Snowmass2021 - Letter of Interest

Electroweak Symmetry non-Restoration and Delayed Electroweak Phase Transitions

Thematic Areas: (check all that apply □/■)

■ (EF02) Higgs Portal
■ (EF09) General BSM
■ (TF07) Collider Phenomenology
■ (TF08) BSM Model Building
■ (TF09) Astro-particle Physics & Cosmology
■ (RF06) Dark Sector Studies at High Intensities

Contact Information:
Submitter Name/Institution: Claudius Krause, Fermilab
Contact Email: ckrause@fnal.gov

Authors: Marcela Carena - Fermilab/UChicago, Claudius Krause - Fermilab, Zhen Liu - UMD, Yikun Wang - Fermilab/UChicago

Note that this list of signatories is preliminary, and everyone will be welcome to contribute to the studies towards the whitepaper within each Topical Group.

Electroweak baryogenesis provides a unique solution to the puzzle of the observed matter-antimatter asymmetry of our universe. The electroweak phase transition of the Standard Model (SM) is a smooth crossover, and takes place at a low scale that is inconsistent with many precision CP-violation measurements. All together, this does not fulfill the needs for electroweak baryogenesis. Alternatively, we can imagine a modified Higgs sector where the electroweak symmetry is never restored, or only restored at very high energy. Such possibilities of "delayed" electroweak symmetry breaking or non-restoration allow new considerations for viable baryogenesis mechanisms. In Fig. 1 we show diagrammatically an illustration of the thermal history from Ref.[1].

In the case where the electroweak symmetry breaking is "delayed", meaning it took place at a high critical temperature due to the modified scalar sector as for instance considered in Refs.[1–5], one has more freedom in introducing high scale CP-violation that are still consistent with the precision CP tests such as the electron EDM.

In the case where the electroweak symmetry is never restored, for instance in the setup of Refs.[2,6], other baryogenesis mechanisms such as GUT baryogenesis are possible. It partially avoids the sphalerons erasure problem, but one needs to quantify the total amount of erasure through the long evolution from high temperatures to the current low temperature, setting requirements for the needed asymmetries at a given scale.

In the above scenarios, one usually needs to introduce large number of scalars to modify the Higgs

potential without hitting Landau poles at nearby scales. Furthermore, these scenarios all rely on large thermal correction for the scalar potentials. It is critical to check whether such construction is robust against corrections, including renormalization-group flow, various resummations (e.g, daisy and super-daisy resummation) of the thermal effects, etc. These scenarios potentially generate new cosmological probes, collider tests in the energy frontier, and precision tests at the intensity frontier. In this LOI, we express our interests in studying the viable models and the allowed baryogenesis mechanisms, and in addition explore many of the phenomenological implications at various frontiers.

References

[1] Marcela Carena, Claudius Krause, Zhen Liu, and Yikun Wang. Symmetry non-restoration in extended scalar sectors. *In preparation.*

[2] Iason Baldes and Géraldine Servant. High scale electroweak phase transition: baryogenesis & symmetry non-restoration. *JHEP*, 10:053, 2018. arXiv:1807.08770, doi:10.1007/JHEP10(2018)053.

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[4] Oleksii Matsedonskyi and Geraldine Servant. High-Temperature Electroweak Symmetry Non-Restoration from New Fermions and Implications for Baryogenesis. 2020. arXiv:2002.05174.

[5] Seyda Ipek and Tim M. P. Tait. Early Cosmological Period of QCD Confinement. *Phys. Rev. Lett.*, 122(11):112001, 2019. arXiv:1811.00559, doi:10.1103/PhysRevLett.122.112001.

[6] Patrick Meade and Harikrishnan Ramani. Unrestored Electroweak Symmetry. *Phys. Rev. Lett.*, 122(4):041802, 2019. arXiv:1807.07578, doi:10.1103/PhysRevLett.122.041802.

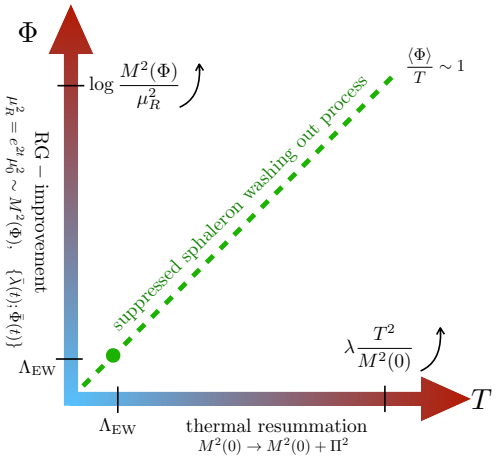

Figure 1: Diagrammatic of the field and temperature regime of the electroweak non-restoration/delayed restoration scenarios.