Recent Physical Results using GRACE/SUSY

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(presented by T.Kon)

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$ Introduction

- SUSY model
  : a hopeful candidate for the BSM
    * naturalness, dark-matter, gauge unification
  : many new particles with mass O(TeV)
    are predicted
- SUSY-particles = sparticles (and light Higgs)
  : important targets of High Energy Exp & Obs
- We must handle a large number of
  Feynman diagrams in the SUSY phenomenology

GRACE/SUSY

$ GRACE/SUSY

* tree ver. Ref. **Comput.Phys.Commun.153:106-134,2003**
download : http://minami-home.kek.jp/

* 1-loop ver. Ref. **Phys.Rev.D75:113002,2007**

Cf. Jimbo-san's talk "sfermion NLG"

Input file (example)

Tree $\tilde{t}_1 \to b e^+ \tilde{\nu}_e$ 1-loop (QCD)

```
Model="mssm.mdl";
 Process;
  elwk = {2}; qcd = {0};
  Initial={st1};
  Final  ={b positron snu-e};
 kinem="1301";
Pend;
```

```
Model="mssmnlg_j2_q.mdl";
 Process;
  elwk = {2,2}; qcd = {0,2};
  Initial={st1};
  Final  ={b positron snu-e};
 kinem="1301";
Pend;
```

$ MSSM parameter sets for stop decay

- Why stop decay？

$$\begin{pmatrix}\tilde{t}_L\\ \tilde{t}_R\end{pmatrix}\leftrightarrow\begin{pmatrix}t_L\\ t_R\end{pmatrix}$$

$$-L_{\tilde{t}}^{mass}=\begin{pmatrix}\tilde{t}_L^* & \tilde{t}_R^*\end{pmatrix}\begin{pmatrix}m_{\tilde{t}_L}^2 & m_{\tilde{t}_{LR}}^2\\ m_{\tilde{t}_{LR}}^2 & m_{\tilde{t}_R}^2\end{pmatrix}\begin{pmatrix}\tilde{t}_L\\ \tilde{t}_R\end{pmatrix}$$

$$m_{\tilde{t}_{LR}}^2\equiv -m_t\left(\mu\cot\beta+A_t\right)$$

$$\begin{pmatrix}\tilde{t}_1\\ \tilde{t}_2\end{pmatrix}=\begin{pmatrix}\cos\theta_t & \sin\theta_t\\ -\sin\theta_t & \cos\theta_t\end{pmatrix}\begin{pmatrix}\tilde{t}_L\\ \tilde{t}_R\end{pmatrix}$$

$$m_{\tilde{t}_{1,2}}^2=\frac{1}{2}\left[\left(m_{\tilde{t}_L}^2+m_{\tilde{t}_R}^2\right)\mp\sqrt{\left(m_{\tilde{t}_L}^2-m_{\tilde{t}_R}^2\right)^2+4m_{\tilde{t}_{LR}}^4}\right]$$

Possibly

- $m_{\tilde{t}_1}<m_{\tilde{q}}$ $\quad\tilde{q}=\tilde{u},\tilde{d},\tilde{c},\tilde{s},\tilde{b}$
- simple 2-body decay modes : Forbidden

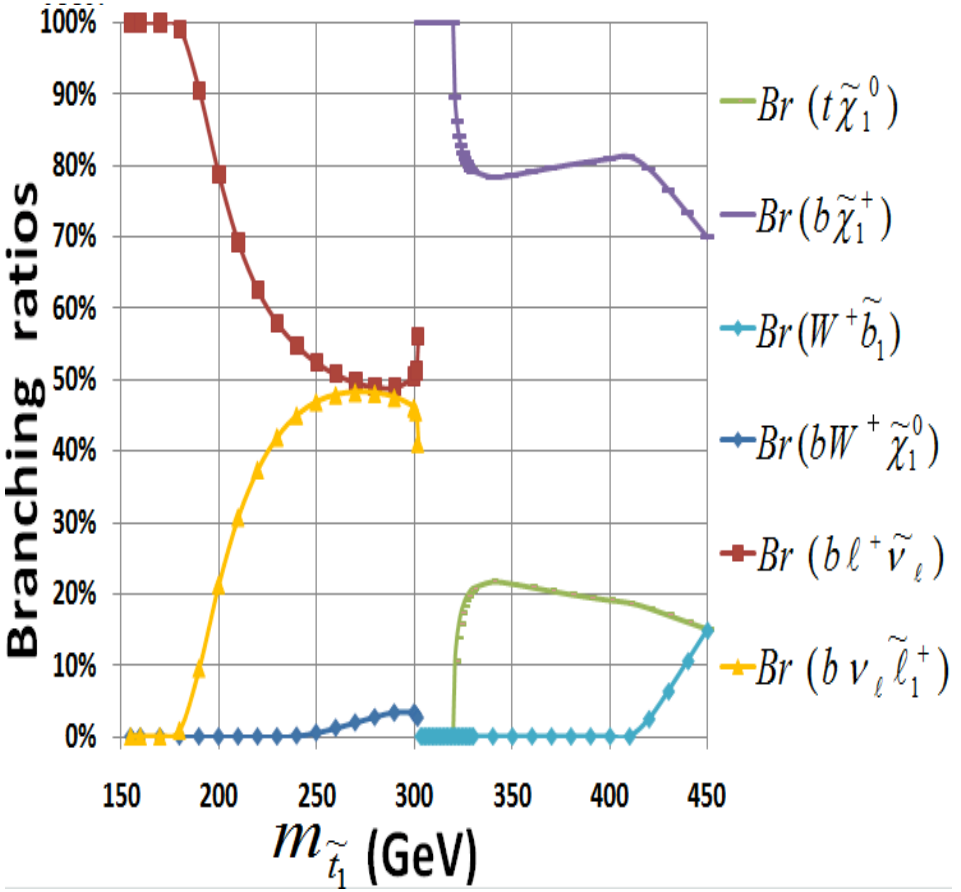
$$\tilde{t}_1\not\to t\tilde{\chi}_1^0 \qquad \tilde{t}_1\not\to t\tilde{g}$$

☆mass, decay modes
: depend sensitively on
MSSM parameters

- Typical MSSM parameter sets

	Set A	Set B
$\tan\beta$	10	10
μ	-750	-750
M_2	400	300
$m_{\tilde{\chi}_1^0}$	194.6	146.1
$m_{\tilde{\chi}_1^+}$	396.1	298.0
$m_{\tilde{g}}$	1390	1042
θ_t	0.8π	0.8π
$m_{\tilde{\ell}_1}$	325.0	170.0
$m_{\tilde{\nu}_\ell}$	317.0	150.0

(masses in GeV)



$ 1-loop correction for decay widths

	# of Feynman diagrams		
	Tree	QCD	ELWK
$\tilde{t}_1 \to W^+ b \tilde{\chi}_1^0$	5	78	1786
$\tilde{t}_1 \to b \ell^+ \tilde{\nu}_\ell$	2	12	490
$\tilde{t}_1 \to b \nu_\ell \tilde{\ell}_1^+$	2	12	426
$\tilde{t}_1 \to b \tilde{\chi}_1^+$	1	6	86
$\tilde{t}_1 \to t \tilde{\chi}_1^0$	1	6	104
$\tilde{t}_1 \to \tilde{b}_1 W^+$	1	17	126

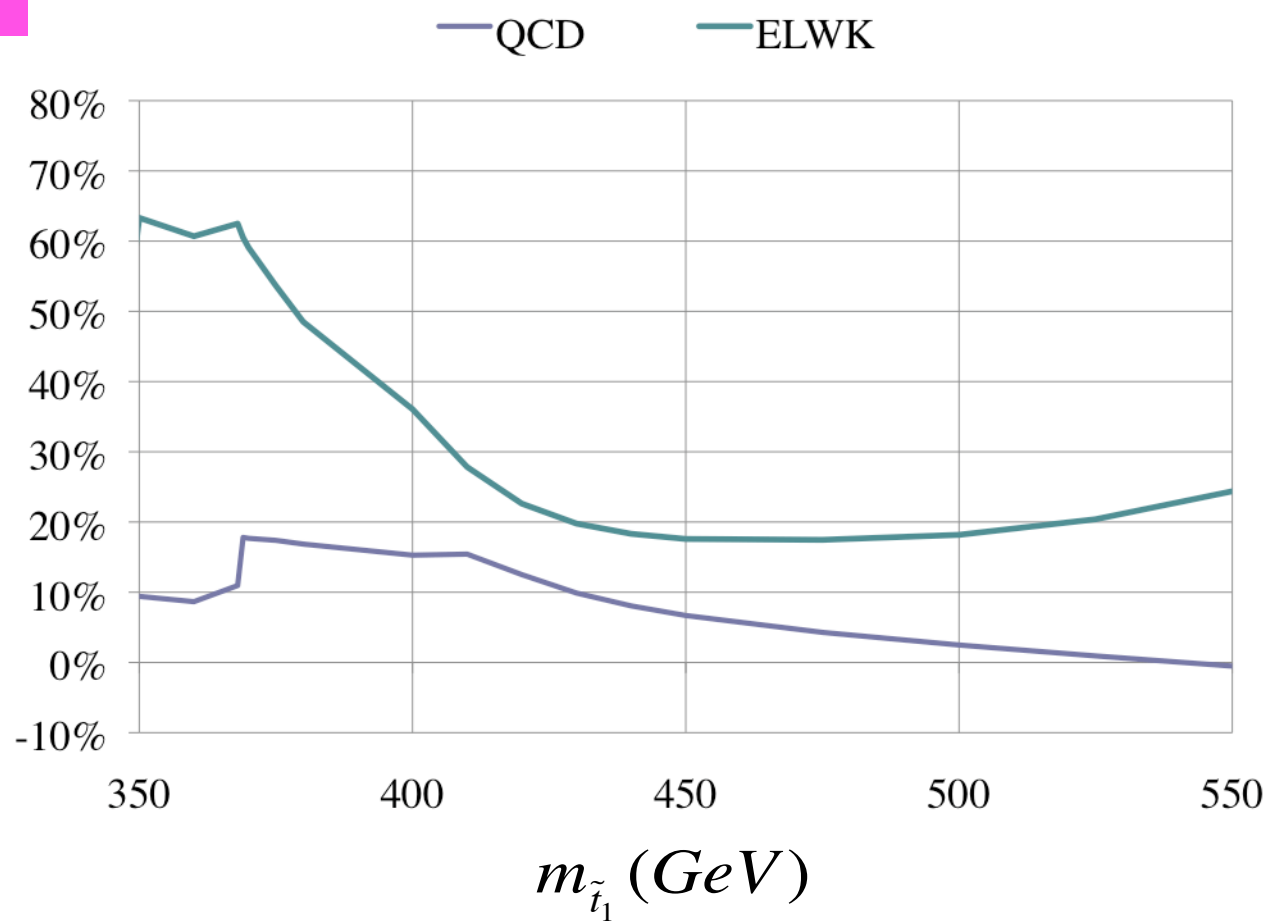
For Set A

For Set B

$m_{\tilde{t}_1}$ dependence of corrections for total width

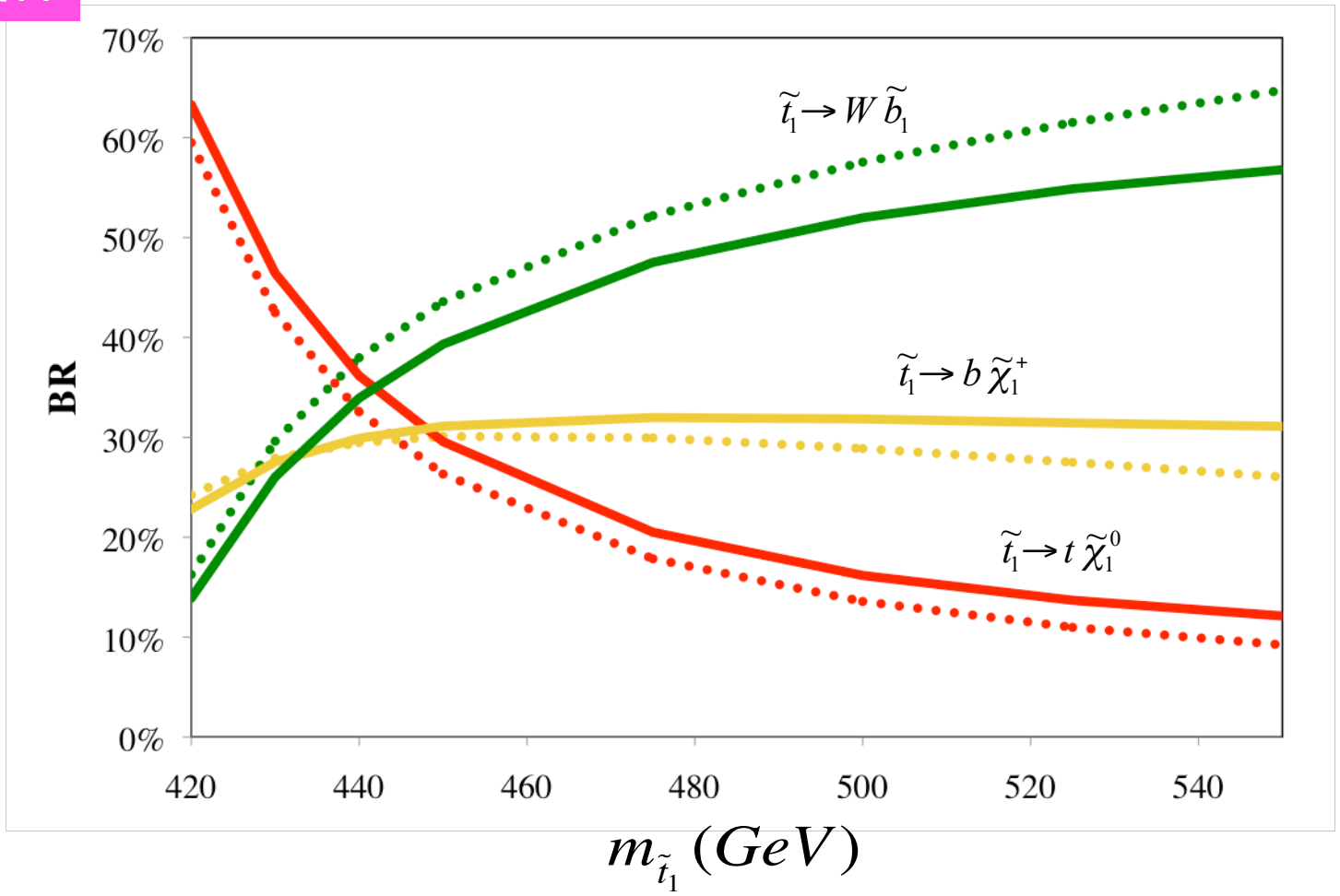
For Set A

$$\frac{\delta\Gamma(\tilde{t}_1)}{\Gamma_{tree}(\tilde{t}_1)}$$



$m_{\tilde{t}_1}$ dependence of branching ratios

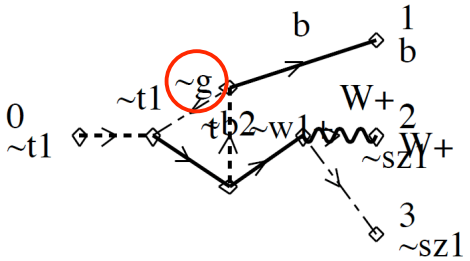
For Set A



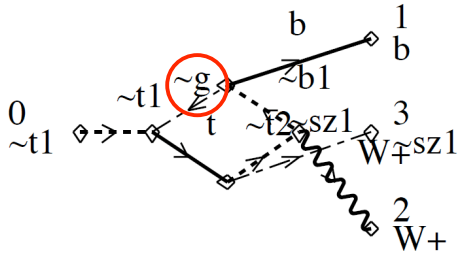
$m_{\tilde{g}}$ dependence of QCD corrections

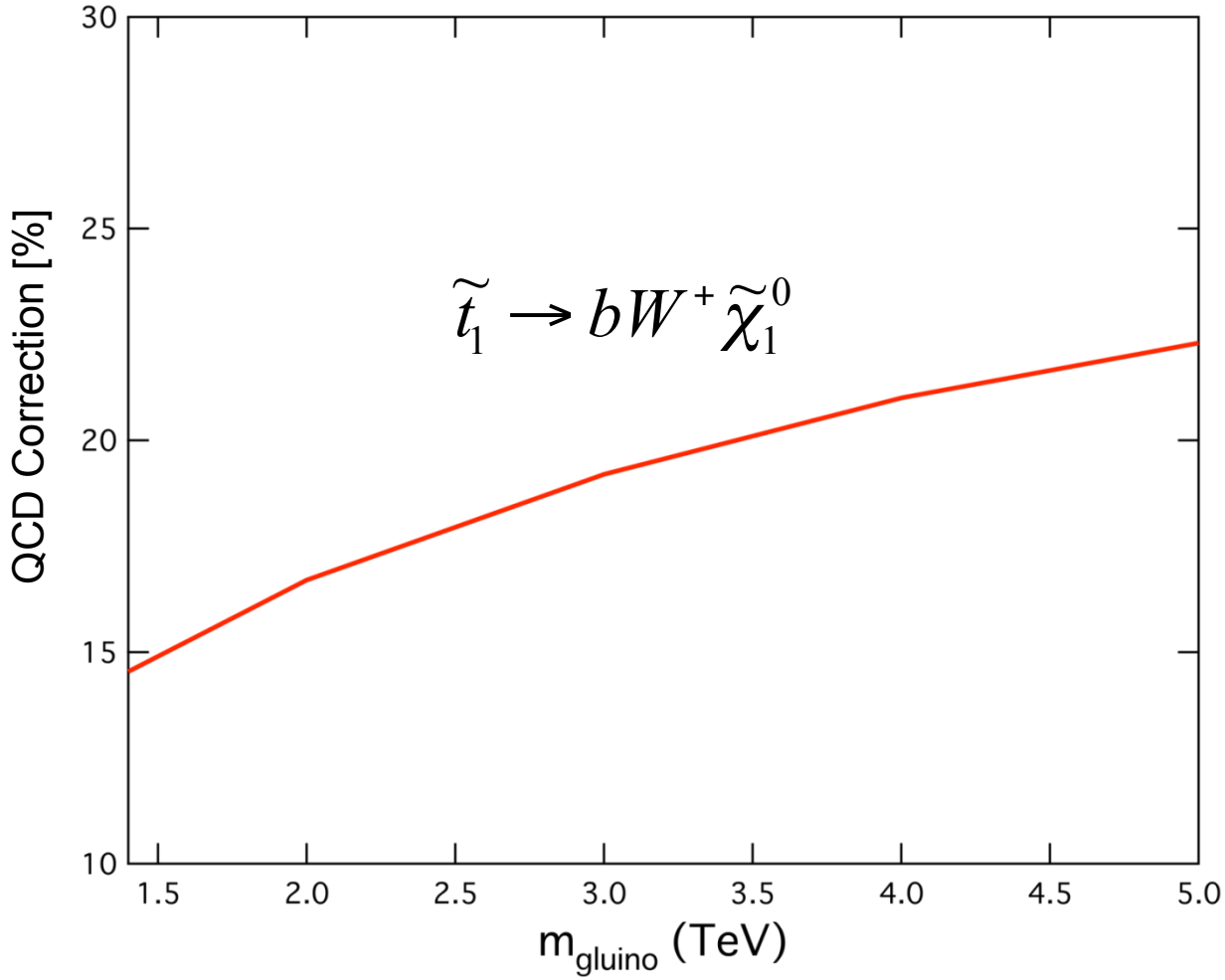
For Set A

Graph 22



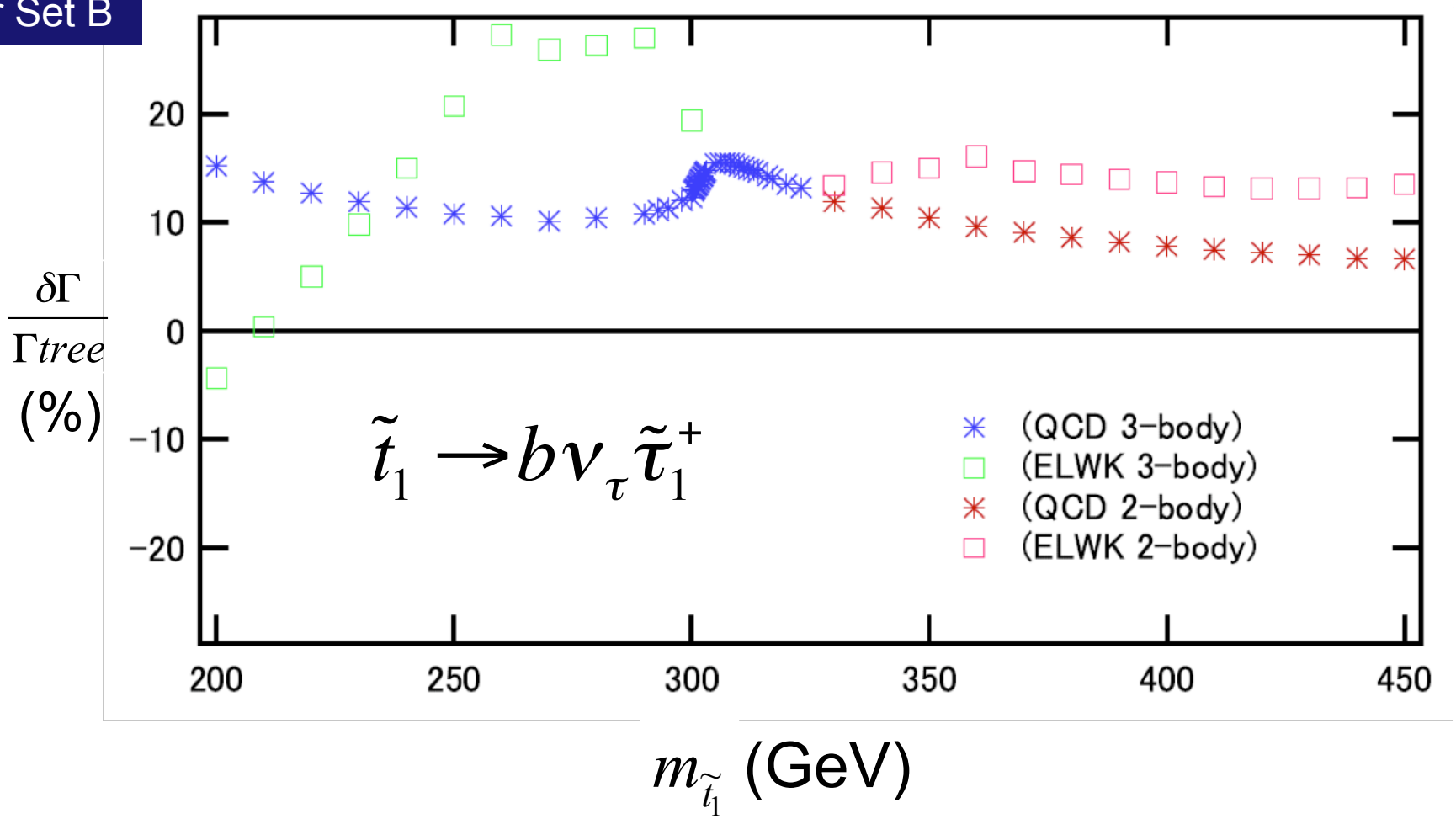
Graph 32



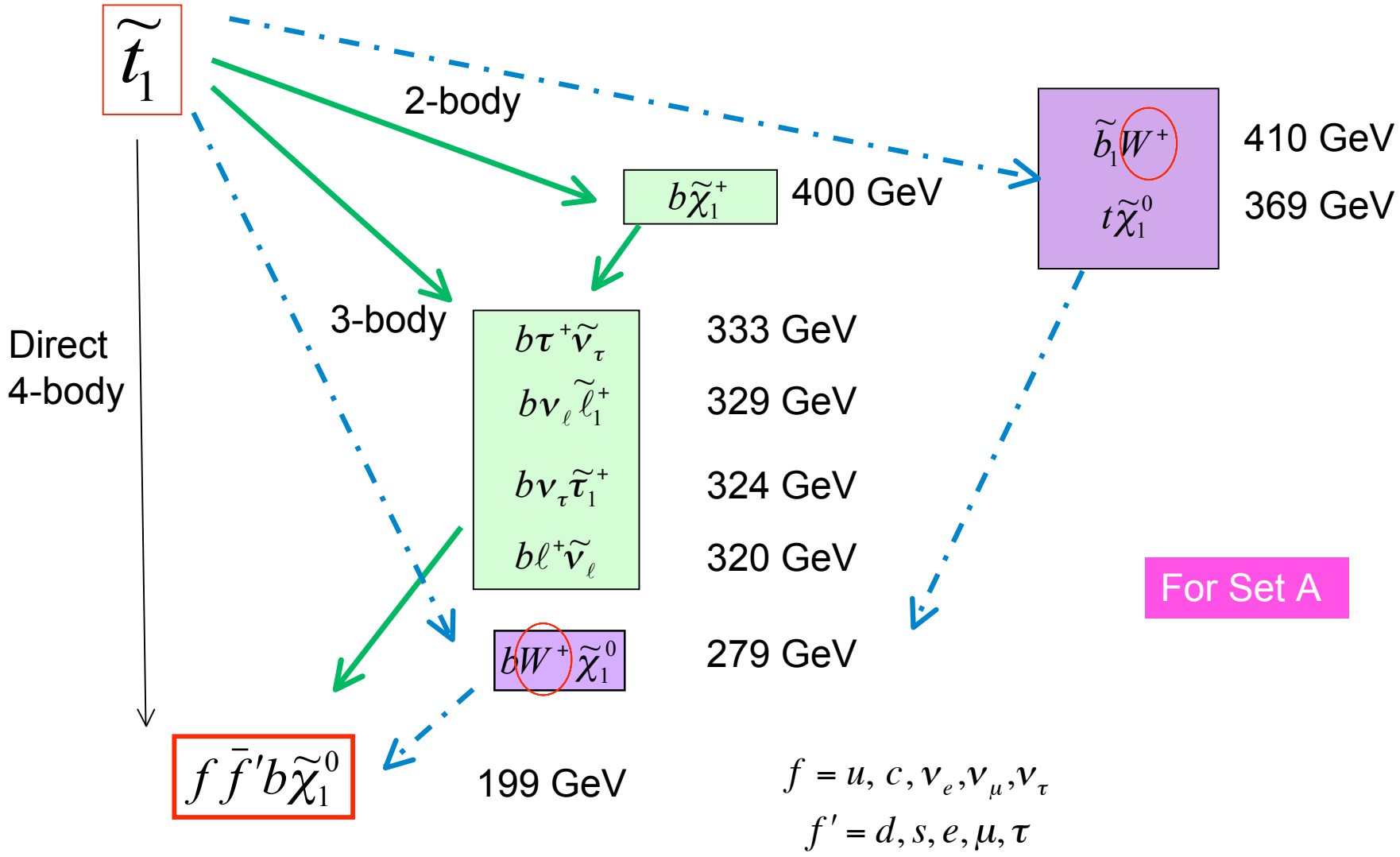


$m_{\tilde{t}_1}$ dependence of corrections for partial width

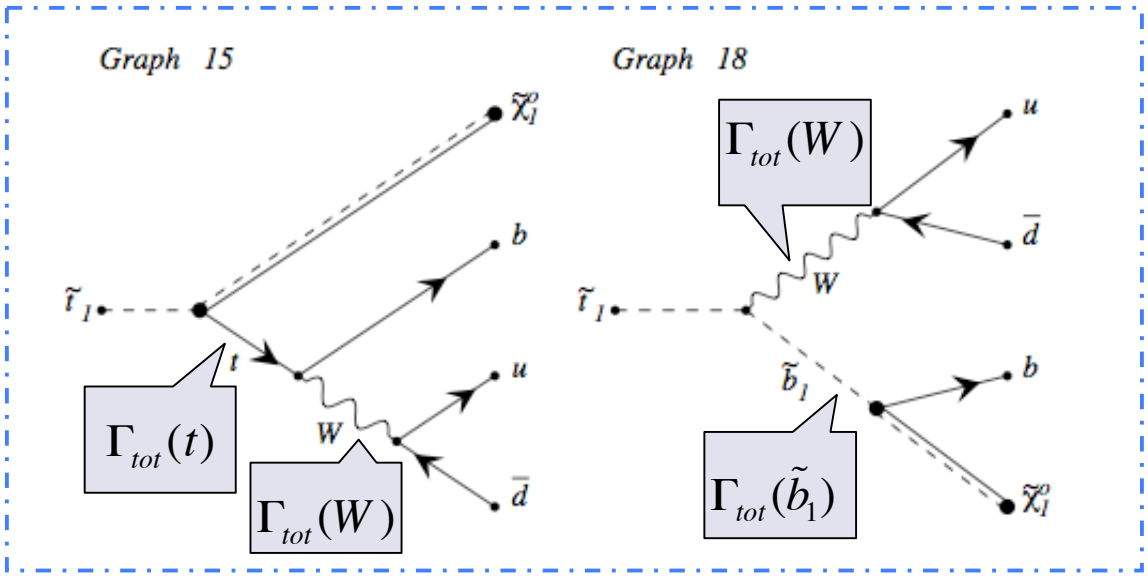
For Set B

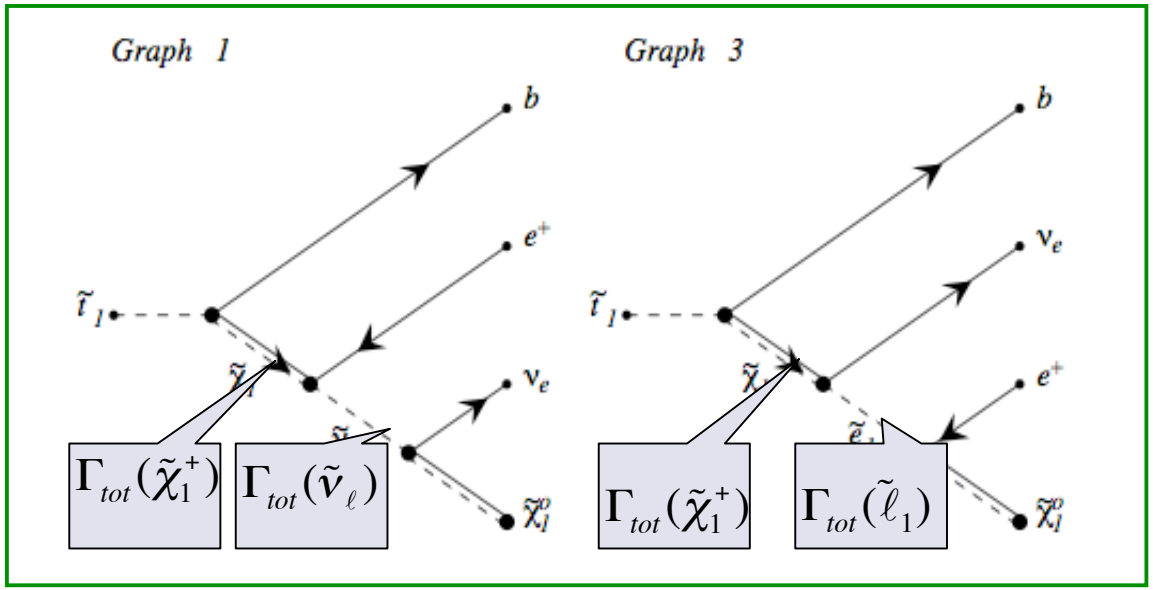


$ Analysis of 4-body decays



Feynman diagrams for “W-mode” and “lepton-mode”



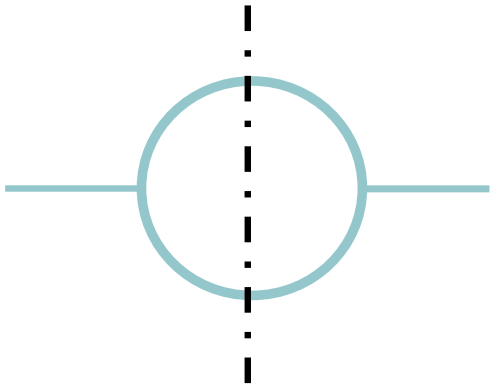


To obtain accurate cascade decay width

We need
Correct total decay widths
Of corresponding particles

Systematic calculation of total decay widths with 1-loop 2-point function library in GRACE/SUSY-loop

	GeV
$\Gamma(\tilde{b}_1)$	0.0801
$\Gamma(\tilde{\chi}_1^+)$	1.0622
$\Gamma(\tilde{\nu}_e)$	0.1545
$\Gamma(\tilde{e}_1)$	0.1795



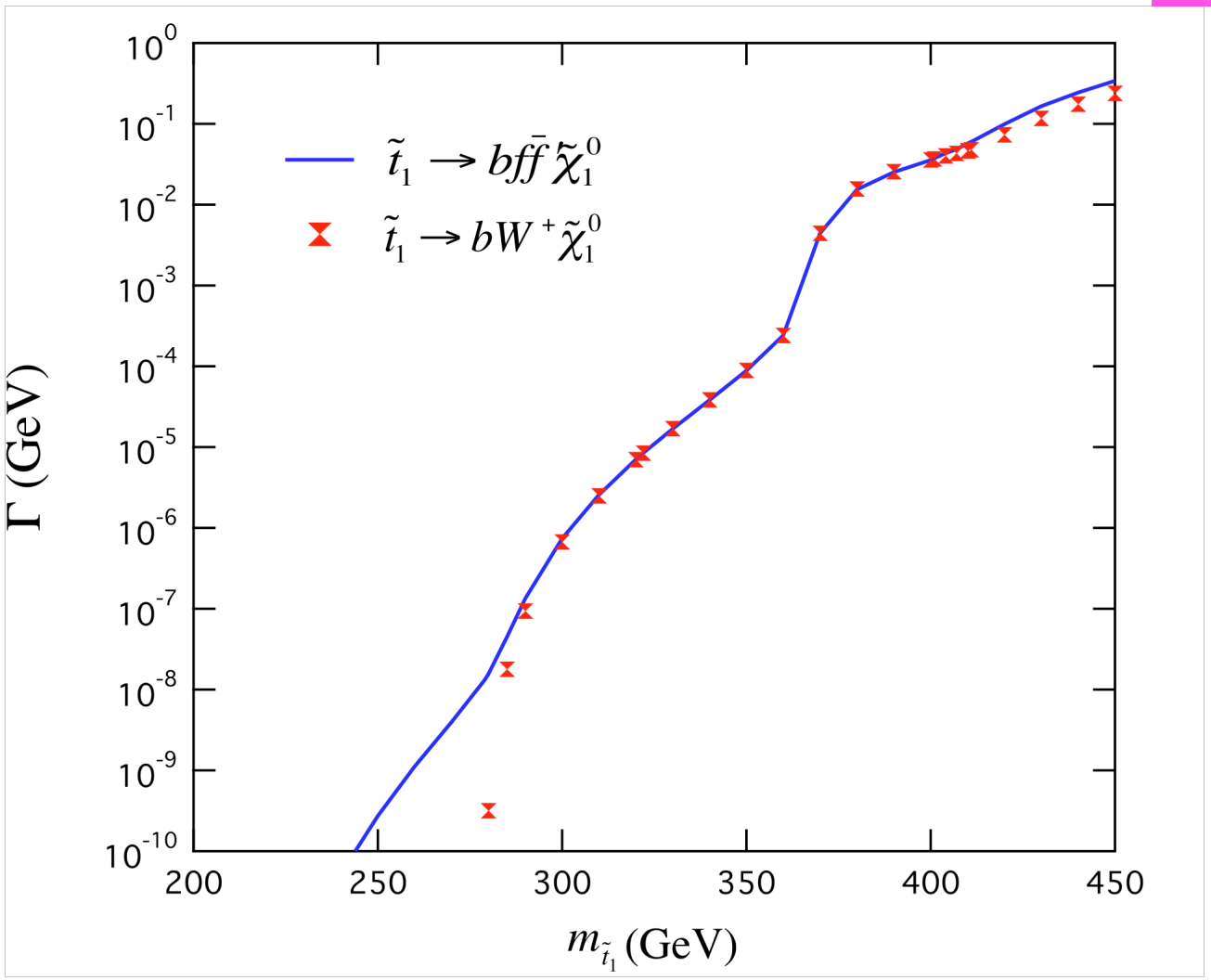
$$\Gamma_S = -\frac{\mathrm{Im}\sum_s^S(m_s^2)}{m_s}$$

$$\Gamma_F = -2\,\mathrm{Im}\left(\sum_f^S(m_f^2) + m_f\sum_f^V(m_f^2)\right)$$

All 2-point functions : automatically calculated

$m_{\tilde{t}_1}$ dependence of total width

For Set A



$ Summary

- Various stop decays :
  calculated using GRACE/SUSY
- QCD and ELW 1-loop corrections :
  both important for SUSY phenomenology
  with high accuracy
- 1-loop 2-point function library :
  useful in calculation of cascade decays
  of heavy sparticles