

# Implications of the Measured $B_s^0 - \bar{B}_s^0$ Mass Difference $\Delta M_s$ : Constrained Minimal Flavour Violation and Beyond

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The recent measurement of the  $B_s^0 - \bar{B}_s^0$  mass difference by the CDF collaboration [1]

$$\Delta M_s = (17.77 \pm 0.10 \pm 0.07) \text{ ps}^{-1} \quad (1)$$

provided still another constraint on the Standard Model (SM) and its possible extensions. Of particular interest is the fact that the SM predictions prior to the measurement displayed the central value of  $(\Delta M_s)_{\text{SM}}$  in the ballpark of  $21 \text{ ps}^{-1}$ , albeit still compatible with the data due to large hadronic uncertainties.

On the other hand, the simplest and most famous extensions of the Standard Model predict  $\Delta M_s > (\Delta M_s)_{\text{SM}}$ , with a notable exception being the MSSM with Minimal Flavour Violation (MFV) and large  $\tan\beta$ . Indeed, it has recently been shown [2] that in models with Constrained Minimal Flavour Violation (CMFV) [3], where

1. the CKM matrix is the only source of flavour and CP violation,
2. only the SM operators are relevant,

$\Delta M_s > (\Delta M_s)_{\text{SM}}$  appears to be a general property. In order to explain a possible suppression of  $\Delta M_s$  below its SM expectation, either new sources of flavour violation or new operators have to be present in the theory, unless the contributions from neutral gauge bosons or Majorana fermions present in box diagrams in a given model turn out to be dominant.

Unfortunately, due to sizable non-perturbative uncertainties in the relevant hadronic parameters  $\hat{B}_{B_s} F_{B_s}^2$ , it will still take some time before we will know through direct calculation whether  $\Delta M_s > (\Delta M_s)_{\text{SM}}$  or  $\Delta M_s < (\Delta M_s)_{\text{SM}}$  or even  $\Delta M_s \simeq (\Delta M_s)_{\text{SM}}$  with high precision. Some proposals for clarifying this issue with the help of the CP-violating asymmetry  $S_{\psi\phi}$  and the semi-leptonic CP asymmetry  $A_{\text{SL}}^s$  have been put forward in [4], but they are very challenging as well.

In spite of that, the measurement of  $\Delta M_s$  turned out to be extremely useful, as it allowed for the first time to test the CMFV hypothesis in a non-trivial manner. Therefore it is useful to recall the unitarity triangle (UT) with the sides

$$R_b = \left| \frac{V_{ub}^* V_{ud}}{V_{cb}^* V_{cd}} \right|, \quad R_t = \left| \frac{V_{tb}^* V_{td}}{V_{cb}^* V_{cd}} \right|, \quad (2)$$

and the angles  $\beta$  and  $\gamma$ , as shown in Fig. 1.

While the side  $R_b$  and the angle  $\gamma$  can be determined directly from tree level decays and therefore independently of any new physics contribution, the side  $R_t$  and the angle

$\beta$  have to be determined from loop induced processes and are therefore sensitive to new physics. In particular,  $R_t$  and  $\beta$  can be determined from the ratio  $\Delta M_d/\Delta M_s$  and from the CP asymmetry  $S_{\psi K_S}$  and turn out to be universal within all CMFV models. A discrepancy between the *reference* UT, constructed from the tree level values of  $R_b$  and  $\gamma$ , and the *universal* UT, constructed from the CMFV values of  $R_t$  and  $\beta$ , therefore, would not only signal physics beyond the SM, but would at the same time rule out the whole class of CMFV models.

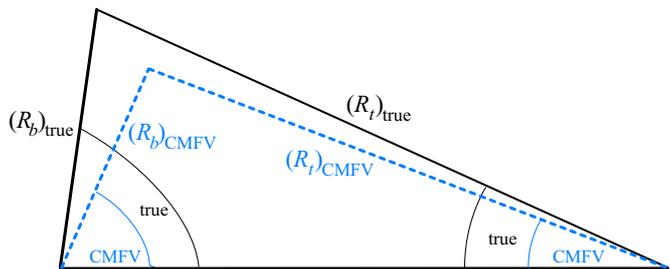


Fig. 1: Reference UT (solid) and universal UT (dashed), constructed from the central values for  $R_b$ ,  $\gamma$  and  $R_t$ ,  $\beta$  [4].

The present status of this determination is displayed in Fig. 1, where the reference UT and the universal UT have been constructed from the central values of  $R_b$ ,  $\gamma$  and  $R_t$ ,  $\beta$ . While both triangles agree quite well with each other and therefore display the CMFV hypothesis in a reasonable shape, there appears a small ( $\sim 2\sigma$ ) discrepancy between these two triangles, which, if turning out one day to be statistically significant, would require either the presence of new operators or of new CP violating phases beyond the SM and CMFV.

Clearly, nothing definite on the validity of the CMFV hypothesis can be said at present. However, once the lattice calculations for the relevant hadronic parameters will reach a sufficiently high level of precision, and the experimental errors in particular in the determination of  $\gamma$  will be significantly reduced, the bound on  $\Delta M_s$  derived in [2] and the comparison of the reference UT and the universal UT will offer excellent means to reveal the flavour structure of any new physics present beyond the SM.

## References

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