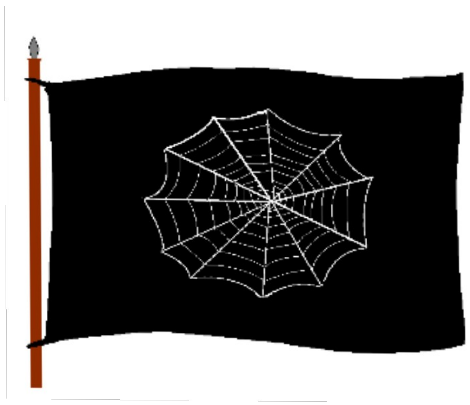
Effects of Sfermion Mixing induced by RGE in the CMSSM



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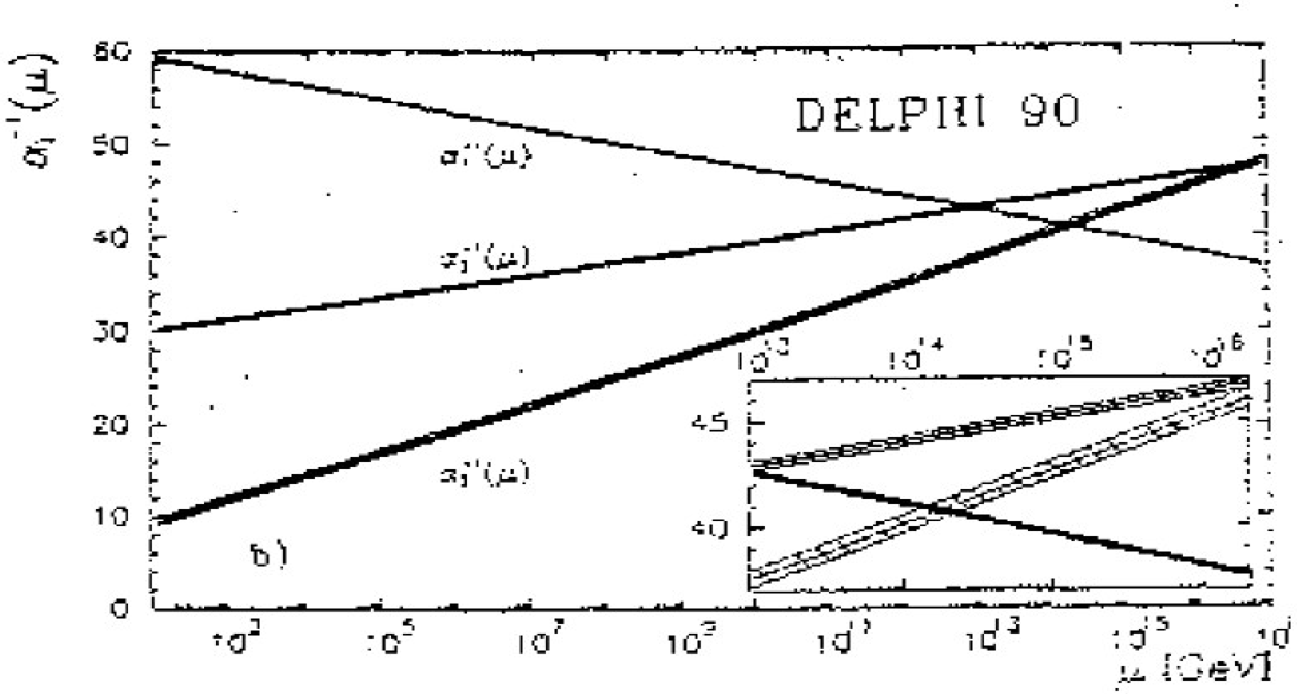
Colaboration with M. Rehman and S. Heinemeyer ArXiv:1501.02258 (Eur.Phys.J.C), arXiv:1408.0663 (PRD) and work in progress ..

- Still SUSY with universal soft terms.
- Sfermion Flavor mixing through the CKM matrix.
- 1-loop contribution to $m_w, \sin^2\theta_w, m_h$
- Mixing in the Slepton sector in the MSSM+ see-saw Typ. I.

SUSY promises

- Divergence cancellations
- Gauge unification
- Particles in the range of coming accelerators.
- DM candidate.
- Small but sizeable contribution to SM processes...

Gran Unification in the SM



$$\mu \frac{d\alpha_i(\mu)}{d\mu} = -\frac{1}{2\pi}\left[b_i + \frac{1}{4\pi}\sum_j b_{ij}\alpha_j(\mu)\right]\alpha_i^2(\mu)$$

$$b_i = (0, -22/3, -11) + N_F(4/3, 4/3, 4/3) + N_H(1/10, 1/6, 0)$$

SUSY extension of the SM

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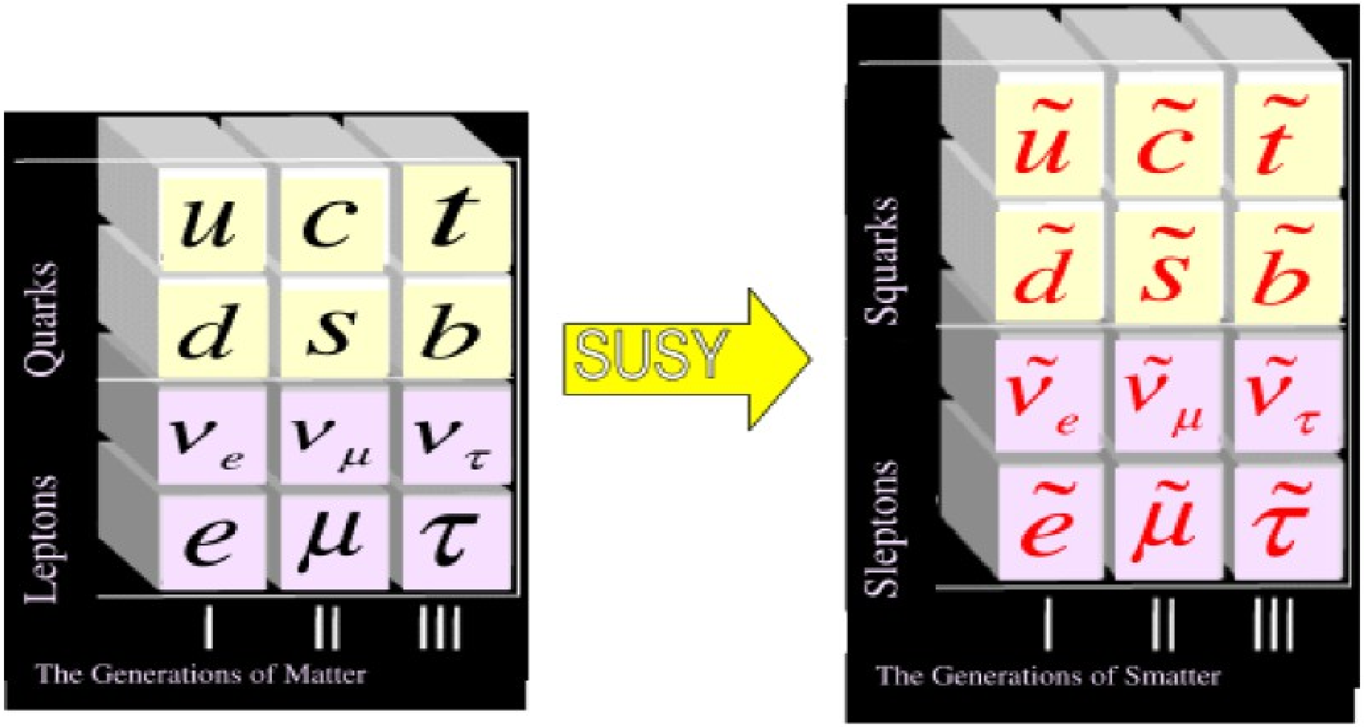
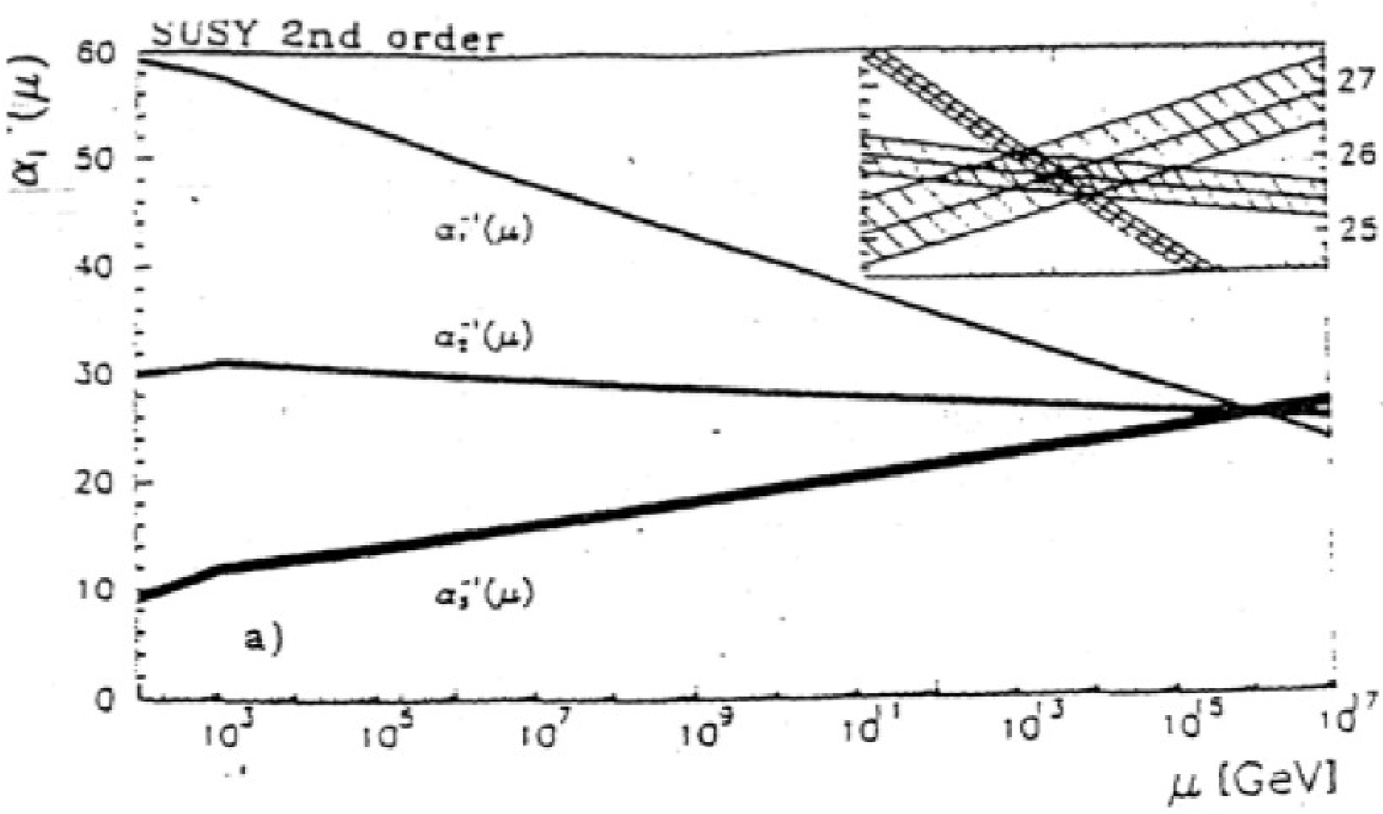


SUSY-> fermion-boson Symmetry:

$$Q|Boson\rangle = |Fermion\rangle; \quad Q|Fermion\rangle = |Boson\rangle$$

SUSY Grand Unification



$$b_i = (0,-6,-9) + N_F(2,2,2) + N_H(3/10,1/2,0)$$

Soft SUSY Breaking Terms

The soft SUSY breaking masses

$$-\mathcal{L}_{\rm soft} = -\frac{1}{2}\left(M_3\,\lambda^a_{\tilde g}\lambda^a_{\tilde g} + M_2\,\lambda^i_{\widetilde W}\lambda^i_{\widetilde W} + M_1\,\lambda_{\widetilde B}\lambda_{\widetilde B} + \text{h.c.}\right)$$
$$+M_L^2\widetilde L^\dagger\widetilde L + M_Q^2\widetilde Q^\dagger\widetilde Q + M_U^2\widetilde U^*\widetilde U + M_D^2\widetilde D^*\widetilde D + M_E^2\widetilde E^*\widetilde E +$$
$$m^2_{H_d}\,\widetilde H_d^\dagger\widetilde H_d + m^2_{H_u}\,H_u^\dagger H_u - \left(B\mu\,\widetilde H_d^T H_u + \text{h.c.}\right)$$
$$+\left(y_\ell A_\ell\,H_d^\dagger\widetilde L\widetilde E + y_d A_d\,H_d^\dagger\widetilde Q\widetilde D - y_u A_u\,H_u^T\widetilde Q\widetilde U + \text{h.c.}\right),$$

Inspired from supergravity assume universal soft breaking, $\mathcal{L}_{\rm soft}$:

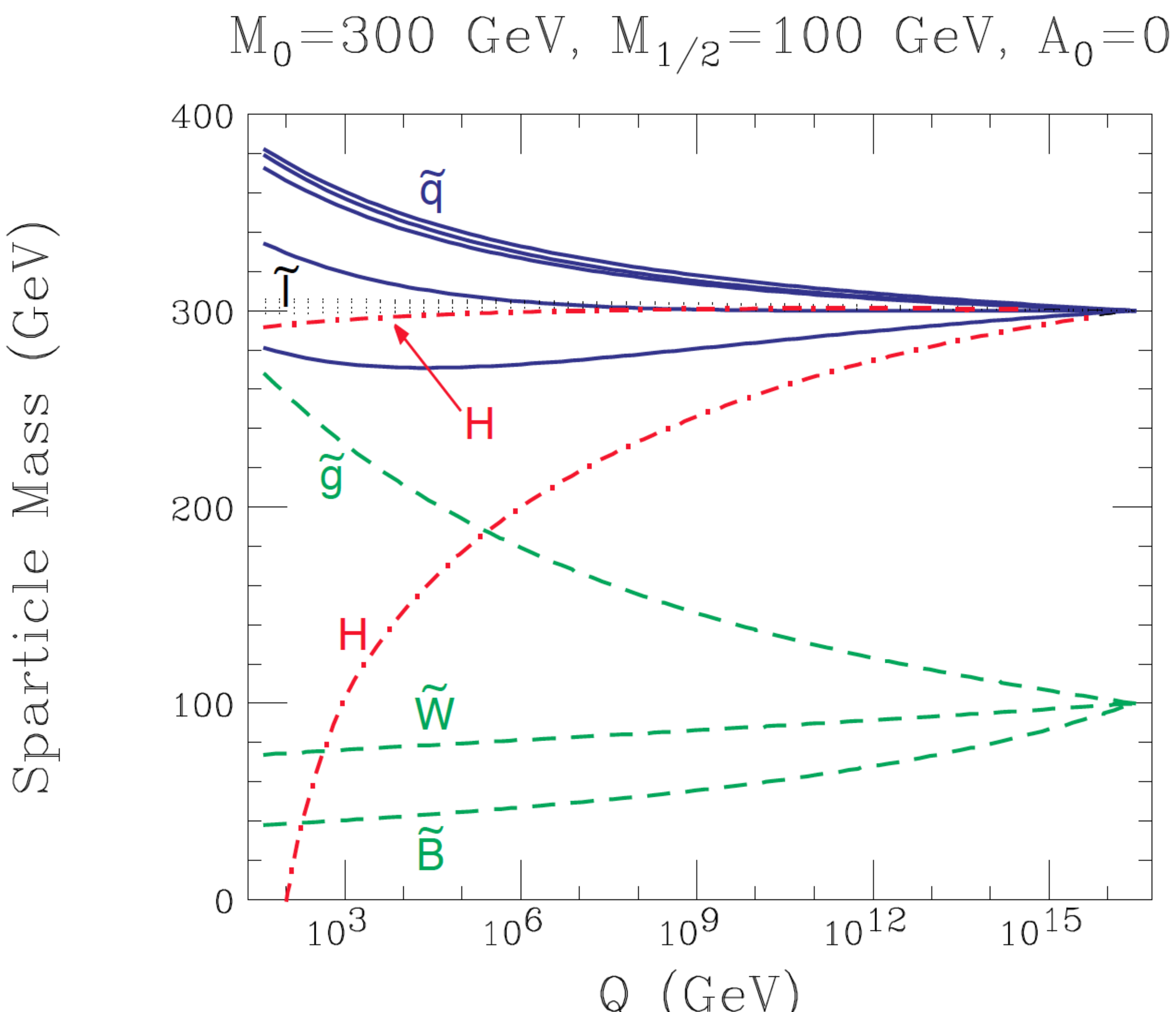
$$\sum_{f,H} m_0^2\tilde f\tilde f + \sum_\lambda m_{\frac{1}{2}}\lambda\lambda + \sum_f A_0 Y_f\tilde f\tilde F H_f + B\mu H_u H_d$$

m_0, $m_{\frac{1}{2}}$, A_0, $\tan\beta$, sign(μ)

μ and A_0 can be complex, however their phases contraint to be $< 0{,}2$ rad by the bounds c

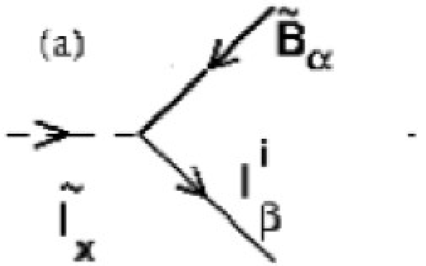
the fermion EDM.

Many new particles at an affordable price

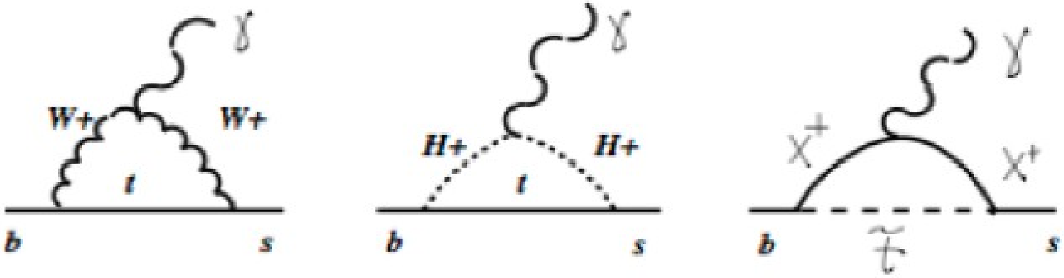


SUSY FLAVOR

R-parity warranties that SUSY particles only appear in pairs:



therefore SM model phenomenology is only modified at *loops level*:



The present average given by the

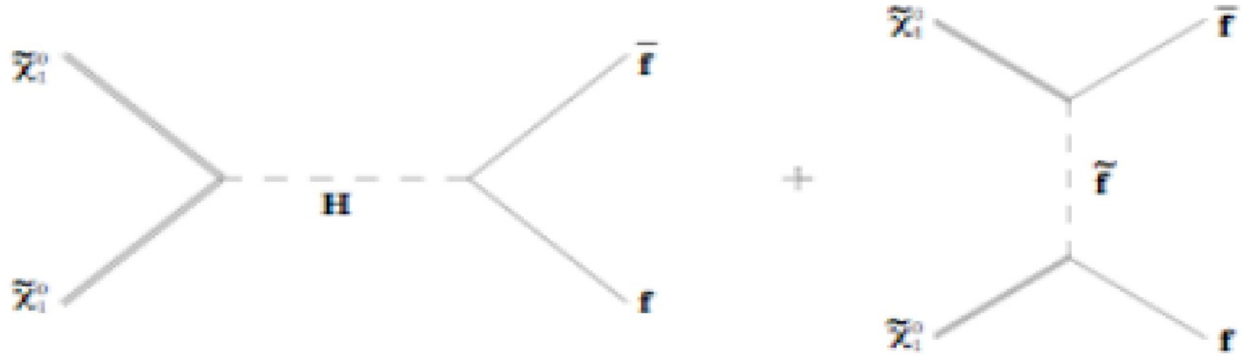
$$BR(b \to s\gamma) = (3{,}55 \pm 0{,}24^{+0{,}09}_{-0{,}10} \pm 0{,}03) \times 10^{-4}$$

The SM prediction: $$BR(b \to s\gamma) = (3.15 \pm 0.30) \times 10^{-4}$$

The lightest SUSY particle (LSP or χ) is in general the lightest neutralin

$$\begin{pmatrix} M_1 & 0 & -m_Z s_{\theta_W} c_\beta & m_Z s_{\theta_W} s_\beta \\ 0 & M_2 & m_Z c_{\theta_W} c_\beta & -m_Z c_{\theta_W} s_\beta \\ -m_Z s_{\theta_W} c_\beta & m_Z c_{\theta_W} c_\beta & 0 & -\mu \\ m_Z s_{\theta_W} s_\beta & -m_Z c_{\theta_W} s_\beta & -\mu & 0 \end{pmatrix}$$

in the basis $\tilde{B}, \tilde{W}_3, \tilde{H}_u, \tilde{H}_d$. They can only coanihilate when they find eac



its relic density is of the order of magnitude needed to fit WMAP data

$$\Omega h^2 \sim \frac{3 \times 10^{-27} \mathrm{cm}^3 s^{-1}}{\langle \sigma_{\mathrm{ann}} v_{Mol} \rangle}$$

H. Goldberg, "Constraint On The Photino Mass From Cosmology," Phys. Rev. Lett. **50**, 1419 (1983).

Minimal Supersymmetric Standard Model (MSSM)

- $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauge invariant and renormalizable superpotential of MSSM is

$$\begin{aligned} W_{\rm MSSM} &= Y_e^{ij}\epsilon_{\alpha\beta}H_1^\alpha E_i^c L_j^\beta + Y_d^{ij}\epsilon_{\alpha\beta}H_1^\alpha D_i^c Q_j^\beta + Y_u^{ij}\epsilon_{\alpha\beta}H_2^\alpha U_i^c Q_j^\beta \\ &+\mu\epsilon_{\alpha\beta}H_1^\alpha H_2^\beta \end{aligned} \quad (3)$$

- Soft SUSY-breaking terms are given by

$$\begin{aligned} -\mathcal{L}_{\rm soft} &= (m^2_{\tilde Q})^j_i \tilde q_L^{\dagger i}\tilde q_{Lj} + (m^2_{\tilde u})^i_j \tilde u^*_{Ri}\tilde u^j_R + (m^2_{\tilde d})^i_j \tilde d^*_{Ri}\tilde d^j_R \\ &+(m^2_{\tilde L})^j_i \tilde l_L^{\dagger i}\tilde l_{Lj} + (m^2_{\tilde e})^i_j \tilde e^*_{Ri}\tilde e^j_R \\ &+\tilde m_1^2 h_1^\dagger h_1 + \tilde m_2^2 h_2^\dagger h_2 + (B\mu h_1 h_2 + {\rm h.c.}) \\ &+(A_d^{ij} h_1 \tilde d^*_{Ri}\tilde q_{Lj} + A_u^{ij} h_2 \tilde u^*_{Ri}\tilde q_{Lj} + A_l^{ij} h_1 \tilde e^*_{Ri}\tilde l_{Lj} \\ &+\frac{1}{2}M_1 \tilde B_L^0 \tilde B_L^0 + \frac{1}{2}M_2 \tilde W_L^a \tilde W_L^a + \frac{1}{2}M_3 \tilde G^a \tilde G^a + {\rm h.c.}). \end{aligned} \quad (4)$$

Soft Susy parameters at GUT

$$(m^2_Q)_{ij} = (m^2_U)_{ij} = (m^2_D)_{ij} = (m^2_L)_{ij} = (m^2_E)_{ij} = m^2_0 \ \delta_{ij},$$
$$m^2_{H_1} = m^2_{H_2} = m^2_0,$$
$$m_{\tilde{g}} = m_{\tilde{W}} = m_{\tilde{B}} = m_{1/2},$$
$$(A_U)_{ij} = A_0 e^{i\phi_A}(Y_U)_{ij}, \quad (A_D)_{ij} = A_0 e^{i\phi_A}(Y_D)_{ij}, \quad (A_E)_{ij} = A_0 e^{i\phi_A}(Y_E)_{ij}.$$

CMSSM choice:

- *m0 Universal soft masses.*
- m1/2 *Universal gaugino masses.*
- A0 *Universal Trilinear terms.*

Yukawa couplings.

- The fermion mass matrices can be obtained trought the quark masses+RGE.
- At the GUT scale:

$$Y_D = diag\left(y_d, y_s, y_b\right);$$

$$Y_U = V^{\dagger}_{CKM}\, diag\left(y_u, y_c, y_t\right);$$

- Superfileds can be rotated. Universal soft terms, remain universal :

$$m_0 I \rightarrow U^{\dagger} \cdot \left(m_0 I\right) \cdot U = m_0 I$$

RGE Evolution

$$\beta^{(1)}_{\mathbf{m}^2_Q} = (\mathbf{m}^2_Q + 2m^2_{H_u})\mathbf{Y}^\dagger_u\mathbf{Y}_u + (\mathbf{m}^2_Q + 2m^2_{H_d})\mathbf{Y}^\dagger_d\mathbf{Y}_d + [\mathbf{Y}^\dagger_u\mathbf{Y}_u + \mathbf{Y}^\dagger_d\mathbf{Y}_d]\mathbf{m}^2_Q + 2\mathbf{Y}^\dagger_u\mathbf{m}^2_u\mathbf{Y}_u$$
$$+ 2\mathbf{Y}^\dagger_d\mathbf{m}^2_d\mathbf{Y}_d + 2\mathbf{h}^\dagger_u\mathbf{h}_u + 2\mathbf{h}^\dagger_d\mathbf{h}_d - \frac{32}{3}g_3^2|M_3|^2 - 6g_2^2|M_2|^2 - \frac{2}{15}g_1^2|M_1|^2 + \frac{1}{5}g_1^2\mathcal{S}$$

$$\beta^{(1)}_{\mathbf{m}^2_u} = (2\mathbf{m}^2_u + 4m^2_{H_u})\mathbf{Y}_u\mathbf{Y}^\dagger_u + 4\mathbf{Y}_u\mathbf{m}^2_Q\mathbf{Y}^\dagger_u + 2\mathbf{Y}_u\mathbf{Y}^\dagger_u\mathbf{m}^2_u + 4\mathbf{h}_u\mathbf{h}^\dagger_u$$
$$- \frac{32}{3}g_3^2|M_3|^2 - \frac{32}{15}g_1^2|M_1|^2 - \frac{4}{5}g_1^2\mathcal{S}$$

$$\beta^{(1)}_{\mathbf{m}^2_d} = (2\mathbf{m}^2_d + 4m^2_{H_d})\mathbf{Y}_d\mathbf{Y}^\dagger_d + 4\mathbf{Y}_d\mathbf{m}^2_Q\mathbf{Y}^\dagger_d + 2\mathbf{Y}_d\mathbf{Y}^\dagger_d\mathbf{m}^2_d + 4\mathbf{h}_d\mathbf{h}^\dagger_d$$
$$- \frac{32}{3}g_3^2|M_3|^2 - \frac{8}{15}g_1^2|M_1|^2 + \frac{2}{5}g_1^2\mathcal{S}$$

$$m^2_{\tilde{U}_L} = \begin{pmatrix} m^2_{\tilde{Q}_1} & \delta^{QLL}_{12} m_{\tilde{Q}_1} m_{\tilde{Q}_2} & \delta^{QLL}_{13} m_{\tilde{Q}_1} m_{\tilde{Q}_3} \\ \delta^{QLL}_{21} m_{\tilde{Q}_2} m_{\tilde{Q}_1} & m^2_{\tilde{Q}_2} & \delta^{QLL}_{23} m_{\tilde{Q}_2} m_{\tilde{Q}_3} \\ \delta^{QLL}_{31} m_{\tilde{Q}_3} m_{\tilde{Q}_1} & \delta^{QLL}_{32} m_{\tilde{Q}_3} m_{\tilde{Q}_2} & m^2_{\tilde{Q}_3} \end{pmatrix}$$

$$m^2_{\tilde{D}_L} = V^\dagger_{\rm CKM}\, m^2_{\tilde{U}_L}\, V_{\rm CKM} ,$$

$$m^2_{\tilde{U}_R} = \begin{pmatrix} m^2_{\tilde{U}_1} & \delta^{URR}_{12} m_{\tilde{U}_1} m_{\tilde{U}_2} & \delta^{URR}_{13} m_{\tilde{U}_1} m_{\tilde{U}_3} \\ \delta^{URR}_{21} m_{\tilde{U}_2} m_{\tilde{U}_1} & m^2_{\tilde{U}_2} & \delta^{URR}_{23} m_{\tilde{U}_2} m_{\tilde{U}_3} \\ \delta^{URR}_{31} m_{\tilde{U}_3} m_{\tilde{U}_1} & \delta^{URR}_{32} m_{\tilde{U}_3} m_{\tilde{U}_2} & m^2_{\tilde{U}_3} \end{pmatrix}$$

$$m^2_{\tilde{D}_R} = \begin{pmatrix} m^2_{\tilde{D}_1} & \delta^{DRR}_{12} m_{\tilde{D}_1} m_{\tilde{D}_2} & \delta^{DRR}_{13} m_{\tilde{D}_1} m_{\tilde{D}_3} \\ \delta^{DRR}_{21} m_{\tilde{D}_2} m_{\tilde{D}_1} & m^2_{\tilde{D}_2} & \delta^{DRR}_{23} m_{\tilde{D}_2} m_{\tilde{D}_3} \\ \delta^{DRR}_{31} m_{\tilde{D}_3} m_{\tilde{D}_1} & \delta^{DRR}_{32} m_{\tilde{D}_3} m_{\tilde{D}_2} & m^2_{\tilde{D}_3} \end{pmatrix}$$

$$v_2 \mathcal{A}^u = \begin{pmatrix} m_u A_u & \delta^{ULR}_{12} m_{\tilde{Q}_1} m_{\tilde{U}_2} & \delta^{ULR}_{13} m_{\tilde{Q}_1} m_{\tilde{U}_3} \\ \delta^{ULR}_{21} m_{\tilde{Q}_2} m_{\tilde{U}_1} & m_c A_c & \delta^{ULR}_{23} m_{\tilde{Q}_2} m_{\tilde{U}_3} \\ \delta^{ULR}_{31} m_{\tilde{Q}_3} m_{\tilde{U}_1} & \delta^{ULR}_{32} m_{\tilde{Q}_3} m_{\tilde{U}_2} & m_t A_t \end{pmatrix}$$

$\delta^{AB}_{ij} \neq 0$ Due of the presence of the CKM

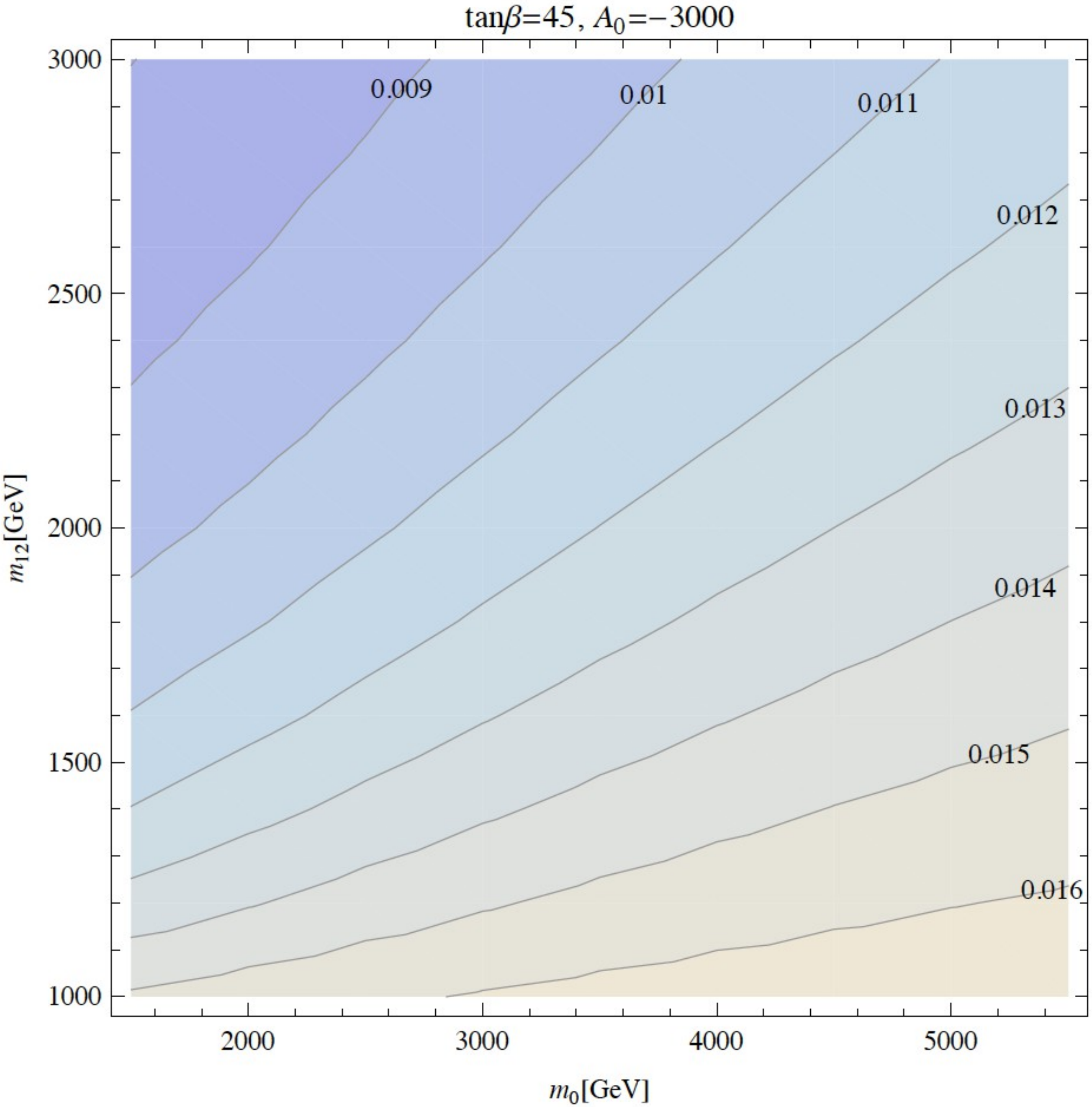
Sfermion masses diagonalization

$$\mathcal{M}_{\tilde{q}}^2 = \begin{pmatrix} M^2_{\tilde{q}\,LL} & M^2_{\tilde{q}\,LR} \\ M^{2\,\dagger}_{\tilde{q}\,LR} & M^2_{\tilde{q}\,RR} \end{pmatrix}, \qquad \tilde{q} = \tilde{u}, \tilde{d}\ ,$$

$$\begin{aligned} \mathrm{diag}\{m^2_{\tilde{u}_1}, m^2_{\tilde{u}_2}, m^2_{\tilde{u}_3}, m^2_{\tilde{u}_4}, m^2_{\tilde{u}_5}, m^2_{\tilde{u}_6}\} &= R^{\tilde{u}}\, \mathcal{M}^2_{\tilde{u}}\, R^{\tilde{u}\dagger}\ , \\ \mathrm{diag}\{m^2_{\tilde{d}_1}, m^2_{\tilde{d}_2}, m^2_{\tilde{d}_3}, m^2_{\tilde{d}_4}, m^2_{\tilde{d}_5}, m^2_{\tilde{d}_6}\} &= R^{\tilde{d}}\, \mathcal{M}^2_{\tilde{d}}\, R^{\tilde{d}\dagger}\ . \end{aligned}$$

- *Use Spheno to run MSSM RGE's from GUT to low energy. The full 3-generations RGE are used.*

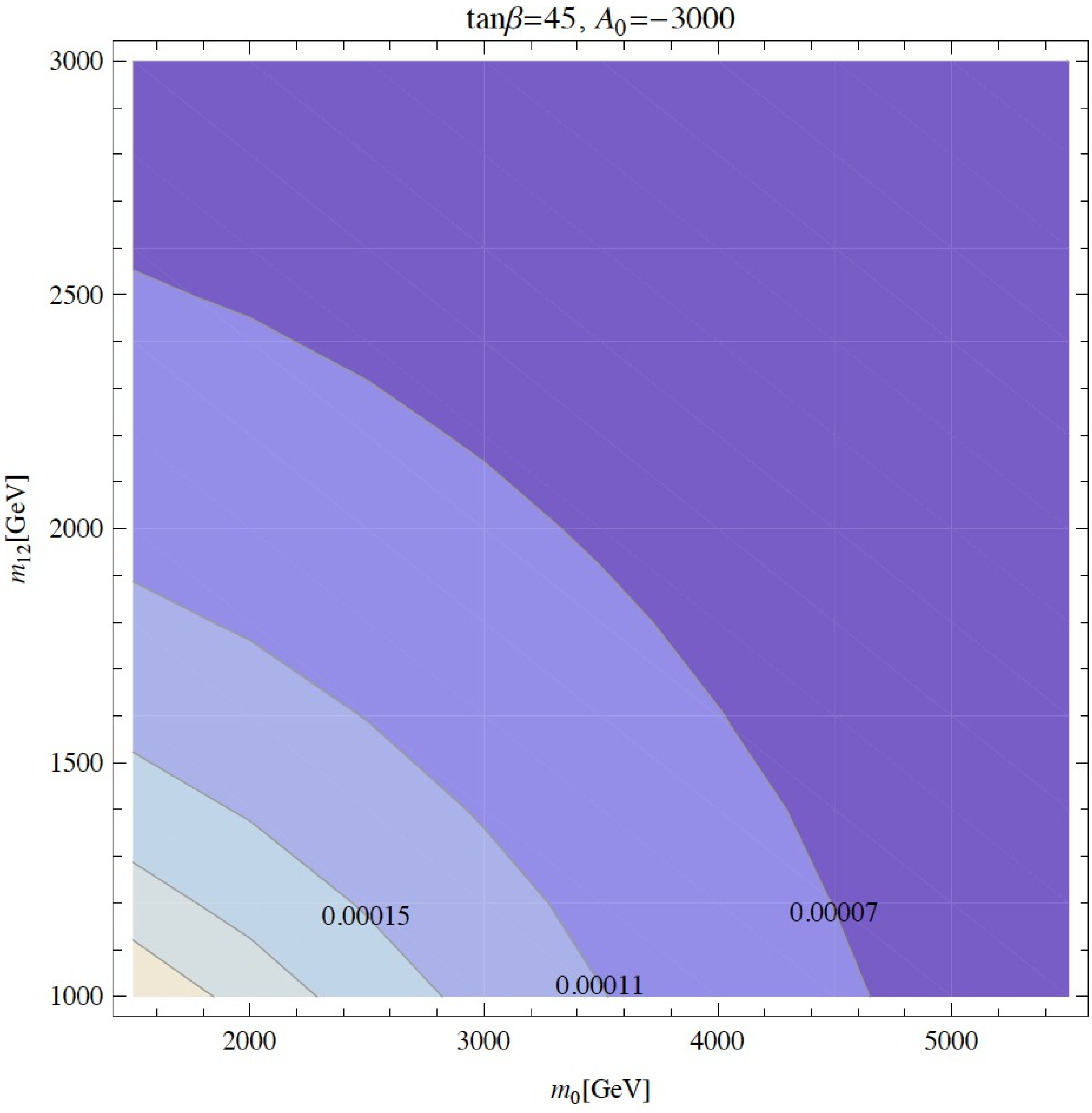
$$
\begin{aligned}
m_0 &= 500 \text{ GeV} \ldots 5000 \text{ GeV} \ , \\
m_{1/2} &= 1000 \text{ GeV} \ldots 3000 \text{ GeV} \ , \\
A_0 &= -3000, -2000, -1000, 0 \text{ GeV} \ , \\
\tan\beta &= 10, 20, 35, 45 \ ,
\end{aligned}
$$



LL Squark flavor mixing

$$\delta_{23}^{QLL}$$

Non decoupling at lage m0



LR Squark flavor mixing

δ_{23}^{ULR}

Decoupling at large m0, since A0 is fixed.

Computational Setup

- Use ***FeynArts*** to compute observables. Modified version to ***include compete 6x6 sfermion mass matrices***.
- Use ***FeynHiggs*** to compute SUSY Higgs masses.
- Use ***SuFla*** to compute B-Physics observables.
- Use ***Spheno*** to run MSSM RGE's from GUT to low energy. ***The full 3.generations RGE are used***.

Electroweak ρ parameter

- ρ parameter is a measure of relative strength of neutral and charged-current interactions at zero momentum transfer. In SM at tree level

$$\rho = \frac{M_W^2}{Cos^2\theta_W M_Z^2} = 1 \tag{16}$$

- Higher order corrections modify this relation to

$$\rho = \frac{1}{1 - \Delta\rho} \tag{17}$$

- Here $\Delta\rho$ parametrizes the leading universal corrections to EWPO induced by the mass splitting between the fields in an isospin doublet

$$\Delta\rho = \frac{\Sigma_{ZZ}(0)}{M_Z} - \frac{\Sigma_{WW}(0)}{M_W} \tag{18}$$

Here $\Sigma_{ZZ}(0)$ and $\Sigma_{WW}(0)$ are unrenormalized Z and W boson self-energies.

δM_W and $\delta Sin^2\theta_{eff}$

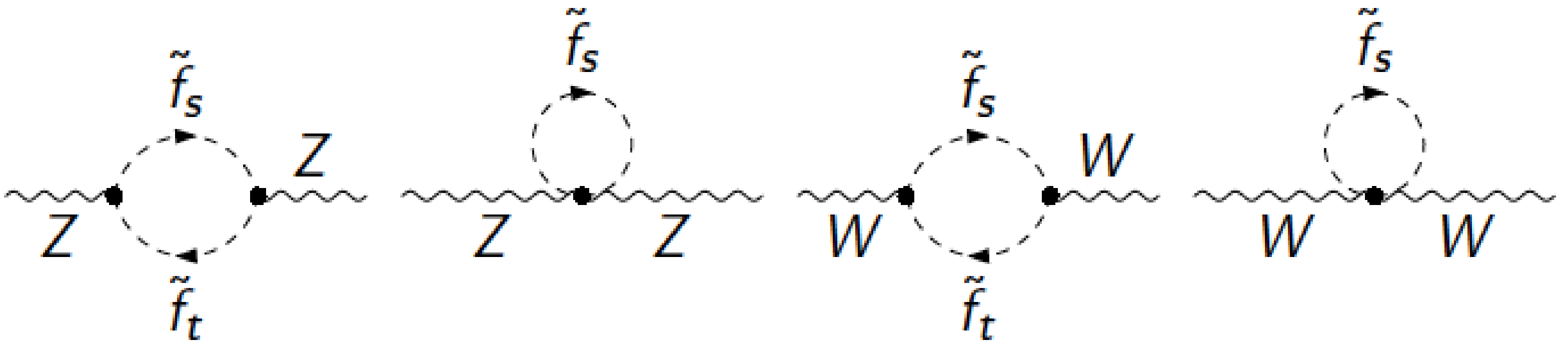
- $\Delta\rho$ enters in δM_W and $\delta Sin^2\theta_{eff}$ through the equation

$$\delta M_W = \frac{M_W}{2}\frac{Cos^2\theta_W}{Cos^2\theta_W - Sin^2\theta_W}\Delta\rho \quad (19)$$

$$\delta Sin^2\theta_{eff} = -\frac{Cos^2\theta_W Sin^2\theta_W}{Cos^2\theta_W - Sin^2\theta_W}\Delta\rho \quad (20)$$

$$(21)$$

Generic Feynman diagrams for the W or Z boson self-energies.



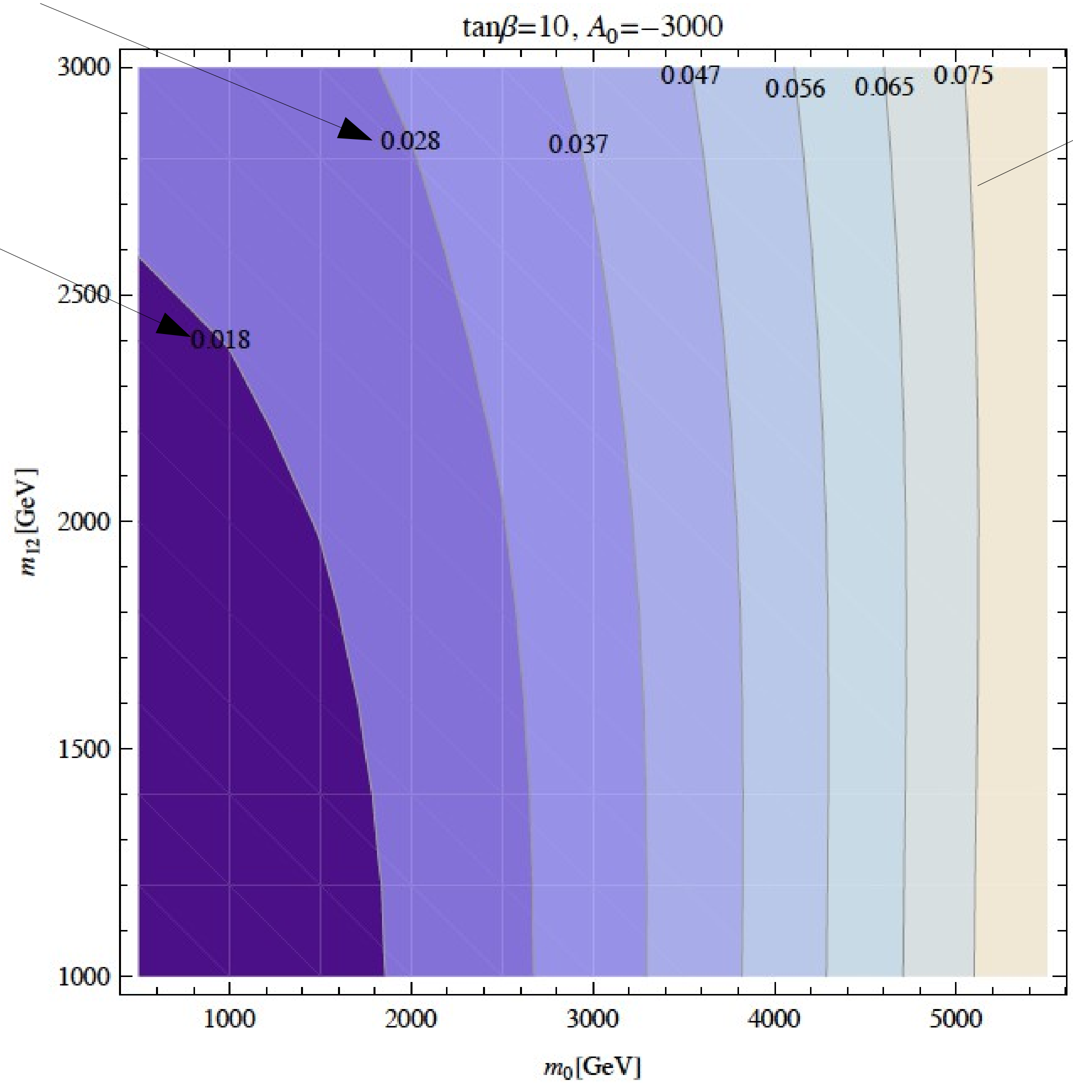
Observables

	Current Values		Future Values
$\delta M_W^{\exp}$	~15 MeV	→	< 4 MeV
δM_W^{theory}	~5-10 MeV	→	< 2 - 4 MeV

$$\Delta M_W^{\mathrm{MFV}} = M_W - M_W^{\mathrm{MSSM}}$$

28 MeV

18 MeV



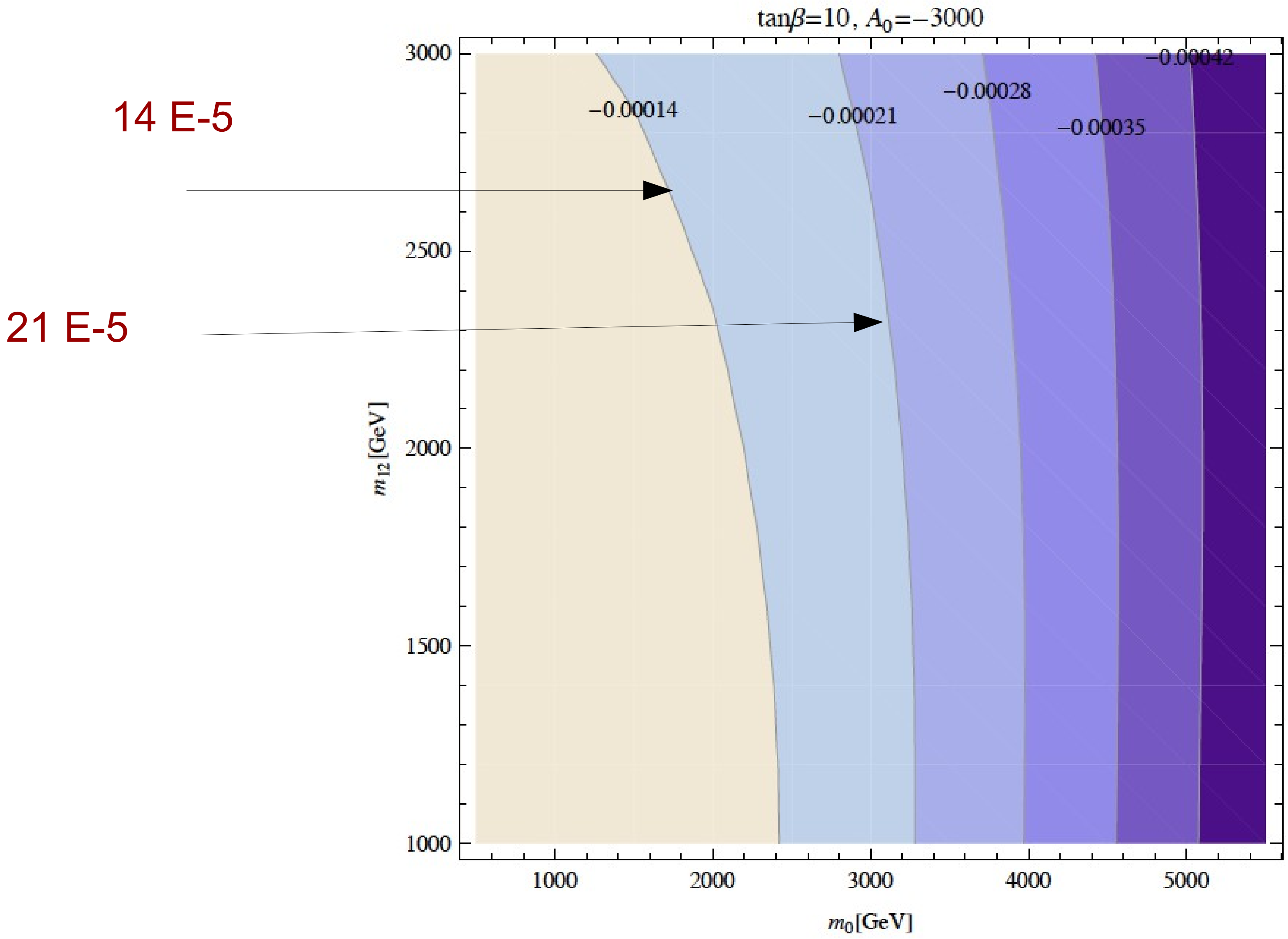
GeV Units

Upper limit for m0??

Observables

	Current Values		Future Values
$\delta \sin^2\theta_{eff}^{exp}$	~15 E-5	→	< 1.3 E-5
$\delta \sin^2\theta_{eff}^{theo}$	~5-7 E-5	→	< 2 -4 E-5

$$\Delta \sin^2 \theta_{\rm eff}^{\rm MFV} = \sin^2 \theta_{\rm eff} - \sin^2 \theta_{\rm eff}^{\rm MSSM}$$



Higgs Masses

- There are two higgs doublets in MSSM resulting in five physical (h, H, A, H^+, H^-) Higgs Bosons.
- Neutral CP-even Higgs boson masses are derived by solving the equation

$$\left[p^2 - m^2_{h,tree} + \hat{\Sigma}_{hh}(p^2)\right]\left[p^2 - m^2_{H,tree} + \hat{\Sigma}_{HH}(p^2)\right] - \left[\hat{\Sigma}_{hH}(p^2)\right]^2 = 0\,. \tag{22}$$

- Charged Higgs mass is derived by the position of the pole in the charged Higgs propagator,

$$p^2 - m^2_{H^\pm,\text{tree}} + \hat{\Sigma}_{H^-H^+}\left(p^2\right) = 0. \tag{23}$$

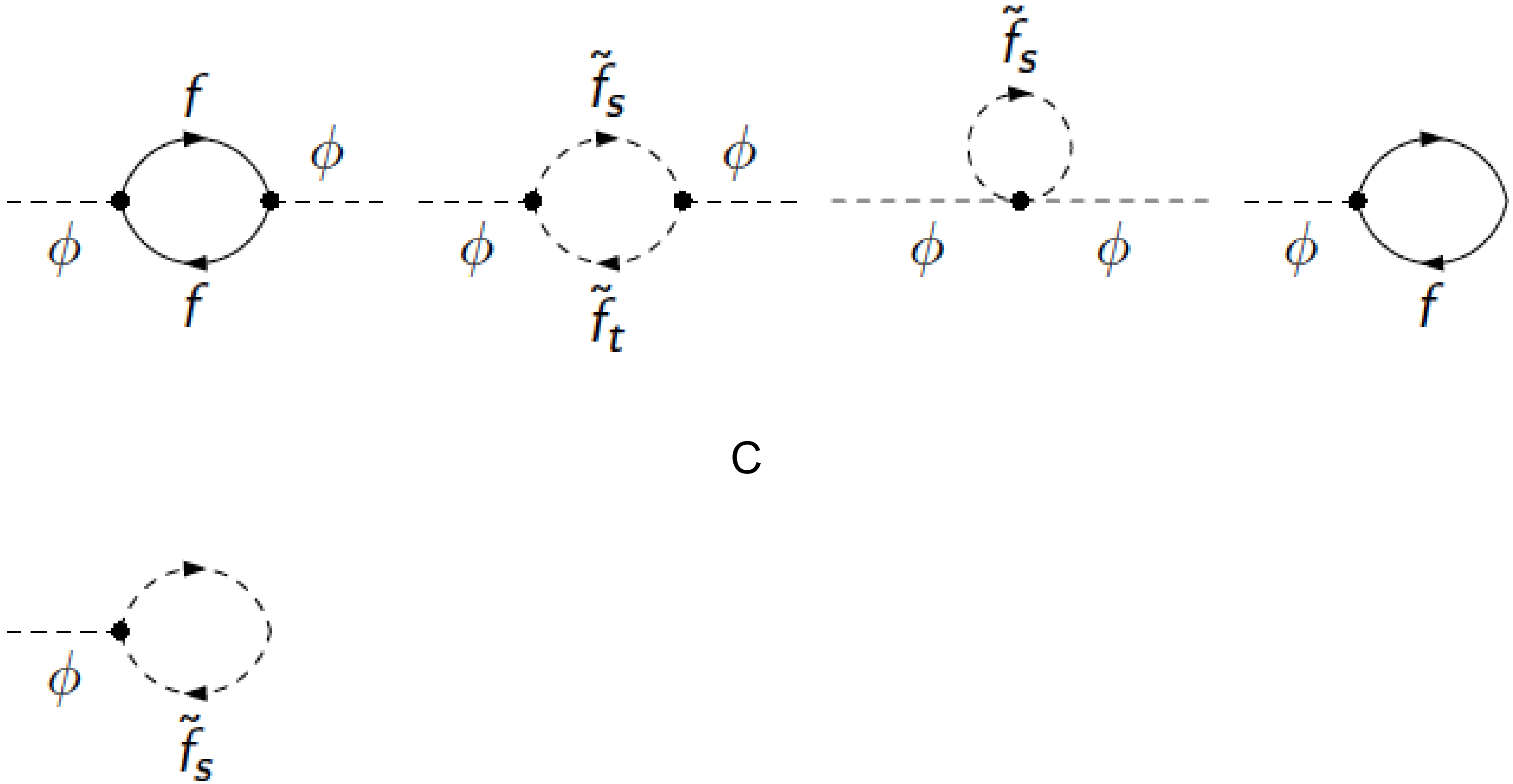
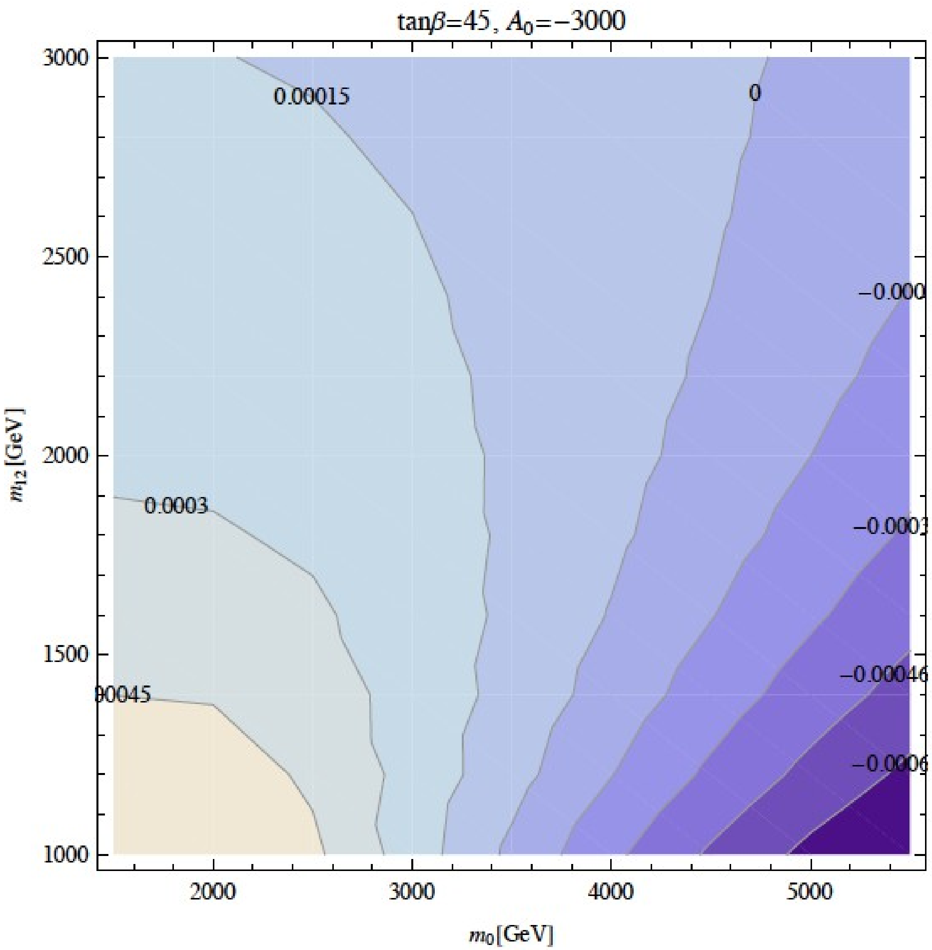


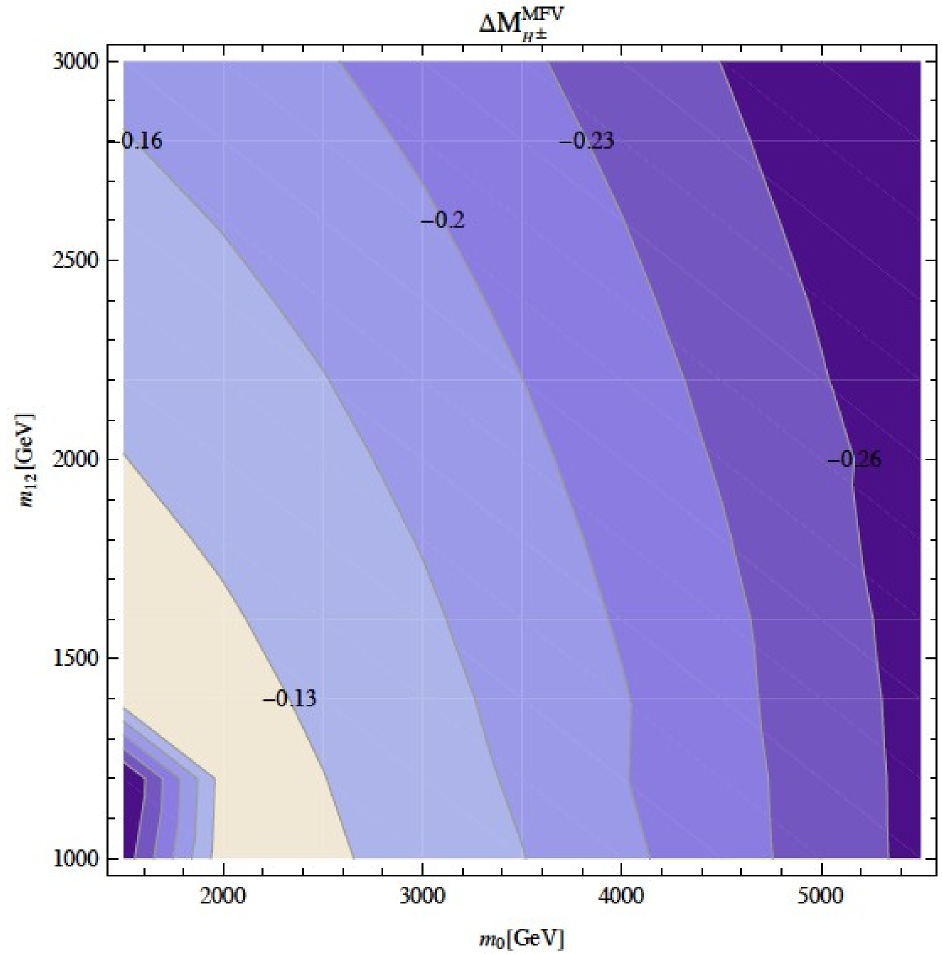
Figure: Generic Feynman diagrams for the Higgs self-energies and tadpoles. ϕ denotes Higgs boson.

Observables

	Current Values		Future Values
$\delta M_h^{\exp}$	~200 MeV	→	< 50 MeV
δM_h^{theory}	~3 GeV	→	< 0.5 GeV

$$\Delta M_h^{\mathrm{MFV}} = M_h - M_h^{\mathrm{MSSM}} \qquad \Delta M_{H^\pm}^{\mathrm{MFV}} = M_{H^\pm} - M_{H^\pm}^{\mathrm{MSSM}}$$





B-Physics Obsevables

1. For $\mathrm{BR}(B \to X_s\gamma)$, loop contributions to the Wilson coefficients come from
   1. Loops with Higgs bosons.
   2. Loops with charginos.
   3. Loops with gluinos.
2. For $\mathrm{BR}(B_s \to \mu^+\mu^-)$, loop contributions to the Wilson coefficients come from
   1. Box diagrams.
   2. Z-penguin diagrams and
   3. Neutral Higgs boson ϕ-penguin diagrams.
3. For ΔM_{B_s}, loop contributions to the Wilson coefficients come from
   1. Box diagrams.
   2. Z-penguin diagrams.
   3. double Higgs-penguin diagrams

B-Phyiscs Observables

Observable	Experimental Value	SM Prediction
$\mathrm{BR}(B \to X_s \gamma)$	$3.43 \pm 0.22 \times 10^{-4}$	$3.15 \pm 0.23 \times 10^{-4}$
$\mathrm{BR}(B_s \to \mu^+ \mu^-)$	$(3.0)^{+1.0}_{-0.9} \times 10^{-9}$	$3.23 \pm 0.27 \times 10^{-9}$
ΔM_{B_s}	$116.4 \pm 0.5 \times 10^{-10}$ MeV	$(117.1)^{+17.2}_{-16.4} \times 10^{-10}$ MeV

The values we get are 1-2 orders of magnitude below limits

Neutrino Oscillations

$$\mathcal{L}_{\mathrm{CC}} = -\frac{g}{\sqrt{2}} \sum_{l=e,\mu,\tau} \overline{l_L}(x)\, \gamma_\alpha\, \nu_{lL}(x)\, W^{\alpha\dagger}(x) + h.c.\,,$$

$$\nu_{l\mathrm{L}}(x) = \sum_{j=1}^{3} U_{lj}\, \nu_{j\mathrm{L}}(x),$$

EW interaction Mixes Lepton Flavor.

There is a matrix: PVMS=U Equivalent to CKM in the Quark sector.

$$P(\nu_{l(l')} \to \nu_{l'(l)}) \cong P(\bar{\nu}_{l(l')} \to \bar{\nu}_{l'(l)}) \cong \delta_{ll'} - 2|U_{ln}|^2 \left[\delta_{ll'} - |U_{l'n}|^2\right] \left(1 - \cos\frac{\Delta m^2_{n1}}{2p} L\right).$$

$$U = \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{bmatrix} \times \mathrm{diag}(1,\ e^{i\frac{\alpha_{21}}{2}},\ e^{i\frac{\alpha_{31}}{2}})\ .$$

Atmospheric problem	Solar problem
$\Delta m^2_{atm} = \left(2.6^{+0.4}_{-0.7}\right) \times 10^{-3}$ eV^2	$\Delta m^2_{sol} = \left(8.1^{+0.5}_{-0.5}\right) \times 10^{-5}$ eV^2
$\sin^2 2\theta_{atm} > 0.90$	$\sin^2 2\theta_{sol} = \left(0.86^{+0.05}_{-0.06}\right)$

$0.06 < \sin^2 2\theta_{13} < 0.13$

Reactor data (RENO, Daya Bay).

MSSM extended by seesaw mechanism

- The superpotential for MSSM-Seesaw I can be written as

$$W = W_{\rm MSSM} + Y_\nu^{ij}\epsilon_{\alpha\beta}H_2^\alpha N_i^c L_j^\beta + \frac{1}{2}M_N^{ij}N_i^c N_j^c, \quad (5)$$

- The full set of soft SUSY-breaking terms is given by,

$$\begin{aligned} -\mathcal{L}_{\rm soft,SI} &= -\mathcal{L}_{\rm soft} + (m_{\tilde\nu}^2)_j^i \tilde\nu_{Ri}^* \tilde\nu_R^j + (\frac{1}{2}B_\nu^{ij}M_N^{ij}\tilde\nu_{Ri}^*\tilde\nu_{Rj}^* \\ &\quad + A_\nu^{ij}h_2\tilde\nu_{Ri}^*\tilde l_{Lj} + {\rm h.c.})\,, \end{aligned} \quad (6)$$

With $W_{\rm MSSM}$ and $\mathcal{L}_{\rm soft}$ given in Eq. 3 and 4 respectively.

$$\mathcal{M} = \begin{pmatrix} 0 & m_\nu^D \\ m_\nu^{D^T} & M_R \end{pmatrix}$$

"See-Saw" explanation for tiny masses.

- The physical masses are:
  1. $m_1 \equiv m_{light} \simeq \frac{(m_\nu^D)^2}{M_R}$
  2. $m_2 \simeq M_R$
- For $(m_\nu^D)_{33} \approx (200 \text{ GeV})$ $(\lambda_\nu \approx \lambda_t)$ and $M_{N_3} \approx O(10^{14} \text{ GeV})$, $m_{eff} \approx 0.05$ eV

$$W = W_{\rm MSSM} + \frac{1}{2}(Y_\nu L H_2)^T M_N^{-1}(Y_\nu L H_2).$$

$$m_{\rm eff} = -\frac{1}{2}v_u^2 Y_\nu \cdot M_N^{-1} \cdot Y_\nu^T, \qquad m_\nu^\delta = U^T m_{\rm eff} U$$

Slepton flavor mixings

$$(m^2_{\tilde{L}})_{ij} \sim \frac{1}{16\pi^2}(6m_0^2 + 2A_0^2)\left({Y_\nu}^\dagger Y_\nu\right)_{ij} \log\left(\frac{M_{\mathrm{GUT}}}{M_N}\right)$$

$$(m^2_{\tilde{e}})_{ij} \sim 0$$

$$(A_l)_{ij} \sim \frac{3}{8\pi^2} A_0 Y_{l\,i}\left({Y_\nu}^\dagger Y_\nu\right)_{ij} \log\left(\frac{M_{\mathrm{GUT}}}{M_N}\right)$$

Orthogonal matrix

$$Y_\nu = \frac{\sqrt{2}}{v_u}\sqrt{M_R^\delta}\,R\,\sqrt{m_\nu^\delta}\,U^\dagger$$

Casas + Ibarra

Diagonal Universal
1E14 GeV

Order 1

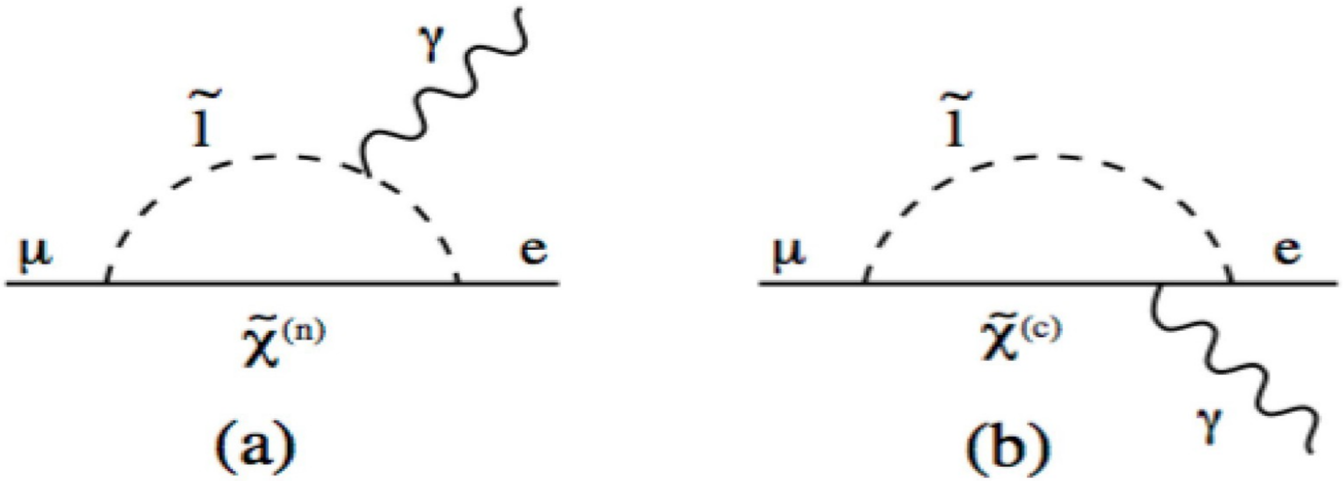
$$Y_\nu^\dagger Y_\nu = \frac{2}{v_u^2} M_R U m_\nu^\delta U^\dagger$$

Limit case of degenerate MR

$$\mathrm{diag}\{m^2_{\tilde{l}_1}, m^2_{\tilde{l}_2}, m^2_{\tilde{l}_3}, m^2_{\tilde{l}_4}, m^2_{\tilde{l}_5}, m^2_{\tilde{l}_6}\} = R^{\tilde{l}}\ \mathcal{M}^2_{\tilde{l}}\ R^{\tilde{l}\dagger}$$

$$\mathrm{diag}\{m^2_{\tilde{\nu}_1}, m^2_{\tilde{\nu}_2}, m^2_{\tilde{\nu}_3}\} = R^{\tilde{\nu}}\ \mathcal{M}^2_{\tilde{\nu}}\ R^{\tilde{\nu}\dagger}$$

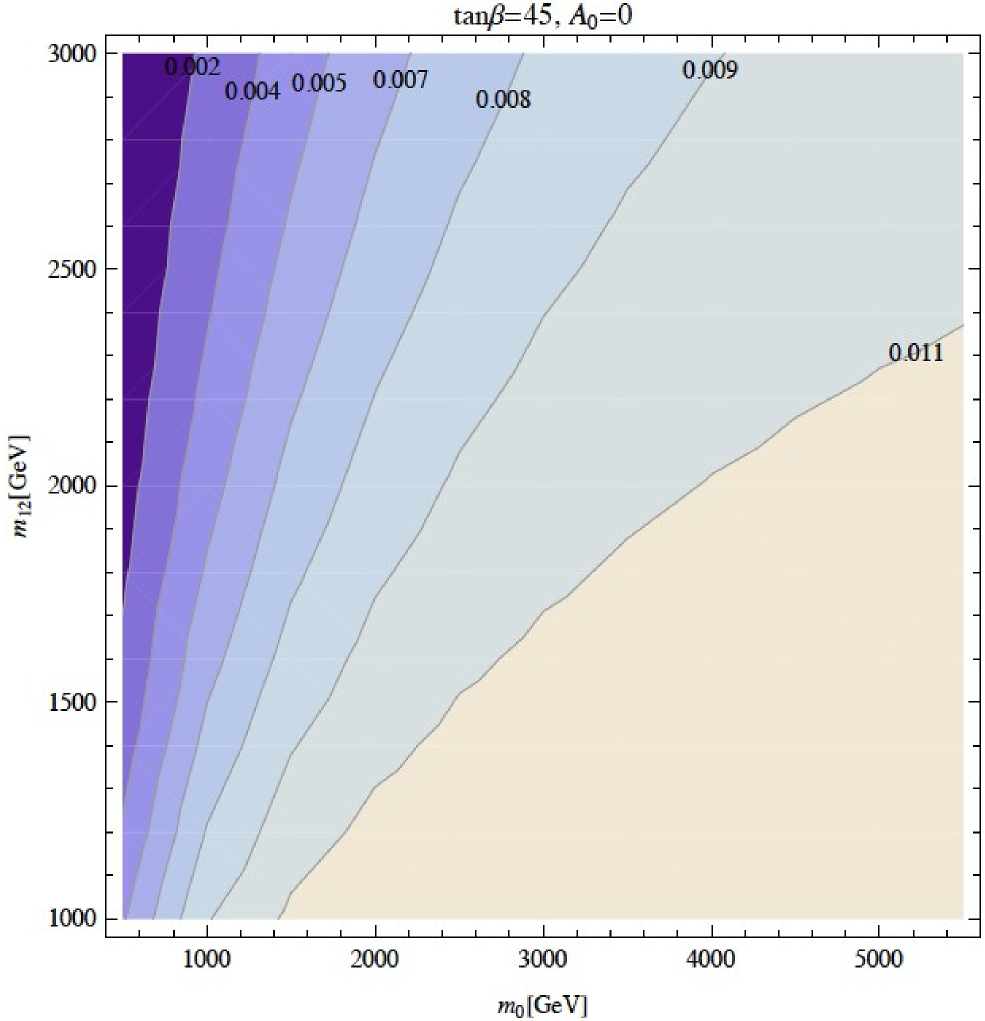
In SUSY flavor mixing lepton-slepton vertices can induce LFV diagrams:

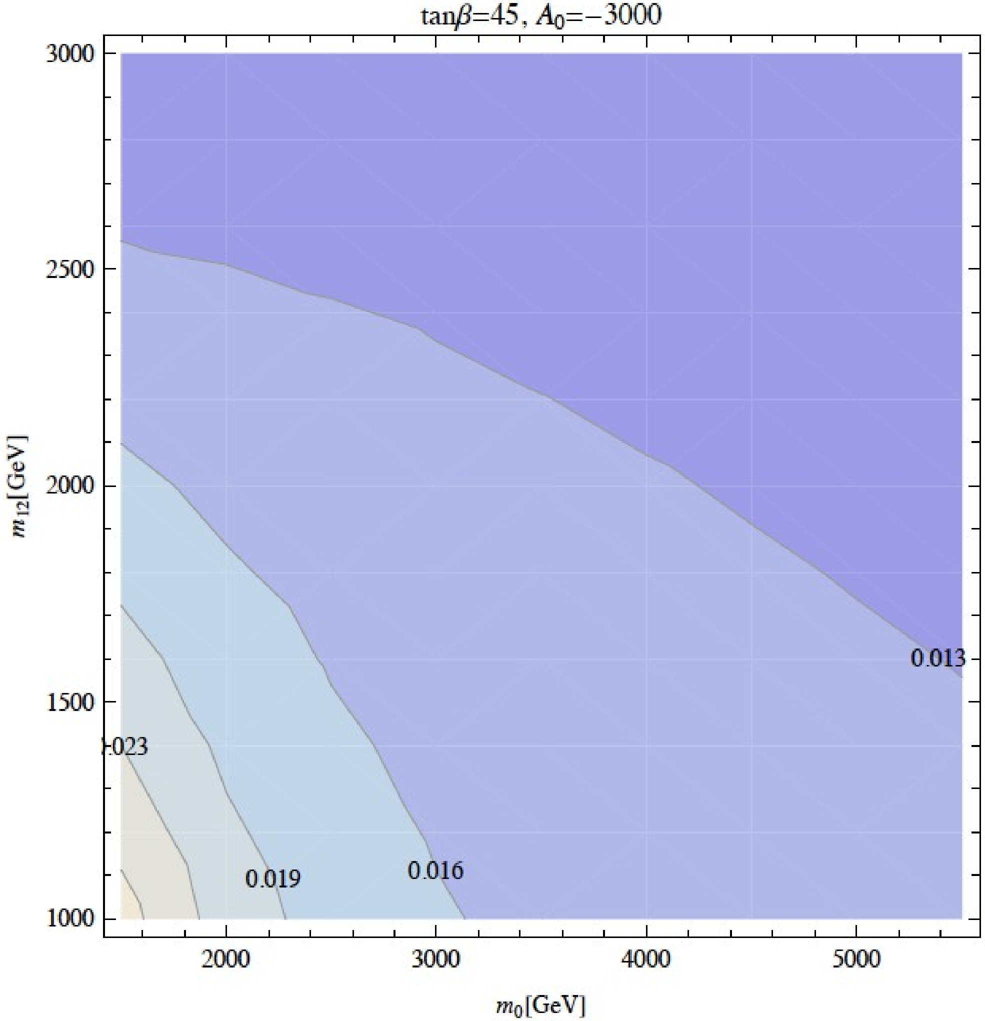


Lepton-slepton flavor mixing is very constrained by the experimental limits:

$$BR(\mu \to e\gamma) < 5.7\,x\,10^{-13}$$
$$BR(\tau \to \mu\gamma) < 4.4\,x\,10^{-8}$$
$$BR(\tau \to e\gamma) < 3.3\,x\,10^{-8}$$

CMSSM-seesaw I

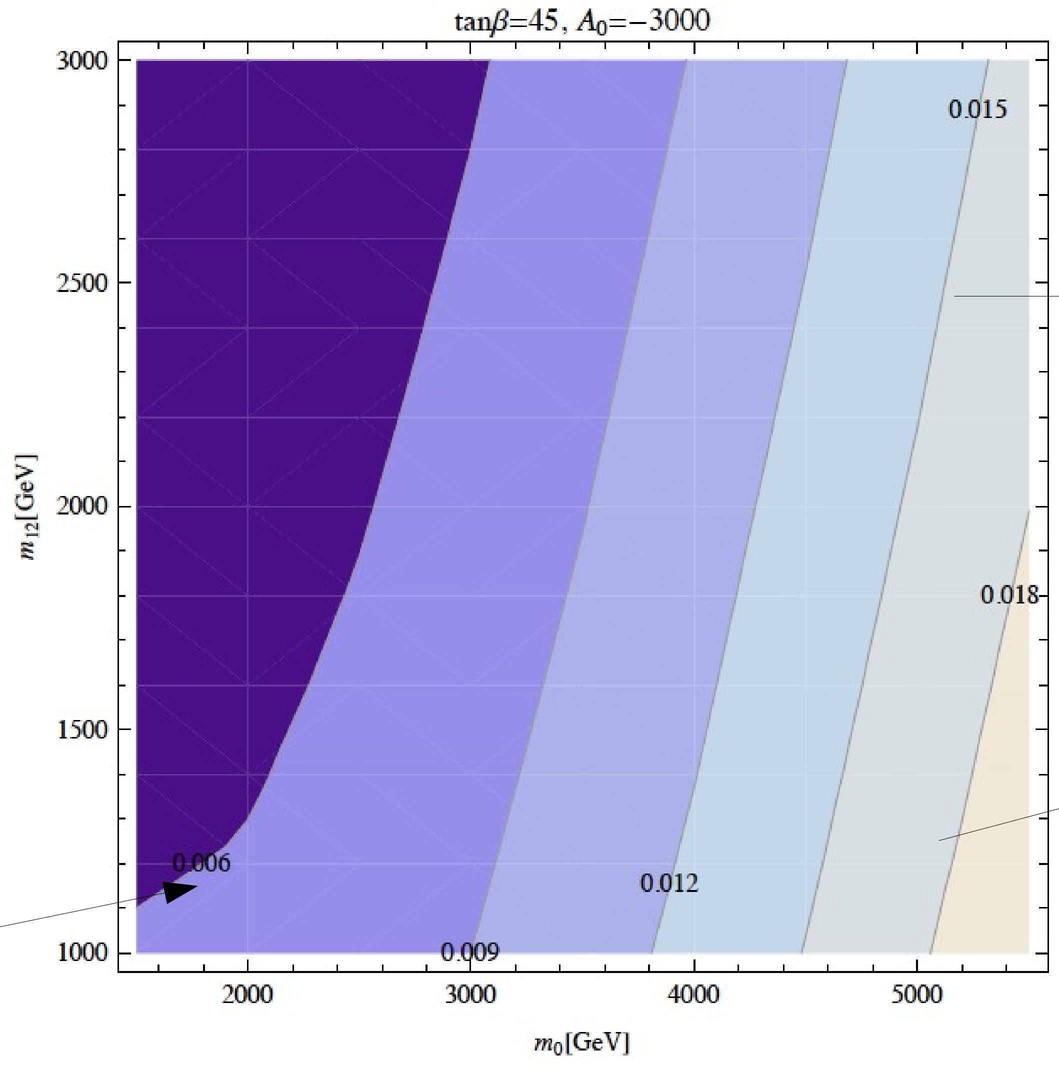




δ_{23}^{LLL}

Big dependence on A0

$$\Delta M_W^{\mathrm{MFV}} = M_W - M_W^{\mathrm{MSSM}}$$

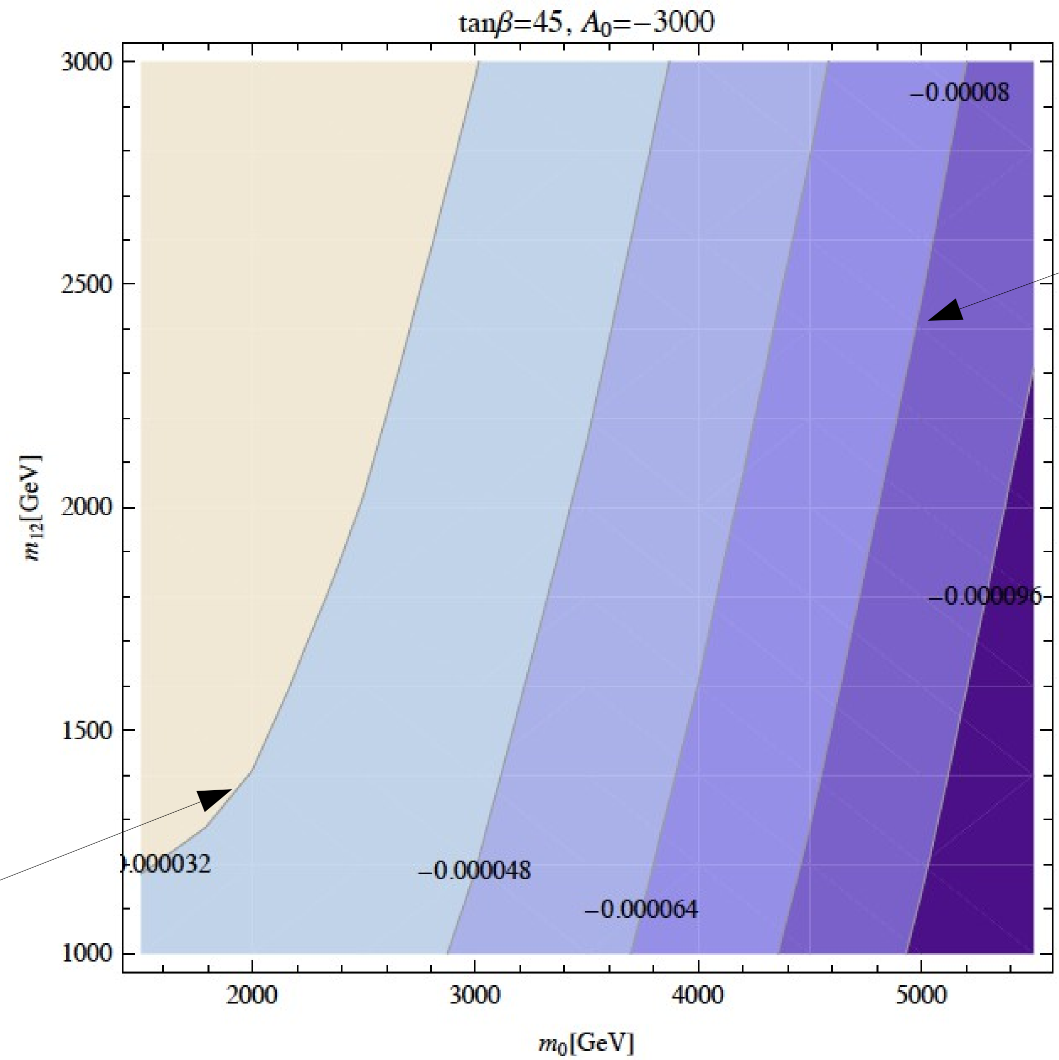


15 MeV

Values in GeV

6 MeV

$$\Delta \sin^2 \theta_{\rm eff}^{\rm MFV} = \sin^2 \theta_{\rm eff} - \sin^2 \theta_{\rm eff}^{\rm MSSM}$$



8 E-5

3.2 E-5

- No significant contribution to Higgs masses (order 1E-7 for Mh and 1E-3 for MH+)

Conclusions

- Analyis of the flavour mixing in the SUSY sector as induced by the CKM. We still work on the CMSSM framwork.
- Diagonalisation matrices included in the susy-vertices

  → taking into account on the 1-loop computations.
- No significant contribution to Higgs masses.
- Non decoupling mixings → contributions to M_W

  and $\sin^2\theta_W$ increases with m0 → Bounds on m0.
- CMSSM+seesaw also has a significant contribution to

  M_W and $\sin^2\theta_W$.