



Associated charged Higgs and W boson production at the LHC

David Eriksson

High Energy Physics, Uppsala University

S. Hesselbach, J. Rathsman

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- Motivation
- Signal and event generation
 - Signal, $b\bar{b} \rightarrow H^+W^-$
 - Background, $pp \rightarrow W^+ + 2jets$
 - Cut variables
- Results
 - MSSM
 - Complex MSSM
 - Resonant enhancement in MSSM
- Summary and outlook



Motivation

Previous H^+W^- studies

Mostly total cross sections studies

[Barrientos Bendezú, Kniehl, '98; Brein, '02; Hollik, Zhu '02;
Asakawa, Brein, Kanemura '05]

One study with $H^+ \rightarrow tb$ [Moretti, Odagiri, '98]

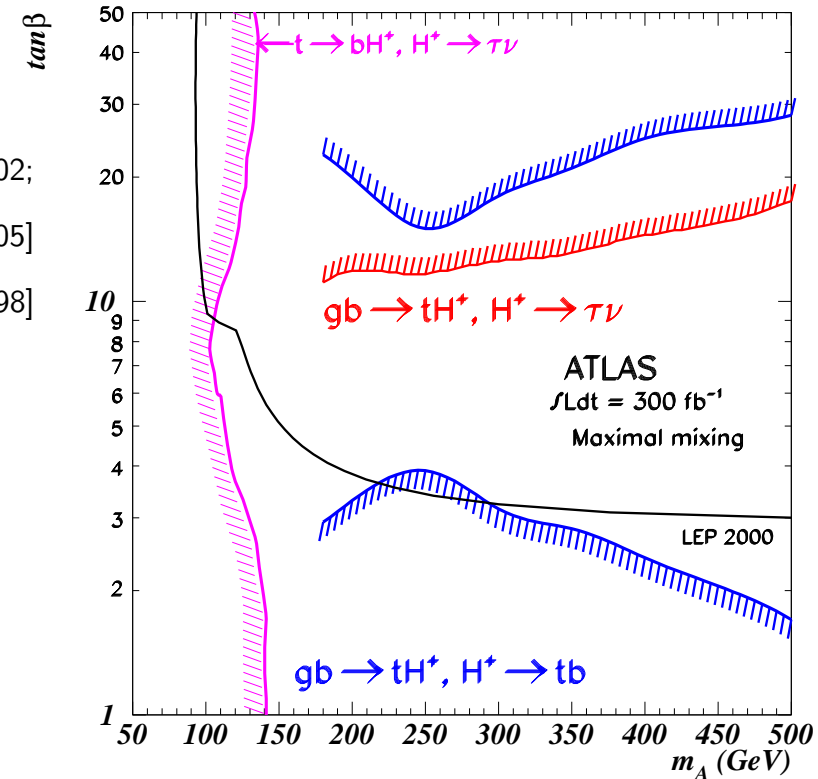
↪ No detectable signal,
irreducible background from $t\bar{t}$

Our study

$b\bar{b} \rightarrow H^+W^-$ with leptonic decay of H^+

Main focuses

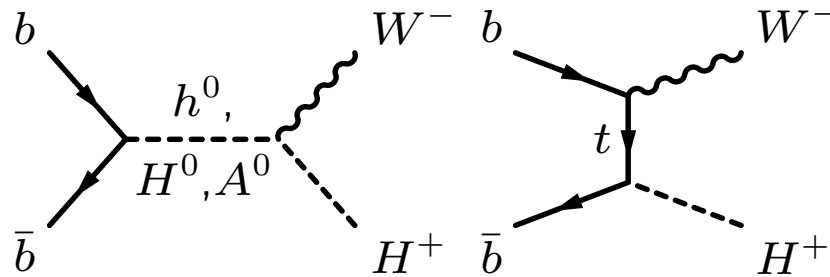
- Detectability of the signal
- Effects beyond MSSM
 - Complex MSSM: CP asymmetries
 - General 2HDM





Signal, production

The signal $b\bar{b} \rightarrow H^+W^-$

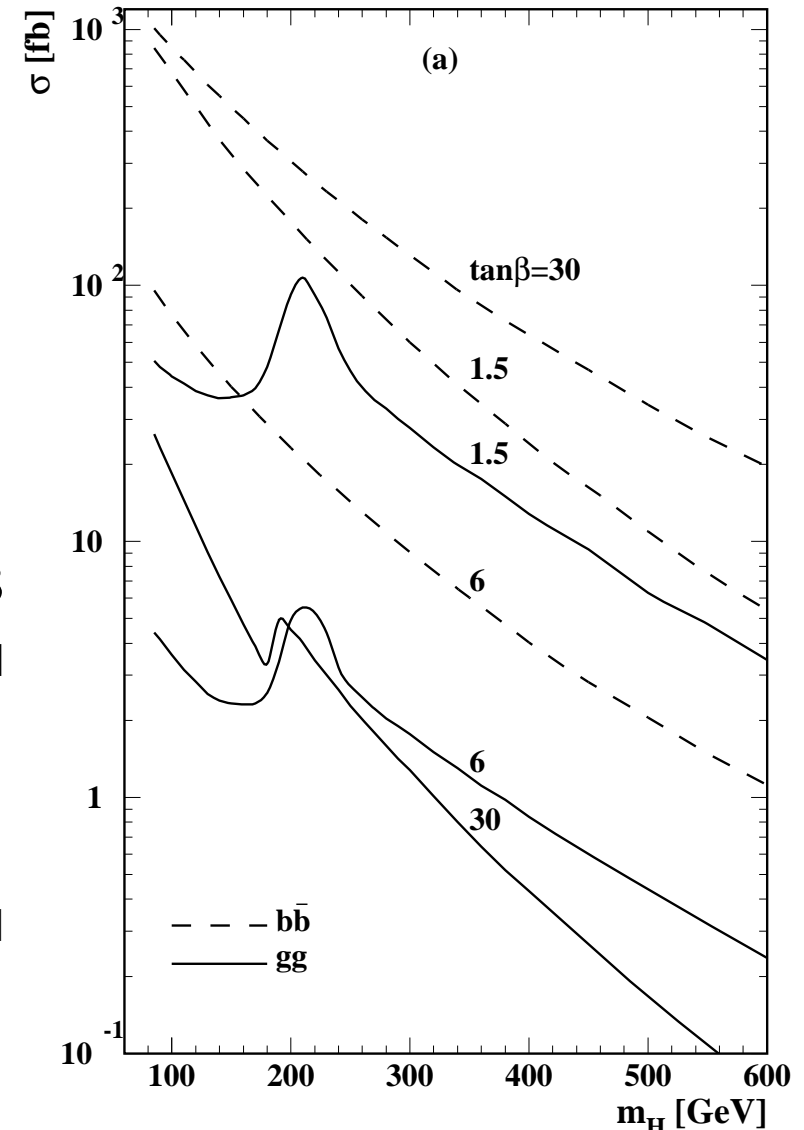


Our implementation

- External process for Pythia
- Running b -mass
 - ↪ Cross section reduced with a factor 3
 - ↪ Better agreement with NLO [Hollik, Zhu]
- Couplings ready for 2HDM
- Width on H^\pm and W^\mp
- SUSY scenario calculated with FeynHiggs [Hahn, Heinemeyer, Hollik, Weiglein]

Main interest large $\tan \beta$

- ↪ Scales as $(m_b \tan \beta)^2$
- ↪ $gg \rightarrow H^+W^-$ negligible



[Barrientos Bendezú, Kniehl, '98]



Signal, signature

Signature

- Leptonic H^\pm decay
- Hadronic W^\pm decay
- $b\bar{b} \rightarrow H^+W^- \rightarrow \tau \cancel{p}_\perp + 2jets$

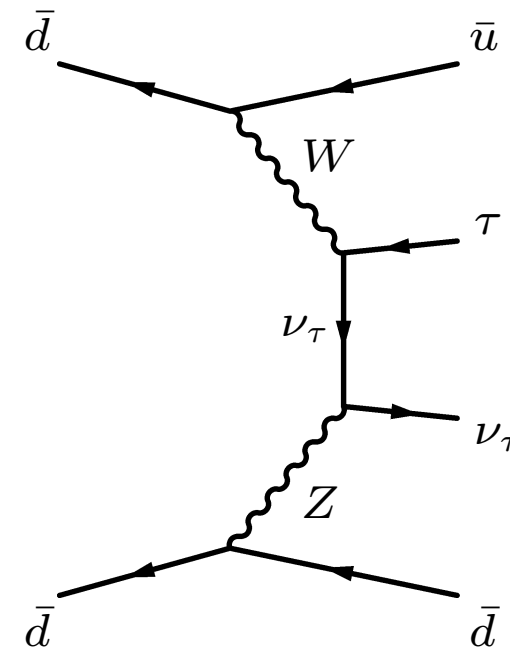
Event generation

- Pure parton level
 - $BR(H^\pm \rightarrow \tau\nu_\tau)$ from FeynHiggs
 - Tau decay performed with TAOULA
- [Golonka, Kersevan, Pierzchala, Richter-Was, Was, Worek]
- Momenta smeared to simulate detector effects
 - Complete events give two additional b -jets
↪ Mostly out of signal region, $p_\perp < 20$ GeV or $|\eta| > 2.5$



Background

- Main background
 - $W + 2jets$
- Secondary background
 - WWZ
 - $t\bar{t}$
- Generated background
 - $W + 2jets$ with ALPGEN
 - [Mangano, Moretti, Piccinini, Pittau, Polosa, '02]
 - $\hookrightarrow \tau\nu_\tau + 2jets$
 - Not necessarily $W^\pm \rightarrow \tau\nu_\tau$
- Total cross section $\mathcal{O}(10^3)$ pb
- Cross checks with Madgraph [Maltoni, Stelzer]





Cut variables

Basic cut

$$p_{\perp\tau} > 50 \text{ GeV}$$

$$\cancel{p}_{\perp} > 50 \text{ GeV}$$

$$p_{\perp\text{hardjet}} > 20 \text{ GeV}$$

$$p_{\perp\text{softjet}} > 20 \text{ GeV}$$

$$70 \text{ GeV} < m_{jj} < 90 \text{ GeV}$$

$$m_{\perp} > 100 \text{ GeV}$$

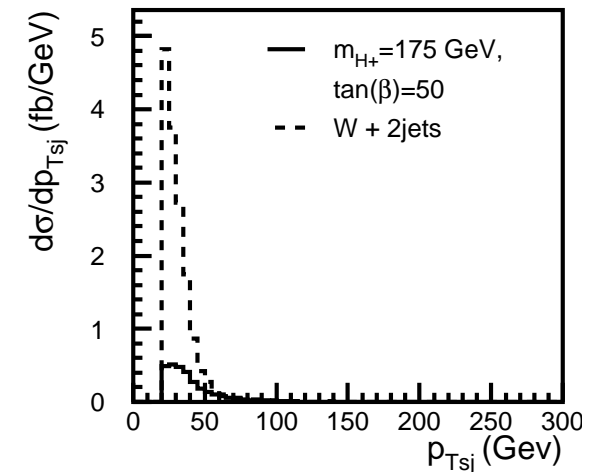
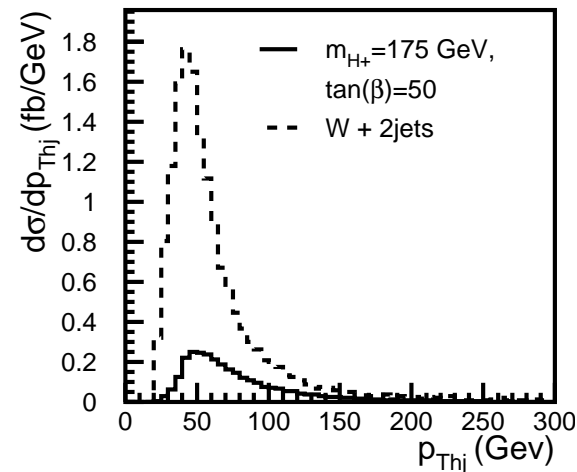
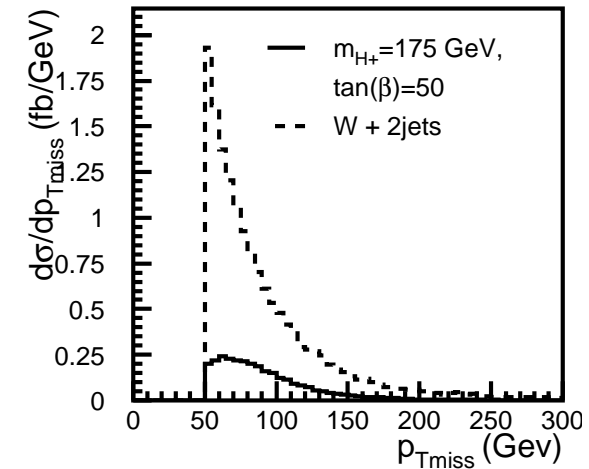
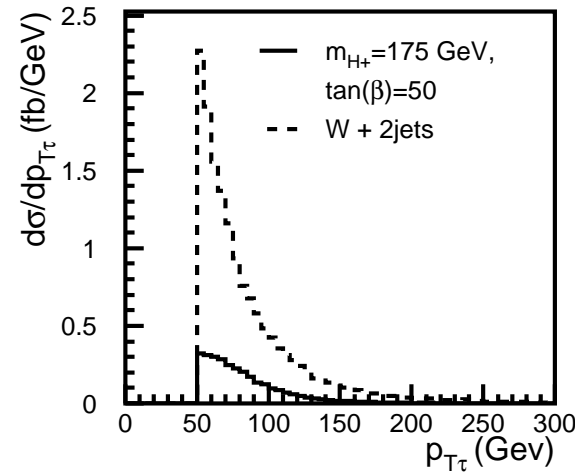
$$|\eta_{\tau}| < 2.5$$

$$|\eta_j| < 2.5$$

$$\Delta R_{jj} > 0.4$$

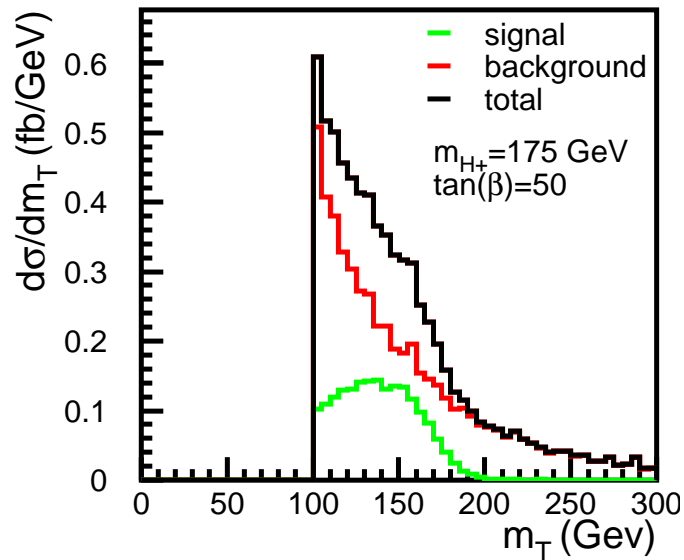
$$\Delta R_{\tau j} > 0.5$$

$$m_{\perp} = \sqrt{2p_{\perp\tau} \cancel{p}_{\perp} [1 - \cos(\Delta\phi)]}$$

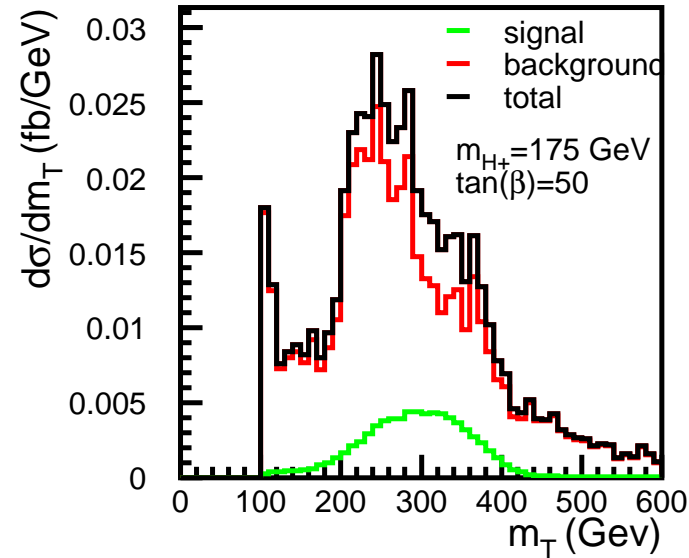




Results MSSM



- $m_{H^+} = 175$ GeV
- Additional cut:
 - $p_{\perp hardjet} > 50$
 - $p_{\perp softjet} > 25$
- $S/\sqrt{B} = 17$
 - $\int \mathcal{L} = 300 \text{ fb}^{-1}$
 - τ efficiency 30%



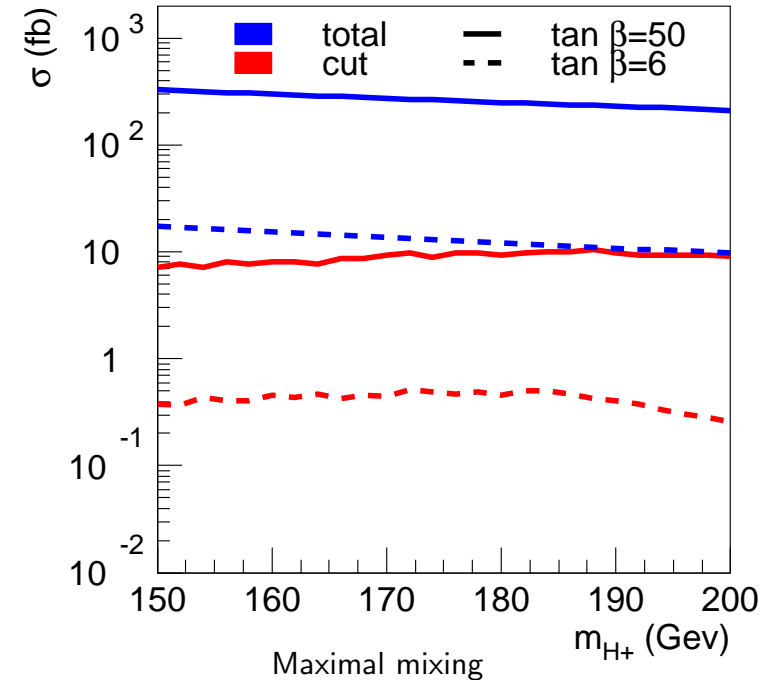
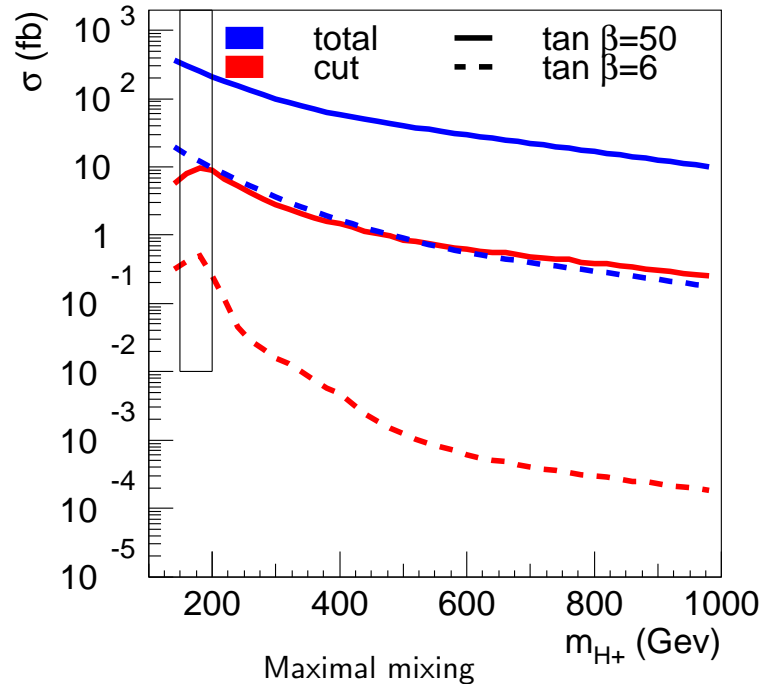
- $m_{H^+} = 400$ GeV
- Additional cut:
 - $p_{\perp \tau} > 100$
 - $\cancel{p}_{\perp} > 100$
 - $p_{\perp hardjet} > 50$
 - $p_{\perp softjet} > 25$
- $S/\sqrt{B} = 3$
 - $\int \mathcal{L} = 300 \text{ fb}^{-1}$
 - τ efficiency 30%

SUSY Parameters Maximal mixing

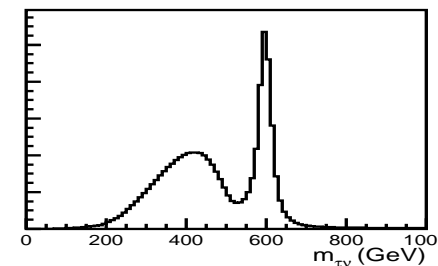
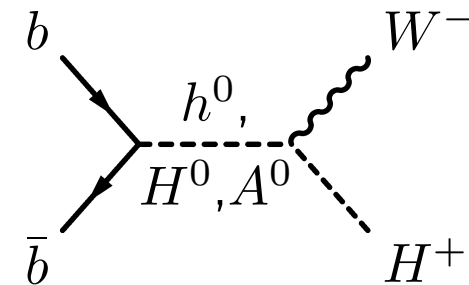
$\tan \beta$	50
μ	200
$M3SL$	1000
$M3SE$	1000
$M3SQ$	1000
$M3SU$	1000
$M3SD$	1000
A_t	2000
A_b	2000



Mass dependence



- Low mass and high $\tan \beta$
 - $150 < m_{H^\pm} < 200$ GeV
 - $\tan(\beta) \gtrsim 28$
 - ↪ Detectable signal $S/\sqrt{B} \gtrsim 5$
- Off-shell resonant enhancement
 - ↪ Large cross section for high masses
 - ↪ Broader peak in $m_{\tau\nu_\tau}$ and m_\perp
 - ↪ Harder to detect

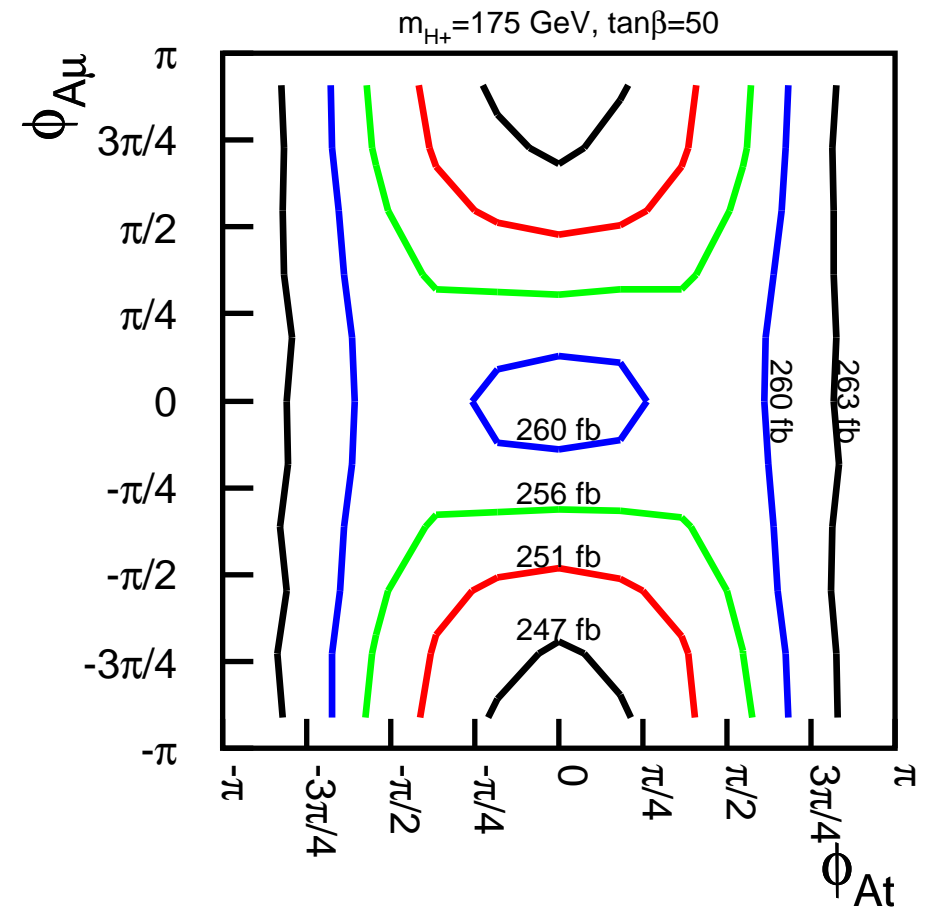




Phase dependence

Complex MSSM

- Many complex parameters
- Cross section may depend on SUSY phases
- Here most important
 - ϕ_μ
 - ϕ_{A_t}
- No strong dependence found
- CP asymmetry $\frac{\sigma_{H^+} - \sigma_{H^-}}{\sigma_{H^+} + \sigma_{H^-}}$ is very small
- Checking consistency with
 - $g_\mu - 2$
 - $\delta\rho$
 - EDM



Total cross section as a function of ϕ_μ and ϕ_{A_t}
for Maximal mixing scenario



Resonant enhancement in MSSM

- Tree level in MSSM

$$\hookrightarrow m_{H^\pm}^2 - m_{A^0}^2 = m_{W^\pm}^2$$

- Loop corrections

$$\hookrightarrow \propto -\frac{\mu^2}{4M_{SUSY}^2} v^2 \text{ (1-loop order)}$$

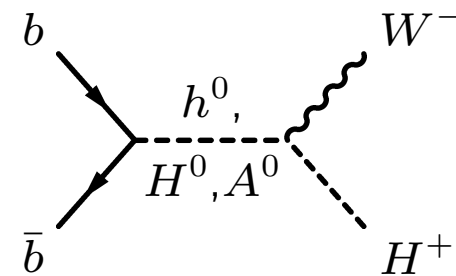
$$\hookrightarrow m_{A^0} - m_{H^\pm} > m_{W^\pm}$$

\hookrightarrow Resonant s -channel enhancement

– We have used 2-loop corrections in FeynHiggs

[Akeroyd, Baek 02]

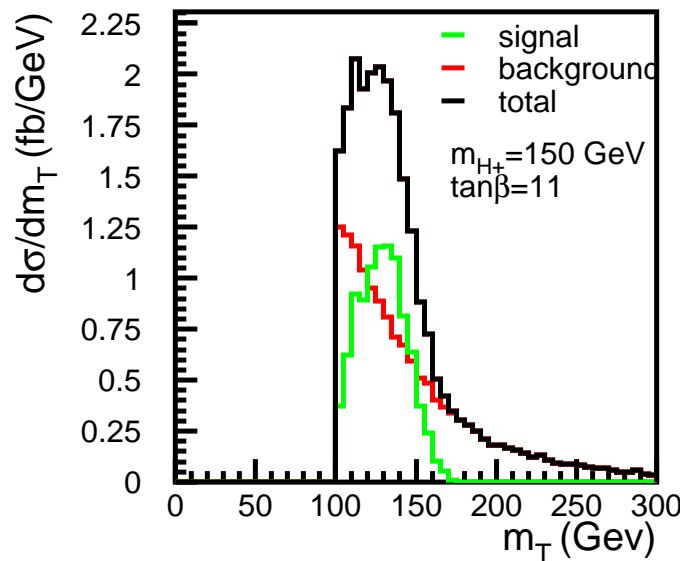
	MaxMix	Resonant
m_{h^0}	136 GeV	101 GeV
m_{H^0}	151 GeV	126 GeV
m_{A^0}	151 GeV	251 GeV
m_{H^\pm}	175 GeV	150 GeV



- More natural in a general 2HDM



Results resonant enhancement



- $m_{H^+} = 150$ GeV
- Cut: Basic cut
- $S/\sqrt{B} = 52$
 - Luminosity: 300 fb^{-1}
 - τ efficiency 30%
- Checking consistency with
 - $g_\mu = 2$
 - $\delta\rho$
 - EDM
 - squark masses
 - Higgs masses
- Phase dependence
 - Strong dependence
 - σ_{tot} : 1200-3400 fb
 - Still small
 - CP-asymmetry

SUSY Parameters
Resonant scenario

$\tan \beta$	11
μ	3300
$M3SL$	500
$M3SE$	500
$M3SQ$	400
$M3SU$	150
$M3SD$	550
A_t	0
A_b	0



Summary and outlook

Our study

- Signal
 $b\bar{b} \rightarrow H^+W^- \rightarrow \tau p_{\perp} + 2jets$
- Background
 $W + 2jets$

In MSSM the signal is detectable for

- Large $\tan \beta$ and
- Low m_{H^+}
- Special resonant scenarios

Outlook

- General 2HDM
 - Detectable signal for larger mass range and/or lower $\tan \beta$?
 - Stronger phase dependence?
 - Detectable CP-asymmetry?

