Observing The Hidden Sector Of Supersymmetric Theories

(Guide Des Voyeurs)

Bruce A. Campbell, John Ellis, and David W. Maybury

PLANCK 2010 Conference, CERN

References:

References

Observing The Hidden Sector
B.A Campbell, J. Ellis, and D.W. Maybury
arXiv:0810.4877

Hidden Sector Dynamics And The Supersymmetric Seesaw
B.A Campbell, J. Ellis, and D.W. Maybury
arXiv:0810.4881

SUSY Δ Operators [Linear]

Gaugino mass operator:

(1) $$\mathcal{O}_\lambda : \qquad \int d^2\theta \, c_\lambda^S \frac{S}{M} \mathcal{W}^{a\alpha} \mathcal{W}^a_\alpha + \text{h.c.},$$

A and B parameters:

(2) $$\mathcal{O}_A : \qquad \int d^4\theta \, c_A^S \frac{S}{M} \phi^\dagger \phi + \text{h.c.}.$$

μ parameter:

(3) $$\mathcal{O}_\mu : \qquad \int d^4\theta \, c_\mu^S \frac{S^\dagger}{M} H_u H_d + \text{h.c.},$$

SUSY Δ Operators [Quadratic]

Scalar squared masses:

(4) $\mathcal{O}_\phi$: $\int d^4\theta\, c^F_\phi \frac{F^\dagger F}{M^2}\phi^\dagger\phi, \qquad \int d^4\theta\, c^S_\phi \frac{S^\dagger S}{M^2}\phi^\dagger\phi.$

$B\mu$ parameter: $\mathcal{O}_{B\mu}$:

(5) $\int d^4\theta\, c^F_{B\mu} \frac{F^\dagger F}{M^2} H_u H_d + \text{h.c.}, \qquad \int d^4\theta\, c^S_{B\mu} \frac{S^\dagger S}{M^2} H_u H_d + \text{h.c.},$

N.B. Quadratic operators renormalized by 1PI diagram hidden sector contributions!

Operators in $\mathcal{O}_\phi$ mix under renormalization,

and with linear operators, to give scalar m^2.

RGE For Soft Masses

Mediation interactions generating the scalar and gaugino masses:

$$\int d^4\theta\, k_i \frac{X^\dagger X}{M^2} \phi_i^\dagger \phi_i + \int d^2\theta\, c_\lambda^S \frac{S}{M} \mathcal{W}^{a\alpha} \mathcal{W}^a_\alpha + \text{h.c.}, \tag{6}$$

Example: renormalization of k_i involving the hidden and gauge sectors:

$$\frac{d}{dt} k_i = \gamma(t) k_i - \frac{1}{16\pi^2} \sum_n 8 C_2^n(R_i) g_n^6(t) G, \tag{7}$$

where $\gamma(t)$ is anomalous dimension arising from hidden-sector interactions (we use a holomorphic renormalization scheme)

RGE Solution And Hidden Sector

Has solution:

$$k_i(t) = \exp\left(-\int_t^0 dt'\gamma(t')\right) k_i(0) + \frac{1}{16\pi^2}\sum 8C_2^n(R_i)\int_t^0 ds g_n^6(s)\exp\left(-\int_t^s dt'\gamma(t')\right) G.$$

NB. Information on hidden sector is in function $\gamma(t)$, to be calculated from underlying hidden sector theory.

This talk demonstrates a method to, in principle, distinguish and parameter fix functions $\gamma(t)$ characterizing hidden sector, from experimental observations of sparticles.

Toy Hidden Sector Example

Consider toy self-interacting hidden sector with superpotential term:

(8) $$W_{\rm h} = \frac{\lambda}{3!} X^3.$$

Hidden-sector Yukawa interactions at lowest order in λ yield:
$\gamma(t) = (2\lambda^*(t)\lambda(t))/(16\pi^2)$

With $\lambda(t)$the running hidden-sector Yukawa coupling, which to lowest order satisfies:

(9) $$\frac{d\lambda}{dt} = \frac{3}{32\pi^2}\lambda^3.$$

Toy RGE Running Of Scalar Masses

Hidden-sector contribution to the running of k_i given by:

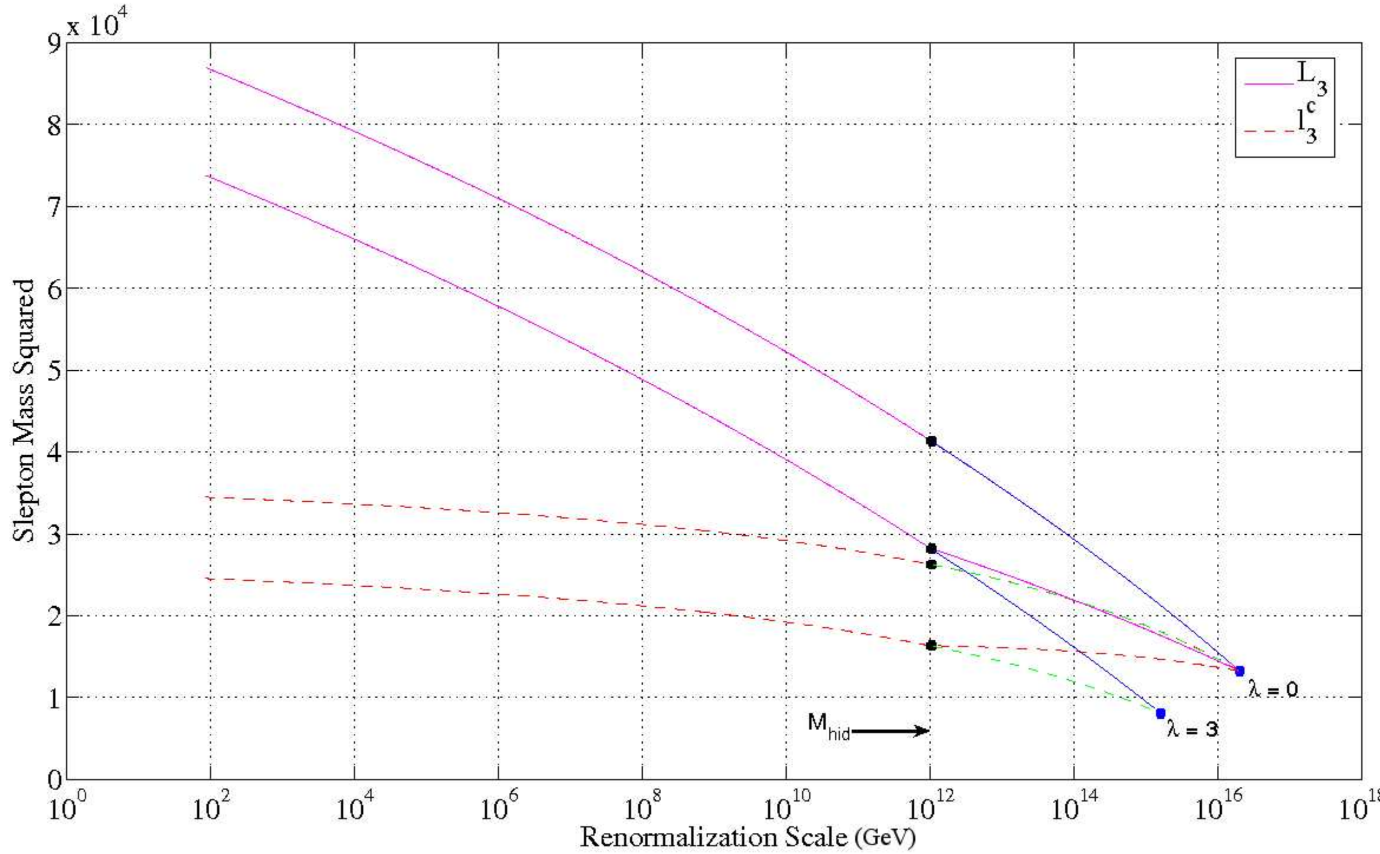
$$\frac{dk_i}{dt} = \frac{2\lambda^*\lambda}{16\pi^2} k_i, \tag{10}$$

Have scalar mass RGEs between mediation and hidden-sector scales:

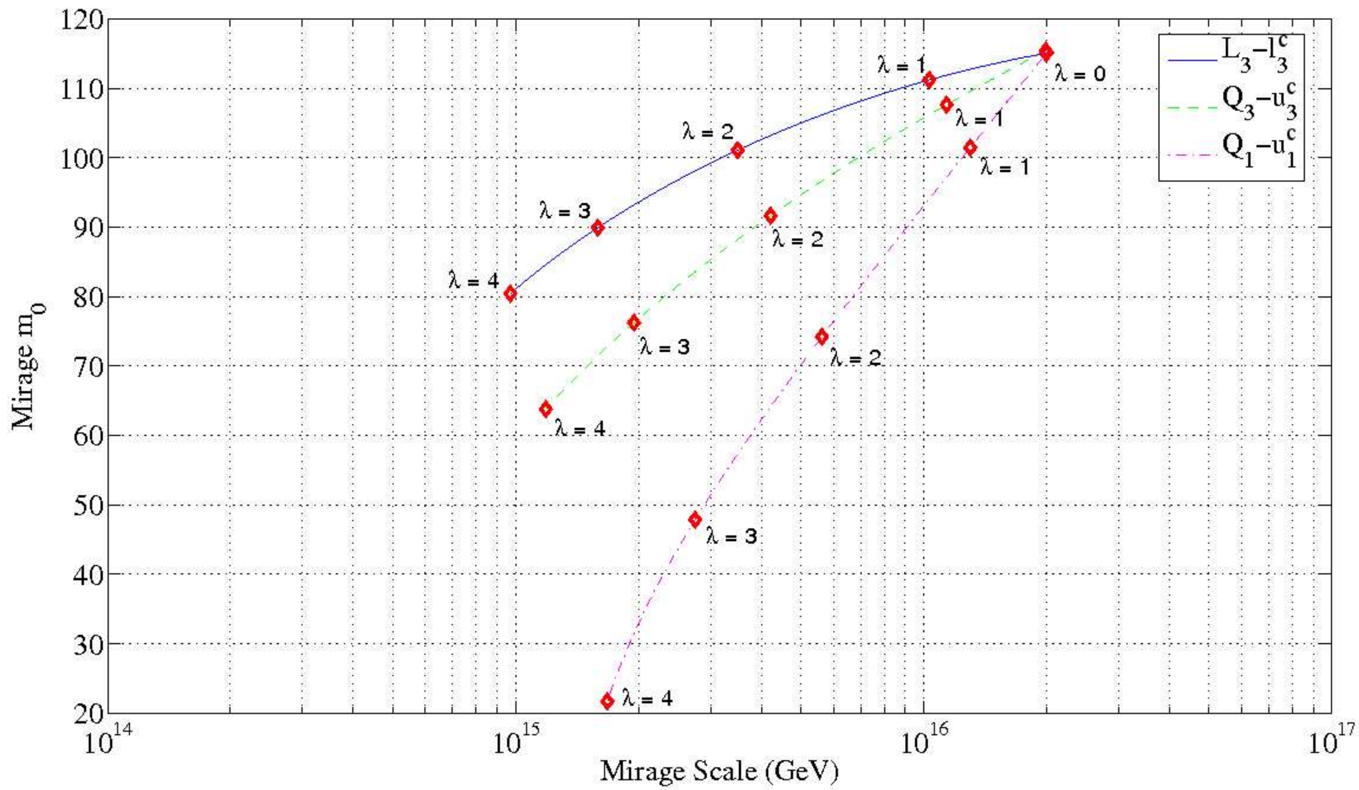
$$\frac{d\mathbf{m_S}^2}{dt} \to \frac{d\mathbf{m_S}^2}{dt} + \frac{2\lambda^*\lambda}{16\pi^2} \mathbf{m_S}^2. \tag{11}$$

First work out consequences assuming universal scalar mass squared at the mediation scale (or unification scale).

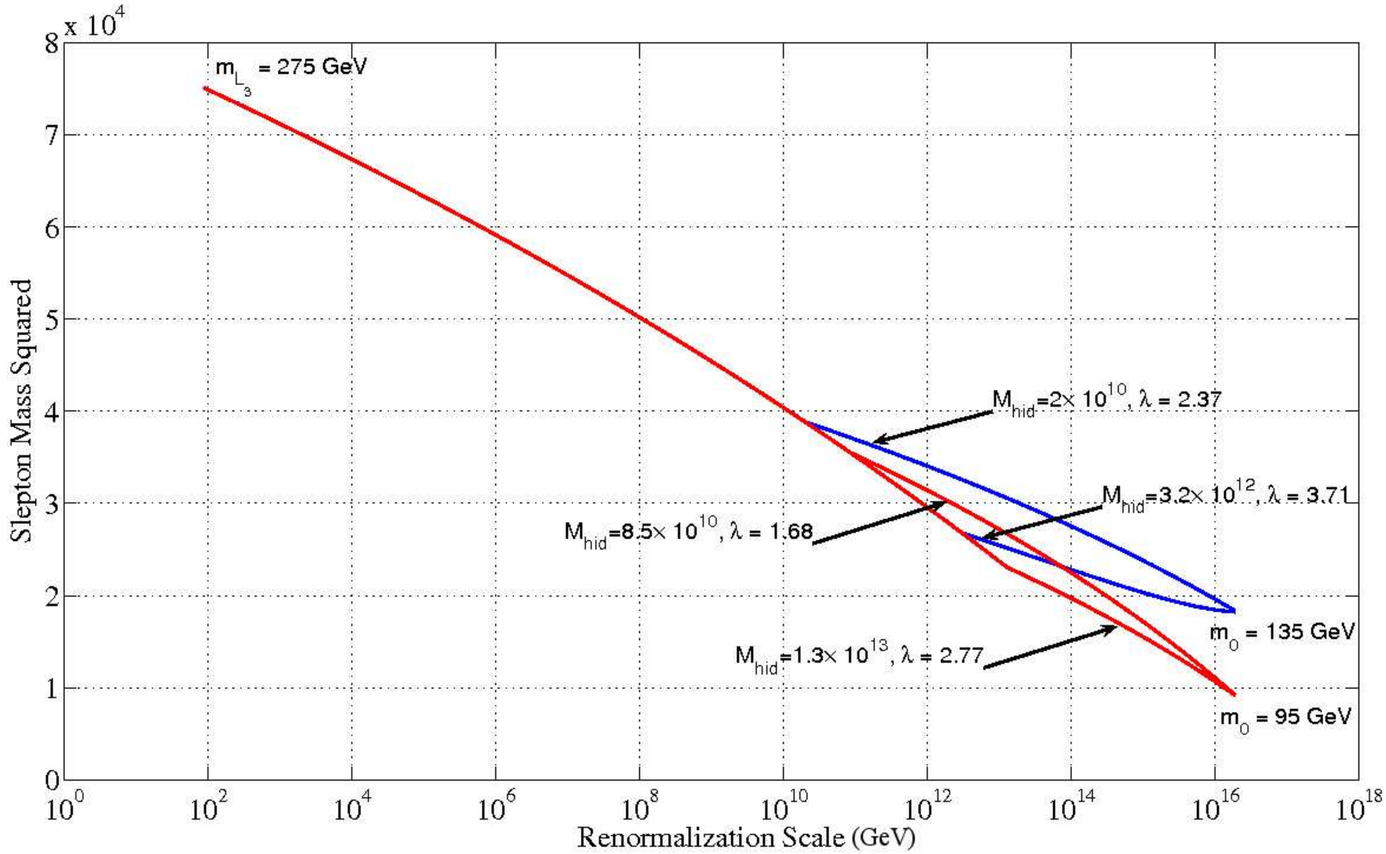
Largest $m_{\tilde{L}_3}$ And $m_{\tilde{l}_3^c}$ Eigenvalues



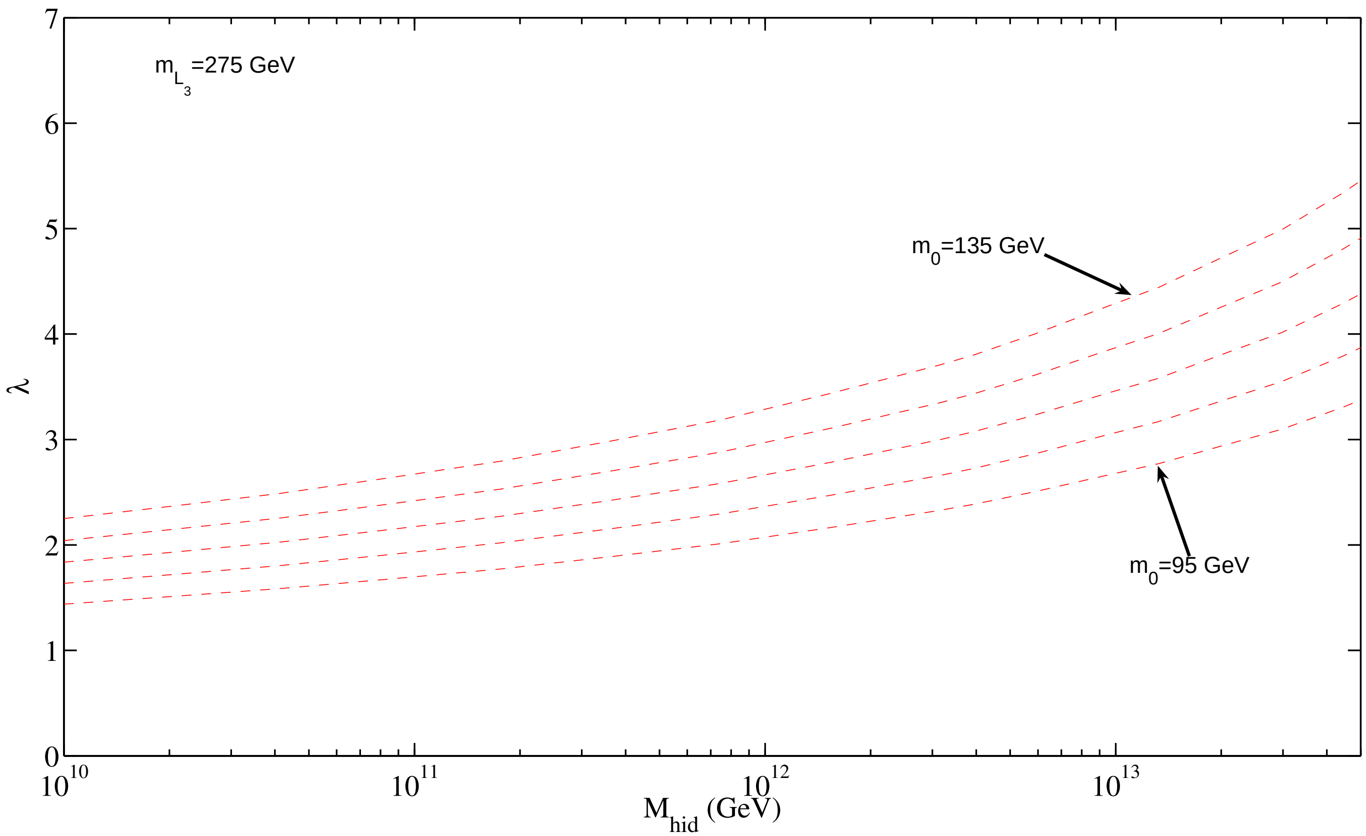
"Mirage" Unification Scales



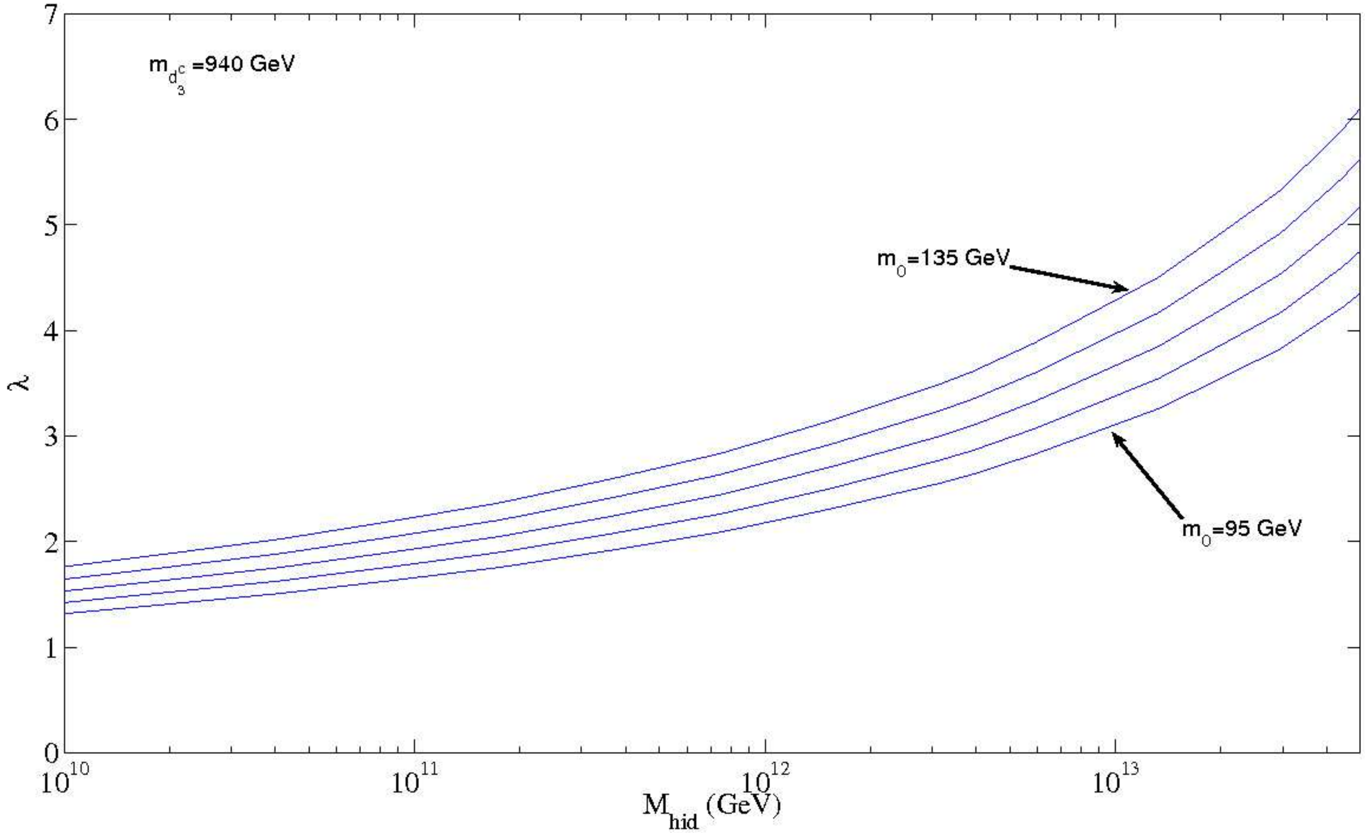
m_o For m_{hid} And λ



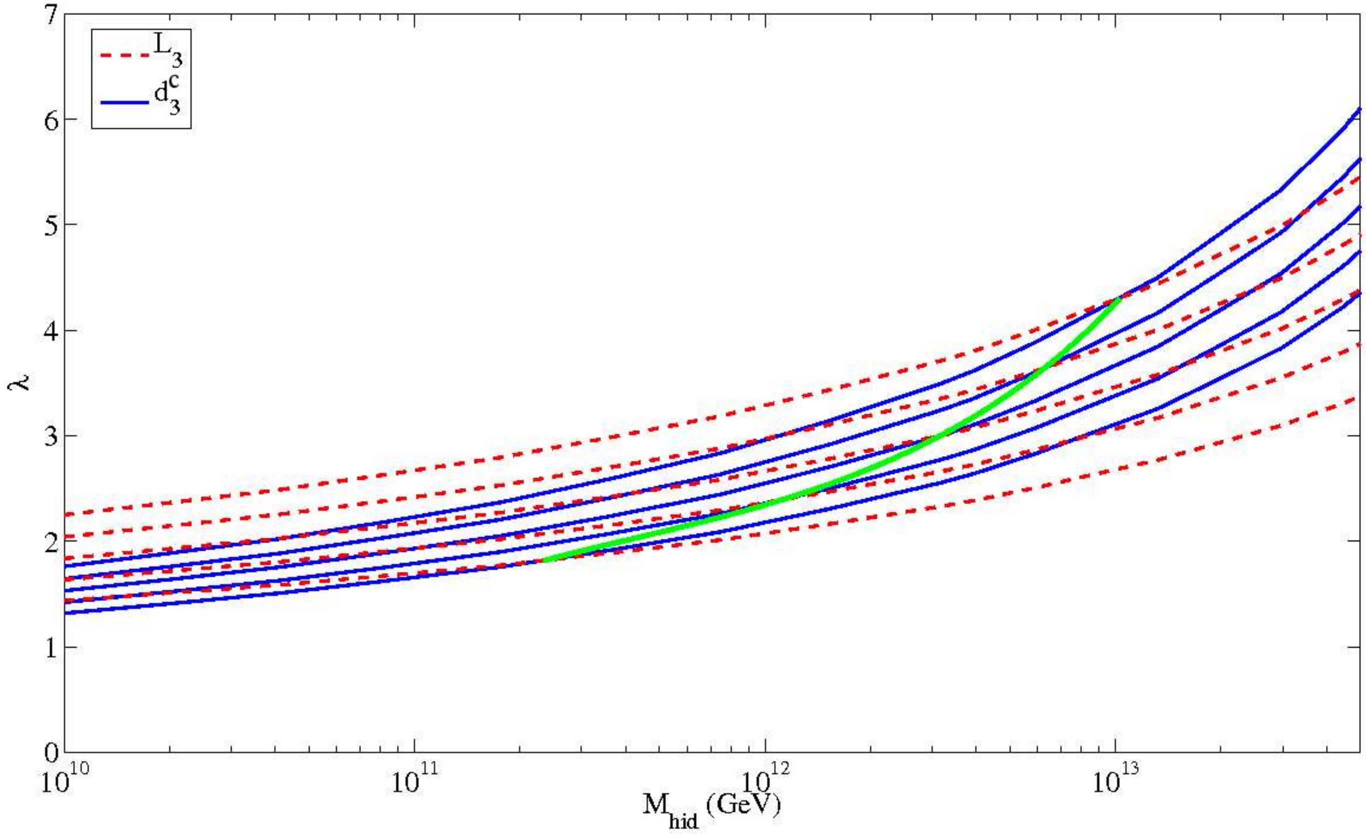
m_o Contours For $m_{\tilde{L}_3} = 275GeV$



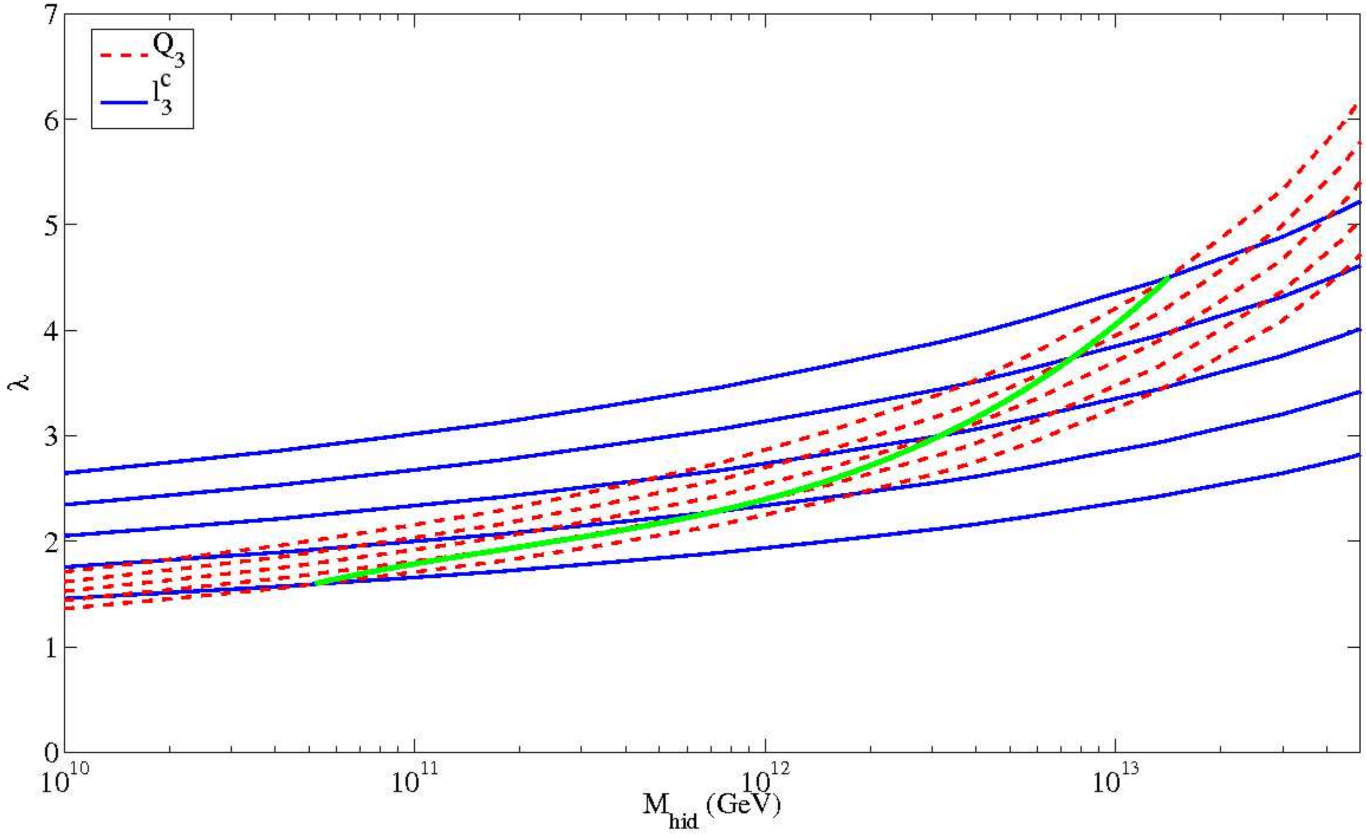
m_o **Contours For** $m_{\tilde{d}_3^c} = 940 GeV$



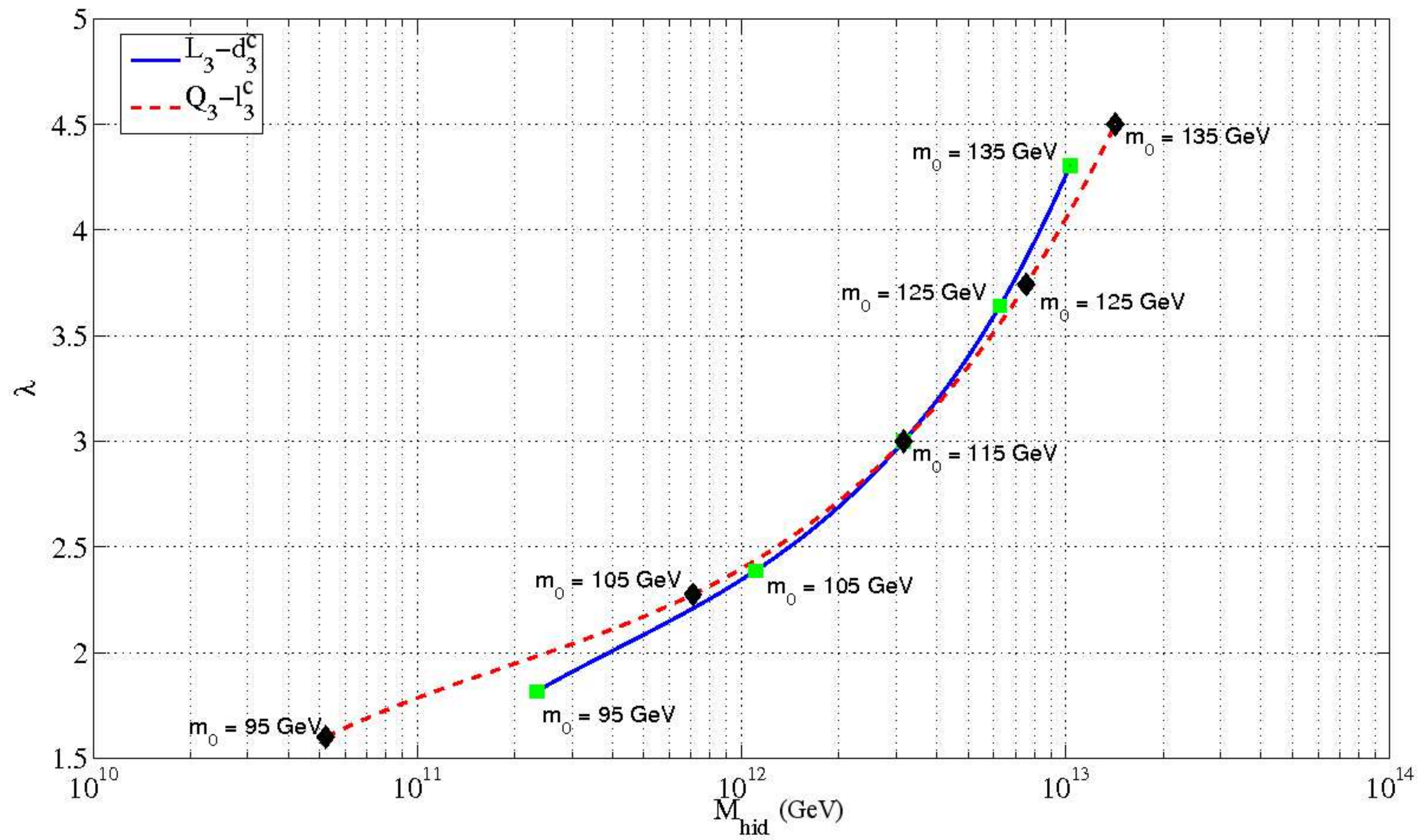
$m_{\tilde{L}_3}$ And $m_{\tilde{d}_3^c}$ Overlay



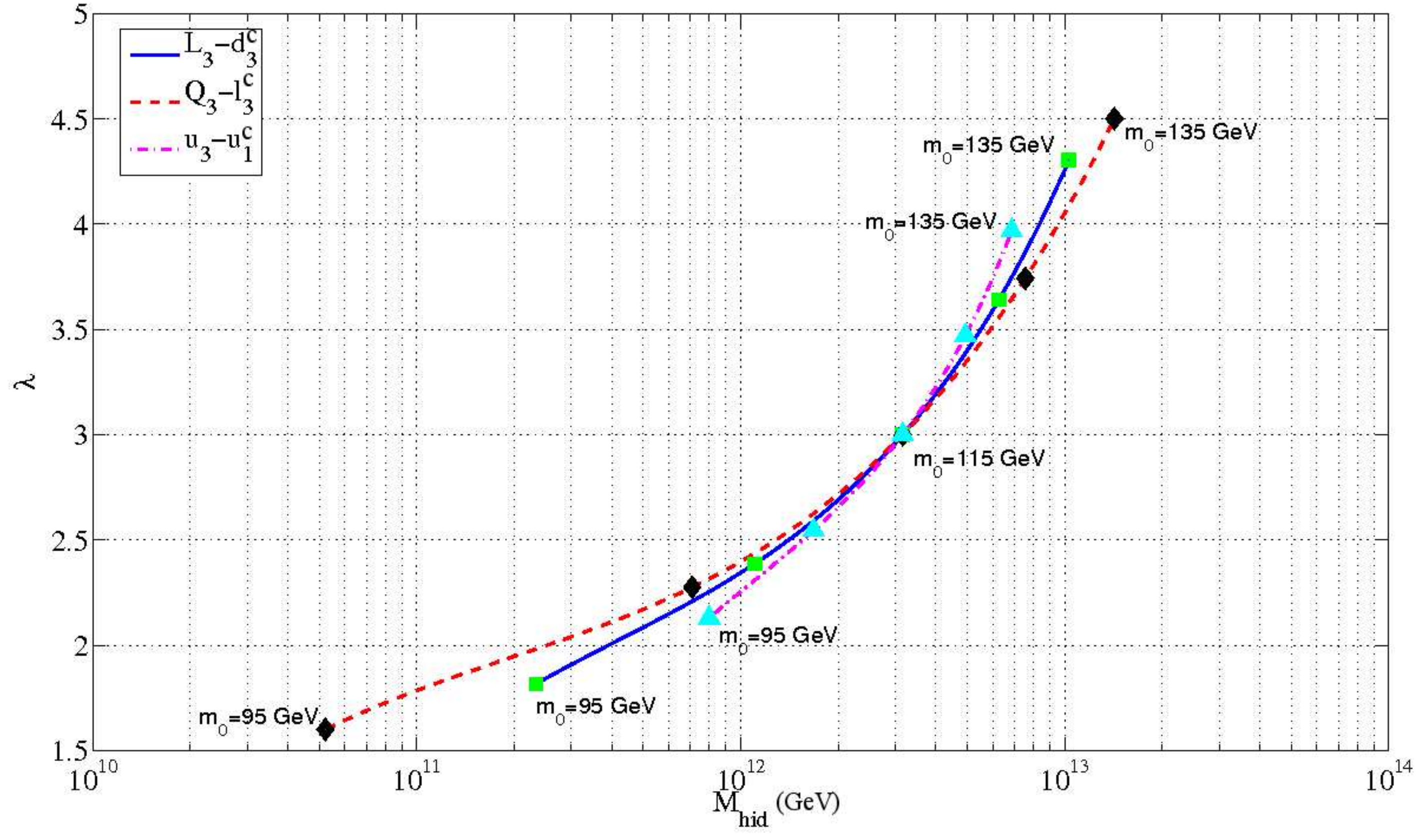
$m_{\tilde{Q}_3}$ And $m_{\tilde{l}_3^c}$ Overlay



Intersection Overlay



Intersection Triple Overlay



Non-Universal Scalar Masses

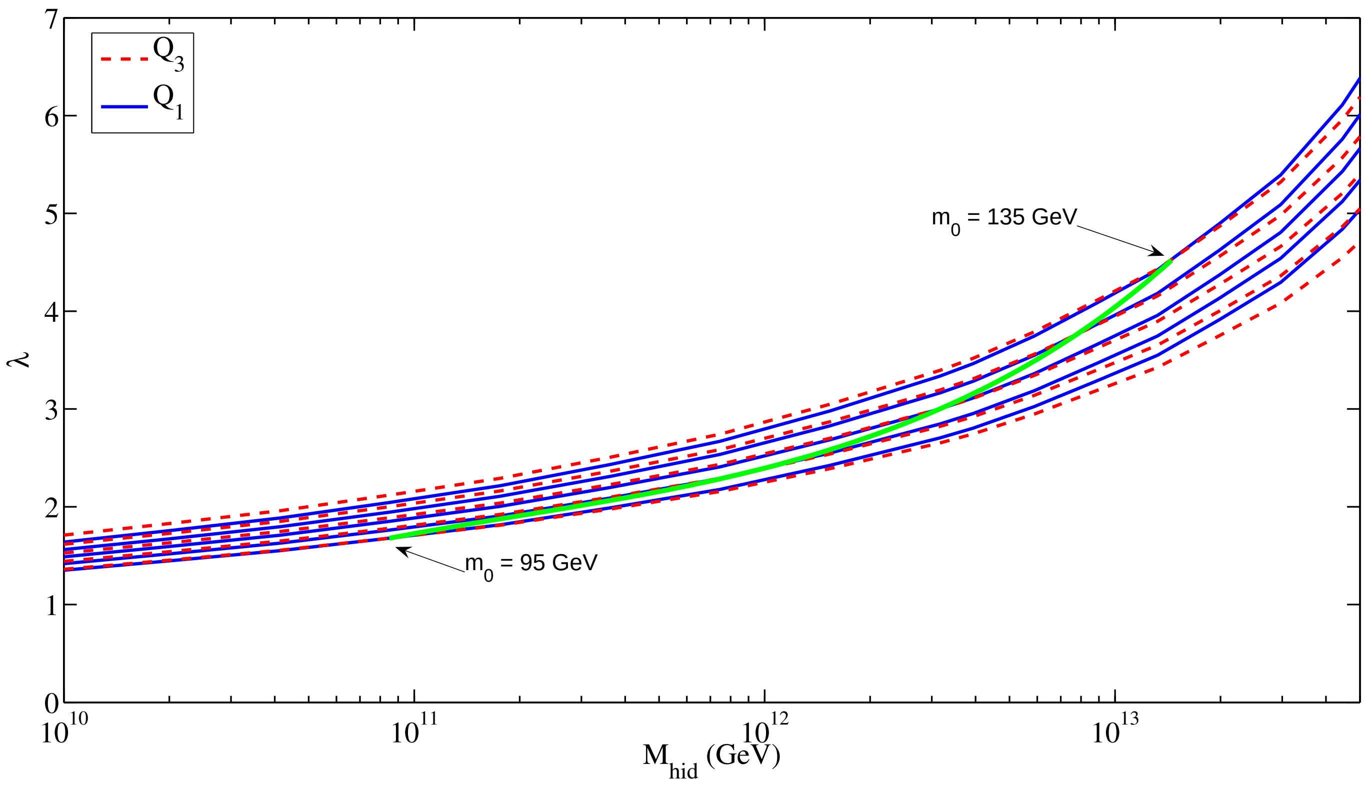
Do not, in general, expect degeneracy of mediation scale scalar masses

GIM violation limits imply DO EXPECT degeneracy for scalar $\tilde{q}$ or $\tilde{l}$ of SAME gauge charge

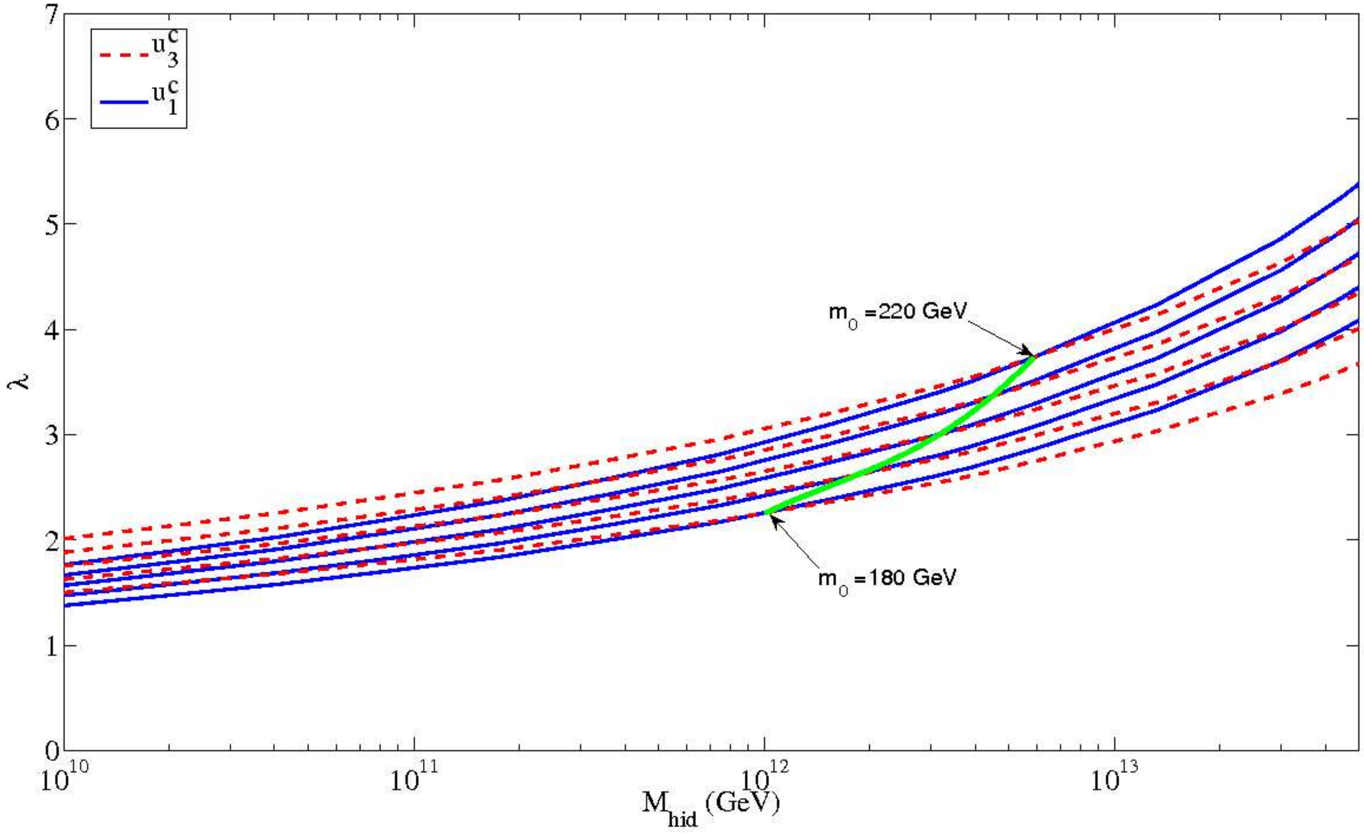
Can still interfere hidden sector dynamics against (generation dependent) Yukawa superpotential interactions

ie. can use mass of t, b, τ, to interfere with hidden sector interactions

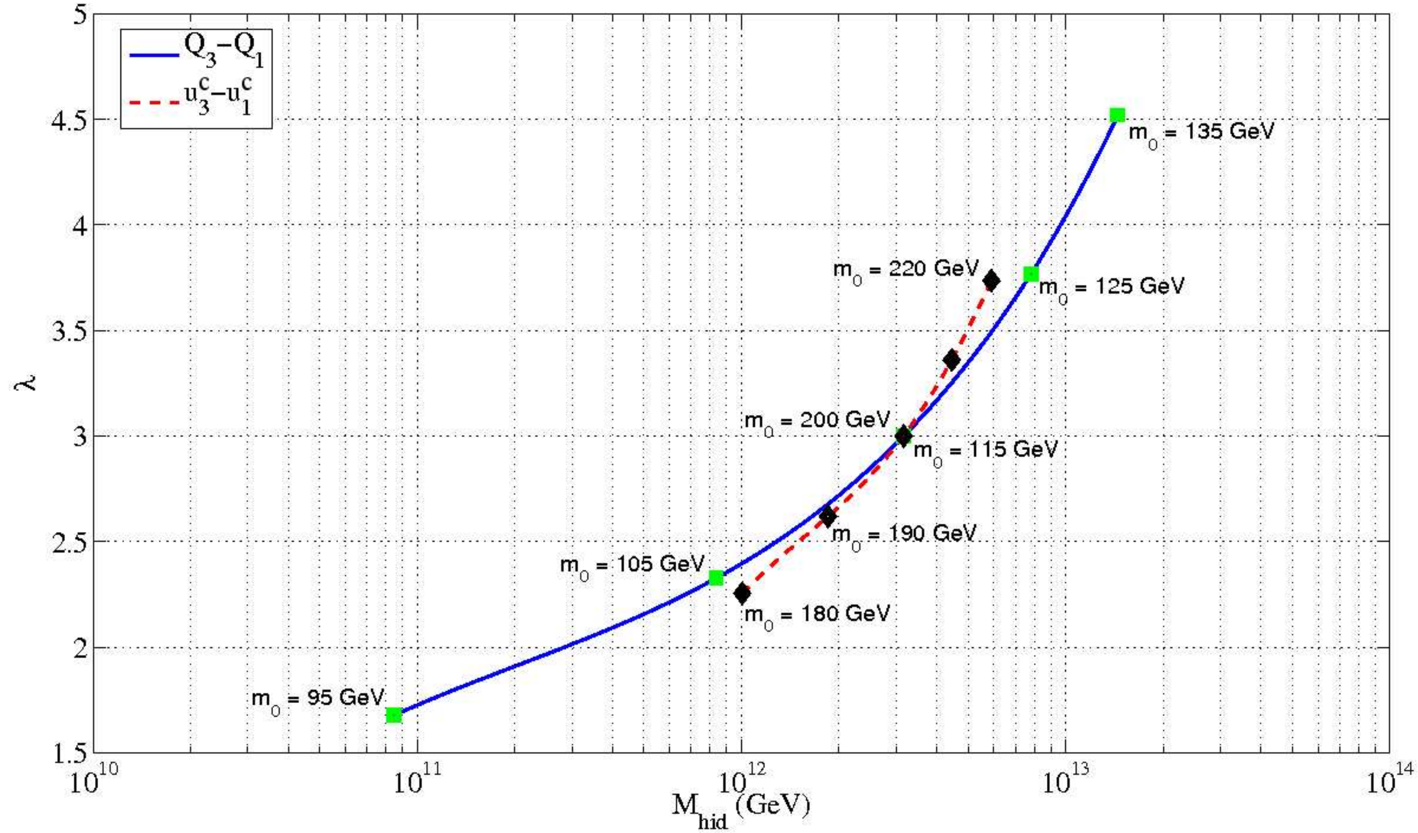
$m_{\tilde{Q}_3}$ And $m_{\tilde{Q}_1}$ Overlay



$m_{\tilde{u}_3^c}$ And $m_{\tilde{u}_1^c}$ Overlay



Intersection Overlay



General Reconstruction Strategy

Measure complete SUSY spectrum. Gauginos provide undistorted (by 1PI hidden sector renormalization) probe of SUSY Δ mechanism.

Use $\tilde{Q}_3$ - $\tilde{Q}_1$ and $\tilde{u}_3^c$ - $\tilde{u}_1^c$ pairings to fix parameters for 2 parameter models of hidden sector.

Use additional pairing $\tilde{d}_3^c$ - $\tilde{d}_1^c$ to distinguish different 2-parameter models of hidden sector, or parameter fix 3-parameter models (for large enough $tan(\beta)$).

Use additional pairing $\tilde{l}_3^c$ - $\tilde{l}_1^c$ to distinguish different 3-parameter models of hidden sector, or provide redundant checks on 2-parameter models (for large enough $tan(\beta)$).

Conclusions

Certain properties of SUSY Δ hidden sector are reconstructable, in principle, from effects on masses of $\tilde{q}$ and $\tilde{l}$.

Need to find full low-scale SUSY superpartner spectrum (at LHC?), before can begin analysis of hidden sector reconstruction.

Need detailed studies with theoretical uncertainties and experimental errors to determine practical accuracy of method. Also need similar studies on other mediation models.

For SUSY models with ν "see-saw", see-saw reconstruction depends on hidden sector reconstruction!