DOCTORAL

DEFENSE

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Mirror Color Symmetry Breaking in Twin Higgs Model

Abstract: Many conventional approaches aiming to explain the hierarchy between the electroweak scale and any high new physics scales necessitate colored top partners around the TeV scale, which are increasingly in tension with bounds from direct searches for these states at the Large Hadron Collider (LHC) experiments. The Mirror Twin Higgs (MTH) and other 'Neutral Naturalness' models address this issue by positing top partners that are neutral under the Standard Model (SM) gauge group. In the MTH model the SM Higgs doublet emerges as a pseudo Nambu Goldstone boson (pNGB) from a spontaneously broken accidental global symmetry and is naturally light in comparison to the ultraviolet (UV) cutoff of the low energy effective theory. A crucial ingredient in this construction is a Z_2 mirror symmetry that exchanges SM fields with their partner fields in a mirror sector, enforcing the equality of visible and mirror sector couplings and removing the dangerous quadratic sensitivity of the Higgs squared mass to the UV cutoff. However, an exact mirror symmetry is in conflict with electroweak and Higgs coupling measurements as well as cosmological bounds on the effective number of relativistic degrees of freedom, and the Z_2 symmetry must be broken to achieve a phenomenologically viable model.

In this thesis, we describe a new dynamical approach to mirror symmetry breaking with a variety of potential phenomenological and cosmological implications. Rather than assuming a soft or hard breaking of the Z_2 symmetry 'by hand', we investigate the simultaneous spontaneous breakdown of mirror $SU(3)_c$ color gauge symmetry and Z_2 symmetry. Starting from an exact Z_2 symmetry, we introduce an additional colored scalar field in the visible sector along with its twin partner field. Given a suitable scalar potential, the mirror sector color scalar field obtains a vacuum expectation value and spontaneously breaks both the twin color gauge symmetry and mirror Z_2 symmetry. This allows for a proper dynamical alignment of the electroweak vacuum that is in accord with electroweak precision and Higgs coupling measurements.

Meanwhile, the spontaneous mirror color symmetry breaking leads to dramatic differences between the twin and visible sectors at low energies in terms of the residual unbroken gauge symmetries, strong sector confinement scales, and particle spectra. Assuming a single new colored scalar in the triplet, sextet, or octet representation we describe five minimal possibilities for the gauge symmetry breaking pattern. In several cases there is a residual unbroken mirror color gauge symmetry, either $SU(2)_c$ or $SO(3)_c$, which feature a very low confinement scale in comparison to ΛQCD. Furthermore, there can be one or more unbroken abelian gauge symmetries. Couplings between the colored scalar and matter are also allowed by all symmetries, providing a new dynamical source of twin fermion masses. This can potentially be used to construct a fraternal-like Twin Higgs scenario by lifting the first and second generation twin fermions. Given the exact Z_2 symmetry in our setup, these couplings lead to a variety of correlated visible sector effects that can be probed trough precision measurements and collider searches. We have surveyed the constraints on the structure and size of these couplings coming from measurements in several classes of phenomena, including baryon and lepton number violation, quark and lepton flavor changing processes, electroweak measurements, CP-violation, Higgs couplings, and direct searches at the LHC. This construction opens up new possibilities for obtaining a viable twin Higgs cosmology with interesting implications for dark sector physics.