Higgs and DM Production via SUSY Decays at the LC

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based on collaboration with
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1. Introduction

2. SUSY decays to Higgs bosons

3. SUSY decays to Dark Matter

4. Conclusions

1. Introduction

Production of SUSY particles at the LC:

$$e^+e^- \to \tilde{t}_2\,\tilde{t}_1^\dagger \to h\,\tilde{t}_1\,\tilde{t}_1^\dagger \to h\,t\,\tilde{\chi}_1^0\,\bar{t}\,\tilde{\chi}_1^0$$

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Always: production of the lightest SUSY particle: $\tilde{\chi}_1^0$ $\Rightarrow$ Dark Matter

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Production of SUSY particles at the LC:

$$e^+e^- \to \tilde{t}_2\, \tilde{t}_1^\dagger \to h\, \tilde{t}_1\, \tilde{t}_1^\dagger \to h\, t\, \tilde{\chi}_1^0\, \bar{t}\, \tilde{\chi}_1^0$$

Possible: production of Higgs bosons: $\tilde{t}_2 \to \tilde{t}_1 h_i, \ldots$ $\Rightarrow$ light $\mathcal{CP}$-even Higgs

Always: production of the lightest SUSY particle: $\tilde{\chi}_1^0$ $\Rightarrow$ Dark Matter

$\Rightarrow$ important source for information on Higgs

$\Rightarrow$ important source for information on LSP/DM

$\Rightarrow$ precision prediction (at least) of BR's necessary

Enlarged Higgs sector: Two Higgs doublets

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2 (\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}} (H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}} |H_1 \bar{H}_2|^2$$

gauge couplings, in contrast to SM

physical states: $h^0, H^0, A^0, H^\pm$

Goldstone bosons: $G^0, G^\pm$

Input parameters: (to be determined experimentally)

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_A^2 = -m_{12}^2 (\tan\beta + \cot\beta)$$

Enlarged Higgs sector: Two Higgs doublets with $\mathcal{CP}$ violation

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix} e^{i\xi}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2 (\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}}(H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}} |H_1 \bar{H}_2|^2$$

gauge couplings, in contrast to SM

physical states: $h^0, H^0, A^0, H^\pm$

2 $\mathcal{CP}$-violating phases: ξ, arg(m_{12}) $\Rightarrow$ can be set/rotated to zero

Input parameters: (to be determined experimentally)

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_{H^\pm}^2$$

Complex parameters:

– μ : Higgsino mass parameter

– $A_{t,b,\tau}$: trilinear couplings $\Rightarrow X_{t,b,\tau} = A_{t,b} - \mu^*\{\cot\beta\,,\tan\beta\}$ complex

– $M_{1,2}$: gaugino mass parameter (one phase can be eliminated)

– $m_{\tilde{g}}$: gluino mass

$\Rightarrow$ can induce $\mathcal{CP}$-violating effects

Effects of complex parameters in the Higgs sector:

Complex parameters enter via loop corrections:

Result:

$$(A, H, h) \to (h_3, h_2, h_1(=\phi))$$

with

$$M_{h_3} > M_{h_2} > M_{h_1}$$

More on complex phases: $\tilde{t}/\tilde{b}$ sector of the MSSM:

Stop, sbottom mass matrices ($X_t = A_t - \mu^*/\tan\beta$, $X_b = A_b - \mu^* \tan\beta$):

$$\mathbf{M}^2_{\tilde{t}} = \begin{pmatrix} M^2_{\tilde{t}_L} + m_t^2 + DT_{t_1} & m_t X_t^* \\ m_t X_t & M^2_{\tilde{t}_R} + m_t^2 + DT_{t_2} \end{pmatrix} \xrightarrow{\theta_{\tilde{t}}} \begin{pmatrix} m^2_{\tilde{t}_1} & 0 \\ 0 & m^2_{\tilde{t}_2} \end{pmatrix}$$

$$\mathbf{M}^2_{\tilde{b}} = \begin{pmatrix} M^2_{\tilde{b}_L} + m_b^2 + DT_{b_1} & m_b X_b^* \\ m_b X_b & M^2_{\tilde{b}_R} + m_b^2 + DT_{b_2} \end{pmatrix} \xrightarrow{\theta_{\tilde{b}}} \begin{pmatrix} m^2_{\tilde{b}_1} & 0 \\ 0 & m^2_{\tilde{b}_2} \end{pmatrix}$$

mixing important in stop sector (also in sbottom sector for large $\tan\beta$)

$SU(2)$ relation $\Rightarrow M_{\tilde{t}_L} = M_{\tilde{b}_L}$

$\Rightarrow$ relation between $m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}}, m_{\tilde{b}_1}, m_{\tilde{b}_2}, \theta_{\tilde{b}}$

More on complex phases: Neutralinos and charginos:

Higgsinos and electroweak gauginos mix

charged:

$$\tilde{W}^+, \tilde{h}_u^+ \to \tilde{\chi}_1^+, \tilde{\chi}_2^+, \qquad \tilde{W}^-, \tilde{h}_d^- \to \tilde{\chi}_1^-, \tilde{\chi}_2^-$$

⇒ charginos: mass eigenstates

mass matrix given in terms of M_2, μ, $\tan\beta$

neutral:

$$\underbrace{\tilde{\gamma}, \tilde{Z},}_{\tilde{W}^0,\, \tilde{B}^0} \tilde{h}_u^0, \tilde{h}_d^0 \to \tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$$

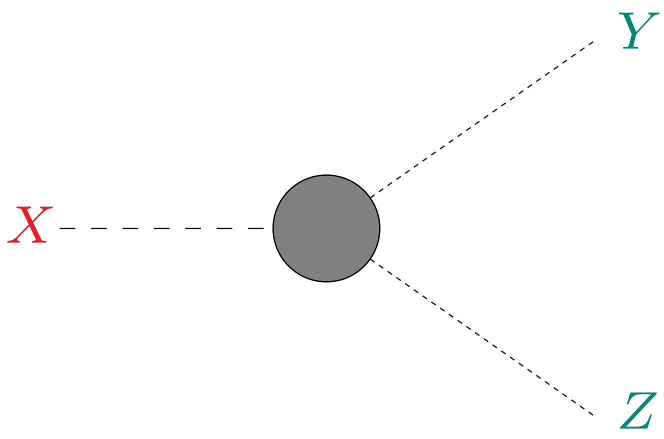
⇒ neutralinos: mass eigenstates

mass matrix given in terms of M_1, M_2, μ, $\tan\beta$

⇒ only one new parameter

⇒ MSSM predicts mass relations between neutralinos and charginos

The bigger picture: SUSY decays in the cMSSM

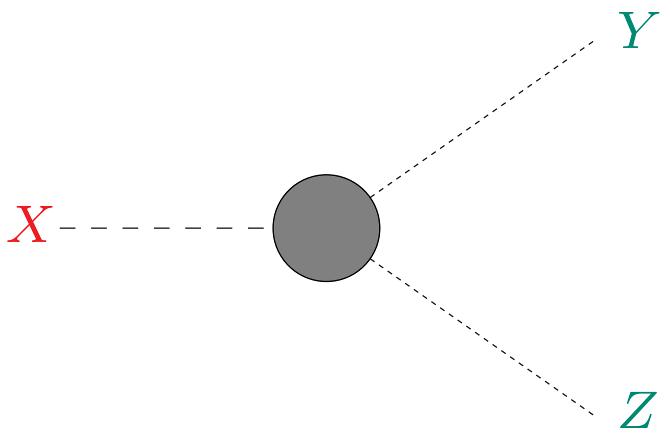


$\Rightarrow$ to get BRs right $\Rightarrow$ all decays needed

$\Rightarrow$ (nearly) all sectors of the cMSSM enter as external particles

$\Rightarrow$ (nearly) all sectors of the cMSSM have to be renormalized simultaneously

The bigger picture: SUSY decays in the cMSSM



⇒ to get BRs right ⇒ all decays needed

⇒ (nearly) all sectors of the cMSSM enter as external particles

⇒ (nearly) all sectors of the cMSSM have to be renormalized simultaneously

now ready:

– (heavy) stop, sbottom and stau decays ⇒ relevant for Higgs, LSP
– gluino decays
– (non-hadronic) chargino decays ⇒ relevant for Higgs, LSP
– (non-hadronic) neutralino decays ⇒ relevant for Higgs, LSP

LC potential:

The clean environment of the LC would permit a detailed study of the SUSY decays

The LC environment would result in an accuracy of the relative branching ratio

$$\mathrm{BR}^{\mathrm{full}} \equiv \frac{\Gamma^{\mathrm{full\ 1L}}(\mathrm{SUSY} \to \mathrm{xy})}{\Gamma^{\mathrm{full\ 1L}}_{\mathrm{tot}}}$$

$$\frac{\delta \mathrm{BR}}{\mathrm{BR}} \equiv \frac{\mathrm{BR}^{\mathrm{full}} - \mathrm{BR}^{\mathrm{tree}}}{\mathrm{BR}^{\mathrm{full}}}$$

close to the statistical uncertainty

$\Rightarrow$ Precision at the per-cent level possible!

2. SUSY decays to Higgs bosons

2A) Heavy Stop decays

$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 h_i) \qquad (i = 1, 2, 3) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 Z) \ ,$$

$$\Gamma(\tilde{t}_2 \to t\tilde{\chi}_k^0) \qquad (k = 1 \ldots 4) \ ,$$

$$\Gamma(\tilde{t}_2 \to t\tilde{g}) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{b}_i H^+) \qquad (i = 1, 2) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{b}_i W^+) \qquad (i = 1, 2) \ ,$$

$$\Gamma(\tilde{t}_2 \to b\tilde{\chi}_k^+) \qquad (k = 1, 2) \ .$$

Calculation of partial widths and branching ratios:

– all diagrams created with FeynArts $\to$ T

$\to$ model file with all counterterms in the cMSSM

– including all soft/hard QED/QCD diagrams

– further evaluation with FormCalc

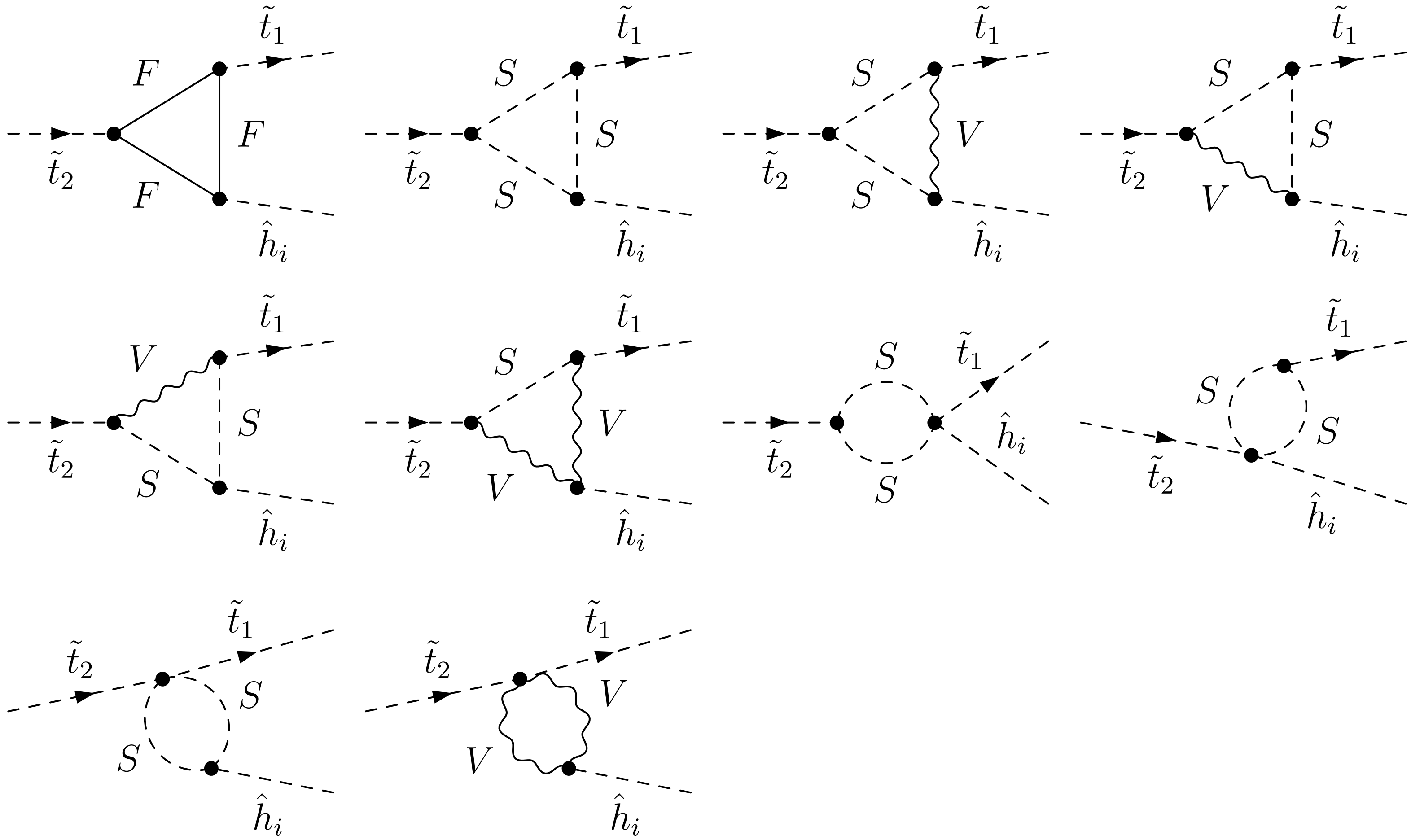
– Dimensional REDuction

– all UV and IR divergences cancel

– results will be included into FeynHiggs (www.feynhiggs.de)

$\to$ example plots will focus on BR($\tilde{t}_2 \to \tilde{t}_1 h_1$)

Feynman diagrams for $\tilde{t}_2 \to \tilde{t}_1 h_i$



– including Z–A or G–A transition contribution on the external Higgs boson leg

– including all soft/hard QED/QCD diagrams

Numerical scenarios:

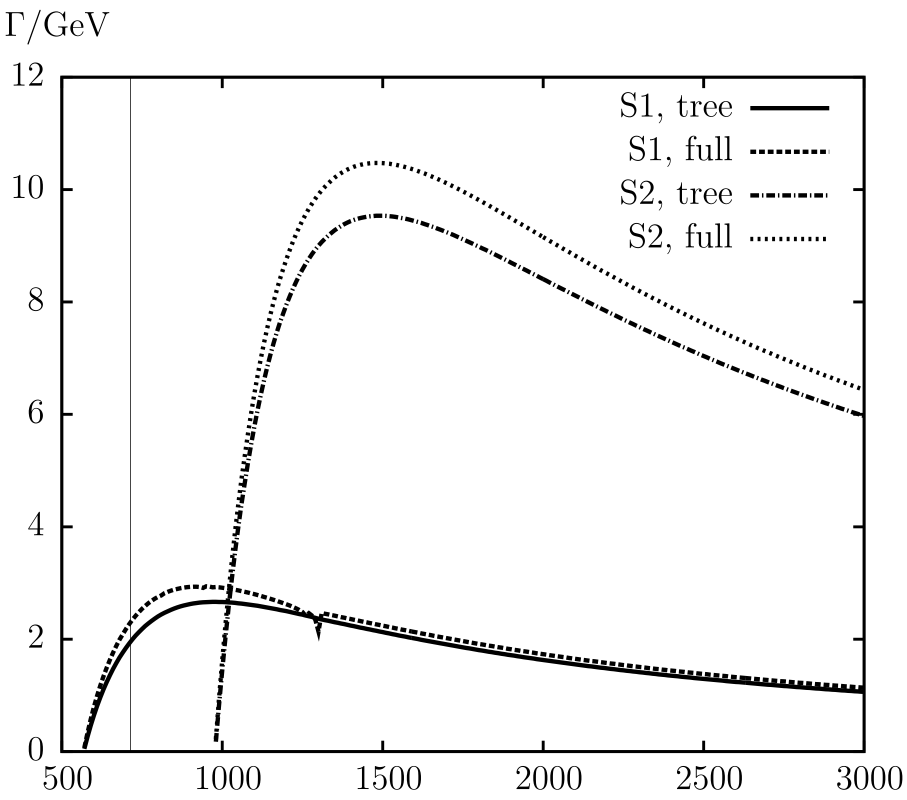
Scen.	$M_{H^\pm}$	$m_{\tilde{t}_2}$	$m_{\tilde{t}_1}$	$m_{\tilde{b}_2}$	μ	A_t	A_b	M_1	M_2	M_3
S1	150	650	$0.4\, m_{\tilde{t}_2}$	$0.7\, m_{\tilde{t}_2}$	200	900	400	200	300	800
S2	180	1200	$0.6\, m_{\tilde{t}_2}$	$0.8\, m_{\tilde{t}_2}$	300	1800	1600	150	200	400

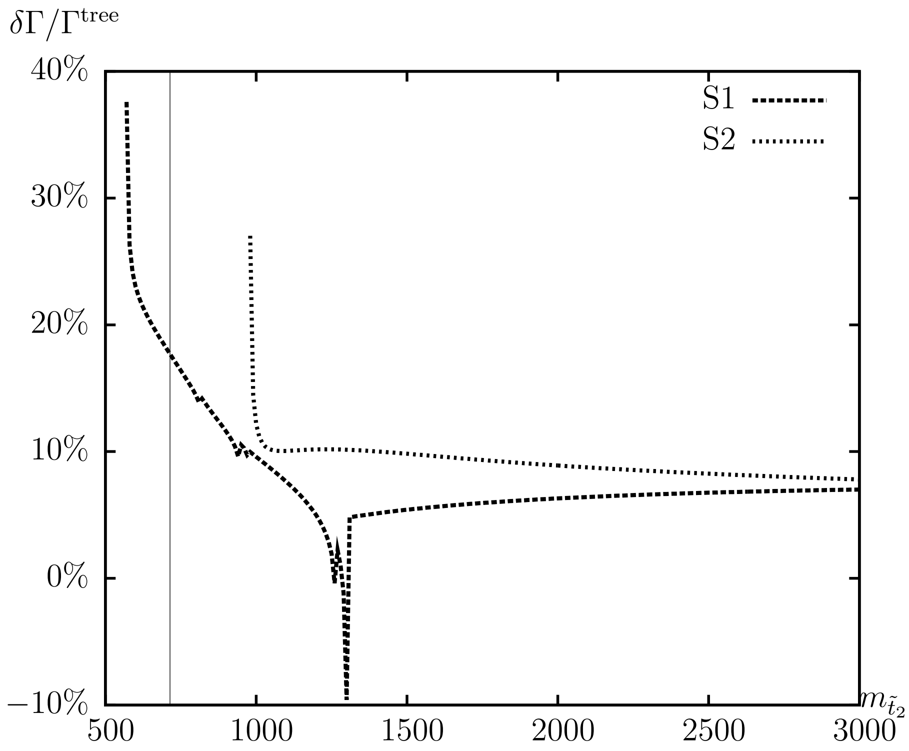
Scen.	$\tan\beta$	$m_{\tilde{t}_1}$	$m_{\tilde{t}_2}$	$m_{\tilde{b}_1}$	$m_{\tilde{b}_2}$
S1	2	260.000	650.000	305.436	455.000
	20	260.000	650.000	333.572	455.000
	50	260.000	650.000	329.755	455.000
S2	2	720.000	1200.000	769.801	960.000
	20	720.000	1200.000	783.300	960.000
	50	720.000	1200.000	783.094	960.000

Scenarios chosen such that *all* decay channels are open

$\Gamma(\tilde{t}_2 \to \tilde{t}_1 h_1)$: dependence on $m_{\tilde{t}_2}$

[T. Fritzsche, S.H., H. Rzehak, C. Schappacher '11]



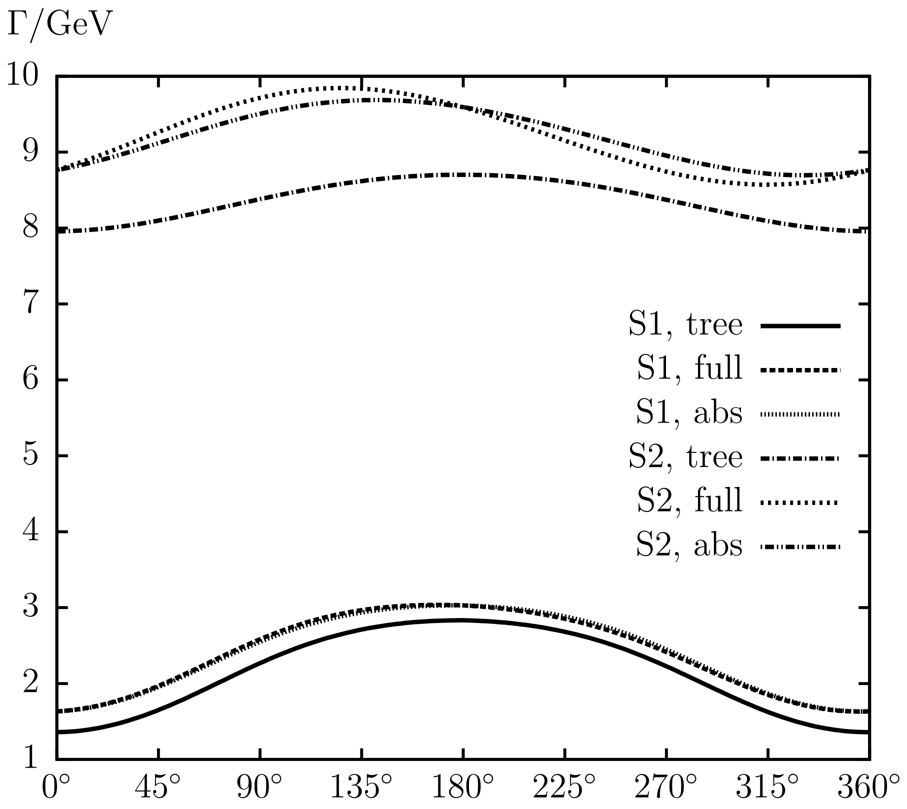


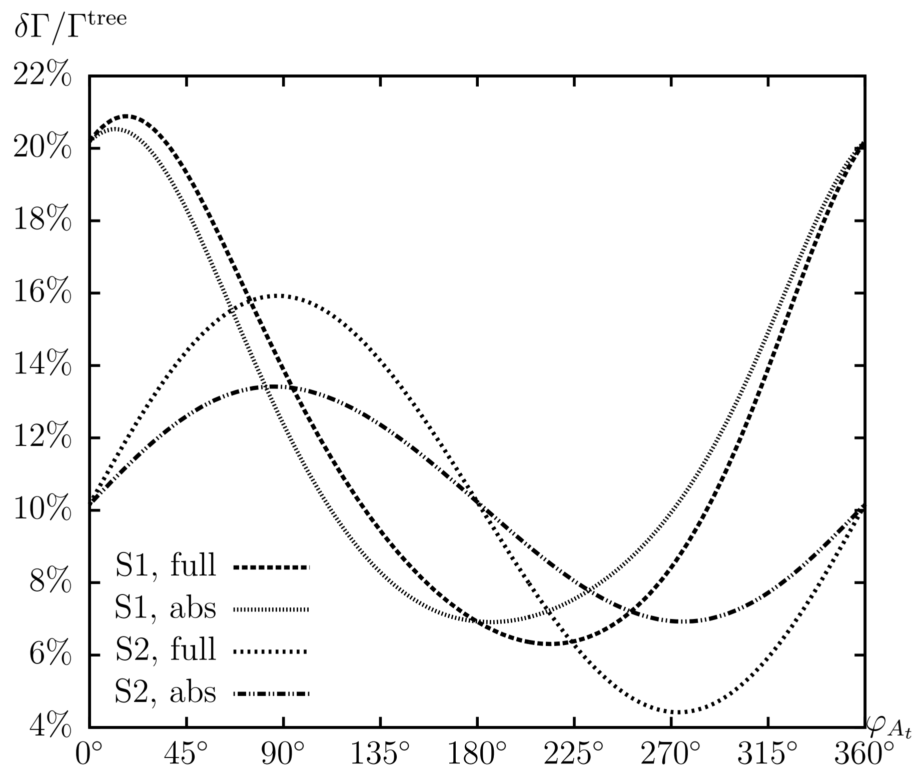
$\Rightarrow$ one-loop corrections under control and non-negligible

$\Rightarrow$ size of BR highly scenario dependent

$\Gamma(\tilde{t}_2 \to \tilde{t}_1 h_1)$: dependence on ϕ_{A_t}

[T. Fritzsche, S.H., H. Rzehak, C. Schappacher '11]





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2B) Heavy Stau decays

$$\Gamma(\tilde{\tau}_2 \to \tilde{\tau}_1 h_i) \qquad (i = 1, 2, 3) \ ,$$

$$\Gamma(\tilde{\tau}_2 \to \tilde{\tau}_1 Z) \ ,$$

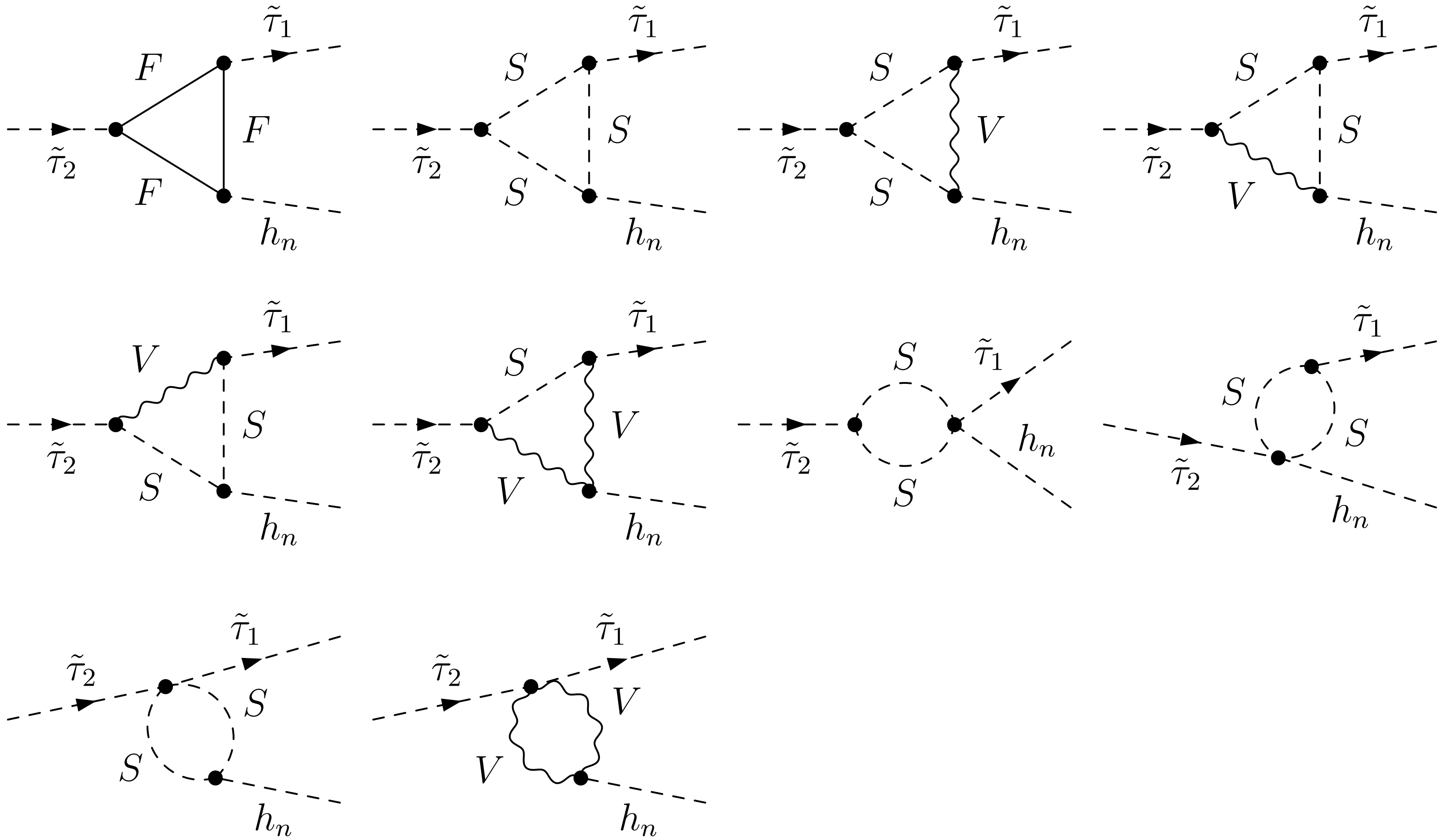
$$\Gamma(\tilde{\tau}_2 \to \tau \tilde{\chi}^0_k) \qquad (k = 1 \ldots 4) \ ,$$

$$\Gamma(\tilde{\tau}_2 \to \tilde{\nu}_\tau H^+) \ ,$$

$$\Gamma(\tilde{\tau}_2 \to \tilde{\nu}_\tau W^+) \ ,$$

$$\Gamma(\tilde{\tau}_2 \to \nu_\tau \tilde{\chi}^+_k) \qquad (k = 1, 2) \ .$$

Feynman diagrams for $\tilde{\tau}_2 \to \tilde{\tau}_1 h_n$



– including Z–A or G–A transition contribution
on the external Higgs boson leg

– including all soft/hard QED diagrams

Numerical scenario:

Scen.	$\tan\beta$	$M_{H^\pm}$	$m_{\tilde{\tau}_2}$	$m_{\tilde{\tau}_1}$	$M_{\tilde{q}_{L,R}}$	μ
S1	5	200	550	$\frac{1}{2}m_{\tilde{\tau}_2}$	1000	150
		A_l	A_q	M_1	M_2	M_3
		$\frac{9}{5}m_{\tilde{\tau}_2}$	2000	$\sim \frac{1}{2}M_2$	250	1500

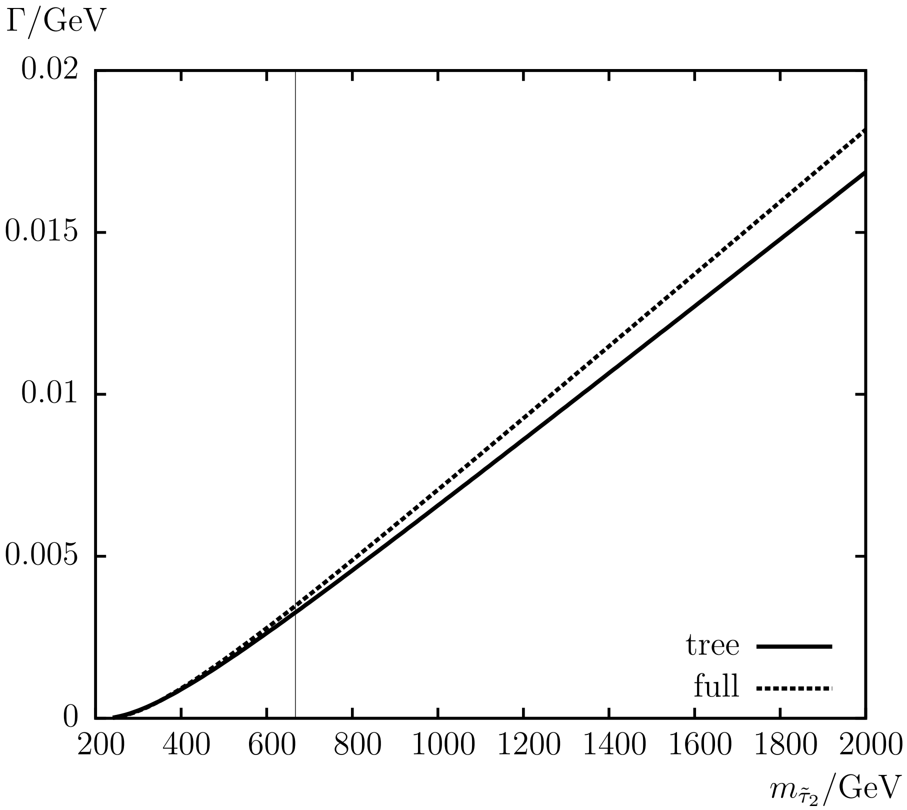
$m_{\tilde{\tau}_1}$	$m_{\tilde{\tau}_2}$	$m_{\tilde{\nu}_\tau}$
274.478	550.000	263.924

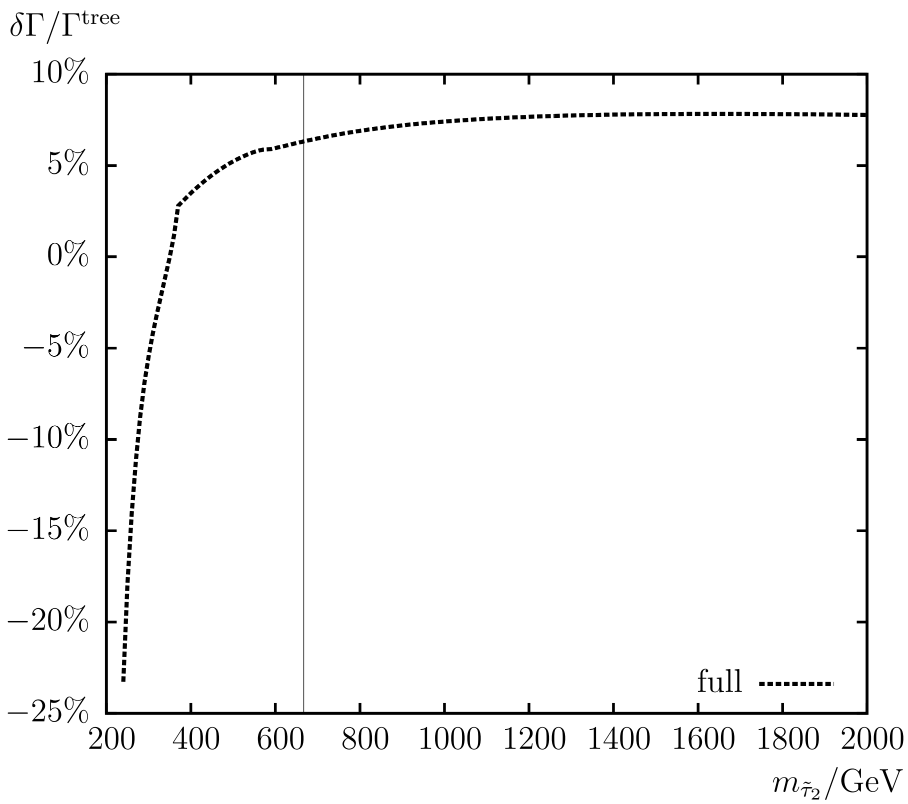
S1: $e^+e^- \to \tilde{\tau}_2\tilde{\tau}_1 \to \tilde{\tau}_1 h_n \, \tilde{\tau}_1$ possible at the LC(1000)

Scenario chosen such that *all* decay channels are open

$\Gamma(\tilde{\tau}_2 \to \tilde{\tau}_1 h_1)$: dependence on $m_{\tilde{\tau}_2}$

[S.H., C. Schappacher '12]



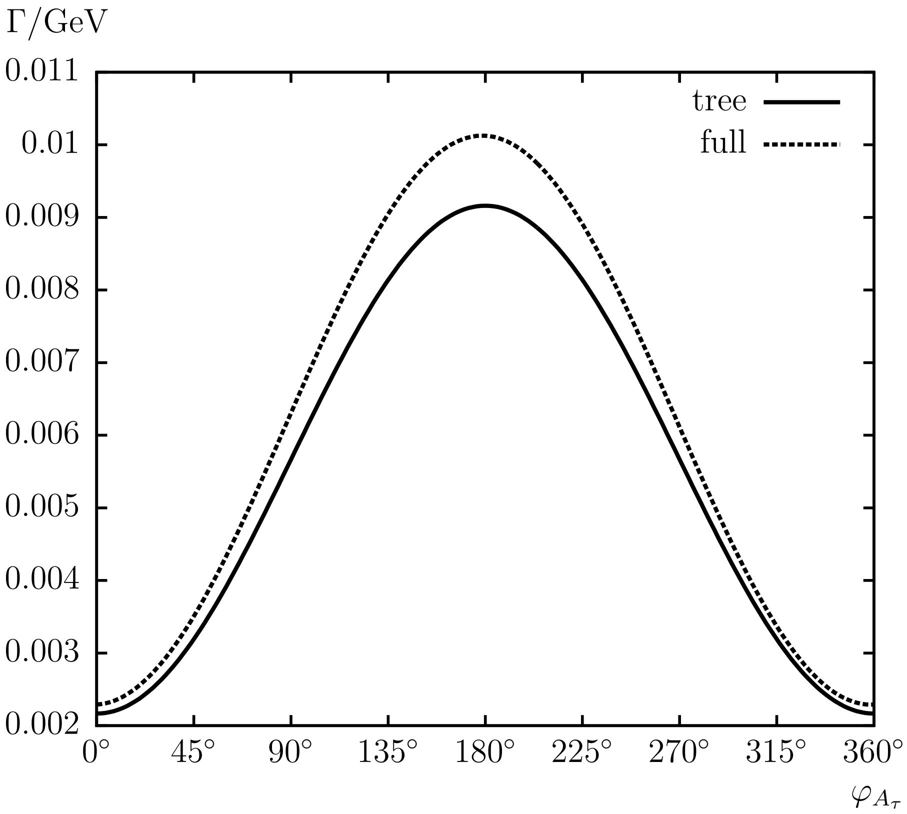


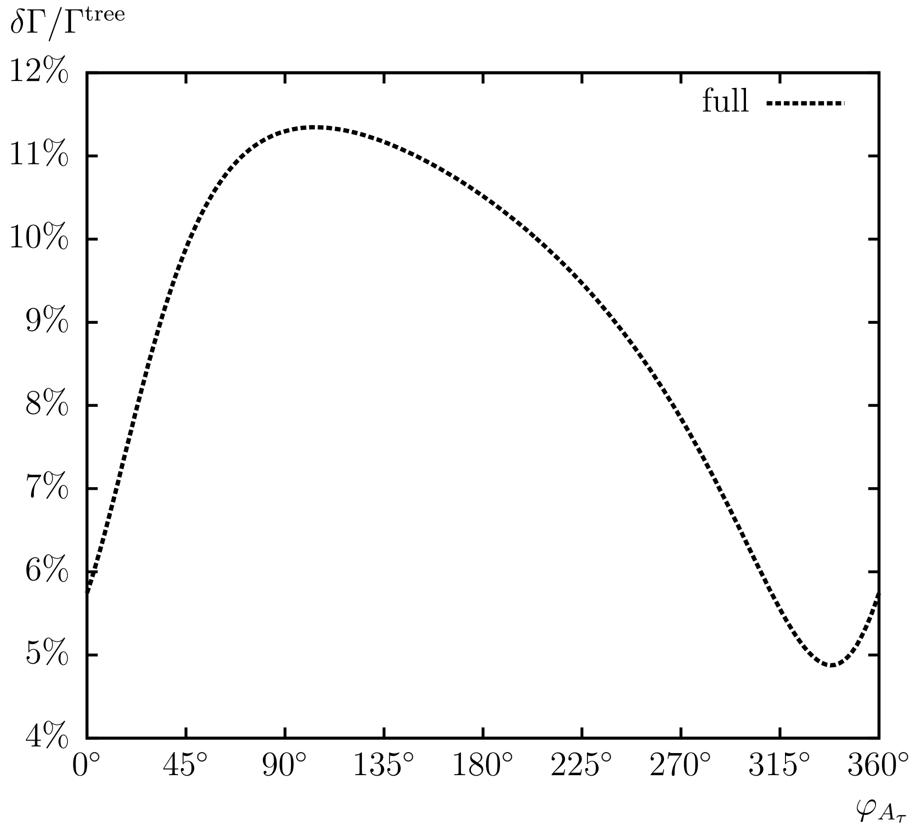
⇒ one-loop corrections under control and non-negligible

⇒ size of BR highly scenario dependent

$\Gamma(\tilde{\tau}_2 \to \tilde{\tau}_1 h_1)$: dependence on ϕ_{A_τ}

[S.H., C. Schappacher '12]





⇒ one-loop corrections under control and non-negligible

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2C) Chargino decays

$$\Gamma(\tilde{\chi}_2^\pm \to \tilde{\chi}_1^\pm h_k) \qquad (k = 1, 2, 3) \ ,$$
$$\Gamma(\tilde{\chi}_2^\pm \to \tilde{\chi}_1^\pm Z) \ ,$$
$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\chi}_j^0 H^\pm) \qquad (i = 1, 2, \ j = 1, 2, 3, 4) \ ,$$
$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\chi}_j^0 W^\pm) \qquad (i = 1, 2, \ j = 1, 2, 3, 4) \ ,$$
$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{l}_k^\pm \nu_l) \qquad (i = 1, 2, \ l = e, \mu, \tau, \ k = 1, 2) \ ,$$
$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\nu}_l \, l^\pm) \qquad (i = 1, 2, \ l = e, \mu, \tau) \ .$$

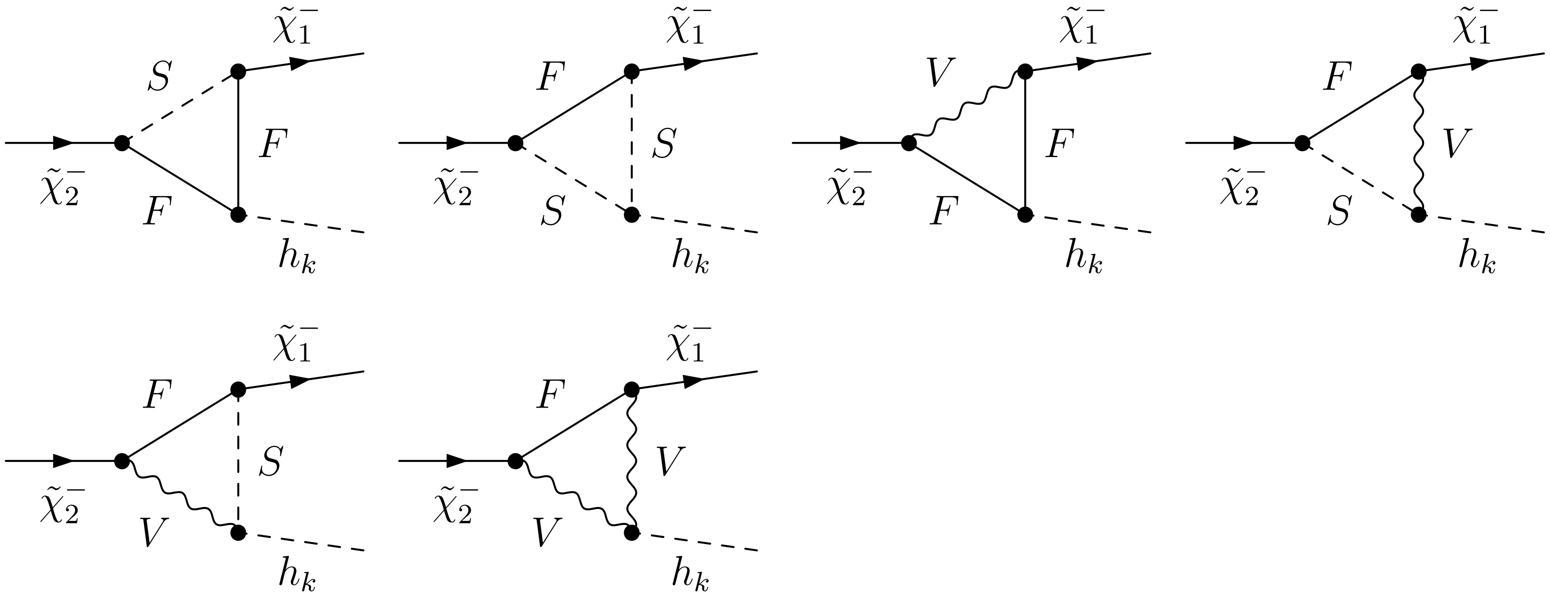
No hadronic decays yet . . .

Scen.	$\tan\beta$	$M_{H^\pm}$	$m_{\tilde{\chi}_2^\pm}$	$m_{\tilde{\chi}_1^\pm}$	$M_{\tilde{l}_L}$	$M_{\tilde{l}_R}$	A_l
$\mathcal{S}$	20	160	650	350	300	310	400

$\mathcal{S}_> : \mu > M_2$ ($\tilde{\chi}_2^\pm$ more higgsino-like)

$\mathcal{S}_< : \mu < M_2$ ($\tilde{\chi}_2^\pm$ more gaugino-like)

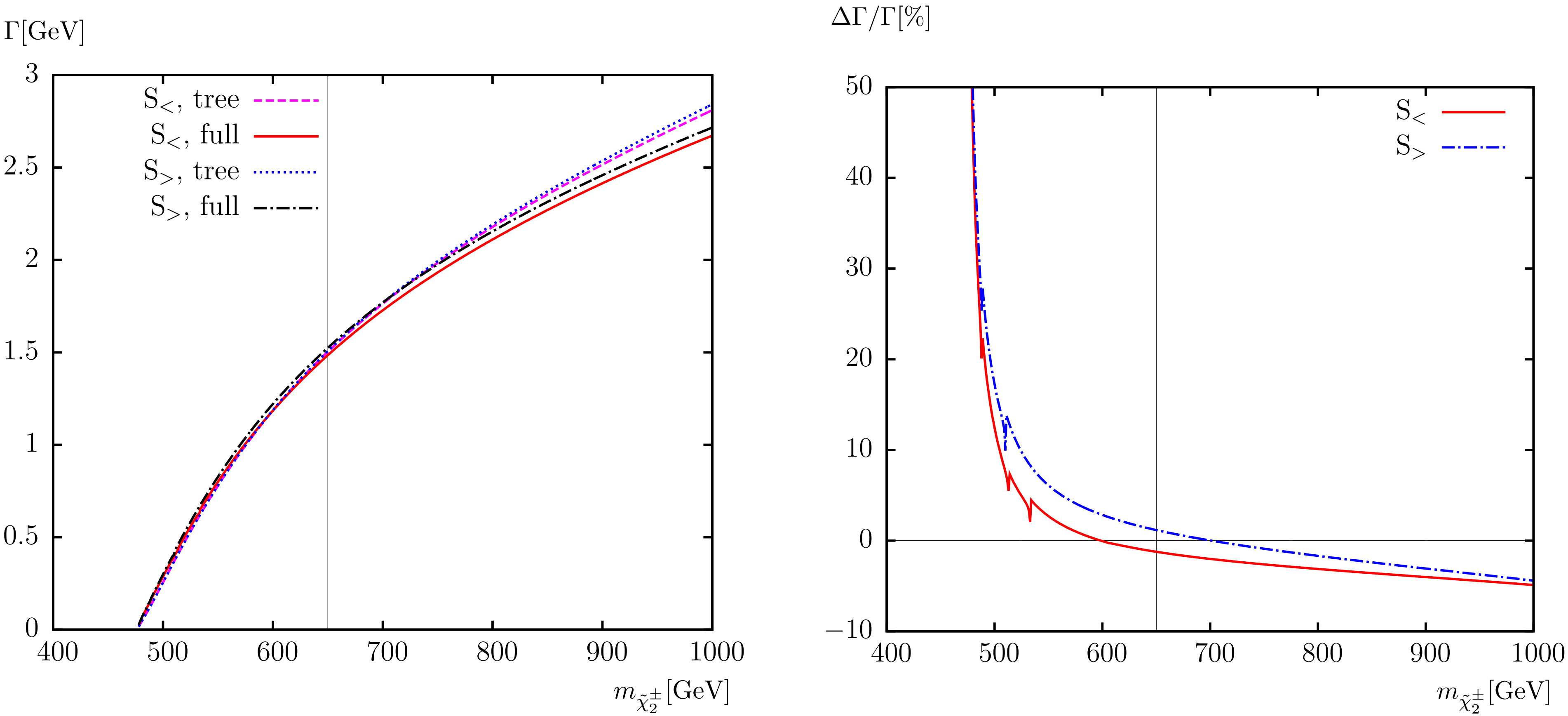
Feynman diagrams for $\tilde{\chi}_2^- \to \tilde{\chi}_1^- h_k$



– including Z–A or G–A transition contribution on the external Higgs boson leg

– including all soft/hard QED diagrams

$\Gamma(\tilde{\chi}_2^- \to \tilde{\chi}_1^- h_1)$: dependence on $m_{\tilde{\chi}_2^\pm}$ [S.H., F. v.d. Pahlen, C. Schappacher '11]



$\Rightarrow$ one-loop corrections under control and non-negligible

$\Rightarrow$ size of BR highly scenario dependent

3. Decays to the LSP

3A) Heavy Stop decays

$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 h_i) \qquad (i = 1, 2, 3) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 Z) \ ,$$

$$\Gamma(\tilde{t}_2 \to t\tilde{\chi}^0_k) \qquad (k = 1 \ldots 4) \ ,$$

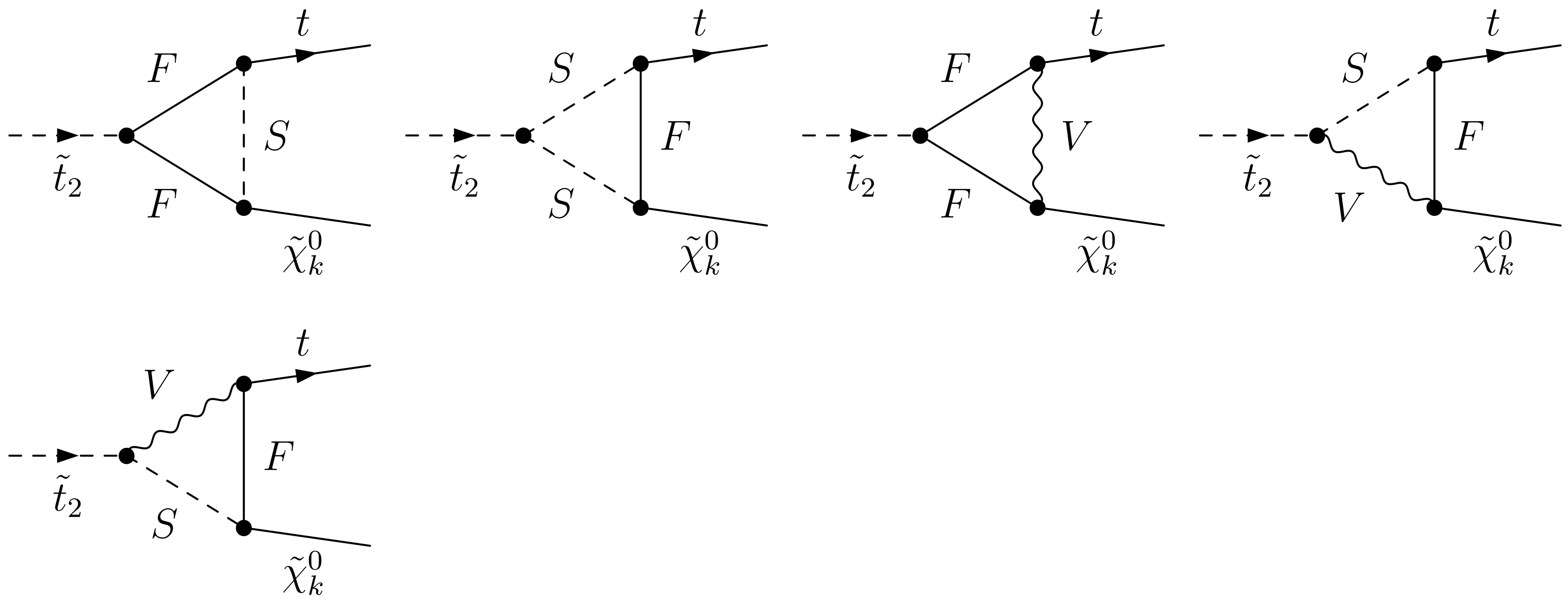
$$\Gamma(\tilde{t}_2 \to t\tilde{g}) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{b}_i H^+) \qquad (i = 1, 2) \ ,$$

$$\Gamma(\tilde{t}_2 \to \tilde{b}_i W^+) \qquad (i = 1, 2) \ ,$$

$$\Gamma(\tilde{t}_2 \to b\tilde{\chi}^+_k) \qquad (k = 1, 2) \ .$$

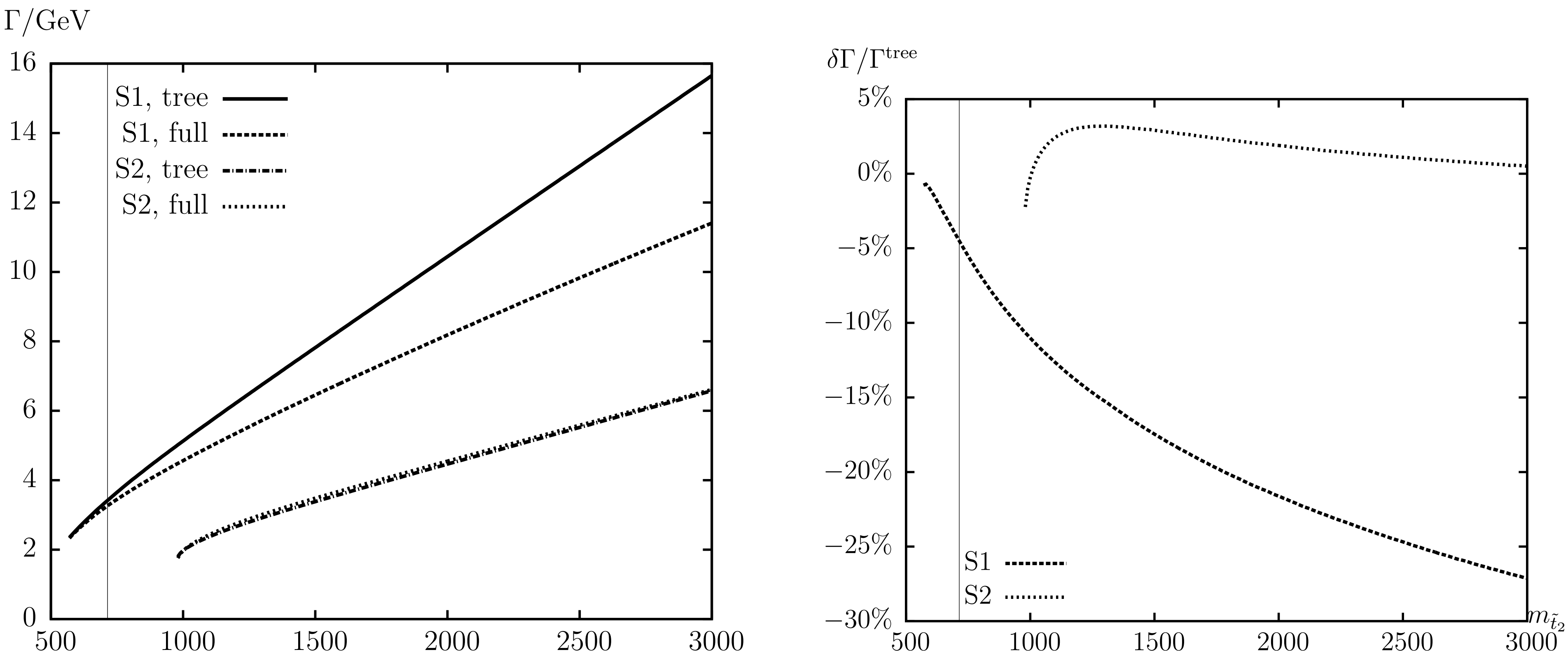
Feynman diagrams for $\tilde{t}_2 \to t\tilde{\chi}^0_1$



– including all soft/hard QED/QCD diagrams

$\Gamma(\tilde{t}_2 \to t\tilde{\chi}_1^0)$: dependence on $m_{\tilde{t}_2}$

[T. Fritzsche, S.H., H. Rzehak, C. Schappacher '11]

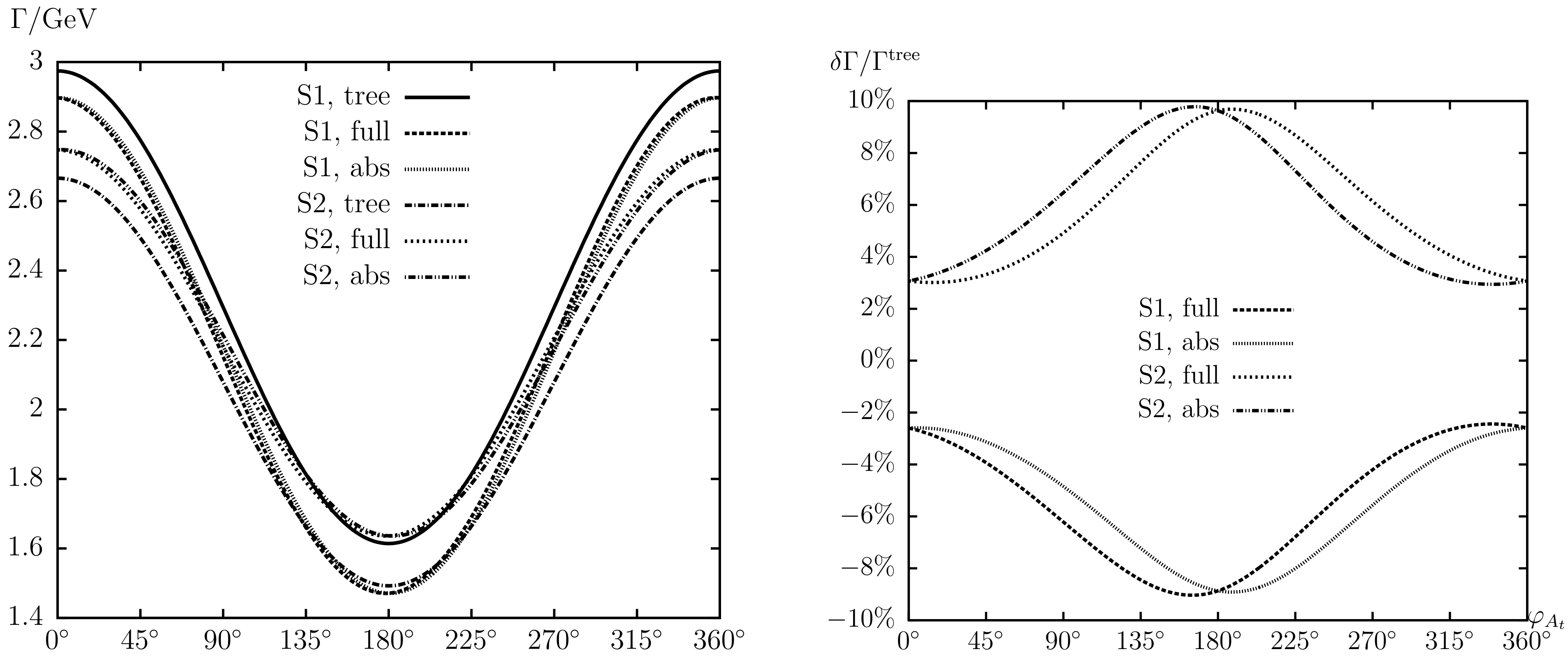


$\Rightarrow$ one-loop corrections under control and non-negligible

$\Rightarrow$ size of BR highly scenario dependent

$\Gamma(\tilde{t}_2 \to t\tilde{\chi}_1^0)$: dependence on ϕ_{A_t}

[*T. Fritzsche, S.H., H. Rzehak, C. Schappacher '11*]



⇒ one-loop corrections under control and non-negligible

⇒ size of BR highly scenario dependent

3B) Chargino decays

$$\Gamma(\tilde{\chi}_2^\pm \to \tilde{\chi}_1^\pm h_k) \qquad (k = 1, 2, 3) \ ,$$

$$\Gamma(\tilde{\chi}_2^\pm \to \tilde{\chi}_1^\pm Z) \ ,$$

$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\chi}_j^0 H^\pm) \qquad (i = 1, 2, \ j = 1, 2, 3, 4) \ ,$$

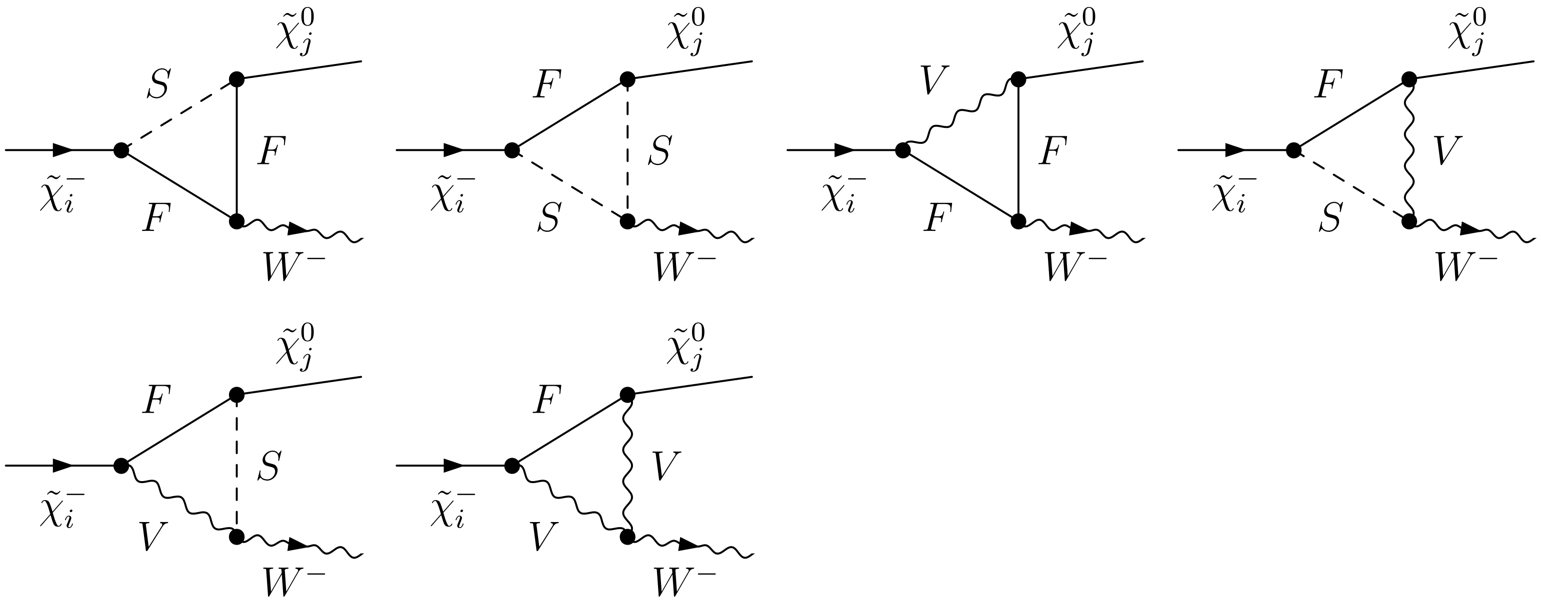
$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\chi}_j^0 W^\pm) \qquad (i = 1, 2, \ j = 1, 2, 3, 4) \ ,$$

$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{l}_k^\pm \nu_l) \qquad (i = 1, 2, \ l = e, \mu, \tau, \ k = 1, 2) \ ,$$

$$\Gamma(\tilde{\chi}_i^\pm \to \tilde{\nu}_l \, l^\pm) \qquad (i = 1, 2, \ l = e, \mu, \tau) \ .$$

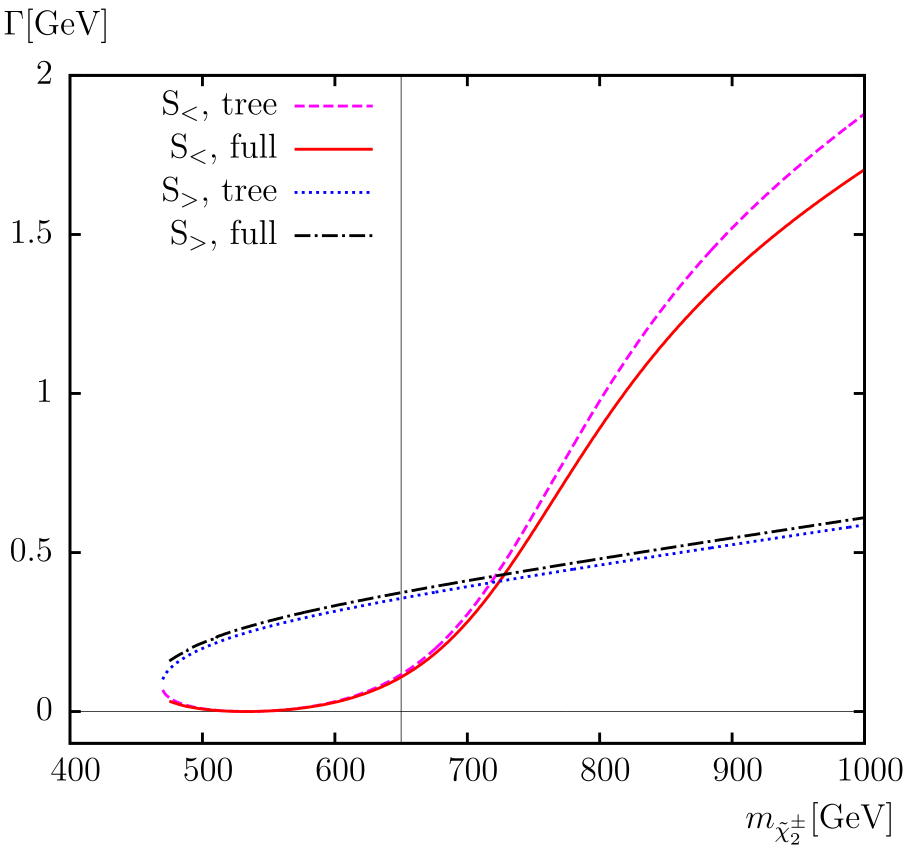
No hadronic decays yet . . .

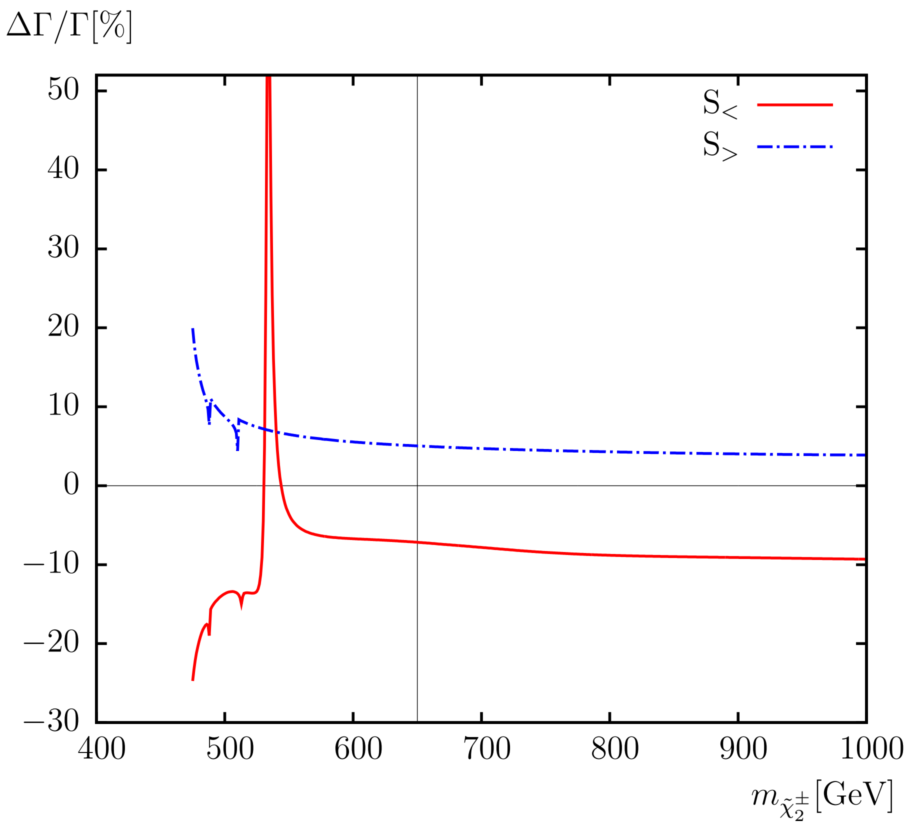
Feynman diagrams for $\tilde{\chi}_i^{\pm} \to \tilde{\chi}_j^0 W^{\pm}$



– including all soft/hard QED diagrams

$\Gamma(\tilde{\chi}_2^- \to \tilde{\chi}_1^0 W^-)$: dependence on $m_{\tilde{\chi}_2^\pm}$ [S.H., F. v.d. Pahlen, C. Schappacher '11]

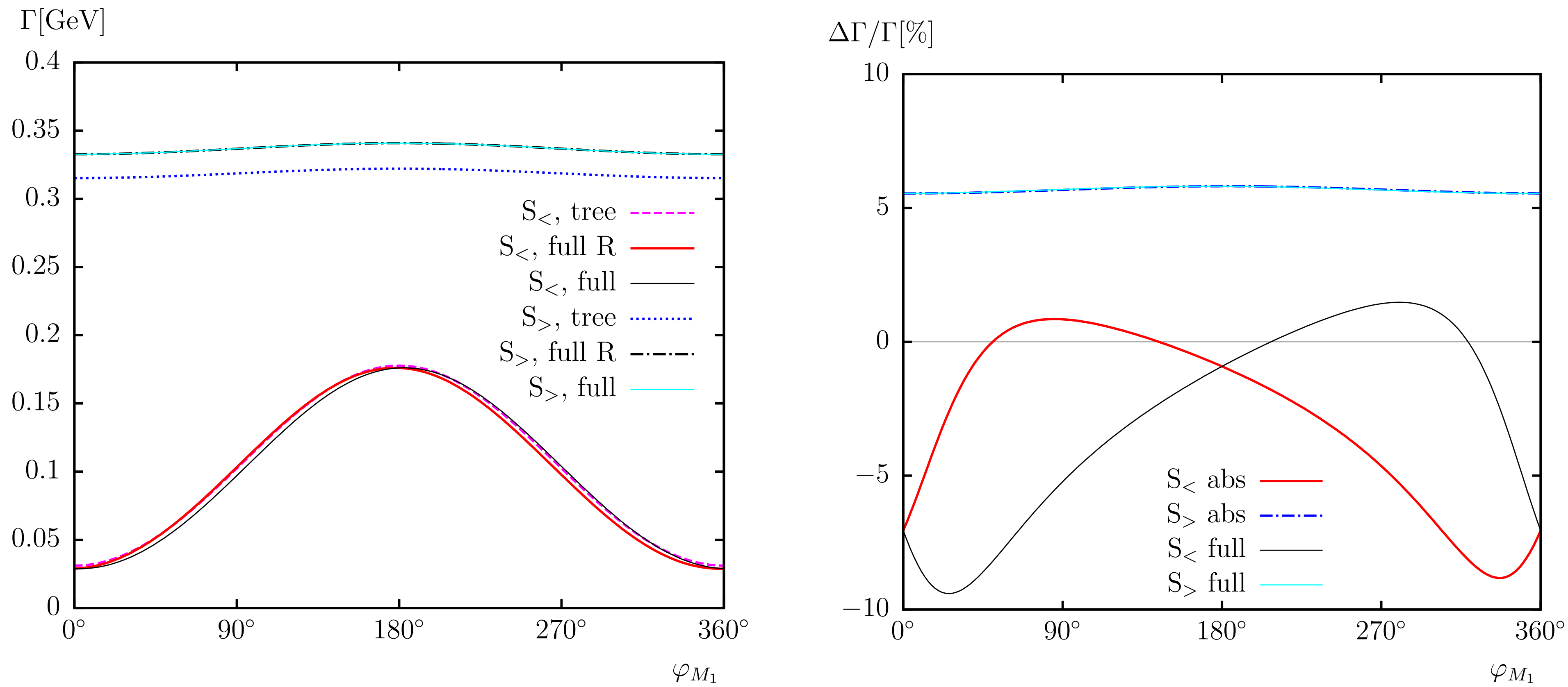




⇒ one-loop corrections under control and non-negligible

⇒ size of BR highly scenario dependent

$\Gamma(\tilde{\chi}_2^- \to \tilde{\chi}_1^0 W^-)$: dependence on φ_{M_1} [S.H., F. v.d. Pahlen, C. Schappacher '11]



⇒ one-loop corrections under control and non-negligible

⇒ size of BR highly scenario dependent

3C) Neutralino decays

$$\Gamma(\tilde{\chi}_i^0 \to \tilde{\chi}_j^0 h_k) \qquad (i = 2,3,4;\ j < i;\ k = 1,2,3)\ ,$$
$$\Gamma(\tilde{\chi}_i^0 \to \tilde{\chi}_j^\mp H^\pm) \qquad (i = 2,3,4;\ j = 1,2)\ ,$$
$$\Gamma(\tilde{\chi}_i^0 \to \tilde{\chi}_j^\mp W^\pm) \qquad (i = 2,3,4;\ j = 1,2)\ ,$$
$$\Gamma(\tilde{\chi}_i^0 \to \tilde{\chi}_j^0 Z) \qquad (i = 2,3,4;\ j < i)\ ,$$
$$\Gamma(\tilde{\chi}_i^0 \to \ell^\mp \tilde{\ell}_k^\pm) \qquad (i = 2,3,4;\ \ell = e,\mu,\tau;\ k = 1,2)\ ,$$
$$\Gamma(\tilde{\chi}_i^0 \to \bar{\nu}_\ell \tilde{\nu}_\ell / \nu_\ell \tilde{\nu}_\ell^\dagger) \qquad (i = 2,3,4;\ \ell = e,\mu,\tau)\ .$$

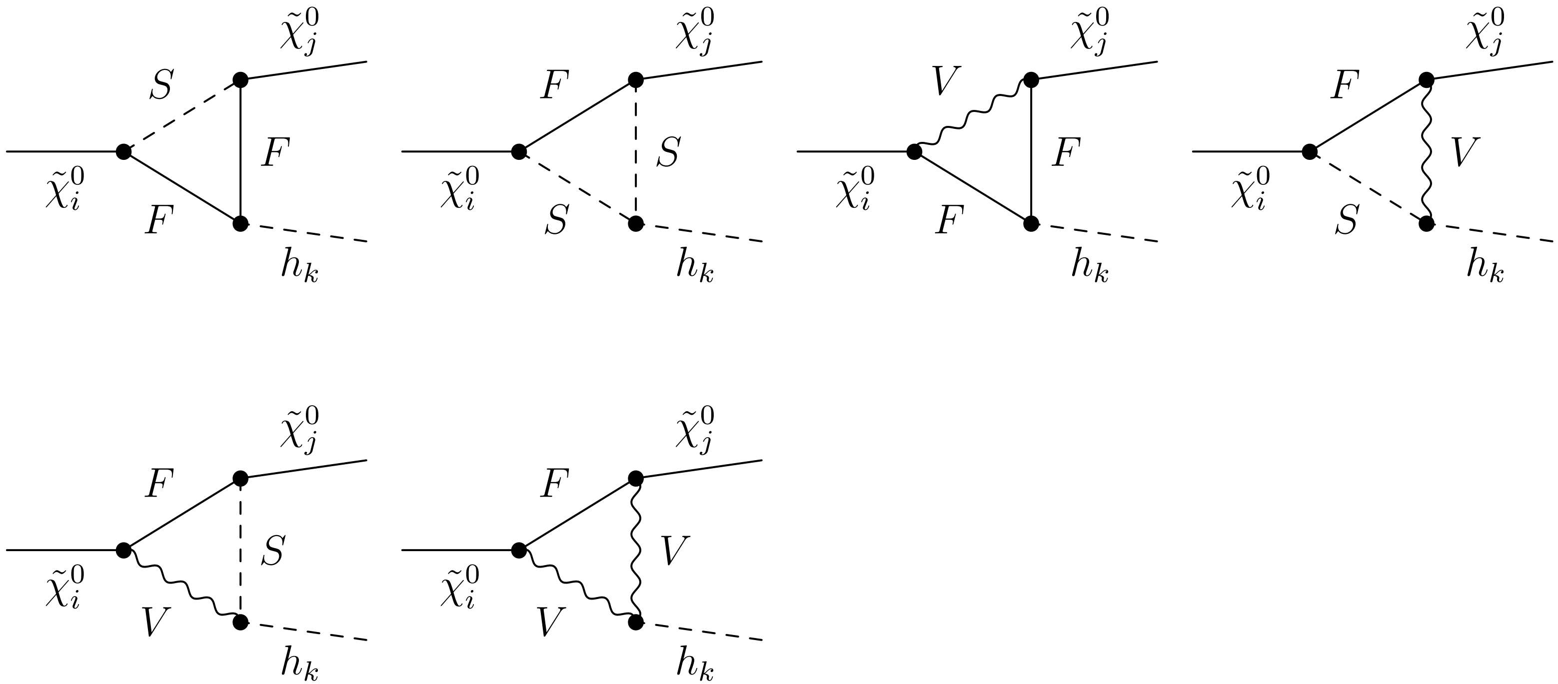
No hadronic decays yet . . .

$\tan\beta$	$M_{H^\pm}$	$m_{\tilde{\chi}_2^\pm}$	$m_{\tilde{\chi}_1^\pm}$	$M_{\tilde{l}_L}$	$M_{\tilde{l}_R}$	A_l	$M_{\tilde{q}_L}$	$M_{\tilde{q}_R}$	A_q
20	160	600	350	300	310	400	1300	1100	2000

$\mathcal{S}_h : \mu > M_2$ ($\tilde{\chi}_4^0$ more higgsino-like)

$\mathcal{S}_g : \mu < M_2$ ($\tilde{\chi}_4^0$ more gaugino-like)

Feynman diagrams for $\tilde{\chi}^0_i \to \tilde{\chi}^0_j h_k$

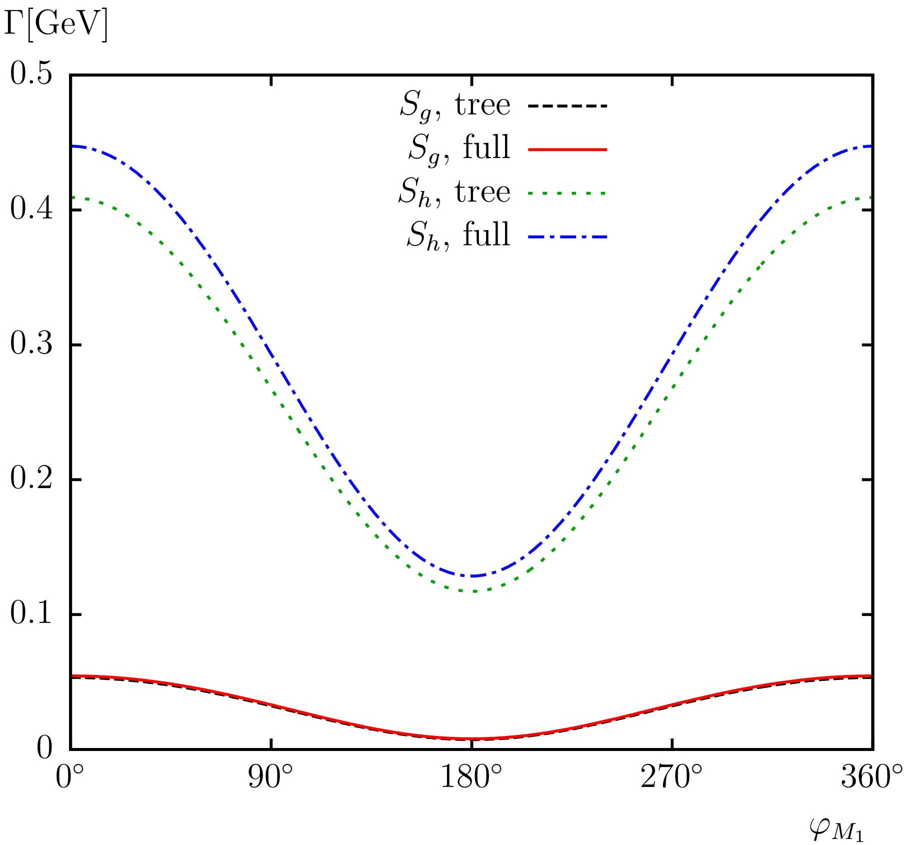


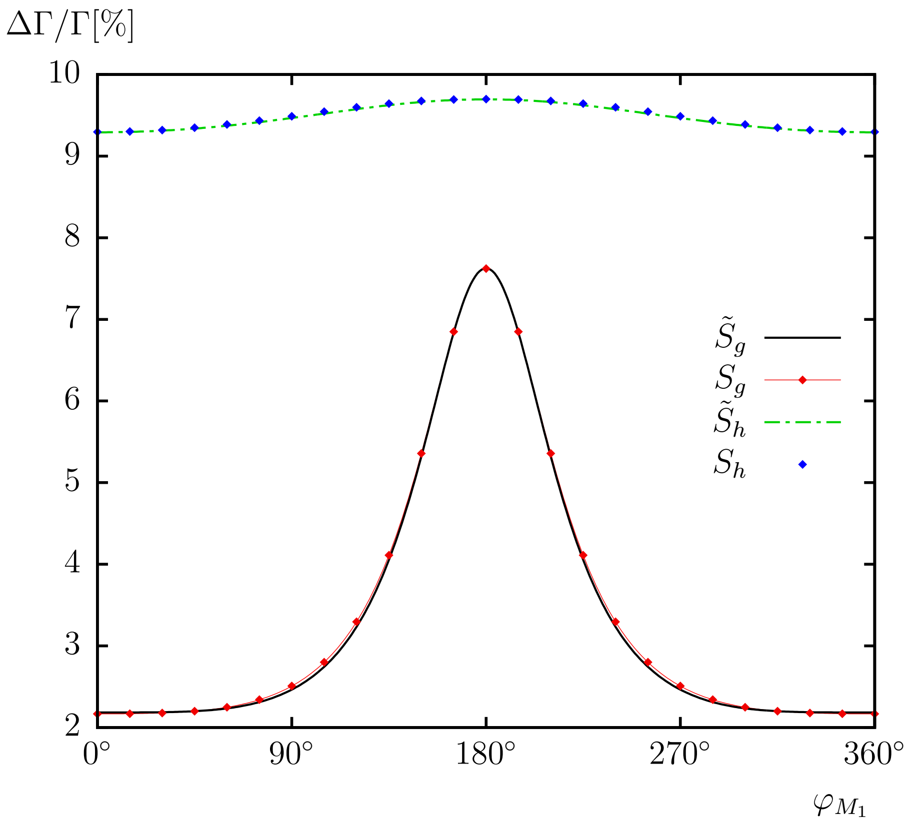
– including Z–A or G–A transition contribution on the external Higgs boson leg

– including all soft/hard QED diagrams

$\Gamma(\tilde{\chi}_4^0 \to \tilde{\chi}_1^0 h_1)$: dependence on φ_{M_1}

[*A. Bharoucha, S.H., F. v.d. Pahlen, C. Schappacher '12*]





$\Rightarrow$ one-loop corrections under control and non-negligible

$\Rightarrow$ size of BR highly scenario dependent

4. Conclusinos

- Needed: reliable prediction for SUSY decays at the LC
  Of special intrest: decays involving Higgs and/or LSP

- Our work:
  Calculation of decay widths and branching ratios
  - all two-body decays of
    scalar top, scalar bottom, scalar tau, gluino, chargino, neutralino
  - full one-loop (incl. hard QED/QCD radiation)
  - in the complex MSSM for arbirtrary parameters
  - renormalization of the full cMSSM!

- Heavy Stop decays: $\tilde{t}_2 \to \tilde{t}_1 h_1, \tilde{t}_1 \to t\tilde{\chi}_1^0$: $\sim$ 20%, stong dep. on ϕ_{A_t}

- Heavy Sau decays: $\tilde{\tau}_2 \to \tilde{\tau}_1 h_1, \tilde{\tau}_1 \to \tau\tilde{\chi}_1^0$: $\sim$ 10%, strong dep. on ϕ_{A_τ}

- Chargino decays: $\tilde{\chi}_2^- \to \tilde{\chi}_1^- h_1, \tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0$: $\sim$ 10%

- Neutralino decays: $\tilde{\chi}_4^0 \to \tilde{\chi}_1^0 h_1$: $\sim$ 10%, dep. on φ_{M_1}

- Full corrections must be taken into account in any LC analysis!