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Phenomenological Study of the Nambu–Jona-Lasinio Composite Model at the LHC and HL-LHC

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Within a new physics scenario, four-fermion operators of the Nambu–Jona-Lasinio (NJL) type exhibit a strong-coupling ultraviolet (UV) fixed point at the TeV scale \[1\]. At this scale, a quark and a lepton—two Standard Model (SM) elementary fermions—form a bound state, resulting in a composite bosons, which couples to its constituents via effective contact interactions at the compositeness scale $\Lambda \approx \mathcal{O}(\text{TeV})$. As a first step, we implement this model in the Universal FeynRules Output (UFO) format and focus on the collider phenomenology of scalars at the LHC, including its High-Luminosity upgrade.

Initial studies have explored the phenomenology of leptoquarks (LQs), which can be produced at hadron colliders through various mechanisms, including quark or gluon fusion, t-channel exchange, and single production processes. In our detailed phenomenological analysis \[2\], we compute LQ production cross sections for both proton-proton (pp) and photon-proton (γp) collisions, as relevant to LHC experiments. For γp scenarios, we consider both elastic and inelastic photon emission. Additionally, we investigate lepton-induced processes by exploiting the possibility of lepton emission from protons. A targeted study of LQs coupling to a μ–c quark pair demonstrates improved sensitivity relative to existing search strategies. Based on this enhanced discovery potential, we recommend incorporating dedicated LQ search channels in future LHC analyses.

Ongoing research is focused on quark-antiquark interactions at the LHC. Specifically, we are exploring the production mechanisms of composite scalar particles that decay into diphoton or diquark final states. A central goal is to extract constraints on these final states using existing experimental data.

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