ABSTRACT

The Large Hadron Collider (LHC) before its long shutdown in 2018 has collected data equivalent to $\sim 200\ fb^{-1}$ integrated luminosity. Apart from the discovery of Higgs in 2012 no statistically significant deviation from the Standard Model (SM) has been reported by the two collaborations CMS and ATLAS. These null results can be translated to stringent constraints on the parameter space of scenarios Beyond the Standard Model. Strongly interacting models of electroweak symmetry breaking once pared down to their low energy effective Lagrangian usually predict same spin exotic partners of the SM states. The central theme of this thesis is to explore aspects of LHC constraints on these models from direct searches of the exotic states and to study the corresponding HL-LHC reaches.

We consider a non-minimal universal extra dimensional scenario with the extra spatial dimension compactified on an $S^1/\mathbb{Z}_2$ orbifold. The SM states are allowed to propagate the bulk with nontrivial brane localized kinetic terms. The flavour structure of brane kinetic terms for the standard model fermions are dictated by stringent flavour bounds on the first two generations implying an $U(2)_{Q_L} \otimes U(2)_{u_R} \otimes U(2)_{d_R}$ flavour symmetry. We translate the results reported in the dilepton channel of LHC into constraints on the parameter space of this model. We additionally consider the constraints on such a scenario arising from dark matter relic density and direct detection measurements, precision electroweak data and Higgs physics. We discuss the possibility of such a scenario providing an explanation of the measured anomaly in $R_{K^{(*)}}$ within the allowed region of the parameter space.

Composite Higgs framework where the Higgs is identified as a pNGB of a strong sector provides a solution to the gauge hierarchy problem and may be realized as a holographic dual to extra dimensional models. We take a bottom-up approach and capture the impacts of the strongly interacting sector by incorporating large decay width of the low lying resonances of the strong sector. We incorporate the full 1PI resummed propagator for vector and fermionic resonances corresponding to gluon and

top partners at the event generation level and study aspects of their phenomenology at collider experiments like the LHC.

In this context we reappraise the collider constraints from leptonic final states on the vectorlike colored top partner taking into account the impact of exotic gluon partner. We translate the recent results in the *monolepton + jets* channel as reported by CMS with an integrated luminosity of 35.8 fb^{-1}, and *dilepton + jets* and *trilepton + jets* channels as reported by ATLAS with an integrated luminosity of 36.1 fb^{-1} to constrain the parameter space of these class of models. We also comment on the impact and modification of the derived constraints due to the expected fatness of the gluon partner, when accounted for beyond the narrow-width approximation by simulating the full one-particle irreducible resummed propagator. We find that for mass of the gluon partner ≤ 3 TeV top partner mass > 1.5 TeV can be excluded from current LHC results. The top partners arising from underlying strong sectors are also expected to have large decay widths pushing them beyond the narrow width approximation. We consider the top like top partner to strongly couple to an exotic pseudoscalar. We use the full 1PI resummed propagator for the top partner to recast the present LHC constraints ruling out masses below ~ 1.2 (1.1) TeV for width to mass ratio of 0.1 (0.6). We utilize machine learning techniques that are demonstratively more efficient than traditional cut based searches to present the reach of HL-LHC on the parameter space of this broad resonance. We find that at 3 ab^{-1} the HL-LHC has a discovery potential up to 1.6 TeV dominated by the pair production channel. We study the feasibility of using machine learning techniques to analyze the broad resonance peaks expected from these exotic quarks at collider experiments like the LHC.

Remnants of an underlying strong sector can be searched for indirectly in the modification of SM couplings. In composite Higgs models the Higgs boson is considered to be a composite scalar with a finite extension in space. Owing to the momentum dependence of its couplings the imprints of such a composite pseudo Goldstone Higgs may show up in the tails of various kinematic distributions at the LHC, distinguish-

ing it from an elementary state. From the bottom up we construct the momentum dependent form factors to capture the interactions of the composite Higgs with the weak gauge bosons. We demonstrate their impact in the differential distributions of various kinematic parameters for the $pp \to Z^*H \to l^+l^-b\bar{b}$ channel. We show that this channel can provide an important handle to probe the Higgs' substructure at the HL-LHC.