Getting the correct Higgs mass in R-symmetric models

Thomas Grégoire

Carleton University

based on work done with Enrico Bertuzzo, Claudia Frugiuele and Eduardo Ponton

MSSM

Superpotential

$$W = \lambda_u Q U^c H_u + \lambda_d Q D^c H_d + \lambda_e L E^c H_d + \mu H_u H_d$$

R-parity, subgroup of U(1)-R withcharge assignments

$$R(Q, U^c, D^c, L, E) = 1 \qquad R(H_u, H_d) = 0 \qquad R(W_\alpha^a) = 0$$

$$W_{\not R} = \lambda'' D^c D^c U^c + \lambda' Q D^c L + \lambda L L E^c + \mu_l H_u L$$

Forbidden by R-parity

Dirac gauginos

In the MSSM gauginos are Majorana

$$M\lambda\lambda$$

$$\int d^2\theta\, X W_\alpha W^\alpha \qquad X \to F_X\theta^2$$

Can be Dirac if new superfields are added

$$W^1_\alpha, W^2_\alpha, W^3_\alpha \qquad S, T, G$$

$$M_D \lambda \Psi$$

N=2 supersymmetry

extra-dimension

Supersoft SUSY breaking

Fox, Nelson, Weiner '02

$D'\theta_\alpha$ ← D-term breaking

$$\int d^2\theta\, W'_\alpha W_i^\alpha \Phi_i$$

Dirac gauginos do not feed into scalar masses through renormalization

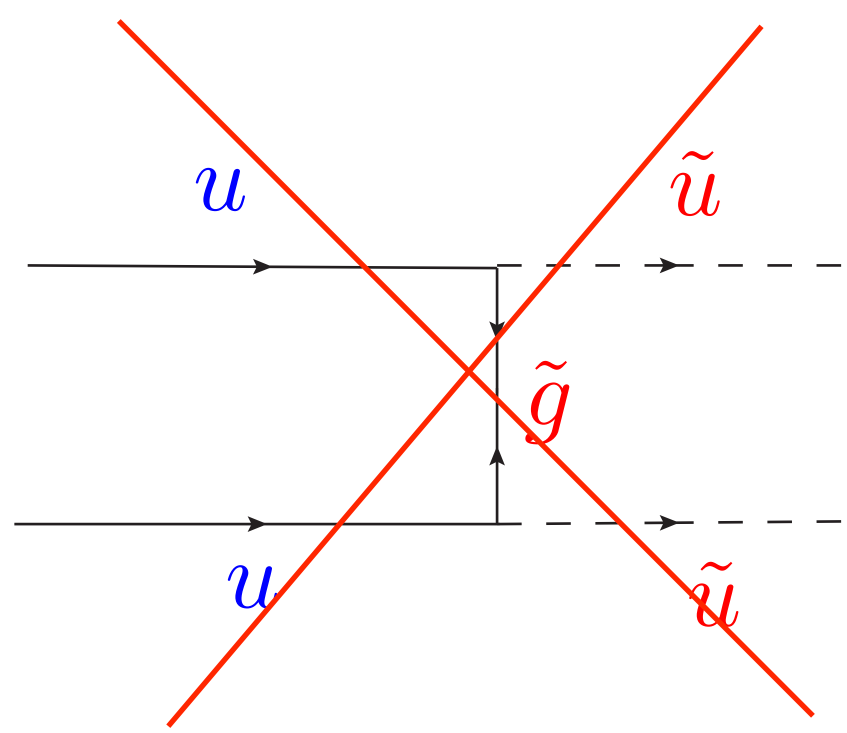
$$m^2 = \frac{C_i(r)\,\alpha_i m_i^2}{\pi}\log\left(\frac{\delta^2}{m_i^2}\right)$$

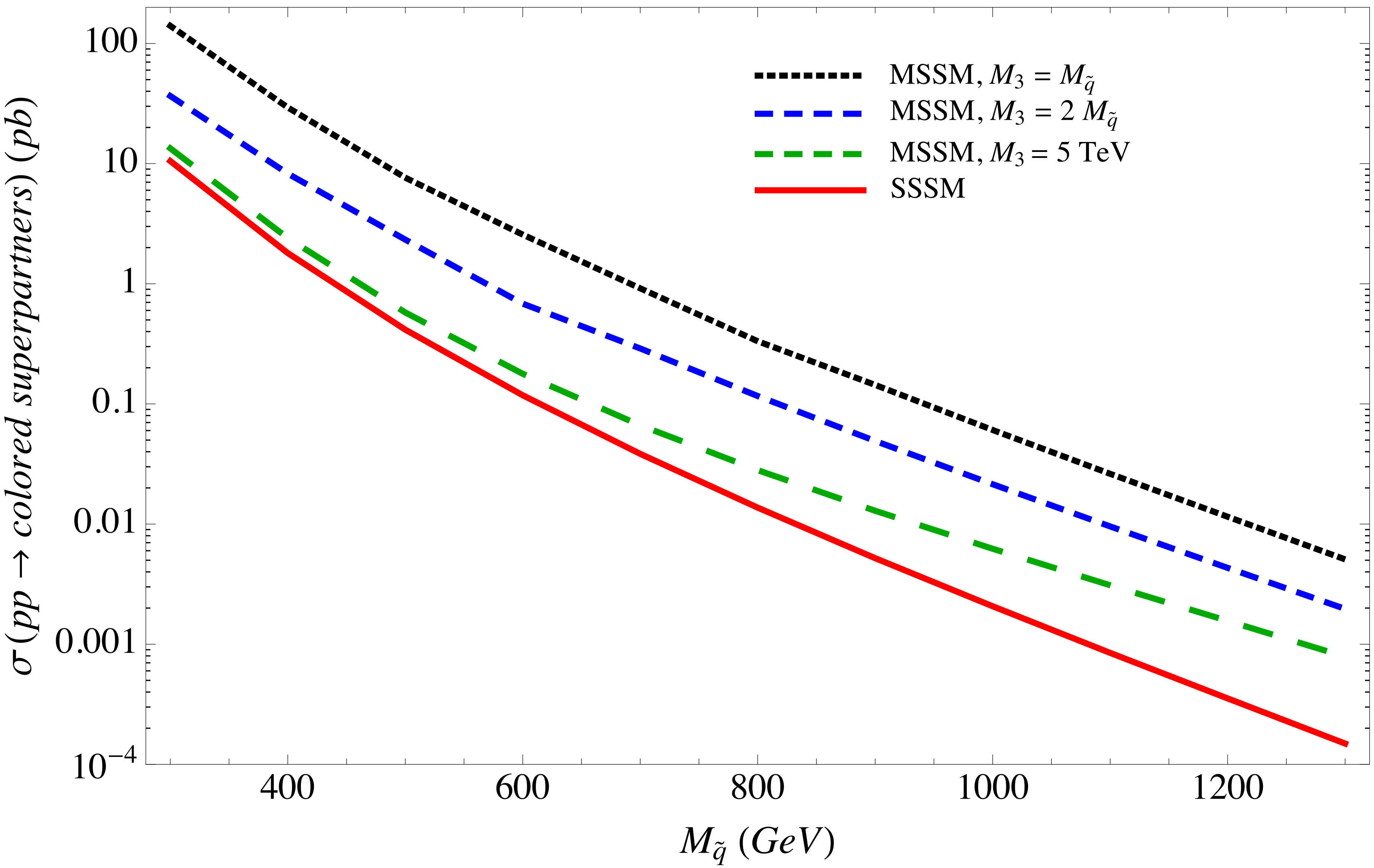
They can be naturally heavier than scalars

LHC will have a harder time seeing the gluino...

M. Heikinheimo, M. Kellerstein, V. Sanz '12
Kribs, Martin '12

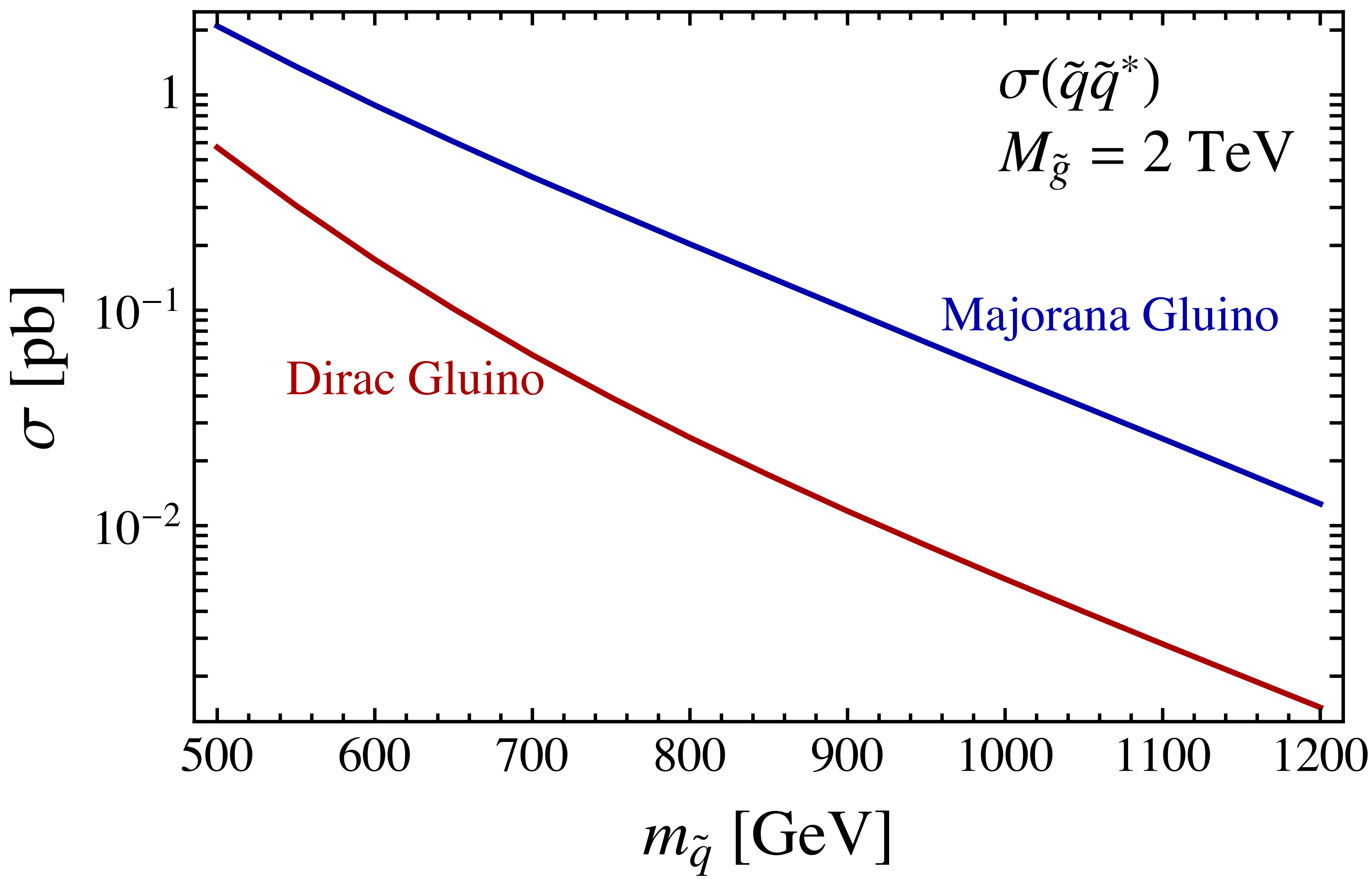
...and squarks





G. Kribs, A. Martin, 2012

Squark production



Frugiuele, T.G., Kumar, Ponton

R-symmetry

With Dirac gaugino: possible to impose an U(1) R-symmetry

$$M_D \lambda \Psi$$

Kribs,Poppitz,Weiner '02

- Bounds from FCNC are weaker: off diagonal m_{ij}

$$R[Q, U^c, D^c, L, E^c] = 1 \qquad R[H_u, H_d] = 0$$

$$\mu H_u H_d$$

MRSSM:

add two additional Higgs doublets: $R_u \; R_d$

Adjoint partners

$$W = \sqrt{2}\lambda_T^u H_u T R_d + 2\lambda_T^d R_u T H_d + \lambda_S^u H_u S R_d + \lambda_S^d R_u S H_d$$
$$+ \mu_u H_u R_d + \mu_d H_d R_u$$

R-charge 2, do not get vets

Gherghetta, Pomarol '03
Frugiuele, T.G. '11
Frugiuele, T.G, Kumar, Ponton '12

Other possibility:

$U(1)_R$ can be identified with a lepton number

Superpartners have different lepton numbers

e.g.: quarks have lepton number 0
squarks have lepton number 1

$$R(Q, U^c, D^c) = 1 \qquad R(H_u, L) = 0 \qquad R(R_d, E) = 2$$

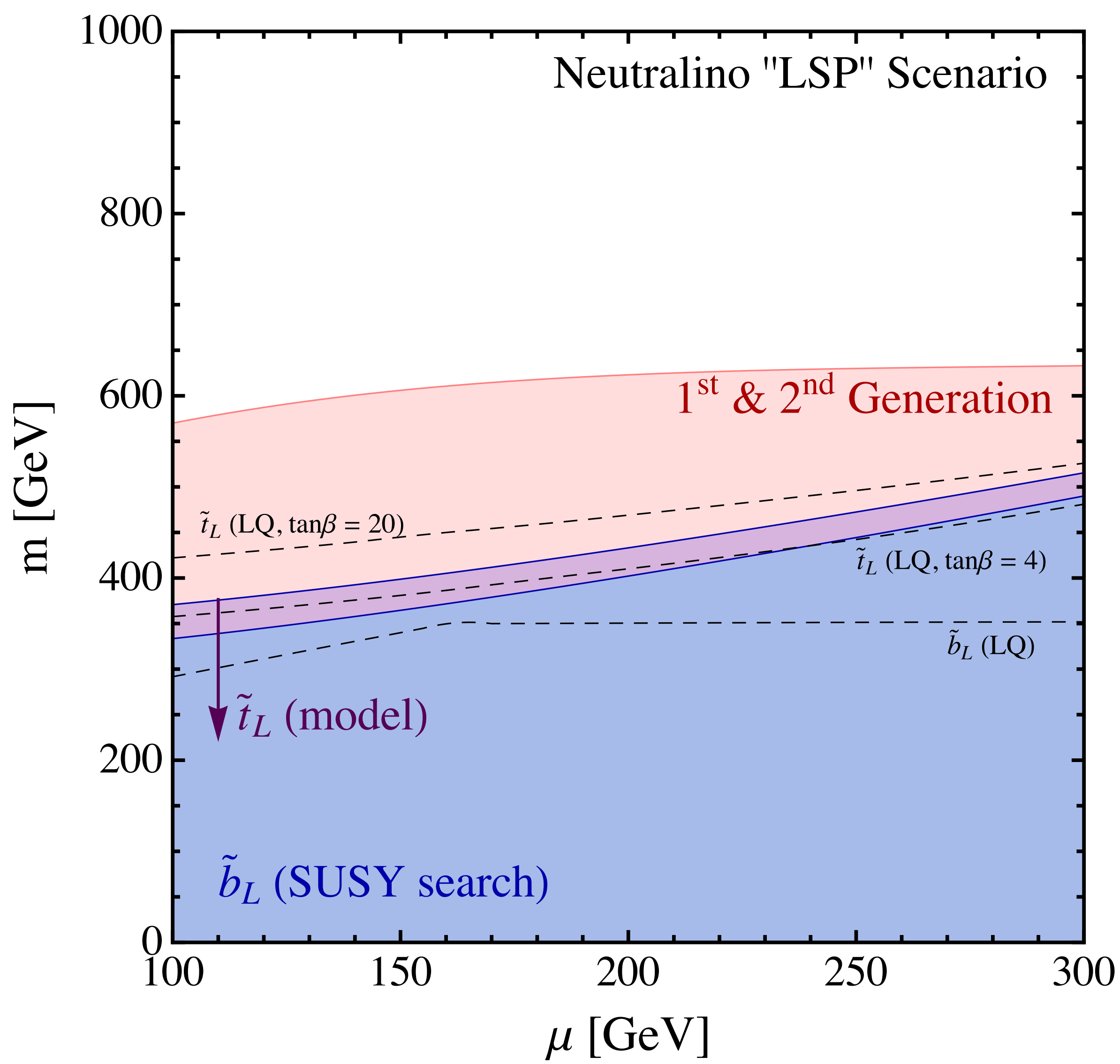
$$W = \lambda_u Q H_u U + \lambda_d Q L D + \lambda_e L L E + \\ \mu H_u R_d + \lambda_T H_u T R_d + \lambda_S H_u S R_d$$

Sneutrino plays the role of the down quark

squarks are lepto-quark

Unusual phenomenology

Frugiuele, T.G, Kumar, Ponton '12



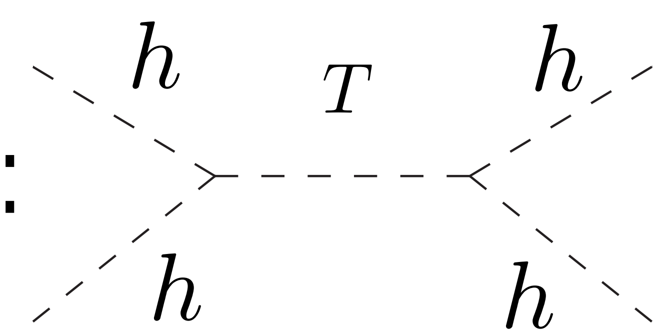
Higgs mass

Tree-level:

Reduced quartic, usual of Dirac gauginos

$$\int d^2\theta W'_\alpha W_i^\alpha \Phi_i \quad \longrightarrow \quad D_2 = M_2 T^a + H_u^\dagger \sigma^a H_u + \ldots$$

When the scalar T is integrated out:



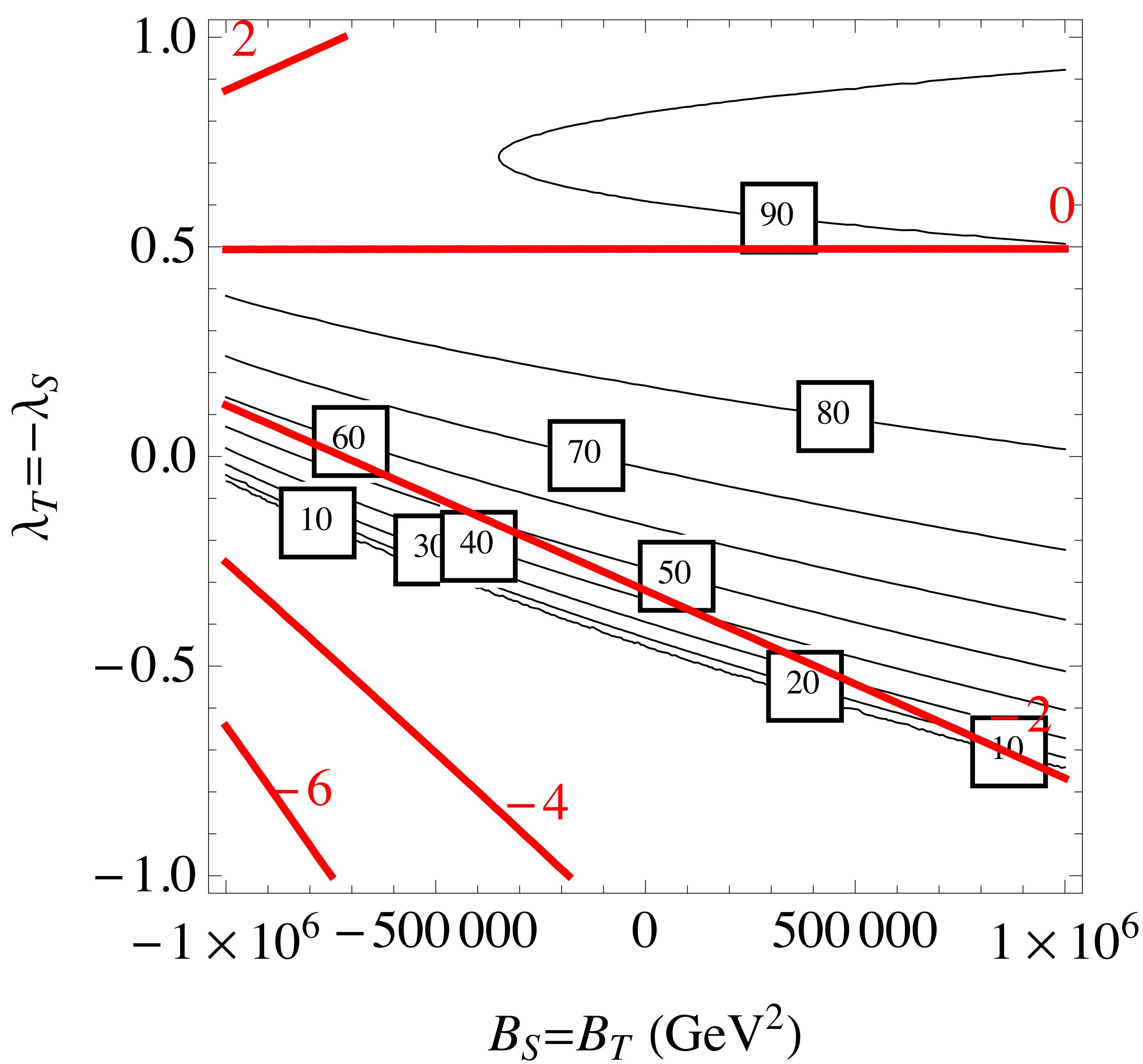
$$\boxed{\lambda \to 0}$$

Higgs quartic

If the mass of T is set by M_2 and $\lambda_T = 0$

With soft SUSY breaking mass terms for T (m_T) and $\lambda_T \neq 0$

$$\delta\lambda = -\frac{(-\sqrt{2}gM_2 + 2\lambda_T\mu)^2}{m_{T_R}^2}$$



$M_2 = 600\text{GeV}$

$m_T = 1500\text{GeV}$

No help (at tree-level) from

$$\lambda_T H_u T R_d + \lambda_S H_u S R_d$$

don't get a vev (In the limit of exact R-symmetry)

But do help in models without an R-symmetry

Benakli, Goodsell, Staub 1211.0552

Conclusions

Dirac gauginos can lead to reduced tree-level Higgs mass

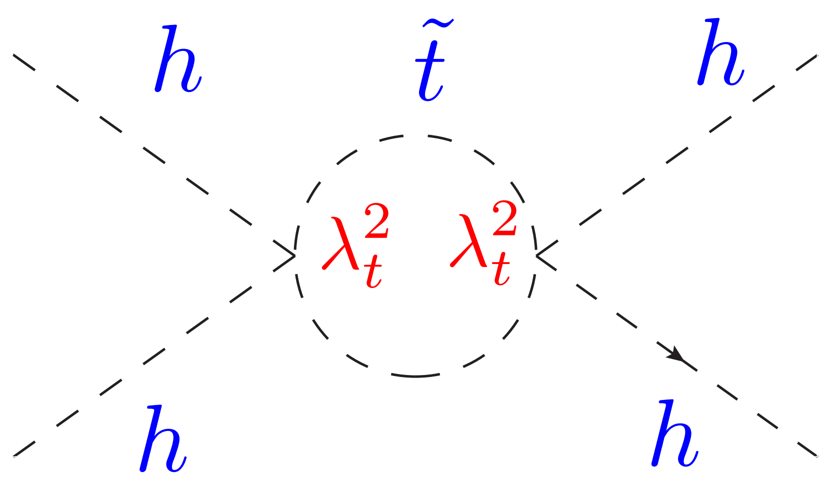
Presence of the new adjoint superfields can be used to overcome this problem

With R-symmetry, one has to rely on loop effects that are very sensitive to the coupling

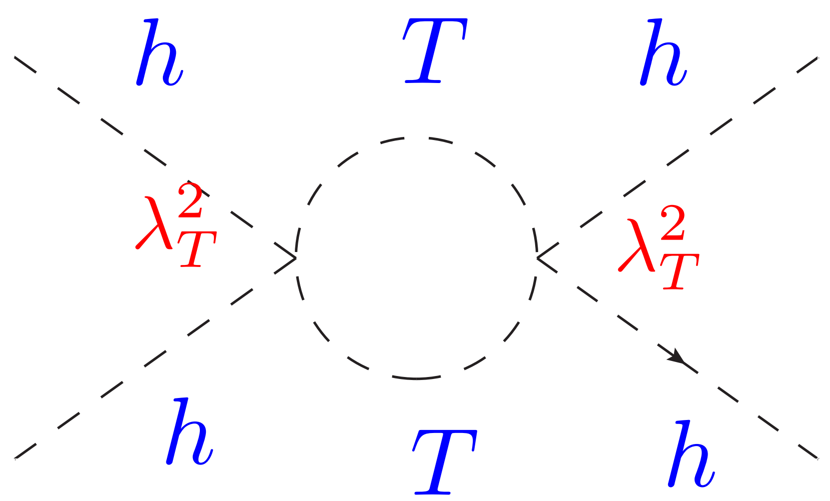
Possible tension with EWPM, but possible to raise the Higgs mass with reasonable masses.

Loop-level

Usual stop correction (but A-terms are 0)



Similar loop from the triplet



$$V_{\mathrm{CW}} \sim \frac{1}{16\pi^2}\left(5\lambda_T^4 \log\frac{m_T^2}{M_2^2} + 3\lambda_t^4 \log\frac{m_{\tilde{t}}^2}{m_t^2}\right)$$

Very sensitive to λ_T

….but so are electroweak precision measurements

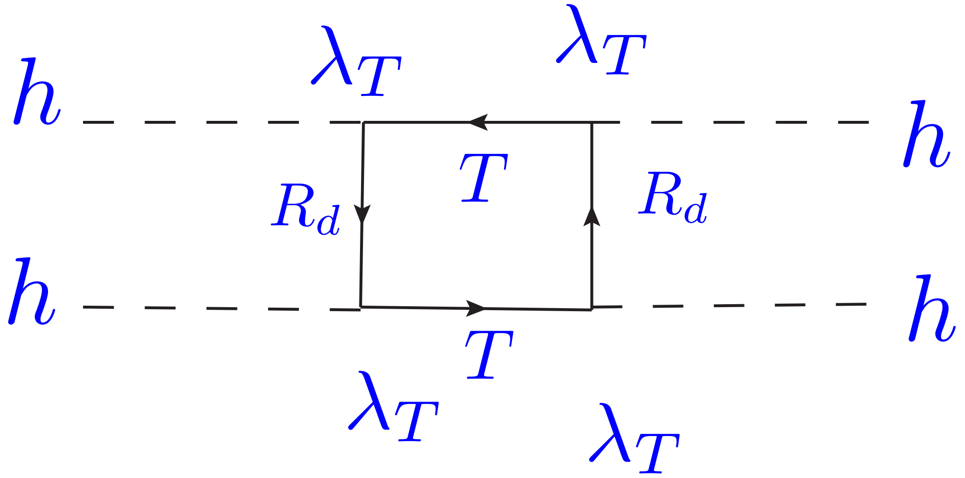
Tree-level

vev of the triplet

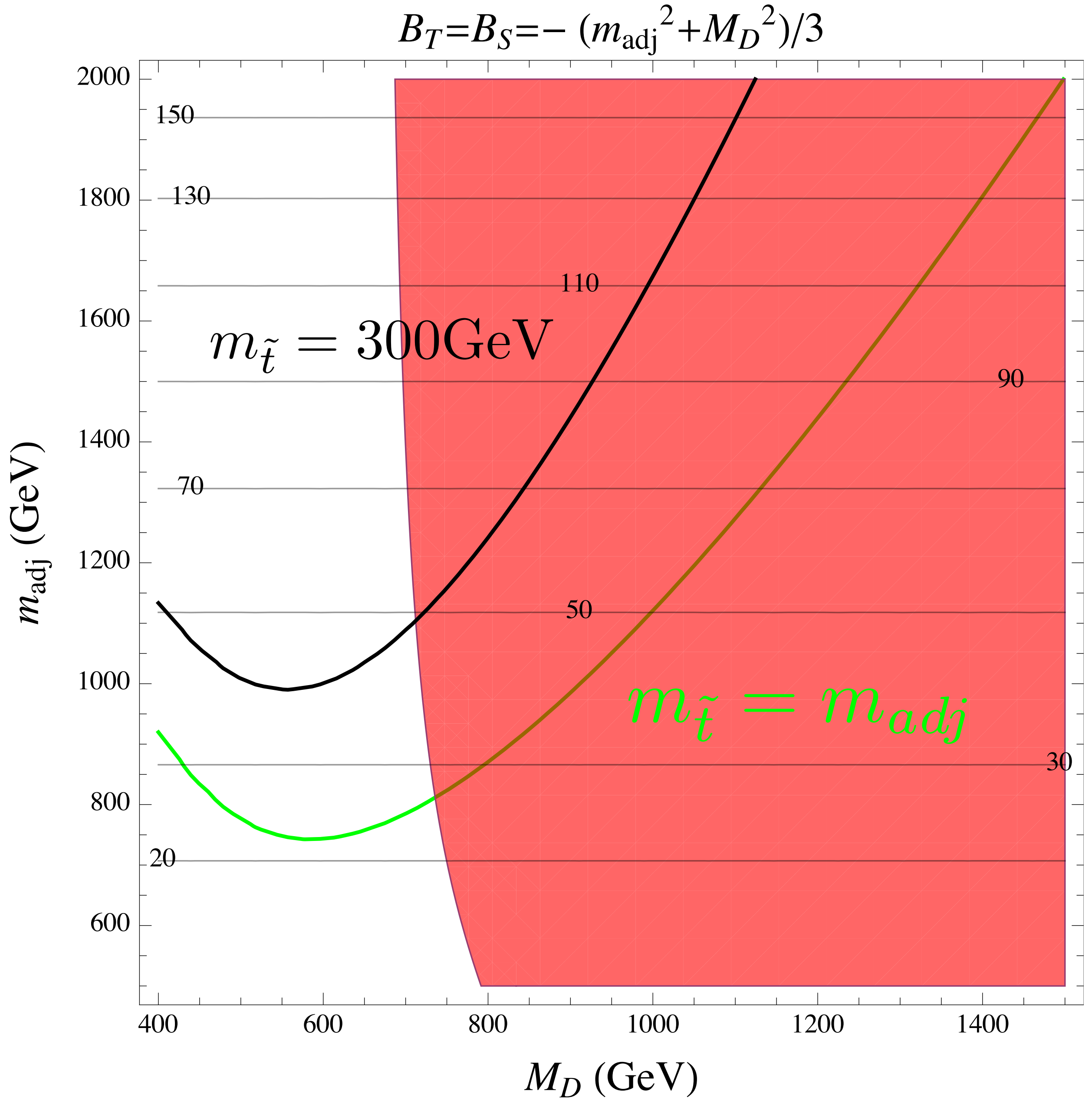
$$\hat{T} = 4\frac{v_T^2}{v^2}$$

$$v_T = \frac{\sqrt{2}gM_2 - 2\lambda_T\mu}{2m_{T_R}^2}v^2$$

loop effect also important



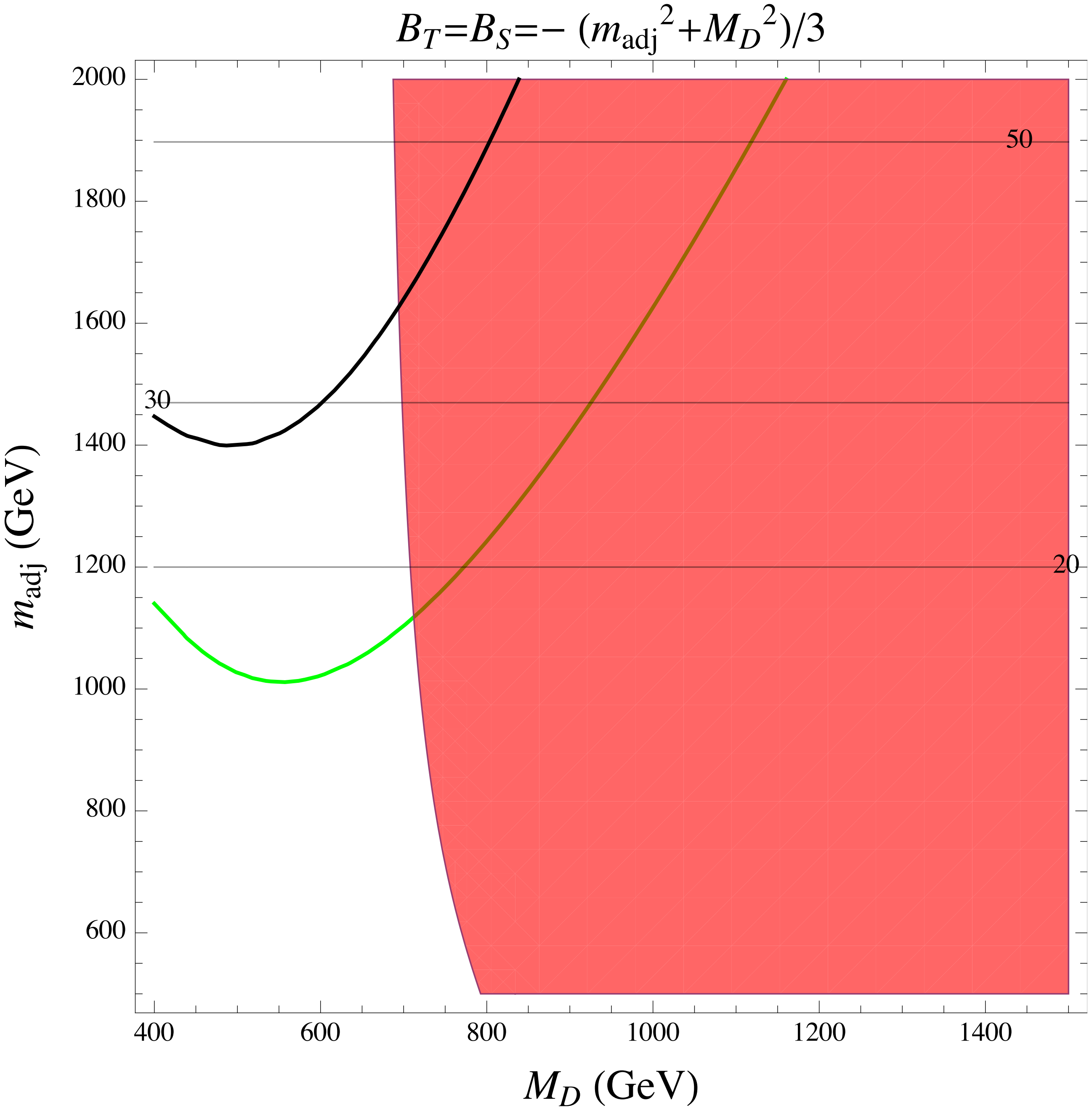
$$\longrightarrow \frac{\left|h^\dagger D_\mu h\right|^2}{\Lambda^2}$$



$$\lambda_T = -\lambda_S = 1$$

$$m_{R_d} = m_{adj}$$

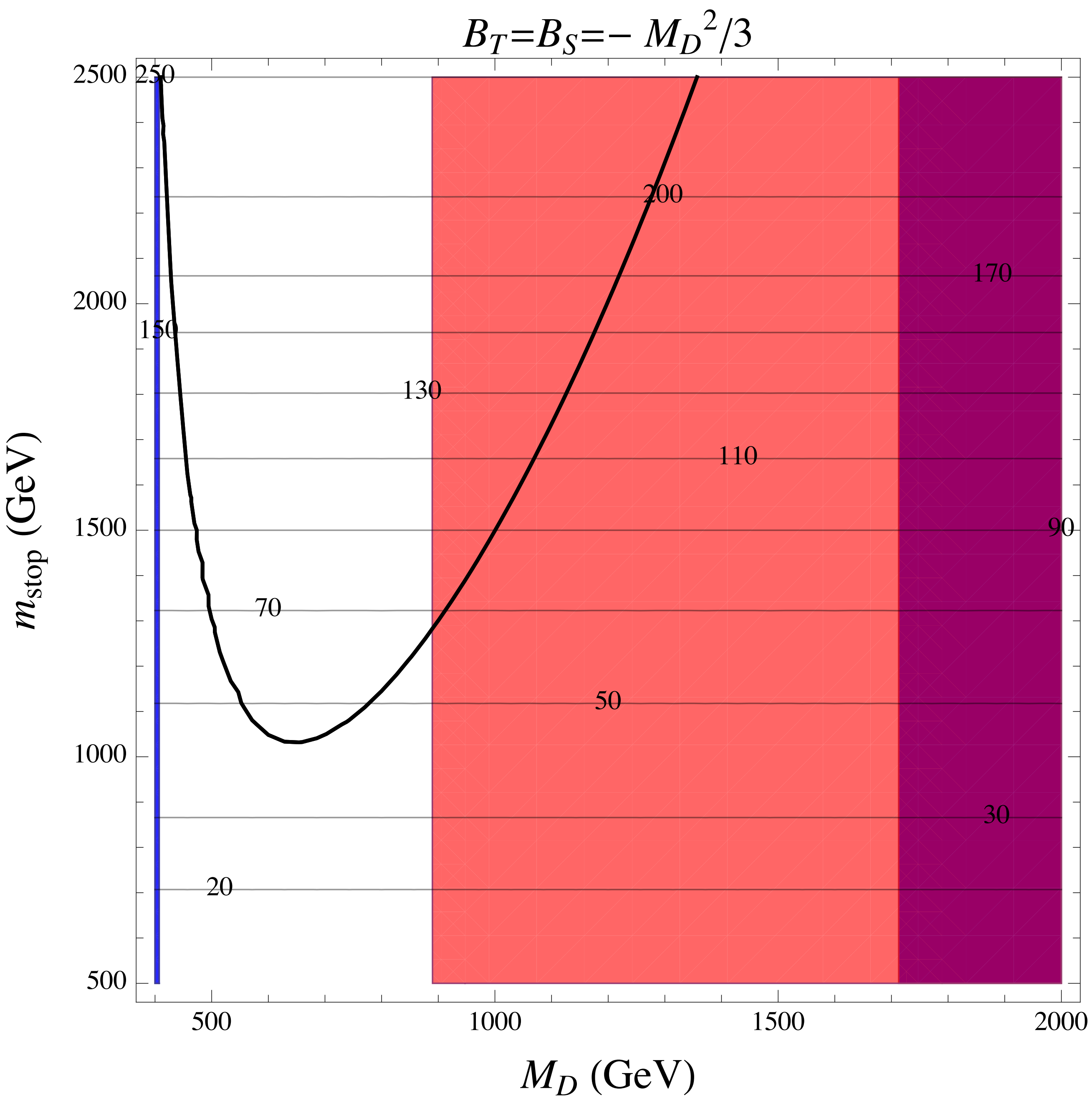
Tuning dominated by R_d



$$\lambda_T = -\lambda_S = 1$$

$$m_{R_d} = m_{adj}/2$$

$m_T = 0$



$m_{R_d} = m_{\tilde{t}}$