1 Motivation for the study of the SM

The properties of the new resonance observed at the LHC in 2012 [1, 2], discovery of the SM Higgs proposed by (for instance, see [3, 4]). The particle spectrum predicted by the SM has now been fully confirmed.

Questions left unanswered:

the smallness of neutrino masses, the fermion mass hierarchy, the colossal asymmetry between the quantity of matter and antimatter in the universe the nature of dark matter

They are usually taken as hints for the existence of new physics (NP) beyond the SM (BSM).

Typical BSM scenarios that aim to fix one or more such shortcomings of the SM often end up extending the scalar sector of the SM. In these extensions, the 125 GeV scalar observed at the LHC is not the only scalar in the spectrum but the first one in a series of others to follow.

This is an intriguing possibility which motivates us for a closer inspection of the properties of the observed scalar and inspires us to carry on our efforts to look for new resonances at the collider experiments.

When it comes to extending the scalar sector of the SM, adding replicas of the SM Higgs-doublet is one of the simplest ways to do it. Such extensions do not alter the tree level value of the electroweak (EW) ρ-parameter. Two Higgs-doublet models (2HDMs), which add only one extra doublet to the SM Higgs sector, have received its fair share of attention through the years. They were proposed by T.D. Lee in 1973 [5] as a means to obtain a spontaneous breaking of the CP symmetry, and boast a rich phenomenology. Other than the possibility of spontaneous CP breaking, such models contain a richer particle spectrum, with a charged scalar and a total of three neutral ones, may feature dark matter candidates in certain scenarios, and generically give rise to the tree-level scalar-mediated flavour changing neutral currents (FCNCs).

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Indeed, one ominous outcome of adding extra scalar doublets is that the fermions of a particular charge will now receive their masses from multiple Yukawa matrices and consequently, diagonalization of their mass matrices will no longer guarantee the simultaneous diagonalization of the Yukawa matrices. Therefore, in general, there will exist FCNCs at tree-level mediated by neutral scalars.

Experimental data from the flavour sector – to wit, neutral meson mass differences for Kaons and B-mesons, or ϵ_K data – strongly constrain such FCNCs, typically forcing the extra scalars to have masses above 1 TeV [6]. An alternative is to fine-tune the FCNC interactions so that they are very small, though for some models cancellations between CP-even and CP-odd contributions to the amplitudes off the observables mentioned allow for below-TeV scalars with a minimal fine-tuning (see, for instance, [7–9]).

2 Motivation for the BLSM

3 Motivation for the 3HDM