Phenomenology of the $\mathscr{Z}_N \times \mathscr{Z}_M$ flavour symmetry and the Standard HVM

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Chapter 6

Summary

The flavour problem is intriguing and fascinating theoretical challenge of the SM, and its origin requires us to go beyond the SM. There are several theoretical frameworks based on top-down or bottom-up approaches to address this problem. These solutions are discussed in detail in this thesis.

One of the most popular frameworks to explain the flavour structure of the SM is by extending the scalar sector of the SM by a flavon field through a continuous $U(1)$ symmetry. This results in the so-called FN mechanism. We implement the FN mechanism replacing the continuous $U(1)$ symmetry by a novel discrete $\mathcal{Z}_{\rm N} \times \mathcal{Z}_{\rm M}$ flavour symmetry. This implementation does not require one to gauge a continuous $U(1)$ symmetry, thus leading to a different phenomenology of the flavon field. We have presented a comprehensive and thorough investigation of the flavour models based on the $\mathcal{Z}_{\rm N} \times \mathcal{Z}_{\rm M}$ flavour symmetries by deriving the flavour bounds on their parameter space using quark and lepton flavour physics data. In particular, we have discussed inclusive, associative and di-flavon collider signatures of the flavour models based on the $\mathcal{Z}_{\rm N} \times \mathcal{Z}_{\rm M}$ flavour symmetries at the HL-LHC, HE-LHC, and a 100 TeV collider such as FCC-hh.

An unconventional way to address the flavour problem is the SHVM, where the flavour structure is explained in terms of new energy scales created by the VEVs of the gauge singlet scalar fields. This framework has its origin in a UV theory based on strongly interacting dark technicolour paradigm where the VEVs are multi-fermions chiral condensates. This framework can predict the quark mixing angle θ_{13}. The main achievement of the SHVM, apart from addressing the flavour problem, is that the leptonic mixing angles are predicted very precisely, which can be probed in the next generation of neutrino experiments such as DUNE and JUNO. Moreover, the SHVM gives rise to multiple ALPs scenario, which may provide a dark matter candidate.

We have presented an extensive investigation of the SHVM in this thesis by deriving the flavour bounds on the parameter space of the SHVM using the quark and lepton flavour physics data. Moreover, phenomenology of the multiple ALPs scenario is also investigated, and we are able to exclude masses of several SHVM ALPs using several the bounds given by astrophysical experiments. Furthermore, we have discussed several inclusive collider signatures of the SHVM in a soft-symmetry breaking scenario at the HL-LHC, HE-LHC and a 100 TeV collider such as FCC-hh.