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# MSSM with Large tan$\beta$ Constrained by Minimal SO(10) Unification *

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**Abstract**

Study of the MSSM in large tan$\beta$ regime has to include correlations between the constraints presented by the low energy values of the b quark mass and $BR(b \to s\gamma)$. Both quantities receive SUSY contributions enhanced by tan$\beta$ and have a major impact on the MSSM analysis. Here we summarize the results of such a study constrained by minimal SO(10) unification. We show the best fits, in the $(m_0, M_{1/2})$ plane, obtained in the global analysis spanned over the gauge, Yukawa and SUSY parameter space at the unification scale. Two distinct fits describe the available low-energy data very well. The fits differ by the overall sign of the $b \to s\gamma$ decay amplitude. We conclude that an attractive SO(10)-derived regime of the MSSM remains a viable option.

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# MSSM WITH LARGE tan$\beta$ CONSTRAINED BY MINIMAL SO(10) UNIFICATION

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Study of the MSSM in large tan$\beta$ regime has to include correlations between the constraints presented by the low energy values of the b quark mass and $BR(b \to s\gamma)$. Both quantities receive SUSY contributions enhanced by tan$\beta$ and have a major impact on the MSSM analysis. Here we summarize the results of such a study constrained by minimal SO(10) unification. We show the best fits, in the $(m_0, M_{1/2})$ plane, obtained in the global analysis spanned over the gauge, Yukawa and SUSY parameter space at the unification scale. Two distinct fits describe the available low-energy data very well. The fits differ by the overall sign of the $b \to s\gamma$ decay amplitude. We conclude that an attractive SO(10)-derived regime of the MSSM remains a viable option.

## 1 Motivation

Detailed global analysis of the unconstrained Minimal Supersymmetric Standard Model (MSSM) is of utmost importance. However, the MSSM is understood as just an effective description of more fundamental interactions. Pursuing a search for such a more fundamental theory, global analysis can then also be used to evaluate different models which break down to the MSSM at some high scale. In this sense, our work was motivated by simple SO(10) grand unified theories[1] (GUTs). Amazingly, these can be made simple enough to have positive number of degrees of freedom and thus yield a sensible analysis. Note that simplicity of these models implies large tan$\beta$, and that in turn requires to include the supersymmetric (SUSY) sector into the analysis because of potentially significant SUSY threshold corrections. To simplify the analysis we assumed universal sparticle masses (with the exception of the non-universal scalar Higgs masses) and scalar couplings emerging at the GUT scale. That leaves flavor physics (the SO(10)-derived fermion mass matrices) as the main issue of the analysis. The point of this talk is not, however, the origin of flavor. The point here is that once a candidate model which fits the observed fermion masses and mixings very well is found, an SO(10) global analysis resumes the role of the MSSM global analysis constrained by unification. In fact, it is only the fermionic sector which substantially distinguishes the two.

In particular, it was shown in ref.[2] that model 4c is an example of such a nice model. When $\chi^2 < 2$ *per d.o.f.*, only 20-50% of the total $\chi^2$ comes from the masses of the lighter-generation fermions and fermion mixings while the remaining $\chi^2$ contributions originate from the observables like gauge boson masses[a], gauge couplings, third-generation fermion masses, and $BR(b \to s\gamma)$ — the observables traditionally included in the MSSM analysis constrained by unification. For this reason the features of the model 4c best fits are the features which come out of the MSSM analysis with unification constraints.

## 2 Results

The results indicate that there are two major constraints imposed on the MSSM with large tan$\beta$: the observed $b \to s\gamma$ decay rate and the value of the bottom quark mass $m_b$. Both get a SUSY contribution enhanced by large tan$\beta$. When considered separately in the SUSY parameter space, each one tends to prefer a different sign of the $\mu$ parameter[b]. However, they can both be satisfied by the sign of $\mu$ favored by $b \to s\gamma$. Fits with the opposite sign of $\mu$ can reproduce the observed $BR(b \to s\gamma)$ only for the SUSY spectrum deep in the TeV region. The correct sign of $\mu$ (positive in our notation) means a destructive interference among the chargino and (SM + charged Higgs) contributions to $b \to s\gamma$, and positive SUSY threshold correction to $m_b$. Both have grave consequences.

The destructive interference among the $b \to s\gamma$ amplitudes can result in having the net amplitude $C_7^{MSSM}$ of the same sign as $C_7^{SM}$, or of the opposite sign. The opposite sign does not look too unnatural — after all, the chargino contribution is enhanced by tan$\beta$ (and suppressed only by sparticle masses) compared to the SM contribution[c]. Hence two distinct fits are possible (figs.1a-b). Note that the fit with the flipped sign (fig.1b) allows for lighter SUSY spectrum to make the destructive interference work. For the same reason the charged Higgs (and then the rest of the Higgs sector) tends to be heavier when the sign is flipped and lighter (in the best fits, as light as experimentally allowed) in the fit of fig.1a. The detailed analysis[3] of $C_7^{MSSM}$ shows that one cannot neglect the contribution from the inter-generational squark mixing as is sometimes assumed. However, this term makes the analysis dependent on the choice of a GUT model (in addition to the pattern of SUSY breaking).

The $b$ quark mass is a tight constraint in this regime. The best fits make

[a] In our global analysis, we assume a pure top-down approach with $\mu$ and $B\mu$ as initial parameters instead of the $Z$ boson mass, pseudoscalar mass $m_{A^0}$, or tan$\beta$ used in bottom-up approach. The conditions for 1-loop radiative electroweak symmetry breaking can then result in inaccurate gauge boson masses which are brought down to the agreement with the data only in the course of optimization.
[b] In fact, we should talk about the sign of $\mu A_t$, but at the electroweak scale the stop trilinear coupling always turns out negative in acceptable fits.
[c] That also explains why the other sign of $\mu$ is so strongly constrained.

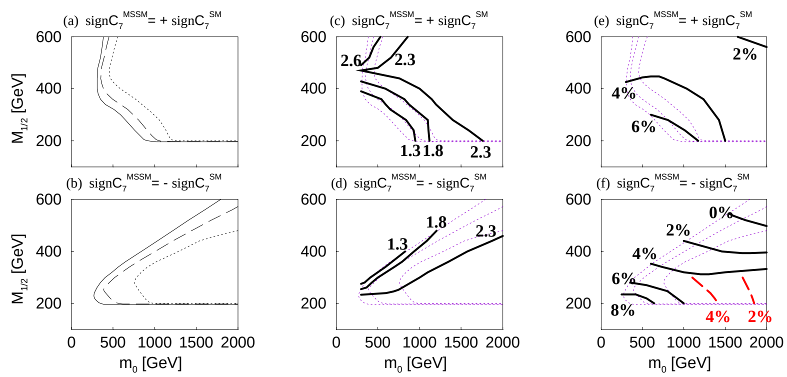


Figure 1: Model 4c global analysis results for two possible signs of $C_7^{MSSM}$. In (a) and (b), the best fit contour plots of $\chi^2$ are shown. Solid (dashed, dotted) lines correspond to $\chi^2 = 6\,(3,1)\,per\,3\,d.o.f.$. Figures (c) and (d), and (e) and (f), show the best fit contour plots of $BR(b \to s\gamma) \times 10^4$ and $\delta m_b^{SUSY}$, respectively, with the $\chi^2$ contour lines of (a) and (b) in the background for better reference.

$\alpha_s(M_Z)$ low to minimize the renormalization of $m_b$ at low energies. $\alpha_s(M_Z) \leq 0.118$ is achieved by a negative 3-5% GUT threshold correction to $\alpha_s$ coming from mass splits in superheavy multiplets. SUSY parameters are also adjusted to prevent too large $\delta m_b^{SUSY} > 0$. Most importantly, the magnitude of $\mu$ is obtained as low as allowed by sparticle searches. Thus the lightest possible higgsino-like chargino and neutralino are present in the best fits (but are not necessary: good fits — shifted towards greater $m_0$, $M_{1/2}$ as the price to pay — survive a further increase of the experimental gaugino mass limits).

The best fit value of $A_t(M_Z)$ varies across the $(m_0, M_{1/2})$ plane by about 1000GeV, (and universal coupling $A_0$ varies even more) since it is a major player in the chargino contribution to both $b \to s\gamma$ and $\delta m_b^{SUSY} > 0$. As a result of sizable $A_t$, a significant left-right mixing is induced, leading to the lightest stop, sbottom and stau decoupled by up to few hundred GeV from the rest of the sfermions. In fact, the experimental lower limit on the stau mass starts affecting the analysis as soon as $m_0$ gets below 500GeV.

To conclude, the results show that the MSSM with large tan$\beta$ constrained by minimal SO(10) remains an option for physics beyond the Standard Model.

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## References

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