Looking for the Charged Higgs Boson @LHC

hep-ph/0406102
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1. Charged Higgs Boson in MSSM

2. $H^\pm$ Lighter than top(t): $t \to b H^+$

3. $H^\pm$ Heavier " " : NLO QCD CORRECTION

$H^+ \longrightarrow t\bar{b}$
$\tau^+\nu$
W^+h^0

4. Beyond the MSSM

- SUSY QCD CORRECTION

MSSM $\Rightarrow$ $\begin{pmatrix}\phi_1^0\\ \phi_1^-\end{pmatrix}_{b,\tau..}$ $\begin{pmatrix}\phi_2^+\\ \phi_2^0\end{pmatrix}_{t,c...}$ $\tan\beta = \frac{\langle\phi_2^0\rangle}{\langle\phi_1^0\rangle}$

8 states $-$ 3 Goldstone $= 5 \Rightarrow h^0, H^0, A^0$ & $H^\pm = \phi_2^\pm \cos\beta - \phi_1^\pm \sin\beta$

$$\mathcal{L} = \frac{g}{\sqrt{2}\,M_W} H^+ \left\{ \cot\beta \underbrace{m_t}_{170\,GeV} \bar{t} b_L + \tan\beta \underbrace{m_b}_{3} \bar{t} b_R \right\} + \text{h.c.}$$

$$\text{QCD Corr.} \Rightarrow \quad \underbrace{m_c}_{1} \bar{c} s_L + \underbrace{m_\tau}_{2} \bar{\nu}_\tau \tau_R$$

$m_t > M_{H^\pm} \Rightarrow$ large $t \to b H^+$ at

$\tan\beta \lesssim 1$ & $\gtrsim m_t/m_b$

$H^\pm$ Decay:

$\tan\beta < 1$ | $\tan\beta > 1$ ✓

Keith, Ma, Roy PR '97

X $H^\pm \to c s$ (CDF, DØ)

$H^\pm \to \tau \nu$

$H^\pm \to \bar{t}^* b \to W^\pm \bar{b} b$

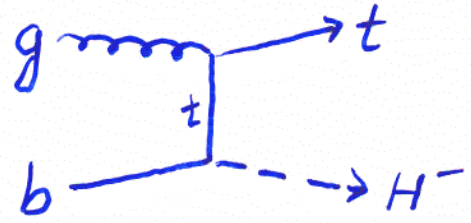
Dominant for $M_{H^\pm} > 130$ GeV

Ma, Roy & Wudka: PRL, 80, 1162 '98

Moretti & Sterling: PL '95 ; Djouadi, Kalinowski & Zerwas: ZP '96

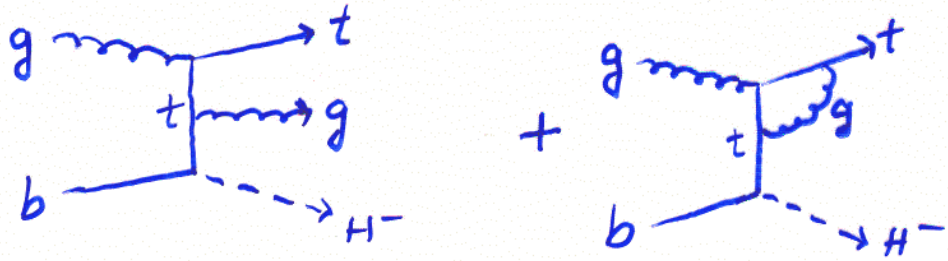
Production of Heavy $H^\pm$ ($M_{H^\pm} > m_t$) @ LHC

LO



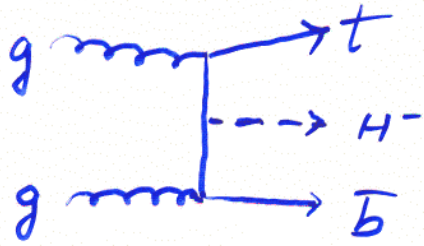
NLO QCD CORRN. $\Rightarrow$ $K \simeq 1.5$ Zhu : PR '03, Plehn : PR '03, " etal : hep-ph/0312286

a)



$\Rightarrow$ 0.8 (0.6)

b)



– Overlapping cont. from LO $\Rightarrow -0.3$ ($\simeq 0$)

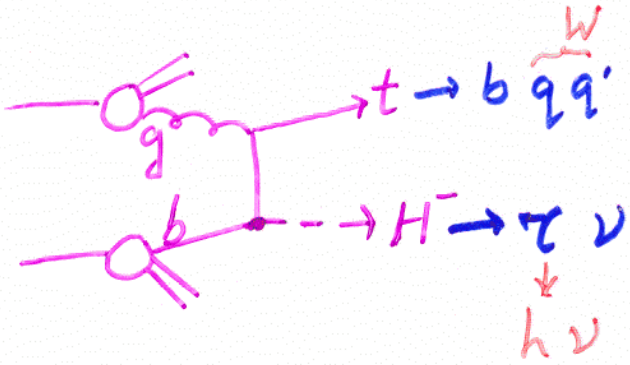
$\mu_R = \mu_F = M_{H^\pm} + m_t$

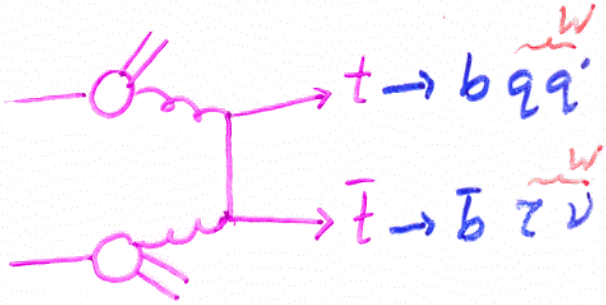
$(\mu_F = (M_{H^\pm} + m_t)/5)$

Decay Modes ($M_{H^\pm} > 200$ GeV)

$H^+ \to t\bar{b}$	$H^+ \to \tau\nu$	$H^+ \to h^0 W^+$
BR $\gtrsim$ 80 %	$\sim$ 20 %	$\lesssim$ 5 %
(QCD Bg)	$\tan\beta \gtrsim 15$ (τ Pol. Effect)	$\tan\beta \sim 2$??
3 b-tag ch : Moretti & Roy PL '99	Roy, PL '99	Drees, Guchait & Roy, PL '99
4 b-tag ch : Miller, Moretti, Roy & Sterling, PR '00		

Heavy Charged Higgs Search @ LHC via τ decay





b-tag ($\epsilon_b \sim 0.5$), $M_{qq'} = M_W \pm 15$ GeV, $M_{bqq'} = m_t \pm 25$

$Bg \sim 10^{2-3} \times Sig$!

- Very Hard $p_{\tau\text{-jet}}^T \equiv p_h^T > 100$ GeV ($M_{H^\pm} > 200$ GeV)

  (Enhanced via τ-pol. effect)

- $\phi_{\tau \not{p}_T}$ dist $\Rightarrow$ backward peak for Sig.
  forward " " Bg.

- $m_T = 2 p_\tau^T \not{p}_T (1 - \cos\phi_{\tau \not{p}_T}) \longrightarrow M_{H^\pm}$ for Sig.
  $\longrightarrow M_W$ for Bg.

1-Prong hadronic τ-jet (80% of τ_h)

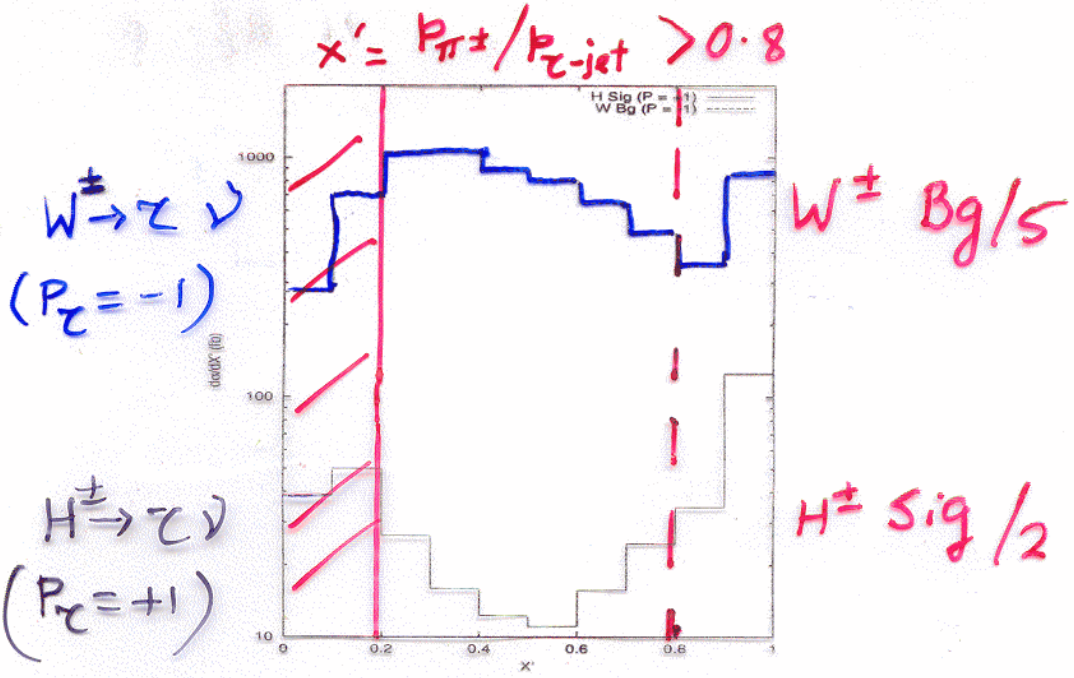


Figure 5: The LHC cross-section for a 300 GeV $H^\pm$ signal at $\tan\beta = 40$ shown along with the $t\bar{t}$ background in the 1-prong τ-jet channel, as functions of the τ-jet momentum fraction carried by the charged pion.

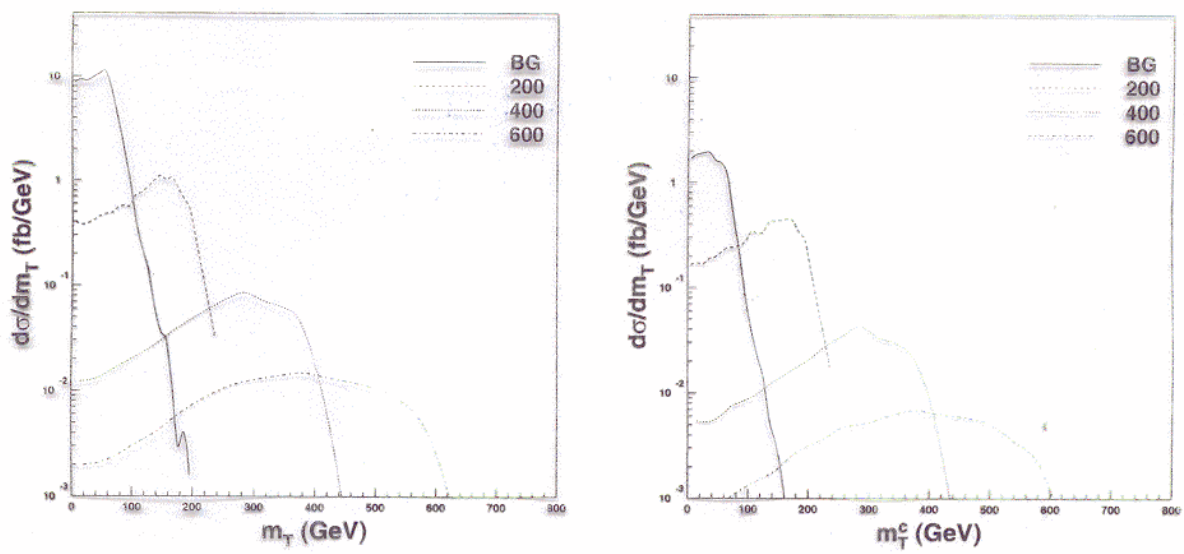
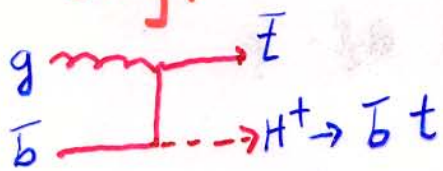


Figure 6: Distributions of the H^+ signal and the $t\bar{t}$ background cross-sections in the transverse mass of the τ-jet with $\not{p}_T$ for (left) all 1-prong τ-jets, and (right) those with the charged pion carrying > 80% of the τ-jet momentum ($M_{H^\pm}$ = 200,400,600 GeV and $\tan\beta = 40$) [23].

Detecting Heavy $H^\pm$ at LHC with 3 b-Tags

Moretti & Roy : Phys Lett. '99

Sig.



$g\bar{b} \to \bar{t}\,H^+ \to \bar{t}\,\bar{b}\,t$

$\bar{b}\,l^-\bar{\nu}$ $\quad b\,\bar{q}\,q$

Bg.

$gg \to \bar{t}\,t\,\bar{b}\,b$

$gb \to \bar{t}\,t\,b$

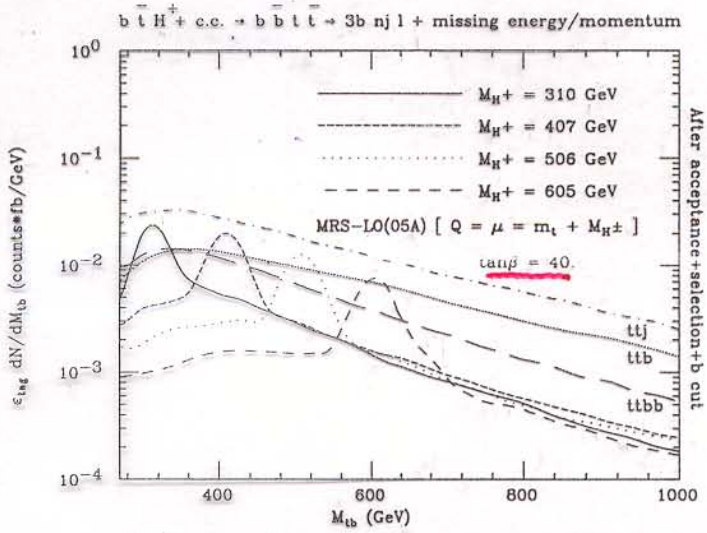
$gg \to \bar{t}\,t\,q$

q mistagged as b ~ 1%

$P_T > 30$ GeV

$|\eta| < 2.5$

$\Delta R > 0.4$



~ Sig (tanβ = 1.5)

$M_{t\,b_3}$

$P_T^{b3} > 80$ GeV

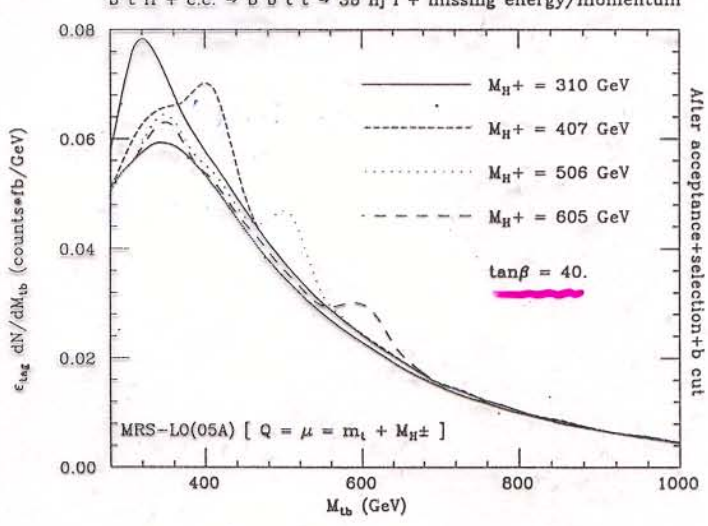


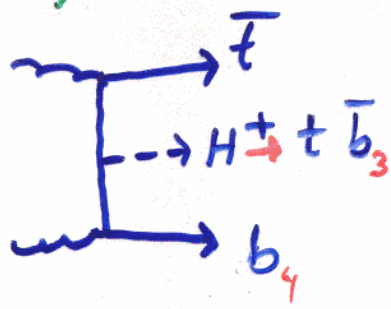
Figure 4: (Top plot) Differential distribution (two entries per each event generated) in the reconstructed charged Higgs mass for the signal (2)–(3), corresponding to four selected values of $M_{H^\pm}$ in the heavy mass range, for $\tan\beta = 40$, after the acceptance and selection cuts described in the text: i.e. eqs. (15)–(16) and steps (a)–(d) as well as the transverse momentum cut (17) on the b-jet accompanying the top-antitop pair. The PDF set used was MRS-LO(05A) with renormalisation and factorisation scales set equal to $m_t + M_{H^\pm}$. The (fine-dotted)[long-dashed]{dot-dashed} curve represents the shape of the background process ((10))[(11)]{(12)}. (Bottom plot) As above, after summing each signal to all backgrounds. Tagging efficiencies have been included here, in both plots.

Detecting Heavy $H^\pm$ at LHC with 4 b-quark Tags

Miller, Moretti, Roy & Sterling: Phys. Rev. D (2000)

Sig: $gg \to \bar{t}\, b\, H^+ \to \bar{t}\, b\, \bar{b}\, t$

$\bar{t} \to \bar{b} l^- \nu$; $t \to b \bar{q} q$



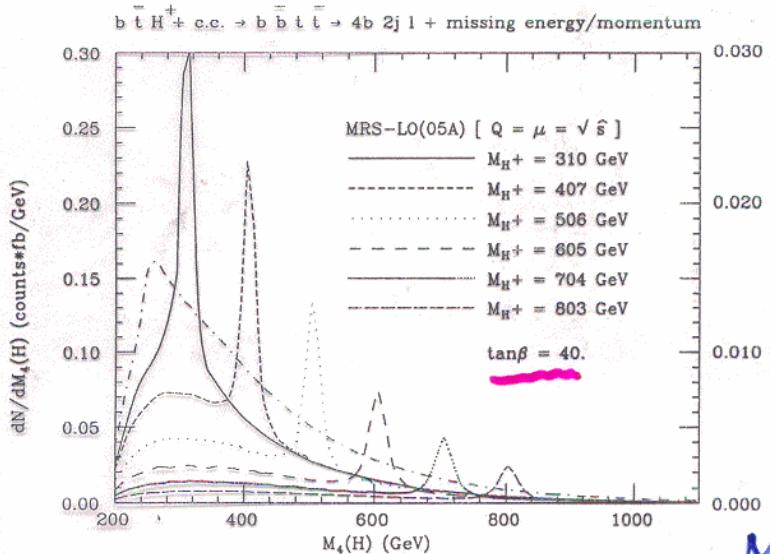
Bg: $gg \to \bar{t}\, t\, q^* \to \bar{t}\, t\, \bar{b}_3 b_4$

$p_T > 20$ GeV

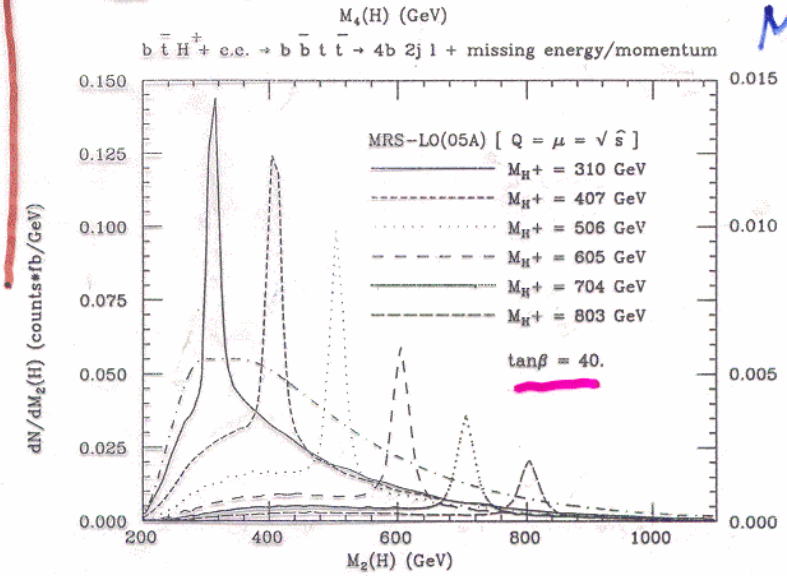
$E_{b^3} > 120$ GeV

$M_{bb} > $ "

$\cos\theta_{bb} < 0.75$



M_{tb}

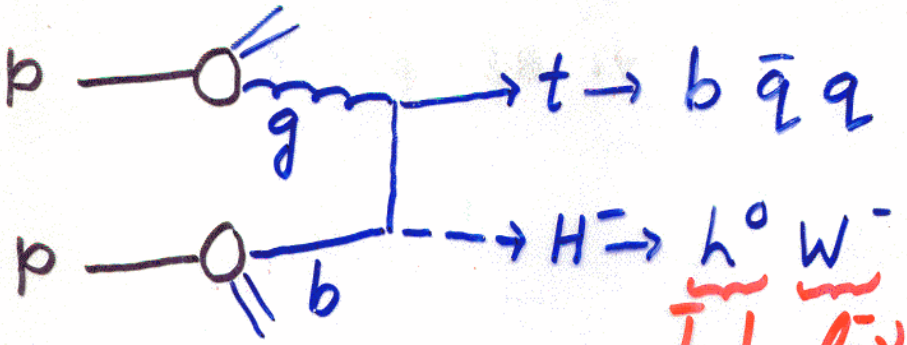


M_{tb^3}

Figure 4: Differential distributions in the reconstructed charged Higgs mass for process (4) (and its charge conjugate) in the decay channel (31) for six selected values of $M_{H^\pm}$ in the heavy mass range, for $\tan\beta = 40$. Acceptance and selection cuts have been implemented here, along with the additional cuts (39) on the $2b$–system accompanying the $t\bar{t}$ pair. The PDF set used was MRS-LO(05A) with renormalisation and factorisation scales set equal to the partonic CM energy. The seventh (dot-dashed) curve represents the shape of the background (5) yielding the same signature (31). Normalisation is to the total cross sections times the number of possible '$2\,b + 2$ jet mass' combinations: four (top) and two (bottom). The right-hand scale corresponds to a b-tagging efficiency factor of $\epsilon_b^4 = 0.1$, i.e., $\epsilon_b = 56\%$.

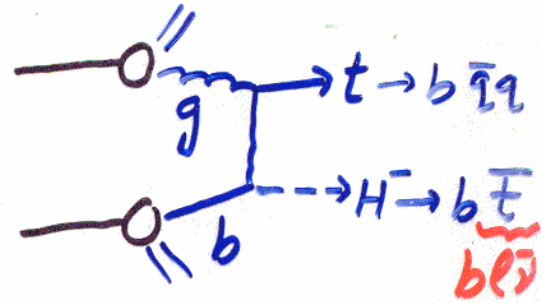
Sig. of $H^{\pm} \to h^0 W^{\pm}$ Decay at LHC

Drees, Guchait & Roy: Phys. Lett. '99



5 % BR

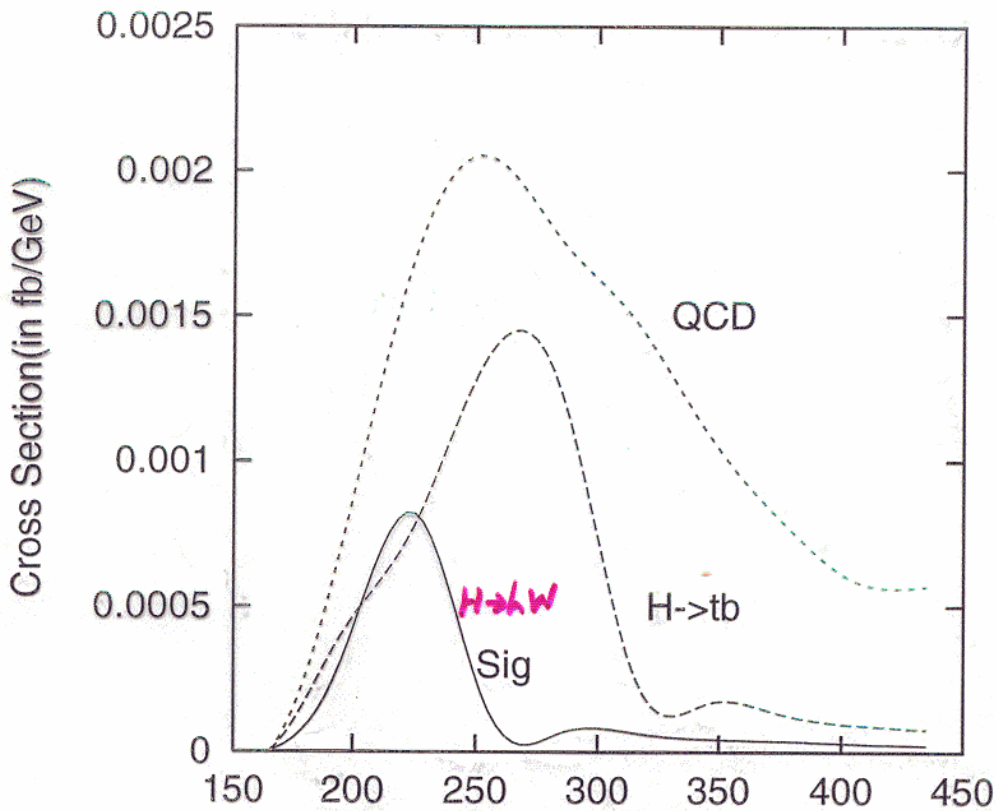
Sig.



+

QCD Bg.

MSSM: $m_{h^0} > 110$, $\tan\beta = 2\text{-}4$ $\Rightarrow$ $m_{h^0} + M_W > 190$ GeV



$H^{\pm} \to t b$

$h^0 W$

NMSSM

$t \to b H^{\pm}$ (140 GeV)

$W^{\pm} h^0$ (50 GeV)

(~~CP~~ MSSM)

Assamagan, Ghosh, Godbole & Roy...

Figure 2: The $H^{\pm} \to W h^0$ signal cross-section at LHC is shown against the reconstructed $H^{\pm}$ mass for $m_{H^{\pm}} = 220$ GeV and $\tan\beta = 2$ along with $H^{\pm} \to t\bar{b}$ and the QCD backgrounds.

Bisset, Guchait & Moretti, EPJ '01

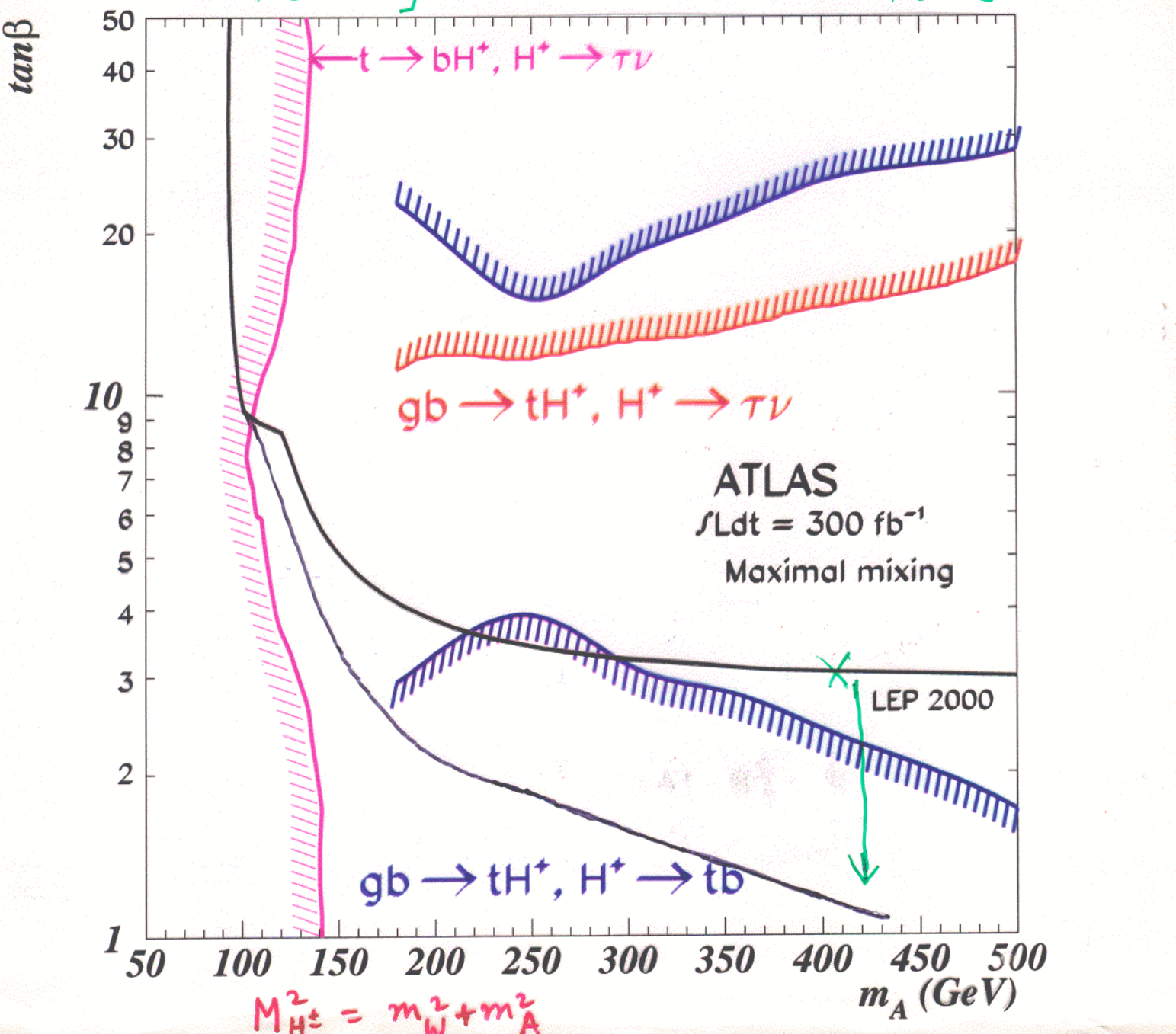
Datta, Djouadi, Guchait & Mambrini, PR '02

$\tilde{q} \to H^{\pm} \ldots$

$\tilde{g} \to H^{+} \ldots$

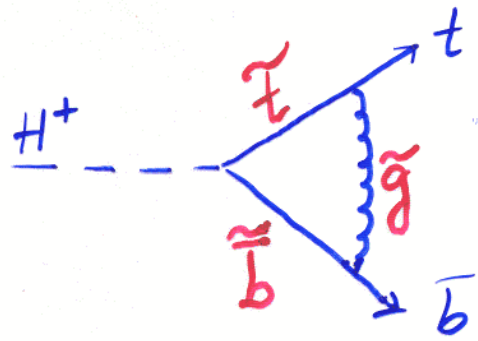
} Can fill up the Intermediate $\tan\beta$ region for Favourable SUSY Parameters

Assamagan, Coadou & Deandrea, EPJ '02



SUSY QCD CORRECTION : Non decoupling

Hall et al. '94, Carena et al. '94, Coarasa et al. '96, Bartl et al. '96



$$\frac{g}{\sqrt{2}\,M_W}\left(\frac{m_t \cdot \cot\beta}{1+\Delta_t} + \frac{m_b \cdot \tan\beta}{1+\Delta_b}\right)$$

$$\Delta_b \simeq \frac{2\alpha_s}{3\pi}\, m_{\tilde{g}}\,(-A_b + \mu\tan\beta)\, \underbrace{I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}})}_{\frac{1}{\max(m^2_{\tilde{b}_1}, m^2_{\tilde{b}_2}, m^2_{\tilde{g}})}}$$

$\tan\beta \gg 1$ (m_b dom.) & $m_{\tilde{g}} \gg m_{\tilde{b}_{1,2}} \Rightarrow \Delta_b \sim \frac{2\alpha_s}{3\pi} \cdot \frac{\mu\tan\beta}{m_{\tilde{g}}}$

Most SUSY Models: $|\mu| \sim m_Z$ (Naturalness)

$m_{\tilde{g}} \gg$ " $\Rightarrow \Delta_b \ll 1$

Estimate of Δ_b @ Snowmass Points & slopes mSUGRA, GMSB & AMSB Plehn et al '03

$\Rightarrow \Delta_b \lesssim 20\%$ for $\tan\beta \lesssim 30$

($\Delta K_{SM} \sim 20\%$)