Mixed Gluinos

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with G Kribs

TASI 2013

SUPERSOFT SUSY (BREAKING)

MSSM (vanilla)

$$\boxed{c_m \int d^2\theta \frac{X}{M} W^\alpha W_\alpha}$$

Chiral N = 1
Adjoint N = 1
F-term breaking

SSSM (mango)

Fox, Nelson, Weiner
hep-ph/0206096

$$\boxed{c_d \int d^2\theta \sqrt{2} \frac{W'_\alpha}{M} W_j^\alpha A_j}$$

Chiral N = 1
Adjoint N = 2
D-term breaking

SUPERSOFT SUSY (BREAKING)

MSSM (vanilla)

$$\boxed{\mathcal{L} \supset \frac{1}{2} M_m g_a g_a}$$

Chiral N = 1
Adjoint N = 1
F-term breaking

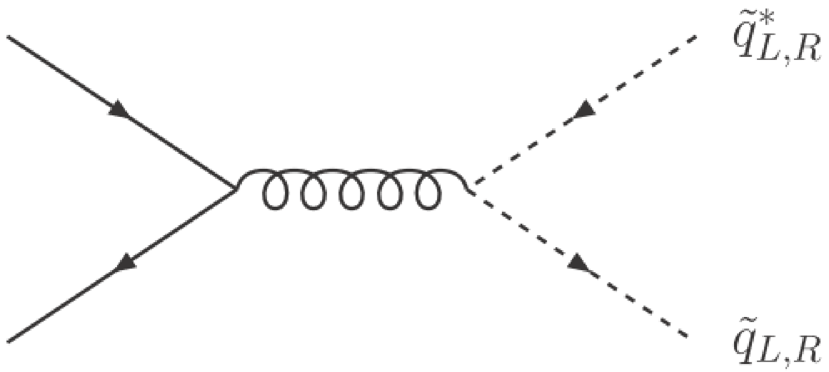
SSSM (mango)

Fox, Nelson, Weiner
hep-ph/0206096

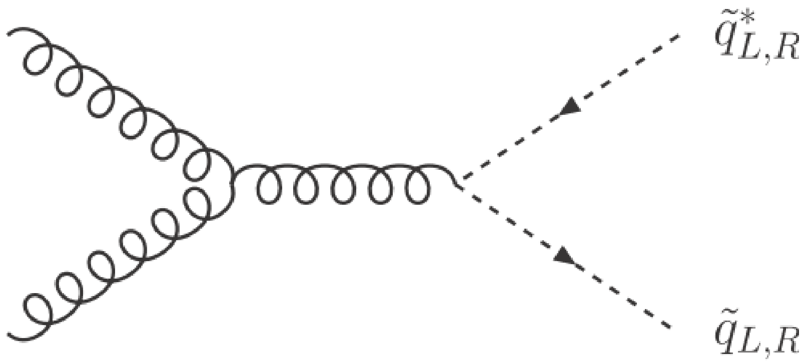
$$\boxed{\mathcal{L} \supset M_d g_a \psi_a}$$

Chiral N = 1
Adjoint N = 2
D-term breaking

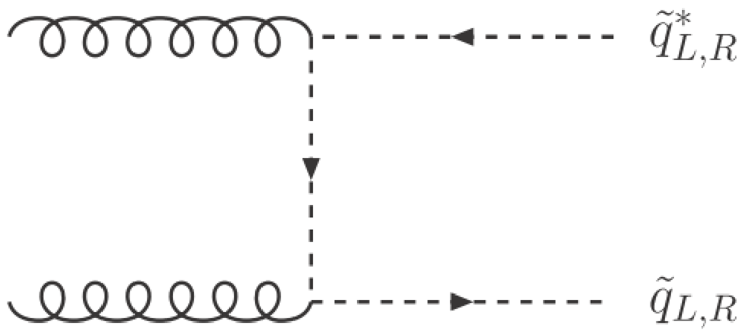
MSSM v SSSM Phenomenology



In SSSM,
same-handed
t-channel
squark pair production
absent.



Here, dominant diagrams



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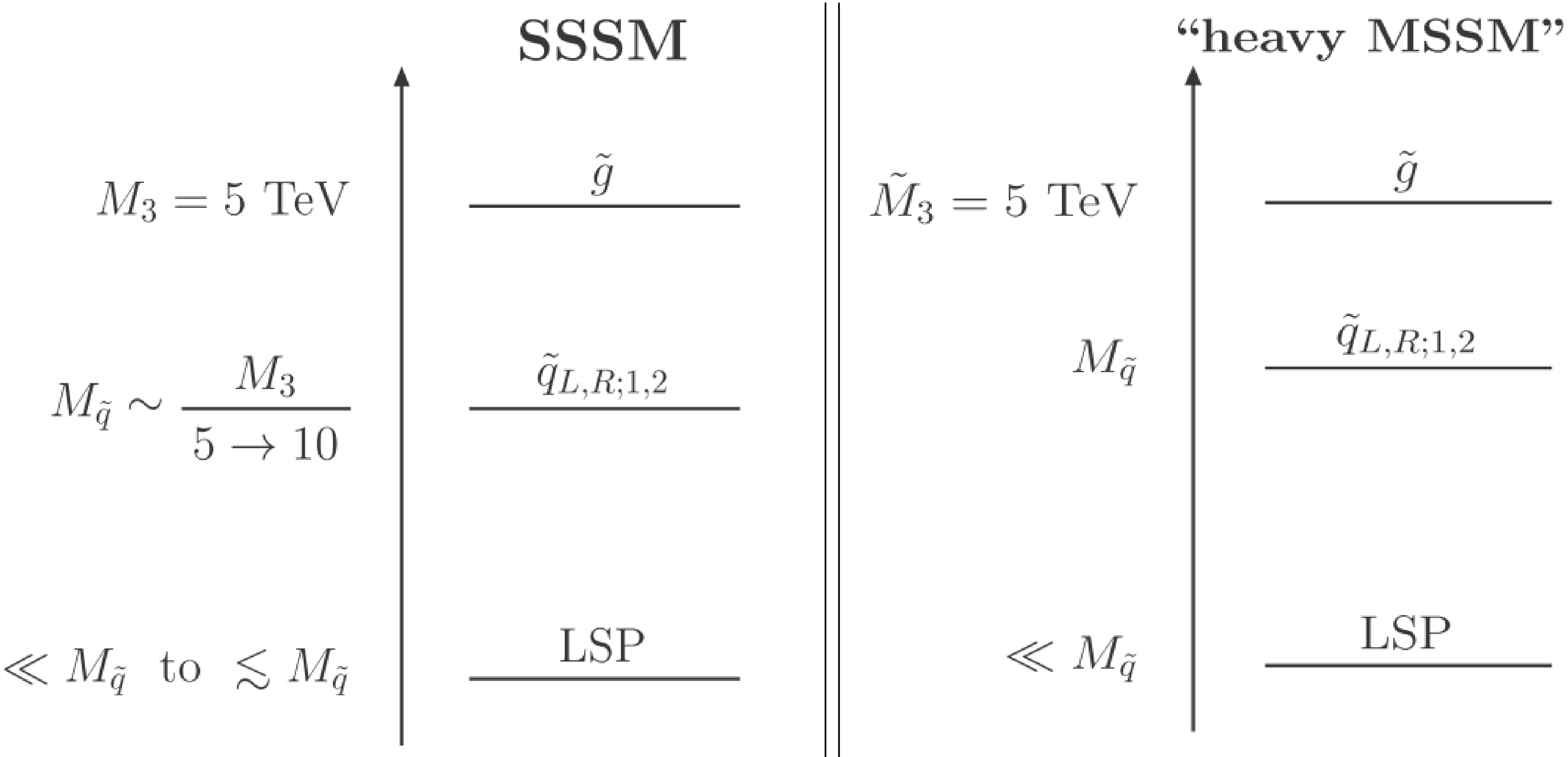
MSSM v SSSM Phenomenology (contd.)

Comparison with a "simplified model"



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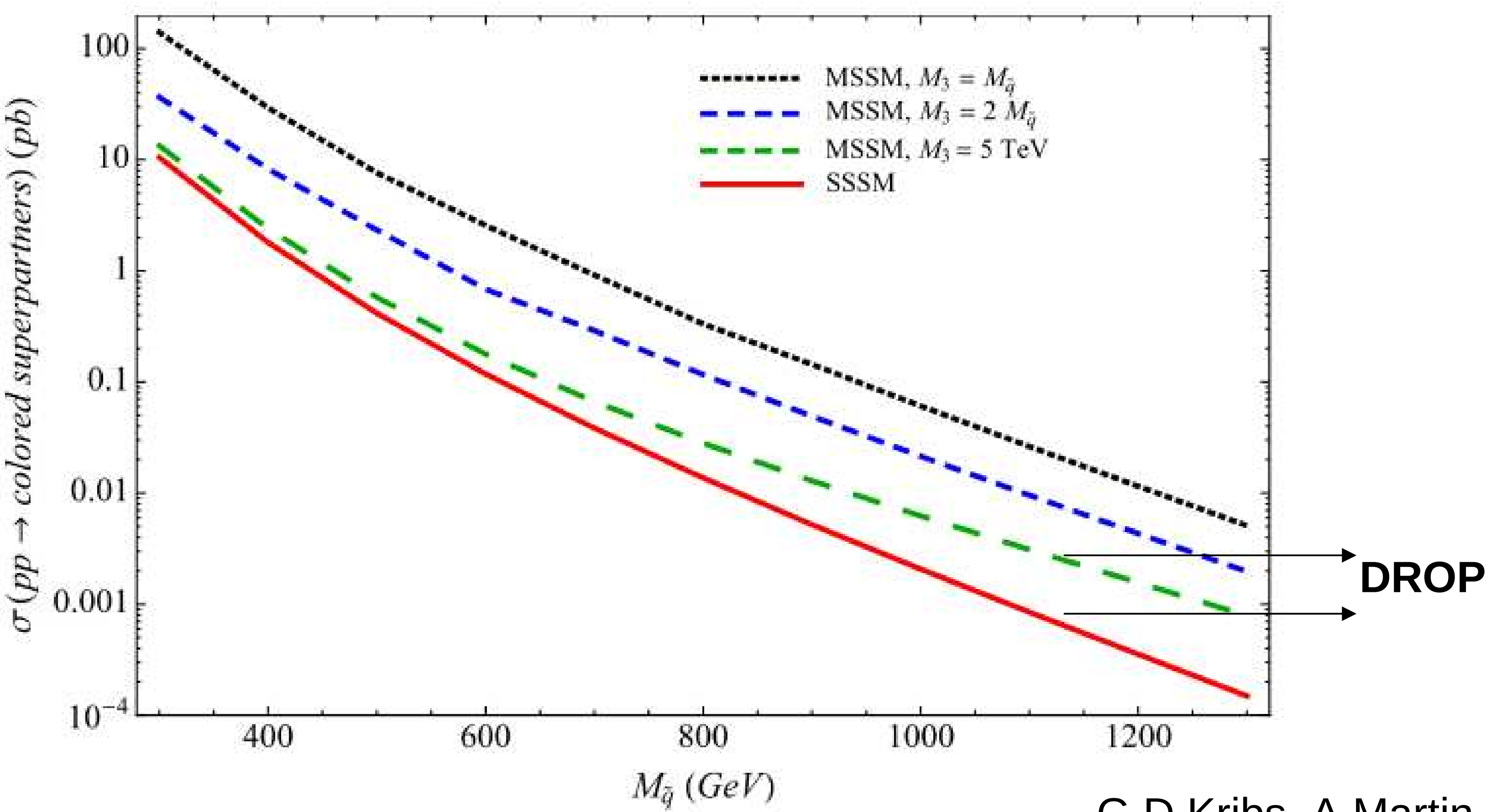
MSSM v SSSM Phenomenology (contd.)

Comparison with "simplified models"



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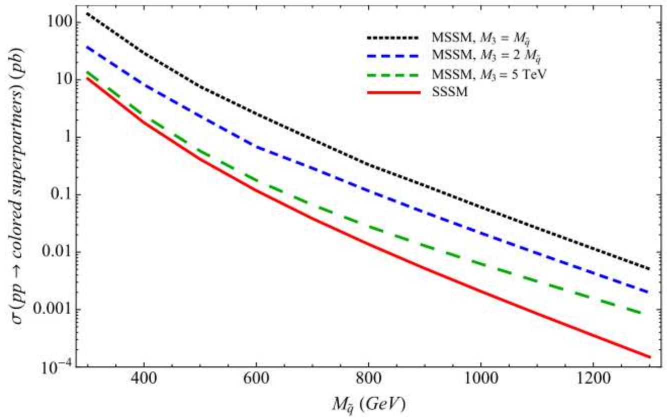
MSSM v SSSM Phenomenology (contd.)

Comparison with “simplified models”



Most conservative theoretical bound:
Sq mass > 750 GeV

Most stringent experimental (ATLAS) bound
[from “Heavy MSSM”]:
Sq mass > 1040 GeV

{Today, > 1.4 TeV}

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Problems with SSSM

(1) Nothing natural in having F-terms
(much) smaller than D-terms

(2) Higgs quartic coupling vanishes
unless electroweakinos
have Majorana masses

Me

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & M_m' \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

(Also generated by supersoft breaking)

$$\begin{pmatrix} g_1 \\ g_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\tilde{g}} & \sin\theta_{\tilde{g}} \\ -\sin\theta_{\tilde{g}} & \cos\theta_{\tilde{g}} \end{pmatrix} \begin{pmatrix} \psi \\ g \end{pmatrix}$$

$$\mathcal{L}_{int} = \\ -\sqrt{2}g_s\Big(\tilde{u}^*_{L,i}\ t^a\ g_a\ u_{L,i} + \tilde{d}^*_{L,i}\ t^a\ g_a\ d_{L,i} \\ -\tilde{u}^*_{R,i}\ t^a\ g_a u_{R,i} - \tilde{d}^*_{R,i}\ t^a\ g_a\ d_{R,i}\Big) + \text{h.c.}$$

$$\mathcal{L}_{int} =$$
$$-\sqrt{2}g_s\Big(\tilde{u}^*_{L,i}\ t^a\ g_a\ u_{L,i} + \tilde{d}^*_{L,i}\ t^a\ g_a\ d_{L,i}$$
$$-\ \tilde{u}^*_{R,i}\ t^a\ g_a u_{R,i} - \tilde{d}^*_{R,i}\ t^a\ g_a\ d_{R,i}\Big) + \text{h.c.}$$

$$-\mathcal{L}_{int}/\sqrt{2}g_s =$$
$$+\ \tilde{u}^*_{L,i}\ t^a\ g_1 \cos\theta_{\tilde{g}}\ u_{L,i} + \tilde{u}^*_{L,i}\ t^a\ g_2 \sin\theta_{\tilde{g}}\ u_{L,i}$$
$$+\ \tilde{d}^*_{L,i}\ t^a\ g_1 \cos\theta_{\tilde{g}}\ d_{L,i} + \tilde{d}^*_{L,i}\ t^a\ g_2 \sin\theta_{\tilde{g}}\ d_{L,i}$$
$$-\ \tilde{u}^*_{R,i}\ t^a\ g_1 \cos\theta_{\tilde{g}}\ u_{R,i} - \tilde{u}^*_{R,i}\ t^a\ g_2 \sin\theta_{\tilde{g}}\ u_{R,i}$$
$$-\ \tilde{d}^*_{R,i}\ t^a\ g_1 \cos\theta_{\tilde{g}}\ d_{R,i} - \tilde{d}^*_{R,i}\ t^a\ g_2 \sin\theta_{\tilde{g}}\ d_{R,i}$$
$$+\ \text{h.c.}$$

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & M'_m \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

Perturbations to Dirac mass: swaths to cover

- $M'_m/M_d \neq 0 \quad M_m = 0$
- $M_m/M_d \neq 0 \quad M_m = M'_m$
- $M_m/M_d \neq 0 \quad M'_m = 0$

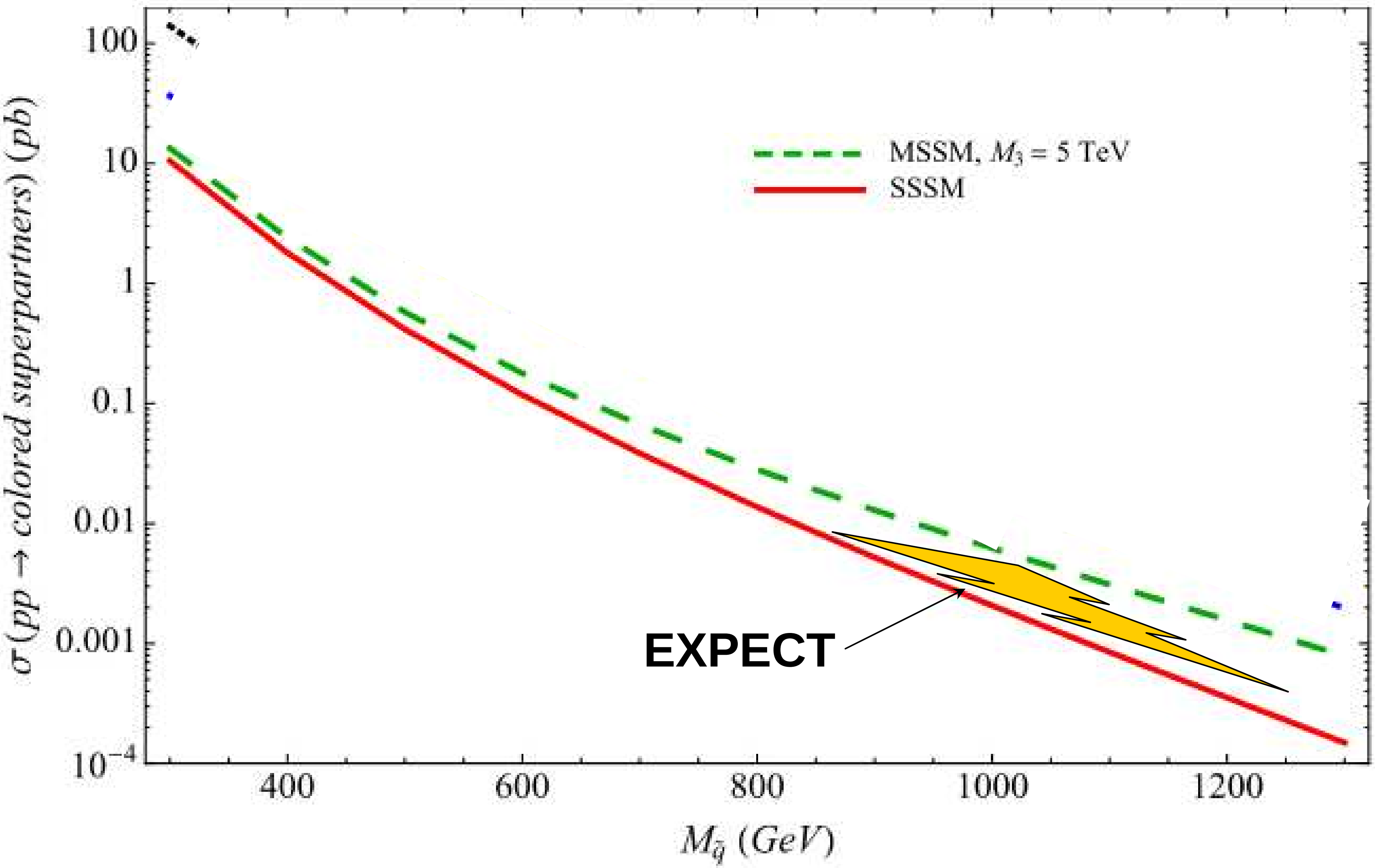
$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

Perturbations to Dirac mass: swaths to cover

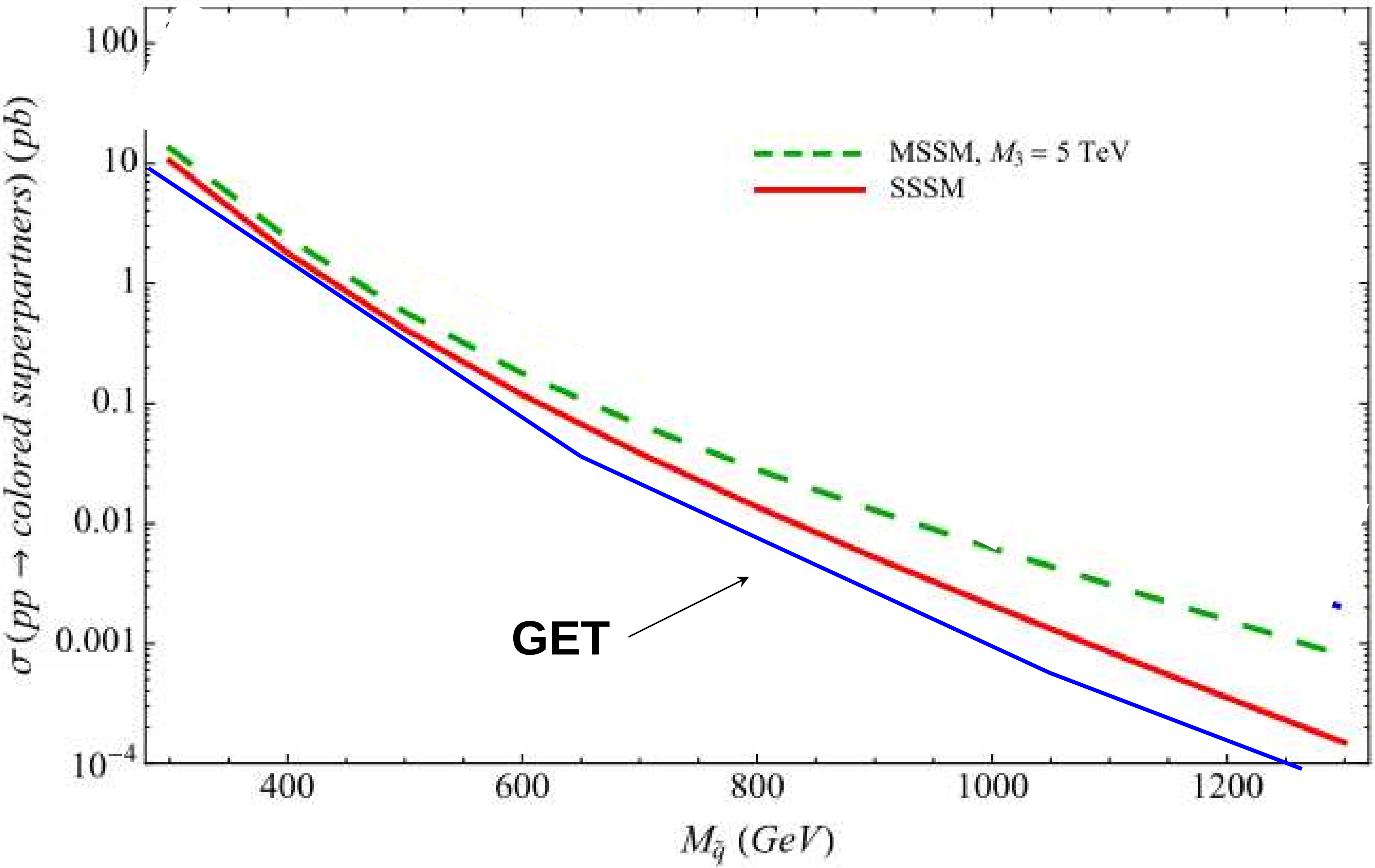
This talk

- $M_m/M_d \neq 0 \quad M'_m = 0$

Spoiler


MSSM, M_3 = 5 TeV
SSSM
EXPECT
$\sigma(pp \to colored\ superpartners)\ (pb)$
$M_{\tilde{q}}\ (GeV)$
100
10
1
0.1
0.01
0.001
10^{-4}
400
600
800
1000
1200

Spoiler


100
10
1
0.1
0.01
0.001
10^{-4}
$\sigma(pp \to colored\ superpartners)\ (pb)$
MSSM, $M_3 = 5$ TeV
SSSM
GET
400
600
800
1000
1200
$M_{\tilde{q}}\ (GeV)$

Legalese

* R-parity assumed

* LSP = Massless gravitino or light bino

* Decay prompt, 100% BR

* Squarks degenerate, don’t mix

* ‘Squarks’ = first two generations

* LO; will explain why if time permits

* CTEQ6L1 PDF’s

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & \\ & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & \\ & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

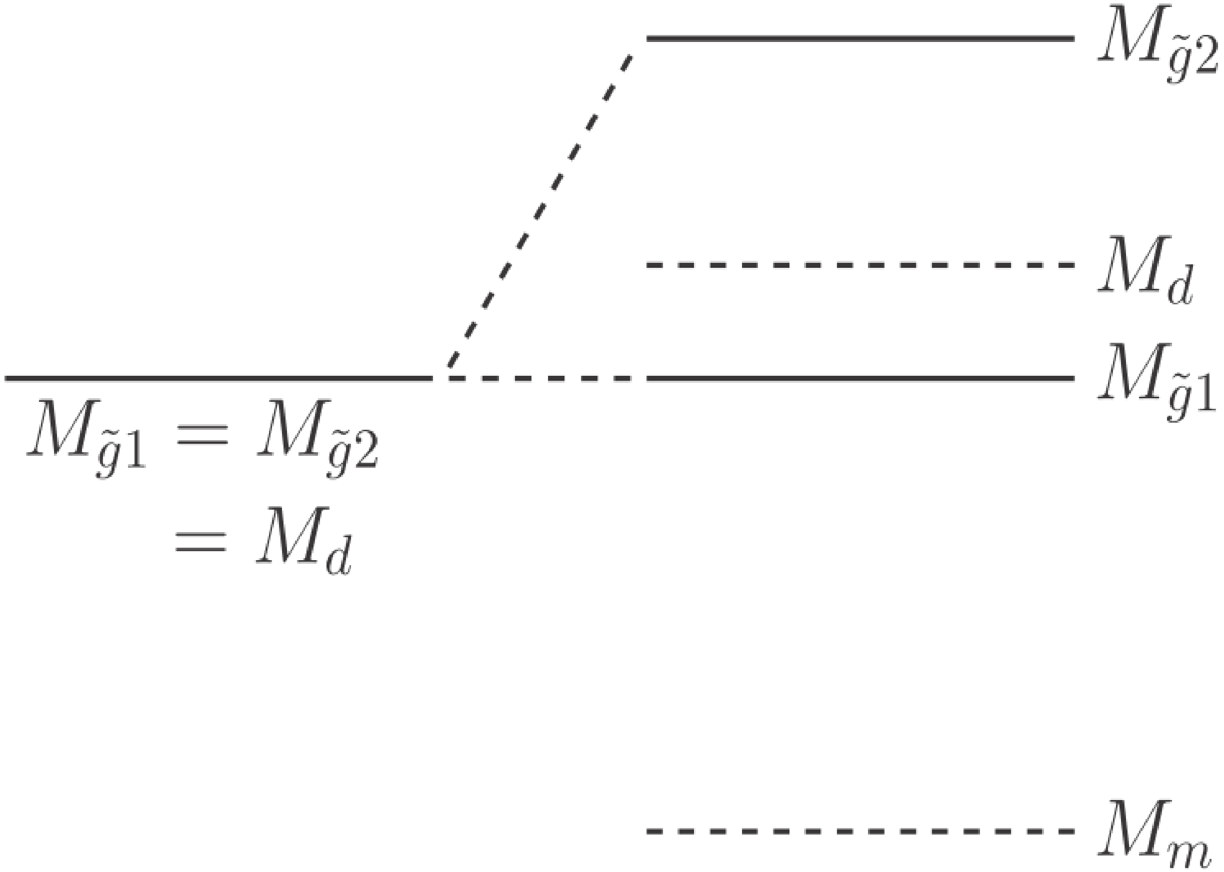
$$\begin{pmatrix} g_1 \\ g_2 \end{pmatrix} = \begin{pmatrix} \mathbf{1} & \mathbf{0} \\ \mathbf{0} & \mathbf{1} \end{pmatrix} \begin{pmatrix} \psi \\ g \end{pmatrix}$$

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

$$\begin{pmatrix} g_1 \\ g_2 \end{pmatrix} = \begin{pmatrix} \mathbf{.707} & \mathbf{.707} \\ \mathbf{-.707} & \mathbf{.707} \end{pmatrix} \begin{pmatrix} \psi \\ g \end{pmatrix}$$

$$\mathcal{L}_{\tilde{g}\,\mathrm{mass}} \;=\; \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \mathrm{h.c.}$$

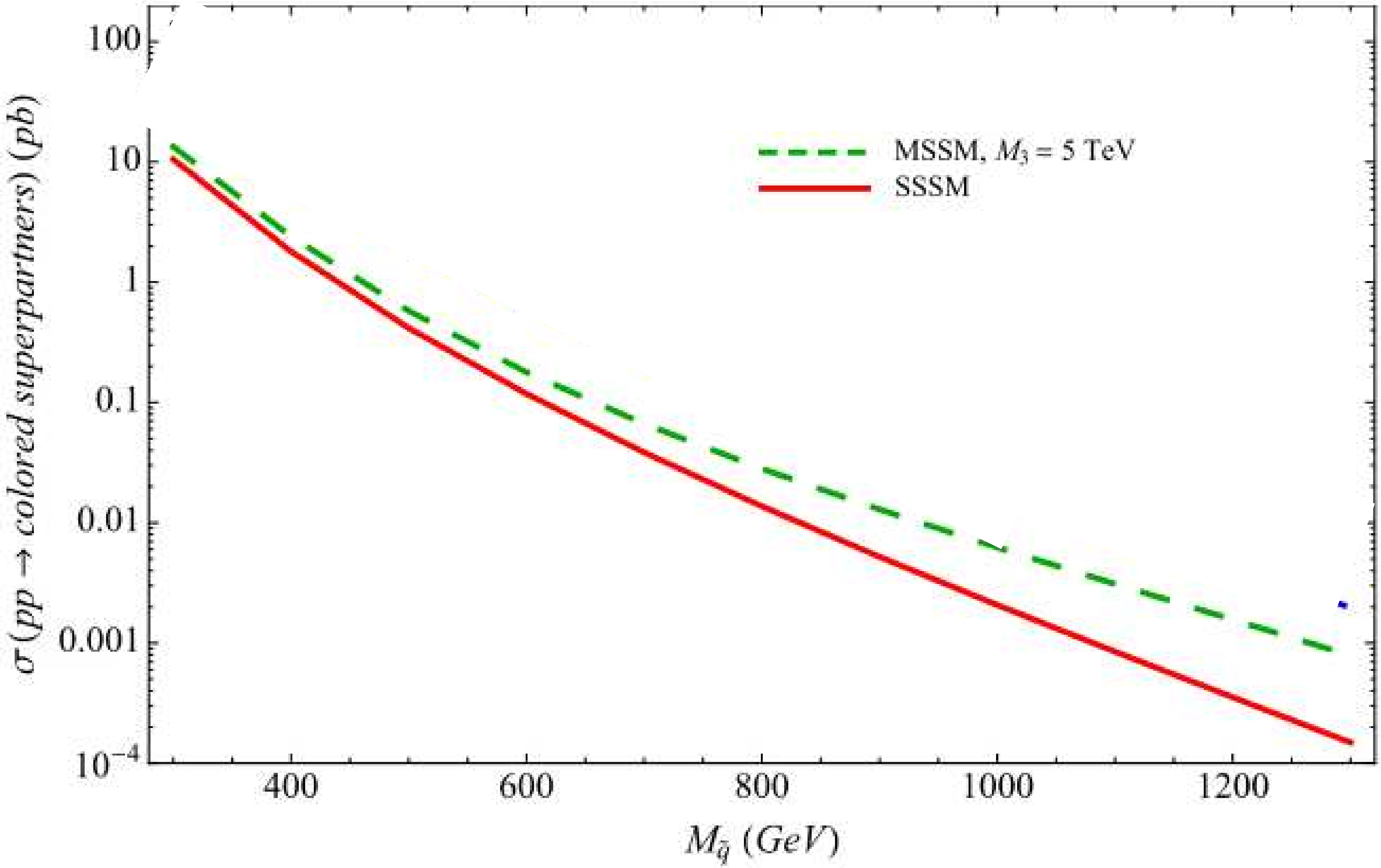
Meaning of M_m/M_d



$M_m, M'_m = 0$
Dirac

$M_m/M_d \neq 0$
Mixed, $M'_m = 0$

Revisit and reinterpretation



$$\mathcal{L}_{\tilde{g}\,\text{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \text{h.c.}$$

M_m/M_d raised => **increases** **decreases**

$$\begin{pmatrix} g_1 \\ g_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\tilde{g}} & \sin\theta_{\tilde{g}} \\ -\sin\theta_{\tilde{g}} & \cos\theta_{\tilde{g}} \end{pmatrix} \begin{pmatrix} \psi \\ g \end{pmatrix}$$

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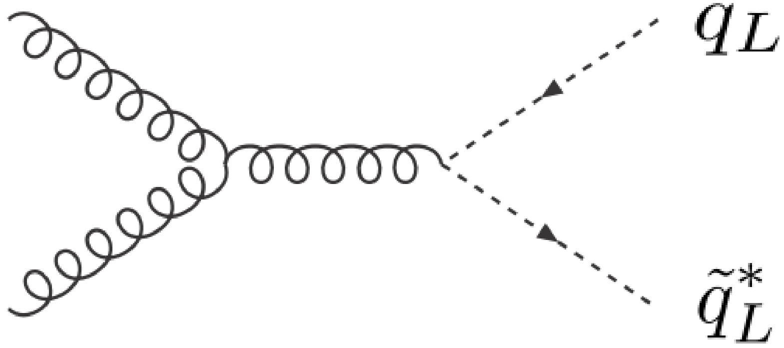
$$\left. -\ \tilde{u}^*_{R,i}\ t^a\ g_a u_{R,i} - \tilde{d}^*_{R,i}\ t^a\ g_a\ d_{R,i}\right) + \text{h.c.}$$

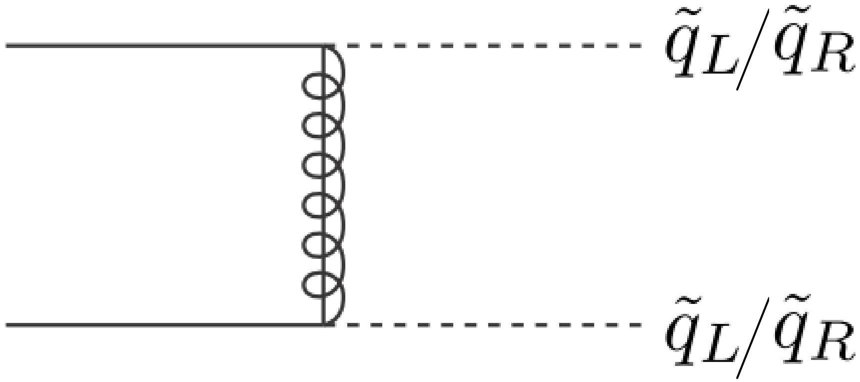
$$\mathcal{L}_{\tilde{g}\,\text{mass}} = \begin{pmatrix} g_a & \psi_a \end{pmatrix} \begin{pmatrix} M_m & M_d \\ M_d & \end{pmatrix} \begin{pmatrix} g_a \\ \psi_a \end{pmatrix} + \text{h.c.}$$

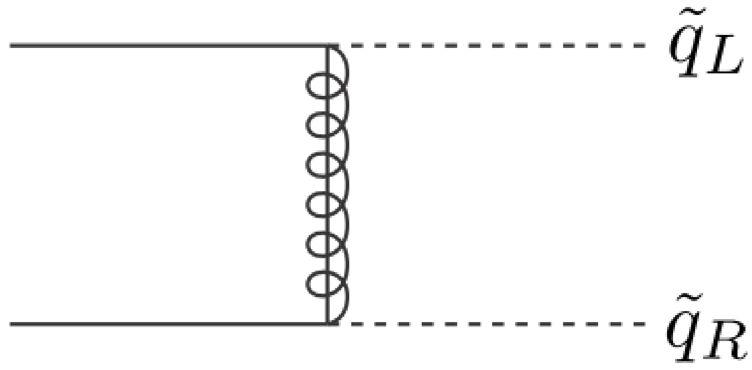
M_m/M_d raised => increases decreases

$$\begin{pmatrix} g_1 \\ g_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\tilde{g}} & \sin\theta_{\tilde{g}} \\ -\sin\theta_{\tilde{g}} & \cos\theta_{\tilde{g}} \end{pmatrix} \begin{pmatrix} \psi \\ g \end{pmatrix}$$

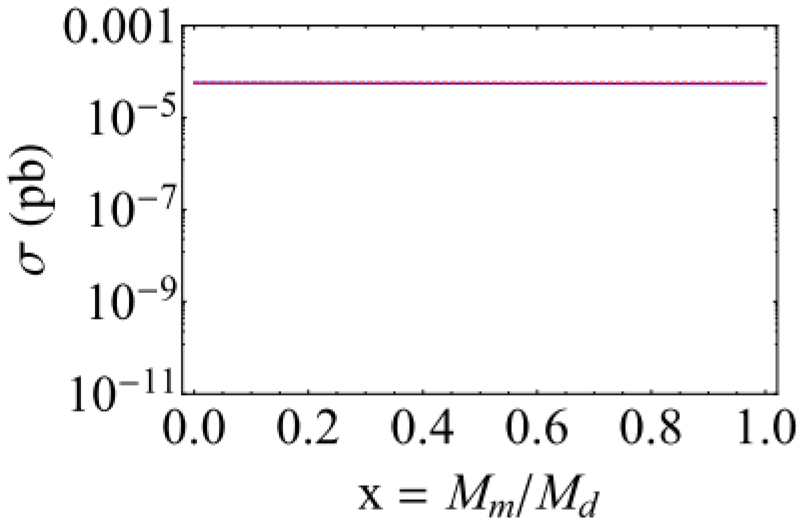
Individual modes
crucial



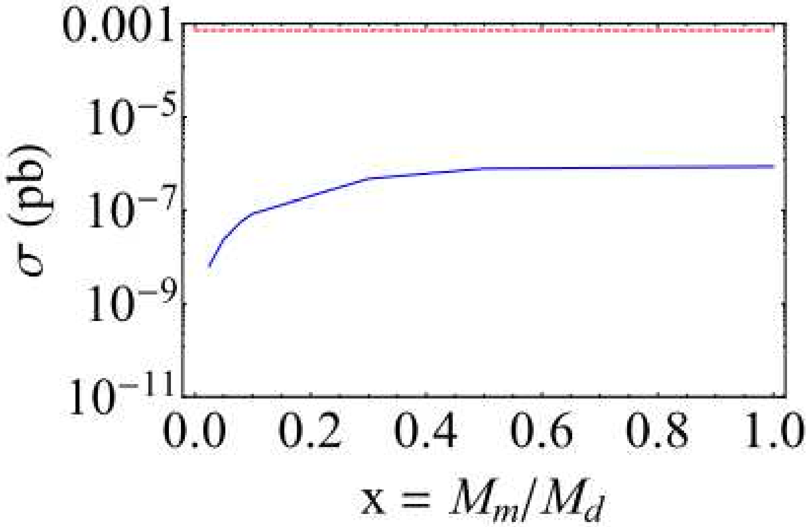




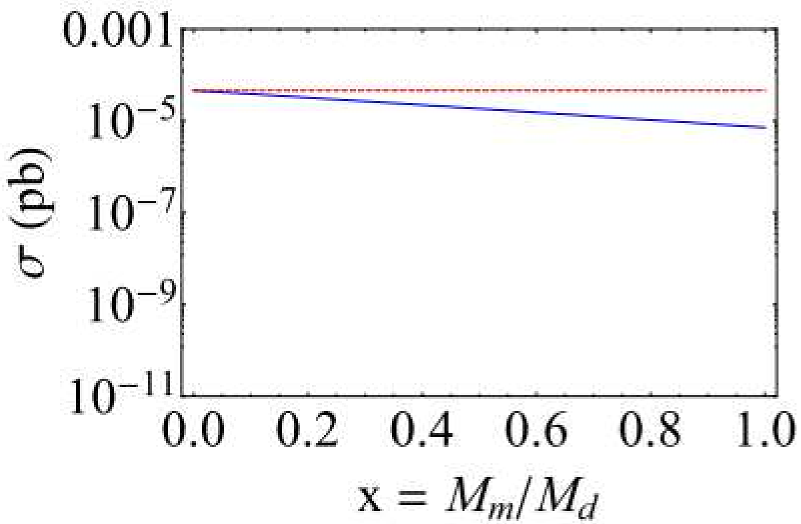
Individual modes *crucial*



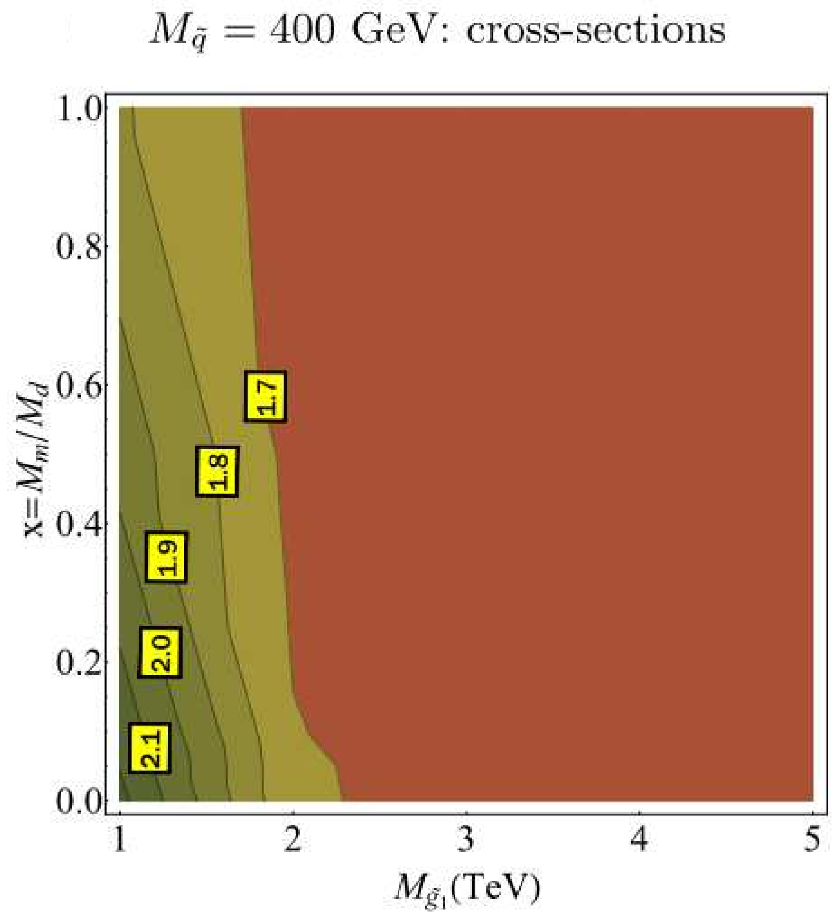
$\tilde{u}_L \tilde{u}_L^*$



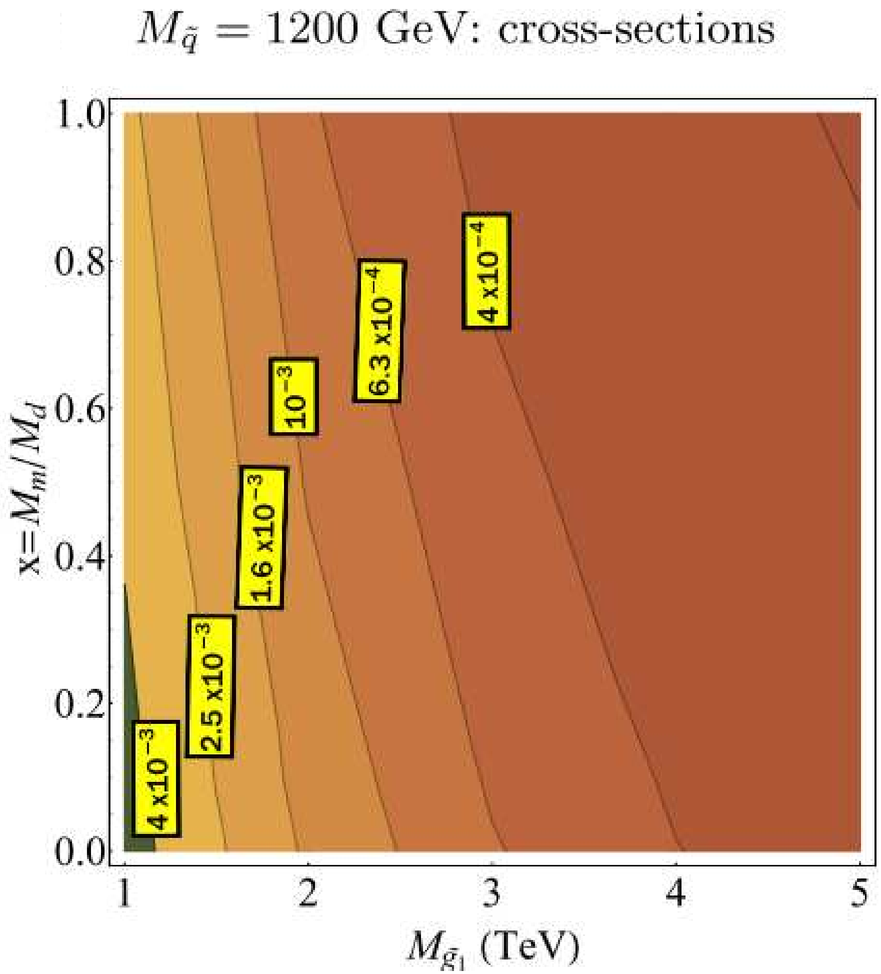
$\tilde{u}_L \tilde{u}_L$



$\tilde{u}_L \tilde{u}_R$



XS↓ in vertical direction

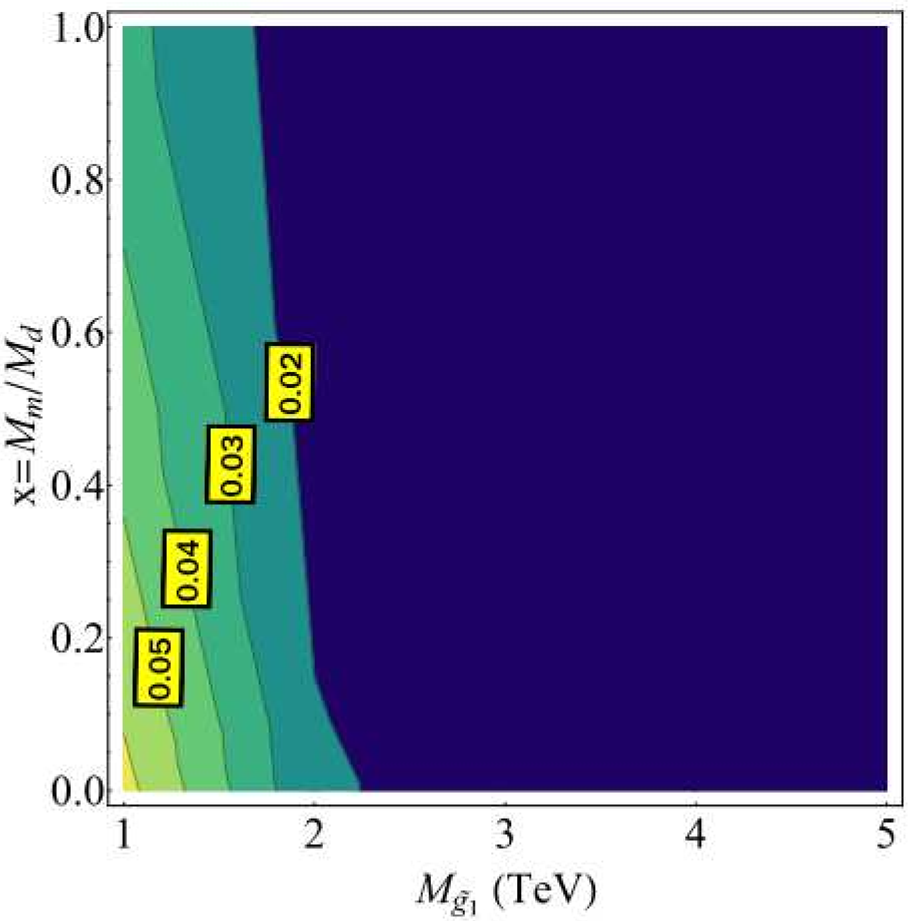


CMS Bound

Search strategy:

$\not{E}_T$ and 0, 1, 2, 3, or ≥ 4 b-jets at $\sqrt{s} = 8$ TeV and $\mathcal{L} = 11.7/\mathrm{fb}$

$M_{\tilde{q}} = 800$ GeV: cross-sections



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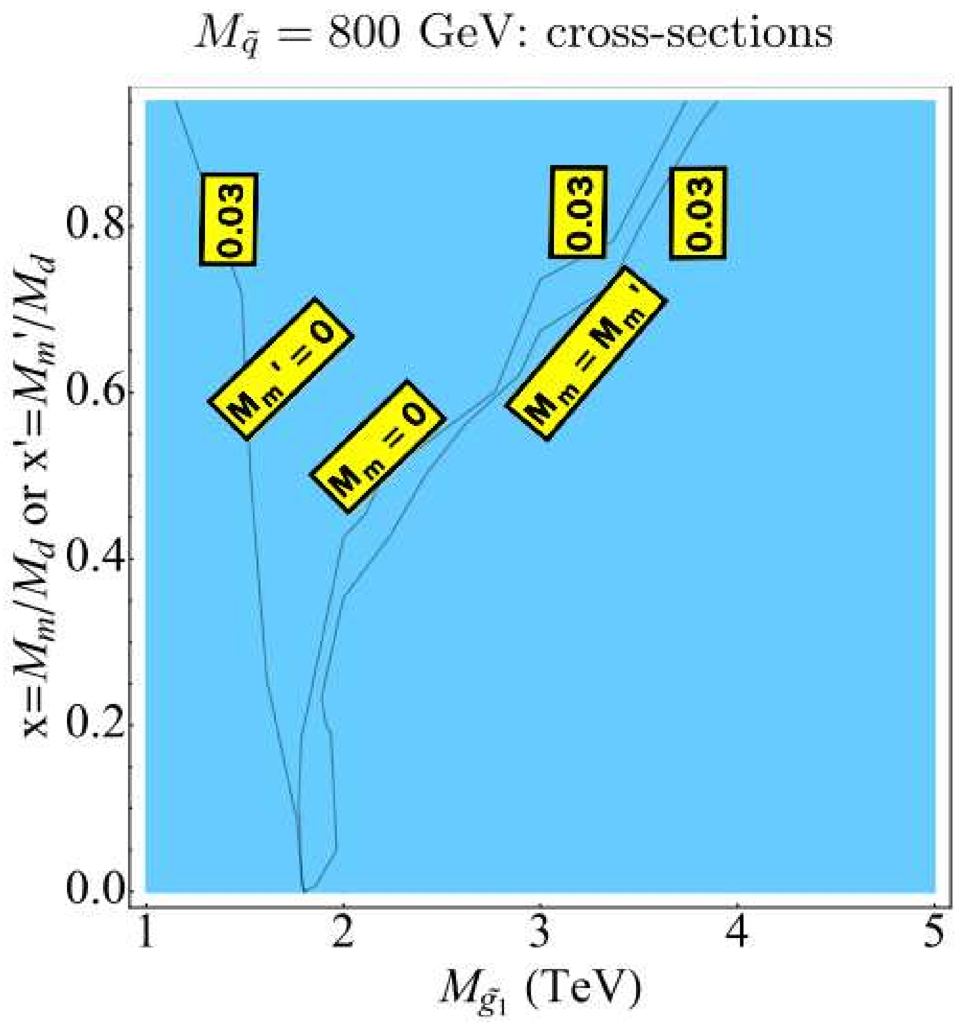


Articles

- *Dirac Gaugino Masses and Supersoft Supersymmetry Breaking*
  Fox, Nelson, Weiner – hep-ph/0206096

- *Supersoft Supersymmetry is Supersafe*
  Kribs, Martin – 1203.4821

- *Mixed Gauginos Sending Mixed Signals to the LHC*
  Kribs, Raj – in progress

- CMS (and ATLAS) results

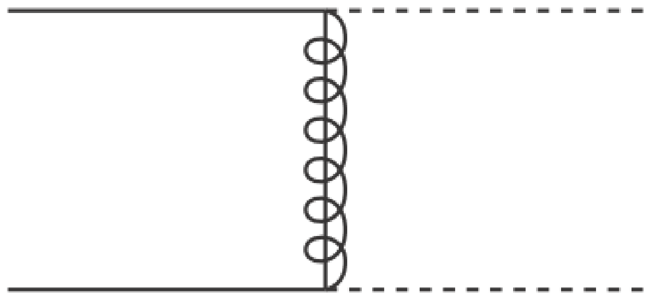
Thanks


PPE REQUIRED
BEYOND THIS POINT
• Hardhats
• Safety Glasses
• Work Boots
• Reflective Vest
• Proper Attire
Kiewit
DANGER
KEEP OUT

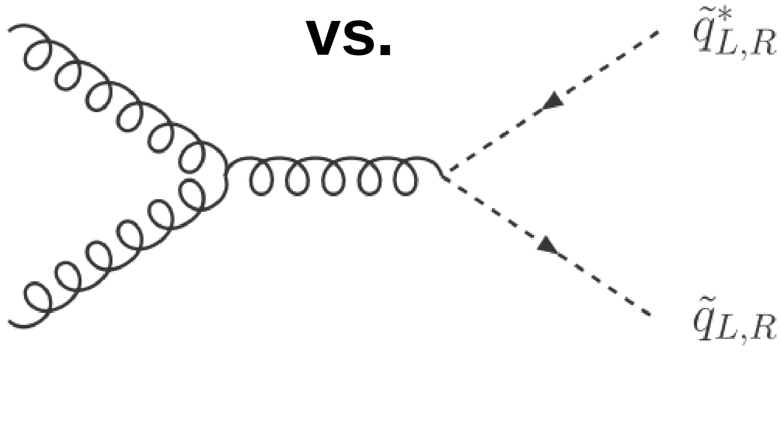
Supplementary Slides

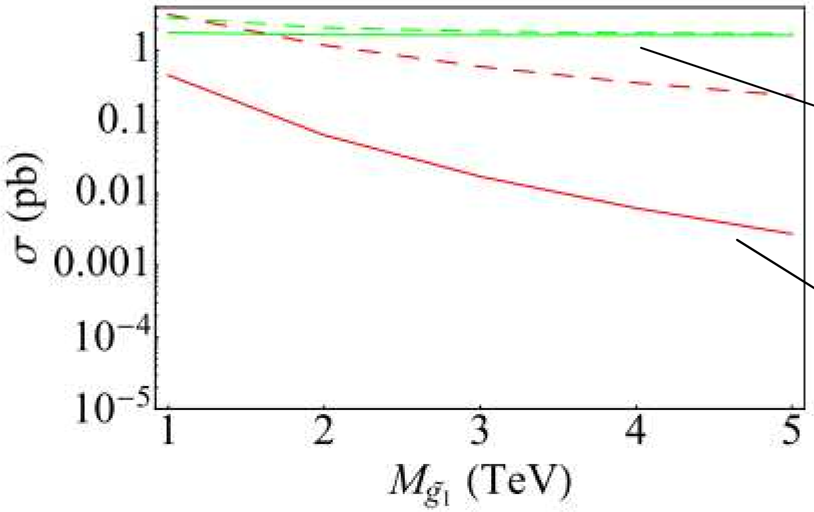
NO SEESAW

Horizontal properties of the contour plots



vs.

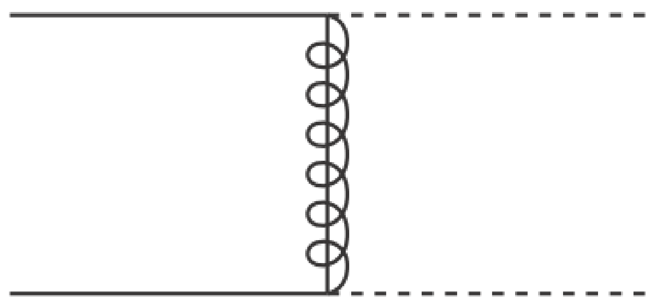




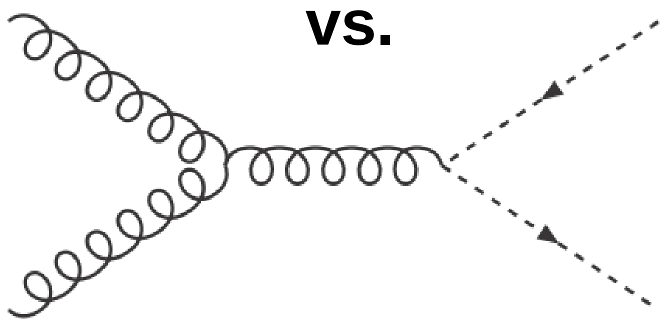
(a) $M_{\tilde{q}} = 400$ GeV

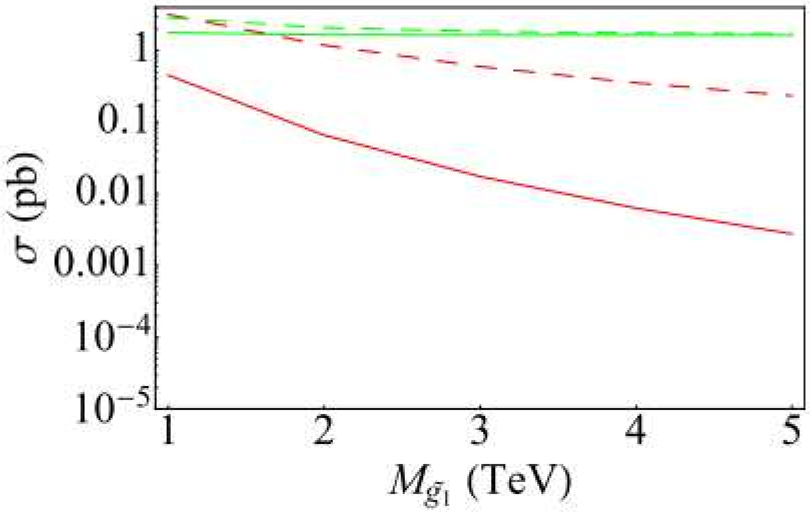
Squark-antisquark

Squark-squark

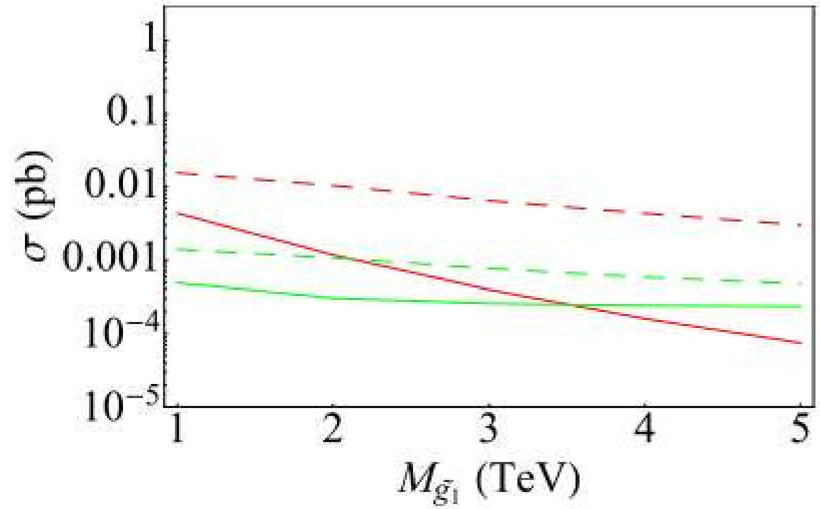


vs.

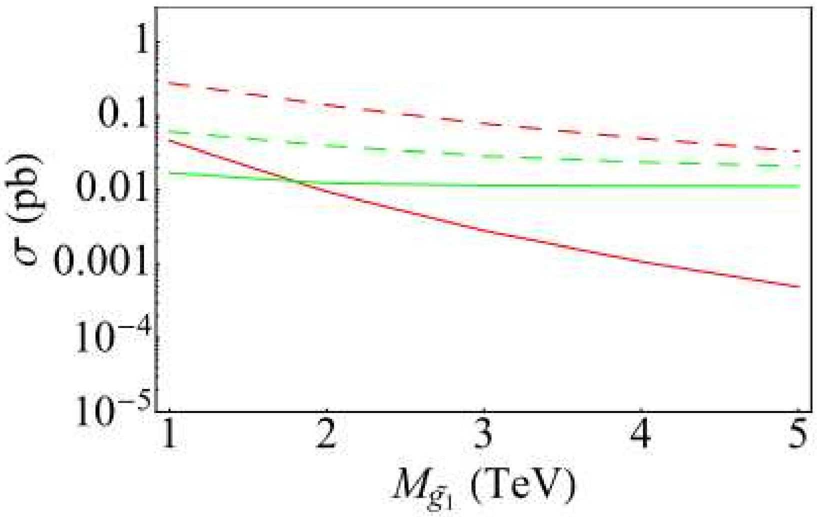




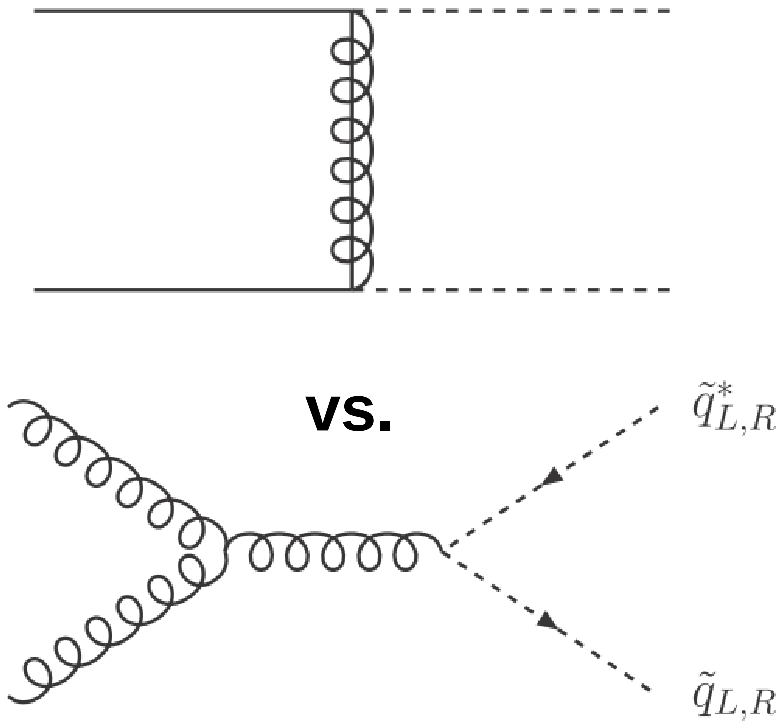
(a) $M_{\tilde{q}} = 400$ GeV

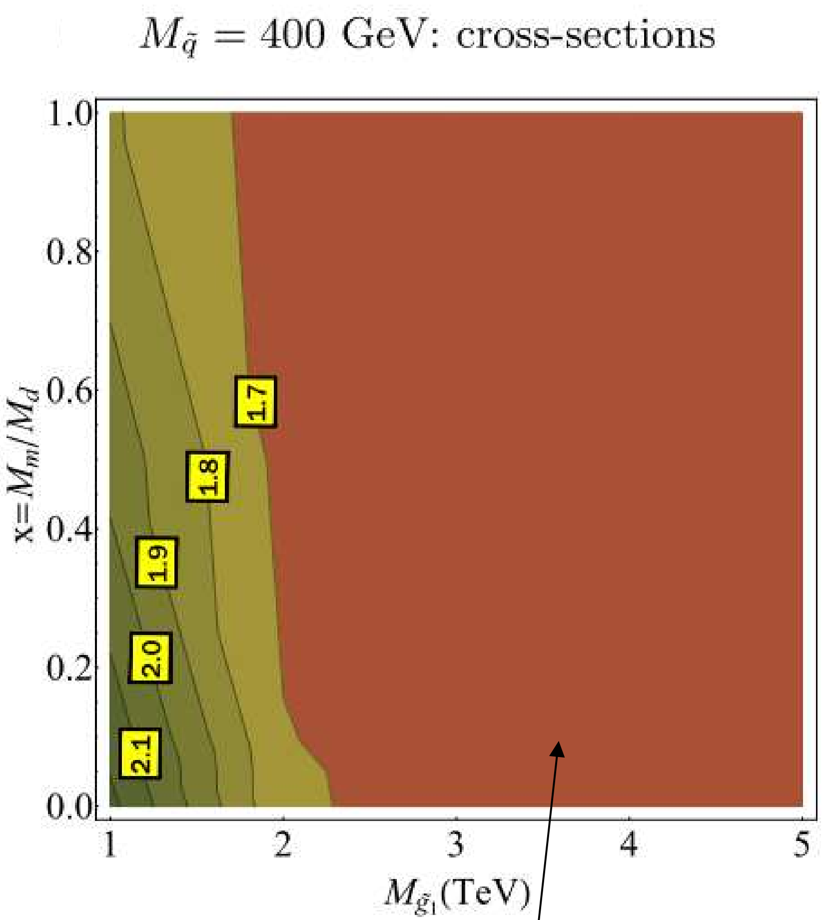


(c) $M_{\tilde{q}} = 1200$ GeV



(b) $M_{\tilde{q}} = 800$ GeV





XS↓ in vertical direction

XS flattens in horizontal direction for light squarks