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Higgs boson coupling to b quarks: targets in the MSSM[1]

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1 Estimate of a possible deviation of the Higgs coupling strength to bottom quarks from the Standard Model value

We define the deviation of the Higgs coupling strength to the bottom quarks as

$$\Delta C_{\rm hbb} = C_{\rm hbb}^{\rm MSSM}/C_{\rm hbb}^{\rm SM} - 1 \tag{1}$$

where $C_{\rm hbb}^{\rm MSSM}$ and $C_{\rm hbb}^{\rm SM}$ are the Higgs coupling to the bottoms quarks in the MSSM and the Standard Model(SM), respectively. In order to estimate the size of the deviation, we approximate the MSSM coupling using analytical formulas for very heavy stops and no-mixing on the one hand, and we make use of the program `FeynHiggs-2.13.0`. We performed a scan focussing on large stop masses

$$5 \le \tan\beta \le 25 \quad \text{step size} = 1 \tag{2}$$

$$300 \text{ GeV} \le M_A \le 700 \text{ GeV} \quad \text{step size} = 1 \text{ GeV}$$

$$1500 \text{ GeV} \le M_{\tilde{Q}_3} = M_{\tilde{t}_R} \le 1800 \text{ GeV} \quad \text{step size} = 300 \text{ GeV}$$

$$\text{with} X_t = A_t - \frac{\mu}{\tan\beta} = 2M_{\tilde{Q}_3} + x : \tag{3}$$

$$-600 \text{ GeV} \le x \le 600 \text{ GeV} \quad \text{step size} = 200 \text{ GeV}$$

$$\tag{4}$$

with $\tan\beta$ being the ratio of the vacuum expectation values, M_A the mass of the CP-odd Higgs boson, $M_{\tilde{Q}_3}$ and $M_{\tilde{t}_R}$ the soft-breaking parameters of the top squark sector, X_t the squark mixing parameter, A_t the trilinear coupling of the top squarks, and μ the μ parameter of the Higgs potential. The other parameters are

$$\begin{aligned} M_{\rm SUSY} = M_{\tilde{Q}_1} = M_{\tilde{Q}_2} = M_{\tilde{\nu}_l,R} = M_{\tilde{l}_R} = M_{\tilde{q}_R} = 1.8 \text{ TeV} \quad \text{with} \quad l = e, \mu, \tau \quad \text{and} \quad q = u, d, c, s, b, \\ \mu = 500 \text{ GeV}, \quad A_f = 500 \text{ GeV} \quad \text{for} \quad f = e, \mu, \tau, u, d, c, s, b, \\ M_1 = \frac{5}{3}\sin^2\theta_W \cos^2\theta_W M_2, \quad M_2 = 500 \text{ GeV}, \quad M_3 = 1.1 \text{ TeV} \\ m_t = 173 \text{ GeV}, \quad M_W = 80.4 \text{ GeV}, \quad M_Z = 91.2 \text{ GeV} \end{aligned} \tag{5}$$

with the soft breaking parameters of the sfermion sector in the first line (exept for the top squarks), the trilinear couplings of the sfermions in the second line, the gaugino mass parameters in the third

[1]Resource note for ILC discussions.

line, and the mass of the top quark, the W boson and the Z boson, respectively, in the last line. We include resummed logs using the loglevel=3. Also, otherwise we are using the recommended flags, i.e. running 2-loop top quark mass and bottom resummation of terms of $\mathcal{O}(\tan^n \beta)$.

The LHC discovery potential is modelled after according to Fig. 1.21 of [1] inspired from chapter 19 in [2], taking into account an additional upper bound in the M_A-$\tan\beta$ plane of

$$\tan\beta \leq \frac{9}{350} M_A - \frac{5}{7} \tag{6}$$

to implement the improvements already made by the LHC. Just using these constraints, one obtains a figure of deviations, see Fig. 1.

One can see that the deviations for lower values of M_A are much larger as expected, reaching a deviation of roughly 30%. Taking into account further improvements of the LHC measurements and using Fig. 15 and Fig. 19 of Ref. [3] as a rough estimate of the prospective reach of the LHC at 300 fb, we consider a point for $M_A = 550$ GeV and $\tan\beta = 6$ and find for both stop masses larger than 1.5 TeV a deviation of

$$\Delta C_{\rm hbb}^{\rm MSSM} = 8.2\% \tag{7}$$

where the Higgs mass is 124.95 GeV, and for $M_A = 600$ GeV and $\tan\beta = 6$

$$\Delta C_{\rm hbb}^{\rm MSSM} = 6.8\% \tag{8}$$

and a Higgs mass of 124.99 GeV. In both points, A_t is 3083.3 GeV and $M_{\tilde{Q}_3} = M_{\tilde{t}_R} = 1.8$ TeV. One should bare in mind that there is an uncertainty on both the MSSM and the SM coupling but it seems reasonable to assume that deviations of 5% of the Higgs to bottom quark coupling do exist, even if the LHC does not find a sign of new physics .

2 ΔC_{hbb} in the no-stop mixing scenario

In the no-stop mixing scenario the the leading radiative correction is only to the '22' element of the mass matrix of the CP -even states,

$$\begin{pmatrix} -M_A^2 \sin^2\beta + M_Z^2 \cos^2\beta & \frac{M_A^2}{2} \sin 2\beta - M_Z^2 \sin\beta\cos\beta \\ \frac{M_A^2}{2} \sin 2\beta - M_Z^2 \sin\beta\cos\beta & -M_A^2 \cos^2\beta + M_Z^2 \sin^2\beta + \Delta_{22}^2 \end{pmatrix} \tag{9}$$

where at leading order,

$$\Delta_{22}^2 = \frac{3\bar{m}_t^4}{\pi^2 v^2 \sin^2\beta} \log\frac{M_s}{\bar{m}_t}.$$

where M_s is the arithmetic mean of the stop masses and $\bar{m}_t$ is the running top mass. For a given value of M_A and $\tan\beta$, Δ_{22}^2 be fixed by requiring the correct Higgs mass $M_h = 125$ GeV. This completely fixes the mass matrix and the mixing angle α. The stop masses required to raise the higgs mass to 125 GeV in the no mixing scenario are very large and easily beyond present or future LHC reach. The hbb coupling deviation from SM can then be evaluated analytically using,

$$\Delta C_{hbb} = -\frac{\sin\alpha}{\cos\beta} - 1 \tag{10}$$

As in the previous section, the largest deviations occur at smallerst allowed M_A values. Using, which summarizes the current bounds in the $M_A - \tan\beta$ plane, we can find the smallest allowed M_A for a given value of $\tan\beta$. This allows us to compute the largest allowed ΔC_{hbb} as a function of $\tan\beta$ as shown in Fig. 2. We see the largest allowed deviation for $\tan\beta = 7$where the lowest allowed value of $M_A = 300$ GeV and $\Delta C_{hbb} = 0.31$.

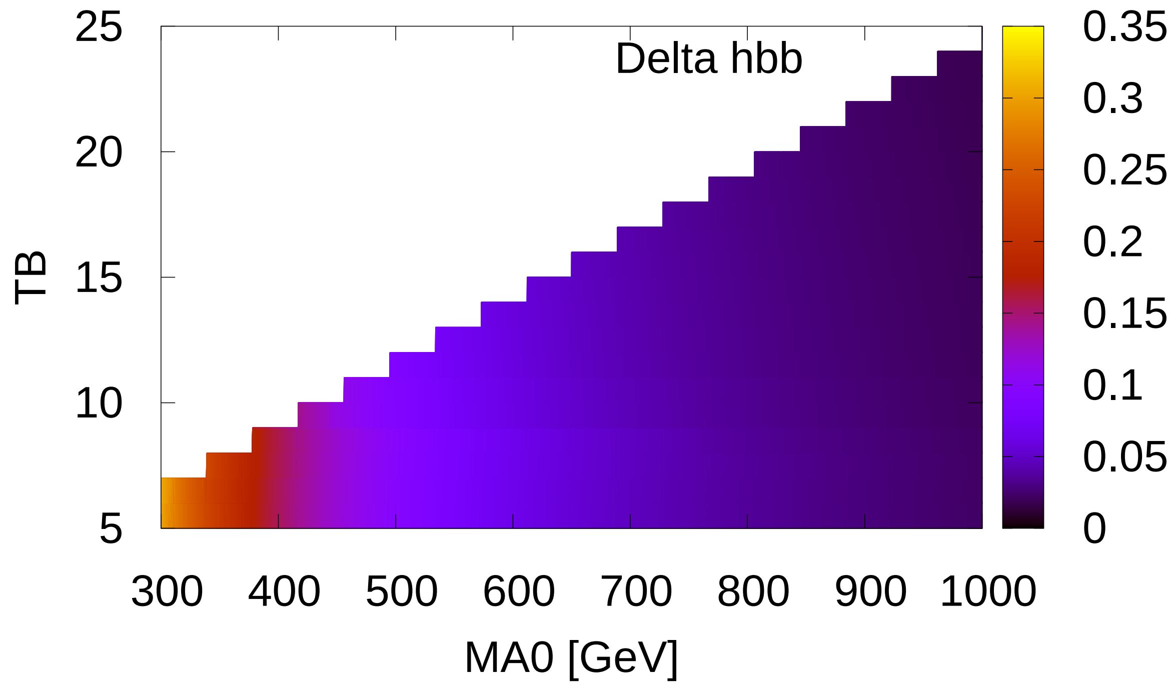

Figure 1: $\Delta C_{hbb} = \frac{C_{hbb}^{\mathrm{MSSM}} - C_{hhh}^{\mathrm{SM}}}{C_{hbb}^{\mathrm{SM}}}$ dependence on $\tan\beta$ and M_A.

References

[1] L. Linssen, A. Miyamoto, M. Stanitzki and H. Weerts, arXiv:1202.5940 [physics.ins-det].

[2] ATLAS Collaboration, "ATLAS: Detector and physics performance technical design report. Volume 2," CERN-LHCC-99-15 (May 1999).

[3] A. Djouadi, L. Maiani, A. Polosa, J. Quevillon and V. Riquer, JHEP **1506** (2015) 168 doi:10.1007/JHEP06(2015)168 [arXiv:1502.05653 [hep-ph]].

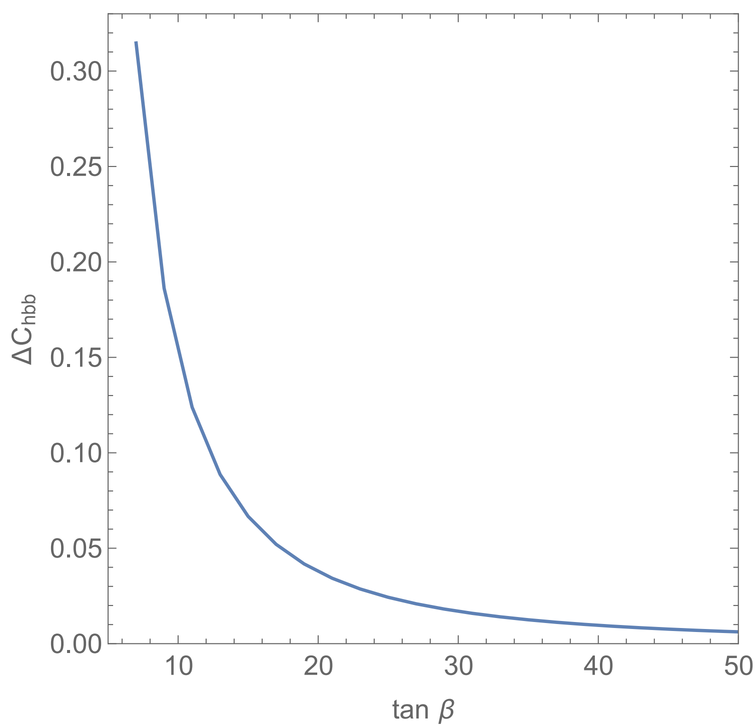

Figure 2: Maximum allowed ΔC_{hbb} in the no stop-mixing scenario.