NLO SQCD corrections to the decay $\tilde{t}_1 \to c\tilde{\chi}_1^0$

Jason Aebischer
In collaboration with A. Crivellin and C. Greub

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Overview

1. Motivation
   - Light stops
   - $\tilde{t}_1 \to c\tilde{\chi}_1^0$
2. Process
   - Tree level
   - α_s-corrections
3. Numerics
4. Summary

Motivation

Motivation for light stops

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RGE

Stop mass driven to lower values

Motivation for light stops

RGE

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Hierarchy problem

Quadratic divergences of Higgs self-energy canceled

Motivation for light stops

RGE

Stop mass driven to lower values

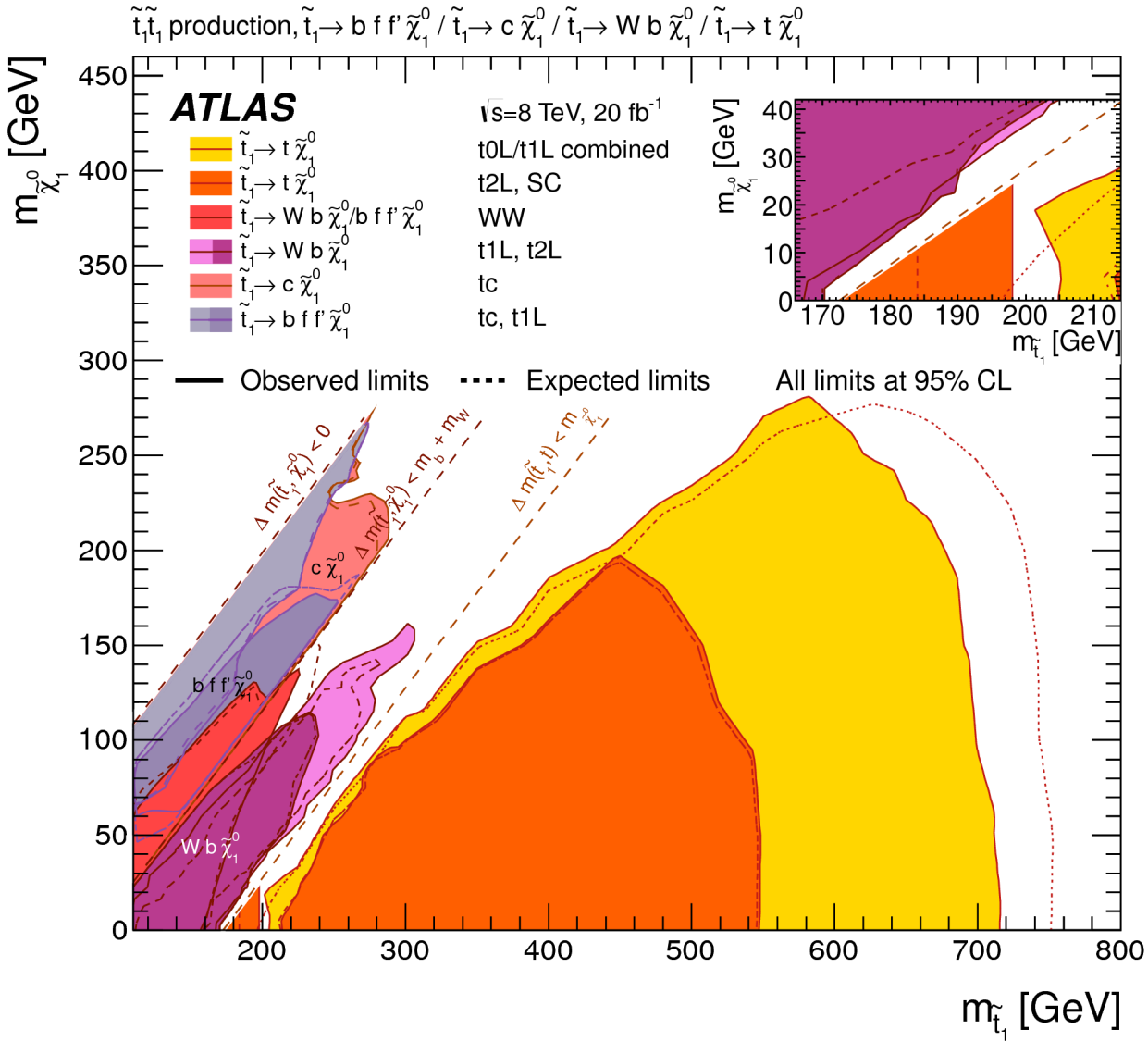
Hierarchy problem

Quadratic divergences of Higgs self-energy canceled

Others

Relic density, Baryogenesis,...

Scalar top search



Assumptions

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$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < m_t$

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$\tilde{t}_1$ is the NLSP

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R-Parity

Dominant decays: $\tilde{t}_1 \to c\tilde{\chi}_1^0$, $\tilde{t}_1 \to bW\tilde{\chi}_1^0$

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Flavour structure

Minimal or Non-minimal flavour violation

Process

Relevant operator

$$\mathcal{L}_{\text{MSSM}} \supset \tilde{u}_s^* \bar{\tilde{\chi}}_p^0 \left[\Gamma^{\tilde{\chi}_p^0 L}_{\tilde{u}_s u_i} P_L + \Gamma^{\tilde{\chi}_p^0 R}_{\tilde{u}_s u_i} P_R \right] u_i \; + \; \text{h.c.}$$

$\tilde{u}_s =$ up-type squark, $\tilde{\chi}_p =$ Neutralino, $u_i =$ up-type quark

Vertices

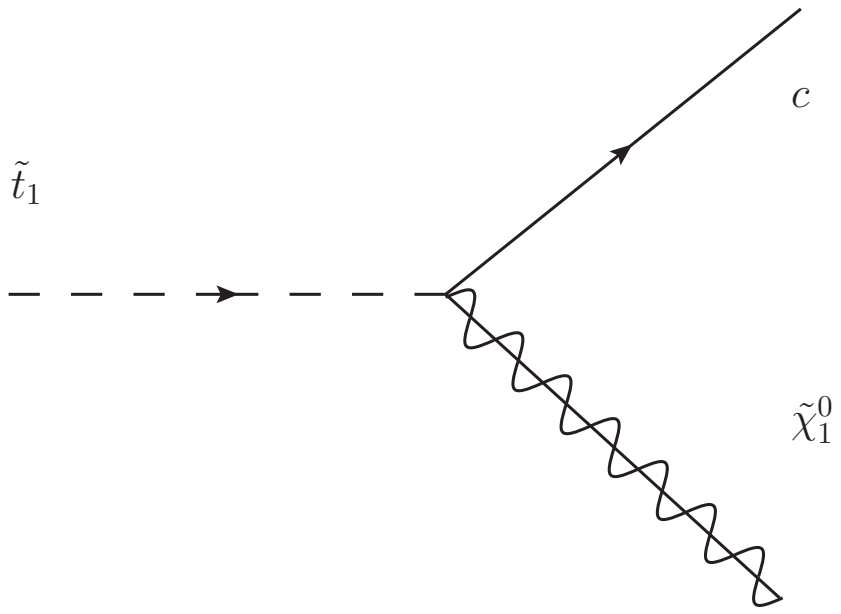
$$\Gamma^{\tilde{\chi}_p^0 L}_{\tilde{u}_s u_i} = \frac{-e}{\sqrt{2} s_W c_W} W^{\tilde{u}*}_{is} \left(\frac{1}{3} Z_N^{1p} s_W + Z_N^{2p} c_W \right) - Y^{u_i *} W^{\tilde{u}*}_{i+3,s} Z_N^{4p} \,,$$

$$\Gamma^{\tilde{\chi}_p^0 R}_{\tilde{u}_s u_i} = \frac{2\sqrt{2} e}{3 c_W} W^{\tilde{u}*}_{i+3,s} Z_N^{1p*} - Y^{u_i} W^{\tilde{u}*}_{is} Z_N^{4p*} \,.$$

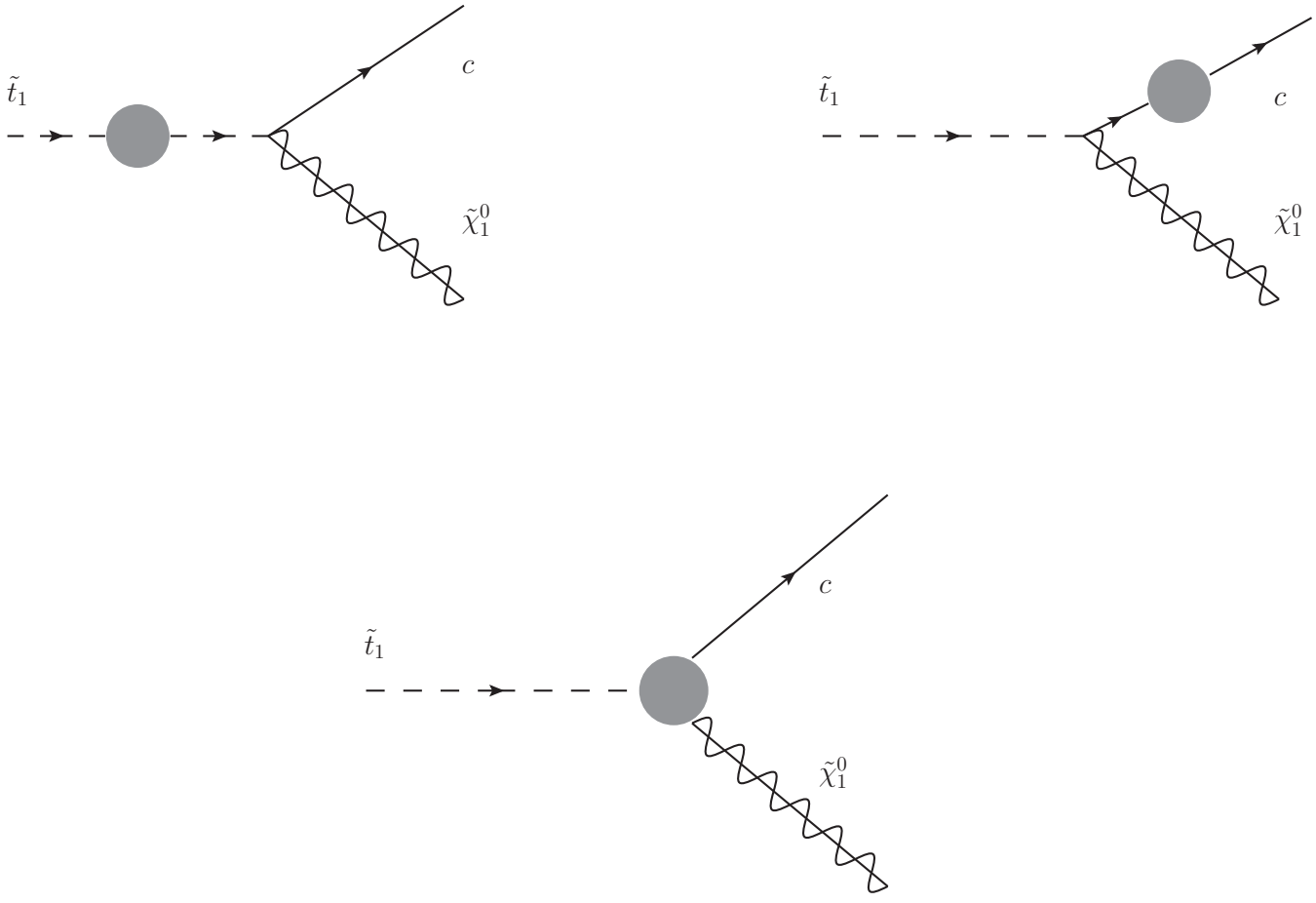
$W^{\tilde{u}*}_{i+3,s}$ = Squark rotation matrix, Z_N^{4p} = Neutralino rotation matrix

e = electric charge, Y^u = Yukawa coupling, $s_W, c_w = \sin(\theta_W), \cos(\theta_W)$

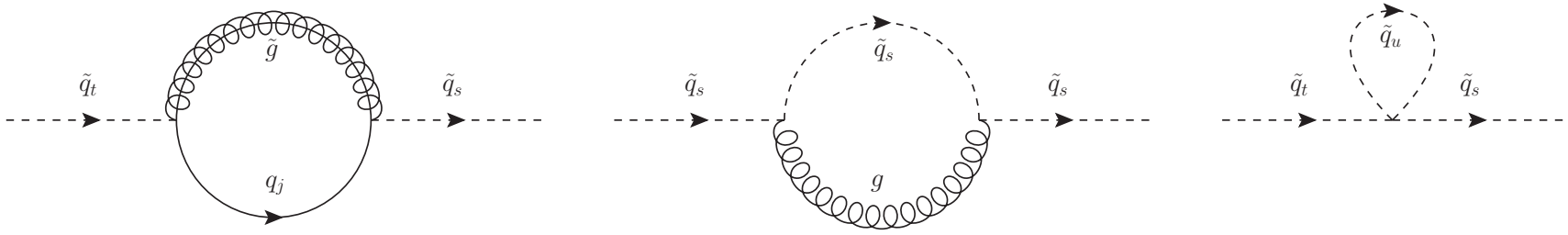
Tree level



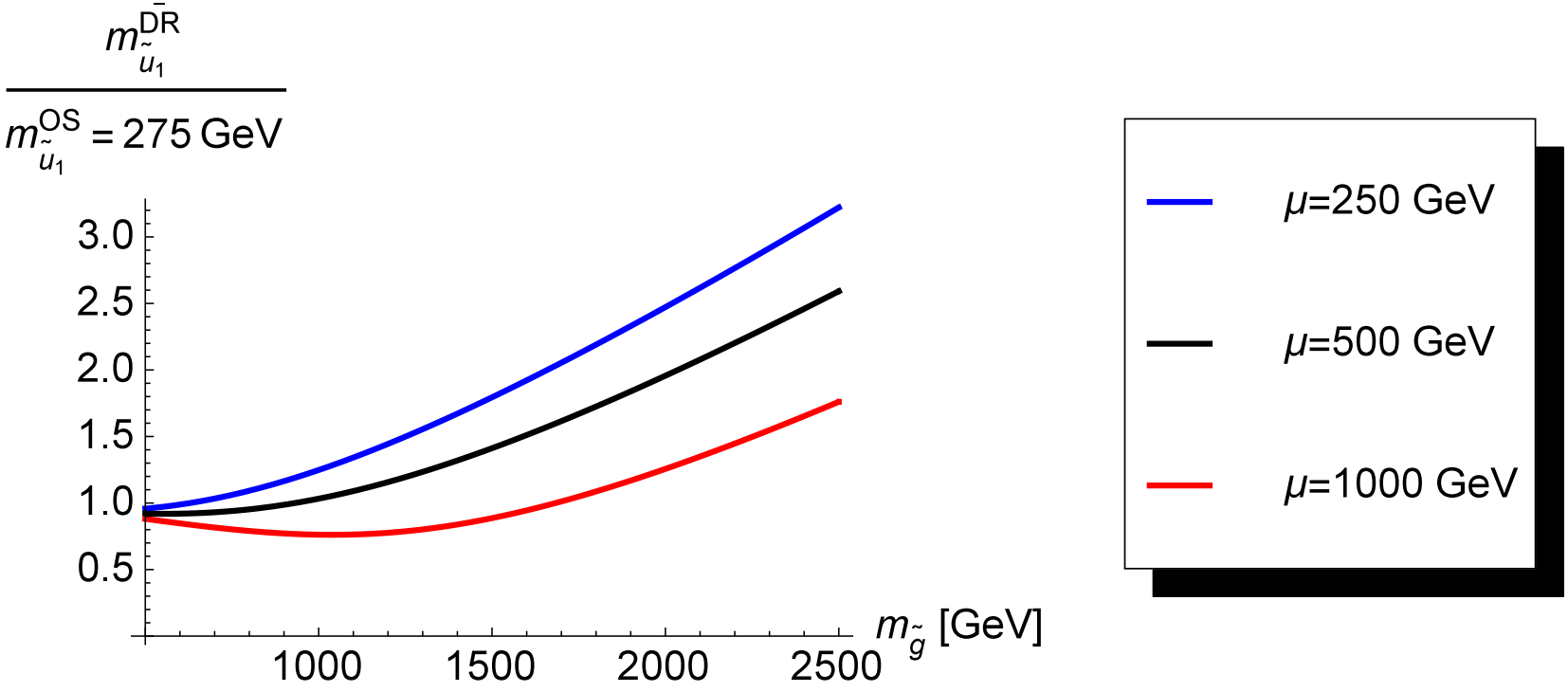
Virtual α_s-corrections to $\tilde{t}_1 \to c\tilde{\chi}_1^0$



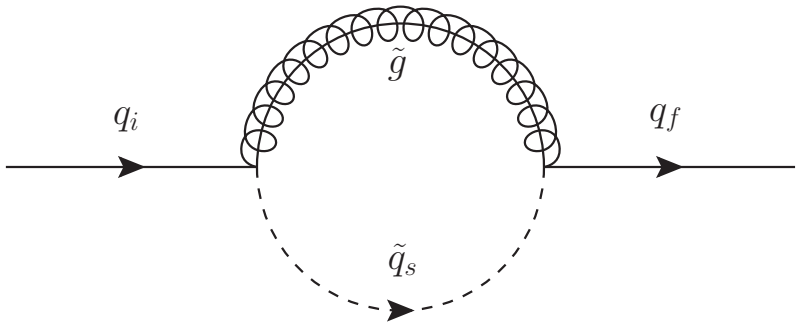
Squark self-energies

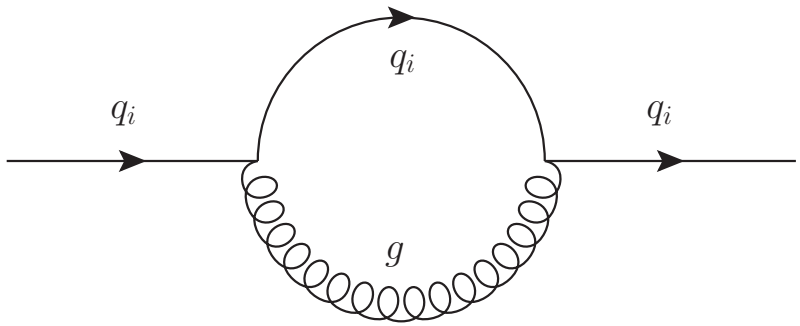


Mass dependence of Squark mass on Gluino mass

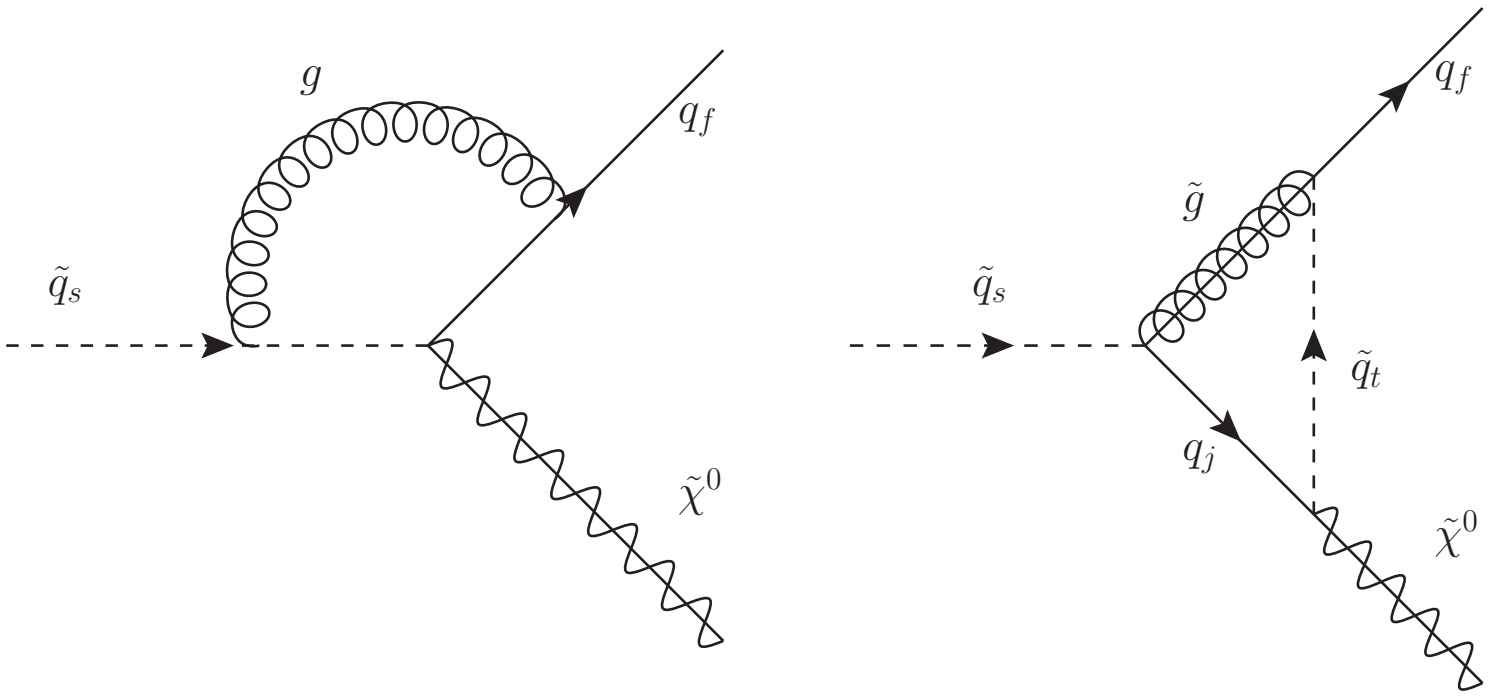


Quark self-energy

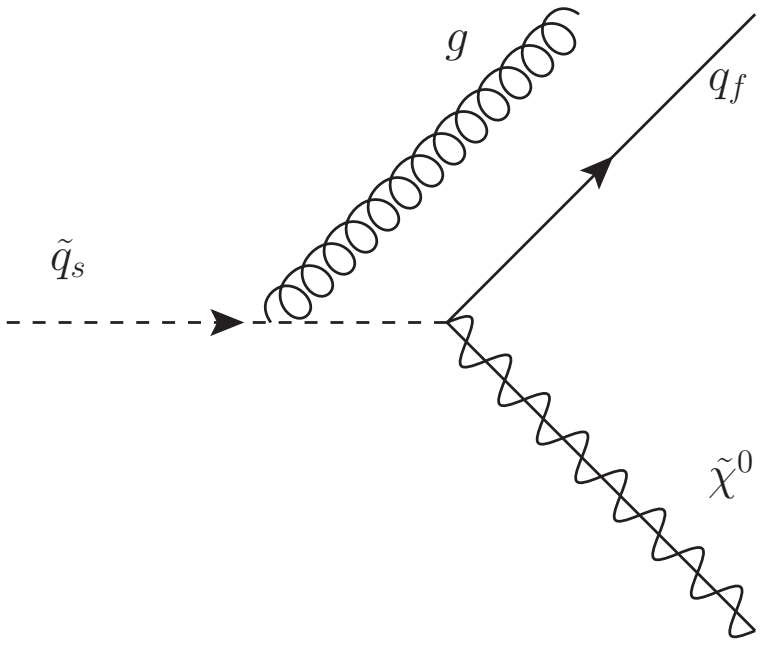


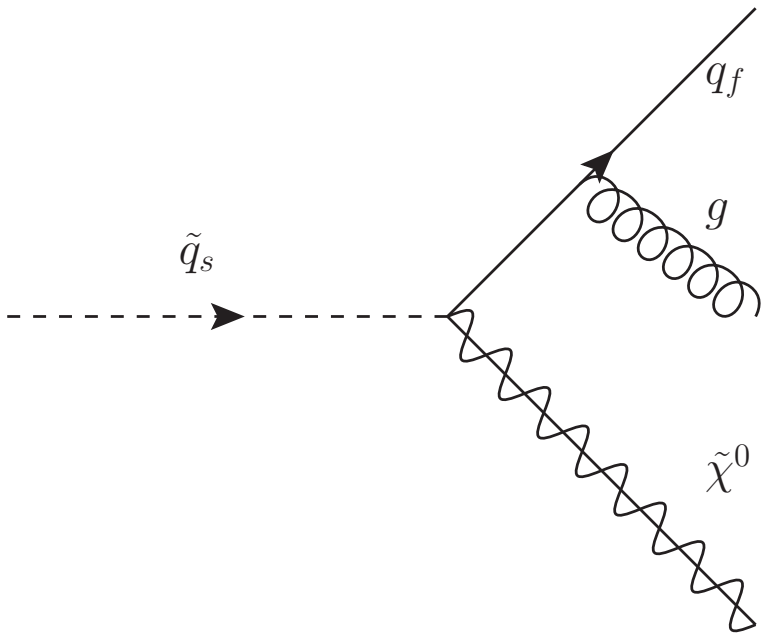


Genuine vertex corrections to $\tilde{t}_1 \to c\tilde{\chi}_1^0$

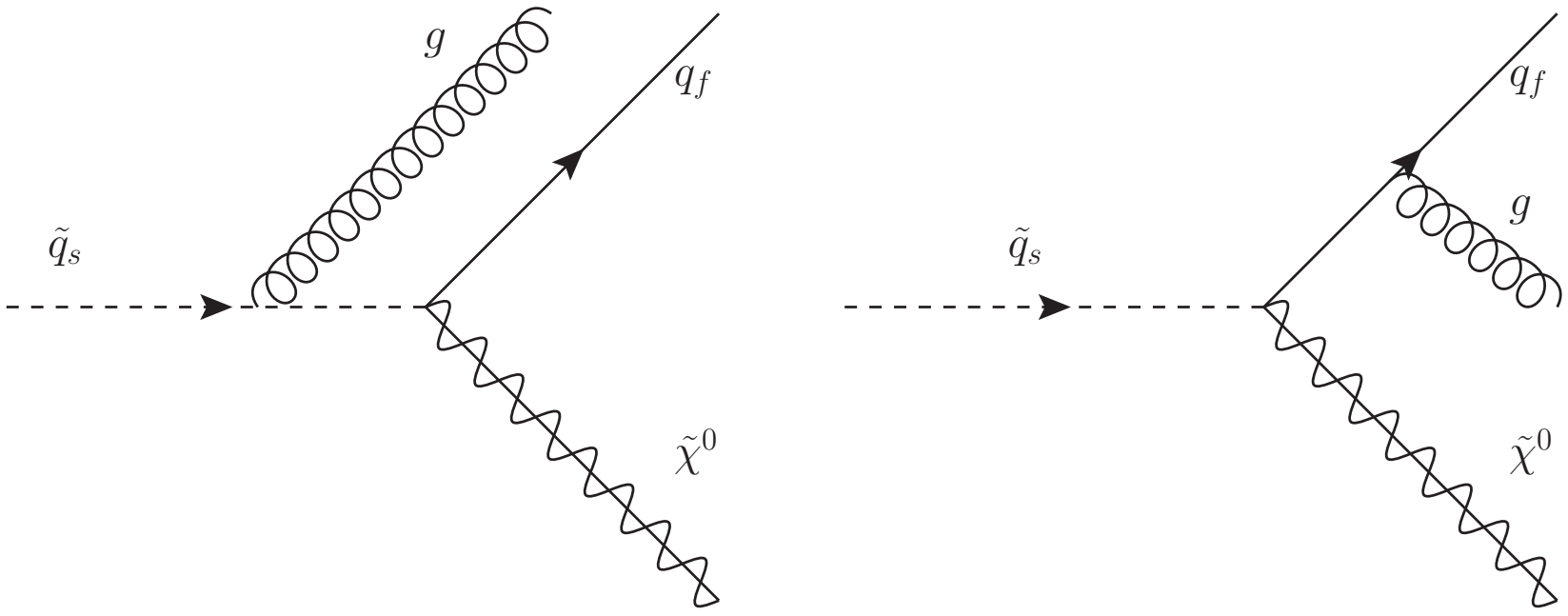


Real emission to $\tilde{t}_1 \to c\tilde{\chi}_1^0$: $\tilde{t}_1 \to c\tilde{\chi}_1^0 g$





Real emission to $\tilde{t}_1 \to c\tilde{\chi}_1^0$: $\tilde{t}_1 \to c\tilde{\chi}_1^0 g$



KLN Theorem: $\Gamma(\tilde{t}_1 \to c\tilde{\chi}_1^0) + \Gamma(\tilde{t}_1 \to c\tilde{\chi}_1^0 g) =$ IR finite

Numerics

Parameters

$$m_{\tilde{t}_1}^{OS} = 275\,GeV$$

$$m_{\tilde{\chi}_1^0} = 250\,GeV$$

$$\mu = 275\,GeV \quad \text{(Renormalization scale)}$$

$$\tan(\beta) = 50$$

Squark mass-squared matrix

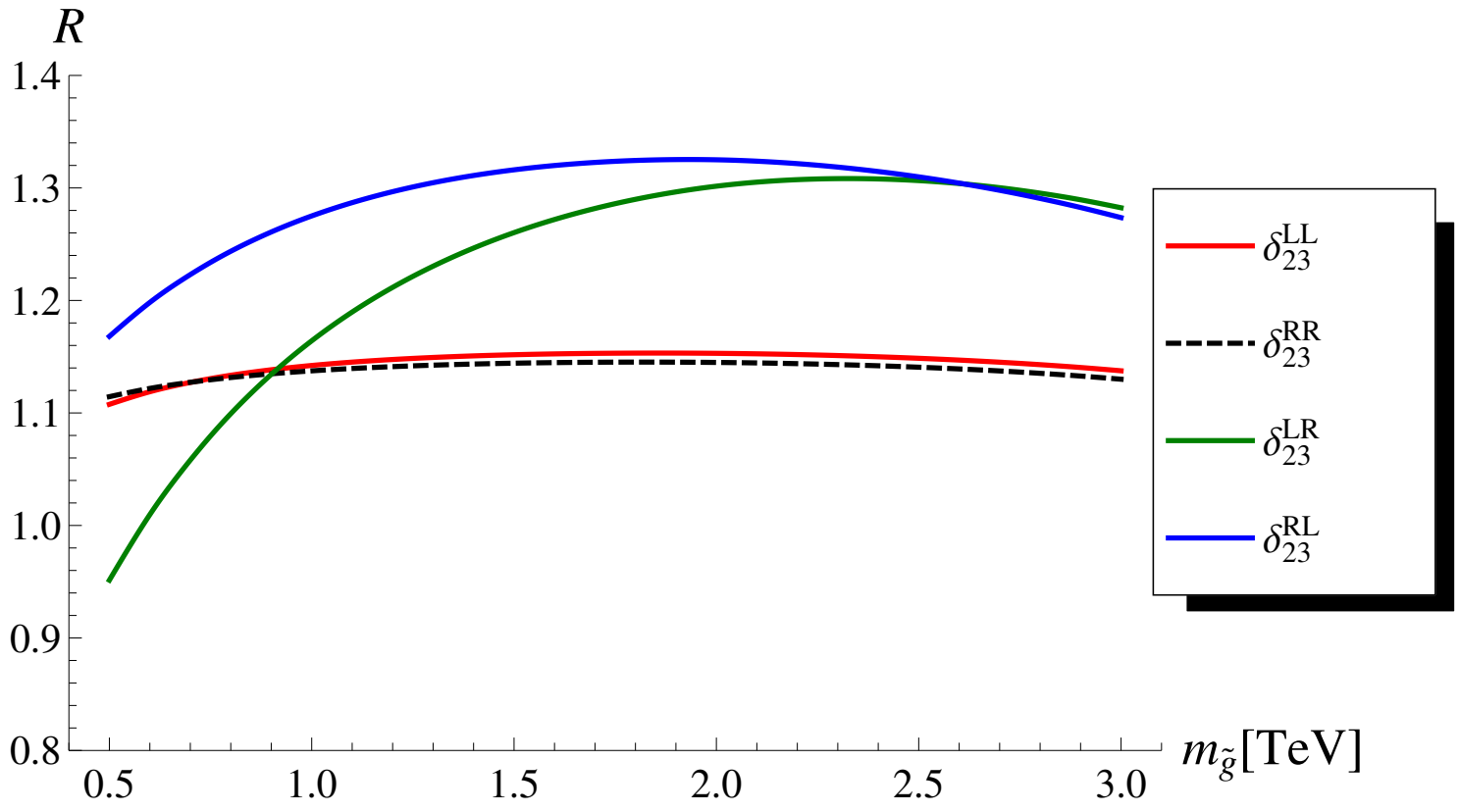
$$\mathcal{M}^2_{\tilde{u}} = \begin{pmatrix} (2\ \mathrm{TeV})^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & (2\ \mathrm{TeV})^2 & \Delta^{LL}_{23} & 0 & 0 & \Delta^{LR}_{23} \\ 0 & \Delta^{LL*}_{23} & \left(m^{LL}_{33}\right)^2 & 0 & \Delta^{RL*}_{23} & -v_u A^t \\ 0 & 0 & 0 & (2\ \mathrm{TeV})^2 & 0 & 0 \\ 0 & 0 & \Delta^{RL}_{23} & 0 & (2\ \mathrm{TeV})^2 & \Delta^{RR}_{23} \\ 0 & \Delta^{LR*}_{23} & -v_u A^t & 0 & \Delta^{RR*}_{23} & \left(m^{RR}_{33}\right)^2 \end{pmatrix}$$

Whereas

$$\Delta^{AB}_{ij} = \delta^{AB}_{ij}\sqrt{\mathcal{M}^2_{\tilde{u},ii}\mathcal{M}^2_{\tilde{u},jj}} \quad \delta^{AB}_{ij}\text{dimensionless}$$

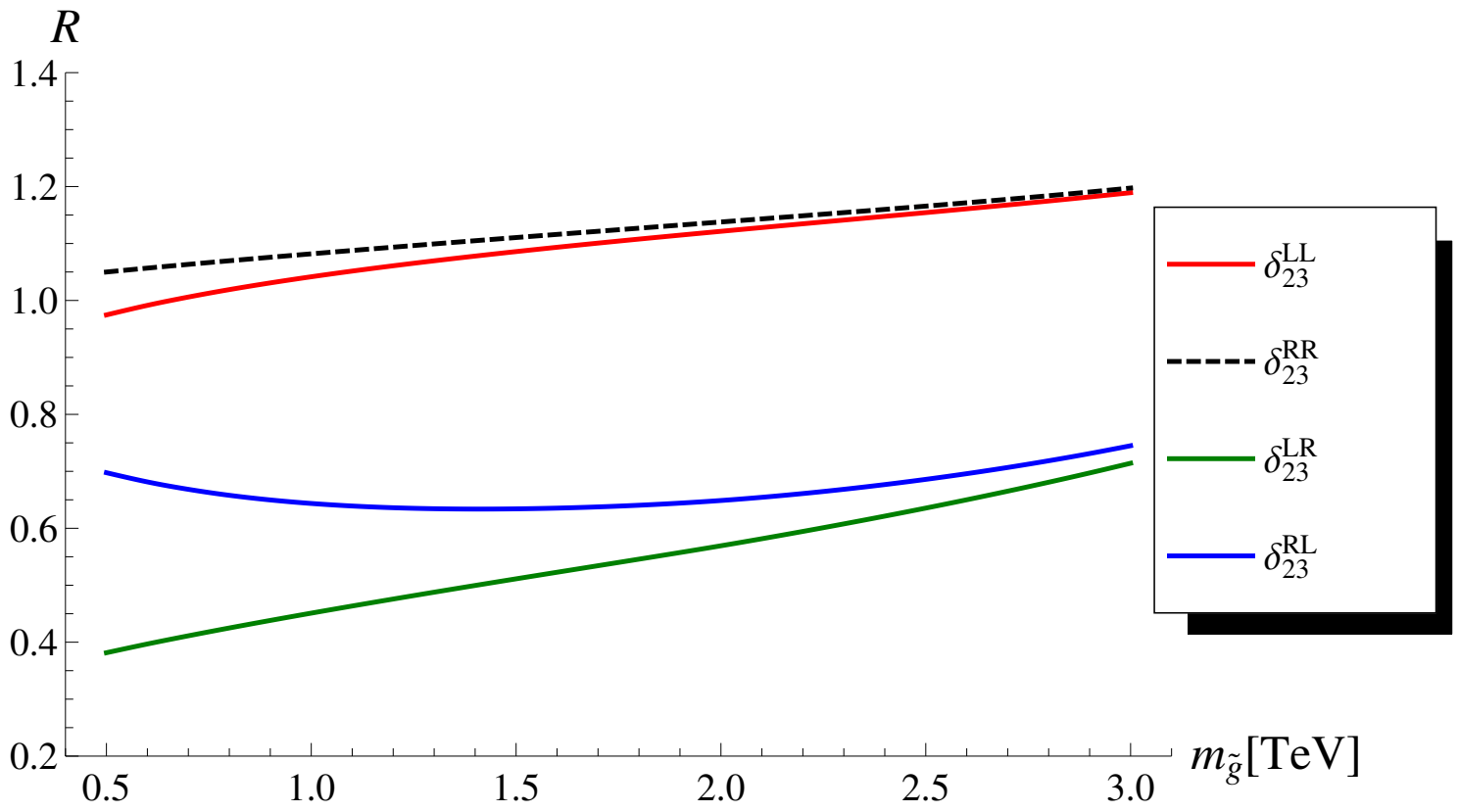
$$m^{LL}_{33} = m^{RR}_{33} \ \ s.t.\ m^{\mathrm{OS}}_{\tilde{t}_1} = 275\,GeV$$

1-loop corrections to the decay width



$R := \frac{\Gamma^{\text{tree}}+\Gamma^{\text{1-loop}}}{\Gamma^{\text{tree}}}$, $A^t = 1\text{TeV}$, $\delta_{23}^{AB} = 0.01$

1-loop corrections to the decay width



$R := \frac{\Gamma^{\text{tree}} + \Gamma^{\text{1-loop}}}{\Gamma^{\text{tree}}}$, $A^t = -1\text{TeV}$

Summary

Light stops

Rich phenomenology

QCD corrections to $\Gamma(\tilde{t}_1 \to c\tilde{\chi}_1^0)$

around 10 % correction from bilinear terms

up to $\pm 50\%$ correction from trilinear terms

Future

Further investigation of Gluino mass dependence of stop mass