GUT Models

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Abstract. I emphasize that a GUT based on the minimal supersymmetric SO(10) remains a possibility in nature. The yukawa couplings of the third generation fermions can all unify to a point provided strong constraints are placed on the SUSY parameters entering the analysis via the low-energy SUSY threshold corrections. This makes the minimal SO(10) a very predictive and testable GUT.

In the second part of the talk the focus is on the relation between the neutrino masses, SUSY, and lepton flavour violation. In a class of GUT models, the large atmospheric mixing angle induces significant $\tau \to \mu\gamma$ branching ratio. This can be tested in present experiments. Chances are that the lepton flavour violation in τ decay will become the first signal of new physics observed at B factories.

Although the minimal supersymmetric (SUSY) grand unified theory (GUT) involving gauge coupling unification appears to be based on SU(5), once the remaining dimensionless couplings of the theory, the yukawa couplings, are included into the analysis the minimal choice is a theory based on the SO(10) gauge group. A 16-dimensional spinorial representation of SO(10) readily describes the fifteen Weyl fermions of a single generation plus a singlet right-handed neutrino state. It can then be argued that the SO(10) unification predicts neutrino masses (in fact, in the right ballpark) as the right-handed neutrino state is no longer protected by the symmetry after the breaking of the rank five SO(10) unification gauge group down to the rank four Standard Model gauge group. Thus it is important for neutrino physics whether minimal SO(10) models are phenomenologically viable or not.

Recent studies [1, 2] have addressed this question in a detailed top-down analysis. As a starting point it was assumed that the sign of the μ parameter is positive as suggested by the BNL experiments on muon $g-2$ [3], the third generation yukawa couplings exactly unify and GUT threshold corrections lead to a discrepancy between $\alpha_s(M_{GUT})$ and $\alpha_1(M_{GUT}) \equiv \alpha_2(M_{GUT})$ at the level of $\leq 6\%$. This regime was not studied in the previous work [4]. In our global analysis the χ^2 was computed based on nine low-energy observables related, at tree level, to the gauge couplings (α_{EM}, G_μ, and $\alpha_s(M_Z)$), third family yukawa couplings (M_{top}, $m_b(m_b)$ and M_τ) and electroweak symmetry breaking (M_Z and M_W), respectively. The measure of the $SU(2)_V$ breaking, the ρ parameter, was chosen as the ninth observable. Each quantity was fully computed at one loop taking into account 2-loop (1-loop) RGE running of the dimensionless (dimensionful) MSSM parameters [5].

The results in figure 1 suggest that the minimal SO(10) is consistent with the low-energy data if the dimensionful SUSY parameters satisfy phenomenologically

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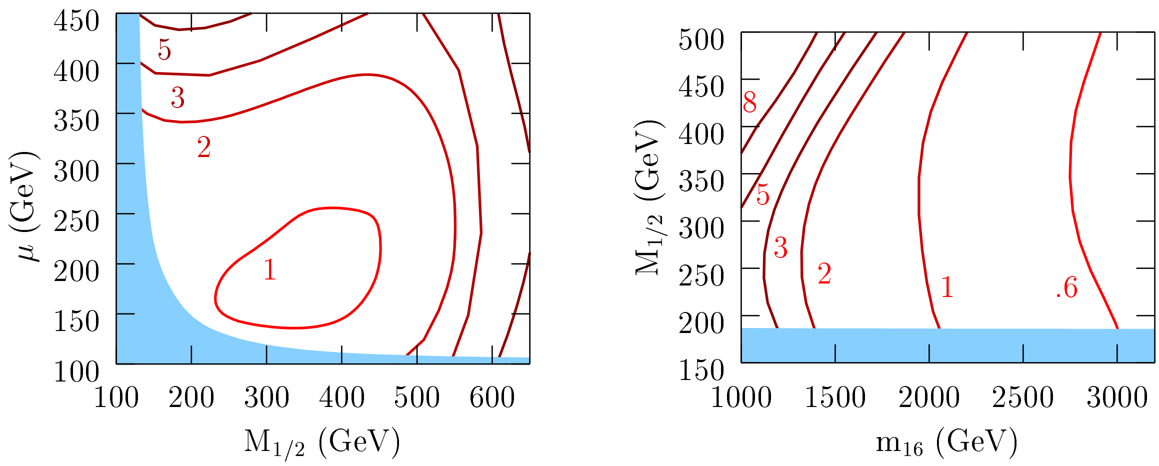

Figure 1. χ^2 contours for $m_{16} = 2000$ GeV (Left) and $\mu = 150$ GeV (Right).

interesting constraints. Most notably, a non-universal just-so Higgs splitting is required

$$m^2_{(H_u,\,H_d)} = m^2_{10}\,(1 \mp \Delta m^2_H) \tag{1}$$

at the GUT scale with $m_{10}/m_{16} = 1.3 - 1.5$ and $\Delta m^2_H = 0.10 - 0.14$ together with low positive value of the μ parameter at the weak scale and large values for the scalar mass $m_{16} > 1200\,\text{GeV}$ and trilinear coupling $A_0 \approx -1.9\,m_{16}$ at the GUT scale. The fits were obtained without taking the right-handed neutrinos into account. Several sources for the splitting in (1) are suggested in [6] and [2]. It was encouraging to find in the discussion in [2] that the decoupling of the right-handed $\overline{\nu}_\tau$ at scale 10^{13} GeV typically induces $\Delta m^2_H \approx 0.10$. The primary constraint comes from the fit to the bottom quark mass. For the positive sign of μ there is a positive non-logarithmic gluino correction to m_b enhanced by large tanβ. However, for large and negative $A_0(M_{GUT})$ this can be balanced out by a negative non-logarithmic chargino loop correction. As a result a large left-right stop mixing is present. In the preferred SUSY region neutralino is the LSP. In the best fits $\mu(M_Z) \approx 150$GeV and thus the LSP, as well as the chargino, are higgsino-like. The mass of the latter is close to the current experimental limit. In the Higgs sector, the Standard-Model-like Higgs has naturally mass 114–120 GeV, while for the rest of the Higgs spectrum there is no clear prediction.

In the second part of the talk I would like to emphasize the relation between the neutrino and SUSY sectors of GUT models. Assuming the see-saw mechanism with masses of the heavy Majorana $\overline{\nu}$ states below the GUT scale there emerges a possibility of observing lepton flavour violating (LFV) decays $\ell_i^\pm \to \ell_j^\pm + \gamma$ [7]. The decay rates are enhanced by $(\tan\beta)^2$ and are only suppressed by the sparticle masses because the LFV is induced in the slepton mass matrix from the loop processes at scales between M_{GUT} and $M_{\overline{\nu}}$ (even if there is no LFV at the unification scale M_{GUT}). In a recent work [8] it was pointed out that the large atmospheric mixing angle may lead to a potentially large $\tau \to \mu\gamma$ decay rate. This prediction is rather insensitive to the details of a particular GUT model. In fact, to avoid fine tuning many GUT

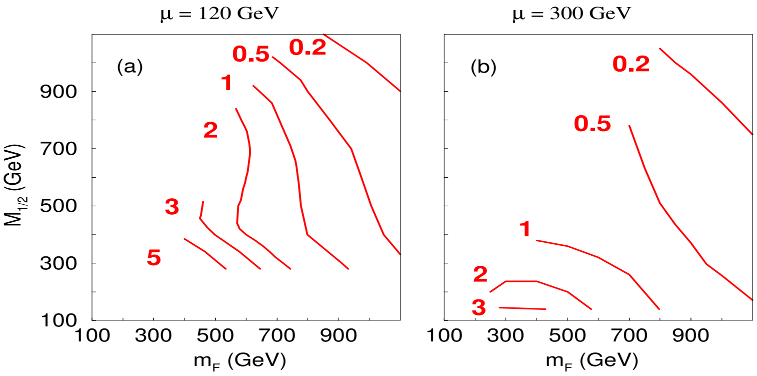

Figure 2. Contour lines of the branching ratio BR($\tau \to \mu\gamma$)$\times 10^6$ for two different values of the μ parameter fixed at scale M_Z. The data is computed for the best fits of the model described in [9]. In these fits tanβ = 50 and A_0 = 0. m_F is the universal sfermion SUSY breaking mass at the GUT scale. The current experimental bound is BR($\tau \to \mu\gamma$) $< 2 \times 10^{-6}$ at 95% C.L..

models with hierarchical neutrino masses lead to the Yukawa matrix

$$Y_\nu \sim \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{pmatrix} \qquad (2)$$

in the basis where charged lepton Yukawa matrix and heavy Majorana matrix are both diagonal. The prediction for BR($\tau \to \mu\gamma$) then does not depend on the subleading entries denoted in (2) as zeros. The results in figure 2, taken from [8], clearly show that if tanβ is large the decay could be observed in the current experiments at B factories. They were obtained for the best fits of a particular string motivated model [9, 10]. Note that the results for $\mu \to e\gamma$ are necessarily dependent on the subleading model dependent entries in (2).

In summary, GUT models can be very predictive and can combine constraints from the neutrino and SUSY sectors. A highlighted example is the prediction for the observation of the LFV decay $\tau \to \mu\gamma$ at the current B factories.

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