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Associated charged Higgs and W boson production at LHC

David Eriksson, Stefan Hesselbach, Johan Rathsman
hep-ph/0612198, slides courtesy David Eriksson

High Energy Physics, Uppsala University

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Higgs sector of MSSM

$H^{\pm}W^{\mp}$ production at LHC

Numerical results

Summary and Outlook

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Higgs sector of MSSM

Two Higgs doublet model

$$\Phi_1 = \begin{pmatrix} \phi_1^+ \\ \phi_1^0 \end{pmatrix}, \Phi_2 = \begin{pmatrix} \phi_2^+ \\ \phi_2^0 \end{pmatrix}$$

- Two vacuum expectation values, v_1, v_2, $\tan\beta = \frac{v_2}{v_1}$

Physical states

- Eight degrees of freedom
  - Three gives mass to $W^{\pm}$, Z
- Five physical Higgs bosons
  - Three neutral and two charged

Tree-level MSSM

- Only two parameters
- $\tan\beta$ and m_A ($m_{H^{\pm}}$)
- gauge couplings

One-loop contributions

- SUSY parameters important
- $t/\tilde{t}$ dominates
- CP violation from phases of SUSY parameters

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Experimental constraints on Charged Higgs

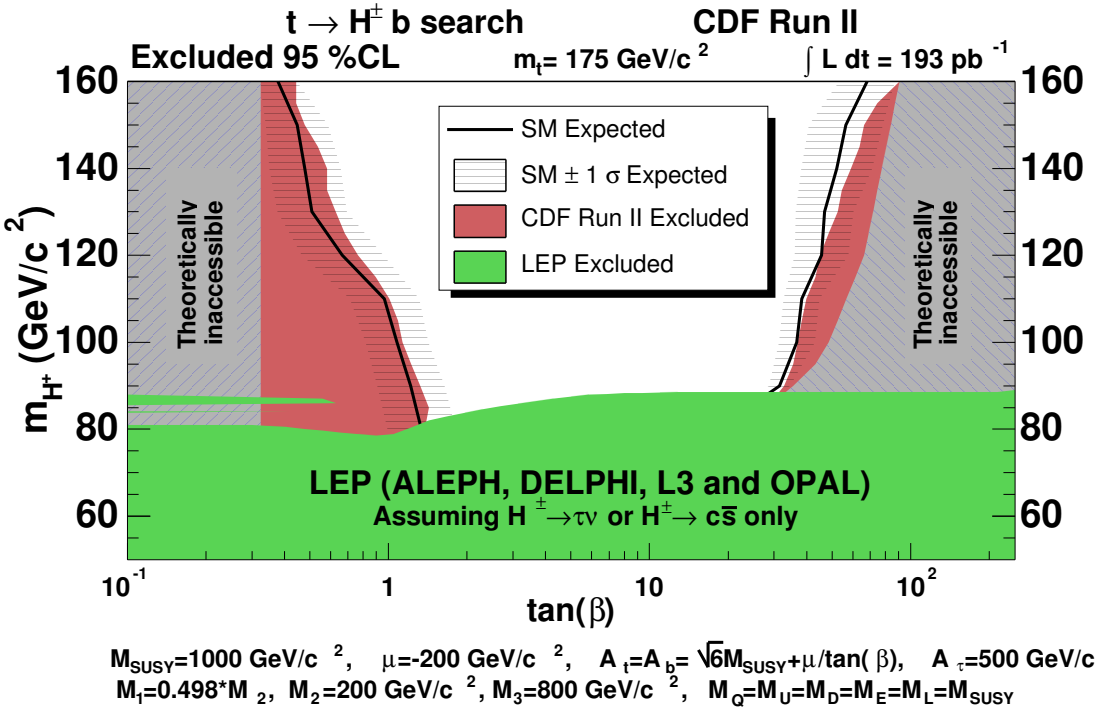
Limits on the mass

LEP $m_{H^{\pm}} \gtrsim 80$ GeV, model independent

Tevatron For $m_{H^{\pm}} < m_t$, slight model dependence

- Small and large $\tan\beta$
- Large BR$(t \to H^{\pm} b)$

B-factories Very model dependent



$m_h^{\max}$ scenario
maximize m_h

$H^\pm$ production in association with a W

Motivation

- Alternative channel
  - Standard production, $t \to H^\pm b$, $gb \to tH^\pm$, $gg \to tbH^\pm$
- CP asymmetries, mixing of neutral Higgs
  $\to \sigma(H^+W^-) \neq \sigma(H^-W^+)$

$H^\pm$ production in association with a W at LHC

- Production modes
  - $b\bar{b} \to H^\pm W^\mp$
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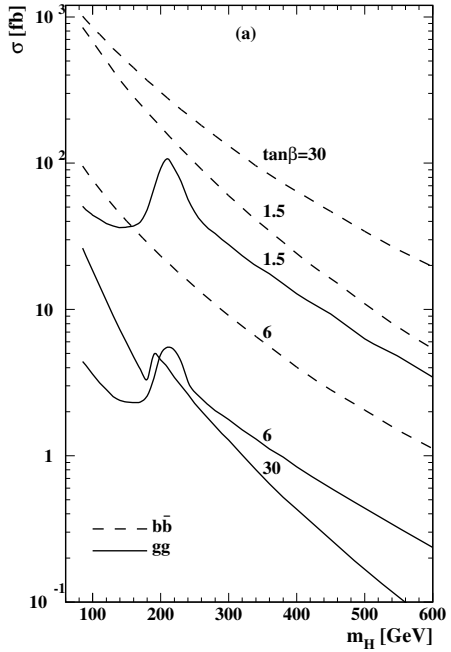

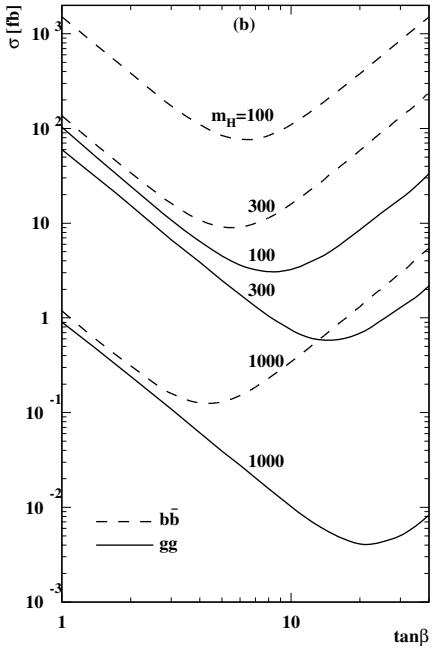

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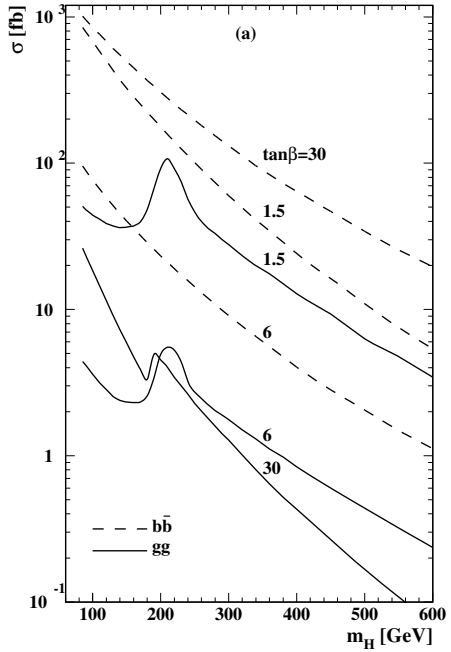
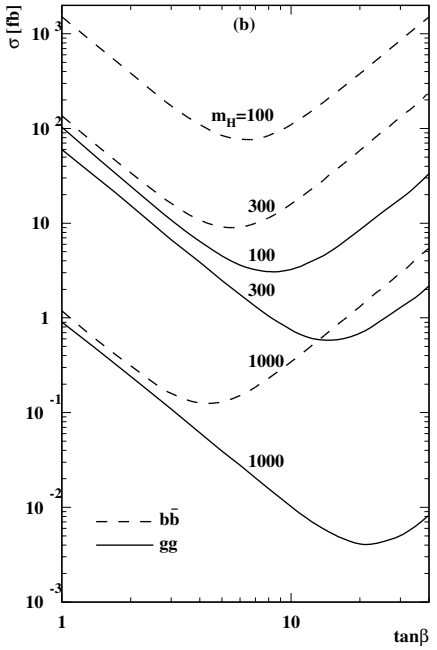
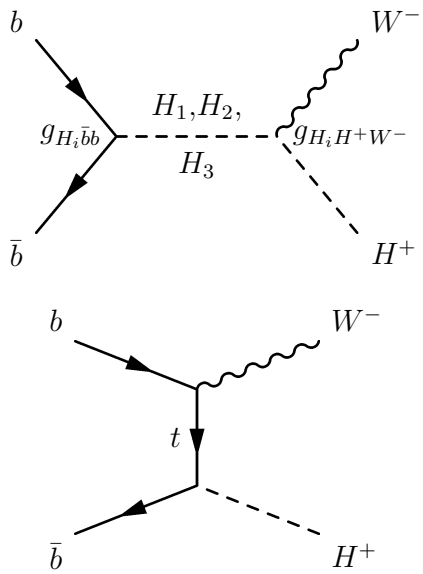




Our study

$b\bar{b} \to H^\pm W^\mp$

- Hadronic decay, $H^\pm \to tb$
  - Study by Moretti et al
  - No detectable signal due to $t\bar{t}$ background
- Leptonic decay, $H^\pm \to \tau\nu$
  - Cleaner signal
  - BR $\sim 10\%$ for $m_t > m_{H^\pm}$ if large $\tan\beta$
- Signature $\tau_{\rm jet}\, \not{p}_\perp + 2$ jets



Irreducible background

- $W + 2$ jets, generated with ALPGEN

Feasibility study

- Only parton level
- τ-decay with Taoula, MSSM scenario with FeynHiggs
- Maximal mixing ($m_h^{\rm max}$), CP-violating, and Resonant scenarios

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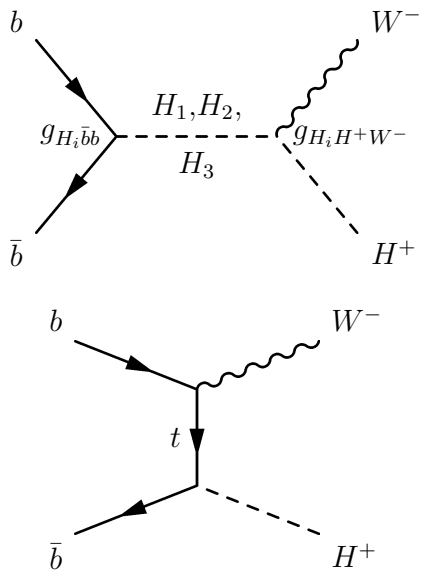

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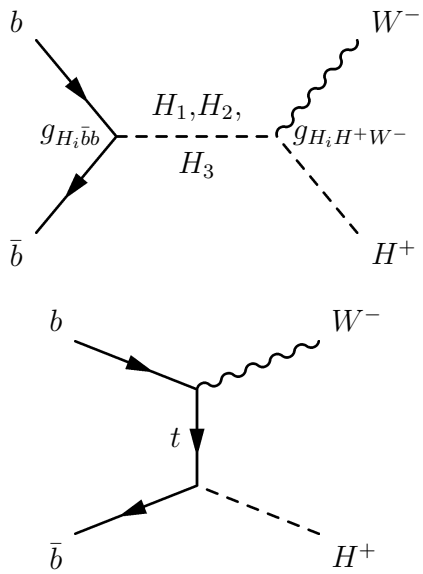

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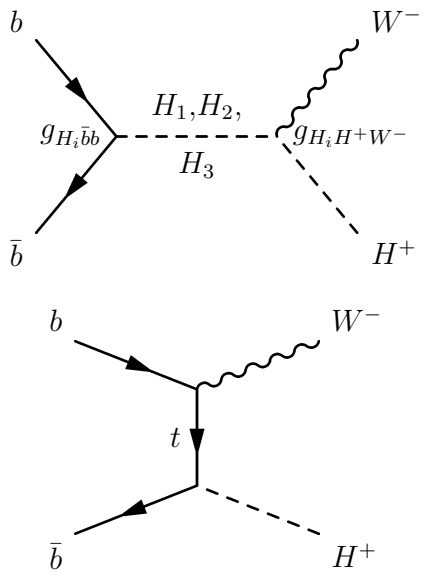

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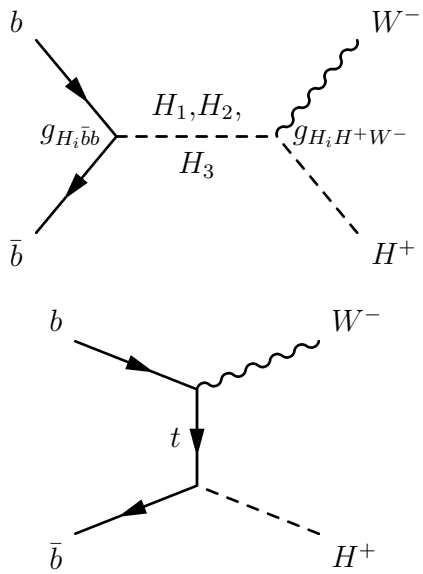

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Signal selection

Signature $\tau_{\rm jet}\,\not{p}_\perp + 2$ jets

Basic cuts

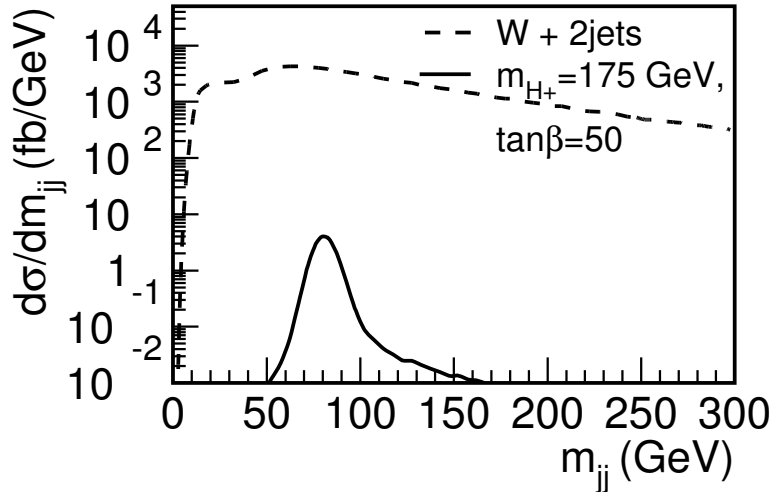
$$|\eta_{\tau_{\rm jet}}| < 2.5$$
$$|\eta_j| < 2.5$$
$$\Delta R_{jj} > 0.4$$
$$\Delta R_{\tau_{\rm jet} j} > 0.5$$
$$p_{\perp jet} > 20 \text{ GeV}$$

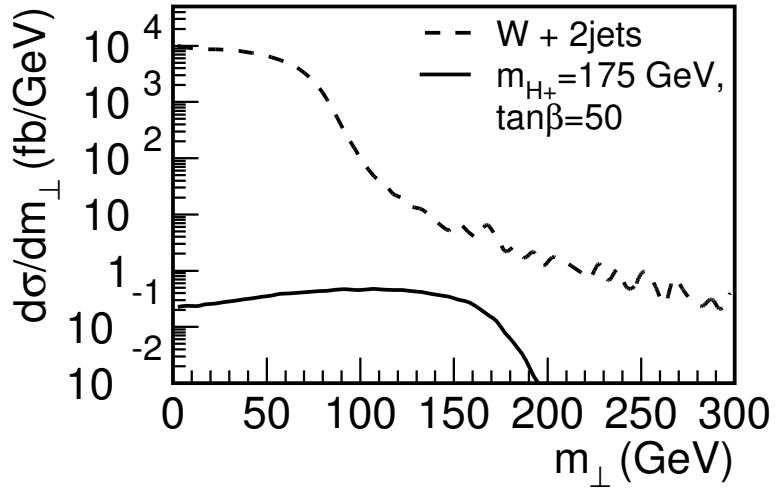
Additional cuts

$$p_{\perp\tau_{\rm jet}} > 50\ (100) \text{ GeV}$$
$$\not{p}_\perp > 50\ (100) \text{ GeV}$$
$$70 \text{ GeV} < m_{jj} < 90 \text{ GeV}$$
$$m_\perp > 100 \text{ GeV}$$
$$p_{\perp hj} > 50 \text{ GeV},\ p_{\perp sj} > 25 \text{ GeV}$$

Reducible backgrounds

alternative cuts on $p_{\perp\tau_{\rm jet}}$, $\not{p}_\perp$





$m_H^{\pm} = 175$ GeV and $\tan\beta = 50$ used for signal selection

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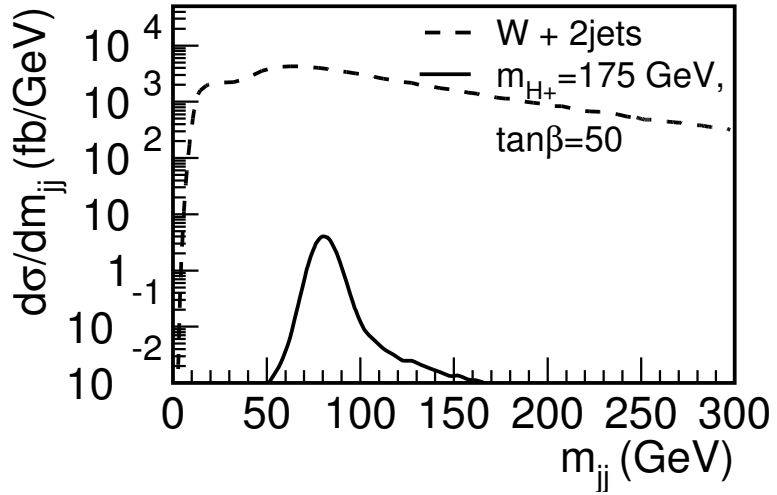

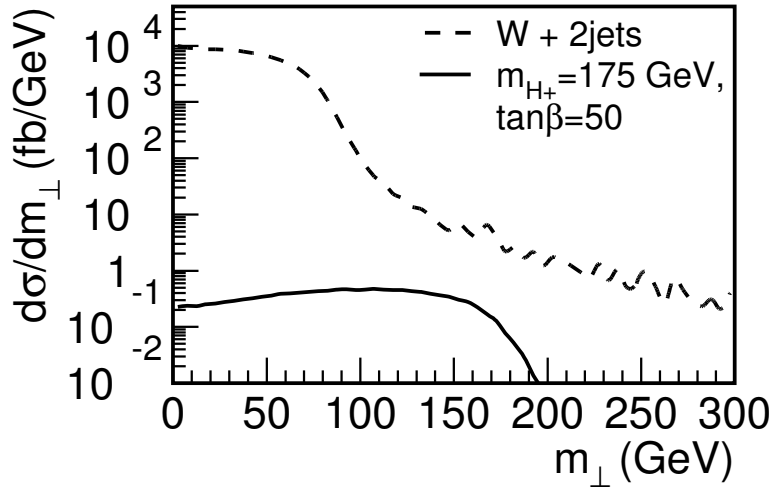

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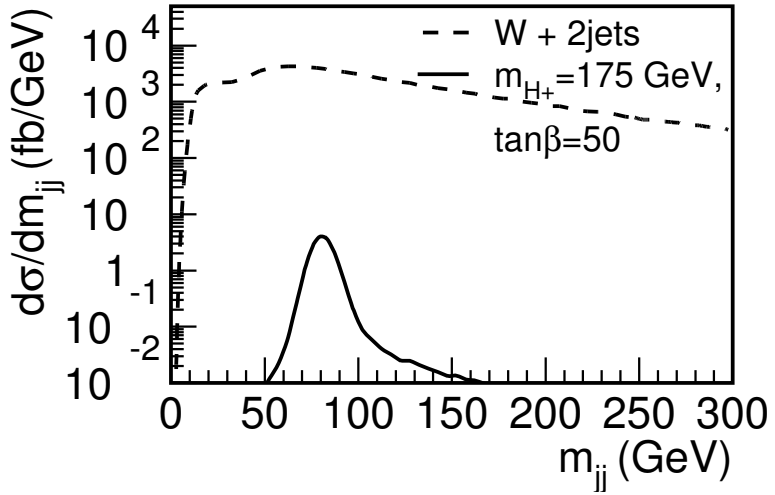

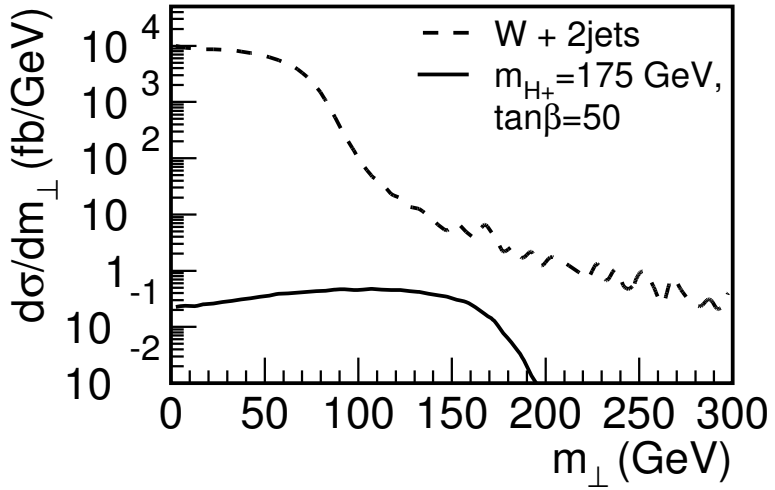

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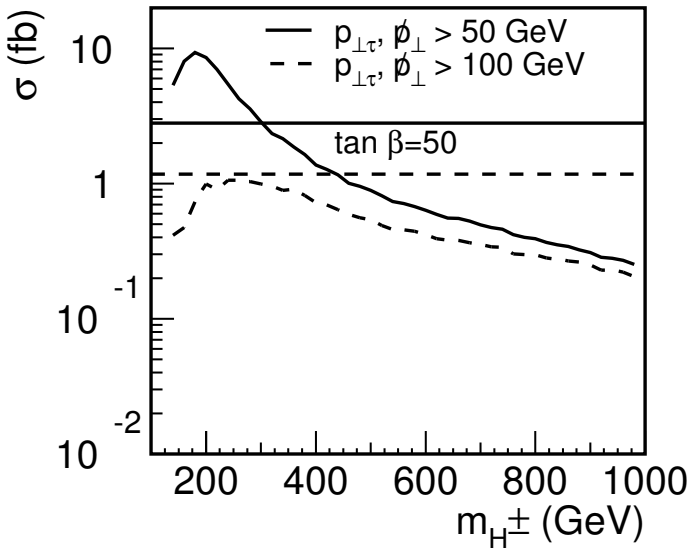
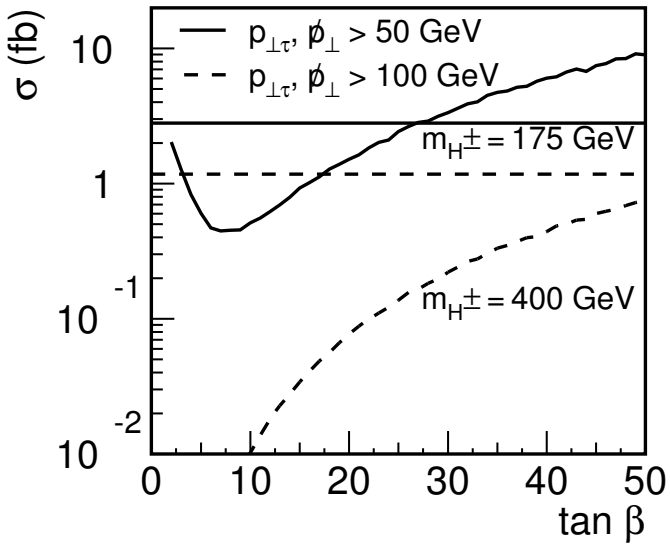
Results for MSSM, $m_h^{\max}$ scenario





Significance

- $\int \mathcal{L} = 300$ fb^{-1} and a τ-efficiency of 30%
- Horizontal lines correspond to $S/\sqrt{B} = 5$

Viable signal

- 150 GeV $\lesssim m_{H^\pm} \lesssim$ 300 GeV for $\tan\beta = 50$ if softer cuts
- $\tan\beta \gtrsim 30$ for $m_{H^\pm} = 175$ GeV if softer cuts

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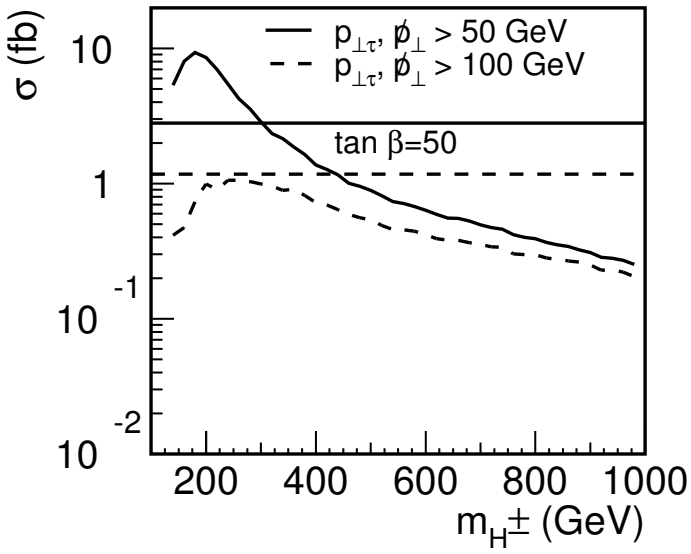

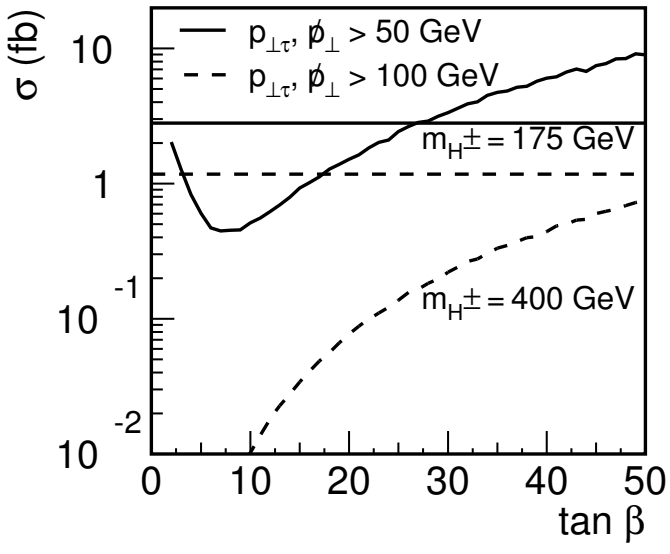

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CP asymmetry

CP violation

- Mixing in the neutral sector, H_1, H_2, H_3
- Different cross-section for H^+ and H^-

CP asymmetry

$$A_{\rm CP} = \frac{\sigma(pp \to H^+W^-) - \sigma(pp \to H^-W^+)}{\sigma(pp \to H^+W^-) + \sigma(pp \to H^-W^+)}$$

How large asymmetry can we get?

- Conditions
  - Mixing in the neutral sector
  - Resonant production, $m_{H_i} > m_{H^\pm} + m_{W^\mp}$
- Kinematics of differential cross-section
  - 1 resonance: $|A_{\rm CP}| \sim \mathcal{O}(\frac{\Gamma}{m})$
  - 2-3 resonance: $|A_{\rm CP}| \sim \mathcal{O}(1)$

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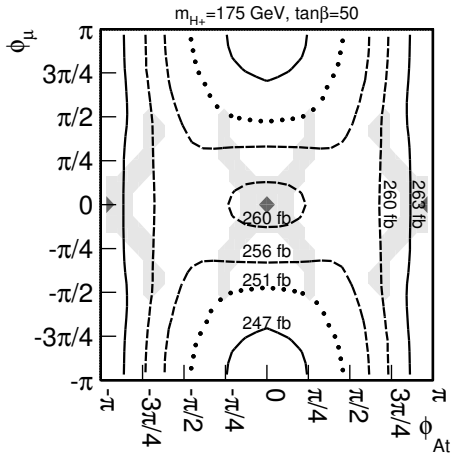
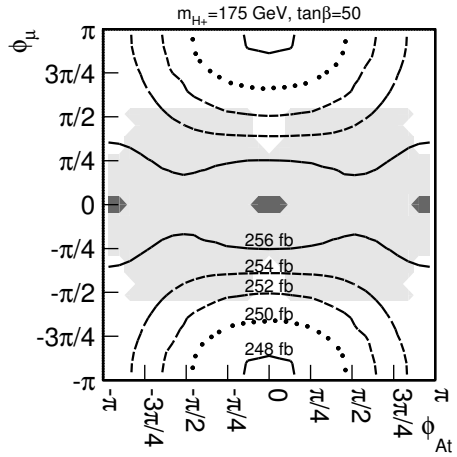
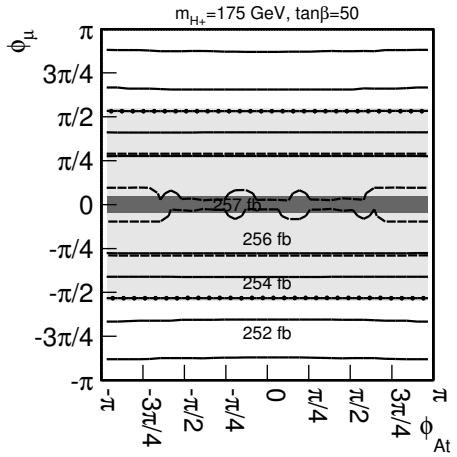
Results for MSSM with complex parameters

Total cross-section in different versions $m_h^{\max}$ scenario

- Expect largest dependence on phases of μ and A_t







Limits on phases

- Muon magnetic moment, $|\phi_\mu| \lesssim \pi/2$ allowed
- The ρ-parameter, light shaded areas allowed
- Electric dipole moments, dark shaded areas allowed

CP asymmetry

- $|A_{\rm CP}| \lesssim 0.3\%$

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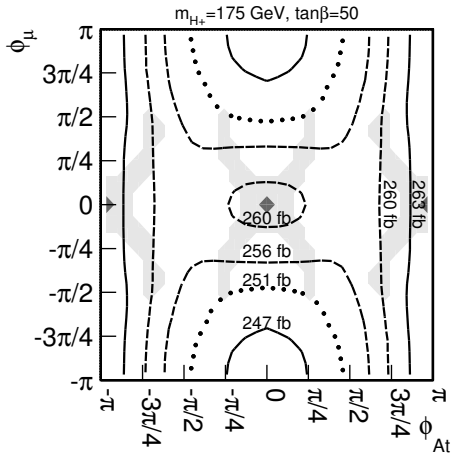

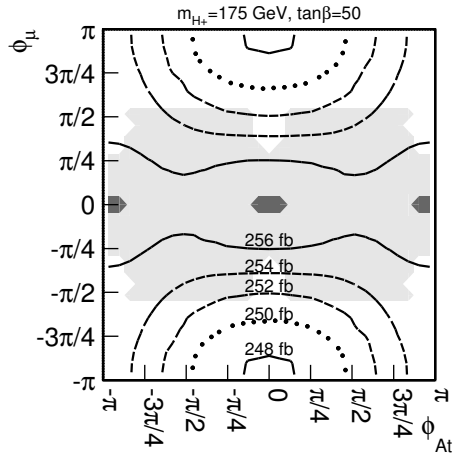

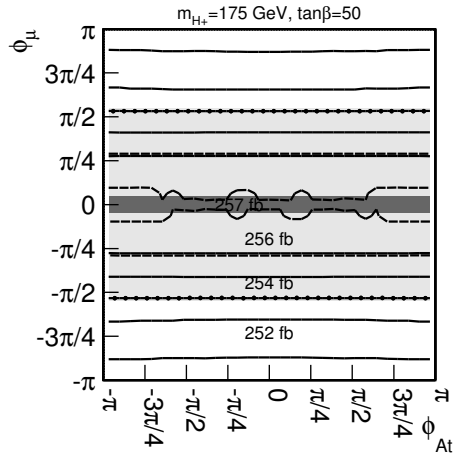

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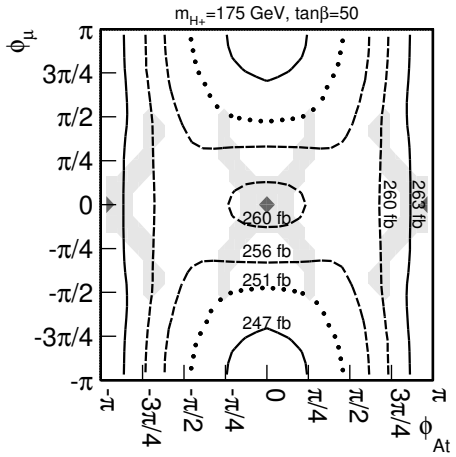
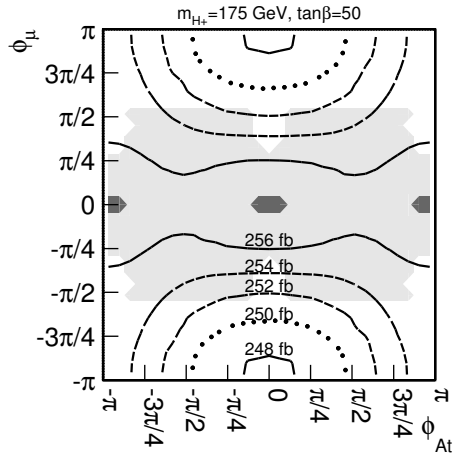
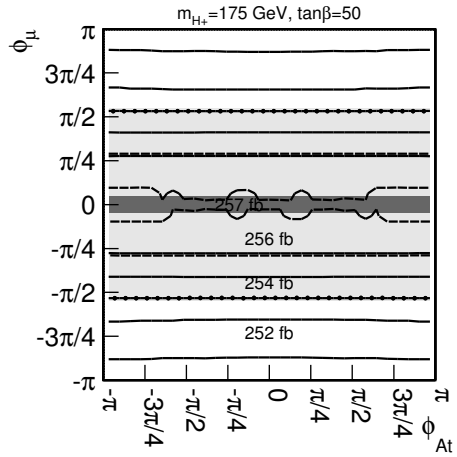






Limits on phases

- Muon magnetic moment, $|\phi_\mu| \lesssim \pi/2$ allowed
- The ρ-parameter, light shaded areas allowed
- Electric dipole moments, dark shaded areas allowed

CP asymmetry

- $|A_{\rm CP}| \lesssim 0.3\%$

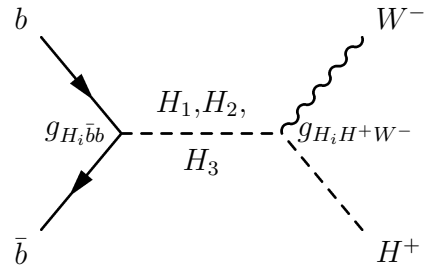
Resonant enhancement

Special MSSM scenarios

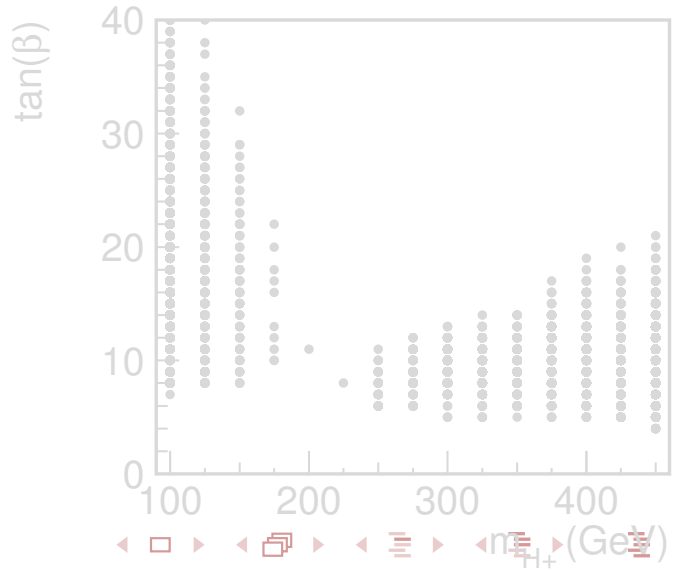
- Large 1-loop and 2-loop corrections
- Large mass splitting between A and $H^\pm$
- Resonant $m_A > m_{H^\pm} + m_{W^\mp}$

How special?

- Perturbative stability
- Fine tuning
  - Parameter scan



	$m_h^{\max}$	Resonant scenario		
	full	tree-level	1-loop	full
m_{h^0}	136	89	95	118
m_{H^0}	151	157	188	168
m_{A^0}	**151**	**155**	**246**	**258**
$m_{H^\pm}$	**175**	**175**	**175**	**175**



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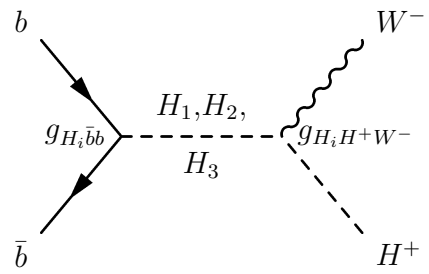

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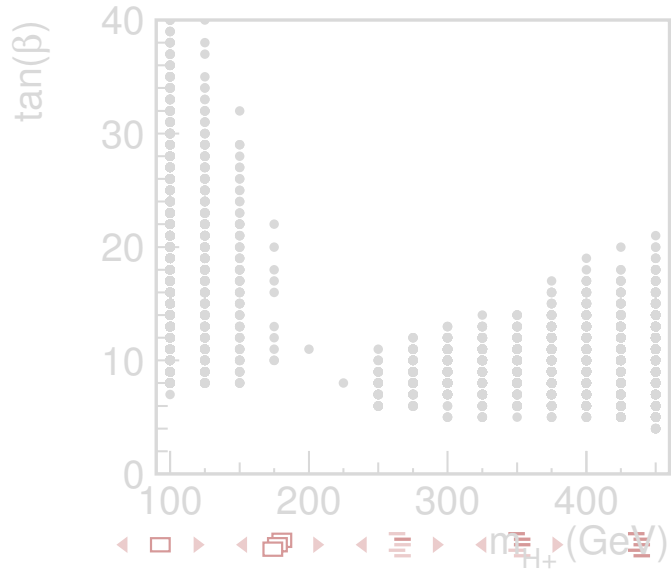

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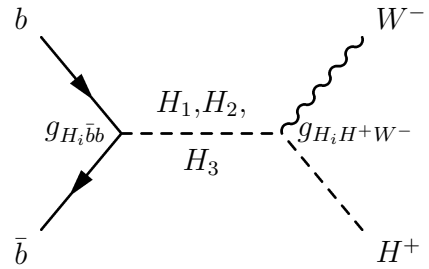

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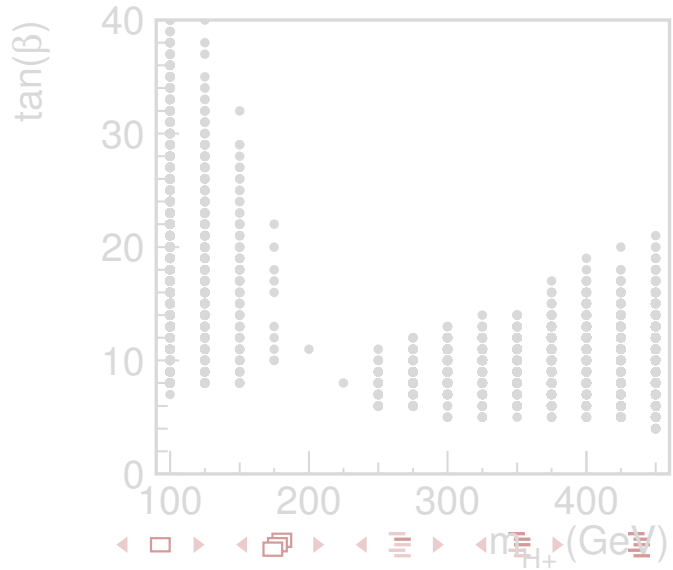

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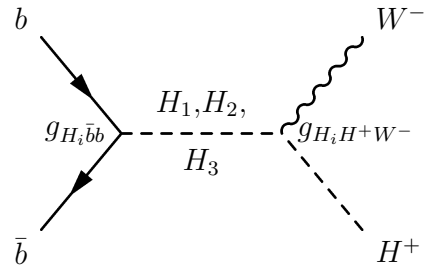

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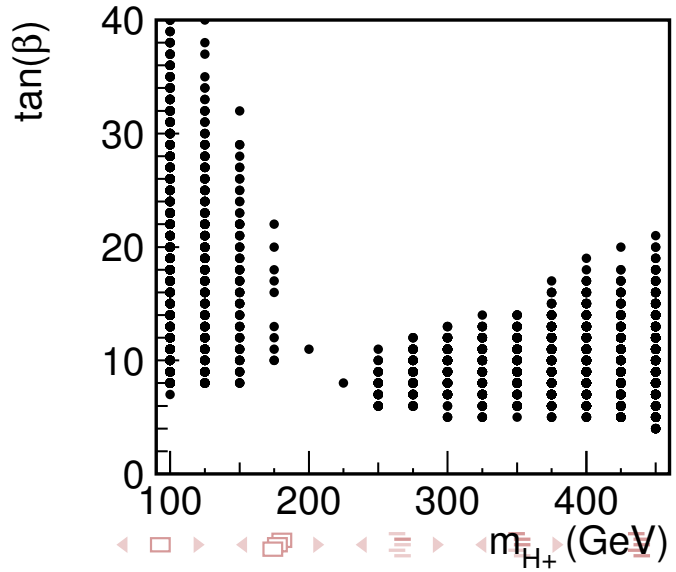

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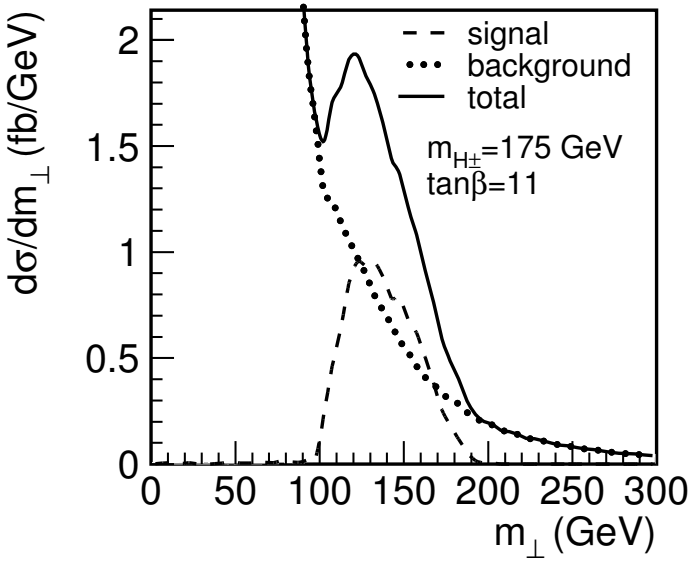

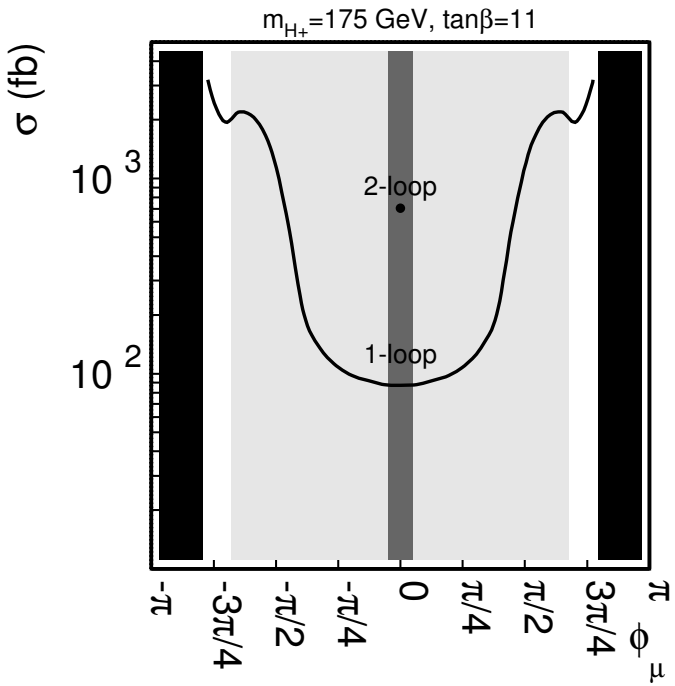

Results for resonant scenario

- Large enhancement of cross-section from resonant effects
- Higher significance, $S/\sqrt{B} = 56$
- Large dependence on CP phase, ϕ_μ
- Small CP asymmetry, with 1-loop calculation

Summary and Outlook

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- $H^{\pm}$ is a clear new physics signal
- $pp \to H^{\pm}W^{\mp}$ supplementary channel
- $m_h^{\max}$, "Standard MSSM", softer cuts
  - 150 GeV $\lesssim m_{H^{\pm}} \lesssim$ 300 GeV for $\tan\beta = 50$
  - $\tan\beta \gtrsim 30$ for $m_{H^{\pm}} = 175$ GeV
  - CP violation hard to detect
- Resonant MSSM scenario
  - Large enhancement of cross-section from resonant effects
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Outlook

- Only parton level so far
- General Two Higgs doublet model or NMSSM
  - Tree-level resonance
  - Enhanced cross-section from resonant production
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