Benemérita Universidad Autónoma de Puebla

Facultad de Ciencias de la Electrónica

and

Dual C-P Institute of High Energy Physics

Some extensions of the Higgs sector and phenomenology of the charged Higgs as signal of new physics.

Present: Jaime Hernández Sánchez

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Outline

- Introduction
- One SUSY model beyond the MSSM
  - Two doublets and a complex Higgs Triplet (MSSM+1CHT)
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  - General 2HDMs
  - 2HDM from extra dimensions
- Some systematic studies of these models
-
- •The vertex *H+i fu fd* and the decay *t* ➡ *Hi+b.*
  - Decays of charged Higgs bosons.
  - Direct charged Higgs production at the LHC.
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Introduction

EWSB dynamics in SM unsatisfactory:

Theory: Higgs boson mass is unstable under radiative corrections (hierarchy problem)

Experiment: no Higgs evidence so far

Hence, it is quite appropriate to explore implications of more complicated Higgs models !

Two major constraints to go beyond the SM:

1. The experimental fact that

$$\rho \equiv \frac{m_W^2}{m_Z^2 \cos^2 \theta_W} \approx 1$$

2. Limits on the existence of FCNCs

1&2 are not a problem in the SM and for any additional singlets !

Motivations

Standard Model: 1 doublet of scalar fields (spontaneous ew symmetry breaking)

→ 1 neutral scalar particle is predicted: the Higgs boson H^0

Simple extension of the Higgs sector: 2 doublets of scalar fields (SUSY)

→ 5 Higgs bosons are predicted

- 3 neutral (h^0, H^0, A^0)
- 1 pair of charged bosons $H^\pm$

at tree-level, Higgs sector defined by $(M_{A^0}, tan\beta)$

observation of $H^\pm$
important role in the proof of
an extended SM Higgs sector

MSSM Charged Higgs
LEP limit: $M_{H^\pm} > 78.6$ GeV
(model independent)

Electroweak ρ parameter is experimentally close to 1

→ constraints on Higgs representations

$$\rho \equiv \frac{m_W^2}{m_Z^2 \cos^2\theta_W} = \frac{\sum_{T,Y} \left[4T(T+1) - Y^2 \right] \left|V_{T,Y}\right|^2 c_{T,Y}}{\sum_{T,Y} 2Y^2 \left|V_{T,Y}\right|^2} \approx 1 \ ,$$

$$V_{T,Y} = \langle \phi(T,Y) \rangle, \quad c_{T,Y} = \begin{cases} 1, & (T,Y) \in \text{complex representation} \\ \frac{1}{2}, & (T,Y) \in \text{real representation} \end{cases}$$

Real representation: consists of a real multiplet of fields with integer weak isospin and zero hypercharge

One can choose arbitrary Higgs representations and fine tune the Higgs potential parameters to produce $\rho \approx 1$.

Take a model with multiple \`bad' Higgs representations and arrange \`custodial' SU(2) symmetry among the copies (i.e., VEVs arranged suitably), so that ρ=1 at tree-level. This can be done for triplets.

Absence of (tree-level) FCNCs

→ constraints on Higgs couplings

In SM FCNC automatically absent as same operation diagonalising the mass matrix automatically diagonalises the Higgs-fermion couplings.

There are two ways:

Make Higgs masses large (1 TeV or more) so that tree-level FCNCs mediated by Higgs are suppressed to comply with experimental data.

Glashow & Weinberg theorem (more elegant): FCNCs absent in models with more than one Higgs doublet if all fermions of a given electric charge couple to no more than one Higgs doublet.

(MSSM is an example: Y=-1(+1) doublet couples to down(up)-type fermions, as required by SUSY.)

- The Higgs spectrum of many well motivated extensions of SM include charged Higgs bosons whose detection at future colliders would constitute a clear evidence of a Higgs sector beyond SM.

- A definitive test of the mechanism of EWSB will require further studies of complete Higgs spectrum.

- Probing the properties of charged Higgs bosons could help to find out whether they are associated with a weakly-interacting theory or with a strongly-interacting theory.

- Probing the symmetries of the Higgs potential could help to determine whether the charged Higgs bosons belong to a weak doublet or to some larger multiplet.

A. The Higgs potential of the model

The MSSM+1CHT model includes two Higgs doublets and a complex Higgs triplet given by

$$\Phi_1 = \begin{pmatrix} {\phi_1}^0 \\ {\phi_1}^- \end{pmatrix} \ , \ \Phi_2 = \begin{pmatrix} {\phi_2}^+ \\ {\phi_2}^0 \end{pmatrix} \ , \ \sum = \begin{pmatrix} \sqrt{\frac{1}{2}}\xi^0 & -\xi_2^+ \\ \xi_1^- & -\sqrt{\frac{1}{2}}\xi^0 \end{pmatrix} \ . \tag{1}$$

The Higgs triplet, of zero hypercharge, is described in terms of a 2×2 matrix representation: ξ^0 is the complex neutral field and ξ_1^-, ξ_2^+ denote the charged fields. The most general gauge invariant and renormalizable Superpotential that can be written for the Higgs Superfields $\Phi_{1,2}$ and Σ is given by:

$$W = \lambda \Phi_1 \cdot \Sigma \Phi_2 + \mu_1 \Phi_1 \cdot \Phi_2 + \mu_2 \mathrm{Tr}(\Sigma^2) \ , \tag{2}$$

where we have used the notation $\Phi_1 \cdot \Phi_2 \equiv \epsilon_{ab} \Phi_1^a \Phi_2^b$. The resulting scalar potential involving only the Higgs fields is thus written as

$$V = V_{SB} + V_F + V_D \ ,$$

We can combine the VEVs of the doublet Higgs fields through the relation $v_D^2 \equiv v_1^2 + v_2^2$ and define $\tan\beta \equiv v_2/v_1$. Furthermore, the parameters v_D, v_T, m_W^2 and m_Z^2 are related as follows:

$$
\begin{aligned}
m_W^2 &= \tfrac{1}{2} g^2 (v_D^2 + 4 v_T^2), \\
m_Z^2 &= \frac{\frac{1}{2} g^2 v_D^2}{\cos^2\theta_W} ,
\end{aligned}
$$

which implies that the ρ-parameter is different from 1 at the tree level, namely,

$$
\rho \equiv \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = 1 + 4R^2, \quad R \equiv \frac{v_T}{v_D} \quad . \tag{6}
$$

The bound on R is obtained from the ρ parameter measurement, which presently lies in the range 0.9993–1.0006, from the global fit reported in Refs. [6, 23]. Thus, one has $R \leq 0.012$ and $v_T \leq 3$ GeV. We have taken into account this bound in our numerical analyses.

MSSM+1CHT Higgs Sector

A total of 14 d.o.f to start with, minus 3 longitudinal modes for W's & Z leaves 11 d.o.f which corresponds to:

- 3 CP-even neutral Higgs states
-
- 2 CP-odd neutral Higgs states
-
- 6 C.C. charged Higgs states (3 masses)

- The parameters of the Higgs sector include:
  -gauge: $r = v_T/v_D$ and $\tan\beta = v_2/v_1$
  - superpoptential: $\lambda,\ \mu_D,\ \mu_T$
  - soft: $A,\ B_D,\ B_T$
- In our numerical analysis we shall fix:
  $r = 0.012, 1.5 < \tan\beta < 70$, and
  $\lambda = 0.1, 0.5, 1.$,

J. R. Espinosa and M. Quiros, Nucl. Phys. B384, 113 (1992).

O. Félix-Beltrán, Int. J. Mod. Phys. A17,465 (2002).

Scenario A. It is defined by considering $B_1 = \mu_1 = 0$, $B_2 = -A$ and $\mu_2 = 100$ GeV while for λ we shall consider the values $\lambda = 0.1, 0.5, 1.0$. In this scenario it happens that the additional Higgs triplet plays a significant role in EWSB.

Scenario B. This scenario is defined by choosing: $B_2 = \mu_2 = 0$, $B_1 = -A$, while for λ we shall consider again the values $\lambda = 0.1, 0.5, 1.0$. Most results will take $\mu_1 = 200$ GeV, though other values (such as $\mu_1 = 400, 700$ GeV) will also be considered. Here, the effects of the additional Higgs triplet are smaller, hence the behaviour of the model is similar to that of the MSSM.

E. Barradas-Guevara, O. Félix-Beltrán, J. Hernández-Sánchez and A. Rosado, Phys. Rev. D71, 073004 (2005).

One-loop radiative corrections to the CP-even Higgs bosons masses in the MSSM-1CHT

We study the radiative corrections to the neutral Higgs boson masses because of their apperance in charged Higgs decays.

In some scenarios, at tree level we have a very light CP-even Higgs boson, *O*(0.1) GeV.

• However, in the MSSM, the inclusion of radiative corrections from top and stop loops can alter the neutral CP-even Higgs mass.

• Thus, we can expect that similar effects will appear in the MSSM-1CHT.

• Besides, a possible large correction from Higgs-chargino loops must be considered.

J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti and A. Rosado, Phys. Rev. D77, 035007 (2008).

corrections affect mainly the neutral Higgs bosons sector, in particular the production of the neutral scalar Higgs in e^+e^- collisions, which is the Higgs-strahlung processes $e^+e^- \to H_i^0 Z^0$, whose cross sections can be expressed in terms of the SM Higgs boson (herein denoted by ϕ^0_{SM}) production formula and the Higgs-Z^0Z^0 coupling, as follows [26]:

$$
\begin{aligned}
\sigma_{H_i^0 Z} &= R^2_{H_i^0 Z^0 Z^0} \sigma^{SM}_{H_i^0 Z}, \\
R^2_{H_i^0 Z^0 Z^0} &= \frac{g^2_{H_i^0 Z^0 Z^0}}{g^2_{\phi^0_{SM} Z^0 Z^0}},
\end{aligned}
\tag{11}
$$

where $g^2_{H_i^0 Z^0 Z^0}$ is the coupling $H_i^0 Z^0 Z^0$ in the MSSM+1CHT and $g^2_{\phi^0_{SM} Z^0 Z^0}$ is the SM coupling $\phi^0_{SM} Z^0 Z^0$, which obey the relation

$$
\sum_{i=1}^{3} g^2_{H_i^0 Z^0 Z^0} = g^2_{\phi^0_{SM} Z^0 Z^0}. \tag{12}
$$

J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti and A. Rosado, Phys. Rev. D77, 035007 (2008).

We define the scaling factor

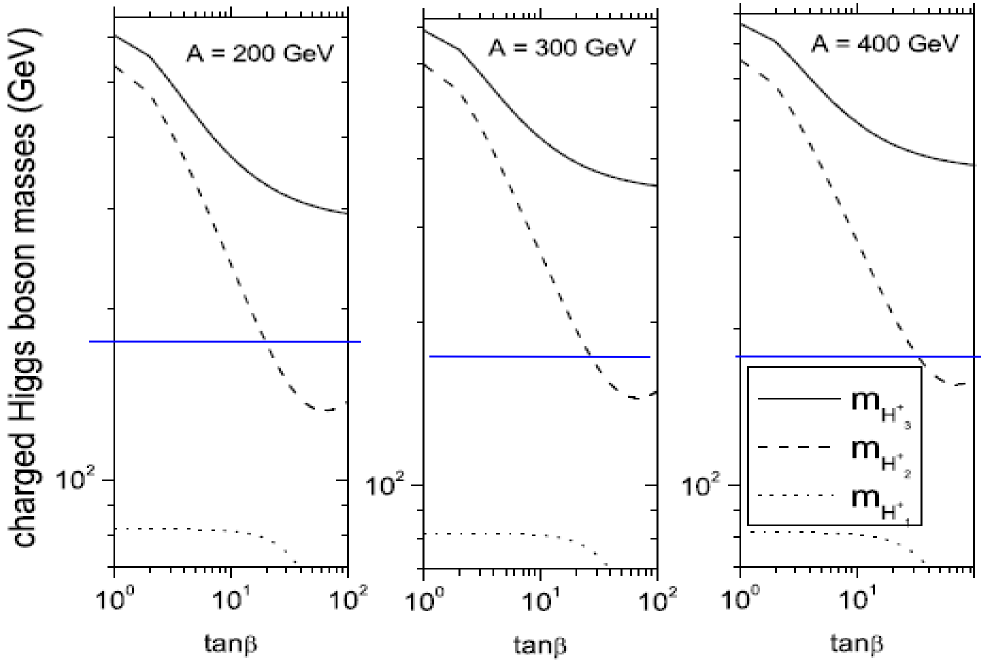
$$S_{95} = \sigma_{\max}/\sigma_{\mathrm{ref}}, \tag{16}$$

where $\sigma_{\max}$ is the largest cross-section compatible with the data, at the 95% CL, and σ_{ref}

$m_{\mathcal{H}_1}$ (GeV/c^2)	(a)	(b)	(c)	$m_{\mathcal{H}_1}$ (GeV/c^2)	(a)	(b)	(c)
12	0.0204	0.0154	0.0925	66	0.0236	0.0218	0.0287
14	0.0176	0.0143	0.0899	68	0.0236	0.0218	0.0287
16	0.0158	0.0134	0.0923	70	0.0271	0.0246	0.0287
18	0.0150	0.0131	0.0933	72	0.0291	0.0274	0.0271
20	0.0156	0.0139	0.1060	74	0.0320	0.0301	0.0297
22	0.0177	0.0156	0.1080	76	0.0421	0.0380	0.0351
24	0.0194	0.0174	0.1110	78	0.0469	0.0424	0.0350
26	0.0207	0.0186	0.1140	80	0.0435	0.0410	0.0316
28	0.0223	0.0195	0.1110	82	0.0467	0.0475	0.0281
30	0.0203	0.0181	0.0893	84	0.0539	0.0585	0.0222
32	0.0193	0.0173	0.0796	86	0.0762	0.0816	0.0257
34	0.0191	0.0172	0.0682	88	0.112	0.118	0.0296
36	0.0241	0.0187	0.0653	90	0.153	0.152	0.0331
38	0.0299	0.0235	0.0634	92	0.179	0.175	0.0354
40	0.0333	0.0267	0.0615	94	0.229	0.214	0.0491
42	0.0367	0.0297	0.0599	96	0.239	0.220	0.0570
44	0.0378	0.0310	0.0594	98	0.256	0.233	0.0565
46	0.0387	0.0328	0.0572	100	0.244	0.216	0.0582
48	0.0391	0.0337	0.0575	102	0.237	0.216	0.0588
50	0.0363	0.0316	0.0445	104	0.255	0.227	0.0704
52	0.0386	0.0344	0.0454	106	0.263	0.223	0.0896
54	0.0387	0.0349	0.0464	108	0.266	0.227	0.110
56	0.0384	0.0360	0.0403	110	0.297	0.244	0.144
58	0.0390	0.0367	0.0427	112	0.435	0.343	0.212
60	0.0398	0.0365	0.0456	114	0.824	0.640	0.410
62	0.0293	0.0264	0.0444	116	1.41	1.79	1.79
64	0.0278	0.0258	0.0394				

S. Schael et. al. [ALEPH Collaboration, DELPHI Collaboration, L3 Collaboration, OPAL Collaboration, and LEP Working Group for Higgs Boson Searches], Eur. Phys. J. C47, 547 (2006)

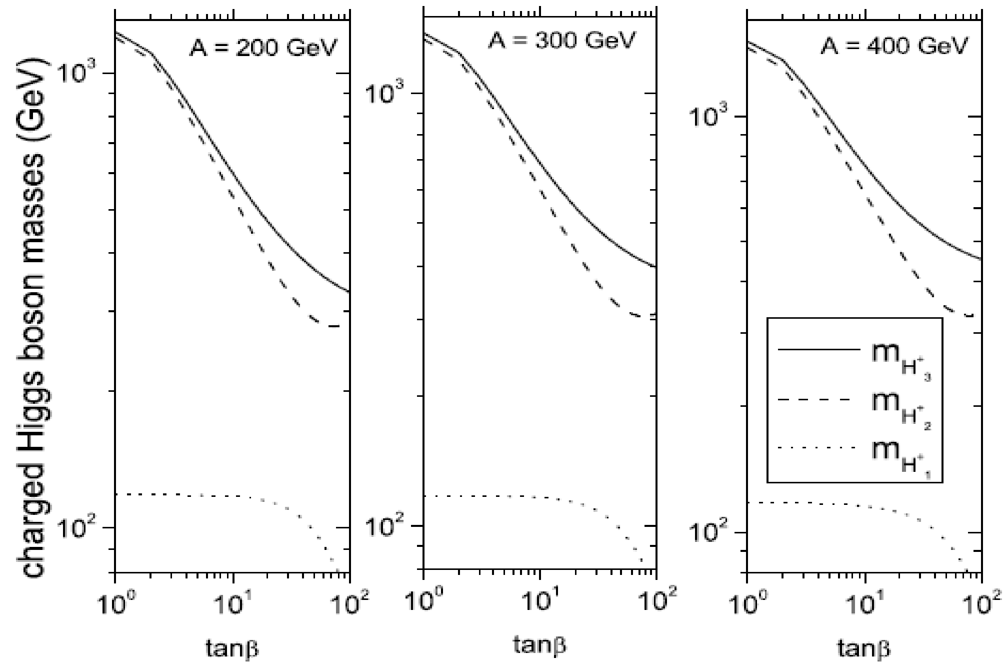
J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti and A. Rosado, Phys. Rev. D77, 035007 (2008).



Scenario A, λ=0.1

Two charged Higgs states below top mass

Scenario A, λ=0.5



J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti and A. Rosado, Phys. Rev. D77, 035007 (2008).

TABLE I: Analysis of $R^2_{H_i^0 Z^0 Z^0}$ consistent with LEP. We consider experimental limits allowed by LEP2 for charged and neutral Higgs bosons, for Scenario A with $A = 200, 300, 400$ GeV and $\mu_2 = 100$ GeV.

$\lambda = 0.1$	$\tan\beta \leq 5$	$m_{H_1^\pm} \approx 81$ GeV 11 GeV $< m_{H_1^0} <$ 50 GeV 111 GeV $< m_{H_2^0} <$ 118 GeV	$0.15 < R^2_{H_1^0 Z^0 Z^0} < 0.8$ $R^2_{H_2^0 Z^0 Z^0} < 0.8$	Excluded by $R^2_{H_1^0 Z^0 Z^0}$
$\lambda = 0.5$	$\tan\beta \leq 77$	79.8 GeV $< m_{H_1^\pm} <$ 118 GeV 12 GeV $< m_{H_1^0} <$ 50 GeV 111 GeV $< m_{H_2^0} <$ 114 GeV	$0.002 < R^2_{H_1^0 Z^0 Z^0} < 0.2$ $0.9 < R^2_{H_2^0 Z^0 Z^0}$	Allowed by $R^2_{H_1^0 Z^0 Z^0}$, but marginal for $R^2_{H_2^0 Z^0 Z^0}$
$\lambda = 1$	$15 \leq \tan\beta$	89 GeV $< m_{H_1^\pm} <$ 187 GeV 14 GeV $< m_{H_1^0} <$ 89 GeV 111 GeV $< m_{H_2^0} <$ 114 GeV	$R^2_{H_1^0 Z^0 Z^0} < 0.01$ $0.9 < R^2_{H_2^0 Z^0 Z^0}$	Allowed by $R^2_{H_1^0 Z^0 Z^0}$, but marginal for $R^2_{H_2^0 Z^0 Z^0}$

We define the marginal regions those cases almost pass LEP2 bounds

The piece of Lagrangian containing the fermion couplings of the charged Higgs bosons is given by:

$$\mathcal{L}_{ffH_i^+} = -\frac{1}{\sqrt{2}v_D}\bar{u}\left[\left(\frac{m_d}{c_\beta}(\phi_1^-)^* - \frac{m_u}{s_\beta}\phi_2^+\right) + \left(\frac{m_d}{c_\beta}(\phi_1^-)^* + \frac{m_u}{s_\beta}\phi_2^+\right)\gamma_5\right] d + h.c. \quad (17)$$

where $(\phi_1^-)^*$, ϕ_2^+ are related to the physical charged Higgs boson states (H_1^+, H_2^+, H_3^+) as follows:

$$\begin{aligned} (\phi_1^-)^* &= \sum_j^3 U_{2,j+1} H_j^+, \quad \phi_2^+ = \sum_j^3 U_{1,j+1} H_j^+, \\ H_j^+ &= (H_1^+, H_2^+, H_3^+). \end{aligned} \quad (18)$$

The U_{jk}'s denote the elements of the mixing-matrix that relates the physical charged Higgs bosons (H_1^+, H_2^+, H_3^+) and the Goldstone boson G^+

Then, the couplings $\bar{u}dH_i^+$, $\bar{\nu}_l l H_i^+$ are given by:

$$
\begin{aligned}
g_{H_i^+\bar{u}d} &= -\frac{i}{v_D\sqrt{2}}(A_i^{ud} + V_i^{ud}\gamma_5), \quad g_{H_i^- u\bar{d}} = -\frac{i}{v_D\sqrt{2}}(A_i^{ud} - V_i^{ud}\gamma_5), \\
g_{H_i^+\bar{\nu}_l l} &= -\frac{i}{v_D\sqrt{2}}A_i^l(1+\gamma_5), \quad g_{H_i^-\nu_l\bar{l}} = -\frac{i}{v_D\sqrt{2}}A_i^l(1-\gamma_5),
\end{aligned}
\tag{20}
$$

where A_i^{ud} and V_i^{ud} are defined as:

$$
\begin{aligned}
A_i^{ud} &= m_d t_\beta \frac{U_{2,i+1}}{s_\beta} - m_u \cot_\beta \frac{U_{1,i+1}}{c_\beta}, \\
V_i^{ud} &= m_d t_\beta \frac{U_{2,i+1}}{s_\beta} + m_u \cot_\beta \frac{U_{1,i+1}}{c_\beta}, \\
A_i^l &= m_l t_\beta \frac{U_{2,i+1}}{s_\beta}.
\end{aligned}
\tag{21}
$$

One can see that the formulae in Eq. (10) become the couplings $\bar{u}dH_i^+$, $\bar{\nu}_l l H_i^+$ of the MSSM when we replace $U_{2,i+1} \to s_\beta$ and $U_{1,i+1} \to -c_\beta$[2]. The vertex $\bar{u}dH_i^+$ induces at tree-level the decay $t \to H^+ b$, which will be studied in the next section.

Top decay $t \to b + H^+$

As Tevatron has obtained bound on charged Higgs using top decays, we like to evaluate such decay within the MSSM+1CHT.
The decay width of these modes, takes the following form:

$$\Gamma(t \to H_i^+ b) = \frac{g^2}{64\pi m_W^2} |V_{tb}|^2 m_t^3 \lambda^{1/2}(1, q_{H_i^+}, q_b) \left[(1 - q_{H_i^+} + q_b)\left(\frac{U_{1,i+1}^2}{s_\beta^2} + q_b \frac{U_{2,i+1}^2}{c_\beta^2}\right) - 4q_b \frac{U_{1,i+1}U_{2,i+1}}{s_\beta c_\beta}\right] \quad (6)$$

Experimental bound on the BR(t--> bH+)

If the decay mode (H+ --> τ+ ν) dominates the charged Higgs boson decay width, then BR(t --> H+ b) is constrained to be less than 0.4 at 95 % C.L.

However, if the decay mode (H+ --> τ+ ν) is not dominant, then BR(t --> H+ b) is constrained to be less than 0.91 at 95 % C.L.

The combined LEP data excluded a charged Higgs boson with mass less than 79.3 GeV at 95 % C. L.

Thus, we need to discuss all the charged Higgs decays.

A. Abulencia et al. (CDF Collaboration), Phys. Rev. Lett. 96, 042003 (2006)

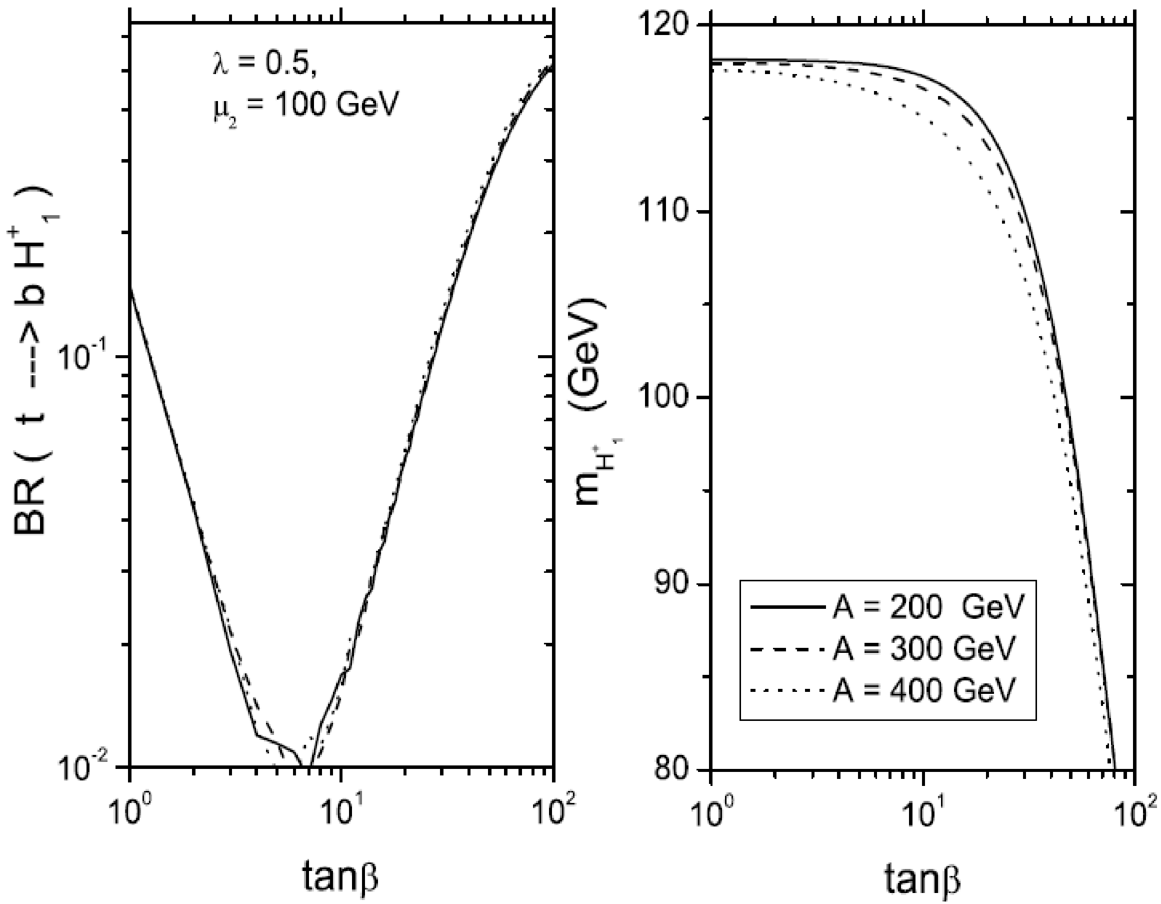


FIG. 17: It is plotted: the BR($t \to b\, H_1^+$) vs. $\tan\beta$ (left), the $\tan\beta - m_{H_1^+}$ plane (right), in Scenario A taking $\lambda = 0.5$, for: $A = 200$ GeV (solid), $A = 300$ GeV (dashes), $A = 400$ GeV (dots).

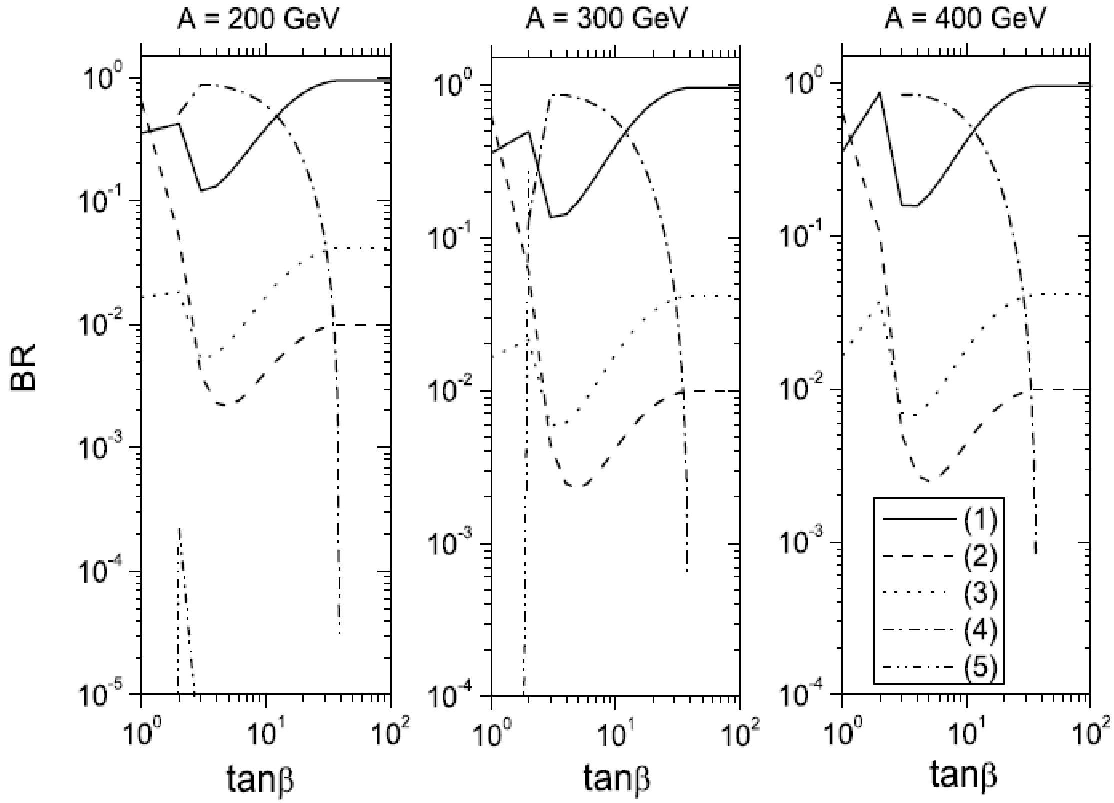


FIG. 18: The figure shows the branching ratios of H_1^+ decaying into the principal modes in Scenario A, with $\lambda = 0.5$ and $\mu_2 = 100$ GeV, for: $A = 200$ GeV (left), $A = 300$ GeV (center), $A = 400$ GeV (right). The lines correspond to: (1) $\mathrm{BR}(H_1^+ \to \tau^+\nu_\tau)$, (2) $\mathrm{BR}(H_1^+ \to c\bar{s})$, (3) $\mathrm{BR}(H_1^+ \to c\bar{b})$, (4) $\mathrm{BR}(H_1^+ \to W^+H_1^0)$, (5) $\mathrm{BR}(H_1^+ \to W^+A_1^0)$.

Decays of the charged Higgs

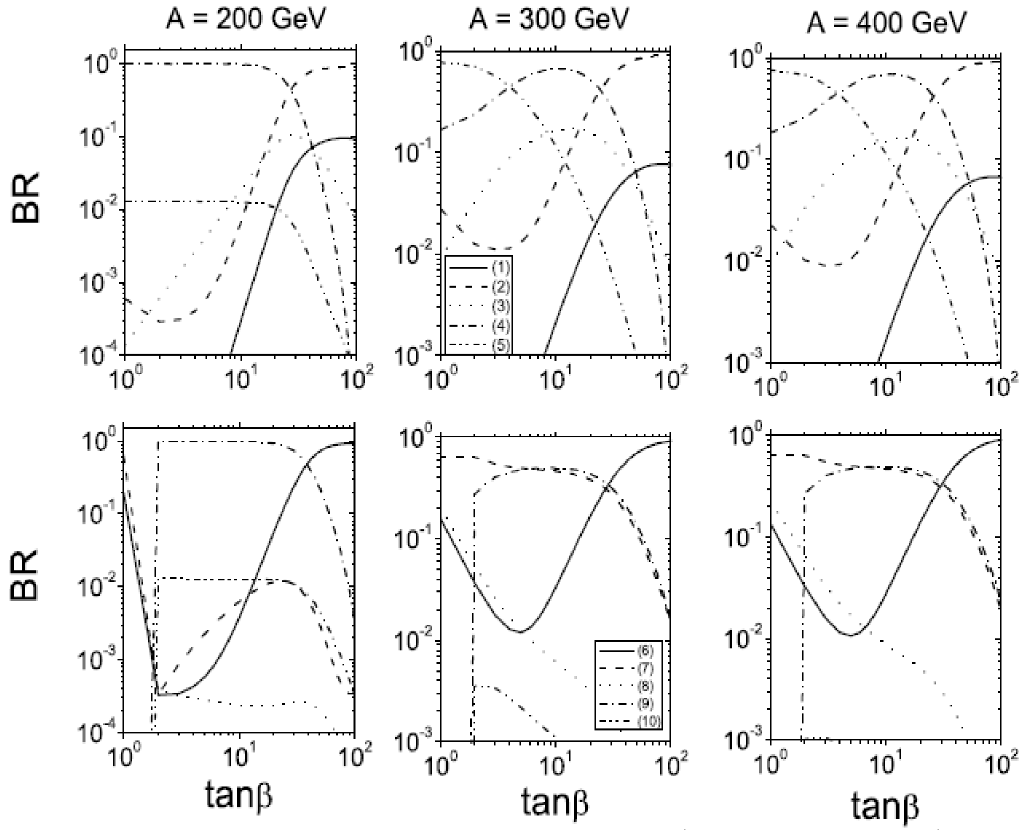


FIG. 26: The figure shows the branching ratios of H_2^+ (top) and H_3^+ (bottom) decaying into the principal modes in Scenario A, taking $\lambda = 0.5$ and $\mu_2 = 100$ GeV for $A = 200$ GeV (left), $A = 300$ GeV (center), $A = 400$ GeV (right). The lines correspond to: (1) BR($H_2^+ \to \tau^+\nu_\tau$), (2) BR($H_2^+ \to t\bar{b}$), (3) BR($H_2^+ \to W^+H_1^0$), (4) BR($H_2^+ \to W^+A_1^0$), (5) BR($H_2^+ \to W^+Z^0$), (6) BR($H_3^+ \to t\bar{b}$),(7) BR($H_3^+ \to W^+H_1^0$), (8) BR($H_3^+ \to W^+H_2^0$), (9) BR($H_3^+ \to W^+A_1^0$), (10) BR($H_3^+ \to W^+Z^0$).

Direct charged Higgs production at LHC in the MSSM-1CHT

- If $m_H{}^+ < mt - mb$ the decay $t \to H^+{}_i\, b$ is the principal process for to produce charged Higgs. The following production chanel is important

$$q\bar{q},\ gg \to t\bar{t} \to t\bar{b}H_i^- + \text{c.c.}$$

- If the charged Higgs mass is above the threshold for $t \to H^+{}_i\, b$, the direct process

$$q\bar{q},\ gg \to t\bar{b}H_i^- + \text{c.c.}$$

Direct charged Higgs production at LHC in the MSSM-1CHT

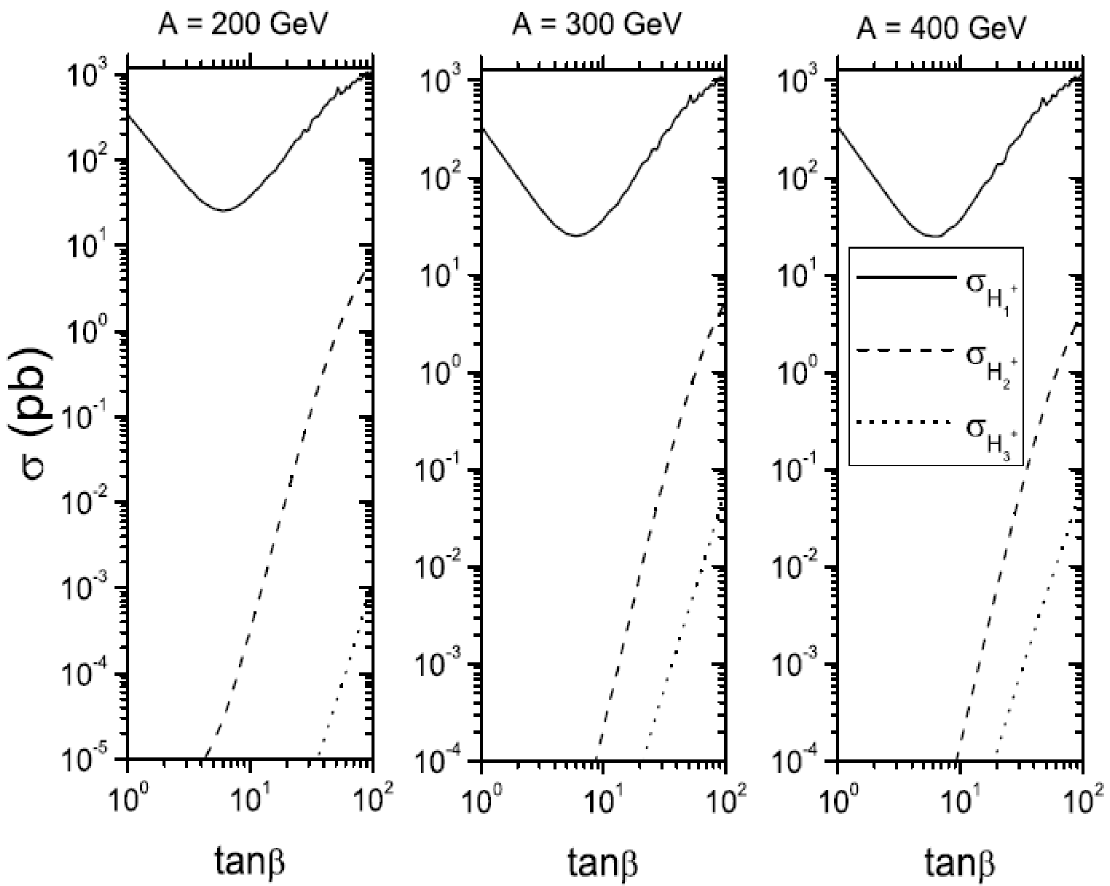
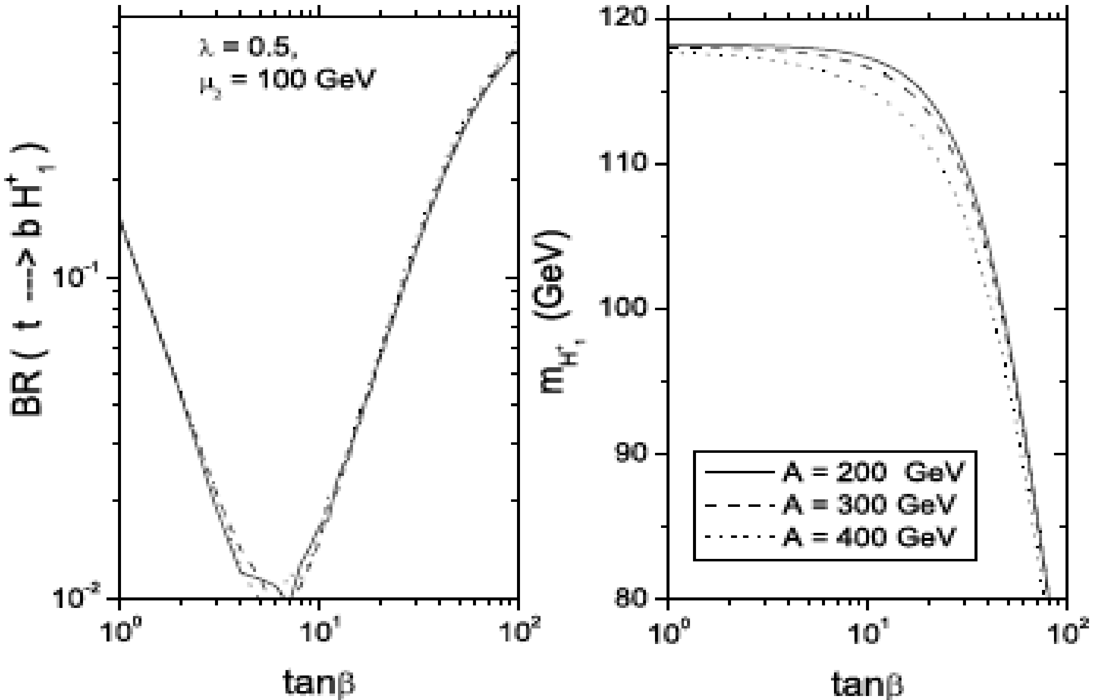


FIG. 38: The figure shows the cross sections of $H^+_{1,2,3}$ at the LHC through the channel $q\bar{q}, gg \to t\bar{b}H^- +$ c.c. in Scenario A with $\lambda = 0.5$ and for: $A = 200, 300, 400$ GeV, respectively.

TABLE V: Summary of LHC event rates for Scenario A with $\mu_2 = 100$ GeV for an integrated luminosity of 10^5 pb^{-1}, for several different signatures.

λ	$(A, \tan\beta)$	$m_{H_i^+}$ in GeV	$\sigma(pp \to H_2^+ tb)$ in pb	Relevant BR's	Nr. Events
0.5	(200,5)	(118,740,790)	1.6×10^{-5}	$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 5.8 \times 10^{-4}$	0
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 9.8 \times 10^{-1}$	1
				$\mathrm{BR}\left(H_2^+ \to W^+ Z^0\right) \approx 1.2 \times 10^{-2}$	0
				$\mathrm{BR}\left(H_2^+ \to W^+ H_1^0\right) \approx 4.2 \times 10^{-3}$	0
0.5	(200,20)	(114,390,470)	1.2×10^{-2}	$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 1.5 \times 10^{-1}$	180
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 7.5 \times 10^{-1}$	900
				$\mathrm{BR}\left(H_2^+ \to W^+ Z^0\right) \approx 1.0 \times 10^{-2}$	12
				$\mathrm{BR}\left(H_2^+ \to W^+ H_1^0\right) \approx 7.7 \times 10^{-2}$	92
0.5	(200,50)	(98,290,370)	8.7×10^{-1}	$\mathrm{BR}\left(H_2^+ \to \tau^+ \nu_\tau\right) \approx 8.2 \times 10^{-2}$	7134
				$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 8.4 \times 10^{-1}$	73080
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 2.4 \times 10^{-2}$	2088
				$\mathrm{BR}\left(H_2^+ \to W^+ H_1^0\right) \approx 4.8 \times 10^{-2}$	4176
1.0	(200,5)	(191,1047,1087)	3.4×10^{-6}	$\mathrm{BR}\left(H_2^+ \to \tau^+ \nu_\tau\right) \approx 4.6 \times 10^{-6}$	0
				$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 3.0 \times 10^{-4}$	0
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 9.8 \times 10^{-1}$	0
				$\mathrm{BR}\left(H_2^+ \to W^+ Z^0\right) \approx 1.3 \times 10^{-2}$	0
1.0	(200,20)	(185,545,610)	4.5×10^{-3}	$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 1.1 \times 10^{-1}$	50
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 7.7 \times 10^{-1}$	349
				$\mathrm{BR}\left(H_2^+ \to W^+ Z^0\right) \approx 1.1 \times 10^{-2}$	5
				$\mathrm{BR}\left(H_2^+ \to W^+ H_1^0\right) \approx 1.0 \times 10^{-2}$	4
1.0	(200,50)	(153,400,450)	3.6×10^{-1}	$\mathrm{BR}\left(H_2^+ \to \tau^+ \nu_\tau\right) \approx 5.0 \times 10^{-2}$	1800
				$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 8.4 \times 10^{-1}$	30240
				$\mathrm{BR}\left(H_2^+ \to W^+ A_1^0\right) \approx 2.6 \times 10^{-2}$	936
				$\mathrm{BR}\left(H_2^+ \to W^+ H_1^0\right) \approx 7.9 \times 10^{-2}$	2844

B2. The point mu2=100 GeV, lambda=0.5, A=200 GeV for tan(beta)=50, see Fig. below. Here, there seems to be scope to access H+/-(1) in top decays as well as H+/-(2) in either tb or W+/-A0(1)/H0(1) or both, see row 3 of Tab. below, at least for the LHC.



Assumes 100 inverse fb

λ	$(A, \tan\beta)$	$m_{H_i^+}$ in GeV	$\sigma(pp \to H_2^+ tb)$ in pb	Relevant BR's	Nr. Events
0.5	(200,50)	(98,290,370)	8.7×10^{-1}	$\mathrm{BR}\left(H_2^+ \to \tau^+\nu_\tau\right) \approx 8.2 \times 10^{-2}$	7134
				$\mathrm{BR}\left(H_2^+ \to tb\right) \approx 8.4 \times 10^{-1}$	73080
				$\mathrm{BR}\left(H_2^+ \to W^+A_1^0\right) \approx 2.4 \times 10^{-2}$	2088
				$\mathrm{BR}\left(H_2^+ \to W^+H_1^0\right) \approx 4.8 \times 10^{-2}$	4176

- Recently, we are studying the rare decays Hi+ --->W+ γ, which appear at one loop level.
- The vertex Hi+ W- Z appear at tree level, this coupling induce more diagrams in the before decay and a enhacement we can get.
- Similarly, the contribution of the other Higgs particles could be important.
- Some results: we have BR´s ~ 10^-3, 10^-4 for the mode W+ γ and BR´s ~ O(1) for the mode W+ Z (work in progress: E. Barradas, O. Félix-Beltrán and J. Hernández-Sánchez)

Conclusions

We have studied the fermion-charged Higgs bosons vertices in the MSSM-1CHT

We have analyzed the decay $t \to H^+_i\, b$

We have found some plausible scenarios for MSSM-1CHT that forbidden in the MSSM. Is possible to have a charged Higgs boson with mass ≈ 90 GeV forbidden in the MSSM, which is not excluded by any of the current data.

If the mass of the charged Higgs is larger than the mass of the quark mass, the direct charged Higgs production can be through the mode

$$q\bar{q},\ gg \rightarrow t\bar{b}H_i^- + \text{c.c.}$$

The detection at LHC of charged Higgs bosons in the regions of parameter space accessible in the MSSM (or THDM) would not contradict the MSSM-1CHT hypothesis.

The observation of several charged Higgs bosons would correspond to a model with a more elaborate Higgs sector, such as the MSSM-1CHT

General 2HDM

The Standard Model with two Higgs doublets ϕ_1 and ϕ_2 → ρ 1.

The simplest extension of the SM with charged Higgs bosons.

As in the MSSM five physical Higgs bosons: h, H, A, $H^{\pm}$

The scalar potential

$$
\begin{aligned}
V(\Phi_1,\Phi_2) &= \mu_1^2\Phi_1^\dagger\Phi_1 + \mu_2^2\Phi_2^\dagger\Phi_2 - (\mu_{12}^2\Phi_1^\dagger\Phi_2 + h.c.) + \lambda_1(\Phi_1^\dagger\Phi_1)^2 \\
&+ \lambda_2(\Phi_2^\dagger\Phi_2)^2 + \lambda_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2) + \lambda_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1) \\
&+ \frac{1}{2}[\lambda_5(\Phi_1^\dagger\Phi_2)^2 + h.c] \qquad (1.2)
\end{aligned}
$$

$$m_{H^\pm}^2 = m_{A^o}^2 + \frac{2m_W^2}{g^2}(\lambda_5 - \lambda_4)$$

$$
\begin{aligned}
G_w^\pm &= \phi_1^\pm \cos\beta + \phi_2^\pm \sin\beta, \\
H^\pm &= -\phi_1^\pm \sin\beta + \phi_2^\pm \cos\beta,
\end{aligned}
\qquad \tan\beta = \frac{v_2}{v_1},
$$

$$m_W^2 = \frac{g^2v^2}{4}, \qquad m_Z^2 = \frac{m_W^2}{c_w^2},$$

Versions of the 2HDM

Type I: one Higgs doublet provides masses to all quarks (up- and down-type quarks) (~SM).

Type II: one Higgs doublet provides masses for up-type quarks and the other for down-type quarks (~MSSM).

Type III: the two doublets provide masses for up and down type quarks, as well as charged leptons.

We could consider this model as a generic description of physics at a higher scale (i. e. Radiative corrections of the MSSM Higgs sector* or from extradimension**).

*J. L. Díaz-Cruz, R. Noriega-Papaqui and A. Rosado, Phys. Rev. D 71, 015014 (2005).

**A. Aranda, J.L. Díaz-Cruz, J. Hernández-Sánchez, R. Noriega-Papaqui, Phys. Lett. B 658, 57 (2007).

How to distinguish 2HDM type II and type III from MSSM using charged Higgs sector ?

1. Mass relations enforced by SUSY and experimental limits on the MSSM (Mh<<MH~MA~MH+) need not be true in the 2HDM

2a. Couplings H+/- H0/h0 W+/- enabling H+ -> W+H0/h0:

$$g_{H^+W^-h^0} = \frac{g}{2}\cos(\beta - \alpha), \; g_{H^+W^-H^0} = \frac{g}{2}\sin(\beta - \alpha)$$

where α is the neutral Higgs mixing angle :

$$h^0 = \sqrt{2}\left[-\left(\mathrm{Re}\,\phi_1^0 - v_1\right)\sin\alpha + \left(\mathrm{Re}\,\phi_2^0 - v_2\right)\cos\alpha\right]$$

α is derived in MSSM, while is free parameter in the 2HDM !

2b. Couplings H+/- A0 W+/- enabling H+ -> W+A0 is pure gauge

2c. Other charged Higgs decay modes are MSSM-like:

$$H^{\pm} \to cs, \tau\nu\,,$$

$H^{\pm} \to tb$, if kinematically possible

3. Only for type III:

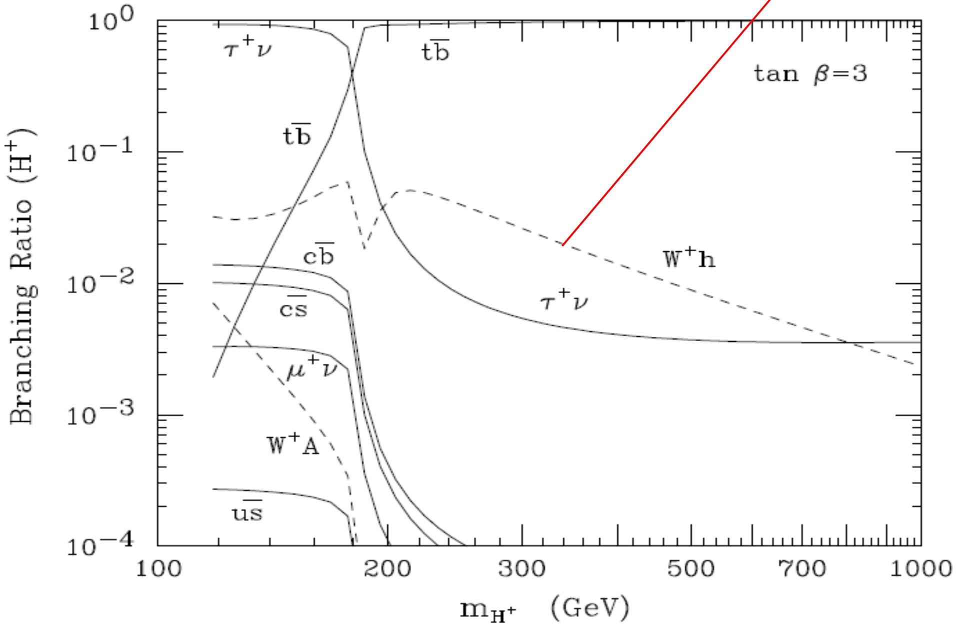
H+ → cb, ts could be important, in some cases dominant !!

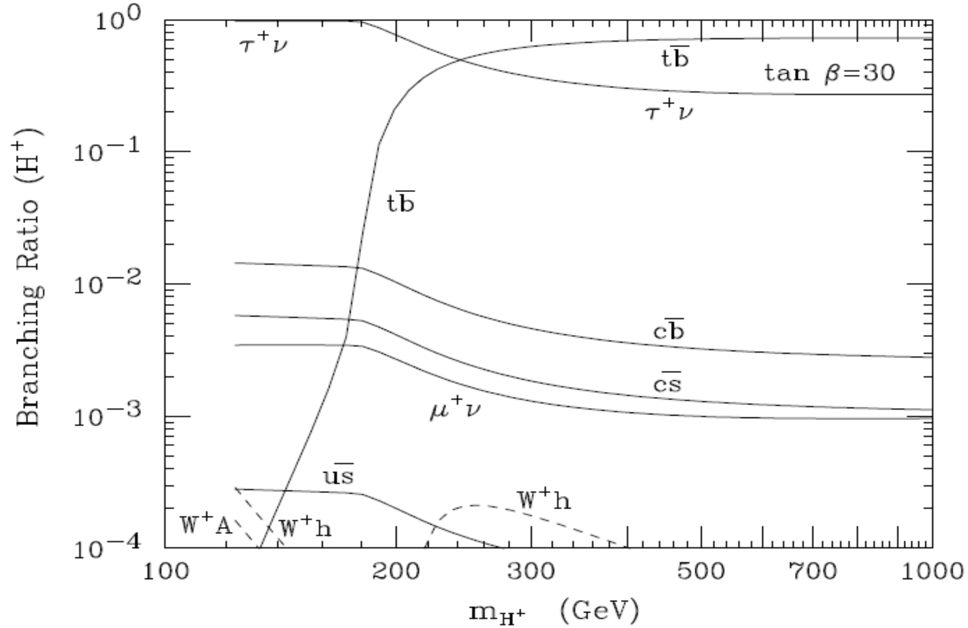
J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti, R. Noriega and A. Rosado, Phys. Rev D. 79:095025 (2009)

Branching ratios of charged Higgses in 2HDM model II

Can be larger than MSSM !
(Only small tanβ though.)

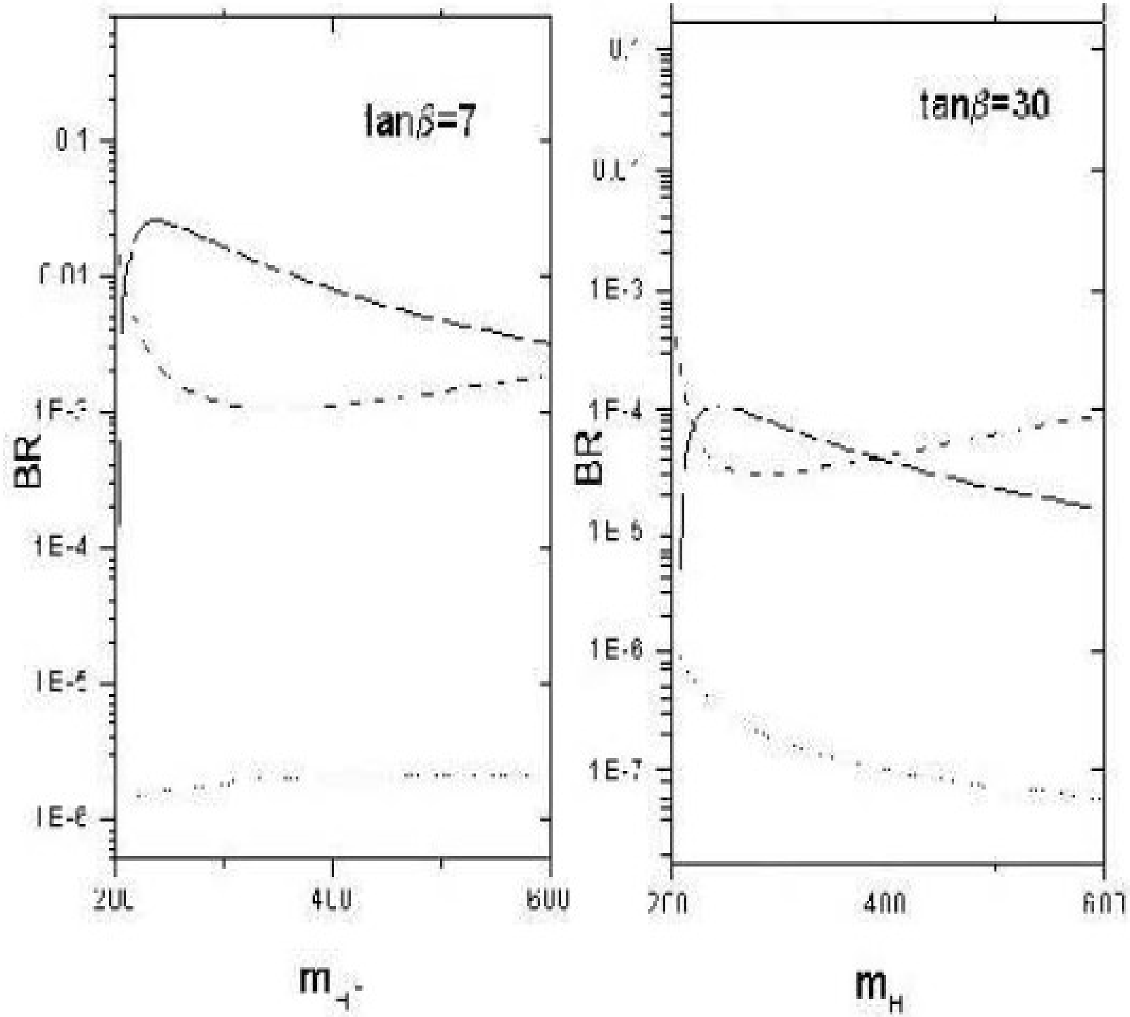
Carena/Haber, 2003





Note that there is no $H^+W^-\gamma$ or H^+W^-Z coupling in 2HDMs at tree-level

➡ No tree-level gauge boson fusion in production at hadron colliders



BR´s $H^+ \to W^+\gamma$, W^+Z, $W^+ h$ in efective theory

J. L. Díaz-Cruz, J. Hernández-Sánchez and J. J. Toscano, Phys. Lett. B 512, 339 (2001)

Figura 5: BR para los decaimientos de Higgs cargados en los modos Wh (línea sólida), WZ (dashes) y $W\gamma$ (puntos) para los parámetros, $m_h = 115$ GeV, $m_{H^\pm} \simeq m_{A^0} \simeq m_H$ y $\alpha \simeq \beta - \pi/2$.

Yukawa Texture and Charged Higgs in 2HDM-III

Thus, in order to derive the interaction of the charged Higgs boson, the Yukawa lagrangian is written as follows:

$$\mathcal{L}_Y Y_1^u \bar{Q}_L \tilde{\Phi}_1 u_R + Y_2^u \bar{Q}_L \tilde{\Phi}_2 u_R + Y_1^d \bar{Q}_L \Phi_1 d_R + Y_2^d \bar{Q}_L \Phi_2 d_R, \qquad (1)$$

where $\Phi_{1,2} = (\phi_{1,2}^+, \phi_{1,2}^0)^T$ refer to the two Higgs doublets, $\tilde{\Phi}_{1,2} = i\sigma_2 \Phi_{1,2}^*$, Q_L denotes the left-handed fermion doublet, u_R and d_R are the right-handed fermions singlets, finally $Y_{1,2}^{u,d}$ denote the (3×3) Yukawa matrices.

After spontaneous symmetry breaking the quark mass matrix is given by

$$M_q = \frac{1}{\sqrt{2}}(v_1 Y_1^q + v_2 Y_2^q). \qquad (3)$$

We will assume that both Yukawa matrices Y_1^q and Y_2^q have the four-texture form and are Hermitic; following the conventions of [18], the quark mass matrix is then written as

$$M_q = \begin{pmatrix} 0 & C_q & 0 \\ C_q^* & \tilde{B}_q & B_q \\ 0 & B_q^* & A_q \end{pmatrix};$$

For diagonalize them we using the matrices O_q and P_q in the following way

$$\bar{M}^q = O_q^T P_q M^q P_q^\dagger O_q$$

J. L. Díaz-Cruz, R. Noriega-Papaqui and A. Rosado, Phys. Rev. D71, 015014, (2005) After spontaneous symmetry breaking (SSB) and including the diagonalizing matrices for quarks and Higgs bosons [1], the interactions of the charge Higgs boson H^+ with quark pairs acquire the following form:

$$\begin{aligned}
\mathcal{L}^q = & \frac{g}{2\sqrt{2}M_W}\bar{u}_i \left\{ (V_{CKM})_{il} \left[\tan\beta\, m_{d_l}\, \delta_{lj} - \sec\beta \left(\frac{\sqrt{2}M_W}{g} \right) \left(\tilde{Y}_2^d \right)_{lj} \right] \right. \\
& + \left[\cot\beta\, m_{u_i}\, \delta_{il} - \csc\beta \left(\frac{\sqrt{2}M_W}{g} \right) \left(\tilde{Y}_1^u \right)^\dagger_{il} \right] (V_{CKM})_{lj} \\
& + (V_{CKM})_{il} \left[\tan\beta\, m_{d_l}\, \delta_{lj} - \sec\beta \left(\frac{\sqrt{2}M_W}{g} \right) \left(\tilde{Y}_2^d \right)_{lj} \right] \gamma^5 \\
& \left. - \left[\cot\beta\, m_{u_i}\, \delta_{il} - \csc\beta \left(\frac{\sqrt{2}M_W}{g} \right) \left(\tilde{Y}_1^u \right)^\dagger_{il} \right] (V_{CKM})_{lj}\, \gamma^5 \right\} d_j\, H^+
\end{aligned} \tag{2}$$

and similarly for the leptons.

The term proportional to δ_{ij} corresponds to the contribution of the 2HDM-II, while the terms proportional to $\tilde{Y}_2^d$ and $\tilde{Y}_1^u$ denote the new contributions from 2HDM-III.

J. L. Díaz-Cruz, J. Hernández-Sánchez, S. Moretti, R. Noriega and A. Rosado, Phys. Rev D. 79:095025 (2009)

To derive a better suited approximation for the product $O_q^T\, P_q\, Y_n^q\, P_q^\dagger\, O_q$ we express the rotated matrix $\tilde{Y}_n^q$ in the form,

$$\left[\tilde{Y}_n^q\right]_{ij} = \frac{\sqrt{m_i^q m_j^q}}{v}\, [\tilde{\chi}_n^q]_{ij} = \frac{\sqrt{m_i^q m_j^q}}{v}\, [\chi_n^q]_{ij}\; e^{i\vartheta_{ij}^q}$$

In order to perform our phenomenological study we find convenient to rewrite the lagrangian given in Eq.2 in terms of the coefficients $[\tilde{\chi}_n^q]_{ij}$ as follows:

$$\begin{aligned}
\mathcal{L}^q \;=\; & \frac{g}{2\sqrt{2}M_W}\bar{u}_i \Bigg\{ (V_{CKM})_{il} \left[\tan\beta\, m_{d_l}\, \delta_{lj} - \frac{\sec\beta}{\sqrt{2}}\, \sqrt{m_{d_l} m_{d_j}}\, \tilde{\chi}_{lj}^d \right] \\
& + \left[\cot\beta\, m_{u_i}\, \delta_{il} - \frac{\csc\beta}{\sqrt{2}}\, \sqrt{m_{u_i} m_{u_l}}\, \tilde{\chi}_{il}^u \right] (V_{CKM})_{lj} \\
& + (V_{CKM})_{il} \left[\tan\beta\, m_{d_l}\, \delta_{lj} - \frac{\sec\beta}{\sqrt{2}}\, \sqrt{m_{d_l} m_{d_j}}\, \tilde{\chi}_{lj}^d \right] \gamma^5 \\
& - \left[\cot\beta\, m_{u_i}\, \delta_{il} - \frac{\csc\beta}{\sqrt{2}}\, \sqrt{m_{u_i} m_{u_l}}\, \tilde{\chi}_{il}^u \right] (V_{CKM})_{lj}\, \gamma^5 \Bigg\}\, d_j\, H^+
\end{aligned}$$

A. The decays $t \to H^+ b$, $H^+ s$

Now we shall discuss the corresponding quarks interactions and their implications for charged Higgs boson production through top quark decays. Then, from Eq. 6 the couplings $\bar{u}_i d_j H^+$ and $u_i \bar{d}_j H^-$ are given by:

$$g_{H^+\bar{u}_i d_j} = -\frac{ig}{2\sqrt{2}M_W}(S_{ij} + A_{ij}\gamma_5), \quad g_{H^- u_i \bar{d}_j} = -\frac{ig}{2\sqrt{2}M_W}(S_{ij} - A_{ij}\gamma_5),$$

where S_{ij} and A_{ij} are defined as:

$$\begin{aligned}
S_{ij} &= (V_{CKM})_{il}\left[\tan\beta\, m_{d_l}\,\delta_{lj} - \frac{\sec\beta}{\sqrt{2}}\sqrt{m_{d_l} m_{d_j}}\,\tilde{\chi}^d_{lj}\right] \\
&\quad + \left[\cot\beta\, m_{u_i}\,\delta_{il} - \frac{\csc\beta}{\sqrt{2}}\sqrt{m_{u_i} m_{u_l}}\,\tilde{\chi}^u_{il}\right](V_{CKM})_{lj} \\
A_{ij} &= (V_{CKM})_{il}\left[\tan\beta\, m_{d_l}\,\delta_{lj} - \frac{\sec\beta}{\sqrt{2}}\sqrt{m_{d_l} m_{d_j}}\,\tilde{\chi}^d_{lj}\right] \\
&\quad - \left[\cot\beta\, m_{u_i}\,\delta_{il} - \frac{\csc\beta}{\sqrt{2}}\sqrt{m_{u_i} m_{u_l}}\,\tilde{\chi}^u_{il}\right](V_{CKM})_{lj}.
\end{aligned}$$

In order to study the top quark BRs we must consider both the decays $t \to H^+ b$ and $t \to H^+ s$, because both modes could be important for several parameter configurations within our model. In particular, the channel decay $t \to H^+ s$ is a consequence our model and could be a viable signal at LHC. The decay width of these modes takes the following form:

$$\Gamma(t \to H^+ d_j) = \frac{g^2}{128\pi m_W^2 m_t^3} \lambda^{1/2}(m_t^2, m_{H+}^2, m_b^2) \times \left(\left[(mt + m_b)^2 - m_{H+}^2 \right] S_{3j}^2 + \left[(mt + m_b)^2 - m_{H+}^2 \right] A_{3j}^2 \right),$$

where λ is the usual kinematic factor $\lambda(a, b, c)(a - b - c)^2 - 4bc$, $j = 2$ for the mode $H^+ s$ and $j = 3$ for the mode $H^+ b$.

Experimental bound on the BR(t--> bH+)

If the decay mode (H+ --> τ+ v) dominates the charged Higgs boson decay width, then BR(t --> H+ b) is constrained to be less than 0.4 at 95 % C.L.

However, if the decay mode (H+ --> τ+ v) is not dominant, then BR(t --> H+ b) is constrained to be less than 0.91 at 95 % C.L.

The combined LEP data excluded a charged Higgs boson with mass less than 79.3 GeV at 95 % C. L.

Thus, we need to discuss all the charged Higgs decays.

A. Abulencia et al. (CDF Collaboration), Phys. Rev. Lett. 96, 042003 (2006)

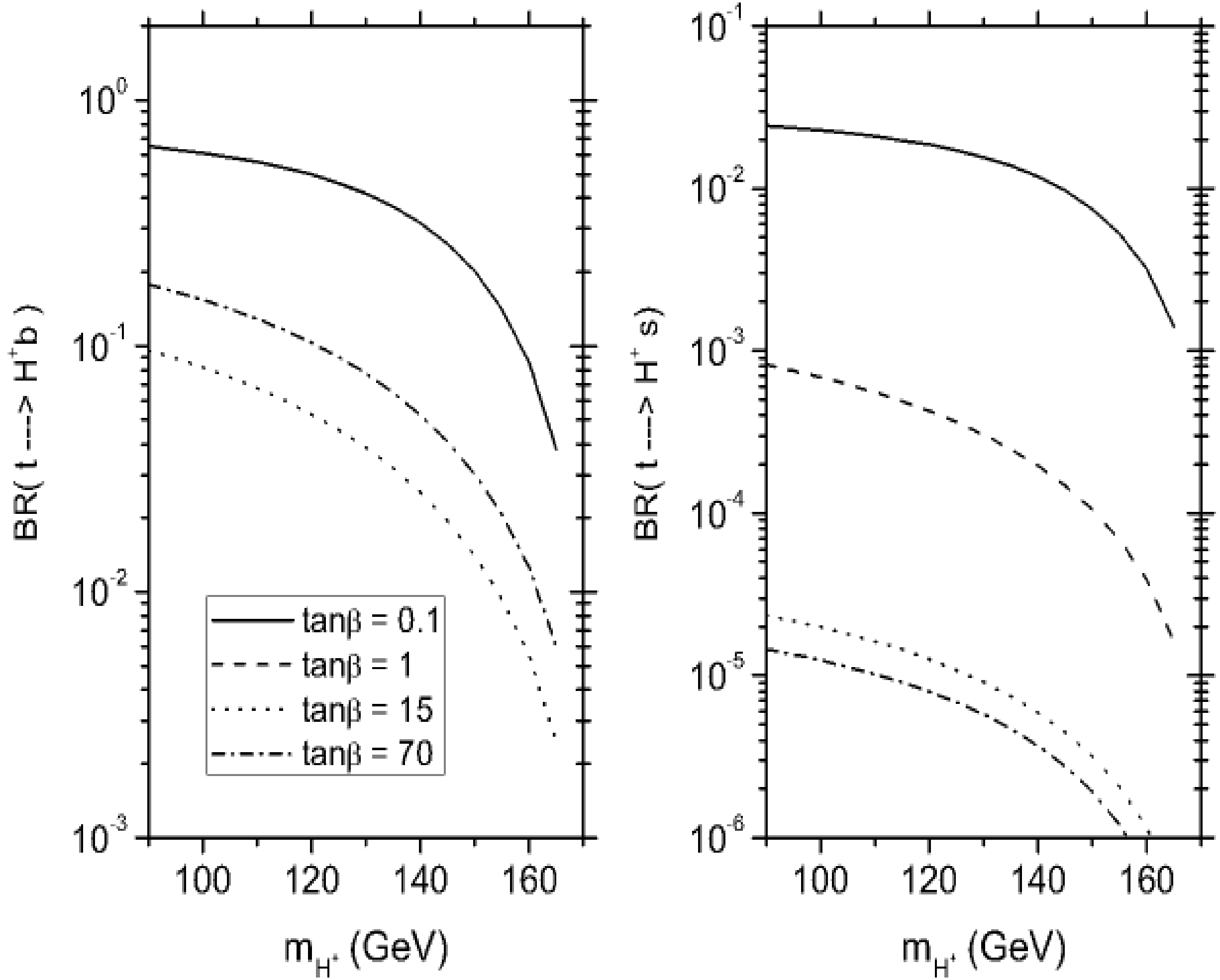


FIG. 5: It is plotted: a) the BR($t \to b\,H^+$) vs. m_{H^+} (left), b) the BR($t \to b\,H_2^+$) vs. m_{H^+} (right), in Scenario A by taking $\tilde{\chi}_{ij}^u = 1$ and $\tilde{\chi}_{ij}^d = 1$, for: $\tan\beta = 0.1$ (solid), $\tan\beta = 1$ (dashes), $\tan\beta = 15$ (dots), $\tan\beta = 70$ (dashes-dots).

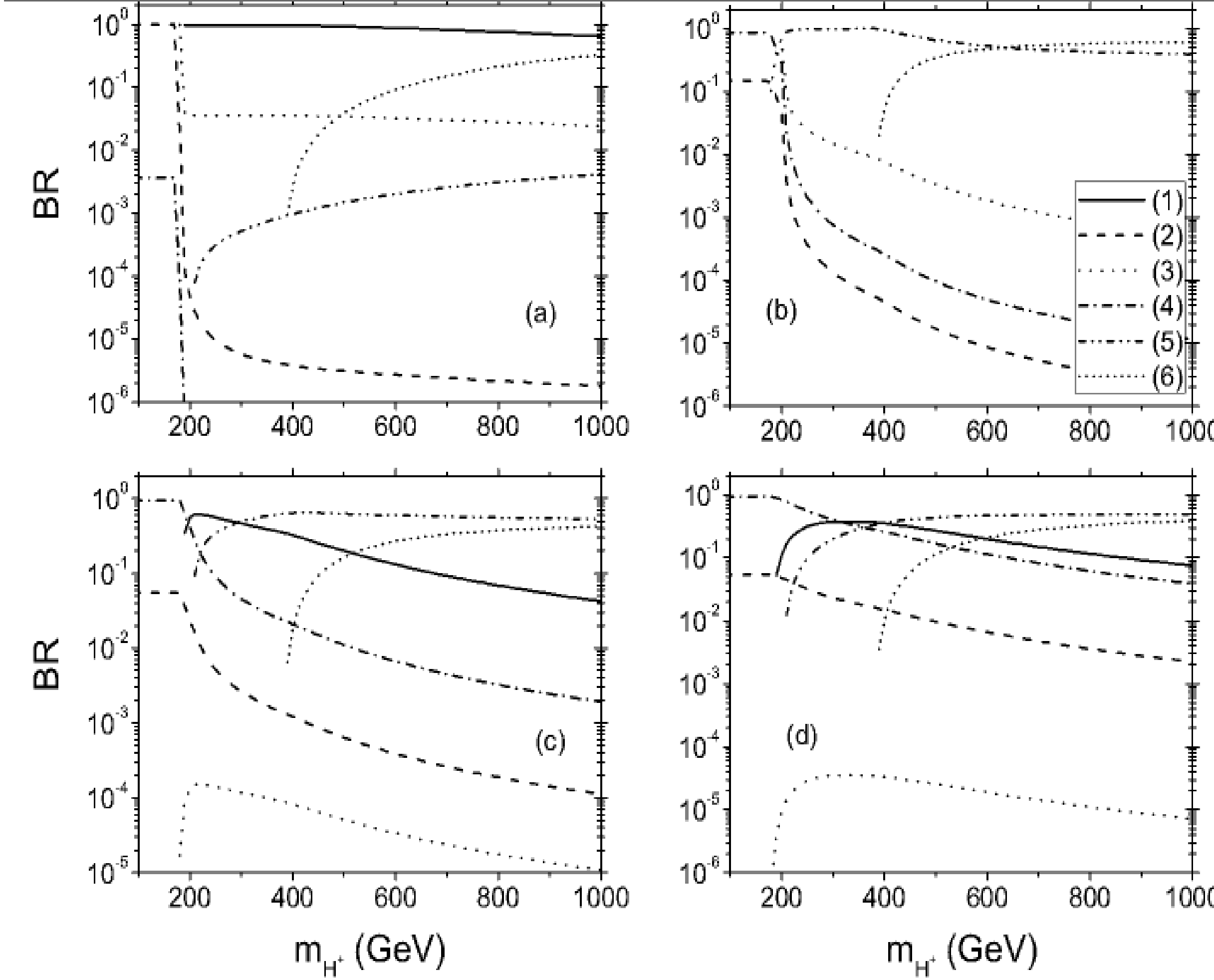


FIG. 1: The figure shows the branching ratios of H^+ decaying into the principal modes in Scenario A, taking $\tilde{\chi}^u_{ij} = 1$, $\tilde{\chi}^d_{ij} = 1$, $m_{h^0}120$ GeV, $m_{A^0} = 120$ GeV and $\alpha = \pi/2$ for: (a) $\tan\beta = 0.1$, (b) $\tan\beta = 1$, (c) $\tan\beta = 15$, (d) $\tan\beta = 70$. The lines in each graph correspond to: (1) BR($H^+ \to t\bar{b}$), (2) BR($H^+ \to c\bar{b}$), (3) BR($H^+ \to t\bar{s}$), (4) BR($H^+ \to \tau^+\nu_\tau$), (5) BR($H^+ \to W^+h^0$), (6) BR($H^+ \to W^+A^0$).

C. s-channel production of charged Higgs boson

Large flavor mixing coupling $H^{\pm}\bar{q}q'$ enables the possibility of studying the production of charged Higgs boson via the partonic s-channel production mechanism, $c\bar{b}, \bar{c}b \to H^{\pm}$. This mechanism was discussed first by He and Yuan

$$\sigma(h_1 h_2(c\bar{b}) \to H^+ X)\frac{\pi}{12s}\left(|C_L|^2 + |C_R|^2\right) I_{c,\bar{b}}^{h_1,h_2}$$

where

$$I_{c,\bar{b}}^{h_1,h_2} = \int_{\tau}^{1} dx \left[f_c^{h_1}(x,\tilde{Q}^2) f_{\bar{b}}^{h_2}(\tau/x,\tilde{Q}^2) + f_{\bar{b}}^{h_1}(x,\tilde{Q}^2) f_c^{h_2}(\tau/x,\tilde{Q}^2)\right]/x$$

and $\tau = m_{H^{\pm}}^2/s$. The parton distribution functions (PDFs) $f_q^{h_i}(x,\tilde{Q}^2)$ describe the quark q content of the hadron i at a scale interaction of $\tilde{Q}^2$. In other words, the PDFs $f_q^{h}(x,\tilde{Q}^2)$ give the probabilities to find a quark q inside a hadron with the fraction x of the hadron momentum, in a scattering process with momentum transfer square $\tilde{Q}^2$, in this case we will take $\tilde{Q}^2 = m_{H^+}^2$.

H. J. He and C.P. Yuan , Phys. Rev. Lett. 83, 28 (1999) we see that for the case of the 2HDM-III, S and A for the subprocess $(c\bar{b}) \rightarrow H^+$ are giving as follows

$$C_L^{III} = -\frac{ig}{\sqrt{2}M_W}\left[\cot\beta\, m_c\,\delta_{2l} - \frac{\csc\beta}{\sqrt{2}}\sqrt{m_c m_{u_l}}\,\tilde{\chi}^u_{2l}\right](V_{CKM})_{l3}$$

and

$$C_R^{III} = -\frac{ig}{\sqrt{2}M_W}(V_{CKM})_{2l}\left[\tan\beta\, m_{d_l}\,\delta_{l3} - \frac{\sec\beta}{\sqrt{2}}\sqrt{m_{d_l} m_{d_3}}\,\tilde{\chi}^d_{l3}\right]$$

where $l = 1,2,3$.

integrated luminosity at LHC is of the order 10^5 pb.

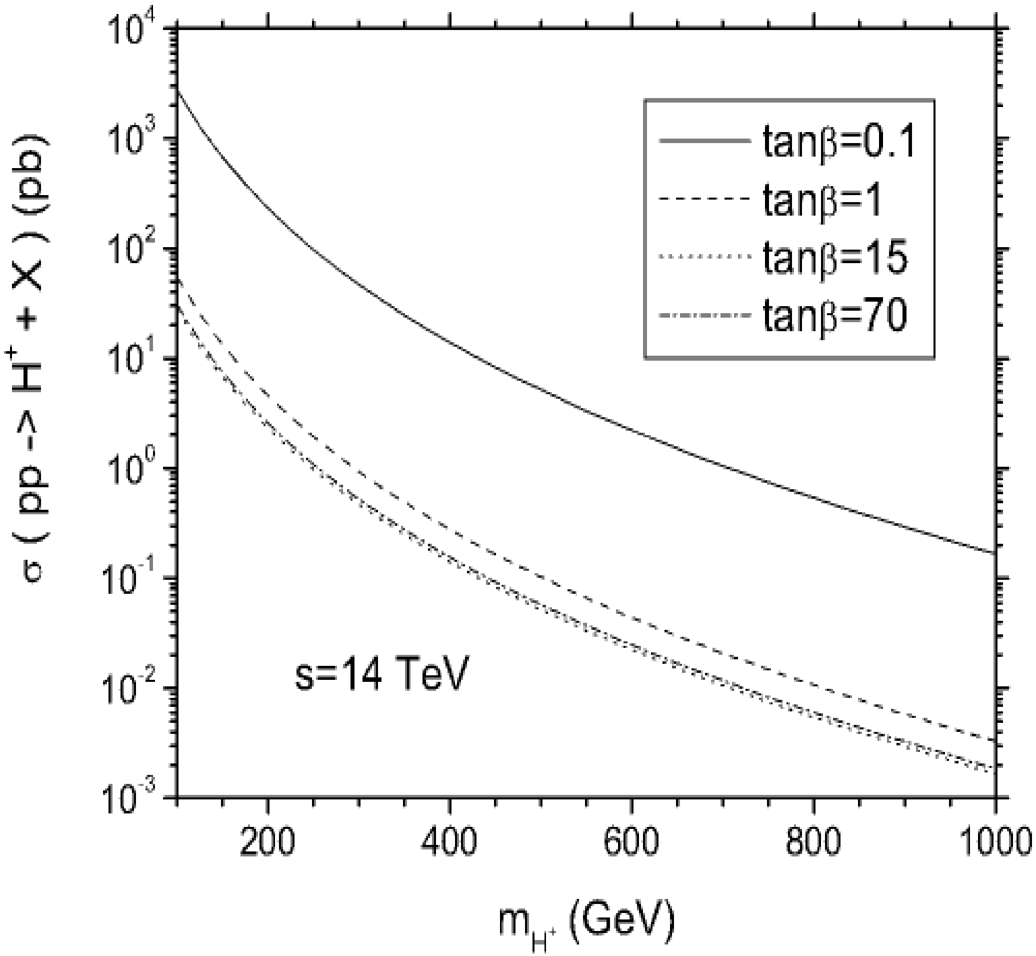


FIG. 9: The figure shows the total cross section rates of process $h_1 h_2(c\bar{b}) \to H^+ X$ as a function of m_{H^+} in the 2HDM-III at LHC energies ($s = 14$ TeV), by taking $\tilde{\chi}^d_{l3} = 1$ and $\tilde{\chi}^u_{2l} = 1$ $(l = 1, 2, 3)$. The lines correspond to: $\tan\beta = 0.1$, $\tan\beta = 1$, $\tan\beta = 15$, and $\tan\beta = 70$.

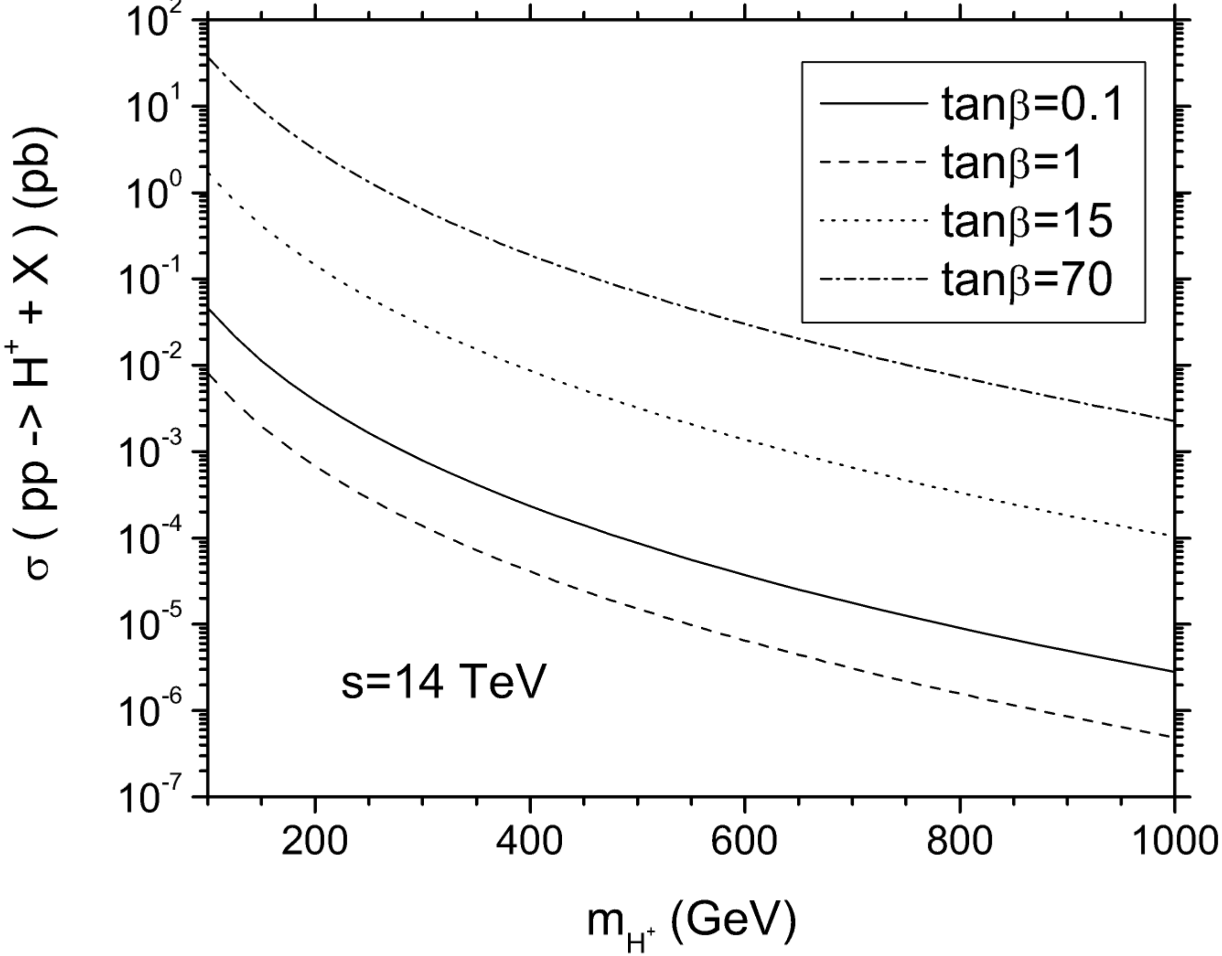


FIG. 10: The figure shows the total cross section rates of process $h_1 h_2(c\bar{b}) \to H^+ X$ as a function of m_{H^+} in the 2HDM-II at LHC energies ($s = 14$ TeV), by taking $(V_{CKM})_{23} = 4.16 \times 10^{-2}$ and $(V_{CKM})_{33} \approx 1$. The lines correspond to: $\tan\beta = 0.1$, $\tan\beta = 1$, $\tan\beta = 15$, and $\tan\beta = 70$.

TABLE I: Summary of LHC event rates for some parameter combinations within Scenarios A, B, C, D with for an integrated luminosity of 10^5 pb^{-1}, for several different signatures, through the channel $q\bar{q}, gg \to \bar{t}bH^+$ + c.c.

$(\tilde{\chi}^u_{ij}, \tilde{\chi}^d_{ij})$	$\tan\beta$	m_{H^+} in GeV	$\sigma(pp \to H^+\bar{t}b)$ in pb	Relevant BRs	Nr. Events
(1,1)	15	400	2.23×10^{-1}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3.2 \times 10^{-1}$	7040
				$\mathrm{BR}(H^+ \to \tau^+\nu^0_\tau) \approx 2.1 \times 10^{-3}$	46
				$\mathrm{BR}(H^+ \to W^+h^0) \approx 6.3 \times 10^{-1}$	13860
				$\mathrm{BR}(H^+_2 \to W^+A^0) \approx 1.7 \times 10^{-2}$	374
(1,1)	70	400	4.3×10^{-1}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3.5 \times 10^{-1}$	15050
				$\mathrm{BR}(H^+ \to c\bar{b}) \approx 1.4 \times 10^{-2}$	602
				$\mathrm{BR}(H^+ \to \tau^+\nu_\tau) \approx 2.5 \times 10^{-1}$	10750
				$\mathrm{BR}(H^+ \to W^+h^0) \approx 3.6 \times 10^{-1}$	15480
(0.1,1)	1	600	1.1×10^{-1}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3 \times 10^{-1}$	3300
				$\mathrm{BR}(H^+ \to t\bar{s}) \approx 9.1 \times 10^{-4}$	10
				$\mathrm{BR}(H^+ \to W^+h^0) \approx 3.6 \times 10^{-1}$	3960
				$\mathrm{BR}(H^+ \to W^+A^0) \approx 3.2 \times 10^{-1}$	3520

TABLE II: Summary of LHC event rates for some parameter combinations within Scenarios A, B, C, D with for an integrated luminosity of 10^5 pb^{-1}, for several different signatures, through the channel $c\bar{b} \to H^+ +$ c.c.

$(\tilde{\chi}^u_{ij}, \tilde{\chi}^d_{ij})$	$\tan\beta$	m_{H^+} in GeV	$\sigma(pp \to H^+ + X)$ in pb	Relevant BRs	Nr. Events
(1,1)	15	400	1.14×10^{-1}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3.2 \times 10^{-1}$	3648
				$\mathrm{BR}(H^+ \to \tau^+ \nu^0_\tau) \approx 2.1 \times 10^{-3}$	24
				$\mathrm{BR}(H^+ \to W^+ h^0) \approx 6.3 \times 10^{-1}$	7182
				$\mathrm{BR}\left(H_2^+ \to W^+ A^0\right) \approx 1.7 \times 10^{-2}$	194
(1,1)	70	400	1.25×10^{-1}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3.5 \times 10^{-1}$	4375
				$\mathrm{BR}(H^+ \to c\bar{b}) \approx 1.4 \times 10^{-2}$	175
				$\mathrm{BR}(H^+ \to \tau^+ \nu_\tau) \approx 2.5 \times 10^{-1}$	3125
				$\mathrm{BR}(H^+ \to W^+ h^0) \approx 3.6 \times 10^{-1}$	4500
(0.1,1)	1	600	3.41×10^{-4}	$\mathrm{BR}(H^+ \to t\bar{b}) \approx 3 \times 10^{-1}$	10
				$\mathrm{BR}(H^+ \to t\bar{s}) \approx 9.1 \times 10^{-4}$	0
				$\mathrm{BR}(H^+ \to W^+ h^0) \approx 3.6 \times 10^{-1}$	12
				$\mathrm{BR}(H^+ \to W^+ A^0) \approx 3.2 \times 10^{-1}$	11

Some conclusions

We have discussed the implications of assuming a four-zero Yukawa texture for the properties of the H+.

We have studied the fermion-charged Higgs vertices in the 2HDM-III

We have analyzed the decay t --> b H+ and the charged Higgs decays

H+ --> cb could be dominant for tan $\beta = 0.1$ and mH+ < 175 GeV

We have evaluated the s-channel production of H+ through (cb) fusion, which could reach detectable rates.

We study pp-->tb H+ and cb---> H+ X

- Implications of the Yukawa texture on the rare decays Hi+ --->W+ γ are studied, which appear at one loop level.
- This mode could have a BR´s ~ 10^-2, 10^-3 for the mode W+ γ (work in progress: E. Barradas, O. Félix-Beltrán and J. Hernández-Sánchez), in the following range of parameters:
- 150 GeV < mH+ < 200 Gev and 0.1<tan β< 10
- Even rates: in qq, gg ---> H+ tb is posible we have nr. events 40 in the LHC.
- In cb --> H+ X is posible that we have nr. Events 5 in the LHC.

2HDM-III from ED Theory

The possible existence of ED has enabled the of several scenarios BSM

In order to study EWSB one can explore a 4D effective theory of ED. With this idea we consider

a) A fundamental scalar field whose ED origin is associated to a gauge-Higgs unification

b)A composite sacalar field also of ED origin.

In our proposal we consider an effective theory SU(2) X U(1) 4D theory with a fundamental and composite scalar (He, Hc).

A. Aranda, J.L. Díaz-Cruz, J. Hernández-Sánchez and R. Noriega- Papaqui, Phys. Lett. B 658 (2007) 57

We focus on the class of models where the cuartic self coupling of He appears at tree level and is related with SU(2) gauge coupling, which require 6-dimensions or higher.

In this model one could have a compactification scale of order TeV, and the renormalization group could be neglected in a firts approximation

For Hc one expect the size of the mass squared term in the potential to be order of the heavy composite state, O (TeV).

Our main interest is the scalar sector and will for the moment assume all the gauge bosons to be fundamental fields. The Lagrangian to be discussed is

$$\mathcal{L}_{\text{eff}} = |D_\mu H_E|^2 + |D_\mu H_C|^2 - V(H_E, H_C), \tag{2}$$

with

$$V(H_E, H_C) = -\mu_e^2 |H_E|^2 - \mu_c^2 |H_C|^2 - \kappa^2 \left(H_E^\dagger H_C + \text{h.c.}\right) + \frac{g^4}{2} \left|H_E^\dagger H_E\right|^2 + \lambda_c \left|H_C^\dagger H_C\right|^2. \tag{3}$$

Yukawa sector

For the elementary sector we consider the types of Yukawa couplings that it comes from gauge-Higgs unification scenario.

We asume that this elementary sector couples predominantly to the third family

$$\mathcal{L}_y = \lambda^u_{ij}\left[\frac{\langle S\rangle}{\Lambda_F}\right]^{n^u_{ij}} \bar{Q}'_{Li}\tilde{H}_C u'_{Rj} + \lambda^d_{ij}\left[\frac{\langle S\rangle}{\Lambda_F}\right]^{n^d_{ij}} \bar{Q}'_{Li}H_C d'_{Rj} + \text{h.c.} \qquad (9)$$

Thus the Yukawa Lagrangian of our model is:

$$\mathcal{L}_y = \left[Y^u_{ij}\bar{Q}'_{Li}\tilde{H}_C u'_{Rj} + Y^d_{ij}\bar{Q}'_{Li}H_C d'_{Rj}\right] + \left[\eta_t\bar{Q}'_{L3}\tilde{H}_E u'_{R3} + \eta_b\bar{Q}'_{L3}H_E d'_{R3}\right] + \text{h.c.}, \qquad (10)$$

where the first term in brackets is the contribution from the composite Higgs, the second one is due to the elementary Higgs which only contributes to the third family

After spontaneous symmetry breaking (SSB), one can derive the quark mass matrices from Eq. (10) namely,

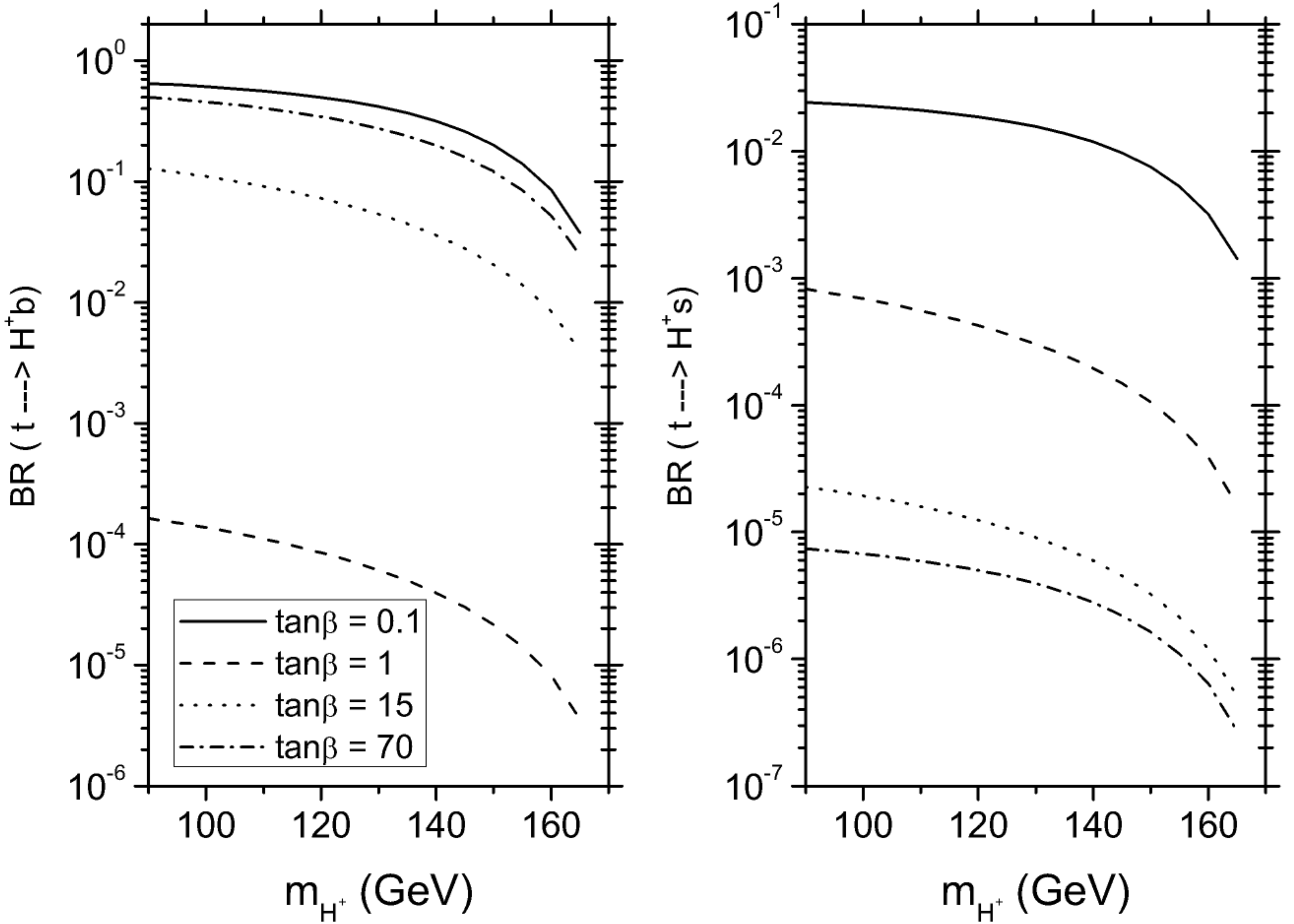
$$[M^u]_{ij} = \frac{1}{\sqrt{2}}\left(v_c Y^u_{ij} + v_e \eta_t \delta_{3i}\delta_{3j}\right), \tag{11}$$

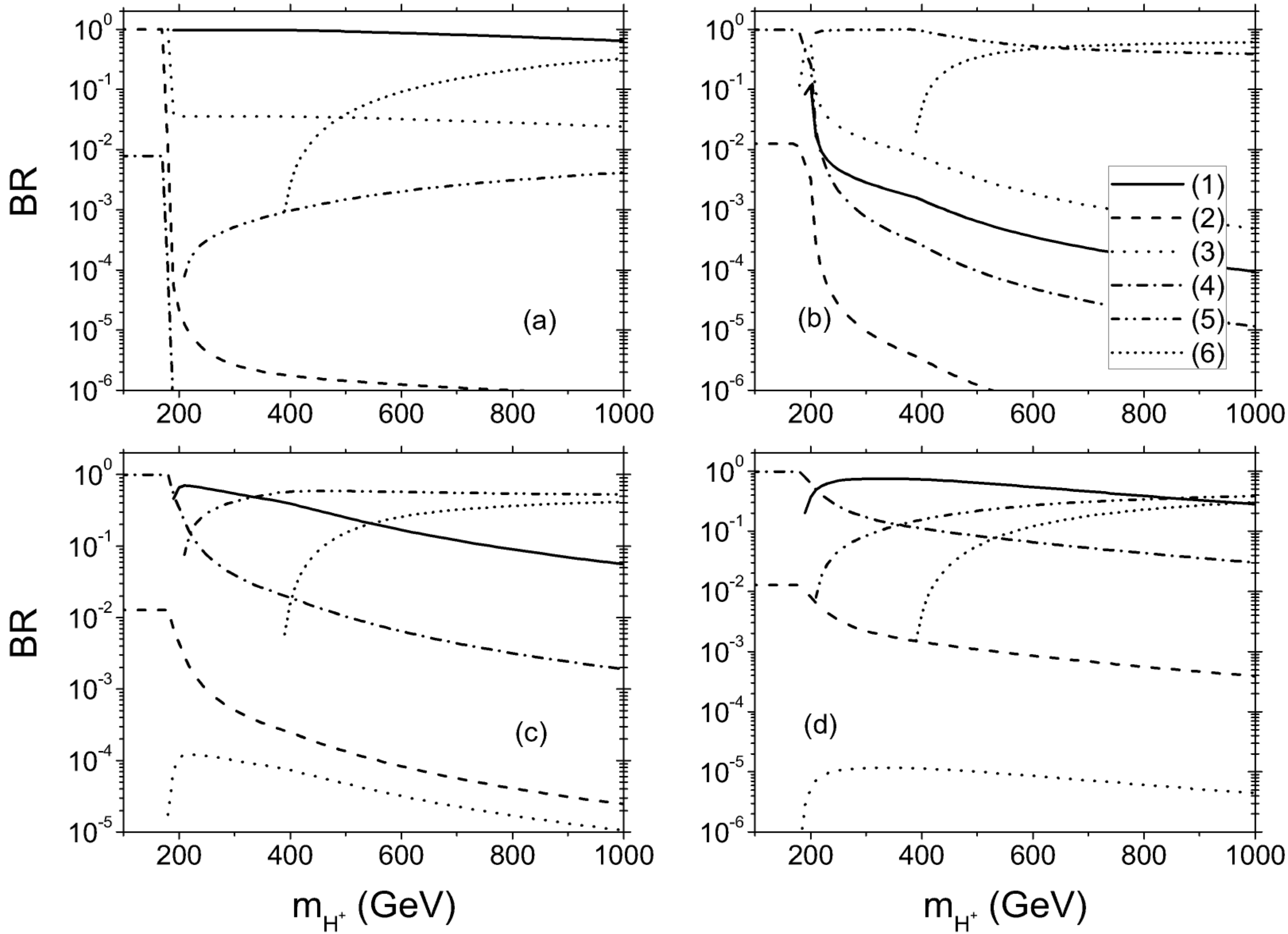
$$[M^d]_{ij} = \frac{1}{\sqrt{2}}\left(v_c Y^d_{ij} + v_e \eta_b \delta_{3i}\delta_{3j}\right). \tag{12}$$

We now assume that the Yukawa composite matrices Y^u and Y^d have the four-Hermitic-texture form [18]. The quark mass has the same form and it is given by:

$$M^q = \begin{pmatrix} 0 & D_q & 0 \\ D_q & C_q & B_q \\ 0 & B_q & A_q \end{pmatrix} \quad (q = u, d),$$

A. Aranda, J. Hernández-Sánchez and R. Noriega- Papaqui, work in progress





BR
BR
(a)
(b)
(c)
(d)
(1)
(2)
(3)
(4)
(5)
(6)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
200
400
600
800
1000
m_{H^+} (GeV)
m_{H^+} (GeV)