Higgs effects in neutralino decays
Higgs production in CP violating scenarios
Loop corrections
Summary

SUSY cascade decays and Higgs effects

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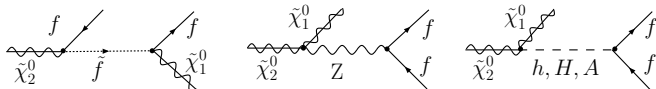
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Outline

1. Higgs effects in neutralino decays

2. Higgs production in CP violating scenarios

3. Loop corrections

4. Summary

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Higgs effects in neutralino decays

$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^-$, $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tau^+ \tau^-$, $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \bar{b} b$

- Drees, Hollik and Xu (2007): 1-loop corrections in rMSSM
  Corrections $\sim 15\%$ for SPS1a-like scenarios
- What about $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tau^+ \tau^-$, $b\bar{b}$ with large $\tan\beta$ or small M_A?
- Loop corrections in Higgs sector large, esp. in cMSSM.

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Sfermion interference

Phalen and Pierce (hep-ph/0705.1366): Interference between sfermion and Z can help reconstruct MSSM parameters.

$$R = \frac{BR(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \bar{b}b)}{BR(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^-)}$$

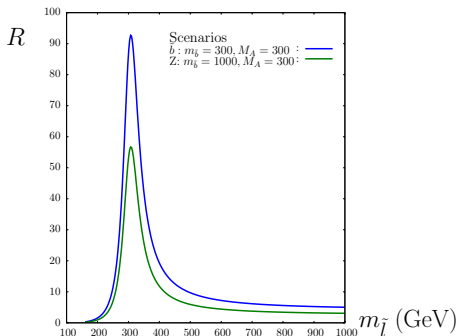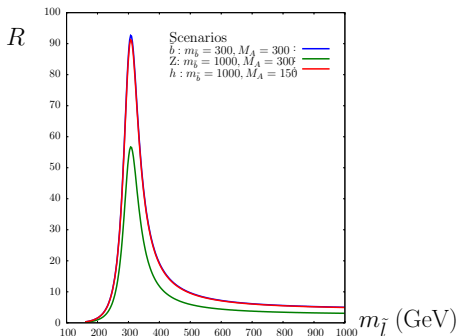Claim can measure with accuracy $\approx 10\%$ at LHC

$$R > R_Z \approx 2.2$$

$\Rightarrow$ Sfermion interference important

Higgs exchange neglected.
$M_A = 300$

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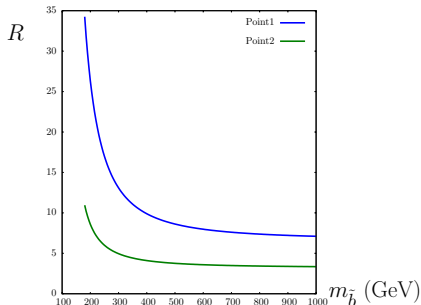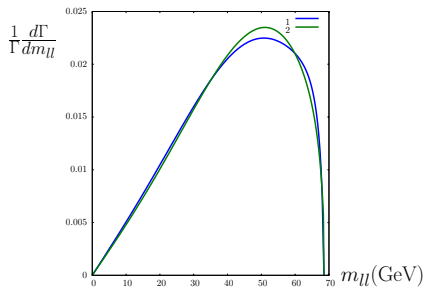Higgs can mimic small $m_{\tilde{b}}$.
$M_A = 150$

Scenarios
$\tilde{b} : m_{\tilde{b}} = 300, M_A = 300$
$Z : m_{\tilde{b}} = 1000, M_A = 300$
$h : m_{\tilde{b}} = 1000, M_A = 150$

$m_{\tilde{l}}$ (GeV)

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R can reveal complementary info to *IMD*. (hep-ph/0705.1366)
Scenarios may have degenerate *IMD*, but different *R*.

1: $M_1 = 57, M_2 = 140, \mu = 310,\ \tan\beta = 4, m_{\tilde{l}_L} = 250, m_{\tilde{l}_R} = 500$

2: $M_1 = 70, M_2 = 140, \mu = -300, \tan\beta = 4, m_{\tilde{l}_L} = 255, m_{\tilde{l}_R} = 255$

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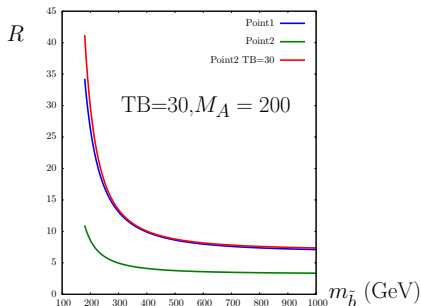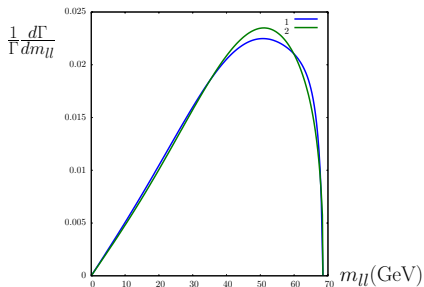## Sfermion interference

But increased $\tan\beta$ enhances Higgs contribution to $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 b\bar{b}$.
Would need input from Higgs sector to disentangle parameters.

eg. Point 2 with $\tan\beta = 30, M_A = 200$ can have degenerate R to Point 1

$\Rightarrow$ R may only be a useful observable in some scenarios...

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Higgs in SUSY cascade decays

- Direct Higgs production by SM-like processes well-known.
- But if Higgs exchange can be important in $\tilde{\chi}^0$ decays...
- SUSY cascade decays: another source of light Higgs.
- Eg. In regions where standard searches only guarantee *h* at the LHC, *H* and *A* can be produced via:(hep-ph/0303095)

  $pp \rightarrow \widetilde{g}\widetilde{g}, \widetilde{q}\widetilde{q}, \widetilde{g}\widetilde{q} \rightarrow \tilde{\chi}_i^0, \tilde{\chi}_i^+ + X \rightarrow \tilde{\chi}_j^0, \tilde{\chi}_j^+ + X + h, H, A, H^{\pm}$
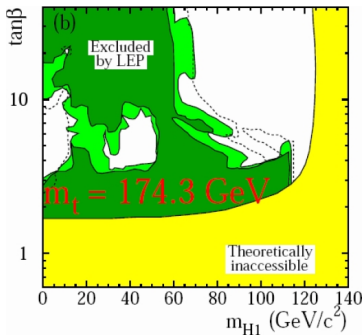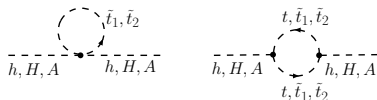
- Search for Higgs via cascade decays may be complementary to standard SM-like searches.
- Also a probe to uncover parameters of EWSB.
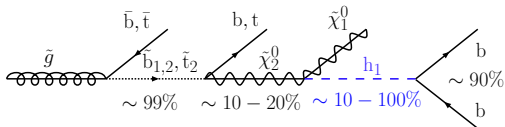
What about even lighter Higgs bosons? 30-40GeV...

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CPX Scenario

$\mu = 2000, M_{\mathrm{SUSY}} = 500, |M_3| = 1000, |A_{\mathrm{t,b},\tau}| = 900, \phi_{M_3} = \frac{\pi}{2}, \phi_A = \frac{\pi}{2}$

Extreme CP violating scenario with large $h - H - A$ mixing.

h_1 mostly CP-odd A^0
$\Rightarrow$ Reduction in ZZh_1 coupling
$\Rightarrow$ LEP hole ... LHC hole?

Possible Cascade:

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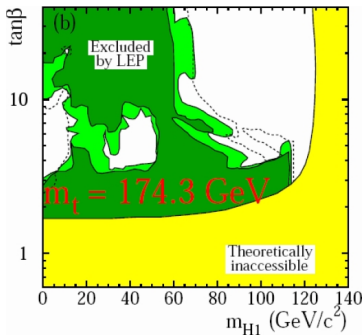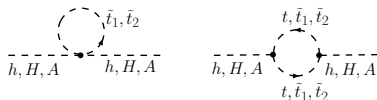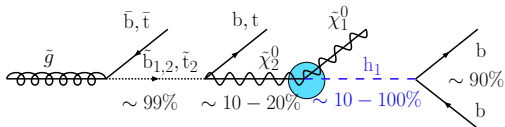$\Rightarrow$ LEP hole ... LHC hole?

Possible Cascade:

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Loop Corrections in the Higgs Sector

Full vertex correction:

(follow Heinemeyer et al. hep-ph/0611326):

- 2 input parameters: $m_{H^\pm}$, $\tan\beta$
- Fix $m_{H^\pm}$ on-shell $\Rightarrow m_h$, m_H, m_A receive corrections.
- Finite normalisation factors Z_{ij}: sum up h, H, A vertices.

Implemented into FeynArts model file
Use 2-loop Z_{ij} and m_i from FeynHiggs

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Loop Corrections in the Neutralino Sector

$$X = \begin{pmatrix} M_2 & \sqrt{2}M_W \sin\beta \\ \sqrt{2}M_W \cos\beta & \mu \end{pmatrix}$$

$$Y = \begin{pmatrix} M_1 & 0 & -m_Z c_\beta s_W & m_Z s_\beta s_W \\ 0 & M_2 & m_Z c_\beta c_W & -m_Z s_\beta c_W \\ -m_Z c_\beta s_W & m_Z c_\beta c_W & 0 & -\mu \\ m_Z s_\beta s_W & -m_Z s_\beta c_W & -\mu & 0 \end{pmatrix}$$
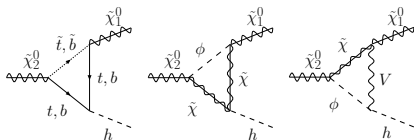
(modified from Fritsche et al. hep-ph/0203159)

- 3 independent parameters: M_1, M_2, μ .... 6 masses
- Require $\tilde{\chi}_1^+$, $\tilde{\chi}_{1,2}^0$ on-shell.
- Masses of $\tilde{\chi}_2^+$, $\tilde{\chi}_{3,4}^0$ receive corrections.

Implemented into FeynArts model file

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Preliminary results

eg.

$$\Gamma(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h_1)$$

CPX: $\tan\beta = 7, M_2 = 200$
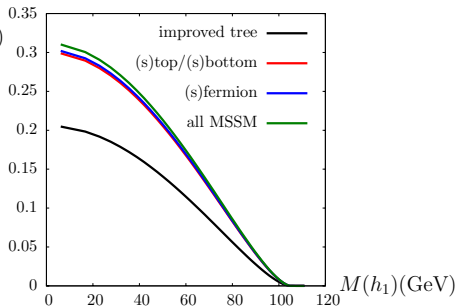
- Improved Born: $Z_{ij}^{(2)}\Gamma_j^{tree}$
- Improved 1-loop: $Z_{ij}^{(2)}\Gamma_j^{(1)}$
- $t, \tilde{t}, b, \tilde{b}$ dominant.
- Genuine vertex corrections up to 40% in extreme CPX scenario.

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- Higgs exchange in $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \bar{b}b$ significant for large $\tan\beta$ and small M_A, contributing to observables such as R.
- In CP violating scenarios, h may be as light as 30-40GeV.
- Such a light h may be significantly produced via $\tilde{\chi}$ decay.
- Genuine vertex corrections to $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h_1$ are large and will need to be included.
- Outlook:
  - More detailed studies of CP violating scenarios at LEP, LHC
  - Other CP violating loop effects from M_1, M_2 and μ