From Flavour to SUSY Flavour Models

Vinzenz Maurer

Max-Planck-Institut für Physik

6th December 2010

IMPRS EPP Workshop

Based on work in progress with Stefan Antusch, Lorenzo Calibbi and Martin Spinrath

Outline

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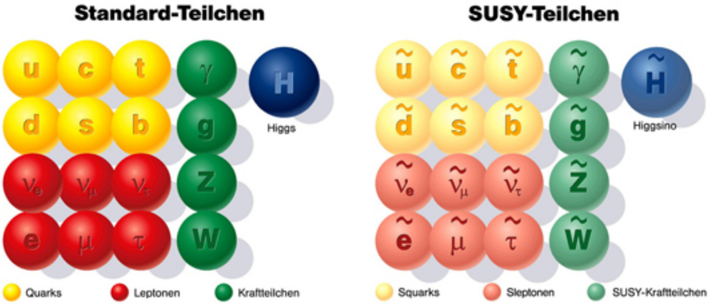
What we want to describe



Outline

Class of Models: Matter Fields

- Symmetries:

$$SU(5) \times G_{\text{family}}$$

- $SU(5) \to$ SM:

$$F = (d^c, L) \quad T = (Q, u^c, e^c)$$

$$Y_d \sim Y_e$$

- Matter fields:

$$F \sim (\bar{5}, 3) \quad T_{1,2,3} \sim (10, 1) \quad N_{1,2} \sim (1, 1)$$

Class of Models: Family Symmetry Breaking

- Flavon fields:

$$\phi_i \sim (1, 3)$$

- G_{family} broken by vevs in the directions [Antusch, King, Spinrath '10]

$$\phi_1 \sim \begin{pmatrix} 0 \\ 1 \\ -1 \end{pmatrix}, \phi_2 \sim \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \tilde{\phi}_2 \sim \begin{pmatrix} 0 \\ \mathrm{i} \\ w \end{pmatrix}, \phi_3 \sim \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

- Yukawa matrices of the form

$$Y \sim \frac{1}{M} \begin{pmatrix} \uparrow & \uparrow & \uparrow \\ \langle\phi_1\rangle & \langle\phi_2\rangle + \langle\tilde{\phi}_2\rangle & \langle\phi_3\rangle \\ \downarrow & \downarrow & \downarrow \end{pmatrix}$$

Matrix Textures

- Y_u, M_N diagonal
- $Y_\nu^T = \begin{pmatrix} 0 & y_1 & -y_1 \\ y_2 & y_2 & y_2 \end{pmatrix}$,

$$Y_d = \begin{pmatrix} 0 & \epsilon_1 & -\epsilon_1 \\ \epsilon_2 & \epsilon_2 + \mathrm{i}\,\tilde{\epsilon}_2 & \epsilon_2 + w\,\tilde{\epsilon}_2 \\ 0 & 0 & \epsilon_3 \end{pmatrix},$$

$$Y_e^T = \begin{pmatrix} 0 & c_1\,\epsilon_1 & -c_1\,\epsilon_1 \\ c_2\,\epsilon_2 & c_2\,\epsilon_2 + \mathrm{i}\,\tilde{c}_2\,\tilde{\epsilon}_2 & c_2\,\epsilon_2 + w\,\tilde{c}_2\,\tilde{\epsilon}_2 \\ 0 & 0 & c_3\,\epsilon_3 \end{pmatrix}$$

with $c_1 = c_2 = c_3 = -\frac{3}{2}, \quad \tilde{c}_2 = 6$ [Antusch, Spinrath '09]

Kähler Potential

- Kähler potential

$$K = F^\dagger F + T_i^\dagger T_i + \frac{\phi_i^\dagger \phi_i}{M^2} F^\dagger F + \frac{\phi_i^\dagger \phi_i}{M^2} T_i^\dagger T_i$$

- Using hierarchy $\epsilon_3 \sim y_b \gg y_{d,s} \sim \epsilon_{1,2,\tilde{2}}$:

$$\tilde{K}_{FF^\dagger} \approx \mathrm{diag}(1, 1, 1 + \zeta^2)$$

with $\zeta^2 \sim \frac{\phi_3^\dagger \phi_3}{M^2}$ $\Rightarrow$ non-canonical kinetic terms

[Antusch, King, Malinsky ’07] [Antusch, Calibbi, V.M., Spinrath in preparation]

Canonical Normalisation

Rescale fields $F \to \mathrm{diag}(1, 1, 1 - \frac{1}{2}\zeta^2)F$

Modified Alignment:

$$Y_\nu^T = \begin{pmatrix} 0 & y_1 & -y_1(1-\frac{1}{2}\zeta^2) \\ y_2 & y_2 & y_2(1-\frac{1}{2}\zeta^2) \end{pmatrix}$$

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- Almost Tribimaximal Mixing [cf. Antusch, King, Malinsky 2008]

$$\sin\theta_{12}^{MNS} \approx \frac{1}{\sqrt{3}}\left(1+\frac{1}{6}\zeta^2\right) \qquad \Rightarrow \theta_{12}^{MNS} \approx 35^\circ$$

$$\sin\theta_{23}^{MNS} \approx \frac{1}{\sqrt{2}}\left(1+\frac{1}{4}\zeta^2\right) \qquad \Rightarrow \theta_{23}^{MNS} \approx 45^\circ$$

$$\theta_{13}^{MNS} \approx \frac{1}{\sqrt{2}}\left(1+\frac{1}{4}\zeta^2\right)\frac{1}{3}\theta_{12}^{CKM} \qquad \Rightarrow \theta_{13}^{MNS} \approx 3^\circ$$

- Normal Hierarchy with

$$0 = m_1 < m_2 < m_3$$

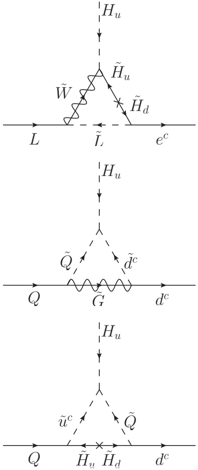
- Maximal CP Violation

$$\delta_{MNS} = -90^\circ$$

Outline

SUSY Threshold Corrections and Parameterisation

Simple formulae for $\tan\beta$ enhanced corrections to Y_d and Y_e



$$y^{SM}_{e,\mu,\tau} \approx (1 + \epsilon_l \tan\beta)\; y^{MSSM}_{e,\mu,\tau} \cos\beta$$
$$y^{SM}_{d,s} \approx (1 + \epsilon_q \tan\beta)\; y^{MSSM}_{d,s} \cos\beta$$
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$$\theta^{SM}_{i3} \approx \frac{1 + \epsilon_q \tan\beta}{1 + (\epsilon_q + \epsilon_A)\tan\beta}\; \theta^{MSSM}_{i3}$$

$$\theta^{SM}_{12} \approx \theta^{MSSM}_{12}$$
$$\delta^{SM}_{CKM} \approx \delta^{MSSM}_{CKM}$$

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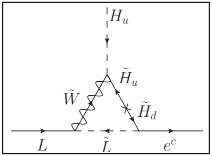

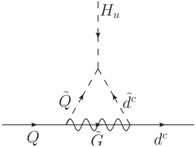

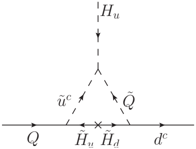

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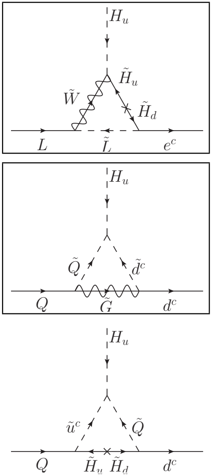

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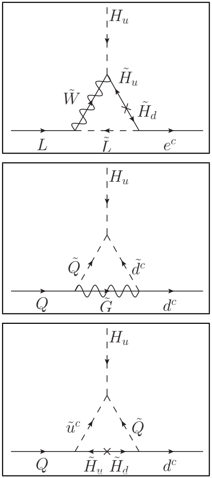

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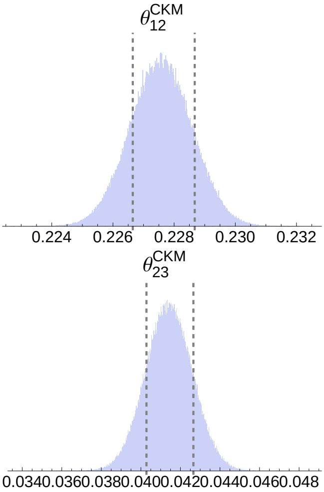
Monte Carlo Markov Chain Results



All masses also in good agreement, minimal total $\chi^2 \approx 1.5$

[Antusch, Calibbi, V.M., Spinrath in preparation]

Constraints on Spectrum

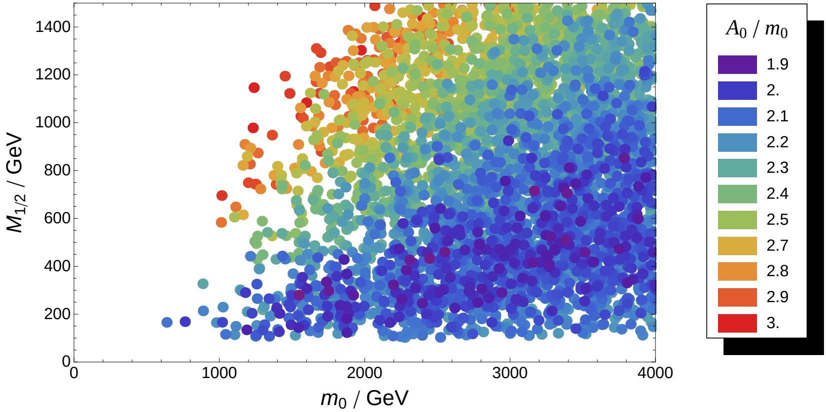


Figure: Points found by Markov chain with $\chi^2 < 3$

[Antusch, Calibbi, V.M., Spinrath in preparation]

Predictions for SUSY Flavour Structure

Incorporate SUSY breaking mediated by supergravity

- Typically SUSY breaking by all fields with vevs

$$F_\phi = \mathcal{O}(1) m_{3/2} \langle \phi \rangle$$

- SUGRA (+ sequestering) results in

$$\tilde{m}^2 = m_{3/2}^2 \tilde{K} - F_{\bar{n}} F_m \partial_{\bar{n}} \partial_m \tilde{K}$$
$$A = A_0 Y + F_m \partial_m Y$$

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Application to our Class of Models

Small Deviations from CMSSM

- Soft masses

$$m^2_{\tilde{F}} = m_0^2 \,\mathrm{diag}(1, 1, 1 - x^2\, \zeta^2)$$

- Trilinear couplings

$$A_d = A_0 \begin{pmatrix} 0 & x_1\, \epsilon_1 & -x_1\, \epsilon_1\, (1 - \frac{1}{2}\zeta^2) \\ x_2\, \epsilon_2 & x_2\, \epsilon_2 + \mathrm{i}\, \tilde{x}_2\, \tilde{\epsilon}_2 & (x_2\, \epsilon_2 + \tilde{x}_2\, w\, \tilde{\epsilon}_2)\, (1 - \frac{1}{2}\zeta^2) \\ 0 & 0 & x_3\, \epsilon_3\, (1 - \frac{1}{2}\zeta^2) \end{pmatrix}$$

$\not\propto Y_d \Rightarrow$ not diagonal in SCKM basis

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Summary

- Extend flavour models to SUSY/SUGRA flavour models
- Keep track of all effects!
  - canonical normalisation
  - SUSY threshold corrections
  - deviations from CMSSM
- Tests for SUSY/SUGRA flavour model
  - SUSY spectrum
  - flavour violation
  - CP violation

Thanks for your attention!