Testing SUSY GUTs through FCNC Processes

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Grand Unified Theories (GUTs) in combination with supersymmetry (SUSY) are known to have a number of theoretically very attractive features. GUTs offer elegant solutions to many of the puzzles of the Standard Model (SM), like charge quantization. The minimal SUSY extension of the SM (MSSM) is known to lead to a unification of the gauge couplings at the GUT scale, while this does not happen in non-SUSY GUTs. Finally, in SUSY GUTs the hierarchy between the electroweak (EW) and the cutoff scale (identified with the GUT scale) is naturally stable because of SUSY itself.

GUTs not only unify fundamental interactions, but also fundamental particles. Therefore, it is natural to expect that the masses and mixings of quarks and leptons at observable energies are correlated. In particular, a common Yukawa coupling for all quarks and leptons of one generation would lead to characteristic relations among the observed masses. Unfortunately, such relations are not viable for the two lightest generations.

For the third generation, however, Yukawa unification of the top quark, the bottom quark and the tau lepton could be achieved if $\tan\beta$, the ratio of vacuum expectation values of the two Higgs doublets in the MSSM, is as large as 50. The success of this unification depends critically on the SUSY parameters, in particular the masses of superpartners, which are yet to be discovered. In the absence of the knowledge of these parameters, flavour-changing neutral current (FCNC) processes, which are sensitive to loop corrections induced by the superpartners, can be used to test SUSY GUTs with Yukawa unification.

In [1], an SO(10) SUSY GUT model featuring third generation Yukawa unification has been proposed and shown to correctly reproduce quark and lepton masses and mixings as well as EW observables in terms of only 24 parameters. Our study [2] investigated the predictions of this model for flavour-changing observables, viz. the rare decays $B_s \to \mu^+\mu^-$, $B \to X_s\gamma$, $B \to X_s\ell^+\ell^-$ and $B^+ \to \tau^+\nu$ as well as the neutral B meson mass differences $\Delta M_{d,s}$. We demonstrated that the simultaneous description of these observables represents a serious challenge for this model and requires extremely heavy SUSY particles to suppress the effects in the flavour sector, making it difficult in turn to test the models at the upcoming LHC experiments.

As a generalization to the above findings, we showed in [3] that incompatibility between exact Yukawa unification and experimental data on EW observables and FCNC processes is a common feature of SUSY GUTs with universal soft terms for gauginos and sfermions at the GUT scale. In other words, this difficulty holds irrespectively of the flavour model embedded in the SUSY GUT to explain quark and lepton masses and mixings.

In [3] we subsequently pointed out a possible remedy. Full agreement with the FCNC data can be recovered if the full Yukawa unification is reduced to unification of the bottom and tau Yukawa couplings. In this case, the predicted SUSY particle masses are basically fixed by the requirements of agreement with FCNCs and the imposed bottom-tau unification. The SUSY spectrum displays a very characteristic pattern and its lightest part is well within reach of the LHC, allowing the outlined scenario to be falsifiable.

All our findings [2,3] are obtained through a global χ^2 analysis of the parameter space, were all the experimental information, in particular on EW observables and FCNC processes, is included directly in the χ^2 function. Therefore our conclusions are manifestly parameterization invariant. Our results have important implications for grand unified model building and demonstrate the constraining power of FCNC processes for models of fermion masses.

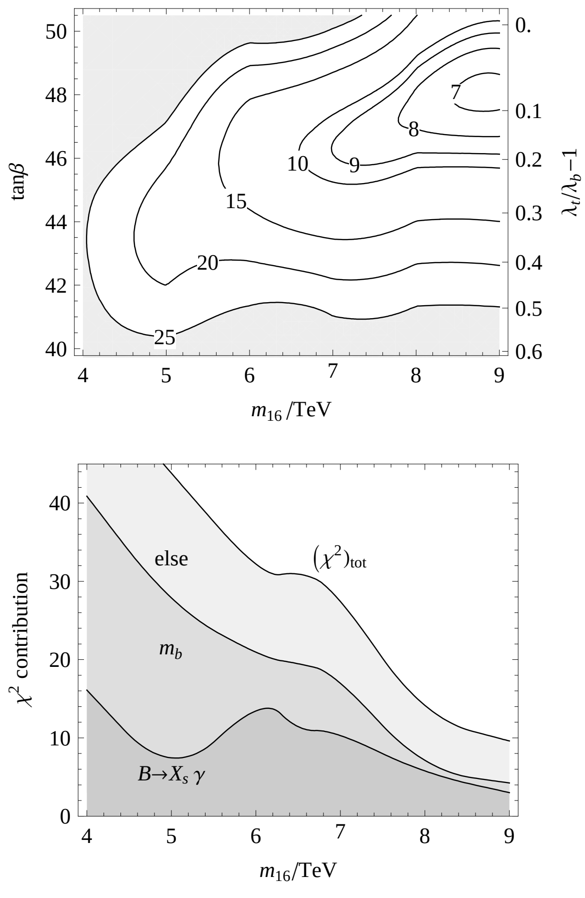

Fig. 1: Top: contours of total χ^2 in the plane of universal sfermion mass m_{16} and $\tan\beta$ in a model with bottom-tau Yukawa unification. The regions with $\chi^2 \gtrsim 10$ are disfavoured. Bottom: total χ^2 in a model with complete third generation Yukawa unification. Values of $m_{16} \lesssim 9\,\text{TeV}$ are disfavoured.

References

[1] R. Dermisek and S. Raby, Phys. Lett. **B622** (2005) 327 [arXiv:hep-ph/0507045].

[2] M. Albrecht, W. Altmannshofer, A.J. Buras, D. Guadagnoli and D. M. Straub, JHEP **0710** (2007) 055 [arXiv:0707.3954 [hep-ph]].

[3] W. Altmannshofer, D. Guadagnoli, S. Raby and D. M. Straub, arXiv:0801.4363 [hep-ph].