Charged Higgs Production via $e^+e^- \to W^\pm H^\mp$ in the MSSM/THDM

Oliver Brein

(Institut für Theoretische Physik E,
RWTH Aachen, Germany)

in collaboration with W. Hollik and T. Hahn

[see also hep-ph/0209124]

e-mail: brein@physik.rwth-aachen.de

outline :

- Introduction
  - charged Higgs search and beyond
- The Process $e^+e^- \to H^\pm W^\mp$
  - facts
  - Feynman diagrams
- Results
  - MSSM/THDM comparison (example)
  - MSSM parameter scan

• Introduction

– charged Higgs search ...

Tevatron/LHC, $H^{\pm}$ production

- $m_{H^{\pm}} < m_t$:

  mainly via $t \to H^{+}b$ and c.c. in $t\bar{t}$ events.

- $m_{H^{\pm}} > m_t$:

  mainly via $gb \to tH^{+}$, $gg \to tbH^{+}$

  other processes with (much) smaller c.s. :
  $gg/b\bar{b} \to H^{\pm}W^{\mp}$ and $gg/q\bar{q} \to H^{+}H^{-}$

$e^{+}e^{-}$ collider ($\sqrt{s}$=0.5-1TeV), $H^{\pm}$ production

- $\sqrt{s} > 2\,m_{H^{\pm}}$:

  via $e^{+}e^{-} \to H^{+}H^{-}$

- $\sqrt{s} \in [m_{H^{\pm}} + m_W, 2\,m_{H^{\pm}}]$:

  via $e^{+}e^{-} \to W^{\pm}H^{\mp}$ / $\tau^{-}\bar{\nu}_{\tau}H^{+}$ and c.c.

- $\sqrt{s} < m_{H^{\pm}} + m_W$:

  only via $e^{+}e^{-} \to \tau^{-}\bar{\nu}_{\tau}H^{+}$ and c.c.

most viable Signal:

excess of tau events

from the decays $H^{+} \to \tau^{+}\nu_{\tau}$ and c.c.

– ... and beyond

Why else study $H^{\pm}W^{\mp}$ production?

$\rightarrow$ processes loop-induced

$\rightarrow$ loop-induced processes are strongly dependent on virtual particles in the loop

$\rightarrow$ the $W^{\pm}H^{\mp}$ production cross section is strongly model dependent

$\rightarrow$ with a measurement of the cross section one would

gain information about the underlying model

(e.g. the MSSM, THDM).

• The Process $e^+e^- \to H^\pm W^\mp$

– facts

- MSSM and THDM have no $ZW^\pm H^\mp$-Vertex.
  $\to$ There is only a neutrino-exchange diagram at tree-level.

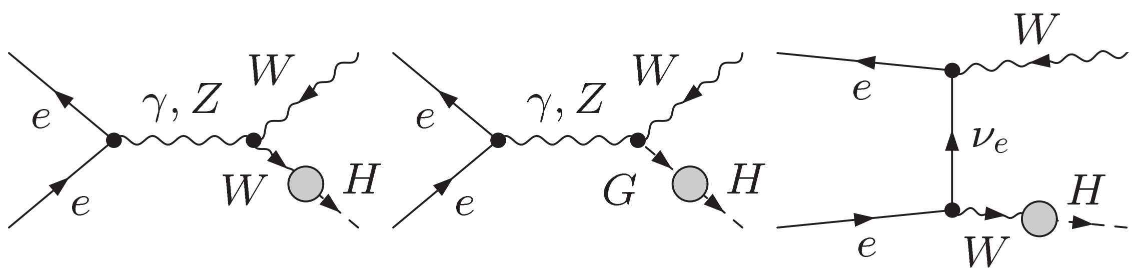
- But this tree-level amplitude is suppressed by $m_e/m_W \approx 6\cdot 10^{-5}$ and vanishes for $m_e \to 0$.
  $\to$ The process is *effectively* loop-induced.

- Still, there appear divergent $W^\pm$-$H^\pm$ and $G^\pm$-$H^\mp$ mixing self energies at one-loop.
  $\to$ some renormalization is required.

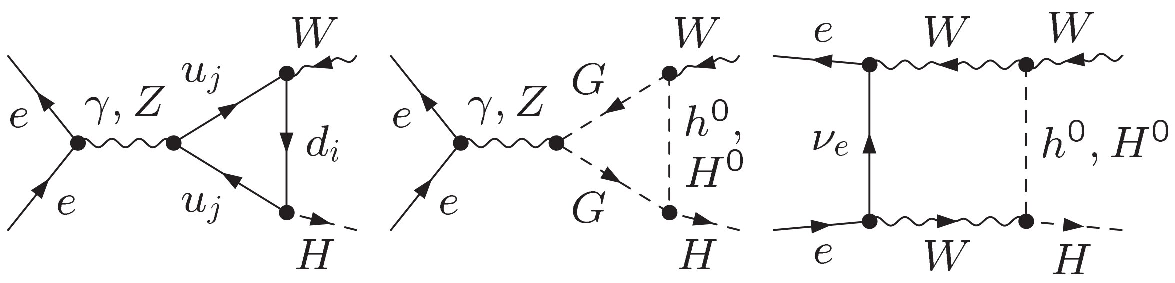
- Relevant real corrections by initial and final state photon radiation appear at NLO.

– Feynman diagrams

self energies

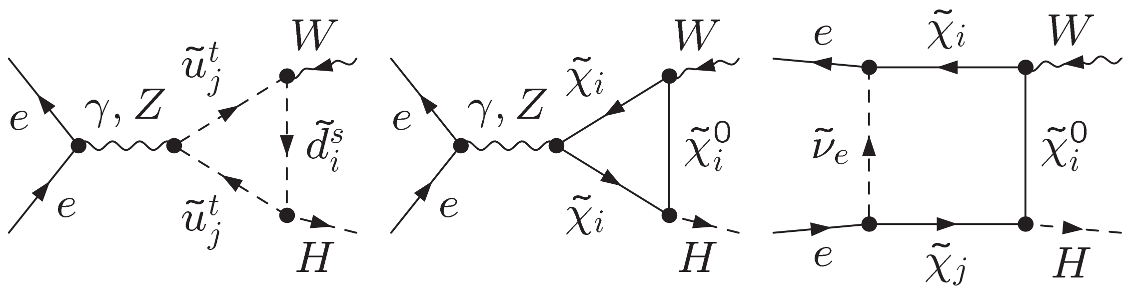


vertices & boxes, THDM like contributions



+ more

vertices & boxes, SUSY contributions



+ more

[THDM: Zhu '99; Arhrib et al. '99; Kanemura '99

MSSM: Logan & Su '02; OBr, Hollik, Hahn '02]

• Results

– MSSM/THDM comparison (example)

MSSM parameter scenario:

interest here:

large effects from virtual squarks (esp. stops)

stop mass matrix in the L-R basis:

$$M_{\tilde{t}}^2 = \begin{pmatrix} M_{\text{Sf.}}^2 + m_t^2 + DT_1 & m_t X_t \\ m_t X_t & M_{\text{Sf.}}^2 + m_t^2 + DT_2 \end{pmatrix}$$

with the stop mixing parameter

$$X_t = A_t - \mu \cot \beta$$

choice of parameters:

common sfermion mass scale
$M_{\text{Sf.}} = 350$ GeV

stop mixing parameter
$X_t = -800$ GeV

supersymmetric Higgs mass term
$\mu = 300$ GeV

gaugino mass terms
$M_1, M_2, M_{\tilde{g}} \approx \mathcal{O}(1\,\text{TeV})$

resulting scenario:

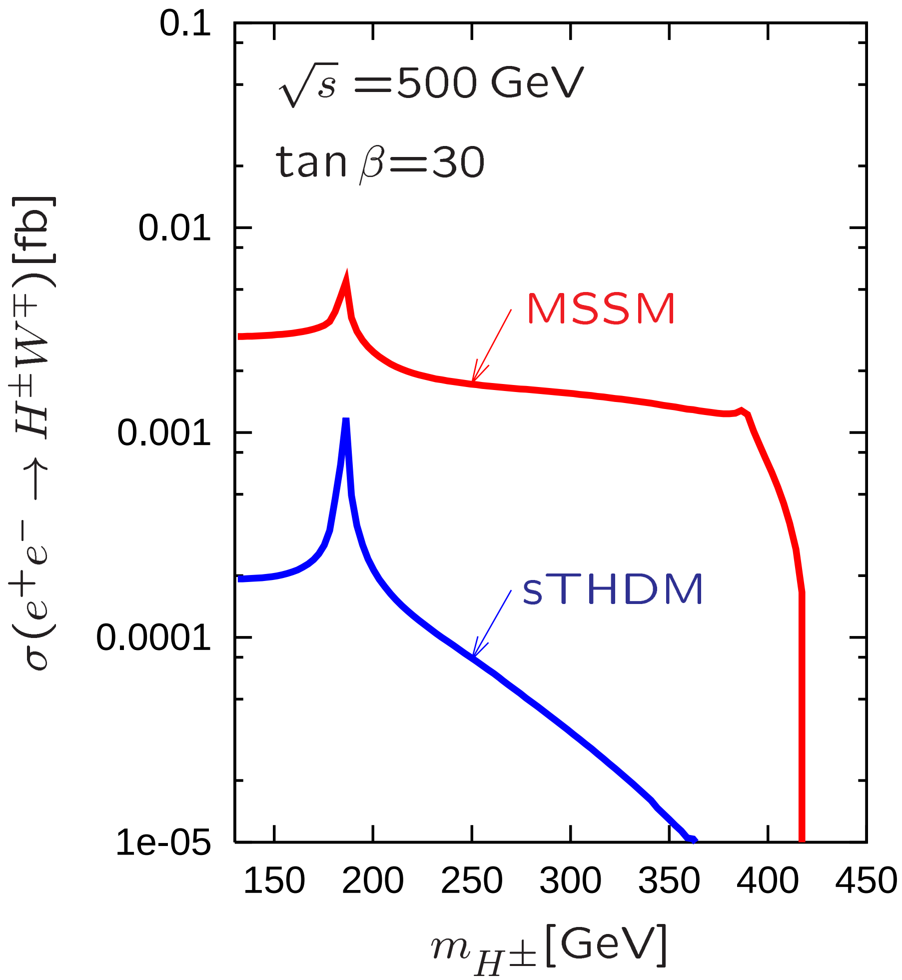
$\rightarrow$ perfectly allowed (all direct & indirect parameter constraints fulfilled)

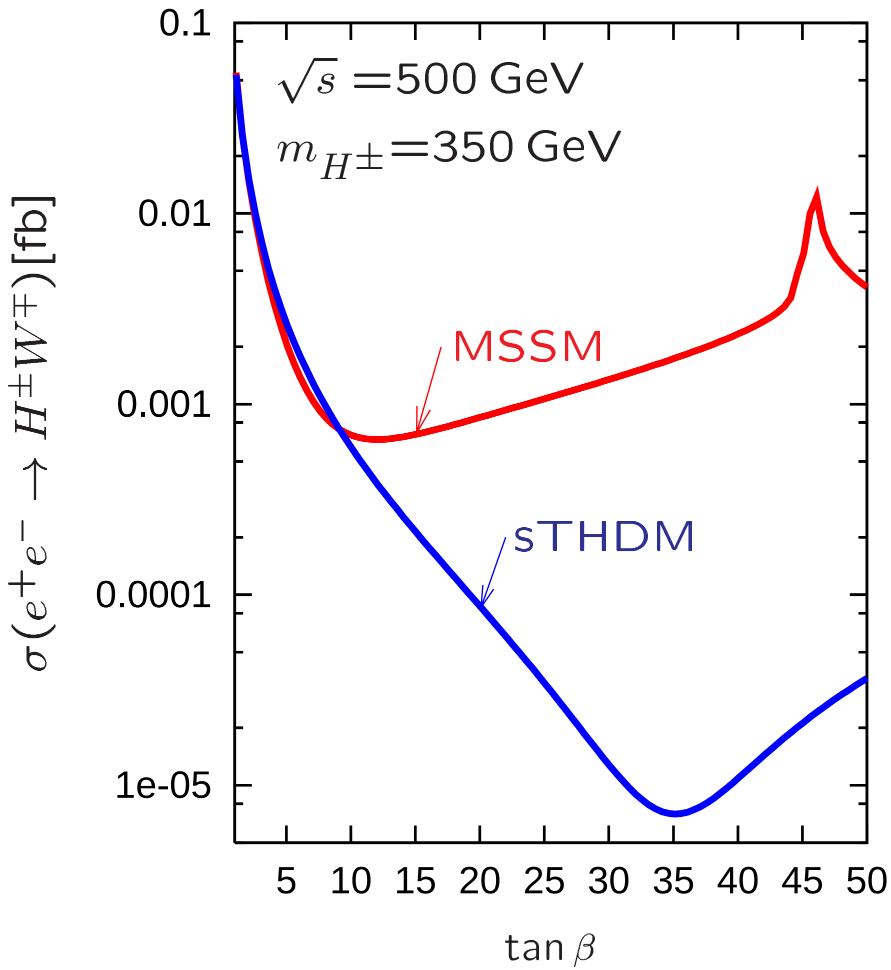
$\rightarrow$ light stop of order 100 GeV, large mass splitting

$\rightarrow$ stop mixing angle $\approx 45°$. Thus: maximal mixing

$\rightarrow$ $|X_t| \approx 2M_{\text{Sf.}}$. Thus: m_h is almost maximal

THDM parameter scenario:
interest here:
difference in the prediction due to the superpartner contributions.
therefore: THDM with MSSM-couplings and Higgs masses is chosen (sTHDM).





$\rightarrow$ Process loop-induced. MSSM and MSSM-like THDM can differ by a factor 10-100.

– MSSM parameter scan

restrictions taken into account:

- mass exclusion limits for Higgs bosons and superpartners
- $\Delta\rho$-constraint on sfermion mixing

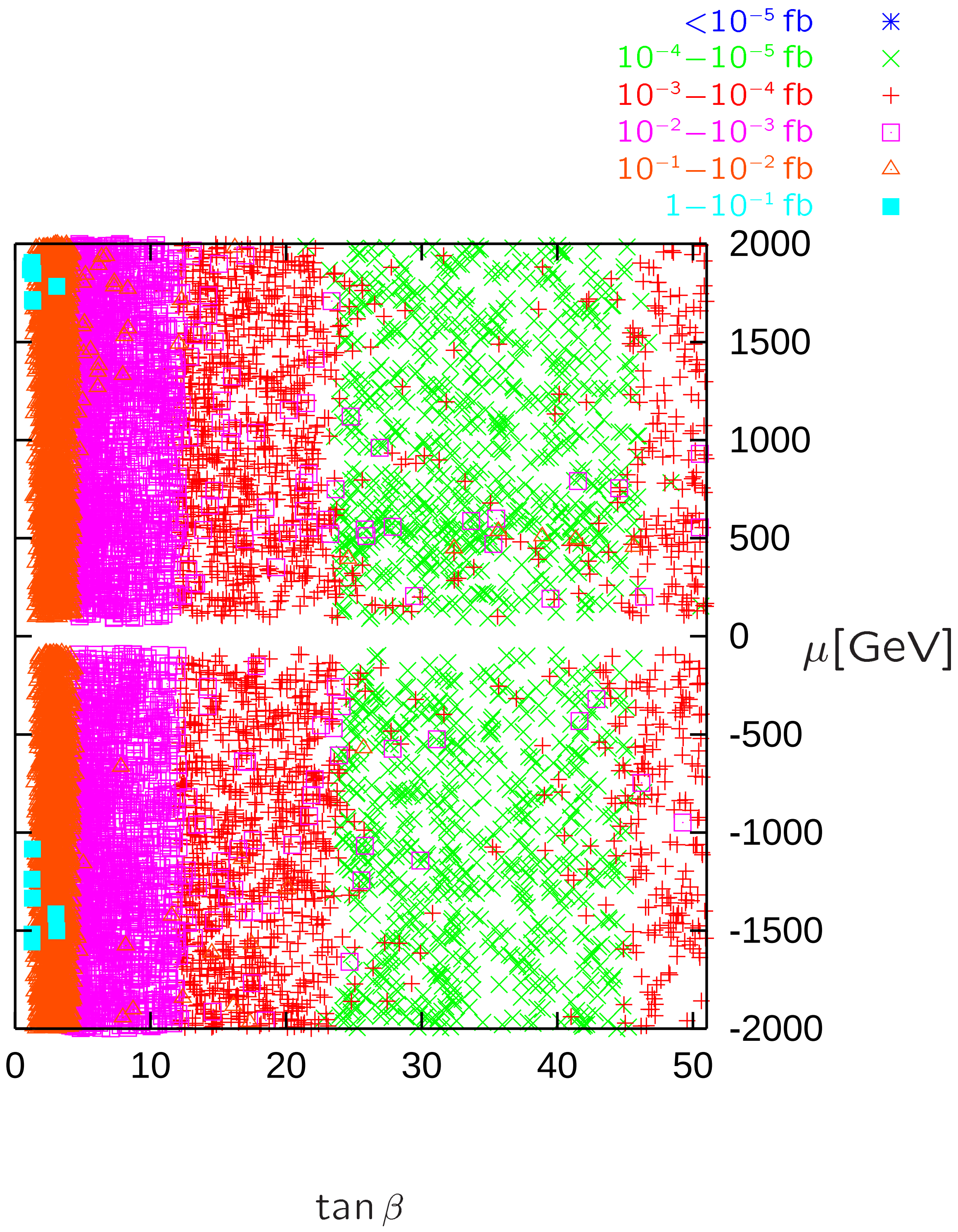
quantities fixed:

$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV

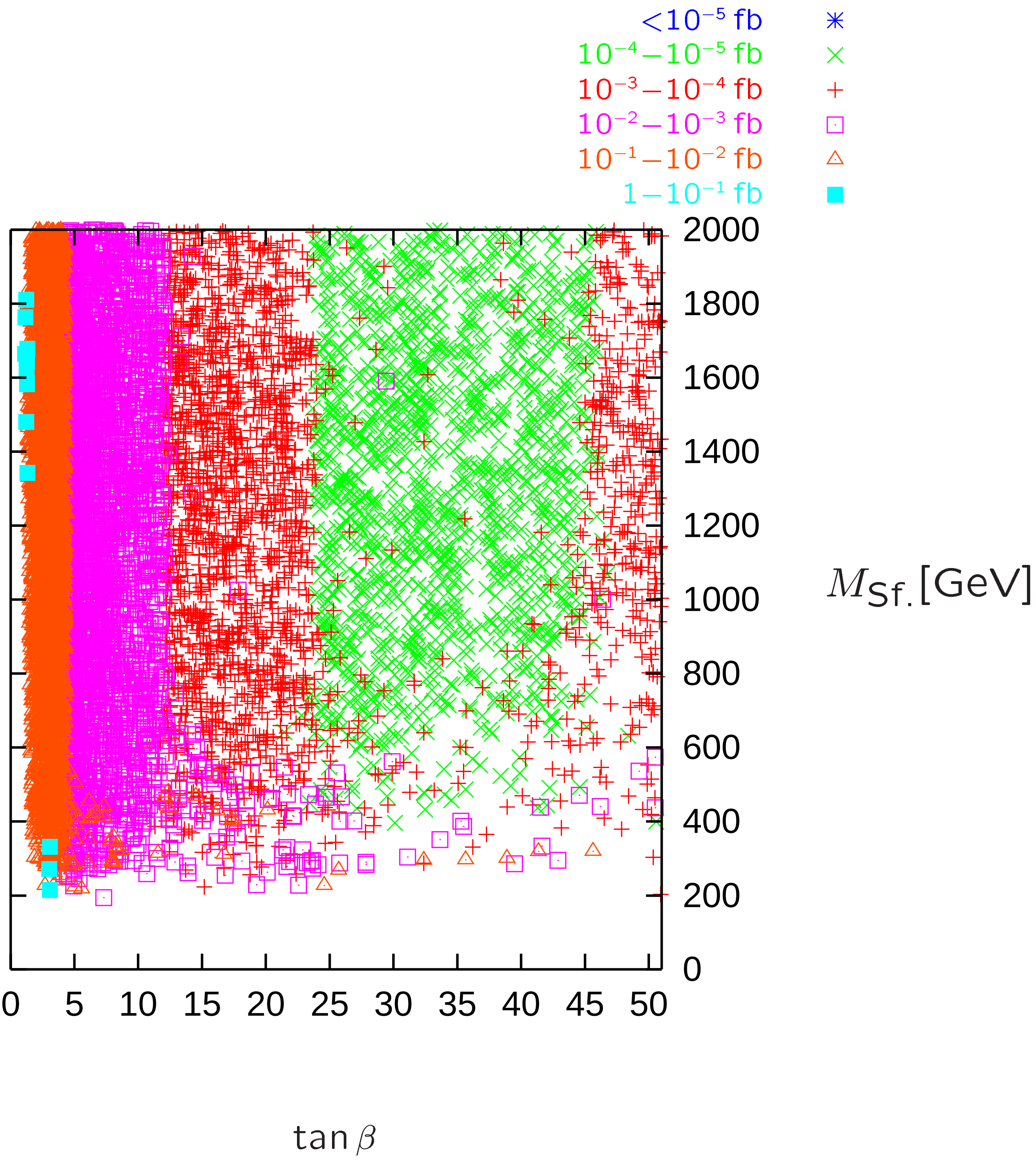
quantities varied:

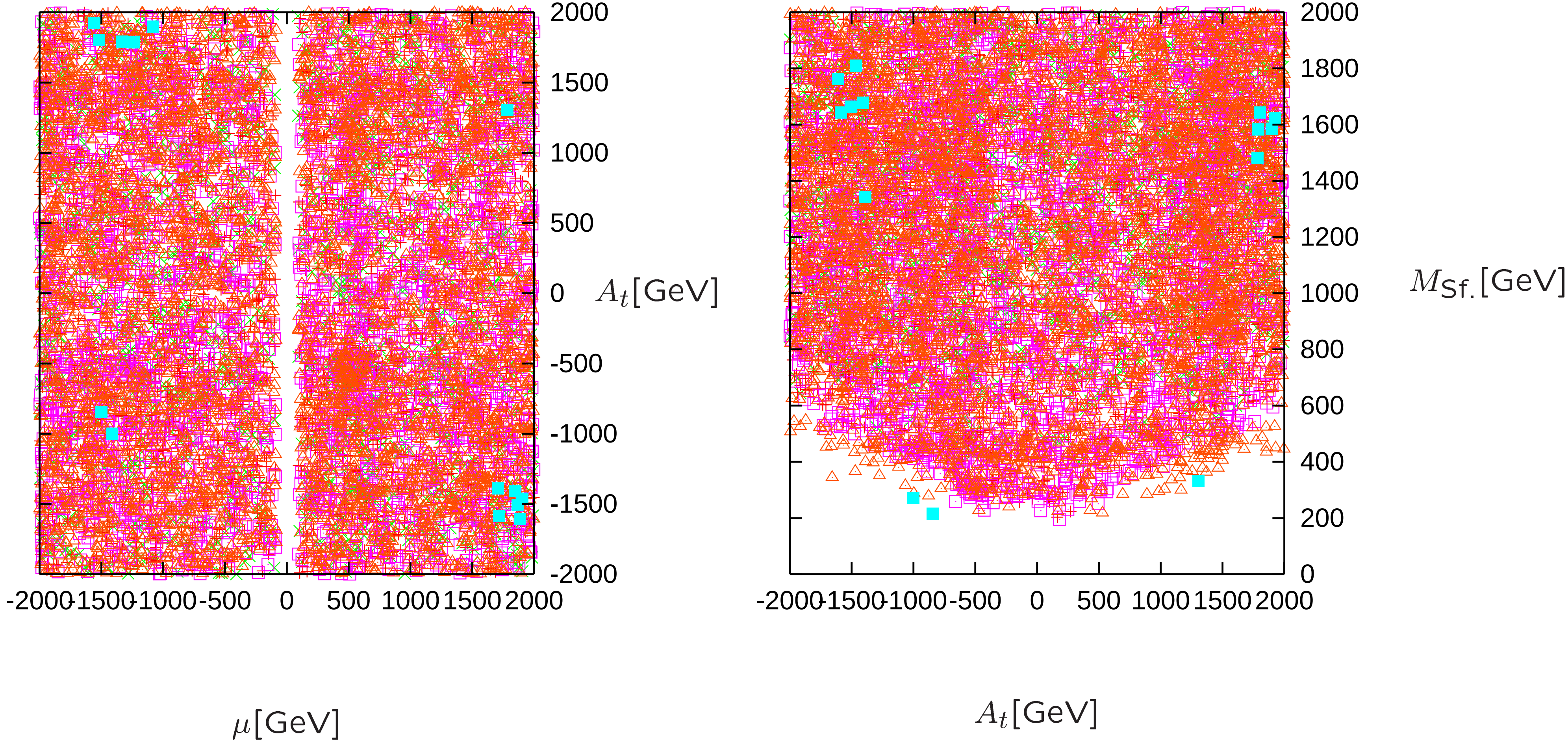
$\tan\beta$	:	$1 \ldots 50$
μ	:	$-2000 \ldots 2000$ GeV
A_t	:	$-2000 \ldots 2000$ GeV
A_b	:	$-2000 \ldots 2000$ GeV
$M_{\text{Sf.}}$	:	$50 \ldots 2000$ GeV
M_2	:	$50 \ldots 2000$ GeV

$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV



$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV





2000
1500
1000
500
0
-500
-1000
-1500
-2000
A_t[GeV]
-2000 -1500 -1000 -500 0 500 1000 1500 2000
μ[GeV]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
$M_{\mathrm{Sf.}}$[GeV]
-2000 -1500 -1000 -500 0 500 1000 1500 2000
A_t[GeV]

– THDM parameter scan

restrictions taken into account:

- tree-level unitarity bounds on all trilinear Higgs couplings
- $\Delta\rho$-constraint on Higgs masses

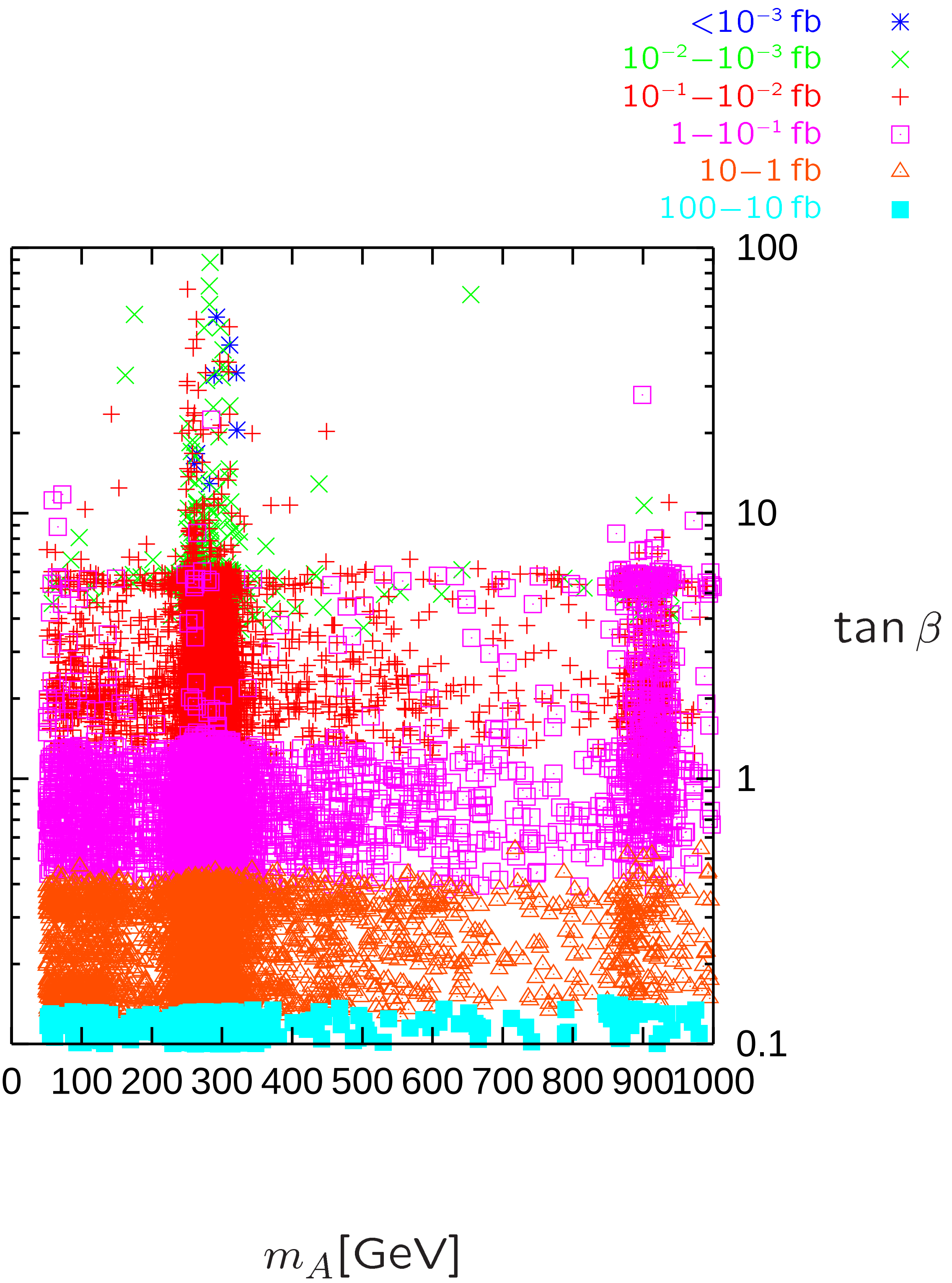
quantities fixed:

$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV

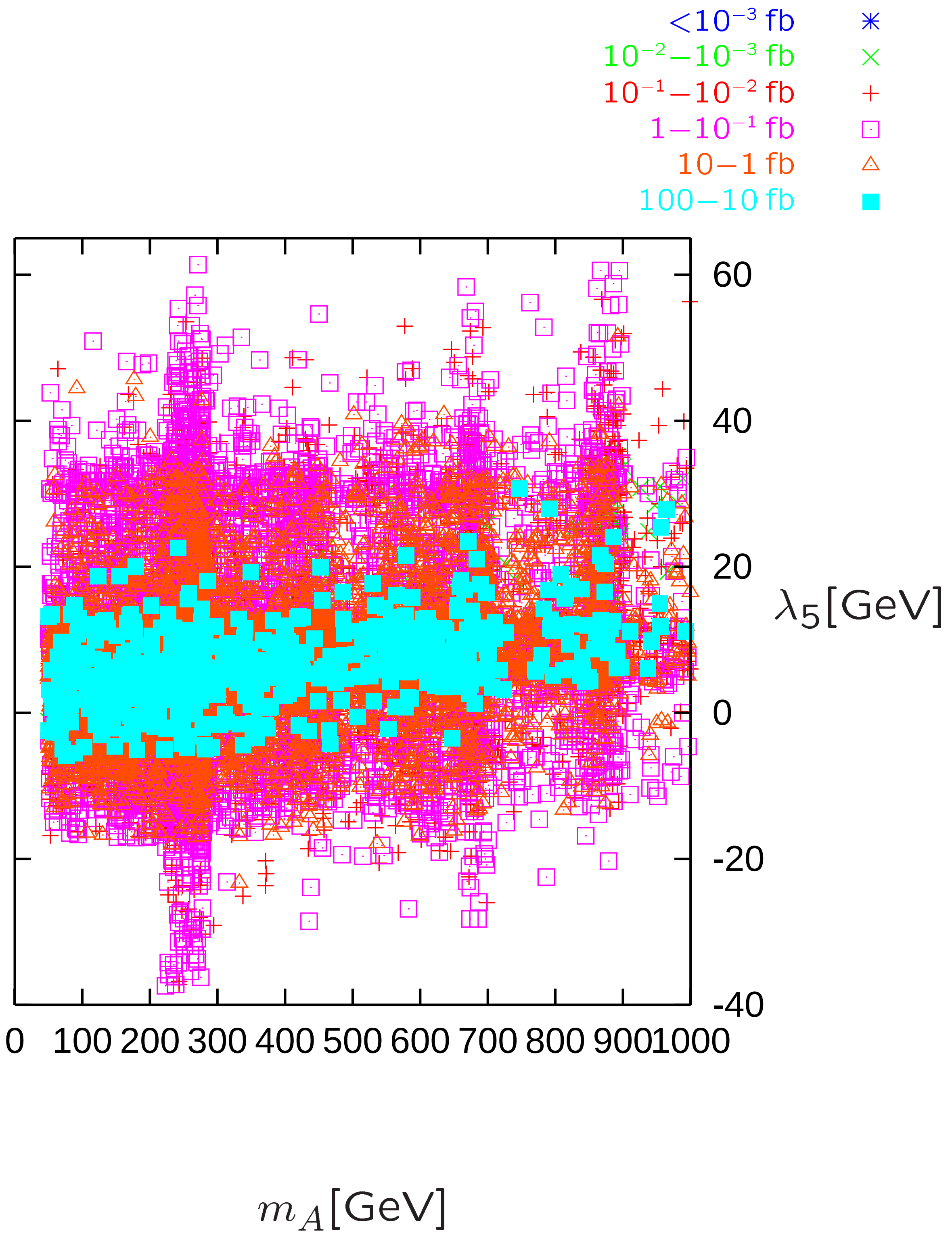
quantities varied:

$\tan\beta$	:	$0.1 \ldots 100$
α	:	$-90° \ldots 90°$
m_A	:	$50 \ldots 1000$ GeV
m_{h^0}	:	$50 \ldots 1000$ GeV
m_{H^0}	:	$50 \ldots 1000$ GeV
λ_5	:	$-1000 \ldots 1000$ GeV

$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV



$\sqrt{\hat{s}} = 500$ GeV, $m_{H^\pm} = 250$ GeV



summary

- $e^+e^- \to H^\pm W^\mp$ important for $H^\pm$ detection if pair production is kinematically forbidden

- Loop-induced processes are highly model dependent
therfore: ideal to gain information on the underlying model.

- MSSM scenarios with large stop mixing can give cross sections which are
significantly different from a MSSM-like THDM.

- For $\sqrt{\hat{s}} = 500\,\mathrm{GeV}$ and $m_{H^\pm} = 250\,\mathrm{GeV}$ the cross section can be at most of order 1 fb (MSSM)/100 fb (THDM).

[see hep-ph/0209124 for (some) information]

By the way:

fortran code available on request
$\to$ brein@physik.rwth-aachen.de