Flavour violations in type II SO(10)

MICHELE FRIGERIO (IPhT, CEA-Saclay)

L.Calibbi, MF, S.Lavignac and A.Romanino, TO APPEAR

[MF, P.Hosteins, S.Lavignac and A.Romanino, NPB 806 (2009) 84]

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Outline

- Supersymmetric Grand Unification (SUSY GUTs) may account for non-zero neutrino masses; matter-antimatter asymmetry; dark matter; hierarchy problem; charge quantization; quark-lepton mass relations; ...

- Type II SO(10): a new and predictive class of models, with no unknown flavour parameters at GUT scale
  - Leptogenesis directly related to neutrino parameters

- SUSY flavour violating effects in type II SO(10) have a specific dependence on fermion masses and mixing
  - Predictions for BR($\mu \to e\gamma$) waiting for the MEG result

A new class of SUSY GUTs

We adopted a different route to embed the flexible SU(5) unification into the more constrained SO(10) unification:

SU(5)

$$Y^U_{ij}\ 10_i\ 10_j\ 5_U + Y^D_{ij}\ 10_i\ \overline{5}_j\ \overline{5}_D$$

type I SO(10)

$$Y^U_{ij}\ 16_i\ 16_j\ 10_U + Y^D_{ij}\ 16_i\ 16_j\ 10_D$$

type II SO(10)

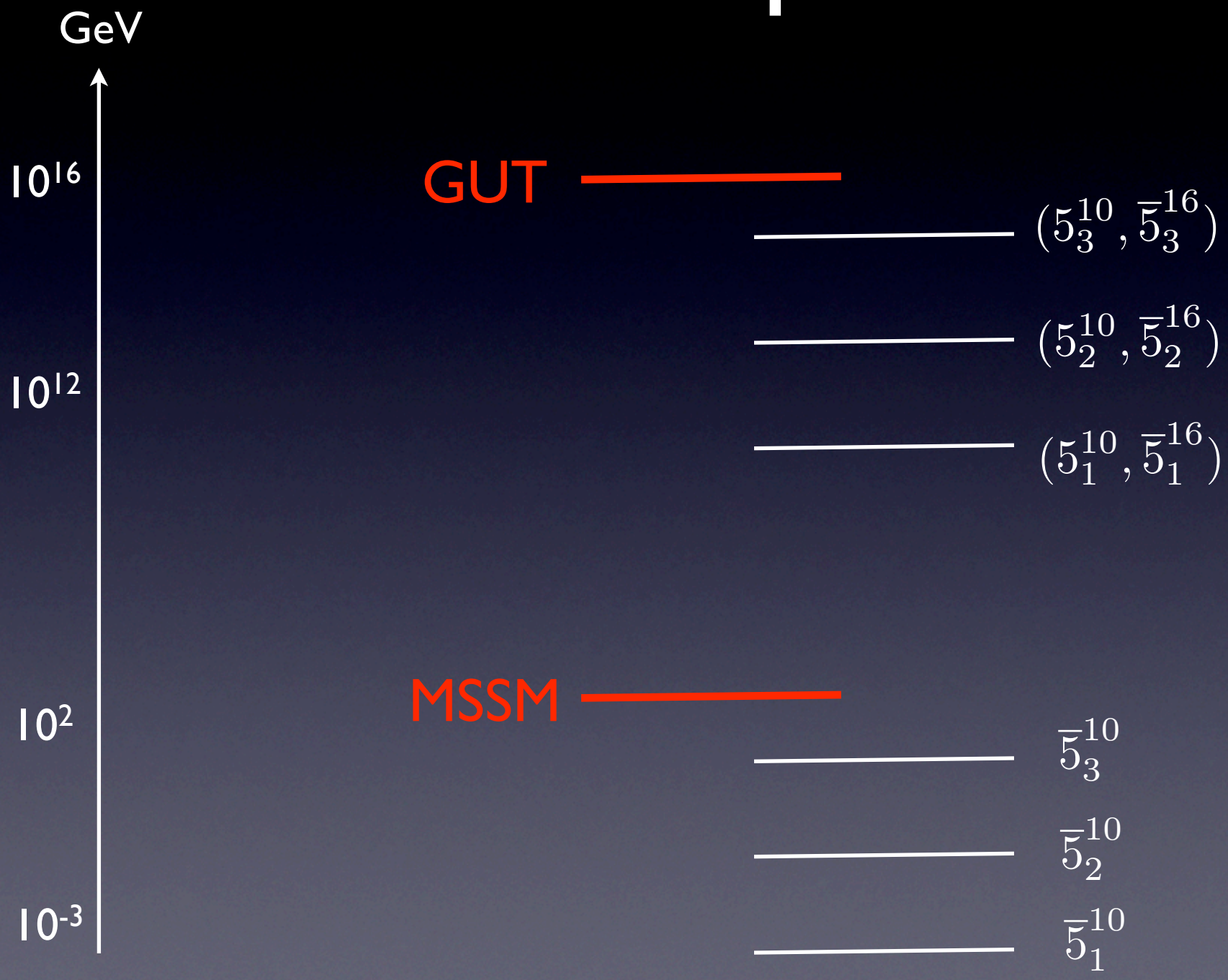
$$Y^U_{ij}\ 16_i\ 16_j\ 10_U + Y^D_{ij}\ 16_i\ 10_j\ 16_D$$

$$16 = (1 + \overline{5} + 10)_{SU(5)}$$
$$10 = (\overline{5} + 5)_{SU(5)}$$

Remarkably, the extra matter fields present in type II are automatically heavy:

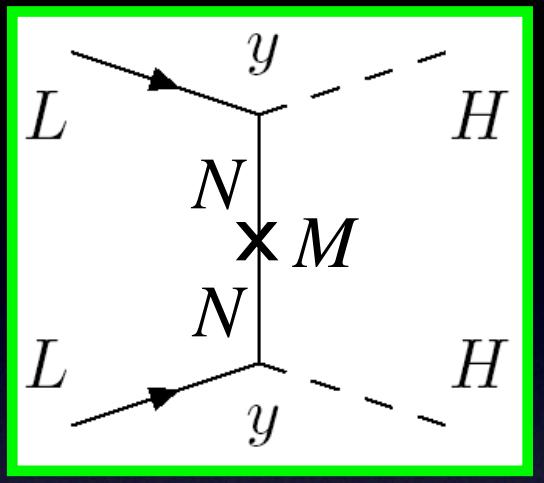
$$Y^D_{ij}\ \overline{5}^{16}_i\ 5^{10}_j\ \langle 1^{16}_D \rangle$$

The mass spectrum



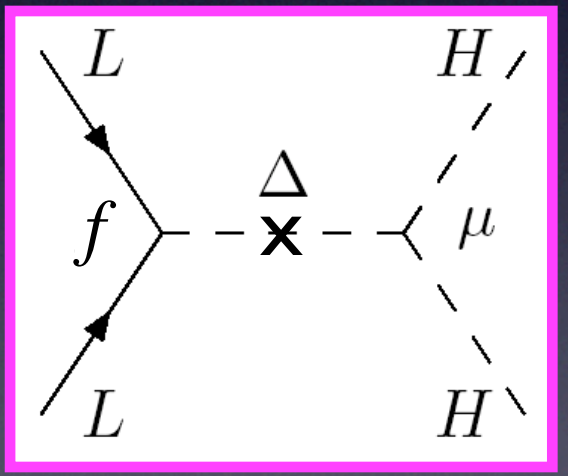
Neutrino mass & the seesaw

In type I SO(10) models, light neutrinos couple through y_{ij} to gauge singlets N's, which have heavy Majorana masses M_{ij} : two sets of flavour parameters



In type II SO(10) models, light neutrinos do not couple to N's ! They can acquire a mass only through a SU(2) triplet Δ

$$f_{ij}\ 10_i\ 10_j\ 54 \supset f_{ij}\ L_i\ L_j\ \Delta$$



The only flavour parameters are given by the light neutrino mass matrix m_{ij}

$$m_{ij} = \frac{\mu v^2}{M_\Delta^2} f_{ij}$$

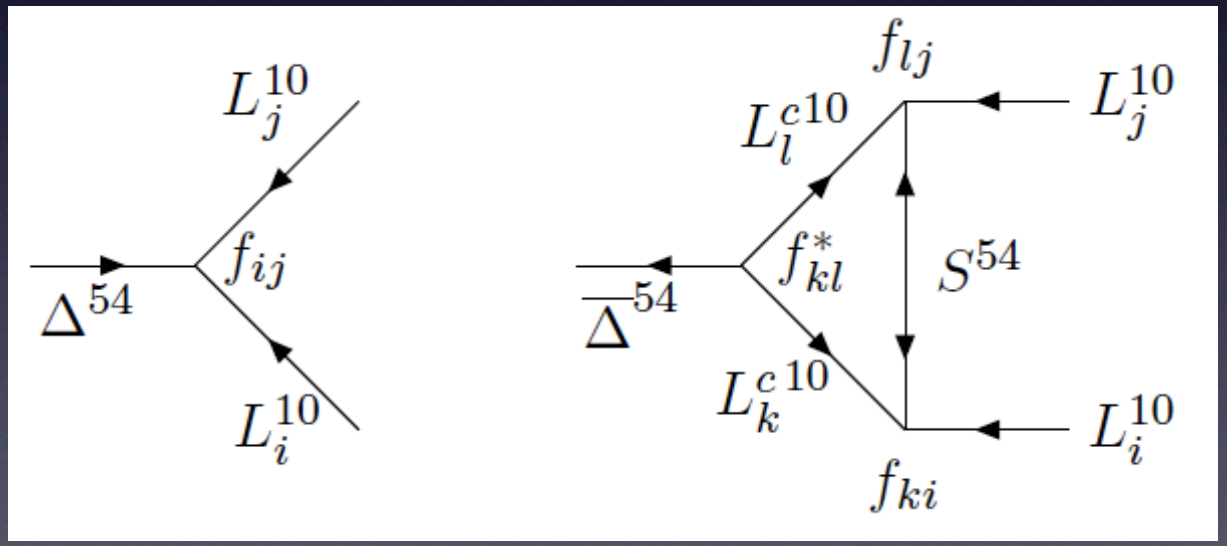
Baryogenesis via leptogenesis

Sakharov

$$\frac{n_B}{s} \approx 0.9\ 10^{-10}$$

WMAP

3 necessary conditions to generate the matter-antimatter asymmetry:
(i) violation of B-L symmetry
(ii) violation of CP symmetry
(iii) epoch out of thermal equilibrium



$$\begin{aligned} W_{SO(10)} &\supset f_{ij}\ 10_i\ 10_j\ 54 \\ &\supset f_{ij}\ L_i\ L_j\ \Delta \\ &+ f_{ij}\ L_i^c\ L_j^c\ \overline{\Delta} \\ &+ f_{ij}\ L_i\ L_j^c\ S \end{aligned}$$

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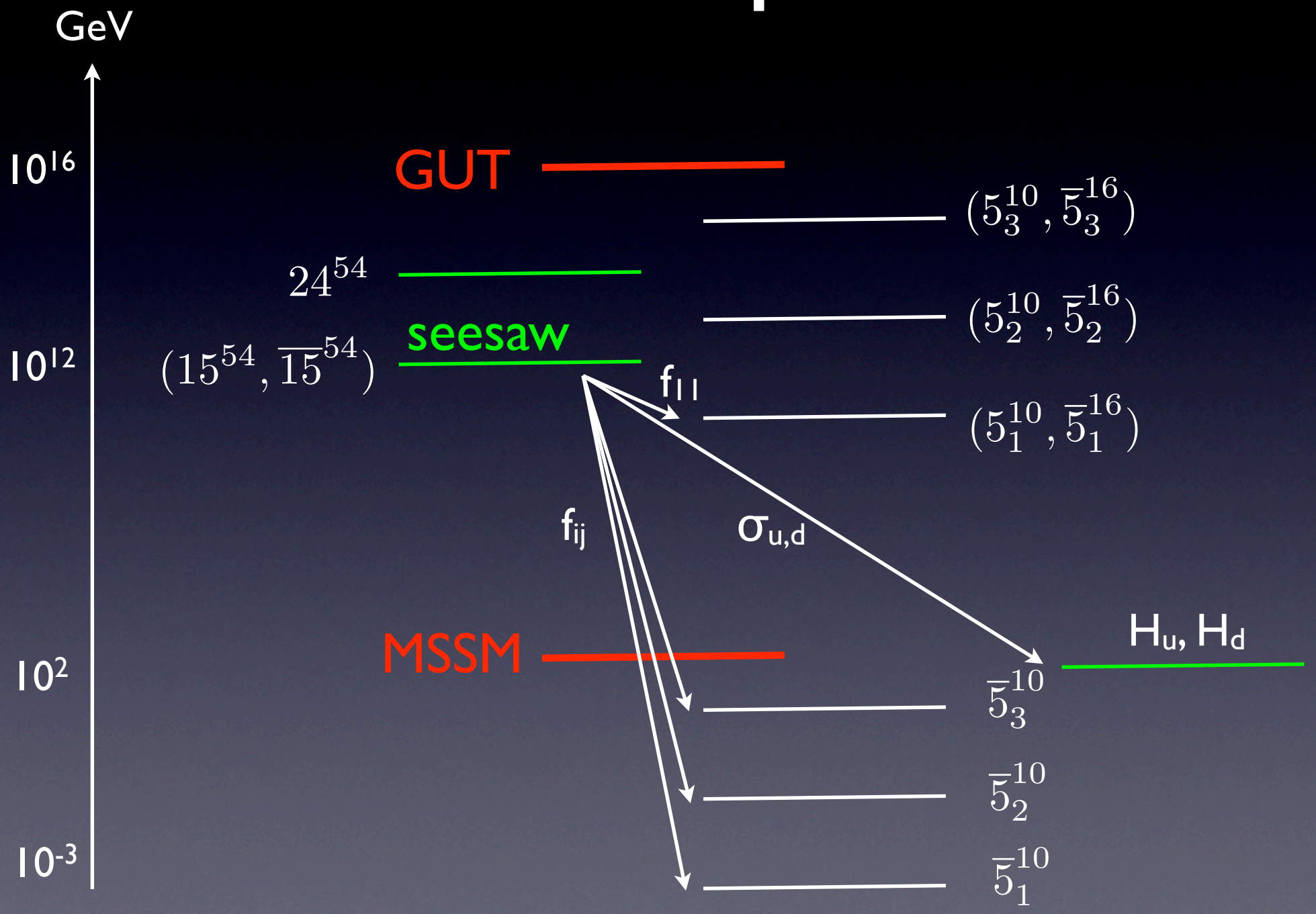
A lepton asymmetry is produced by the observable couplings f_{ij} only !

The mass spectrum



Predictive leptogenesis

- Baryogenesis from the same CP violating phases observable at low energy in the lepton sector !

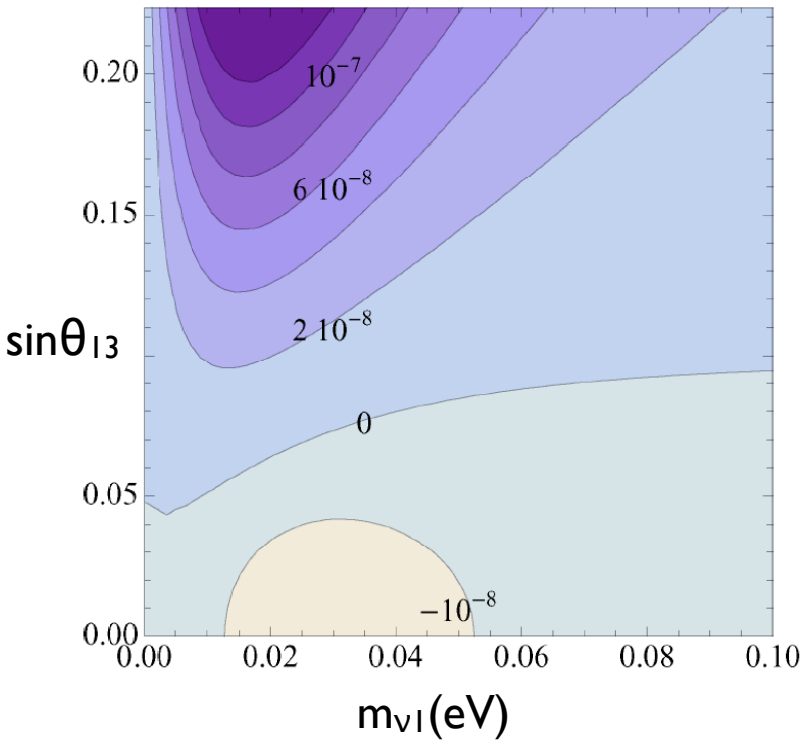
$$\frac{n_B}{s} \propto \frac{\mathrm{Im}[m_{11}^*(mm^*m)_{11}]}{[\mathrm{Tr}(m^*m)]^2}$$

- It turns out that the washout is weak and the CP asymmetry is sufficiently large for $M_\Delta > 10^{11}$GeV and specific ν parameters:

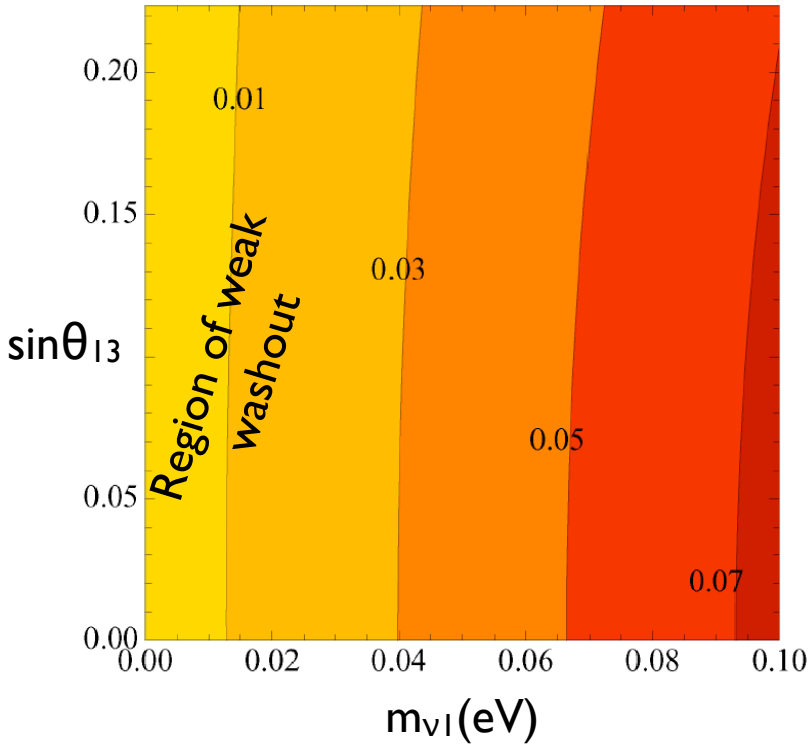
Baryon asymmetry above 10^{11}GeV

Neutrinoless 2β decay of heavy nuclei

ε_{CP}



m_{ee}(eV)



Soft SUSY breaking parameters

Suppose that SUSY breaking mediation occurs above GUT scale and it is flavour universal (mSUGRA boundary conditions at M_{GUT}).

The RGE evolution through the scale of seesaw & leptogenesis leads to flavour (and CP) violations in the soft parameters.

$$(\tilde{m}_L^2)_{ij} \approx (\tilde{m}_{d^c}^2)_{ji} \approx \frac{3m_0^2 + A_0^2}{16\pi^2} \sum_{a=1,2,3} f_{ia}^* \left[6 \log \frac{M_\Delta}{M_{GUT}} + \frac{24}{5} \log \frac{M_S + M_a}{M_{GUT}} \right] f_{aj}$$

type II seesaw à la SU(5)

$$(\tilde{m}_{e^c}^2)_{ij} \approx \frac{3m_0^2 + A_0^2}{16\pi^2} \sum_{a=1,2,3} 4|\alpha_d|^2 y_{ia}^* \log \frac{M_a}{M_{GUT}} y_{aj}$$

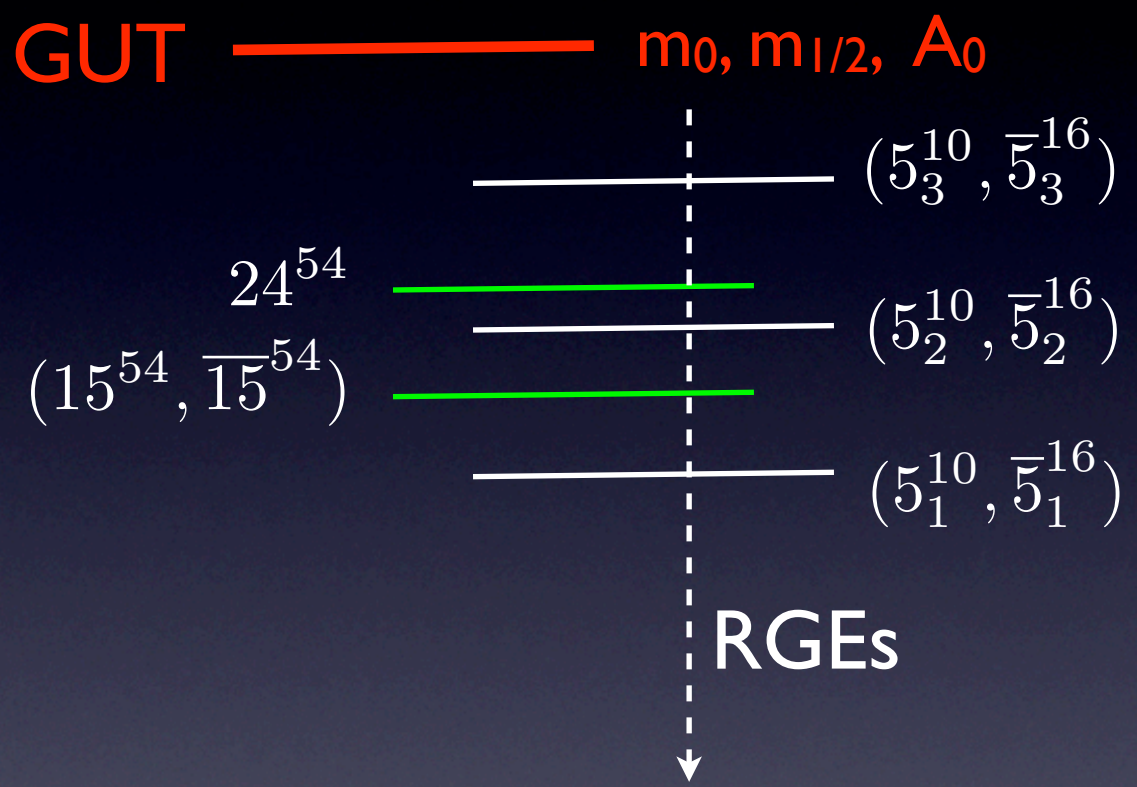
3 heavy matter families from SO(10) breaking

MSSM like effects

$$(\tilde{m}_Q^2)_{ij} \approx \frac{3m_0^2 + A_0^2}{16\pi^2} \sum_{a=1,2,3} y_{ia}^* \left[2|\alpha_u|^2 \log \frac{M_{SUSY}}{M_{GUT}} + 2|\alpha_d|^2 \log \frac{M_a}{M_{GUT}} \right] y_{aj}$$

The mass spectrum

Flavour universal SUSY breaking mediation



Thresholds determined by seesaw and leptogenesis

TeV scale SUSY spectrum

MSSM — $m_{L,e,Q,d,u}$, $M_{1,2,3}$, $a_{e,d,u}$

Flavour and CP violating rare processes

Lepton flavour & CP violations

Rough estimates with all equal soft masses and the choice of parameters that lead to successful leptogenesis (a refined numerical analysis is ongoing ...)

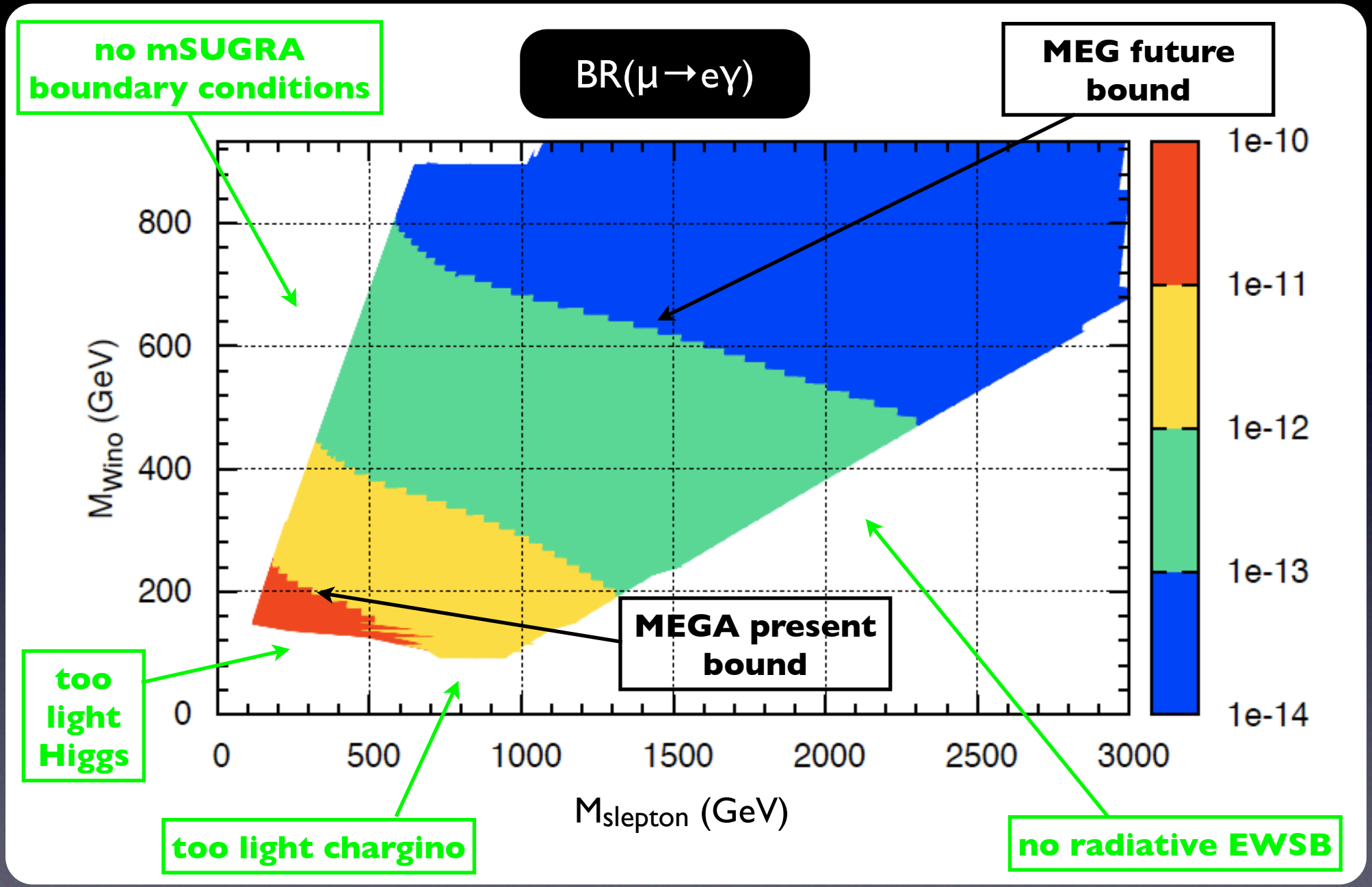
$$BR(\mu \to e\gamma) \sim 5 \cdot 10^{-11} \left(\frac{\tan\beta}{10}\right)^2 \left(\frac{500\ \text{GeV}}{M_S}\right)^4 \frac{\sin^2\theta_{13}}{0.05}$$

The MEG experiment is taking data: from 10^{-11} to 10^{-13} in 3y !
Strong correlations with $\tau \to \mu\gamma, e\gamma$ (*A.Rossi*)

$$EDM_e \sim 5 \cdot 10^{-28} \text{e cm} \ \frac{\tan\beta}{10} \left(\frac{500\ \text{GeV}}{M_S}\right)^2 \left(\frac{\sin^2\theta_{13}}{0.05}\right)^{1/2} \sin\arg(U_{13}V_{31}^*)$$

The present bound is $7\ 10^{-28}$ e cm, prospects to reach 10^{-30} ...

parameters leading to successful leptogenesis at 10^{12} GeV, $\tan\beta = 10$



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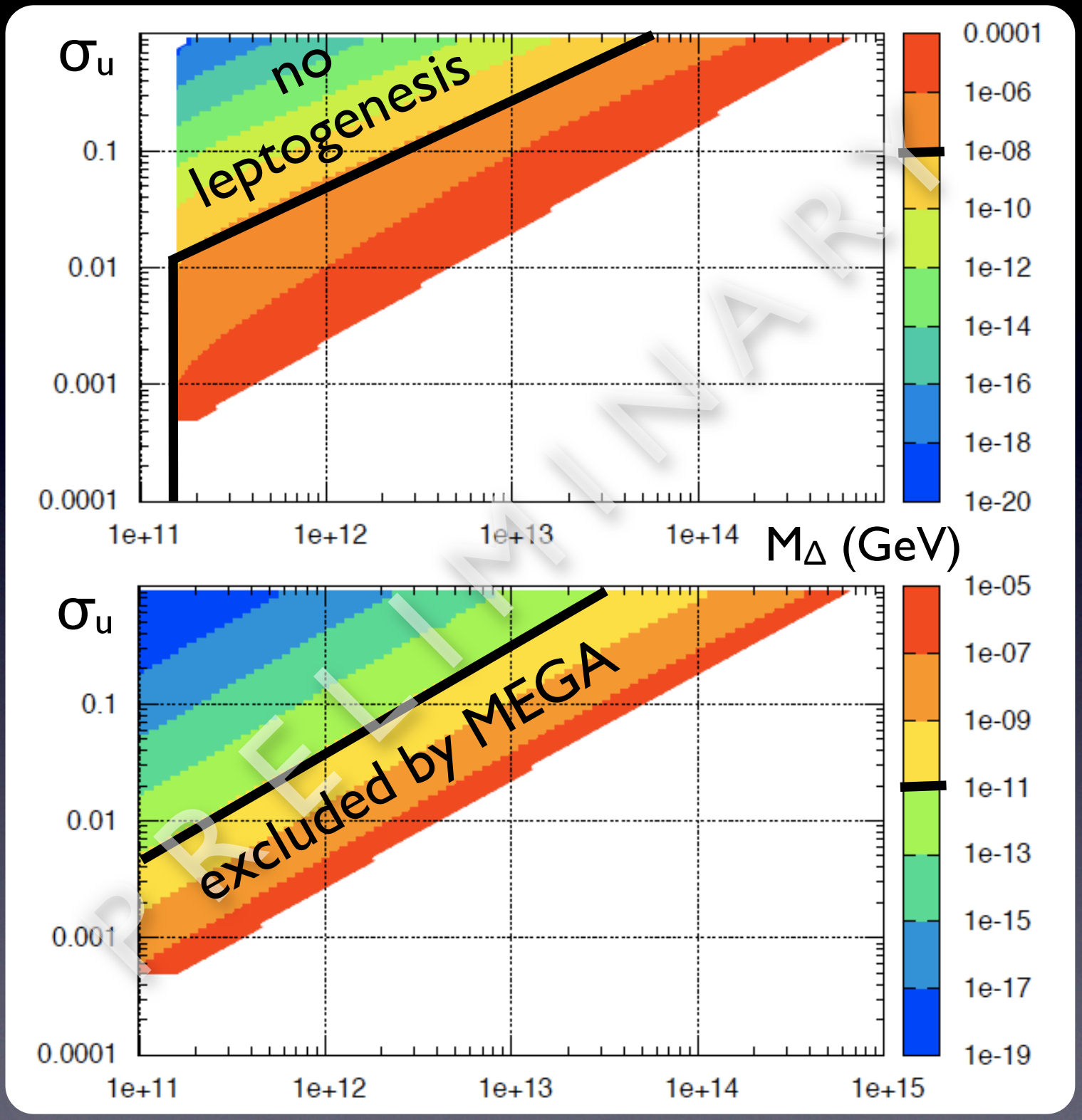
ε_{CP}

the slope of the contours, in both plots, is fixed by the size of neutrino masses

BR($\mu \to e\gamma$)

mSUGRA parameters fixed to
$\tan\beta = 10$
$m_0 = 450$ GeV
$m_{1/2} = 500$ GeV



Quark flavour & CP violations

Correlated analysis of the hadronic observables gives weaker constraints.

Most noticeable difference with the MSSM is $\delta^{RR}_d \neq 0$ at leading log.

$$
\begin{aligned}
BR(b \to s\gamma)|_{\tilde{g}} \quad &\sim \quad \left(\frac{100\ \text{GeV}}{M_S}\right)^4 \left[(3.9 \cdot 10^{-6})_{LL} + (1.9 \cdot 10^{-7})_{RR}\right] \\
&+ \quad \left(\frac{100\ \text{GeV}}{M_S}\right)^2 \left[(5.4 \cdot 10^{-7})_{LR} + (1.2 \cdot 10^{-8})_{RL}\right]
\end{aligned}
$$

The presently allowed range is (1.8 -4.3) 10^{-4}.
RR and RL contributions can be enhanced by the factor $(f_{ij} / 0.05)^4$.

Other constraints from CP violating observables as ε_K or EDM_n.
They are sensitive to both low and high energy CP phases.

Conclusions

- Several upcoming experiments will provide new severe & complementary tests of SUSY GUTs
- In type II SO(10) models, the observable fermion masses & mixing angles are the only flavour parameters of the full theory. Leptogenesis is controlled directly by the neutrino masses.
- A specific pattern of SUSY flavour violating effects. Strong constraints from the present & future bound on BR($\mu \to e\gamma$)