FCNC Processes and the Unitarity Triangle in the Minimal Flavor Violating MSSM

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Supersymmetric (SUSY) extensions of the Standard Model (SM) of particle physics are among the best motivated and most attractive candidates for New Physics. However, in its most general form, already the Minimal Supersymmetric Standard Model (MSSM) introduces $\mathcal{O}(100)$ new parameters in the flavor sector that potentially lead to contributions to Flavor Changing Neutral Current (FCNC) processes much larger than what is allowed by the experimental data. The surviving parameter space then looks rather fine-tuned and unnatural, which is often referred to as the SUSY flavor problem.

A very appealing possibility to address this problem and to introduce a mechanism of "near flavor conservation" [1] is given by the principle of Minimal Flavor Violation (MFV) [1,2]. According to this principle all sources of flavor (and CP) violation have to be functions of the SM Yukawa couplings (the only sources of flavor violation in the SM), which leads to new physics contributions to FCNC processes that are suppressed by the same CKM factors as in the SM and are therefore expected to be naturally small.

In [3] we apply the MFV limit to the MSSM with low $\tan\beta$ and investigate SUSY corrections to the mass differences in the neutral B meson systems, ΔM_d and ΔM_s. We find that these corrections are always positive and typically lie within the present uncertainties of the mass difference determinations. We also point out an important distinction between MFV as defined in [2] and so-called constrained MFV (CMFV) [4]. In models with CMFV it is possible to construct a Universal Unitarity Triangle (UUT) out of the angle β and the side R_t, obtained from the ratio $\Delta M_d/\Delta M_s$, that within CMFV is independent of any new physics contributions. In MFV models on the other hand, new operators can modify the relation between R_t and $\Delta M_d/\Delta M_s$ that then reads

$$R_t = 0.913\left[\frac{\xi}{1.23}\right]\sqrt{\frac{17.8/\text{ps}}{\Delta M_s}}\sqrt{\frac{\Delta M_d}{0.507/\text{ps}}}\sqrt{\frac{1+f_s}{1+f_d}}\,, \quad (1)$$

with $\Delta M_q = \Delta M_q^{\text{SM}}(1+f_q)$ and ξ is a non perturbative parameter determined from lattice QCD $\xi = 1.23(6)$. A Unitarity Triangle (UT) valid in all MFV models should then be constructed from the measured value of $\sin 2\beta$ and the new-physics-free tree-level determinations of the CKM matrix element $|V_{ub}|$ or the angle γ.

Using the known value of $\sin 2\beta_{\psi K_s} = 0.675 \pm 0.026$, figure 1 shows as blue area the correlation between the UT side R_b and γ, which is valid in any MFV model. In models with CMFV, the measurement of $\Delta M_d/\Delta M_s$ establishes another constraint shown as the orange band. While the whole blue band is allowed in MFV, in CMFV it is only the red intersection. The green box shows the 1σ ranges for $R_b \propto |V_{ub}|$ and γ as measured from tree level decays.

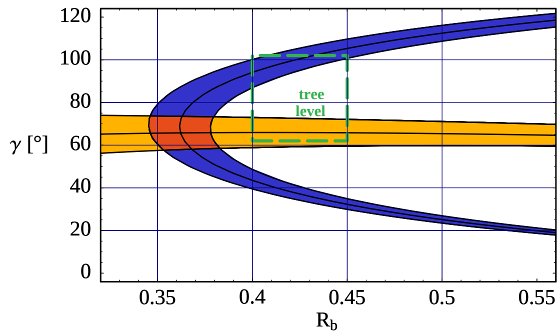

Fig. 1: The R_b-γ plane in models with MFV (blue area) and CMFV (red area).

In [5] we perform the above mentioned MFV UT construction assuming a large inclusive value for $|V_{ub}| = (45.2 \pm 1.9 \pm 2.7) \times 10^{-4}$. The result of our numerical fit is shown in figure 2.

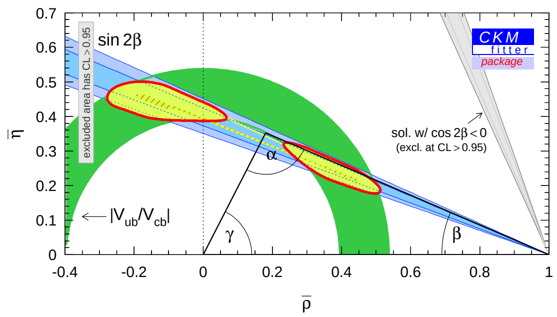

Fig. 2: Results of a MFV fit of the UT. The red contours show the 95% C.L. region in the $\bar\rho$-$\bar\eta$ plane. As reference also the UT from the SM fit is shown.

We find two distinct solutions in the $\bar\rho$-$\bar\eta$ plane, corresponding to values of R_t incompatible with the SM determination. In the light of equation (1) we then discuss if within the MFV MSSM new physics contributions to ΔM_d and ΔM_s can be large enough to explain this discrepancy. We especially investigate the large $\tan\beta$ regime, where so-called Higgs Double Penguin contributions can lead to significant SUSY corrections to the mass differences [6]. However, we find that once the bound on the branching ratio of the rare decay $B_s \to \mu^+\mu^-$ is taken into account, only very fine-tuned regions in the parameter space can lead to large enough contributions, unless the non perturbative parameter ξ is significantly different from the one obtained by lattice methods.

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