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CP Violation In and Beyond The Standard Model: Two Higgs Doublet Model Type II Contributions to Flavour Observables

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Abstract: In this study, we first cover the theory of the Standard Model (SM) and then test the Two Higgs Doublet Model (2HDM) of Type II as an extension to the SM using indicative flavour observables, such as leptonic and semileptonic decays of B and D mesons, $B\bar{B}$ mixing, and the $b \to s\gamma$ radiative decay. Testing the 2HDM parameter space $(m_{H^+}, \tan\beta)$ to find alignment between theoretical calculations and experiment, constraints on the parameters were found for flavour phenomena to work towards a global fit. We perform this fit in both the alignment and wrong sign limits of the 2HDM. Strongly dominated by the $b \to s\gamma$ branching ratio, the mass of a charged Higgs particle would be expected to have a minimum value at 95% CL of 490 GeV in the alignment limit and 740 GeV in the wrong sign limit. The value of $\tan\beta$ is limited by $B_q \to \mu^+\mu^-$ decays, yielding maximum values at 95% CL of 20.8 in the alignment limit and 4.03 in the wrong sign, for the fixed choices of other parameters. This work was then joined with constraints from the oblique parameters S, T, U from another work, to better give judgement on the state of the 2HDM fit. The results of this combined fit are no more conclusive than flavour alone, due to additional parameter dependency in S, T, U; the only additional constraint we definitively find here is that $m_{H^+} \approx m_{H^0} \approx m_{A^0}$ in both the alignment and wrong sign limits. The validity of this fit is heavily influenced by the semileptonic ratio $\mathcal{R}(D^*)$ which remains in disagreement with the 2HDM fit to 3σ; the statistical fit of these observables points to exclusion of this model at 95% CL in the wrong sign limit, and 85% CL in the alignment limit, at 2σ error significance. This model cannot be excluded at 3σ error significance, where $\mathcal{R}(D^*)$ no longer causes disagreement in the fit.