

$H^+ \rightarrow W^+ l_i^- l_j^+$ decay in the two Higgs doublet model

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Abstract

We study the lepton flavor violating $H^+ \rightarrow W^+ l_i^- l_j^+$ and the lepton flavor conserving $H^+ \rightarrow W^+ l_i^- l_i^+$ ($l_i = \tau, l_j = \mu$) decays in the framework of the general two Higgs doublet model, the so-called model III. We estimate the decay width of LFV (LFC) decay at the order of magnitude of $(10^{-11} - 10^{-5}) GeV$ ($(10^{-9} - 10^{-4}) GeV$), for $200 GeV \leq m_{H^\pm} \leq 400 GeV$, and the intermediate values of the coupling $\bar{\xi}_{N,\tau\mu}^E \sim 5 GeV$ ($\bar{\xi}_{N,\tau\tau}^E \sim 30 GeV$). We observe that the experimental result of the process under consideration can give comprehensive information about the physics beyond the standard model and the existing free parameters.

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1 Introduction

The charged Higgs boson carries a distinctive signature of the Higgs sector in the models beyond the standard model (SM), such as two Higgs doublet model (2HDM), minimal extension of the standard model (MSSM). Therefore, its discovery will be an evidence of multi doublet structure of the Higgs sector. In the literature, the charged Higgs decays have been widely studied.

The charged Higgs production in hadron colliders was studied in [1] and more systematic calculations of production process at LHC have been presented in [2]. At the LHC the dominant production channel for H^+ is $gb \rightarrow H^+t$. One expects more than one thousand events for a Higgs mass $m_{H^+} = 400 (GeV)$, with an integrated luminosity of $L = 100fb^{-1}$ [3]. At tevatron, the CDF and D0 collaborations have searched for H^+ bosons through the process $p\bar{p} \rightarrow t\bar{t}$, with at least one of the top quark decaying via $t \rightarrow H^+b$. They have excluded the regions with light H^+ [4]. At present the model independent lower limit on the charged Higgs mass is $m_{H^+} > 77.4 (GeV)$ [5].

The charged Higgs boson decay into tau and neutrino has been analyzed in [6] and in [7] and it was shown that the dominate decay modes of the charged Higgs boson were $H^+ \rightarrow \tau^+\nu$ and $H^+ \rightarrow t\bar{b}$. However, the other candidate for the large branching ratio BR is the process $H^+ \rightarrow W^+h^0$, and it has been examined in [8, 9]. The analysis in [8] was related to the $H^+ \rightarrow W^+h^0$ decay, in the framework of the 2HDM, including loop corrections and for some reasonable choice of free parameters, those corrections could be as large as $\sim 80\%$ of the tree level result. In [9], the chances of detecting charged Higgs boson of the MSSM at Large Hadron Colliders (LHC), in the W^+h^0 mode, have been studied and it was concluded that the charged Higgs boson signal overcomes the background for optimum $\tan\beta$ values, between 2 and 3. In [10] the above decay has been analyzed in the MSSM and the electroweak (EW) corrections have been obtained. It was observed that, for the low $\tan\beta$, these corrections caused an enhancement at the order of 20%.

The work in [11] is devoted to the decays of the charged Higgs boson, including the radiative modes into decays $W^+\gamma$ and W^+Z , mostly in the framework of the 2HDM and MSSM. In [12], the analysis of $H^+ \rightarrow W^+\gamma$, $H^+ \rightarrow W^+Z$ and $H^+ \rightarrow W^+h^0$ decays has been done in the context of the effective lagrangian extension of the 2HDM. In this work the BRs have been obtained at the order of magnitude of 10^{-5} , 10^{-1} and $O(1)$, respectively.

Lepton flavor violating (LFV) interactions are interesting, since they do not exist in the SM and give strong signal about the new physics beyond. Such decays have reached great interest at present and the experimental search has been improved. $H^0 \rightarrow \tau\mu$ decay is an example for

LFV decays and it has been studied in [13, 14]. In [13] a large BR , at the order of magnitude of $0.1 - 0.01$, has been estimated in the framework of the 2HDM. In [14] its BR was obtained in the interval $0.001 - 0.01$ for the Higgs mass range $100 - 160(GeV)$, for the LFV parameter $\kappa_{\mu\tau} = 1$.

Our work is devoted to the analysis of the LFV $H^+ \rightarrow W^+ l_i^- l_j^+$ and the lepton flavor conserving (LFC) $H^+ \rightarrow W^+ l_i^- l_i^+$ ($l_i = \tau, l_j = \mu$) decays in the framework of the general 2HDM, the so-called model III. The present LFV decay exists with the chain processes, $H^+ \rightarrow W^+(h^{0*}, A^{0*}) \rightarrow W^+ l_i^- l_j^+$, where h^0, A^0 are CP even neutral Higgs bosons beyond the SM. This decay is rich in the sense that its decay width depends on the masses of the new particles, namely $m_{H^\pm}, m_{h^0}, m_{A^0}$, the leptonic Yukawa couplings and total decay widths $\Gamma_{h^0}, \Gamma_{A^0}$. In our analysis, we observe large values, at the order of magnitude of $10^{-4} GeV$, for the decay width of the process, for outgoing τ and μ leptons. This is informative in the determination of the upper limits of the Yukawa couplings for LFV interactions and also in the prediction of the new Higgs boson masses and the total decay widths of the new neutral Higgs bosons.

We also analyze the LFC $H^+ \rightarrow W^+ l_i^- l_i^+$ ($l_i = \tau$) decay in the model III. We observe that the decay width of the process reaches to the values $10^{-3} GeV$, depending on the appropriate choice of the free parameters. This analysis ensures a prediction for the leptonic constant, which is responsible for the $\tau - \tau$ transition.

The paper is organized as follows: In Section II, we present the theoretical expression for the decay width of the LFV decay $H^+ \rightarrow W^+ l_i^- l_j^+$ and the LFC decay $H^+ \rightarrow W^+ l_i^- l_i^+$, $l_i = \tau, l_j = \mu$, in the framework of the model III. Section 3 is devoted to discussion and our conclusions.

2 The charged Higgs $H^+ \rightarrow W^+ l_i^- l_j^+$ decay in the two Higgs doublet model

In this section, we derive the expressions for the LFV $H^+ \rightarrow W^+ l_i^- l_j^+$ and LFC $H^+ \rightarrow W^+ l_i^- l_j^+$ ($l_i = \tau, l_j = \mu$) decays in the general 2HDM, the so-called model III. The leptonic part of the process can be regulated by the Yukawa interaction in the leptonic sector

$$\mathcal{L}_Y = \eta_{ij}^E \bar{l}_{iL} \phi_1 E_{jR} + \xi_{ij}^E \bar{l}_{iL} \phi_2 E_{jR} + h.c. \quad , \quad (1)$$

where i, j are family indices of leptons, L and R denote chiral projections $L(R) = 1/2(1 \mp \gamma_5)$, ϕ_i for $i = 1, 2$, are the two scalar doublets, l_{iL} and E_{jR} are lepton doublets and singlets respectively. On the other hand the $H^+ \rightarrow W^+$ transition is possible with the help of the scalar bosons, the SM Higgs boson H^0 and CP even (odd) new particle h^0 (A^0). The part of the lagrangian which

is responsible for these transitions is the so called kinetic term

$$\begin{aligned} (D_\mu \phi_i)^+ D^\mu \phi_i &= (\partial_\mu \phi_i^+ + i \frac{g'}{2} B_\mu \phi_i^+ + i \frac{g}{2} \phi_i^+ \vec{\tau} \vec{W}_\mu) \\ &(\partial^\mu \phi_i - i \frac{g'}{2} B^\mu \phi_i - i \frac{g}{2} \phi_i \vec{\tau} \vec{W}^\mu). \end{aligned} \quad (2)$$

Here ϕ_1 and ϕ_2 are chosen as

$$\phi_1 = \frac{1}{\sqrt{2}} \left[\begin{pmatrix} 0 \\ v + H^0 \end{pmatrix} + \begin{pmatrix} \sqrt{2} \chi^+ \\ i \chi^0 \end{pmatrix} \right]; \phi_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} \sqrt{2} H^+ \\ H_1 + i H_2 \end{pmatrix}, \quad (3)$$

where only ϕ_1 has a vacuum expectation value;

$$\langle \phi_1 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v \end{pmatrix}; \langle \phi_2 \rangle = 0. \quad (4)$$

By considering the gauge and CP invariant Higgs potential which spontaneously breaks $SU(2) \times U(1)$ down to $U(1)$ as:

$$\begin{aligned} V(\phi_1, \phi_2) &= c_1(\phi_1^+ \phi_1 - v^2/2)^2 + c_2(\phi_2^+ \phi_2)^2 \\ &+ c_3[(\phi_1^+ \phi_1 - v^2/2) + \phi_2^+ \phi_2]^2 + c_4[(\phi_1^+ \phi_1)(\phi_2^+ \phi_2) - (\phi_1^+ \phi_2)(\phi_2^+ \phi_1)] \\ &+ c_5[Re(\phi_1^+ \phi_2)]^2 + c_6[Im(\phi_1^+ \phi_2)]^2 + c_7, \end{aligned} \quad (5)$$

with constants c_i , $i = 1, \dots, 7$, H_1 and H_2 are obtained as the mass eigenstates h^0 and A^0 respectively, since no mixing occurs between two CP-even neutral bosons H^0 and h^0 in the tree level and the internal new scalars h^0 and A^0 play the main role for both $H^+ \rightarrow W^+ l_1^- l_2^+$ and $H^+ \rightarrow W^+ l_1^- l_1^+$ decays (see Fig.1).

Now, we consider the lepton flavor changing process $H^+ \rightarrow W^+ l_i^- l_j^+$ where l_i, l_j are different leptons flavors, e, μ, τ . This process is driven by the flavor changing (FC) interaction in the leptonic sector and the strength of this interaction is carried by the Yukawa couplings ξ_{ij}^E , which are the free parameters of the model III version of 2HDM. They can have complex entries in general and be restricted by using experimental measurements. Notice that, in the following, we replace ξ^E with ξ_N^E where "N" denotes the word "neutral".

The vertex function for $H^+ \rightarrow W^+$ is connected to the $l_i^- l_j^+$ out going leptons by intermediate h^0 and A^0 bosons and the matrix element square of the process $H^+ \rightarrow W^+ l_i^- l_j^+$ is obtained as

$$\begin{aligned} |M|^2 &= \frac{g^2}{2} h \left\{ \left((m_{l_j} + m_{l_i})^2 - k^2 \right) |A^2|^2 + \left((m_{l_j} - m_{l_i})^2 - k^2 \right) |B^2|^2 \right\} |p_{h^0}|^2 \\ &+ \left(\left((m_{l_j} + m_{l_i})^2 - k^2 \right) |A'^2|^2 + \left((m_{l_j} - m_{l_i})^2 - k^2 \right) |B'^2|^2 \right) |p_{A^0}|^2 \\ &- 4m_{l_j} m_{l_i} Im[(A A'^* - B B'^*) p_{h^0} p_{A^0}^*] \\ &- 2(m_{l_j}^2 + m_{l_i}^2 - k^2) Im[(A A'^* + B B'^*) p_{h^0} p_{A^0}^*] \end{aligned} \quad (6)$$

where

$$h = \frac{k^2 + (m_{H^\pm}^2 - m_W^2)^2 - 2k^2(m_{H^\pm}^2 + m_W^2)^2}{m_W^2}, \quad (7)$$

and

$$p_S = \frac{i}{k^2 - m_S^2 + im_S \Gamma_S}. \quad (8)$$

with the transfer momentum square k^2 . Γ_S is the total decay width of S boson, for $S = h^0 A^0$. In eq. (6) the factors A, A', B, B' are the functions of the Yukawa couplings;

$$\begin{aligned} A &= -\frac{i}{2\sqrt{2}} (\xi_{N,l_j l_i}^E + \xi_{N,l_i l_j}^{*E}), \\ A' &= \frac{1}{2\sqrt{2}} (\xi_{N,l_j l_i}^E - \xi_{N,l_i l_j}^{*E}), \\ B &= -\frac{i}{2\sqrt{2}} (\xi_{N,l_j l_i}^E - \xi_{N,l_i l_j}^{*E}), \\ B' &= \frac{1}{2\sqrt{2}} (\xi_{N,l_j l_i}^E + \xi_{N,l_i l_j}^{*E}) \end{aligned} \quad (9)$$

Finally, the decay width Γ is obtained in the H^\pm boson rest frame using the well known expression

$$d\Gamma = \frac{(2\pi)^4}{m_{H^\pm}} |M|^2 \delta^4(p - \sum_{i=1}^3 p_i) \prod_{i=1}^3 \frac{d^3 p_i}{(2\pi)^3 2E_i}, \quad (10)$$

where p (p_i , $i=1,2,3$) is four momentum vector of H^\pm boson, (W^\pm boson, incoming l_j , outgoing l_i leptons).

3 Discussion

This section is devoted to the analysis of the charged Higgs decays $H^\pm \rightarrow W^\pm (\tau^- \mu^+ + \tau^+ \mu^-)$ and $H^\pm \rightarrow W^\pm \tau^- \tau^+$. The Yukawa couplings $\xi_{N,\tau\mu}^E$ ($\xi_{N,\tau\tau}^E$) play the main role in the leptonic part of the LFV $H^\pm \rightarrow W^\pm (\tau^- \mu^+ + \tau^+ \mu^-)$ (LFC $H^\pm \rightarrow W^\pm (l_\tau^- l_\tau^+)$) process. These couplings are free parameters of the model used and they should be restricted by respecting the appropriate experimental measurements. The upper limit of the coupling $\xi_{N,\tau\mu}^E$ has been predicted as ~ 0.15 , by using experimental result of anomalous magnetic moment of muon in [15]. However, the strength of the coupling $\xi_{N,\tau\tau}^E$ is an open problem and waiting for new experimental results in the leptonic sector. Furthermore, the total decay widths of h^0 and A^0 are unknown parameters and we expect that they are at the same order of magnitude of $\Gamma_{H^0} \sim (0.1 - 1.0) GeV$, where H^0 is the SM Higgs boson.

Notice that the couplings $\xi_{N,\tau\tau}^E$ and $\xi_{N,\tau\mu}^E$, are complex in general and in the following, we use the parametrization

$$\xi_{N,ij}^E = \sqrt{\frac{4G_F}{\sqrt{2}}} \bar{\xi}_{N,ij}^E, \quad (11)$$

where $G_F = 1.6637 \times 10^{-5} (GeV^{-2})$ is the fermi constant. In our numerical calculations, we take $m_W = 80 GeV$.

At this stage, we would like to discuss the various charged Higgs decays which are dominant and can be used in the calculation of the BRs. The candidates for these decay modes of the charged Higgs boson are $H^+ \rightarrow W^+ h^0$, $H^+ \rightarrow \tau^+ \nu$ and $H^+ \rightarrow t \bar{b}$ [6, 7, 8, 9]. The total decay width of the charged Higgs boson is approximated by

$$\Gamma_{tot}(H^+) = \Gamma(H^+ \rightarrow W^+ h^0) + \Gamma(H^+ \rightarrow t \bar{b}) + \Gamma(H^+ \rightarrow \tau^+ \nu) + \Gamma(H^+ \rightarrow c \bar{s}).$$

Here we present the various BRs of the charged Higgs boson decays:

$$\begin{aligned} BR(H^+ \rightarrow t \bar{b}) &< 1 \\ BR(H^+ \rightarrow \tau^+ \nu) &< 0.1 \\ BR(H^+ \rightarrow W^+ h^0) &< 0.01 \\ BR(H^+ \rightarrow \mu^+ \nu) &< 0.001 \\ BR(H^+ \rightarrow c \bar{s}) &< 0.0001, \end{aligned} \quad (12)$$

have been obtained, for $\tan\beta \sim 10$ and $m_{H^\pm} \sim 400 GeV$, in the MSSM [9]. These results are strongly sensitive to the choice of $\tan\beta$, and increasing values of $\tan\beta$ make $H^+ \rightarrow \tau^+ \nu$ and $H^+ \rightarrow \mu^+ \nu$ more dominant compared to the decay $H^+ \rightarrow W^+ h^0$. In [12], $H^+ \rightarrow W^+ h^0$ has been predicted at the order of $O(1)$, in the context of the effective lagrangian extension of the 2HDM.

Now we start to analyze the 3-body decay $H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-)$. In Fig.2, we present $\bar{\xi}_{N,\tau\mu}^E$ dependence of the decay width Γ for the decay $H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-)$, for the real coupling $\bar{\xi}_{N,\tau\mu}^E$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 GeV$, $m_{h^0} = 85 GeV$ and $m_{A^0} = 90 GeV$. Here solid (dashed, small dashed) line represents the case for the Higgs mass $m_{H^\pm} = 200$ (300, 400) GeV . The Γ is strongly sensitive to the coupling $\bar{\xi}_{N,\tau\mu}^E$, since it is proportional to square of this coupling. Furthermore, this figure shows that the Γ enhances with the increasing values of the charged Higgs mass, as expected. The Γ is at the order of magnitude of $10^{-11} GeV$ for $m_{H^\pm} = 200 GeV$ and it enhances to the values $10^{-5} GeV$ for $m_{H^\pm} = 400 GeV$, for even the intermediate values of $\bar{\xi}_{N,\tau\mu}^E$. Fig. 3 represents the m_{H^\pm} dependence of the Γ for the fixed values of $\bar{\xi}_{N,\tau\mu}^E = 1 GeV$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 GeV$, $m_{h^0} = 85 GeV$ and $m_{A^0} = 90 GeV$. It is observed that the Γ reaches

large values at the order of magnitude of 10^{-5} even for the small coupling $\bar{\xi}_{N,\tau\mu}^E = 1 \text{ GeV}$. This is interesting in the determination of the upper limit for the charged Higgs mass m_{H^\pm} and also the coupling $\bar{\xi}_{N,\tau\mu}^E$.

In Fig. 4 we present the total decay width Γ_{h^0} dependence of the decay width Γ for $\Gamma_{A^0} = \Gamma_{h^0}$, $\bar{\xi}_{N,\tau\mu}^E = 1 \text{ GeV}$, $m_{H^\pm} = 400 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. Γ is sensitive to Γ_{h^0} and decreases with its increasing values.

Here, we will make the same analysis for the lepton conserving process $H^+ \rightarrow W^+ \tau^- \tau^+$. Fig. 5 denotes the $\bar{\xi}_{N,\tau\tau}^E$ dependence of the decay width Γ , for the real coupling, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. Here solid (dashed, small dashed) line represents the case for the mass value $m_{H^\pm} = 200 (300, 400) \text{ GeV}$. The Γ is strongly sensitive to the coupling $\bar{\xi}_{N,\tau\tau}^E$. It enhances with the increasing values of the charged Higgs mass and it is placed in the interval $10^{-9} - 10^{-4} (\text{GeV})$ for $200(\text{GeV}) \leq m_{H^\pm} \leq 400(\text{GeV})$, at the intermediate values of the coupling $\bar{\xi}_{N,\tau\tau}^E$. In Fig. 6, we present the m_{H^\pm} dependence of the Γ for $\bar{\xi}_{N,\tau\tau}^E = 10 \text{ GeV}$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. From the figure it is seen that the Γ reaches the large values at the order of magnitude of 10^{-4} , even for the small coupling $\bar{\xi}_{N,\tau\tau}^E = 10 \text{ GeV}$. The determination of the upper limit for the coupling $\bar{\xi}_{N,\tau\tau}^E$ would be possible with the measurement of the process under consideration.

Fig. 7 represent Γ_{h^0} dependence of the decay width Γ for $\Gamma_{A^0} = \Gamma_{h^0}$, $\bar{\xi}_{N,\tau\tau}^E = 10 \text{ GeV}$, $m_{H^\pm} = 400 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. Γ is sensitive to Γ_{h^0} and decreases with its increasing values, similar to the LFV process $H^+ \rightarrow W^+ \tau^- \mu^+$.

Finally, we consider the coupling $\bar{\xi}_{N,l_i l_j}^E$ complex

$$\bar{\xi}_{N,l_i l_j}^E = |\bar{\xi}_{N,l_i l_j}^E| e^{i\theta_{l_i l_j}}, \quad (13)$$

and study the $\sin \theta_{l_i l_j}$ dependence of the decay width. We observe that the decay width is not sensitive to the complexity of the coupling $\bar{\xi}_{N,l_i l_j}^E$.

At this stage we would like to summarize our results:

- We predict the decay width $\Gamma(H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-))$ ($\Gamma(H^+ \rightarrow W^+ \tau^- \tau^+)$) in the interval $(10^{-11} - 10^{-5}) \text{ GeV}$ ($(10^{-9} - 10^{-4}) \text{ GeV}$), for $200(\text{GeV}) \leq m_{H^\pm} \leq 400(\text{GeV})$, at the intermediate values of the coupling $\bar{\xi}_{N,\tau\mu}^E \sim 5 \text{ GeV}$ ($\bar{\xi}_{N,\tau\tau}^E \sim 30 \text{ GeV}$). With the possible experimental measurement of the processes under consideration, strong clues would be obtained in the prediction of the upper limit of the coupling $\bar{\xi}_{N,\tau\mu}^E$ ($\bar{\xi}_{N,\tau\tau}^E$). This result is also informative in the determination of the charged Higgs mass, m_{H^\pm} .

- We observe that the decay width $\Gamma(H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-))$ ($\Gamma(H^+ \rightarrow W^+ \tau^- \tau^+)$) is strongly sensitive to the charged Higgs mass, m_{H^\pm} .
- We observe that the decay width $\Gamma(H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-))$ ($\Gamma(H^+ \rightarrow W^+ (\tau^- \tau^+))$) is not sensitive to the possible complexity of the Yukawa coupling.

Therefore, the experimental and theoretical analysis of these decays of the charged Higgs boson would ensure strong hints in the determination of the physics beyond the SM and the existing free parameters.

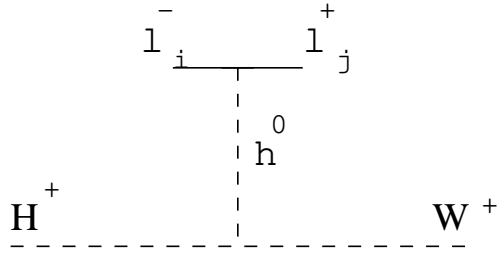
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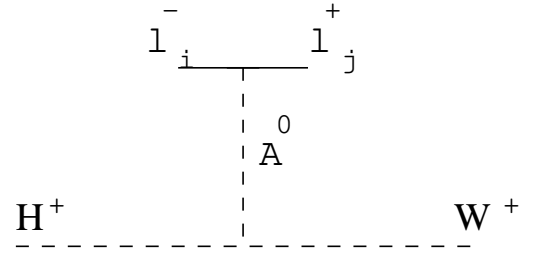
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(a)



(b)

Figure 1: Tree level diagrams contribute to $\Gamma(H^+ \rightarrow W^+ l_i^- l_j^+)$, $i = e, \mu, \tau$ decay in the model III version of 2HDM. Solid lines represent leptons, dashed lines represent the H^+, W^+, h_0 and A_0 fields).

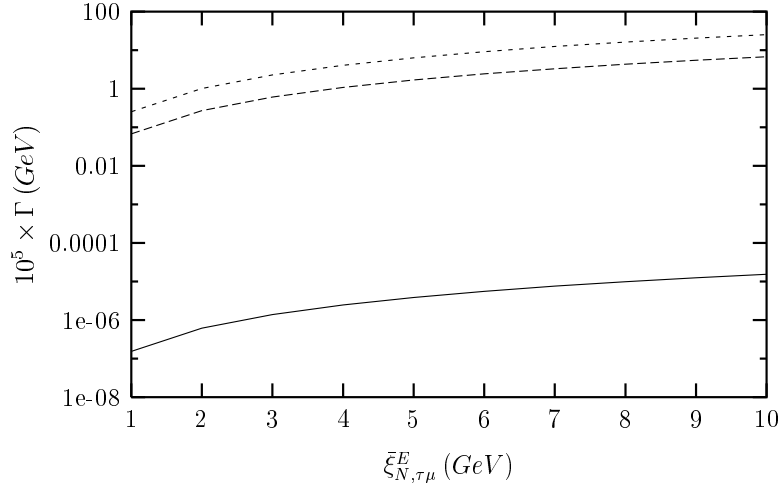


Figure 2: $\bar{\xi}_{N,\tau\mu}^E$ dependence of the decay width $\Gamma(H^+ \rightarrow W^+(\tau^-\mu^+ + \tau^+\mu^-))$, for the real coupling $\bar{\xi}_{N,\tau\mu}^E$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. Here solid (dashed, small dashed) line represents the case for the mass value $m_{H^\pm} = 200$ (300, 400) GeV .

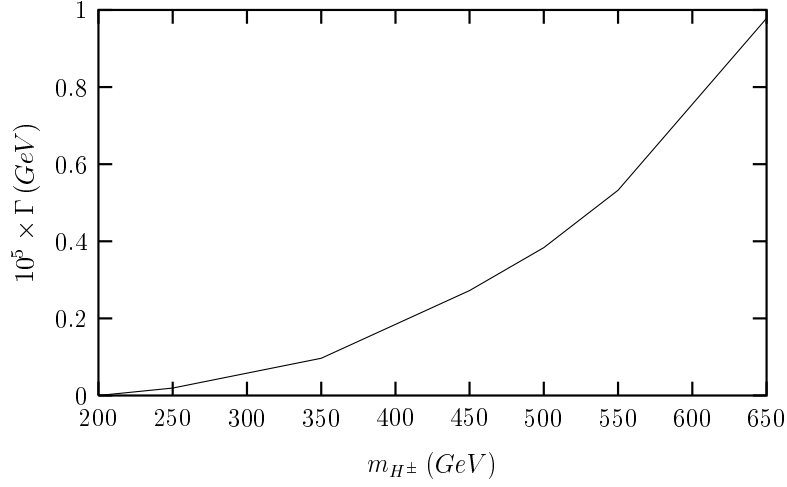


Figure 3: The m_{H^\pm} dependence of the decay width $\Gamma(H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-))$ for the fixed values of $\bar{\xi}_{N,\tau\mu}^E = 1 \text{ GeV}$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$.

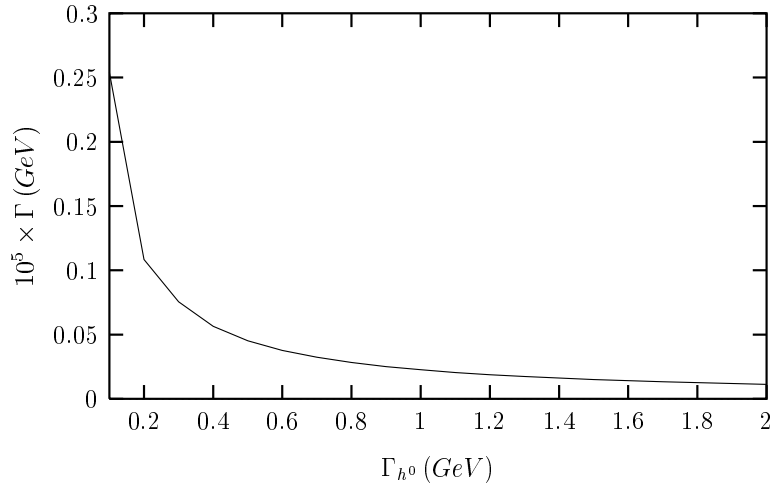


Figure 4: Γ_{h^0} dependence of the decay width $\Gamma(H^+ \rightarrow W^+ (\tau^- \mu^+ + \tau^+ \mu^-))$ for $\Gamma_{A^0} = \Gamma_{h^0}$, $\bar{\xi}_{N,\tau\mu}^E = 1 \text{ GeV}$, $m_{H^\pm} = 400 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$.

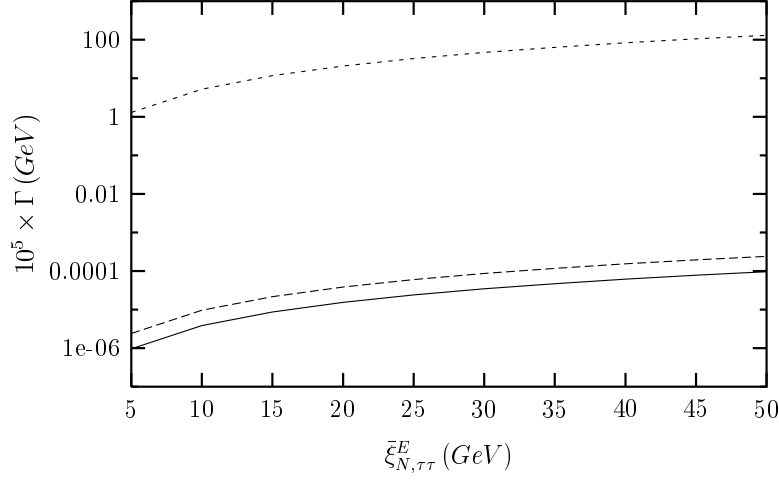


Figure 5: $\bar{\xi}_{N,\tau\tau}^E$ dependence of the decay width $\Gamma(H^+ \rightarrow W^+ \tau^- \tau^+)$, for the real coupling $\bar{\xi}_{N,\tau\tau}^E$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$. Here solid (dashed, small dashed) line represents the case for the mass value $m_{H^\pm} = 200$ (300, 400) GeV .

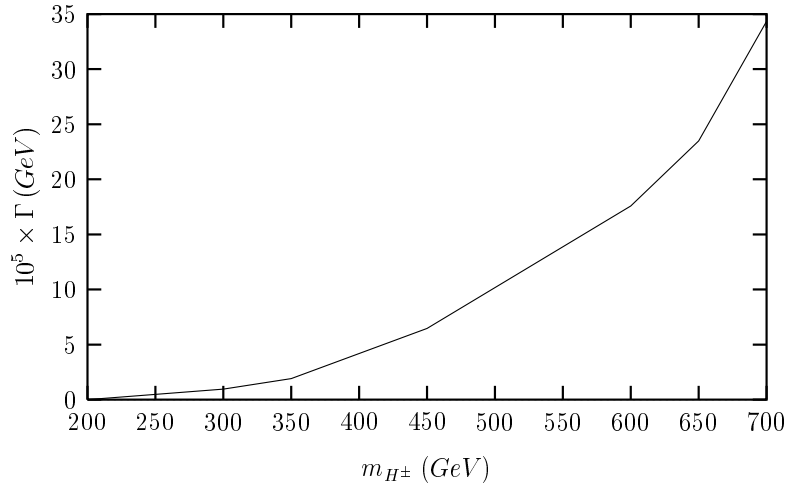


Figure 6: The m_{H^\pm} dependence of the decay width $\Gamma(H^+ \rightarrow W^+ \tau^- \tau^+)$ for the fixed values of $\bar{\xi}_{N,\tau\tau}^E = 10 \text{ GeV}$, $\Gamma_{A^0} = \Gamma_{h^0} = 0.1 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$.

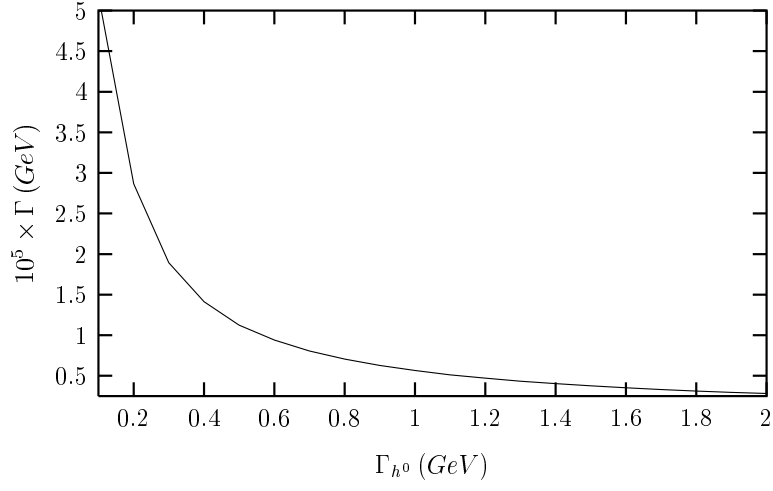


Figure 7: Γ_{h^0} dependence of the decay width $\Gamma(H^+ \rightarrow W^+ \tau^- \tau^+)$ for $\Gamma_{A^0} = \Gamma_{h^0}$, $\bar{\xi}_{N,\tau\tau}^E = 10 \text{ GeV}$, $m_{H^\pm} = 400 \text{ GeV}$, $m_{h^0} = 85 \text{ GeV}$ and $m_{A^0} = 90 \text{ GeV}$.