Higgs masses and constraints on the parameter space in the R-broken SUSY model with right-handed neutrino

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Outline

MSSM

MSSM + neutrino Yukawa interactions

MSSM + neutrino Yukawa interactions + R-parity breaking

The Higgs potential

Higgs boson masses

RG evolution of model parameters

Neutrino-neutralino mixing

Constraints on the model parameters

Conclusions

Supersymmetric Standard Model

	Superfield	Bosons		Fermions		$SU_c(3)$	$SU_L(2)$	$U_Y(1)$
Gauge	$\mathbf{G^a}$	gluon	g^a	gluino	$\tilde{g}^a$	8	1	0
	$\mathbf{V^k}$	Weak	$W^k \; (W^\pm, Z)$	wino, zino	$\tilde{w}^k \; (\tilde{w}^\pm, \tilde{z})$	1	3	0
	$\mathbf{V'}$	Hypercharge	$B \; (\gamma)$	bino	$\tilde{b}(\tilde{\gamma})$	1	1	0
Matter	$\mathbf{L_i}$	sleptons	$\tilde{L}_i = (\tilde{\nu}, \tilde{e})_L$	leptons	$L_i = (\nu, e)_L$	1	2	−1
	$\mathbf{E_i}$		$\tilde{E}_i = \tilde{e}_R$		$E_i = e_R$	1	1	2
	$\mathbf{Q_i}$	squarks	$\tilde{Q}_i = (\tilde{u}, \tilde{d})_L$	quarks	$Q_i = (u, d)_L$	3	2	1/3
	$\mathbf{U_i}$		$\tilde{U}_i = \tilde{u}_R$		$U_i = u_R^c$	3*	1	−4/3
	$\mathbf{D_i}$		$\tilde{D}_i = \tilde{d}_R$		$D_i = d_R^c$	3*	1	2/3
Higgs	$\mathbf{H_1}$	Higgses	$H_1 \quad (h, H, A, H^\pm)$	higgsinos	$\tilde{H}_1 \quad (\tilde{h}_1, \tilde{h}_2, \tilde{h}^\pm)$	1	2	−1
	$\mathbf{H_2}$		H_2		$\tilde{H}_2$	1	2	1

Supersymmetric Standard Model

Superpotential

$$\mathcal{W}_R = y_{\rm u}^{ij}\bar{u}_i Q_j \cdot H_{\rm u} - y_{\rm d}^{ij}\bar{d}_i Q_j \cdot H_{\rm d} - y_{\rm e}^{ij}\bar{e}_i L_j \cdot H_{\rm d} + \mu H_{\rm u} \cdot H_{\rm d},$$

SUSY breaking

$$-\frac{1}{2}(M_3\tilde{g}^\alpha\tilde{g}^\alpha + M_2\tilde{W}^\alpha\tilde{W}^\alpha + M_1\tilde{B}\tilde{B} + \text{h.c.}),$$

$$-m^2_{\tilde{\rm Q}ij}\tilde{Q}_i^\dagger \cdot \tilde{Q}_j - m^2_{\tilde{\bar{\rm u}}ij}\tilde{\bar{u}}_i^\dagger\tilde{\bar{u}}_j - m^2_{\tilde{\bar{\rm d}}ij}\tilde{\bar{d}}_i^\dagger\tilde{\bar{d}}_j,$$

$$-m^2_{\tilde{\rm L}ij}\tilde{L}_i^\dagger \cdot \tilde{L}_j - m^2_{\tilde{\bar{\rm e}}ij}\tilde{\bar{e}}_i^\dagger\tilde{\bar{e}}_j.$$

$$-m^2_{\rm H_u}H_{\rm u}^\dagger \cdot H_{\rm u} - m^2_{\rm H_d}H_{\rm d}^\dagger \cdot H_{\rm d} - (bH_{\rm u} \cdot H_{\rm d} + \text{h.c.})$$

$$-a_{\rm u}^{ij}\tilde{\bar{u}}_i\tilde{Q}_j \cdot H_{\rm u} + a_{\rm d}^{ij}\tilde{\bar{d}}_i\tilde{Q}_j \cdot H_{\rm d} + a_{\rm e}^{ij}\tilde{\bar{e}}_i\tilde{L}_j \cdot H_{\rm d} + \text{h.c.}$$

Supersymmetric Standard Model

Superpotential (R-parity conserving)

$$\mathcal{W}_R = y_{\mathrm{u}}^{ij}\bar{u}_i Q_j \cdot H_{\mathrm{u}} - y_{\mathrm{d}}^{ij}\bar{d}_i Q_j \cdot H_{\mathrm{d}} - y_{\mathrm{e}}^{ij}\bar{e}_i L_j \cdot H_{\mathrm{d}} + \mu H_{\mathrm{u}} \cdot H_{\mathrm{d}},$$

Superpotential (R-parity breaking)

$$W_{\Delta L=1} = \lambda_e^{ijk} L_i \cdot L_j \bar{e}_k + \lambda_L^{ijk} L_i \cdot Q_j \bar{d}_k + \mu_L^i L_i \cdot H_{\mathrm{u}},$$
$$W_{\Delta B=1} = \lambda_B^{ijk} \bar{u}_i \bar{d}_j \bar{d}_k.$$

$$R = (-1)^{3(B-L)+2S}$$

Supersymmetric Standard Model

Superpotential (R-parity conserving)

$$\mathcal{W}_R = y_{\mathrm{u}}^{ij} \bar{u}_i Q_j \cdot H_{\mathrm{u}} - y_{\mathrm{d}}^{ij} \bar{d}_i Q_j \cdot H_{\mathrm{d}} - y_{\mathrm{e}}^{ij} \bar{e}_i L_j \cdot H_{\mathrm{d}} + \mu H_{\mathrm{u}} \cdot H_{\mathrm{d}},$$

Right-handed neutrino contributions to the superpotential and SUSY breaking terms

$$y_\nu^{ij} \bar{\nu}_i L_j \cdot H_{\mathrm{u}},$$

$$\lambda_\nu^i \bar{\nu}_i H_{\mathrm{u}} \cdot H_{\mathrm{d}}.$$

$$- a_\nu^{ij} \tilde{\bar{\nu}}_i \tilde{L}_j \cdot H_{\mathrm{u}} - a_{\not{R}\nu}^i \tilde{\bar{\nu}}_i H_{\mathrm{u}} \cdot H_{\mathrm{d}},$$

The Higgs Potential

The Higgs potential then reads

$$\mathcal{V} = (|\mu|^2 + m^2_{\rm H_u})(|H_{\rm u}^+|^2 + |H_{\rm u}^0|^2) + (|\mu|^2 + m^2_{\rm H_d})(|H_{\rm d}^0|^2 + |H_{\rm d}^-|^2) +$$
$$+ [b(H_{\rm u}^+ H_{\rm d}^- - H_{\rm u}^0 H_{\rm d}^0) + {\rm h.c.}] + \frac{g^2 + g'^2}{8}(|H_{\rm u}^+|^2 + |H_{\rm u}^0|^2 - |H_{\rm d}^0|^2 - |H_{\rm d}^-|^2)^2 +$$
$$+ \frac{g^2}{2}|H_{\rm u}^+ H_{\rm d}^{0\dagger} + H_{\rm u}^0 H_{\rm d}^{-\dagger}|^2 + |\lambda_\nu^i \lambda_\nu^i|\,|H_{\rm u}^+ H_{\rm d}^- - H_{\rm u}^0 H_{\rm d}^0|^2. \qquad (35)$$

To find minima consider its part containing neutral components

$$\mathcal{V}_{\rm n} = (|\mu|^2 + m^2_{\rm H_u})|H_{\rm u}^0|^2 + (|\mu|^2 + m^2_{\rm H_d})|H_{\rm d}^0|^2 - (bH_{\rm u}^0 H_{\rm d}^0 + {\rm h.c.}) +$$
$$+ \frac{g^2 + g'^2}{8}\left(|H_{\rm u}^0|^2 - |H_{\rm d}^0|^2\right)^2 + |\lambda_\nu^i \lambda_\nu^i|\,|H_{\rm u}^0 H_{\rm d}^0|^2.$$

The Higgs Potential

Minimization conditions

$$(|\mu|^2 + m^2_{\mathrm{H_u}})v_{\mathrm{u}} = bv_{\mathrm{d}} + \frac{1}{4}(g^2 + g'^2)(v^2_{\mathrm{d}} - v^2_{\mathrm{u}})v_{\mathrm{u}} - |\lambda|^2 v^2_{\mathrm{d}} v_{\mathrm{u}},$$
$$(|\mu|^2 + m^2_{\mathrm{H_d}})v_{\mathrm{d}} = bv_{\mathrm{u}} - \frac{1}{4}(g^2 + g'^2)(v^2_{\mathrm{d}} - v^2_{\mathrm{u}})v_{\mathrm{d}} - |\lambda|^2 v_{\mathrm{d}} v^2_{\mathrm{u}}.$$

$$|\mu|^2 + m^2_{\mathrm{H_u}} = b\,\mathrm{ctg}\,\beta + \frac{m^2_{\mathrm{Z}}}{2}\cos 2\beta - \varepsilon^2 2m^2_{\mathrm{Z}}\cos^2\beta$$
$$|\mu|^2 + m^2_{\mathrm{H_d}} = b\,\mathrm{tg}\,\beta - \frac{m^2_{\mathrm{Z}}}{2}\cos 2\beta - \varepsilon^2 2m^2_{\mathrm{Z}}\sin^2\beta,$$

$$m^2_{\mathrm{Z}} = \frac{1}{2}(g^2 + g'^2)(v^2_{\mathrm{u}} + v^2_{\mathrm{d}}),$$

$$\mathrm{tg}\,\beta \equiv \frac{v_{\mathrm{u}}}{v_{\mathrm{d}}},$$

$$\varepsilon^2 = \frac{|\lambda|^2}{g^2 + g'^2}.$$

CP-odd neutral Higgs

Mass of the CP-odd Higgs boson A

$$\mathcal{V}_{\mathrm{A}} = (|\mu|^2 + m^2_{\mathrm{H_u}})(\mathrm{Im}H^0_{\mathrm{u}})^2 + (|\mu|^2 + m^2_{\mathrm{H_d}})(\mathrm{Im}H^0_{\mathrm{d}})^2 + 2b(\mathrm{Im}H^0_{\mathrm{u}})(\mathrm{Im}H^0_{\mathrm{d}}) +$$
$$+ \frac{g^2 + g'^2}{8}\left[(\mathrm{Re}H^0_{\mathrm{u}})^2 + (\mathrm{Im}H^0_{\mathrm{u}})^2 - (\mathrm{Re}H^0_{\mathrm{d}})^2 - (\mathrm{Im}H^0_{\mathrm{d}})^2\right]^2 +$$
$$+ |\lambda|^2\left[(\mathrm{Re}H^0_{\mathrm{u}})^2 + (\mathrm{Im}H^0_{\mathrm{u}})^2\right]\left[(\mathrm{Re}H^0_{\mathrm{d}})^2 + (\mathrm{Im}H^0_{\mathrm{d}})^2\right].$$

$$(\mathrm{M}^{\mathrm{sq}}_{\mathrm{A}})_{11} = |\mu|^2 + m^2_{\mathrm{H_u}} + \frac{g^2 + g'^2}{4}(v^2_{\mathrm{u}} - v^2_{\mathrm{d}}) + \lambda^2 v^2_{\mathrm{d}} = b\,\mathrm{ctg}\,\beta.$$

$$\mathrm{M}^{\mathrm{sq}}_{\mathrm{A}} = b\begin{pmatrix}\mathrm{ctg}\,\beta & 1\\ 1 & \mathrm{tg}\,\beta\end{pmatrix}.$$

$$m^2_+ = 0, \quad m^2_- = \frac{2b}{\sin 2\beta}.$$

CP-even neutral Higgses

Masses of the CP-even Higgs bosons h, H

$$\mathcal{V}_{\mathrm{H}} = (|\mu|^2 + m^2_{\mathrm{H_u}})(\mathrm{Re}H^0_{\mathrm{u}})^2 + (|\mu|^2 + m^2_{\mathrm{H_d}})(\mathrm{Re}H^0_{\mathrm{d}})^2 - 2b(\mathrm{Re}H^0_{\mathrm{u}})(\mathrm{Re}H^0_{\mathrm{d}}) +$$
$$+ \frac{g^2 + g'^2}{8}[(\mathrm{Re}H^0_{\mathrm{u}})^2 + (\mathrm{Im}H^0_{\mathrm{u}})^2 - (\mathrm{Re}H^0_{\mathrm{d}})^2 - (\mathrm{Im}H^0_{\mathrm{d}})^2]^2 +$$
$$+ \lambda^2 \left((\mathrm{Re}H^0_{\mathrm{u}})^2 + (\mathrm{Im}H^0_{\mathrm{u}})^2\right)\left((\mathrm{Re}H^0_{\mathrm{d}})^2 + (\mathrm{Im}H^0_{\mathrm{d}})^2\right).$$

$$M^{\mathrm{sq}}_{11} = |\mu|^2 + m^2_{\mathrm{H_u}} + \frac{g^2 + g'^2}{4}(2v^2_{\mathrm{u}} - v^2_{\mathrm{d}}) + \lambda^2 v^2_{\mathrm{d}} = b\,\mathrm{ctg}\,\beta + m^2_{\mathrm{Z}}\sin^2\beta,$$
$$M^{\mathrm{sq}}_{12} = -b - \frac{g^2 + g'^2}{2}v_{\mathrm{u}}v_{\mathrm{d}} + 2\lambda^2 v_{\mathrm{u}}v_{\mathrm{d}} = -b - \frac{1}{2}m^2_{\mathrm{Z}}(1 - 4\varepsilon^2)\sin 2\beta,$$
$$M^{\mathrm{sq}}_{22} = |\mu|^2 + m^2_{\mathrm{H_d}} + \frac{g^2 + g'^2}{4}(2v^2_{\mathrm{d}} - v^2_{\mathrm{u}}) + \lambda^2 v^2_{\mathrm{u}} = b\,\mathrm{tg}\,\beta + m^2_{\mathrm{Z}}\cos^2\beta.$$

CP-even neutral Higgses

Masses of the CP-even Higgs bosons h, H

$$\mathrm{M}^{\mathrm{sq}}_{\mathrm{H,h}} = \begin{pmatrix} b\,\mathrm{ctg}\,\beta + m_{\mathrm{Z}}^2 \sin^2\beta & -b - \frac{1}{2}m_{\mathrm{Z}}^2\,(1-4\varepsilon^2)\sin 2\beta \\ -b - \frac{1}{2}m_{\mathrm{Z}}^2\,(1-4\varepsilon^2)\sin 2\beta & b\,\mathrm{tg}\,\beta + m_{\mathrm{Z}}^2 \cos^2\beta \end{pmatrix}$$

$$m^2_{\mathrm{H}^0,\mathrm{h}^0} = \frac{1}{2}\left(m^2_{\mathrm{A}^0} + m^2_{\mathrm{Z}} \pm \sqrt{(m^2_{\mathrm{A}^0} + m^2_{\mathrm{Z}})^2 - 4m^2_{\mathrm{A}^0} m^2_{\mathrm{Z}} \cos^2 2\beta + \Delta_\varepsilon} \right)$$

$$\Delta_\varepsilon = -8m^2_{\mathrm{A}^0} m^2_{\mathrm{Z}} \varepsilon^2 \sin^2 2\beta - 8m^4_{\mathrm{Z}} \varepsilon^2 (1-2\varepsilon^2) \sin^2 2\beta.$$

CP-even neutral Higgses

Masses of the CP-even Higgs bosons h, H

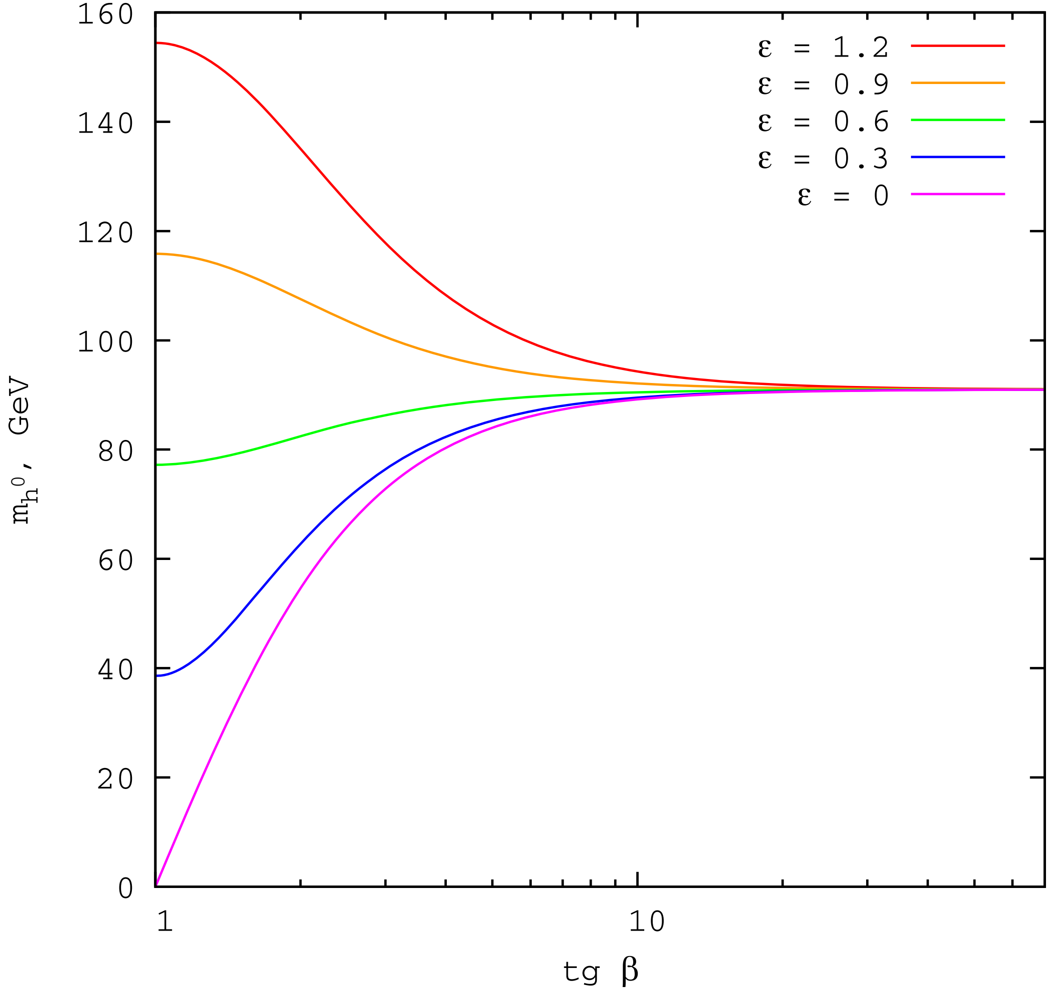
$$m_{\mathrm{h}^0}^2 < m_{\mathrm{Z}}^2 \left(\cos^2 2\beta + 2\varepsilon^2 \sin^2 2\beta\right)$$

$$m_{\mathrm{h}^0}^2 < m_{\mathrm{Z}}^2 \cos^2 2\beta.$$

The situation is similar to the NMSSM case with a singlet Higgs superfield

$$m_{\mathrm{h}^0}^2 \simeq m_{\mathrm{Z}}^2 \cos^2 2\beta + \lambda^2 v^2 \sin^2 2\beta,$$

The lightest Higgs mass



The mass of the lightest Higgs boson as a function of tan β

$$\varepsilon^2 = \frac{|\lambda|^2}{g^2 + g'^2}.$$

Charged Higgses

Masses of charged Higgs bosons

$$\mathcal{V} = (|\mu|^2 + m^2_{\mathrm{H_u}})(|H^+_{\mathrm{u}}|^2 + |H^0_{\mathrm{u}}|^2) + (|\mu|^2 + m^2_{\mathrm{H_d}})(|H^0_{\mathrm{d}}|^2 + |H^-_{\mathrm{d}}|^2) +$$
$$+ [b(H^+_{\mathrm{u}} H^-_{\mathrm{d}} - H^0_{\mathrm{u}} H^0_{\mathrm{d}}) + \mathrm{h.c.}] + \frac{g^2 + g'^2}{8}(|H^+_{\mathrm{u}}|^2 + |H^0_{\mathrm{u}}|^2 - |H^0_{\mathrm{d}}|^2 - |H^-_{\mathrm{d}}|^2)^2 +$$
$$+ \frac{g^2}{2}|H^+_{\mathrm{u}} H^{0\dagger}_{\mathrm{d}} + H^0_{\mathrm{u}} H^{-\dagger}_{\mathrm{d}}|^2 + |\lambda^i_\nu \lambda^i_\nu|\,|H^+_{\mathrm{u}} H^-_{\mathrm{d}} - H^0_{\mathrm{u}} H^0_{\mathrm{d}}|^2. \qquad (35)$$

$$\mathrm{M}^{\mathrm{sq}}_{\mathrm{ch}} = \left[b + v_{\mathrm{u}} v_{\mathrm{d}} \left(\frac{g^2}{2} - |\lambda|^2\right)\right] \begin{pmatrix} \mathrm{ctg}\,\beta & 1 \\ 1 & \mathrm{tg}\,\beta \end{pmatrix}$$

$$m^2_{\mathrm{H}^\pm} = m^2_{\mathrm{A}^0} + m^2_{\mathrm{W}} - 2\varepsilon^2 m^2_{\mathrm{Z}}.$$

RG evolution of model parameters

RG equations for Yukawa couplings

$$\beta_{y_t} \equiv \frac{d}{dt} y_t = \frac{y_t}{16\pi^2}\left(6y_t^* y_t + y_b^* y_b + y_\nu^* y_\nu + \lambda_\nu^* \lambda_\nu - \frac{16}{3} g_3^2 - 3 g_2^2 - \frac{13}{15} g_1^2\right)$$

$$\beta_{y_b} \equiv \frac{d}{dt} y_b = \frac{y_b}{16\pi^2}\left(6y_b^* y_b + y_t^* y_t + y_\tau^* y_\tau + \lambda_\nu^* \lambda_\nu - \frac{16}{3} g_3^2 - 3 g_2^2 - \frac{7}{15} g_1^2\right)$$

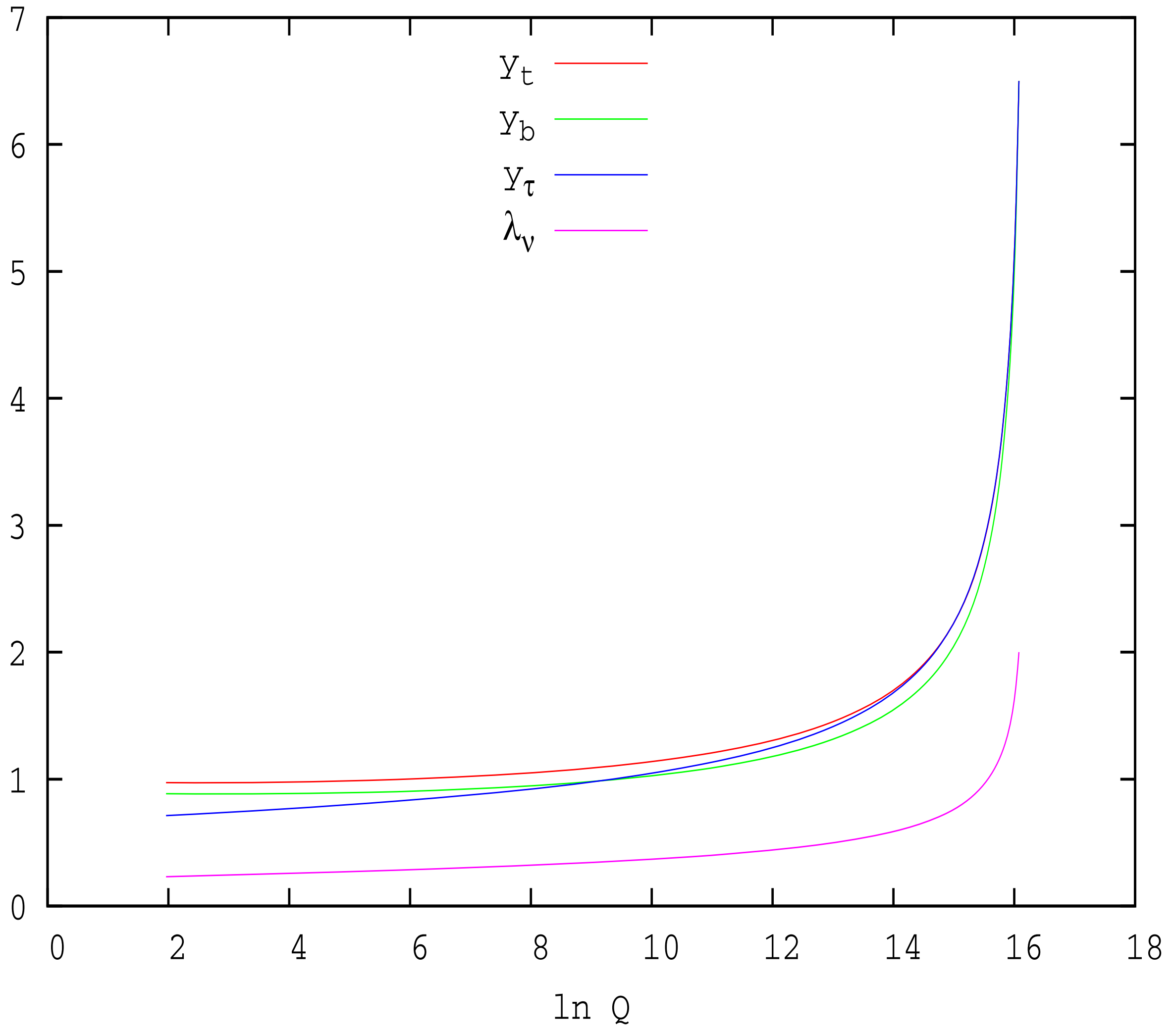
$$\beta_{y_\tau} \equiv \frac{d}{dt} y_\tau = \frac{y_\tau}{16\pi^2}\left(4y_\tau^* y_\tau + 3y_b^* y_b + y_\nu^* y_\nu + \lambda_\nu^* \lambda_\nu - 3 g_2^2 - \frac{9}{5} g_1^2\right),$$

$$\beta_{y_\nu} \equiv \frac{d}{dt} y_\nu = \frac{y_\nu}{16\pi^2}\left(3y_\tau^* y_\tau + y_b^* y_b + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3 g_2^2 - \frac{3}{5} g_1^2\right),$$

$$\beta_{\lambda_\nu} \equiv \frac{d}{dt} \lambda_\nu = \frac{\lambda_\nu}{16\pi^2}\left(3y_\tau^* y_\tau + 3y_b^* y_b + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3 g_2^2 - \frac{3}{5} g_1^2\right),$$

$$\beta_{\mu} \equiv \frac{d}{dt} \mu = \frac{\mu}{16\pi^2}\left(3y_t^* y_t + 3y_b^* y_b + y_\tau^* y_\tau + y_\nu^* y_\nu + 2\lambda_\nu^* \lambda_\nu - 3 g_2^2 - \frac{3}{5} g_1^2\right)$$

RG evolution of model parameters



RG evolution of Yukawa couplings

RG evolution of model parameters

RG equations for SUSY breaking parameters

$$16\pi^2 \frac{d}{dt} a_t = a_t \left(18 y_t^* y_t + y_b^* y_b + y_\nu^* y_\nu + \lambda_\nu^* \lambda_\nu - \frac{16}{3} g_3^2 - 3 g_2^2 - \frac{13}{15} g_1^2 \right) +$$
$$+ 2 y_t \left(a_b y_b^* + a_\nu y_\nu^* + a_{\not{R}\nu} \lambda_\nu^* + \frac{16}{3} g_3^2 M_3 + 3 g_2^2 M_2 + \frac{13}{15} g_1^2 M_1 \right)$$
$$16\pi^2 \frac{d}{dt} a_b = a_b \left(18 y_b^* y_b + y_t^* y_t + y_\tau^* y_\tau + \lambda_\nu^* \lambda_\nu - \frac{16}{3} g_3^2 - 3 g_2^2 - \frac{7}{15} g_1^2 \right) +$$
$$+ 2 y_b \left(a_t y_t^* + a_\tau y_\tau^* + a_{\not{R}\nu} \lambda_\nu^* + \frac{16}{3} g_3^2 M_3 + 3 g_2^2 M_2 + \frac{7}{15} g_1^2 M_1 \right)$$
$$16\pi^2 \frac{d}{dt} a_\tau = a_\tau \left(12 y_\tau^* y_\tau + 3 y_b^* y_b + y_\nu^* y_\nu + \lambda_\nu^* \lambda_\nu - 3 g_2^2 - \frac{9}{5} g_1^2 \right) +$$
$$+ 2 y_\tau \left(3 a_b y_b^* + a_\nu y_\nu^* + a_{\not{R}\nu} \lambda_\nu^* + 3 g_2^2 M_2 + \frac{9}{5} g_1^2 M_1 \right),$$

RG evolution of model parameters

RG equations for SUSY breaking parameters

$$16\pi^2 \frac{d}{dt} a_\nu = a_\nu \left(3y_t^* y_t + y_\tau^* y_\tau + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right) +$$
$$+ 2y_\nu \left(3a_t y_t^* + a_\tau y_\tau^* + 4a_\nu y_\nu^* + 4a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right)$$

$$16\pi^2 \frac{d}{dt} a_{\not{R}\nu} = a_{\not{R}\nu} \left(3y_t^* y_t + 3y_b^* y_b + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right) +$$
$$+ 2y_\tau \left(3a_t y_t^* + 3a_b y_b^* + 4a_\nu y_\nu^* + 4a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right),$$

$$16\pi^2 \frac{d}{dt} b = b \left(3y_t^* y_t + 3y_b^* y_b + y_\tau^* y_\tau + y_\nu^* y_\nu + 2\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right)$$
$$+ 2\mu \left(3a_t y_t^* + 3a_b y_b^* + a_\tau y_\tau^* + a_\nu y_\nu^* + 2a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right)$$

RG evolution of model parameters

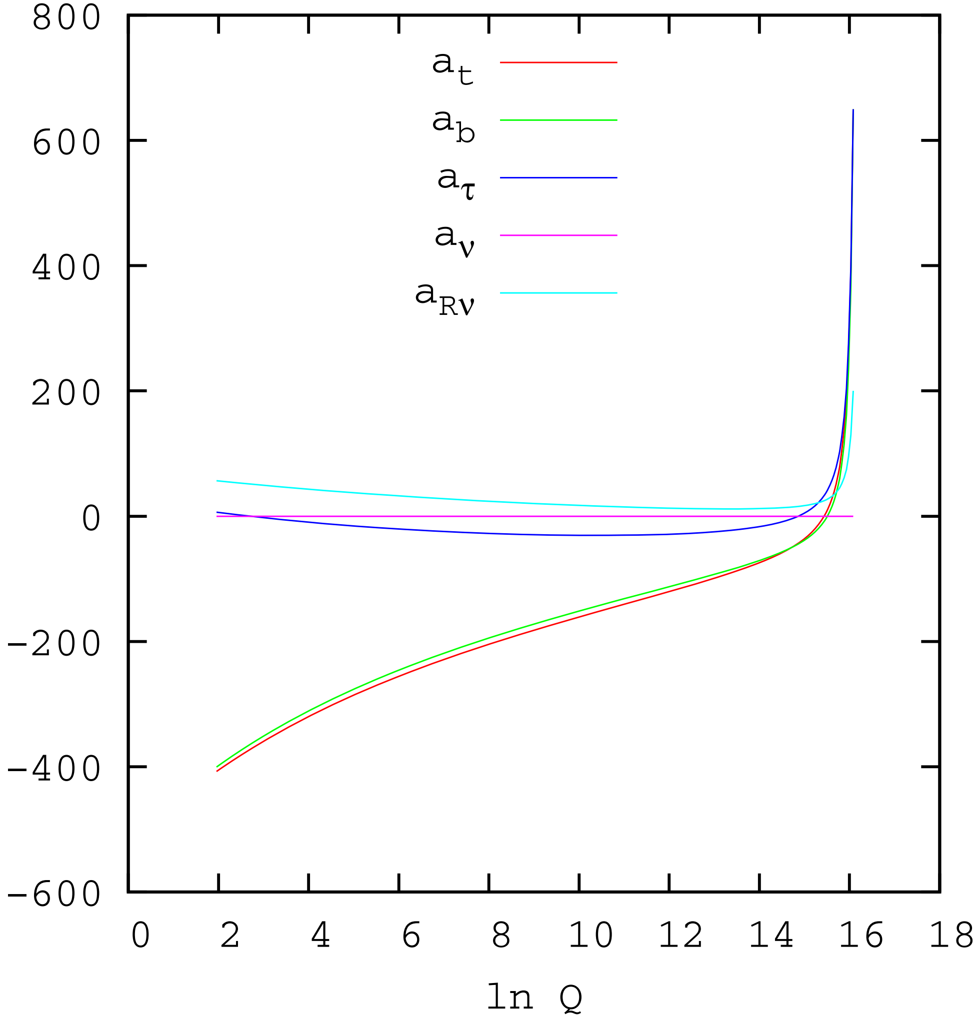
RG equations for SUSY breaking parameters

$$16\pi^2 \frac{d}{dt} a_\nu = a_\nu \left(3y_t^* y_t + y_\tau^* y_\tau + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right) +$$
$$+ 2y_\nu \left(3a_t y_t^* + a_\tau y_\tau^* + 4a_\nu y_\nu^* + 4a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right)$$

$$16\pi^2 \frac{d}{dt} a_{\not{R}\nu} = a_{\not{R}\nu} \left(3y_t^* y_t + 3y_b^* y_b + 4y_\nu^* y_\nu + 4\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right) +$$
$$+ 2y_\tau \left(3a_t y_t^* + 3a_b y_b^* + 4a_\nu y_\nu^* + 4a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right) ,$$

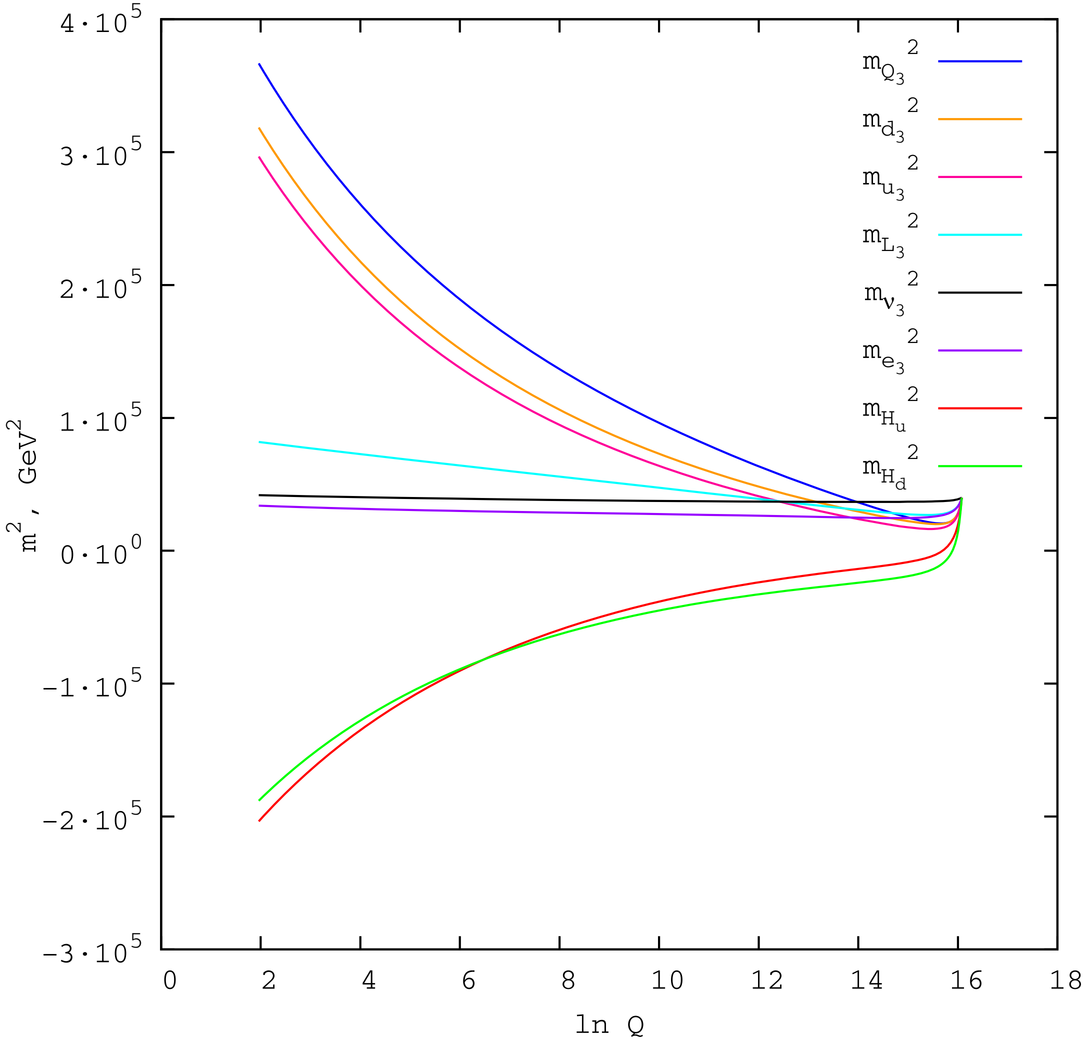
$$16\pi^2 \frac{d}{dt} b = b \left(3y_t^* y_t + 3y_b^* y_b + y_\tau^* y_\tau + y_\nu^* y_\nu + 2\lambda_\nu^* \lambda_\nu - 3g_2^2 - \frac{3}{5} g_1^2 \right)$$
$$+ 2\mu \left(3a_t y_t^* + 3a_b y_b^* + a_\tau y_\tau^* + a_\nu y_\nu^* + 2a_{\not{R}\nu} \lambda_\nu^* + 3g_2^2 M_2 + \frac{3}{5} g_1^2 M_1 \right)$$

RG evolution of model parameters



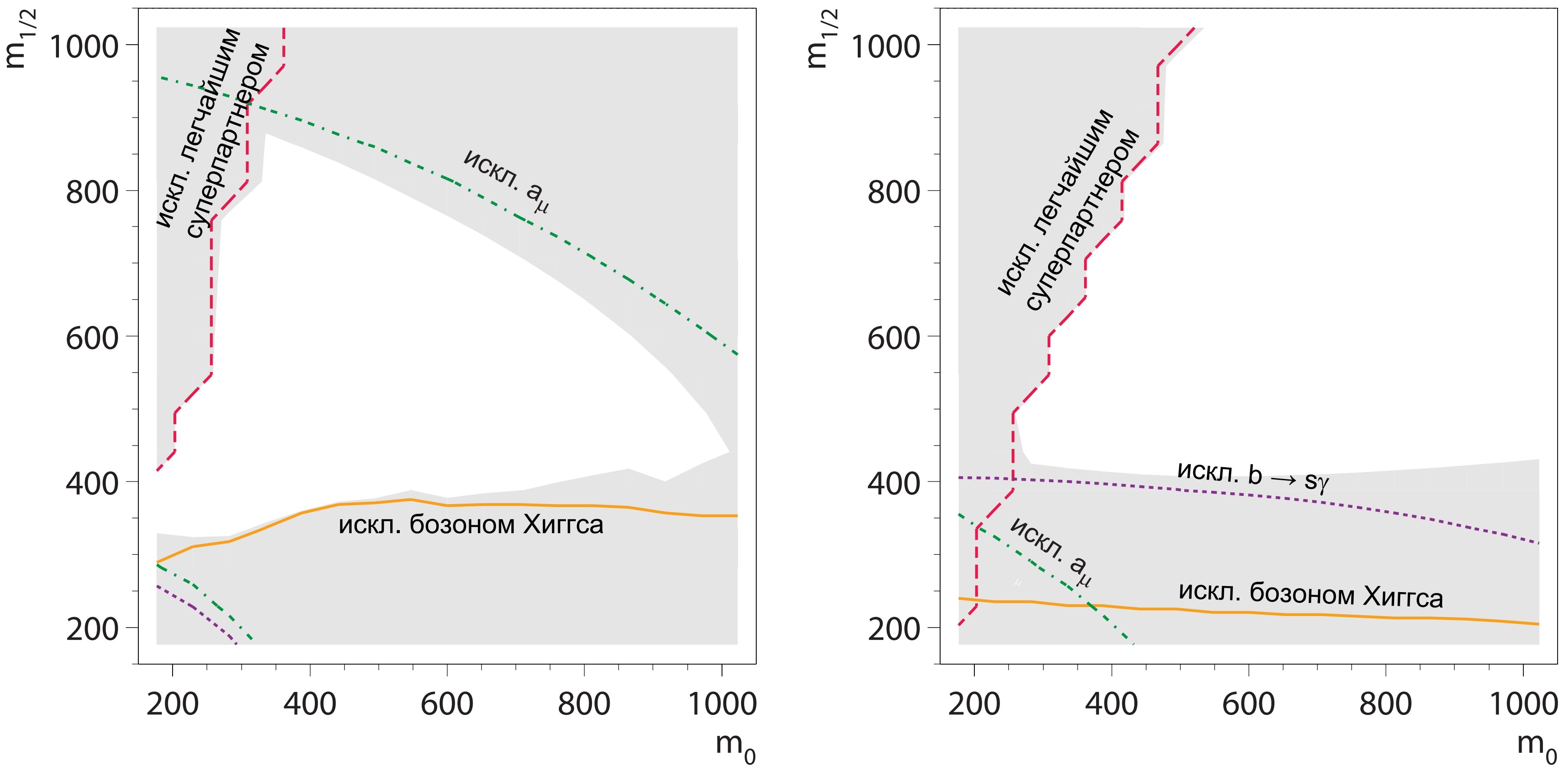
RG evolution of trilinear soft SUSY breaking parameters

RG evolution of model parameters



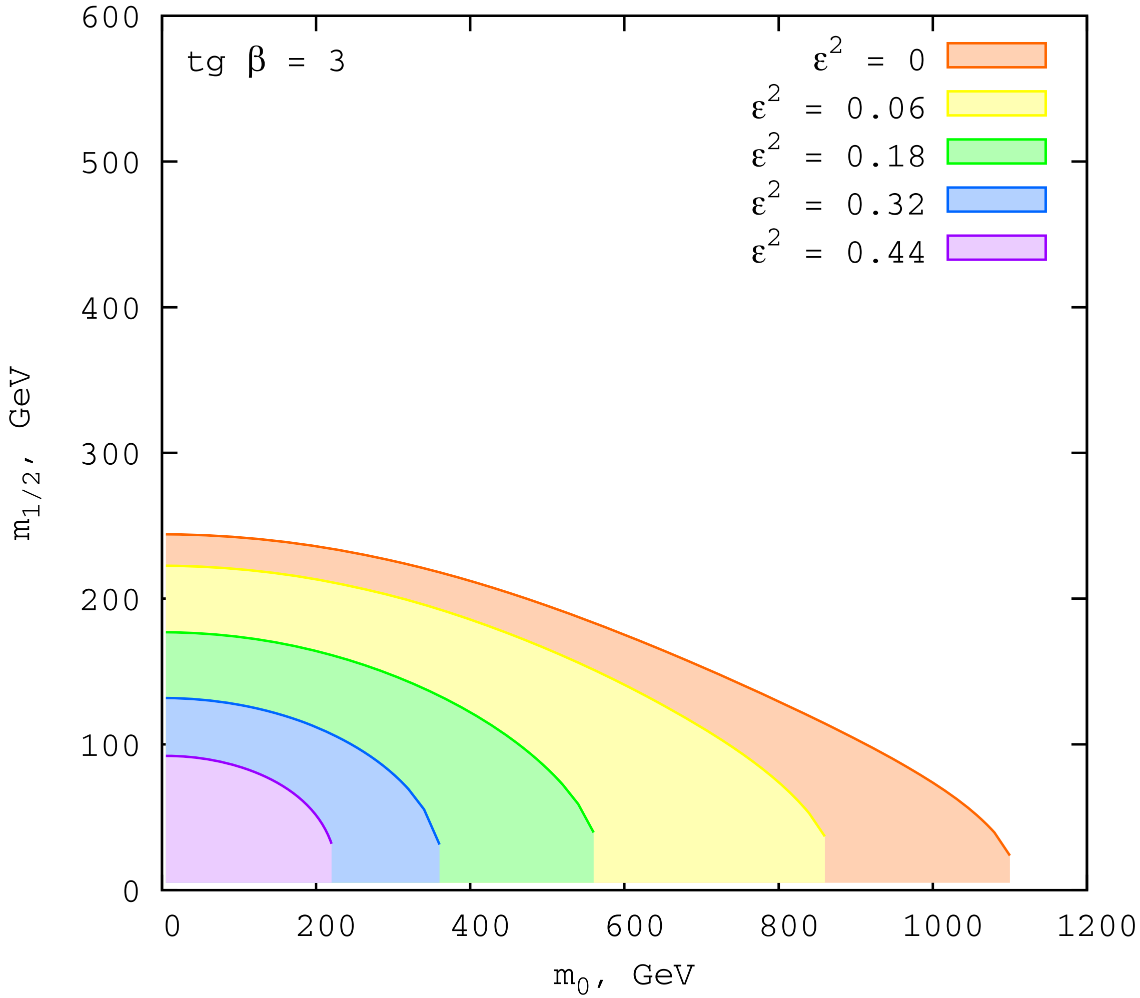
RG evolution of
soft SUSY breaking
mass terms

Constraints on model parameters



Constraints on the parameter space in the MSSM for large tan beta

Constraints on model parameters



Region excluded by non-observation of the light Higgs boson

$$\varepsilon^2 = \frac{|\lambda|^2}{g^2 + g'^2}.$$

Neutrino-neutralino mixing

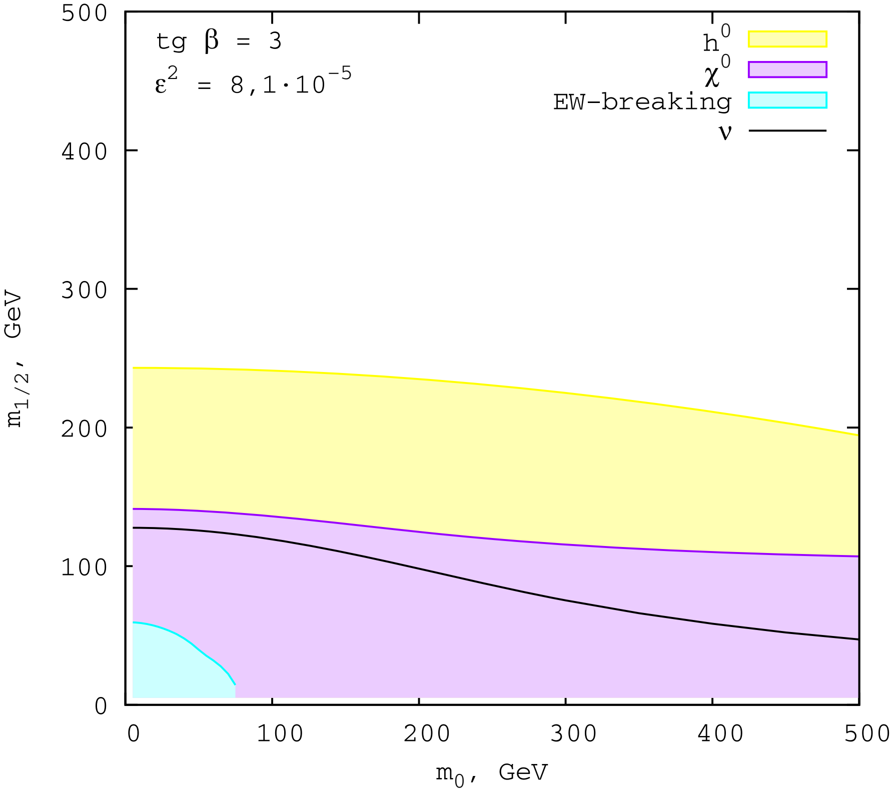
$$-\frac{1}{2}\Big((-\lambda_\nu^i)H_\mathrm{u}^0(\bar{\nu}_i\tilde{H}_\mathrm{d}^0+\tilde{H}_\mathrm{d}^0\bar{\nu}_i)+(-\lambda_\nu^i)H_\mathrm{d}^0(\bar{\nu}_i\tilde{H}_\mathrm{u}^0+\tilde{H}_\mathrm{u}^0\bar{\nu}_i)\Big)$$

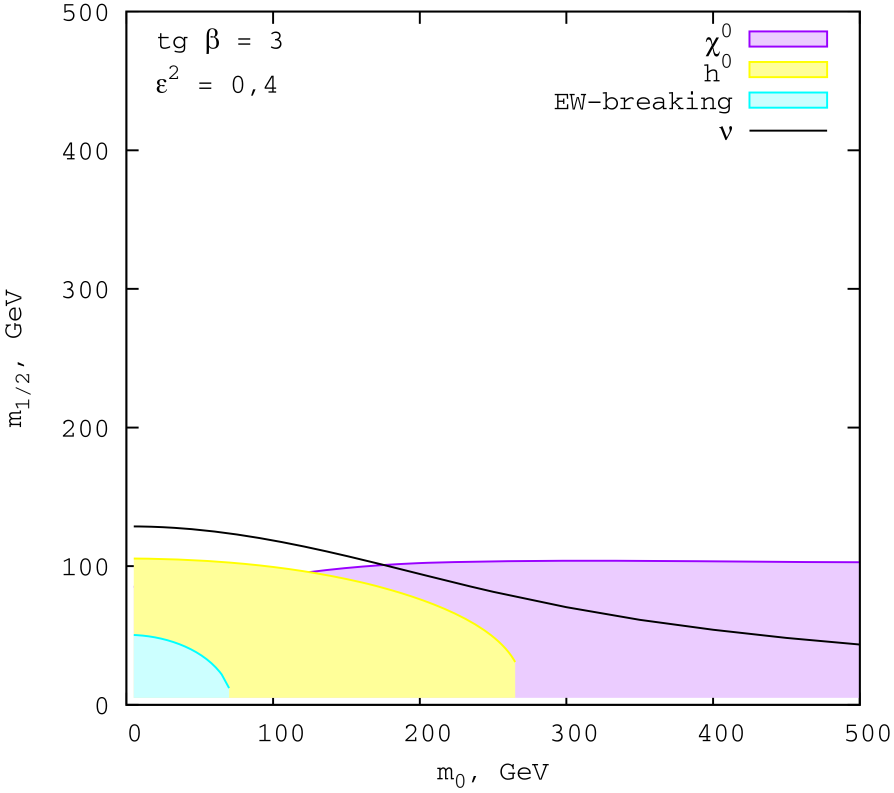
Neutrino-neutralino mass matrix

$$-\frac{1}{2}(\tilde{G}^{0\mathrm{T}}\bar{N}^\mathrm{T}N^\mathrm{T})\begin{pmatrix}\mathbf{M}_{\tilde{G}^0} & \mathbf{M}_{\tilde{G}^0\bar{N}} & 0\\ \mathbf{M}_{\tilde{G}^0\bar{N}}^\mathrm{T} & \mathbf{M}_{\bar{N}} & \mathbf{M}_D\\ 0 & \mathbf{M}_D^\mathrm{T} & 0\end{pmatrix}\begin{pmatrix}\tilde{G}^0\\ \bar{N}\\ N\end{pmatrix}+\mathrm{h.c.},$$

$$\mathbf{M}_{\tilde{G}^0\bar{N}}=\begin{pmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ -\lambda_\nu^1 v_\mathrm{u} & -\lambda_\nu^2 v_\mathrm{u} & -\lambda_\nu^3 v_\mathrm{u}\\ -\lambda_\nu^1 v_\mathrm{d} & -\lambda_\nu^2 v_\mathrm{d} & -\lambda_\nu^3 v_\mathrm{d}\end{pmatrix}=m_\mathrm{Z}\sqrt{\frac{2}{g^2+g'^2}}\begin{pmatrix}0\\ 0\\ -\lambda_\nu^i\sin\beta\\ -\lambda_\nu^i\cos\beta\end{pmatrix}$$

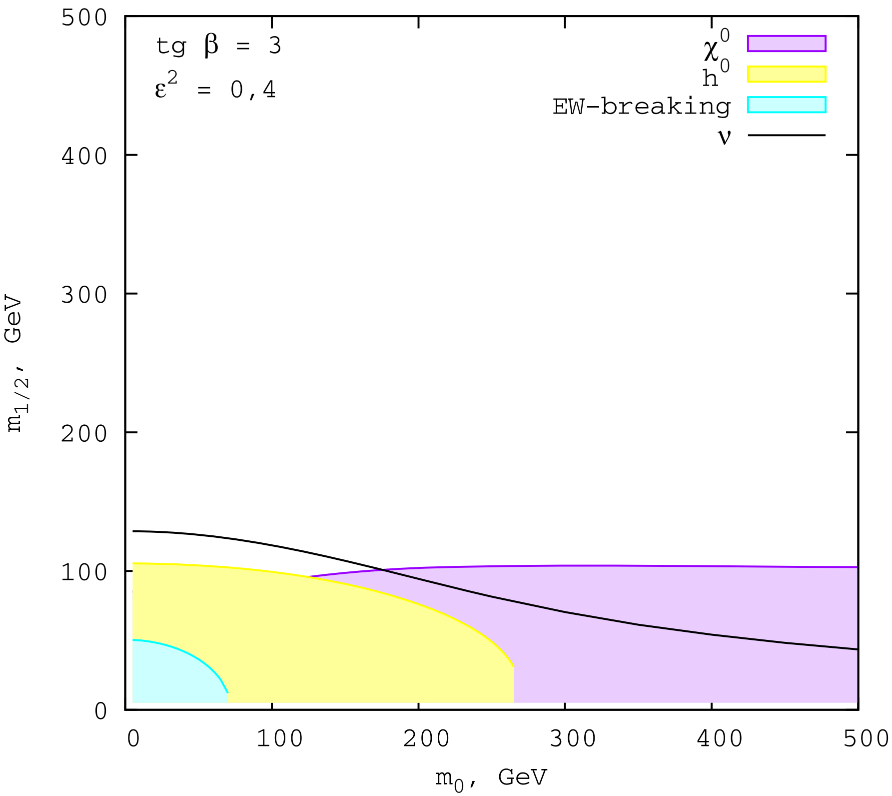
Constraints on model parameters

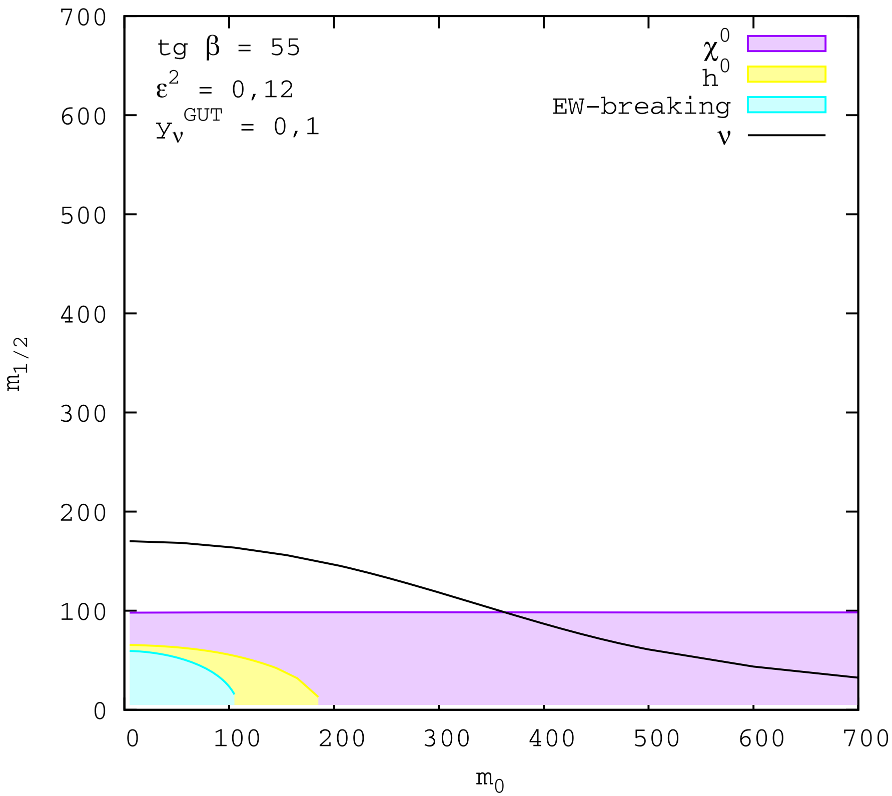




Regions excluded by electroweak symmetry breaking constraint, Higgs and neutralino mass limits

Constraints on model parameters





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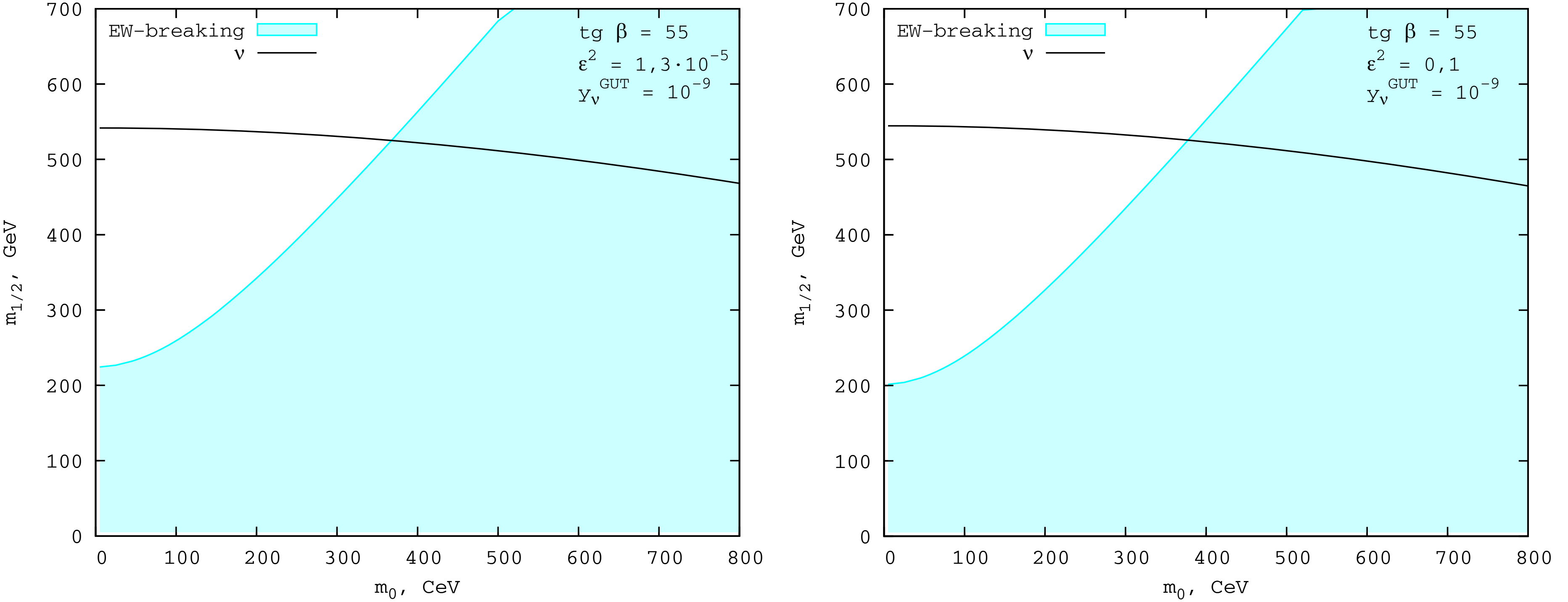

Region excluded by electroweak symmetry breaking constraint

Conclusions

The R-parity broken supersymmetric model with right handed singlet neutrino superfield has been considered

It is shown that Higgs masses are modified due to new couplings

$$m^2_{\mathrm{H}^0,\mathrm{h}^0} = \frac{1}{2}\left(m^2_{\mathrm{A}^0} + m^2_{\mathrm{Z}} \pm \sqrt{(m^2_{\mathrm{A}^0} + m^2_{\mathrm{Z}})^2 - 4m^2_{\mathrm{A}^0} m^2_{\mathrm{Z}} \cos^2 2\beta + \Delta_\varepsilon}\right)$$

$$m^2_{\mathrm{H}\pm} = m^2_{\mathrm{A}^0} + m^2_{\mathrm{W}} - 2\varepsilon^2 m^2_{\mathrm{Z}}. \qquad \varepsilon^2 = \frac{|\bar{\lambda}|^2}{g^2 + g'^2}.$$

RG equations in the model have been obtained

The parameter space of the model is analyzed

Conclusions

The famous MSSM inequality for the lightest Higgs mass is modified

$$m_{h^0}^2 < m_Z^2 \cos^2 2\beta.$$

$$\mathrm{tg}\,\beta \equiv \frac{v_u}{v_d},$$

$$m_{h^0}^2 < m_Z^2 \left(\cos^2 2\beta + 2\varepsilon^2 \sin^2 2\beta\right)$$

$$\varepsilon^2 = \frac{|\lambda|^2}{g^2 + g'^2}.$$

The new contribution could be as large as loop corrections

The low tan beta regime is saved.