# SUSY flavour problem in 5D GUTs

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Based on current work with Felix Brümmer and Sabine Kraml

# Flavour puzzles

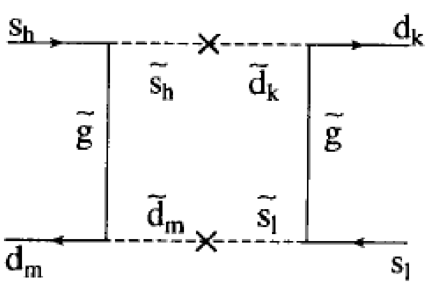


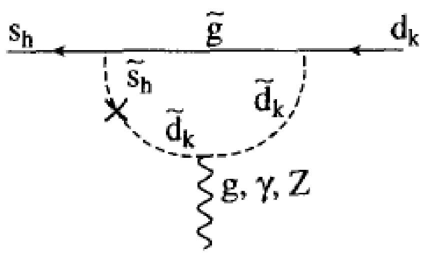
- « SM flavour puzzle » : the CKM matrix and fermion masses have a peculiar, hierarchical structure.

$$m_u \sim \begin{pmatrix} \varepsilon^4 \\ \varepsilon^2 \\ 1 \end{pmatrix} \quad m_d \sim \begin{pmatrix} \varepsilon^3 \\ \varepsilon^2 \\ \varepsilon \end{pmatrix} \quad V_{CKM} \sim \begin{pmatrix} 1 & \varepsilon & \varepsilon^3 \\ \varepsilon & 1 & \varepsilon^2 \\ \varepsilon^3 & \varepsilon^2 & 1 \end{pmatrix}$$

Why ?

- « SUSY flavour problem » : the SUSY breaking mass matrices of sfermions can induce large flavour changing neutral currents (FCNCs).



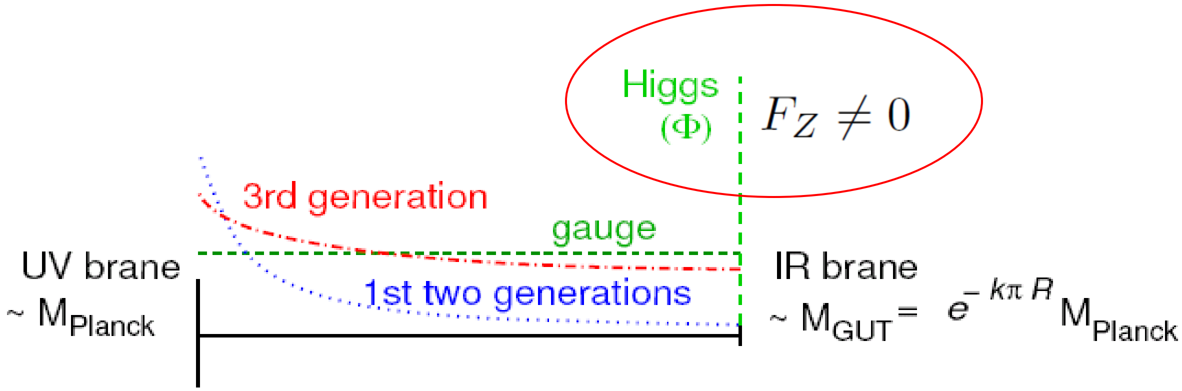




Why not observed ?

Approach (« flavourful SUSY ») : the mechanism producing flavour structure also gives a structure to SUSY breaking mass matrices, avoiding FCNCs.

# A 5D realization

- Holographic GUT framework : Higgses on the IR brane, other fields in the bulk.




- Wave-function localization of matter fields gives the structure to yukawa matrices :

$$Y_u = \begin{pmatrix} \varepsilon^4 & \varepsilon^3 & \varepsilon^2 \\ \varepsilon^3 & \varepsilon^2 & \varepsilon \\ \varepsilon^2 & \varepsilon & 1 \end{pmatrix} \qquad Y_d = Y_l^t = \varepsilon \begin{pmatrix} \varepsilon^2 & \varepsilon^2 & \varepsilon^2 \\ \varepsilon & \varepsilon & \varepsilon \\ 1 & 1 & 1 \end{pmatrix}$$

and SUSY breaking terms :

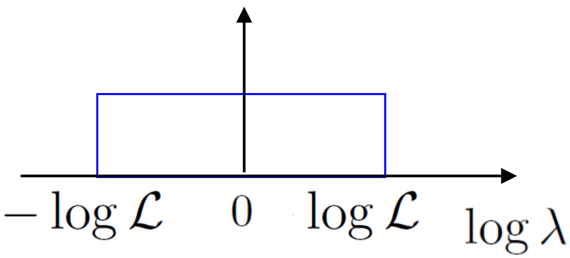
$$A_{u,d,l} \sim \frac{F_Z}{M_*} Y_{u,d,l} \qquad m^2_{Q,U,E} \sim \left|\frac{F_Z}{M_*}\right|^2 \begin{pmatrix} \varepsilon^4 & \varepsilon^3 & \varepsilon^2 \\ \varepsilon^3 & \varepsilon^2 & \varepsilon \\ \varepsilon^2 & \varepsilon & 1 \end{pmatrix} \quad m^2_{D,L} \sim \left|\frac{F_Z}{M_*}\right|^2 \varepsilon^2 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

# O(1) coefficients and parametrization

- In these flavour models, one starts from anarchical matrices, and a mechanism (wave-function localization, Frogatt-Nielsen) produces the hierarchical structure.
  ⇒ each matrix element is defined up to an O(1) coefficient $\lambda_{ij}$ .

- Huge number of $\lambda_{ij}$ : 114
  Neglect CP violation, so take them real. But still freedom on ± signs.

- Magnitude of $\lambda_{ij}$ is unknown.
  We parametrize it on $[1/\mathcal{L}, \mathcal{L}]$ , giving a logarithmic prior :




- Parametrization of the model : $\frac{F_Z}{M_*}$ , $\tan\beta$ , $\mathcal{L}$ , and a coefficient $\alpha_{1/2}$

  such that $M_{1/2} = \alpha_{1/2}\frac{F_Z}{M_*}$ .

# Statistics on the light SUSY spectrum

- The $\lambda_{ij}$ strongly influence the GUT scale eigenvalues, and the sleptons running through the RG invariant S :

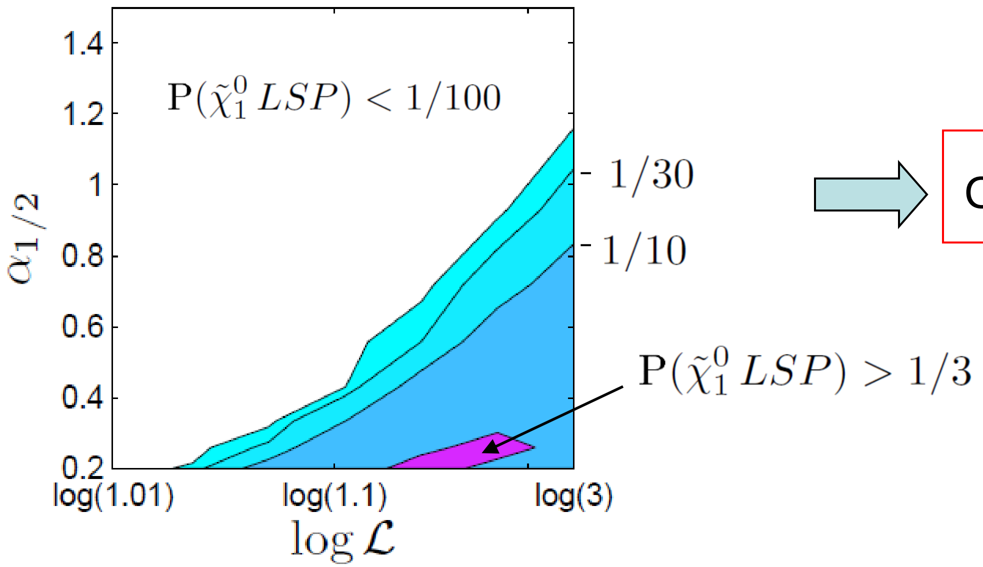
$$S = \left| \frac{F_Z}{M_*} \right|^2 (\lambda^Q_{33} + \lambda^E_{33} - 2\lambda^U_{33})\varepsilon_3^2 + \ldots$$

Sleptons RGEs :

$$16\pi^2 \frac{d}{dt} m^2_{\tilde{e}} = -6 g_2^2 |M_2|^2 - \frac{6}{5} g_1^2 |M_1|^2 - \frac{3}{5} g_1^2 S$$

$$16\pi^2 \frac{d}{dt} m^2_{\tilde{L}} = -\frac{24}{5} g_1^2 |M_1|^2 + \frac{6}{5} g_1^2 S$$

- Probability of having a neutralino LSP :




→ Constraint on $\alpha_{1/2}$ and $\mathcal{L}$

- Depending on $\lambda_{ij}$ sign combinations and $\mathcal{L}$ , mass insertions $\delta_{ij}^X = \frac{\mathcal{M}_{ij}^X}{\sqrt{\mathcal{M}_{ii}^X \mathcal{M}_{jj}^X}}$ responsible of flavour violation can be suppressed.

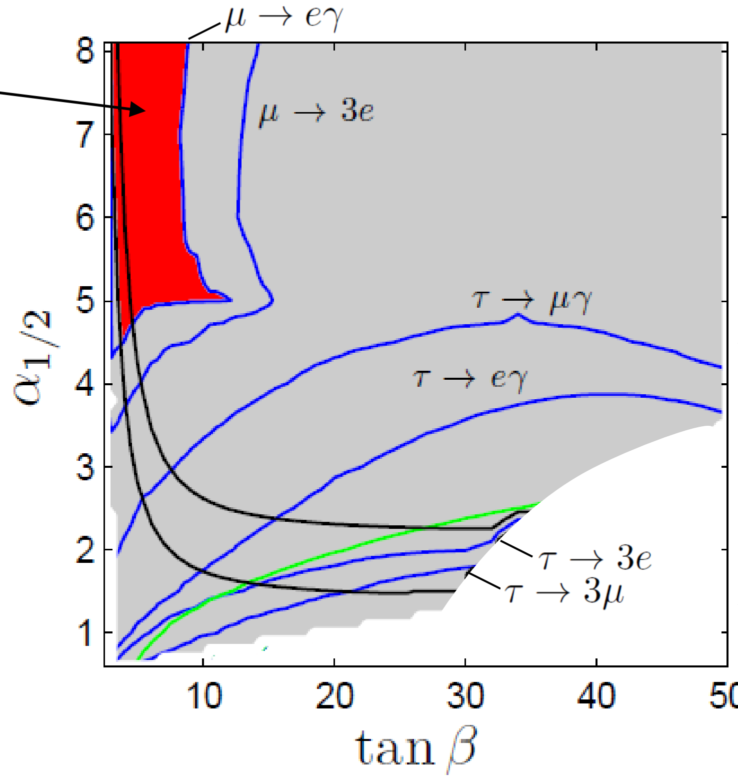
- Case without cancellations : example for $F_Z/M_* = 200\,\mathrm{GeV}$

good

Dark : Higgs mass bound at 111 and 114 GeV

Green : $(g_\mu - 2)/2$

⇨ No neutralino LSP.




gluino mass :

← 2 TeV

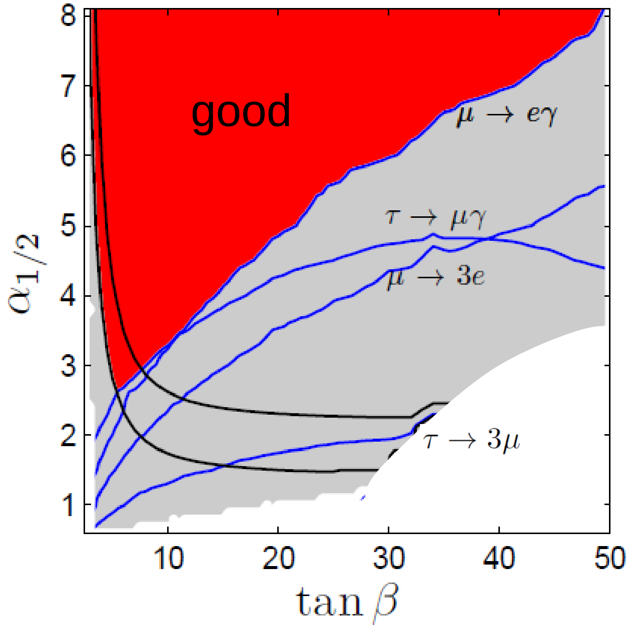
← 700 GeV

Need to go to much higher scale : $F_Z/M_* = 2600\,\mathrm{GeV}$ , or assume an alternative dark matter scenario.

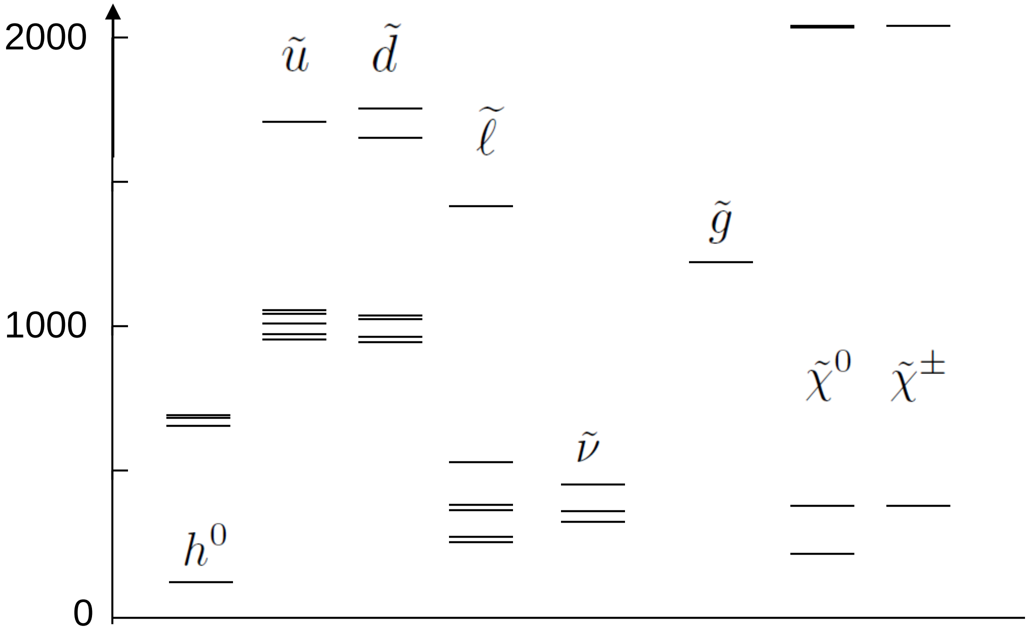
- Case with $\delta_{12}^{LL}$ and $\delta_{12}^{RR}$ suppressed (~3% probability)
  Example for $F_Z/M_* = 200\,\mathrm{GeV}$ :

  ⇨ Neutralino LSP possible for

  $$F_Z/M_* \gtrsim 600\,\mathrm{GeV}$$




- A spectrum at this scale :



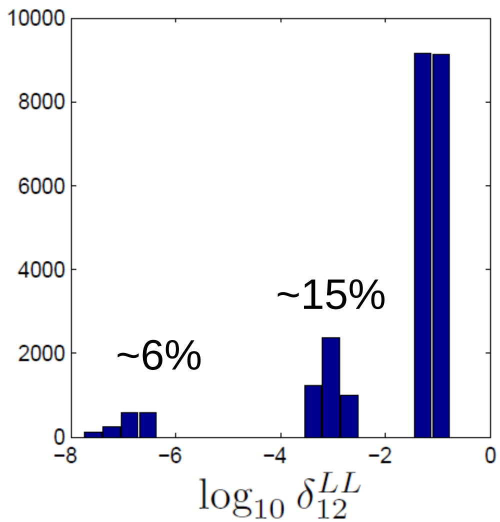
Thanks

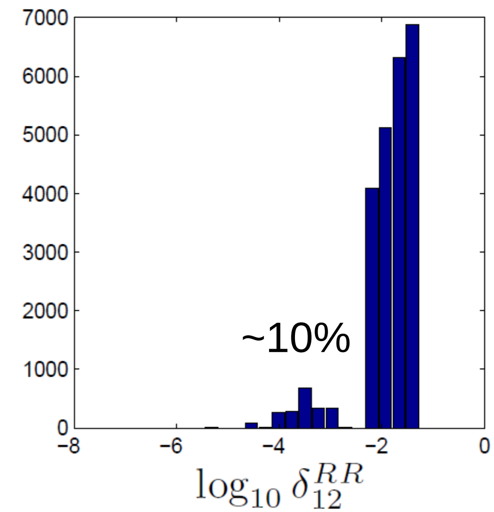
# Extras

# Statistics on FCNCs

- Distribution of mass insertions $\delta_{ij}^X$ among all sign combinations of $\lambda_{ij}$ :

$$\delta_{ij}^X = \frac{\mathcal{M}_{ij}^X}{\sqrt{\mathcal{M}_{ii}^X \mathcal{M}_{jj}^X}}$$

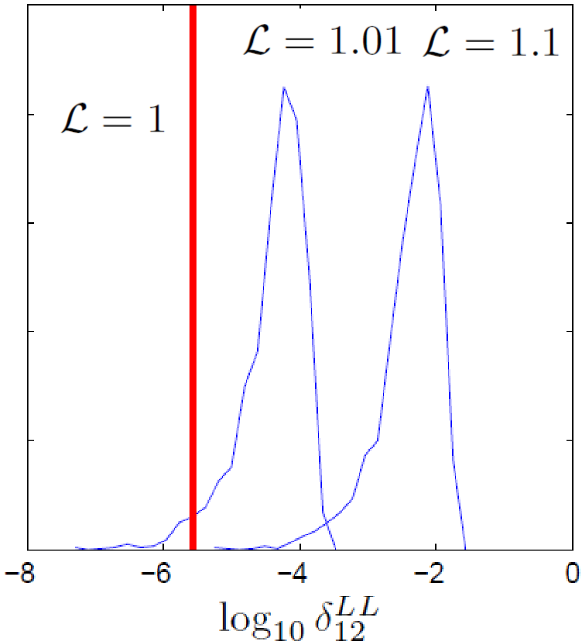



- Clusters with low $\delta_{ij}^X$ due to suppressions in the matrices

- How does the special cancelations survive with $\mathcal{L} \neq 1$ ?

Lower cluster :




Fine-tuned !

Middle cluster :