Associated $W^{\pm}H^{\mp}$ production at e^+e^- and hadron colliders

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outline :

- introduction
  - charged Higgs search and beyond
  - MSSM parameter scenario
- $W^{\pm}H^{\mp}$ production at LHC
  - partonic processes
  - MSSM results
  - THDM results
- $e^+e^- \to W^{\pm}H^{\mp}$
  - amplitude
  - MSSM results

• introduction

– charged Higgs search ...

discovery of a charged Higgs boson
$\to$ sign of an extended Higgs sector

Tevatron/LHC

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

production via top decay in $t\bar{t}$ events.

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

main production processes:
$gb \to tH^+$, $gg \to tbH^+$ [$\to$ Plehn's talk]

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

$m_{H^\pm} < \sqrt{s}/2$:

production via $e^+e^- \to H^+H^-$

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

production via $e^+e^- \to W^\pm H^\mp$

most viable Signal:

excess of tau events

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

– ... and beyond

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

$\rightarrow$ processes (partly) 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
on the underlying model

(e.g. MSSM, THDM).

– MSSM parameter scenario

interest here:

large effects from virtual squarks (esp. Stops)

Stop mass matrix in the L-R basis:

$$M_{\tilde{t}}^2 = \begin{pmatrix} M_{\rm SUSY}^2 + m_t^2 + DT_1 & m_t X_t \\ m_t X_t & M_{\rm SUSY}^2 + m_t^2 + DT_2 \end{pmatrix}$$

with the Stop mixing parameter

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

choice of parameters:

common Sfermion mass scale

$M_{\rm SUSY} = 350$ GeV

Stop mixing parameter

$X_t = -800$ GeV

supersymmetric Higgs mass term

$\mu = 300$ GeV

gaugino mass terms $\approx \mathcal{O}(1\,\text{TeV})$

resulting scenario:

→ perfectly allowed (all direct & indirect parameter constraints fullfilled)

→ light Stop of order 100 GeV, large mass splitting

→ Stop mixing angle ≈ 45°. Thus: maximal mixing

→ $|X_t| \approx 2M_{\mathrm{SUSY}}$. Thus: m_h is almost maximal

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

(with W. Hollik and S. Kanemura)

– partonic processes

(a) $b\bar{b} \to W^{\pm}H^{\mp}$, $b\bar{b}$ annihilation

$\to$ mediated at tree-level

$\to$ naive calc. overestimates cross section

[$\to$ Zhu's talk]

(b) $gg \to W^{\pm}H^{\mp}$, gluon fusion

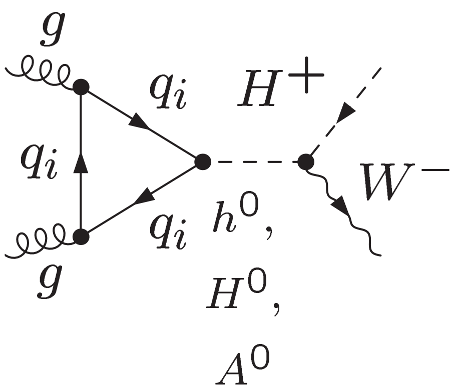
$\to$ loop-induced

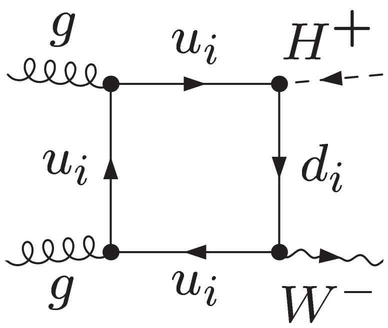
$\to$ large # of gg collisions at high Energy pp colliders

[$W^{\pm}H^{\mp}$ production at LHC, partonic processes]

gluon fusion

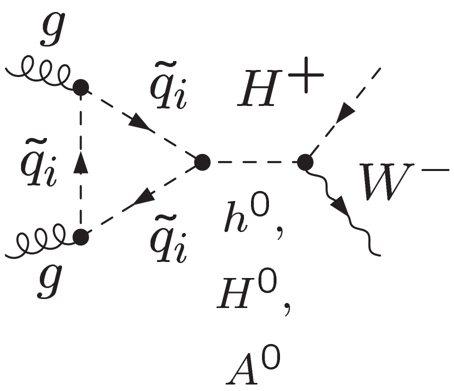
THDM amplitude

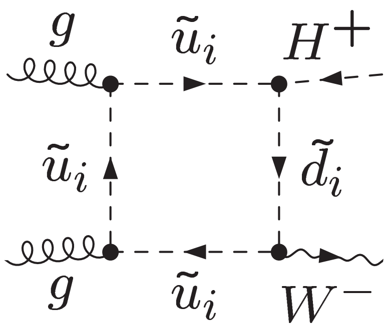




+ more

squark amplitude





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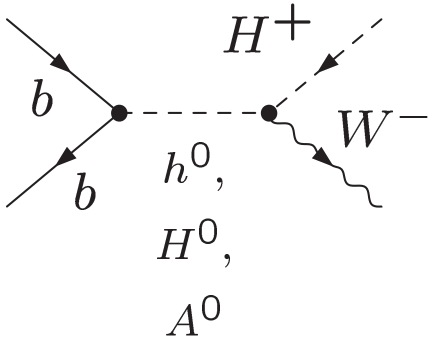
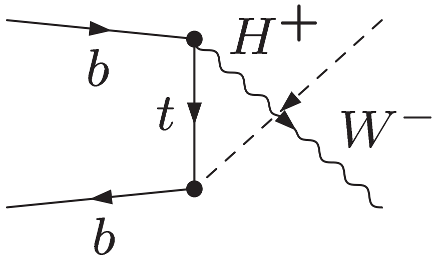
$b\bar{b}$ annihilation





[gg: THDM: Dicus et al. '89; MSSM: Barrientos & Kniehl '99,'00; O.B., Hollik, Kanemura '00
$b\bar{b}$: MSSM: QCD corr. Hollik & Zhu '01]

– MSSM results

features:

$b\bar{b}$ annihilation :

$\rightarrow$ rather insensitive to SUSY-Spectrum

gluon fusion :

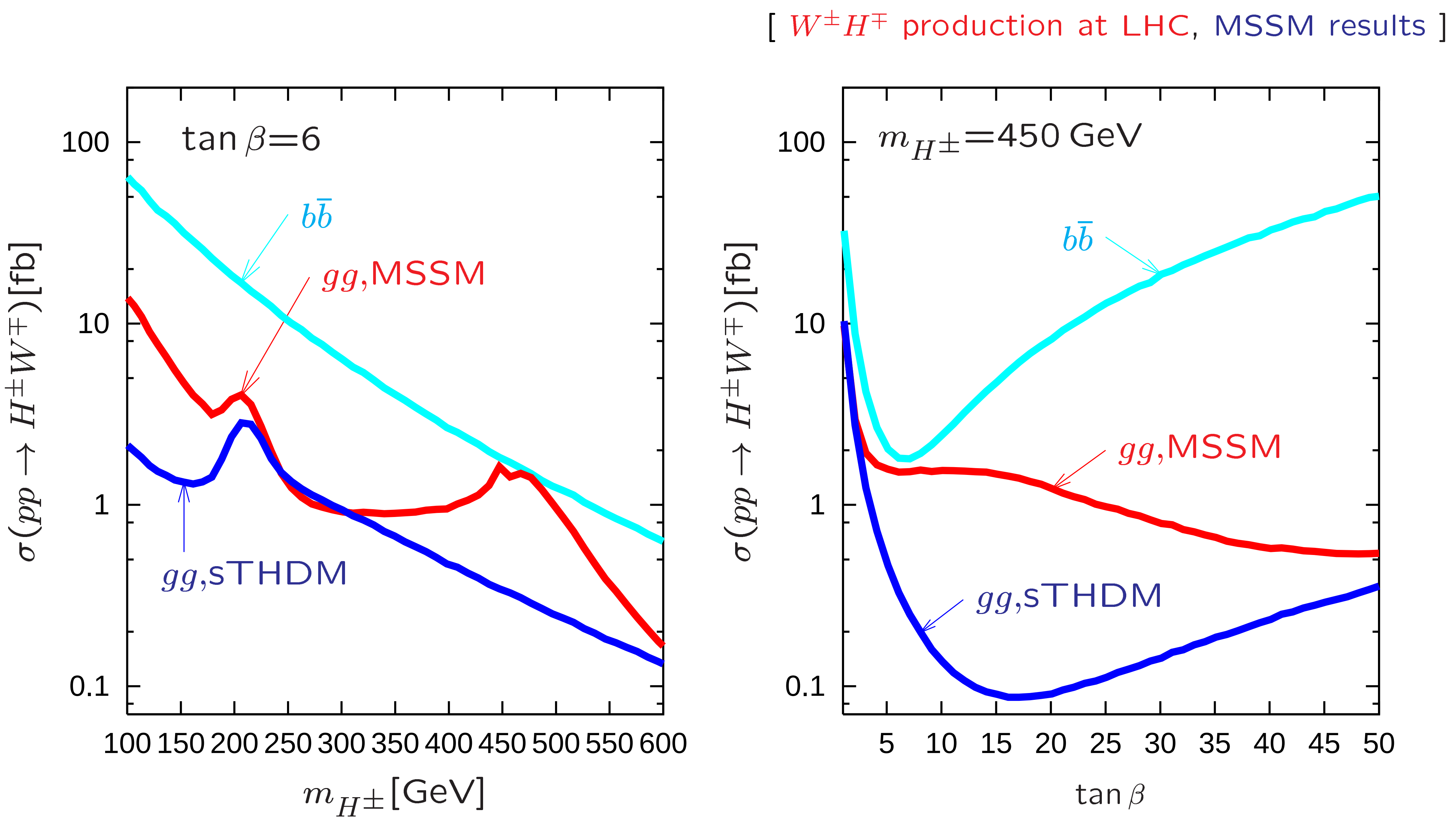
$\rightarrow$ sensitive to virtual SUSY-particles

$\rightarrow$ large destructive interference between quark loops of box and triangle type.

$\rightarrow$ squark contribution can get large due to threshold effects in box loops

both processes:

$\rightarrow$ sensitive to the neutral Higgs sector


[$W^{\pm}H^{\mp}$ production at LHC, MSSM results]
tan β=6
$\sigma(pp \to H^{\pm}W^{\mp})$[fb]
100
10
1
0.1
$b\bar{b}$
gg,MSSM
gg,sTHDM
100 150 200 250 300 350 400 450 500 550 600
$m_{H^{\pm}}$[GeV]
$m_{H^{\pm}}$=450 GeV
$\sigma(pp \to H^{\pm}W^{\mp})$[fb]
100
10
1
0.1
$b\bar{b}$
gg,MSSM
gg,sTHDM
5 10 15 20 25 30 35 40 45 50
tan β

– THDM results

Note !

In the MSSM the mass relations among the Higgs bosons for large $m_{H^\pm}$ lead to:

$$m_{h^0} = \mathcal{O}(100\text{GeV}),\ m_{H^0} \approx m_{A^0} \approx m_{H^\pm}\ .$$

Thus, in the MSSM:

→ contributions of neutral Higgs s-channel exchange cannot decouple from the process

→ no resonant s-channel Higgs exchange possible ($m_{H^\pm} + m_W > m_{h^0,H^0,A^0}$)

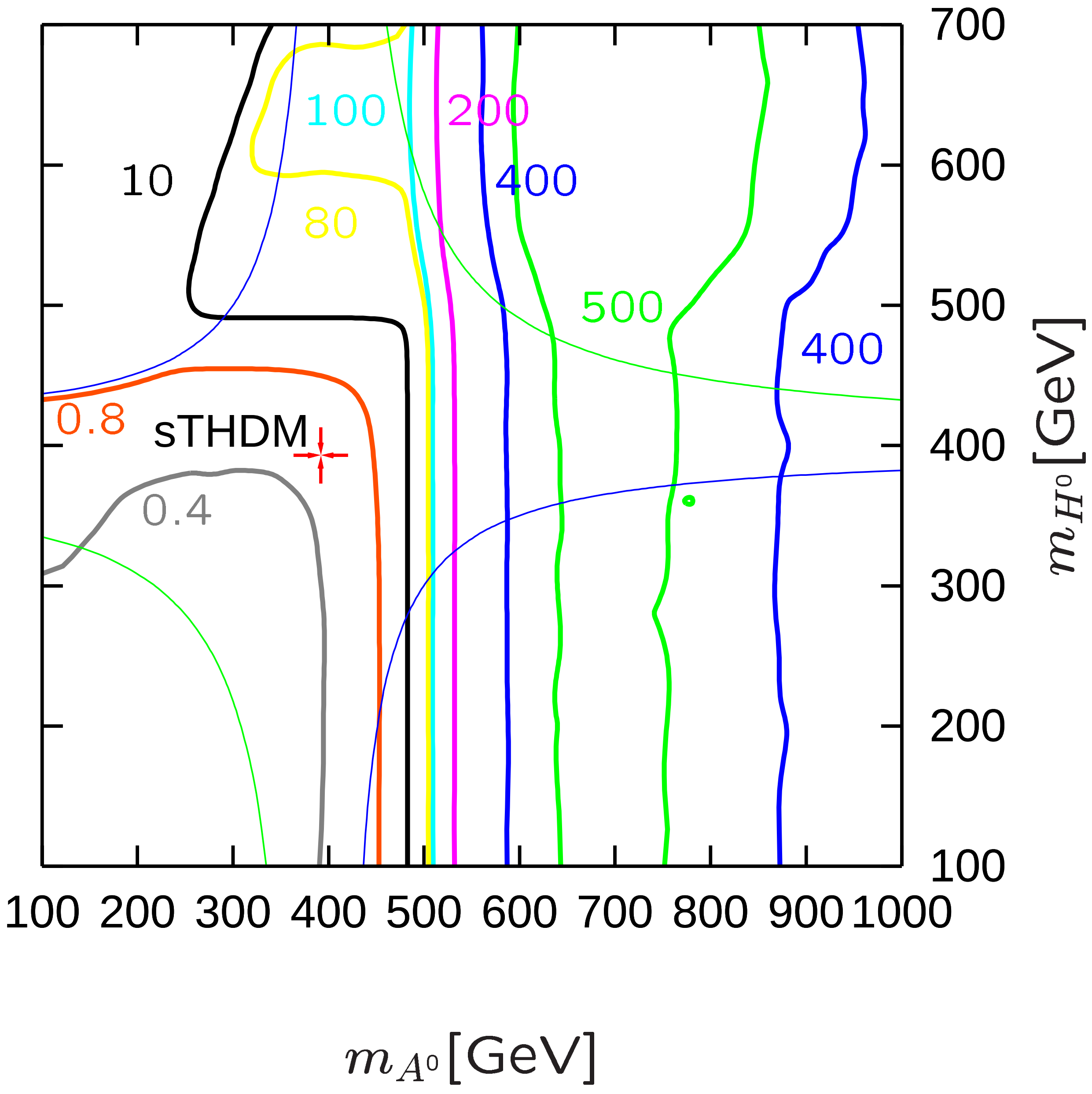
→ negative interference between box- and triangle-type quark loops unavoidable

But this is not true in the THDM !

→ cross section in the THDM can be much larger than in the MSSM

[$W^{\pm}H^{\mp}$ production at LHC, THDM results]

$\sigma(pp \to W^{\pm}H^{\mp})$ [fb]



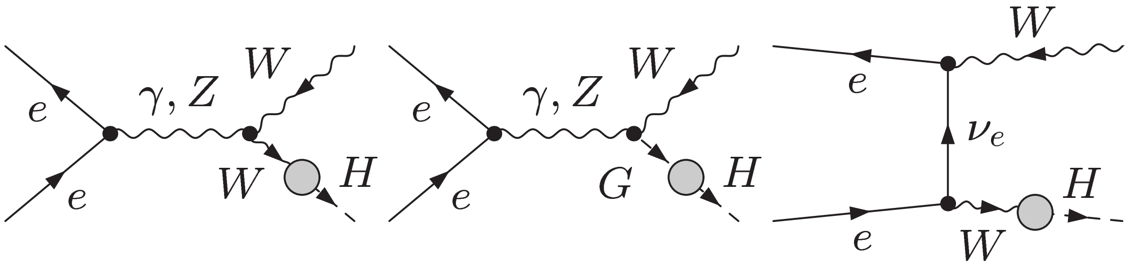
($m_{H^{\pm}} = 400$ GeV, $\tan\beta = 6$)

• $e^+e^- \to W^\pm H^\mp$

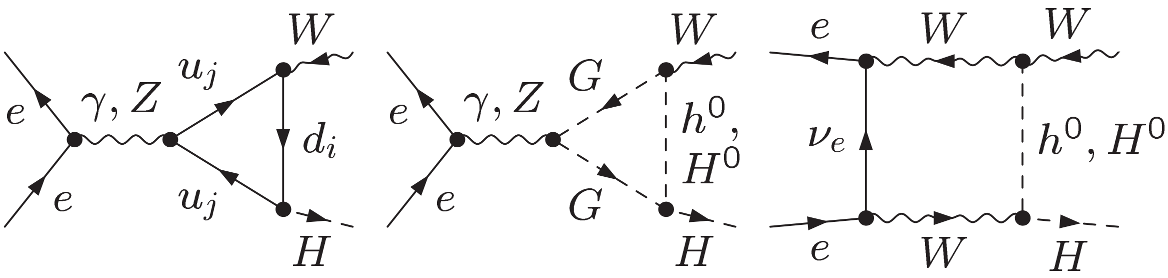
(with W. Hollik and T. Hahn)

– amplitude [→ Su's talk]

self energies

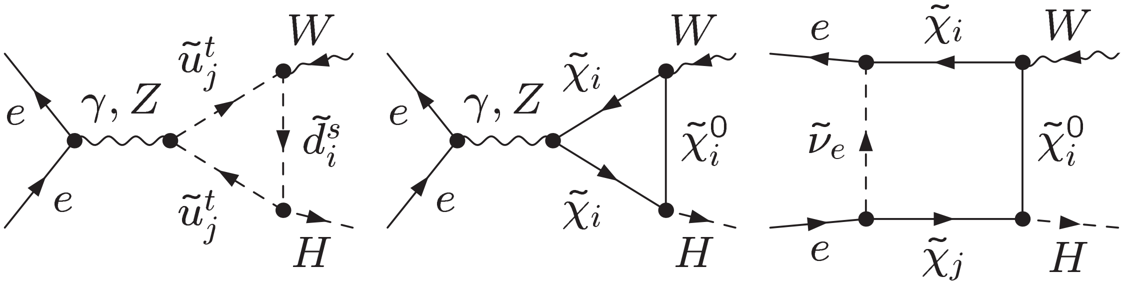


vertices & boxes, THDM like contributions



+ more

vertices & boxes, SUSY contributions



+ more

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

MSSM: Logan & Su '02; O.B., Hollik, Hahn '02]

– MSSM results

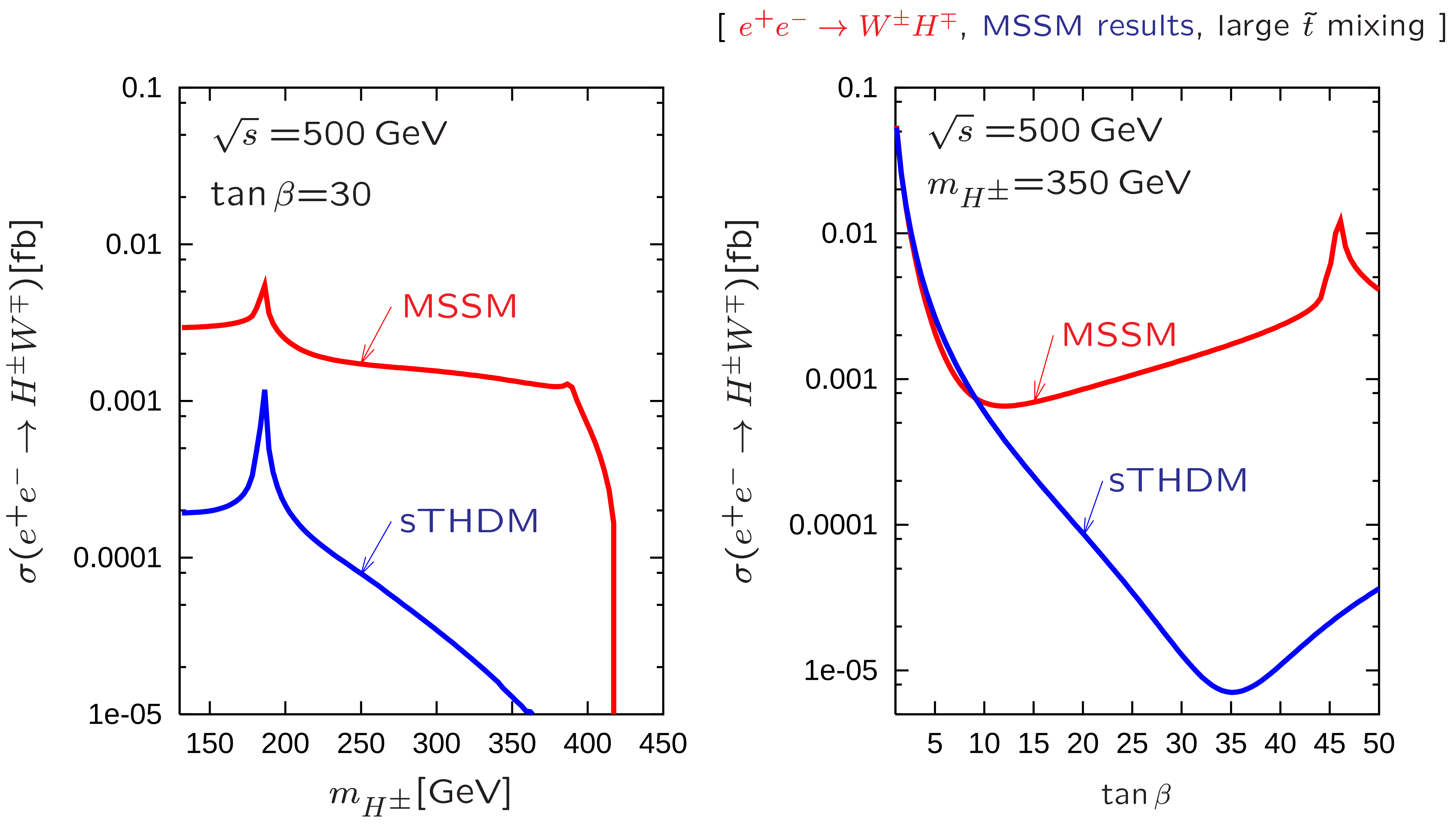
features:

$\to$ vertex diagramms give main contribution to cross section

$\to$ squark loops can enhance the cross section of the MSSM wrt the MSSM-like THDM by a factor 10-100 (large $\tan\beta$ (> 20))

$\to$ optimal polarization of e^- and e^+ can increase the cross section by a factor 4

$\to$ large corrections by neutralino/chargino loops are also possible



[$e^+e^- \to W^\pm H^\mp$, MSSM results, large $\tilde{t}$ mixing]
$\sqrt{s}$ =500 GeV
$\tan\beta$=30
MSSM
sTHDM
$\sigma(e^+e^- \to H^\pm W^\mp)$[fb]
0.1
0.01
0.001
0.0001
1e-05
150
200
250
300
350
400
450
$m_{H^\pm}$[GeV]
$\sqrt{s}$ =500 GeV
$m_{H^\pm}$=350 GeV
MSSM
sTHDM
$\sigma(e^+e^- \to H^\pm W^\mp)$[fb]
0.1
0.01
0.001
0.0001
1e-05
5
10
15
20
25
30
35
40
45
50
$\tan\beta$

summary

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

- gluon-fusion can compete with $b\bar{b}$ annihilation (in certain cases)

- cross section in the general THDM can be much larger than in the MSSM (about a factor 500-1000).

$e^{+}e^{-} \to W^{\pm}H^{\mp}$

- process important for $H^{\pm}$ detection if pair production is kinematically forbidden

general

- (these) 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