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Large squark-mixing impact on H^+ decay in the MSSM*

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ABSTRACT

We present a detailed study of the decays of the charged Higgs boson H^+ within the Minimal Supersymmetric Standard Model. We find that the supersymetric mode $\tilde{t}\tilde{b}$ can dominate the H^+ decays in a wide range of the model parameters due to the large Yukawa couplings and mixings of $\tilde{t}$ and $\tilde{b}$. Compared to the conventional modes $\tau^+\nu_\tau$ and $t\bar{b}$, this mode has very distinctive signatures. This could have a decisive impact on H^+ searches at future colliders. We find also that the QCD corrections to the $\tilde{t}\tilde{b}$ mode are significant, but that they do not invalidate our tree-level conclusion above.

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In the Minimal Supersymmetric Standard Model(MSSM)[3] two Higgs doublets are necessary, leading to five physical Higgs bosons $h^\circ, H^\circ, A^\circ$ and $H^\pm$[4,5]. In this article we present a detailed study of the $H^\pm$ decays within the MSSM [1,2]. If all supersymmetric(SUSY) particles are heavy enough, the H^+decays dominantly into $t\bar{b}$; the decays $H^+\to\tau^+\nu$ and/or $H^+\to W^+h^\circ$ are dominant below the $t\bar{b}$ threshold [4,6]. If the decays into charginos and neutralinos $H^+\to\tilde{\chi}_k^+\tilde{\chi}_l^\circ$ are kinematically allowed, they can be important in a sizable region of the MSSM parameters [7]. Here we extend these studies by including also the SUSY modes $H^+\to\tilde{t}_i\bar{\tilde{b}}_j(i,j=1,2)$. Here $\tilde{t}_i(\tilde{b}_j)$ are the scalar top(scalar bottom) mass eigenstates which are mixtures of $\tilde{t}_L$ and $\tilde{t}_R$ ($\tilde{b}_L$ and $\tilde{b}_R$).

The lighter stop $\tilde{t}_1$ can be much lighter than the other squarks and even lighter than the t quark due to large $\tilde{t}$-mixing being proportional to the top Yukawa coupling h_t and the $\tilde{t}$-mixing parameters A_t and μ[8]. Similarly the lighter sbottom $\tilde{b}_1$ can also be lighter than the other squarks. In the case of large $\tilde{t}$- and $\tilde{b}$-mixings one also expects the $H^+\tilde{t}\tilde{b}$ coupling to be large since it

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*This article is based on Refs.[1,2].

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is essentially proportional to the Yukawa couplings $h_{t,b}$ and the squark-mixing parameters $A_{t,b}$ and μ. Here we show explicitly that the mode $\tilde{t}\bar{\tilde{b}}$ can indeed dominate the H^+ decay in a wide range of the MSSM parameters as is expected by the observation above.

In the MSSM the properties of the charginos $\tilde{\chi}_i^{\pm}$(i=1,2) and neutralinos $\tilde{\chi}_j^{\circ}$ (j=1,...,4) are completely determined by the parameters M, μ and $\tan\beta = v_2/v_1$, assuming $M'=(5/3)\tan^2\theta_W M$. Here M(M') is the SU(2)(U(1)) gaugino mass, μ is the higgsino mass parameter, and $v_1(v_2)$ is the vacuum expectation value of the Higgs $H_1^{\circ}(H_2^{\circ})$[3]. Here $m_{\tilde{\chi}_1^+} < m_{\tilde{\chi}_2^+}$ and $m_{\tilde{\chi}_1^{\circ}} < \ldots < m_{\tilde{\chi}_4^{\circ}}$. To specify the squark sector the additional (soft SUSY breaking) parameters $M_{\tilde{Q}}, M_{\tilde{U}}, M_{\tilde{D}}$ (for each generation), and A(for each flavor) are neccesary. The mass matrix for stops reads[5]:

$$\mathcal{M}_{\tilde{t}}^2 = \begin{pmatrix} m_{\tilde{t}_L}^2 & a_t m_t \\ a_t m_t & m_{\tilde{t}_R}^2 \end{pmatrix} \tag{1}$$

with
$$m_{\tilde{t}_L}^2 = M_{\tilde{Q}}^2 + m_Z^2 \cos 2\beta (I_t^3 - e_t \sin^2\theta_W) + m_t^2 \tag{2}$$
$$m_{\tilde{t}_R}^2 = M_{\tilde{U}}^2 + m_Z^2 \cos 2\beta e_t \sin^2\theta_W + m_t^2 \tag{3}$$
$$a_t m_t = -m_t(A_t + \mu \cot\beta). \tag{4}$$

Here notice our sign conventions of μ and A; for μ we use the sign convention of ref.3. For the $\tilde{b}$ system analogous formulae hold but with $M_{\tilde{U}}^2$ replaced by $M_{\tilde{D}}^2$ in eq.(3), and instead of eq.(4)

$$a_b m_b = -m_b(A_b + \mu \tan\beta). \tag{5}$$

$\tilde{b}_L$-$\tilde{b}_R$ mixing may also be important for large A_b, μ and $\tan\beta$. Analogous formulae hold for the sleptons $\tilde{l}$ and $\tilde{\nu}$, e.g. for $\tilde{\nu}=\tilde{\nu}_{e,\mu,\tau}$

$$m_{\tilde{\nu}}^2 = M_{\tilde{L}}^2 + \frac{1}{2} m_Z^2 \cos 2\beta. \tag{6}$$

The masses and couplings of the Higgs bosons $H^{\pm}$, H°, h° and A°, including radiative corrections, are fixed by $m_{A^{\circ}}$, $\tan\beta$, m_t, $M_{\tilde{Q}}$, $M_{\tilde{U}}$, $M_{\tilde{D}}$, A_t, A_b and μ. $H^{\circ}(h^{\circ})$ and A° are the heavier(lighter) CP-even and CP-odd neutral Higgs

bosons, respectively. For the radiative corrections to the h° and H° masses we use the formulae of Ref.9. For m_{H^+} we take the tree-level relation $m_{H^+}^2 = m_{A^\circ}^2 + m_W^2$, because in all cases considered here the radiative corrections to m_{H^+} turn out to be very small.

In the following, we take for simplicity $M_{\tilde{Q}} = M_{\tilde{U}} = M_{\tilde{D}}$ (for the third generation), $M_{\tilde{L}} = M_{\tilde{Q}}$ ($M_{\tilde{L}}$ being a common soft-SUSY-breaking mass of all sleptons), and $A_t = A_b = A_\tau \equiv A$. Thus we have $m_{H^+}, m_t, M, \mu, \tan\beta, M_{\tilde{Q}}$, and A as free parameters of the MSSM. The theoretical and experimental constraints for the MSSM basic parameters are described in Ref.1.

We calculate the widths of all important modes of H^+ decay: $H^+ \to t\bar{b}, \tau^+\nu$, $c\bar{s}$, $\tilde{t}_i\bar{\tilde{b}}_j$, $\tilde{\chi}_k^+\tilde{\chi}_l^\circ$, W^+h°, $\tilde{l}^+\tilde{\nu}$. Formulae for these widths are found in [4]. As the squarks of the first two generations are supposed to be heavy, these decays will be strongly phase-space suppressed. Even if they were kinematically allowed, they would have a rate at most comparable to that of $H^+ \to \tilde{l}^+\tilde{\nu}$ (see Fig.2 below). Loop induced decay modes such as W^+Z° and $W^+\gamma$ are negligible[10]. The modes W^+H° and W^+A° are kinematically forbidden in the parameter region considered. In order not to vary too many parameters, in the following we fix m_t=150GeV and μ=300GeV, and take the values of M and $\tan\beta$ such that $m_{\tilde{\chi}_1^\circ} \simeq$ 50GeV.

In Fig.1 the contour lines for the branching ratio $B(\tilde{t}\bar{\tilde{b}}) = \Sigma_{i,j=1,2} B(H^+ \to \tilde{t}_i\bar{\tilde{b}}_j)$ are plotted in the A-$M_{\tilde{Q}}$ plane for (a) m_{H^+}=400GeV, $\tan\beta$=2, M=120GeV, and (b) m_{H^+}=200GeV, $\tan\beta$=12, M=110GeV. In the plots we have also required $m_{\tilde{t}_1,\tilde{b}_1,\tilde{l}} > m_{\tilde{\chi}_1^\circ}$ ($\simeq$ 50GeV). As can be seen the branching ratio $B(\tilde{t}\bar{\tilde{b}})$ can be larger than 70% in a sizable region. In this region this decay mode is much more important than the conventional decay modes.

In Fig.2 we show the β dependence of the important branching ratios for (a) $M_{\tilde{Q}}$=85GeV, A=-250GeV, $\tan\beta$=2, M=120GeV, and (b) $M_{\tilde{Q}}$=136GeV, A=-260 GeV, $\tan\beta$=12, M=110GeV. In these two cases we have : (a) $m_{\tilde{t}_1}$=116GeV, $m_{\tilde{t}_2}$=209GeV, $m_{\tilde{b}_1}$=81GeV, $m_{\tilde{b}_2}$=102GeV, $m_{\tilde{\chi}_1^+}$=94GeV, and (b) $m_{\tilde{t}_1}$=61GeV, $m_{\tilde{t}_2}$=272GeV, $m_{\tilde{b}_1}$=62GeV, $m_{\tilde{b}_2}$=193GeV, $m_{\tilde{\chi}_1^+}$=98GeV. We see that in both cases above the $\tilde{t}_1\bar{\tilde{b}}_1$ threshold the

$\tilde{t}\bar{\tilde{b}}$ mode dominates over the conventional modes $\tau+\nu$ (below the $t\bar{b}$ threshold) and $t\bar{b}$(above it). This is particularly remarkable in the case of Fig.2a, where the $\tilde{t}\bar{\tilde{b}}$ mode is disfavoured by phase space compared to the $t\bar{b}$ mode ($m_{\tilde{t}_1}+m_{\tilde{b}_1}=$ 197GeV > m_t+m_b =155GeV).

The reason for the dominance of the $\tilde{t}\bar{\tilde{b}}$ mode is as follows: The modes $t\bar{b}$ and $\tilde{t}\bar{\tilde{b}}$ (whose couplings to H^+ are essentially $\sim h_t\cos\beta + h_b\sin\beta$ and $\sim(A-\mu\tan\beta)h_t\cos\beta + (A-\mu\cot\beta)h_b\sin\beta$, respectively) can be strongly enhanced relative to the other modes due to the large Yukawa couplings $h_{t,b}$. In addition, the $\tilde{t}\bar{\tilde{b}}$ mode can be strongly enhanced relative to the $t\bar{b}$ mode in the case the $\tilde{q}$-mixing parameters A and μ are large. In this case $\tilde{t}_1$ and $\tilde{b}_1$ tend to be light.

Quite generally, $B(\tilde{t}\bar{\tilde{b}})$ depends on the parameters $M_{\tilde{Q}}, A, m_t, \mu, \tan\beta$ and more weakly on M. For a given m_{H^+} the strongest dependence is that on $M_{\tilde{Q}}$ to which $m_{\tilde{t}}$ and $m_{\tilde{b}}$ are sensitive (see Fig.1). $B(\tilde{t}\bar{\tilde{b}})$ can be quite large in a substantial part of the parameter region kinematically allowed for the $\tilde{t}\bar{\tilde{b}}$ mode. We find that the dominance of the $\tilde{t}\bar{\tilde{b}}$ mode is fairly insensitive to the assumption $M_{\tilde{Q}}=M_{\tilde{L}}$. As seen in Fig.1 the dependence on A is also strong. Concerning the assumption $A_t=A_b=A_\tau$, we have found no significant change of $B(\tilde{t}\bar{\tilde{b}})$ as compared to Fig.2, when we take $A_{b,\tau}/A_t = \pm 0.5, \pm 1, \pm 2$ keeping $A_t=A$. The dependence of the $H^+\tilde{t}\bar{\tilde{b}}$ couplings (and $B(\tilde{t}\bar{\tilde{b}})$) on the parameters μ, $\tan\beta$ and m_t is essentially given by the terms $(A-\mu\tan\beta)h_t\cos\beta$ and $(A-\mu\cot\beta)$ $h_b\sin\beta$ as mentioned above, where $h_t \propto m_t$. Hence <u>the dominance of the $\tilde{t}\bar{\tilde{b}}$ mode becomes more pronounced as m_t and/or μ increase</u>. We also find that $B(\tilde{t}\bar{\tilde{b}})$ is nearly invariant under $(\mu, A)\to(-\mu, -A)$.

As for the signatures of the H^+ dcay, typical $\tilde{t}\bar{\tilde{b}}$ signals are shown in Table 1. They have to be compared with the conventional $t\bar{b}$ signals $H^+\to t\bar{b}$ $\to(W^+b)\bar{b} \to f\bar{f}'b\bar{b}$, i.e. 4 jets(j's) or 2 j's + 1 isolated charged lepton (l^+) + missing energy-momentum ($\not{p}$). Note that $B(\tilde{t}_1\to c\tilde{\chi}_1^0) \simeq 1$ if $m_{\tilde{t}_1}<$ $m_{\tilde{\chi}_1^+}, \tilde{l}, \tilde{\nu}, \tilde{b}_1$ <u>and</u> $m_{\tilde{\chi}_1^0}<m_{\tilde{t}_1}<m_{\tilde{\chi}_1^0}+m_{t,W}$ (in cases (a)-(d)), and $B(\tilde{t}_1\to c\tilde{\chi}_1^0)$ $\simeq 0$ otherwise (in cases (e)-(h))[11]. As seen in Table 1, the $\tilde{t}\bar{\tilde{b}}$ signals have general features which distinguish them from the $t\bar{b}$ signals: (i) more $\not{p}$

due to the emission of two LSP's (i.e. $\tilde{\chi}_1^0$'s) and hence less energy-momentum of jets and the isolated l^+ in case of a short decay chain, or (ii) more jets and/or more isolated $l^\pm$'s in case of a longer decay chain. Moreover, depending on the values of the MSSM parameters, the $\tilde{t}\bar{\tilde{b}}$ signals could have remarkable features as see in Table 1: (i)the semileptonic branching ratio of H^+ decay with an isolated l^+ can vary between ~ 0 (e.g. in case $B(H^+\to \tilde{t}_1\bar{\tilde{b}}_1\to c\tilde{\chi}_1^0\bar{b}\tilde{\chi}_1^0) \sim 1$) and ~ 1 (e.g. in case $B(H^+\to \tilde{t}_1\bar{\tilde{b}}_1\to(bl^+\tilde{\nu})(\bar{b}\tilde{\chi}_1^0)\to bl^+\nu\tilde{\chi}_1^0\bar{b}\tilde{\chi}_1^0) \sim 1$); (ii)production of a single "wrong"-sign l^- in H^+ decay (e.g. in case (d,h)) or same-sign dileptons $l^+l'^+$ (e.g. in case (h)), which could yield same-sign isolated dilepton events e^+e^-(or $\gamma\gamma$) $\to H^+H^-\to$ ($l^-l'^-$ or $l^+l'^+$) + j's + $\not{p}$; and so on. The identification of the sign of charged leptons and the tagging of b- ans c-quark jets, h^0, Z^0 and $W^\pm$ would be very useful [4,12] in discriminating the $\tilde{t}\bar{\tilde{b}}$ signals from the $t\bar{b}$ signals as well as in suppressing the background.

The ideal place for $H^\pm$ search would be an e^+e^-(or $\gamma\gamma$) collider[4,12]. If the $\tilde{t}\bar{\tilde{b}}$ mode dominates the H^+ decay, it decisively influences the signatures. If $\tilde{t}$ and $\tilde{b}$ are relatively light, they will most likely be discovered first in pair production either at LEP200 or a linear e^+e^- collider at a higher energy. At hadron colliders it is in general difficult to detect the $H^\pm$[4]. However, if $\tilde{t}$ and $\tilde{b}$ were discovered first, the situation might improve since the $\tilde{t}\bar{\tilde{b}}$ mode could provide also here additional (distinctive) signatures for H^+. Clearly it is necessary to perform a detailed Monte Carlo study to separate the signals from the background. Such a study is , however, beyond the scope of this article.

So far we have not included QCD radiative corrections. The standard QCD corrections are negative and very large for the width of $H^+\to c\bar{s}$[13]. In our case this mode is negligible. They can be large (+10% to -50%) for the width of $H^+\to t\bar{b}$[13]. This suggests that the QCD corrections to $H^+\to \tilde{t}\bar{\tilde{b}}$ could also be large. Therefore it should be examined whether the tree-level result shown above remains valid after including the QCD corrections. In Ref.2 we have calculated the $O(\alpha_s)$ QCD corrections to the width of $H^+\to$

$\tilde{t}_i\bar{\tilde{b}}_j$ within the MSSM. We have obtained the complete $O(\alpha s)$ SUSY-QCD corrected width in the $\overline{DR}$ renormalization scheme(i.e. the $\overline{MS}$ scheme with dimansional reduction) including all quark mass terms and $\tilde{q}_L$-$\tilde{q}_R$ mixings. We have found that the corrections to the $\tilde{t}\bar{\tilde{b}}$ width are significant but that the $\tilde{t}\bar{\tilde{b}}$ mode is still dominant in a wide parameter range (as seen in Fig.3 for example)[2].

We have shown that the SUSY mode $\tilde{t}\bar{\tilde{b}}$ can be the most important H^+ decay channel in a large allowed region of the MSSM parameter space due to large t and b quark Yukawa couplings and large $\tilde{t}$- and $\tilde{b}$-mixings. The $\tilde{t}\bar{\tilde{b}}$ mode has very distinctive signatures as compared to the conventional modes $\tau^+\nu$ and $t\bar{b}$. This could decisively influence the $H^\pm$ search at future colliders. We have also shown that the QCD corrections to the $\tilde{t}\bar{\tilde{b}}$ mode are significant, but that they do not invalidate our tree-level conclusion above. Finally, we can also expect similar implications for the neutral Higgs boson search scince the structures of the couplings of the neutral Higgs bosons (H°,$h^\circ$and A°) to $\tilde{t}\bar{\tilde{t}}$ and $\tilde{b}\bar{\tilde{b}}$ are essentially the same as those of the H^+ to $\tilde{t}\bar{\tilde{b}}$.

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Table 1: The typical $\tilde{t}\bar{\tilde{b}}$ signals of the H^+ decay in comparison to the conventional $t\bar{b}$ signals. The decay chains $(a-d)$ are possible only if $m_{\tilde{t}_1} < m_{\tilde{\chi}_1^+,\tilde{l},\tilde{\nu},\tilde{b}_1}$ and $m_{\tilde{\chi}_1^0} < m_{\tilde{t}_1} < m_{\tilde{\chi}_1^0} + m_{t,W}$. The chains $(f-h)$ are possible if $m_{\tilde{t}_1} > m_{\tilde{\chi}_1^+}$; (e) is possible if $m_{\tilde{t}_1} > m_{\tilde{\chi}_1^0} + m_t$. $\not{p}, j, l^\pm, Z^{(*)}$, and f denote missing energy-momentum, jet, isolated charged lepton, real (or virtual) Z^0 boson, and $(q, l^\pm, \nu)$, respectively.

Typical decay chains	Signatures
(a) $H^+ \to \begin{cases} \tilde{t}_1 \to c\tilde{\chi}_1^0 \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_1^0 \end{cases}$	2 j's + $\not{p}$ (more $\not{p}$, less b activity)
(b) $H^+ \to \begin{cases} \tilde{t}_1 \to c\tilde{\chi}_1^0 \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_2^0 \to \left[\begin{array}{l} \bar{b}(Z^{(*)}\tilde{\chi}_1^0) \to \bar{b}(f\bar{f})\tilde{\chi}_1^0 \\ \text{or} \\ \bar{b}(h^0\tilde{\chi}_1^0) \to \bar{b}(b\bar{b} \text{ or } \tau^+\tau^-)\tilde{\chi}_1^0 \end{array} \right. \end{cases}$	4 j's + $\not{p}$; 2 j's + $\not{p}$; 2 j's + l^+l^- + $\not{p}$ (Z^0 or h^0 emission; more b activity if h^0 or $Z^{(*)} \to b\bar{b}$; less b activity if h^0 or $Z^{(*)} \to l^+l^-$ or $\nu\bar{\nu}$)
(c) $H^+ \to \begin{cases} \tilde{t}_2 \to \left[\begin{array}{l} \tilde{t}_1 Z^0 \to (c\tilde{\chi}_1^0)(f\bar{f}) \\ \text{or} \\ \tilde{t}_1 h^0 \to (c\tilde{\chi}_1^0)(b\bar{b} \text{ or } \tau^+\tau^-) \end{array} \right. \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_1^0 \end{cases}$	4 j's + $\not{p}$; 2 j's + $\not{p}$; 2 j's + l^+l^- + $\not{p}$ (Z^0 or h^0 emission; more b activity if h^0 or $Z^0 \to b\bar{b}$; less b activity if h^0 or $Z^0 \to l^+l^-$ or $\nu\bar{\nu}$)
(d) $H^+ \to \begin{cases} \tilde{t}_1 \to c\tilde{\chi}_1^0 \\ \bar{\tilde{b}}_2 \to \bar{t}\tilde{\chi}_1^+ \to (\bar{b}W^-)(f\bar{f}'\tilde{\chi}_1^0) \to \bar{b}(f\bar{f}')f\bar{f}'\tilde{\chi}_1^0 \end{cases}$	6 j's + $\not{p}$; 4j's + $l^\pm$ + $\not{p}$; 2 j's + $l^+l'^-$ + $\not{p}$ ("wrong"-sign single lepton l^-; less b activity)
(e) $H^+ \to \begin{cases} \tilde{t}_{1,2} \to t\tilde{\chi}_1^0 \to (bW^+)\tilde{\chi}_1^0 \to b(f\bar{f}')\tilde{\chi}_1^0 \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_1^0 \end{cases}$	4 j's + $\not{p}$; 2 j's + l^+ + $\not{p}$ (more $\not{p}$)
(f) $H^+ \to \begin{cases} \tilde{t}_{1,2} \to b\tilde{\chi}_1^+ \to b(f\bar{f}'\tilde{\chi}_1^0) \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_1^0 \end{cases}$	4 j's + $\not{p}$; 2 j's + l^+ + $\not{p}$ (more $\not{p}$)
(g) $H^+ \to \begin{cases} \tilde{t}_{1,2} \to b\tilde{\chi}_1^+ \to b(f\bar{f}'\tilde{\chi}_1^0) \\ \bar{\tilde{b}}_{1,2} \to \bar{b}\tilde{\chi}_2^0 \to \left[\begin{array}{l} \bar{b}(Z^{(*)}\tilde{\chi}_1^0) \to \bar{b}(f\bar{f})\tilde{\chi}_1^0 \\ \text{or} \\ \bar{b}(h^0\tilde{\chi}_1^0) \to \bar{b}(b\bar{b} \text{ or } \tau^+\tau^-)\tilde{\chi}_1^0 \end{array} \right. \end{cases}$	6 j's + $\not{p}$; 4 j's + l^+l^- + $\not{p}$; 4 j's + l^+ + $\not{p}$; 4 j's + $\not{p}$; 2 j's + $l^+l^-l'^+$ + $\not{p}$; 2 j's + l^+ + $\not{p}$ (Z^0 or h^0 emission; more b acitivity if h^0 or $Z^{(*)} \to b\bar{b}$; trilepton)
(h) $H^+ \to \begin{cases} \tilde{t}_{1,2} \to b\tilde{\chi}_1^+ \to b(f\bar{f}'\tilde{\chi}_1^0) \\ \bar{\tilde{b}}_2 \to \bar{t}\tilde{\chi}_1^+ \to (\bar{b}W^-)(f\bar{f}'\tilde{\chi}_1^0) \to \bar{b}(f\bar{f}')f\bar{f}'\tilde{\chi}_1^0 \end{cases}$	8 j's + $\not{p}$; 6 j's + $l^\pm$ + $\not{p}$; 4 j's + $l^+l'^\pm$ + $\not{p}$; 2 j's + $l^+l'^+l''^-$ + $\not{p}$ ("wrong"-sign single lepton l^-; same-sign dilepton; trilepton)

Figure Captions

Fig.1: Contour lines of $B(\tilde{t}\bar{\tilde{b}})$ in the $A - M_{\tilde{Q}}$ plane for (m_{H^+} (GeV), m_t (GeV), M (GeV), μ (GeV), $\tan\beta$) = (400, 150, 120, 300, 2) (a) and (200, 150, 110, 300, 12) (b). The contour of $B(\tilde{t}\bar{\tilde{b}}) = 0$ (dotted line) corresponds to that of $m_{\tilde{t}_1} + m_{\tilde{b}_1} = m_{H^+}$. The shaded area is excluded by the LEP bounds $m_{\tilde{q},\tilde{l},\tilde{\nu}} \gtrsim 45$ GeV and the requirement $m_{\tilde{t}_1,\tilde{b}_1,\tilde{l}} > m_{\tilde{\chi}_1^0} (\simeq 50$ GeV).

Fig.2: The m_{H^+} dependence of all important branching ratios of the H^+ decay for (m_t (GeV), M (GeV), μ (GeV), $\tan\beta$, $M_{\tilde{Q}}$ (GeV), A (GeV)) = (150, 120, 300, 2, 85, -250) (a) and (150, 110, 300, 12, 136, -260) (b). The sum over all mass eigenstates and/or flavours is taken for $B(\tilde{t}\bar{\tilde{b}}), B(\tilde{\chi}^+\tilde{\chi}^0)$, and $B(\tilde{l}^+\tilde{\nu})$. $B(\tilde{t}_1\bar{\tilde{b}}_{1,2})$ are also shown separately. The arrow shows the $t\bar{b}$ threshold.

Fig.3: The m_{H^+} dependence of the tree-level width $\Gamma^{\rm tree}(\Sigma\tilde{t}_i\bar{\tilde{b}}_j)$ (dashed line), the corrected width $\Gamma^{\rm corr}(\Sigma\tilde{t}_i\bar{\tilde{b}}_j)$ (solid line), and the tree-level branching ratio $B^{\rm tree}(H^+\to\Sigma\tilde{t}_i\bar{\tilde{b}}_j) \equiv B^{\rm tree}(\tilde{t}\bar{\tilde{b}})$ (short-dashed line) for (m_t(pole), M, μ, $\tan\beta$, $M_{\tilde{Q}}$, A) = (180GeV, 120GeV, 300GeV, 2, 250GeV, -650 GeV). $\Gamma^{\rm tree}(\tilde{t}_i\bar{\tilde{b}}_j)$ (dashed lines) and $\Gamma^{\rm corr}(\tilde{t}_i\bar{\tilde{b}}_j)$ (solid lines) are separately shown for (i,j)=(1,1) and (1,2).

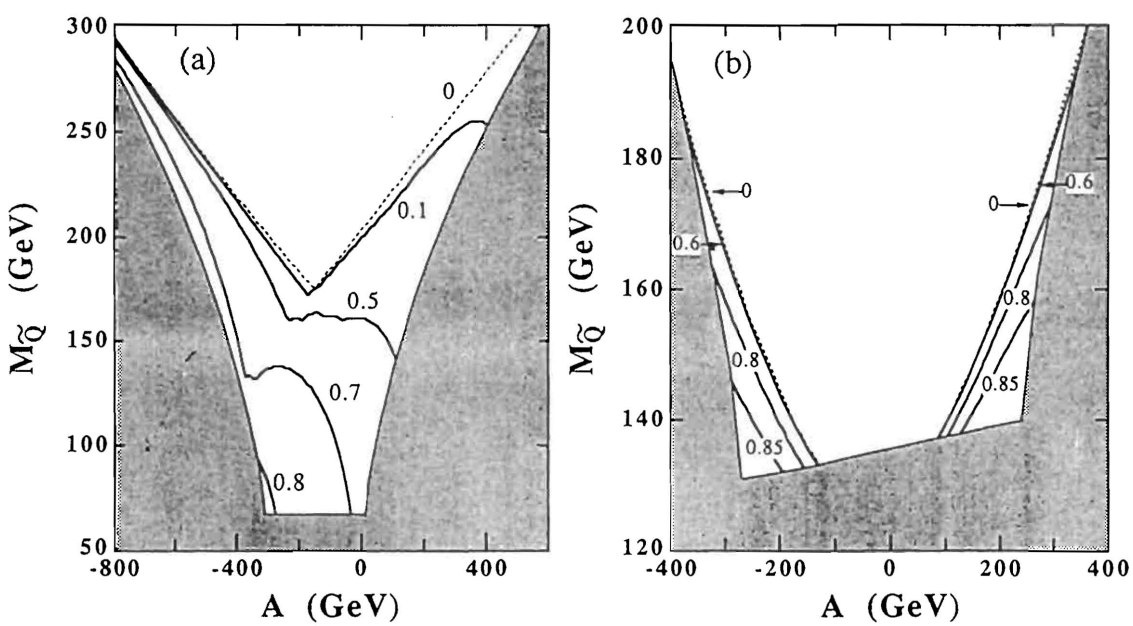

Fig.1

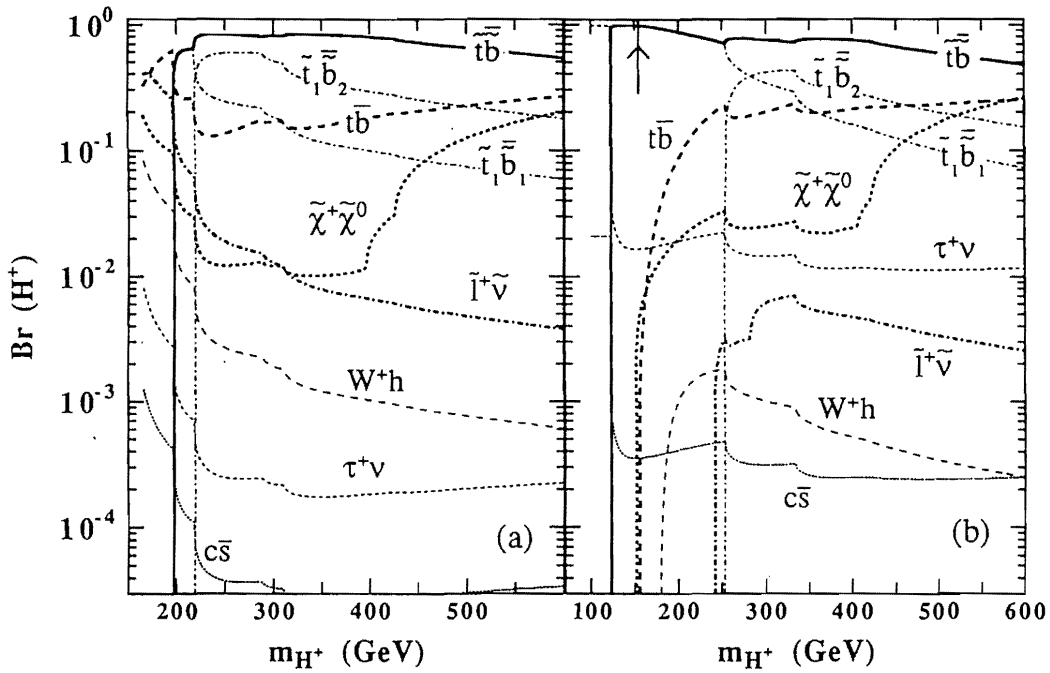
Br (H+)
mH+ (GeV)
(a)
(b)
tb̄
t̃1b̃2
t̃1b̃1
χ̃+χ̃0
l̃+ν̃
W+h
τ+ν
cs̄

Fig.2

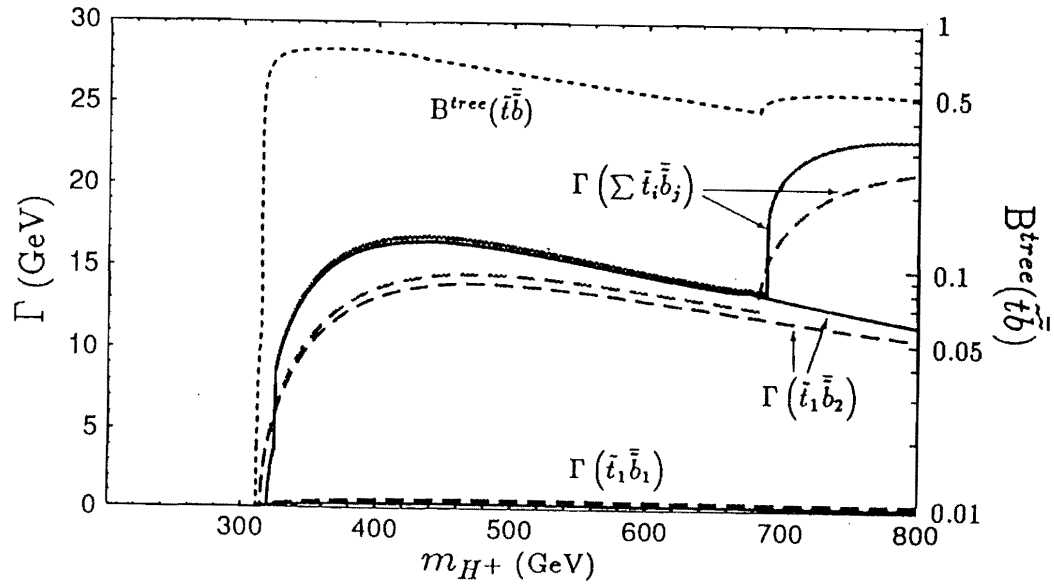
Γ (GeV)
mH+ (GeV)
Btree(t̃b̃)
Γ (Σ t̃ib̃j)
Γ (t̃1b̃2)
Γ (t̃1b̃1)

Fig.3