K-Kbar Mixing in R-symmetric SUSY Models

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Based on A.B., S.-P. Ng, arXiv:0803.3811 [hep-ph]

Motivation

- Kribs, Poppitz, Weiner (0712.2039) show that by imposing an unbroken $U(1)_R$ symmetry we can solve SUSY Flavor Puzzle.
- Preference is for heavy gluinos. We suspect this is generic in such models (Blechman, Kaplan, Luty, Weiner, in progress).
- Cannot be truly unbroken, but breaking effects might be made small in a UV Completion.

Motivation

- Features of RMSSM:
  - No Majorana masses for the gauginos, but there are Dirac masses.
  - No A-terms for the scalars; hence no left-right squark/slepton mixing.
  - No mu-term, but there is a B-term (complicated Higgs sector).
- We will consider QCD corrections to the Kribs, Poppitz, Weiner results. Done in the MSSM by Bagger, Matchev, Zhang, Phys Lett B412, 77 (1997).

Effective Lagrangian

Parametrize mixing: $\delta_L \equiv \frac{m^2_{\tilde{Q}12}}{M^2_{\tilde{q}}}$ $\delta_R \equiv \frac{m^2_{\tilde{d}12}}{M^2_{\tilde{q}}}$

The Low-Energy Effective Lagrangian is:

$$\mathcal{L}_{\rm eff} = \frac{\alpha_s^2(M_{\tilde{g}})}{216}\left(\frac{M^2_{\tilde{q}}}{M^4_{\tilde{g}}}\right)\sum_n C_n(\mu)\mathcal{O}_n(\mu)$$

$$\begin{aligned}
\mathcal{O}_1 &= (\bar{d}^i_L \gamma^\mu s^i_L)(\bar{d}^j_L \gamma_\mu s^j_L) \\
\mathcal{O}_4 &= (\bar{d}^i_R s^i_L)(\bar{d}^j_L s^j_R) \\
\mathcal{O}_5 &= (\bar{d}^i_R s^j_L)(\bar{d}^j_L s^i_R)
\end{aligned}$$

Intermediate Theory

To resum logs between the gluino and the squarks requires an "Intermediate Theory":

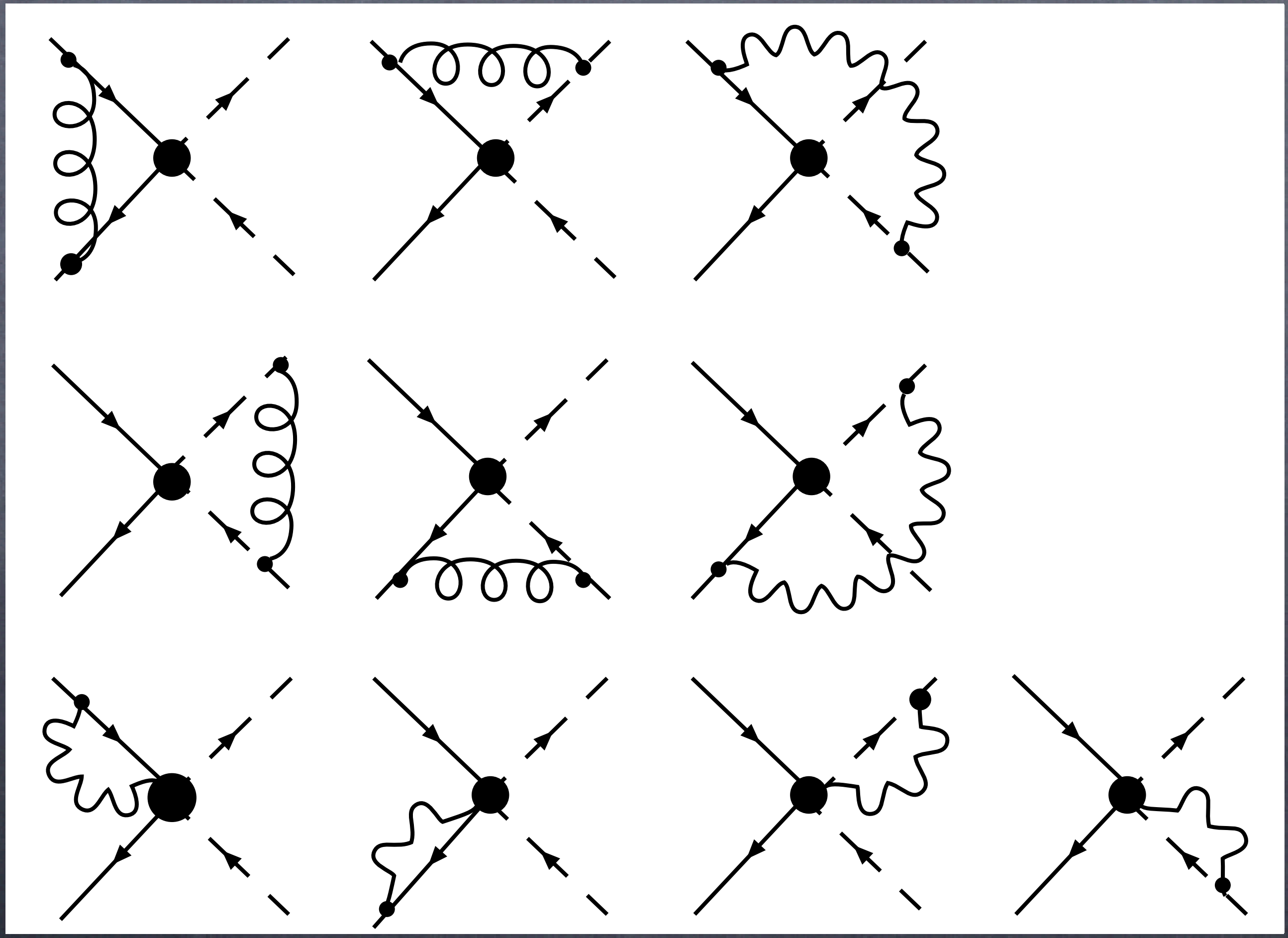
$$\mathcal{L}_{\rm int} = \frac{g_s^2(M_{\tilde g})}{M_{\tilde g}^2}\sum_{i=1}^{6} D_i(\mu)\mathcal{Q}_i(\mu)$$

$$\begin{aligned}
\mathcal{Q}_1 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^i](\tilde q_3^j \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu q_2^i]((i\mathcal{D}_\mu \tilde q_3)^j \tilde q_4^{j*}) \\
\mathcal{Q}_2 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^j](\tilde q_3^i \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu q_2^j]((i\mathcal{D}_\mu \tilde q_3)^i \tilde q_4^{j*}) \\
\mathcal{Q}_3 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^i](\tilde q_3^j \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu (i\mathcal{D}_\mu q_2)^i](\tilde q_3^j \tilde q_4^{j*}) \\
\mathcal{Q}_4 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^j](\tilde q_3^i \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu (i\mathcal{D}_\mu q_2)^j](\tilde q_3^i \tilde q_4^{j*}) \\
\mathcal{Q}_5 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^i](\tilde q_3^j \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu q_2^i](\tilde q_3^j (i\mathcal{D}_\mu \tilde q_4^*)^j) \\
\mathcal{Q}_6 &= [(i\mathcal{D}_\mu \bar q_1)^i \bar\sigma^\mu q_2^j](\tilde q_3^i \tilde q_4^{j*}) + [\bar q_1^i \bar\sigma^\mu q_2^j](\tilde q_3^i (i\mathcal{D}_\mu \tilde q_4^*)^j)
\end{aligned}$$

All different combinations of flavor (4 each)

Intermediate Theory

Now each of those operators gets renormalized by the following loops:



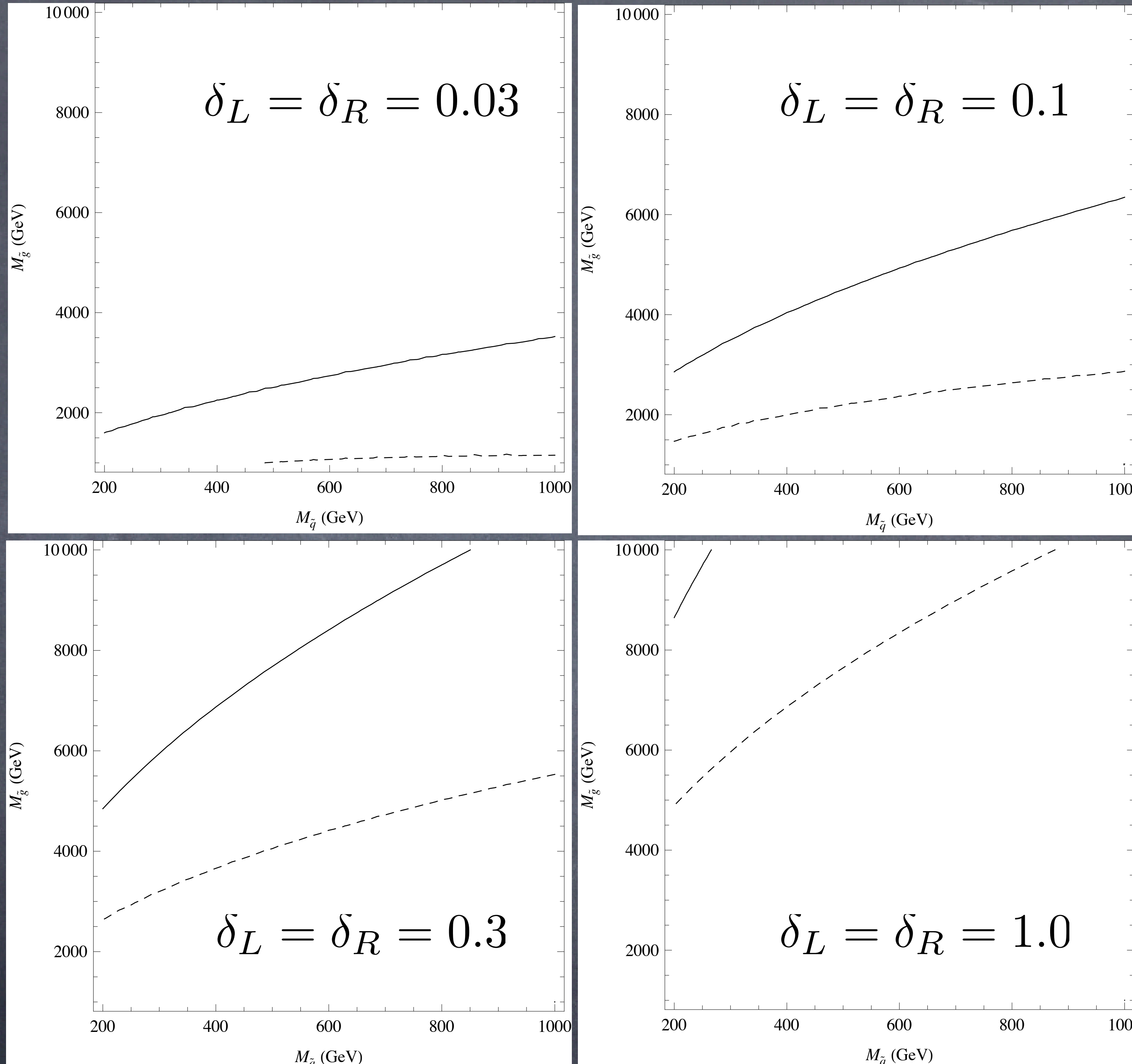
Results

The mass difference is given by:

$$\Delta m_K = 2\mathrm{Re}\left(\langle K|\mathcal{L}_{\mathrm{eff}}|\bar{K}\rangle\right.$$

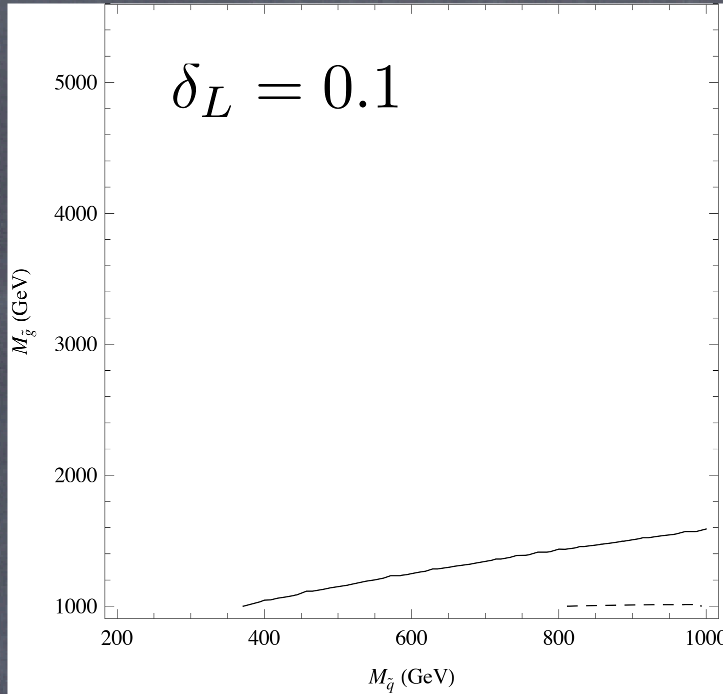
CP-Violation can be quantified by:

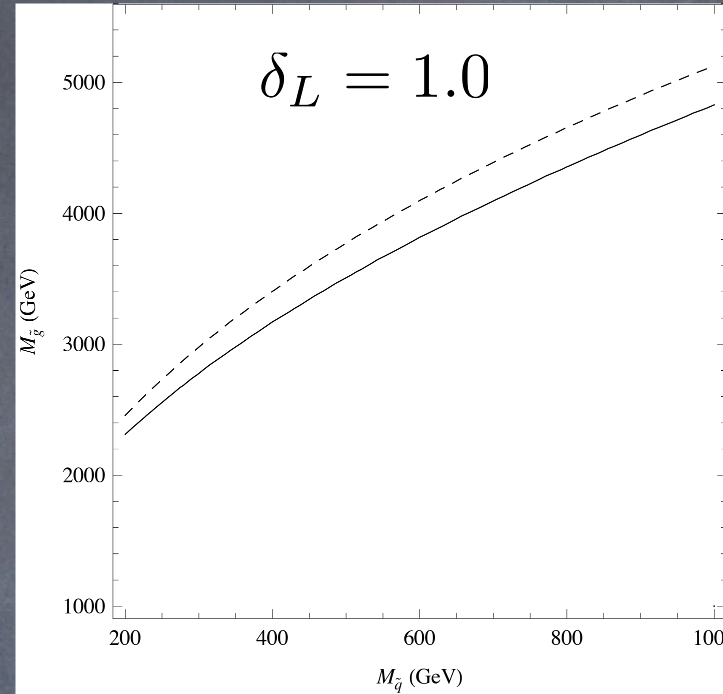
$$|\epsilon_K| = \frac{\mathrm{Im}\left(\langle K|\mathcal{L}_{\mathrm{eff}}|\bar{K}\rangle\right.}{\sqrt{2}\Delta m_K}$$

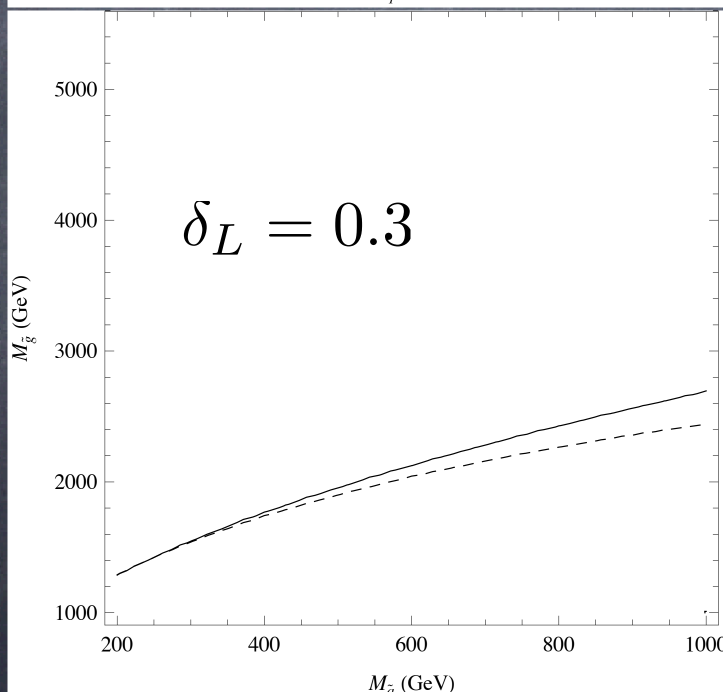


$M_{\tilde{g}}(\mathrm{GeV})$

$M_{\tilde{q}}(\mathrm{GeV})$







$M_{\tilde{g}}(\mathrm{GeV})$

$M_{\tilde{q}}(\mathrm{GeV})$

$\delta_R = 0$ in all plots.

Notice that constraints are much weaker here (only O_1 contributes).

Results: CP Violation

Assuming this contribution saturates the measured bound:

M_g	M_q	delta (L=R)	KPW phase	BN phase
3.5 TeV	400 GeV	0.06	0.15	9.8×10^{-3}
3.5 TeV	400 GeV	0.25	0.01	5.7×10^{-4}

Conclusions

- In the generic case, QCD corrections strengthen bounds by a factor of roughly 3, similar to the MSSM case.
- For $\delta_R = 0$, QCD corrections do almost nothing; could even weaken the bounds a little!
- CP violation is enhanced by QCD corrections by an order of magnitude.