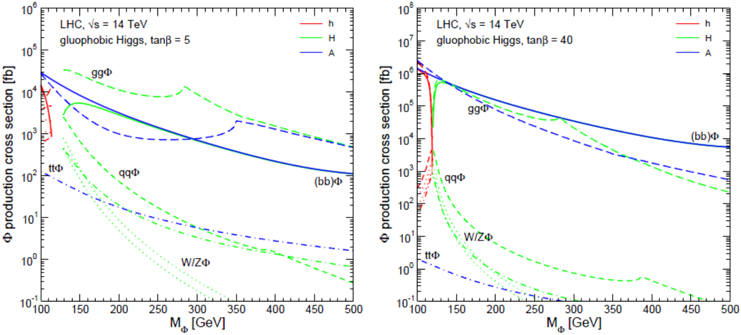
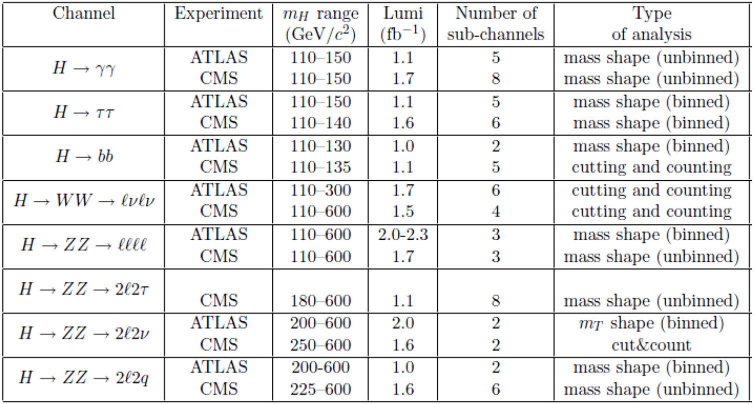


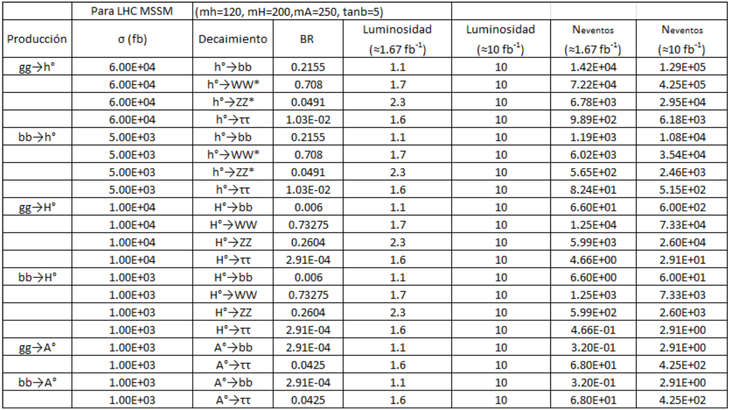
Figure 18: Cross sections in MSSM [5].



Channel	Experiment	m_H range (GeV/c^2)	Lumi (fb^{-1})	Number of sub-channels	Type of analysis
$H \to \gamma\gamma$	ATLAS	110–150	1.1	5	mass shape (unbinned)
	CMS	110–150	1.7	8	mass shape (unbinned)
$H \to \tau\tau$	ATLAS	110–150	1.1	5	mass shape (binned)
	CMS	110–140	1.6	6	mass shape (binned)
$H \to bb$	ATLAS	110–130	1.0	2	mass shape (binned)
	CMS	110–135	1.1	5	cutting and counting
$H \to WW \to \ell\nu\ell\nu$	ATLAS	110–300	1.7	6	cutting and counting
	CMS	110–600	1.5	4	cutting and counting
$H \to ZZ \to \ell\ell\ell\ell$	ATLAS	110–600	2.0-2.3	3	mass shape (binned)
	CMS	110–600	1.7	3	mass shape (unbinned)
$H \to ZZ \to 2\ell 2\tau$	CMS	180–600	1.1	8	mass shape (unbinned)
$H \to ZZ \to 2\ell 2\nu$	ATLAS	200–600	2.0	2	m_T shape (binned)
	CMS	250–600	1.6	2	cut&count
$H \to ZZ \to 2\ell 2q$	ATLAS	200-600	1.0	2	mass shape (binned)
	CMS	225–600	1.6	6	mass shape (unbinned)

Figure 19: Luminosity reached at LHC in november 2011 [4].

We can calculate a prediction for the events number in LHC in the MSSM, like we show in chart 20. We take account the scenario A and scenario B with $m_h = 120$ GeV, $m_H = 200$ GeV, $m_A = 250$ GeV, $\tan\beta = 5$, althoug, this calculation of events number was done for data of november of 2011 and for integrated luminosity of 10 fb^{-1} that probably LHC will reach after 2012 ends.



	Para LHC MSSM	(mh=120, mH=200,mA=250, tanb=5)					
Producción	σ (fb)	Decaimiento	BR	Luminosidad (≈1.67 fb^{-1})	Luminosidad (≈10 fb^{-1})	Neventos (≈1.67 fb^{-1})	Neventos (≈10 fb^{-1})
gg→h°	6.00E+04	h°→bb	0.2155	1.1	10	1.42E+04	1.29E+05
	6.00E+04	h°→WW*	0.708	1.7	10	7.22E+04	4.25E+05
	6.00E+04	h°→ZZ*	0.0491	2.3	10	6.78E+03	2.95E+04
	6.00E+04	h°→ττ	1.03E-02	1.6	10	9.89E+02	6.18E+03
bb→h°	5.00E+03	h°→bb	0.2155	1.1	10	1.19E+03	1.08E+04
	5.00E+03	h°→WW*	0.708	1.7	10	6.02E+03	3.54E+04
	5.00E+03	h°→ZZ*	0.0491	2.3	10	5.65E+02	2.46E+03
	5.00E+03	h°→ττ	1.03E-02	1.6	10	8.24E+01	5.15E+02
gg→H°	1.00E+04	H°→bb	0.006	1.1	10	6.60E+01	6.00E+02
	1.00E+04	H°→WW	0.73275	1.7	10	1.25E+04	7.33E+04
	1.00E+04	H°→ZZ	0.2604	2.3	10	5.99E+03	2.60E+04
	1.00E+04	H°→ττ	2.91E-04	1.6	10	4.66E+00	2.91E+01
bb→H°	1.00E+03	H°→bb	0.006	1.1	10	6.60E+00	6.00E+01
	1.00E+03	H°→WW	0.73275	1.7	10	1.25E+03	7.33E+03
	1.00E+03	H°→ZZ	0.2604	2.3	10	5.99E+02	2.60E+03
	1.00E+03	H°→ττ	2.91E-04	1.6	10	4.66E-01	2.91E+00
gg→A°	1.00E+03	A°→bb	2.91E-04	1.1	10	3.20E-01	2.91E+00
	1.00E+03	A°→ττ	0.0425	1.6	10	6.80E+01	4.25E+02
bb→A°	1.00E+03	A°→bb	2.91E-04	1.1	10	3.20E-01	2.91E+00
	1.00E+03	A°→ττ	0.0425	1.6	10	6.80E+01	4.25E+02

Figure 20: Prediction for events number in LHC using MSSM.

From this data we observe that the events number for $h^0 \rightarrow b\bar{b}$ or $h^0 \rightarrow ZZ^*$ is $O(10^4)$ that could give the viability the detection of the SM Higgs boson, since there is a relevant number of events. Also we need to considere the eficience and aceptance of the detectors. Detections for A^0 searches require a higher number of events (of course more luminosity or energy) reached in another years.

Conclusions

- I studied **THDM type III**, **I calculate Yukawa's Lagrangian**.
- We use **the 4-textures matrices** like a form of the Yukawa's matrices and **using** the **Cheng-Sher "anzats"** we **obtain the vertex** for the neutral Higgs bosons decays.
- **We build a program** where we can **calculate the width decays** and the **BR** in **three scenarios**, **for several** $\tan\beta$ **and** χ_{ij} **values**.
- **We obtain dominant decays** like the modes $b\bar{b}$, ZZ^*, WW^*.
- **We calculate the number of events** for luminosities of ≈ 1.6 fb^{-1} and 10 fb^{-1} in LHC.

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That 4 forces accompany you to full energetic scale...
And beyond

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Eine energetische Leere.
Mit einem spontane symmetriebrechung und eureka!
Materie und Antimaterie wird realitat, dann das Universum, die frage ist: Wo ist das Higgs falls vorhanden.
Arbeit geht weiter...