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Precision Calculations of Effective Potentials and Electroweak Phase Transitions in the Early Universe

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We present a detailed study of the precision calculations of higher-order contributions to effective potential with the application of three-dimensional effective field theories (3D EFTs). Our work focuses on the thermodynamic quantification and description of electroweak phase transitions in the early Universe for the complex singlet extended Standard Model (cxSM). In particular, we address the issue of gauge and scale dependences associated with the effective potential, which can lead to ambiguities when calculating thermodynamical quantities from the effective potential. To overcome this issue, we employ the high temperature 3D EFT framework, which provides a robust approach for consistently taking into account the relevant contributions in physical predictions. In addition, we study the ambiguities in commonly used renormalization schemes of the effective potential. The phenomenological implications of our results are discussed.

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