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RESEARCH OF THE BEHAVIOR OF THE EFFECTIVE POTENTIAL IN SYSTEMS WITH PHASE TRANSITIONS THROUGH THE PRISM OF A–D–E TYPE SINGULARITIES

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The Higgs boson discovery raised new questions about the Standard Model's mysteries, particularly the existence of three matter generations with vastly different masses. New physics might be revealed through electron-positron collider experiments at specific energy levels, as the Standard Model serves as a foundation for examining nature across all scales .

An extended scalar sector enables a sharp first-order electroweak phase transition (FOPT). While the Standard Model with 125 GeV Higgs shows only smooth crossover, introducing new light scalar degrees of freedom—such as in two-Higgs-doublet models—can create a decisive first-order transition. Arnold's classification of simple singularities (A–D–E series) is extensively used in modern critical phenomena theory.

Groebner basis calculations showed that across the physically allowed parameter space: mS = 400 GeV –TeV, $|\sin\theta| \leq 0.3$, $a_2 = 1–8$, $b_4 > 0$, with arbitrary Z_2-breaking b_1, b_3, a_1 within LHC bounds, the Milnor number remains stably $\mu = 9$.

The result has several important implications:

a) Searching for exceptional E_6–E_8 singularities in the scalar sector beyond the Standard Model requires significantly more complicated models (additional singlets, triplets, higher representations, or explicit breaking of global symmetries);

b) The stability of $\mu = 9$ explains the remarkable flatness of the potential along the singlet direction (the well-known "flat direction"in the Higgs portal), with cosmological consequences (inflation, strong first-order phase transitions, etc.);

c) The algebraic technique (Groebner bases + Milnor number) proves to be a powerful and universal tool for classifying critical points in multi-parameter field theories.

Thus, in real scalar extensions of the Standard Model with a single Z_2 singlet, the electroweak vacuum is always characterized by a composite singularity with Milnor number 9, which excludes it from belonging to the exotic simple A–D–E catastrophes, in particular to the theoretically most degenerate E_8.

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