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A Catalog of First-Order Electroweak Phase Transitions in the SMEFT

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A first-order Electroweak Phase Transition (FOEWPT) could explain the observed baryon-antibaryon asymmetry of the Universe, and its dynamics could yield a detectable gravitational wave signature, while the underlying physics would be within the reach of colliders. The Standard Model, however, predicts a crossover transition, so any hope of having a FOEWPT hinges on physics beyond the Standard Model (BSM). Most studies of the possibilities for a FOEWPT consider specific BSM models with new particles around the electroweak scale that help generate a barrier in the effective potential between the true and the false vacuum, facilitating a first-order transition.

On the other hand, the Standard Model Effective Field Theory (SMEFT) is a model-independent effective field theory extension of the SM that encodes new physics at the cutoff scale. It contains all SU(3)xSU(2)xU(1) invariant operators to a given order in the EFT expansion. Previous phenomenological studies of possibilities for a FOEWPT in the SMEFT have considered the case with a tree-level barrier and a negative Higgs quartic coupling. This requires a small new physics scale, which from an EFT perspective is undesirable.

In a recent paper [1] (see also [2]) we have used modern dimensionally-reduced EFT methods with careful power-counting of scale hierarchies to analyze and catalog the different types of FOEWPT that are possible in the SMEFT. These calculations lay the groundwork to performing gauge invariant, properly resummed perturbative expansions addressing the theoretical problems with phase transition calculations.

We find three types of configurations of the scalar potential that allow a FOEWPT: (1) tree-level barriers, (2) radiative barriers, and (3) radiative symmetry breaking through the Coleman-Weinberg mechanism. We also find versions of these with supercooling. We perform a global likelihood scan over the SMEFT Wilson coefficients to identify parameter regions that exhibit these first-order phase transitions and are consistent with experimental and theoretical constraints. We comment on the possibilities for electroweak baryogenesis within the SMEFT, and roughly estimate if the gravitational wave spectra generated by the phase transitions are detectable. In this talk I will also briefly discuss a comparison of the method with the more common 4D QFT calculations of the phase transition parameters, as well as the prospects for probing the allowed parameter space using di-Higgs production in colliders.

[1] E. Camargo-Molina, R. Enberg, J. Löfgren, "A Catalog of First-Order Electroweak Phase Transitions in the Standard Model Effective Field Theory", https://arxiv.org/abs/2410.23210

[2] J.E. Camargo-Molina, R. Enberg, J. Löfgren, "A new perspective on the electroweak phase transition in the Standard Model Effective Field Theory", JHEP 2021, 127 (2021), https://arxiv.org/abs/2103.14022

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