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## No gauge cancellation at high energy in the five-vector $R_\xi$ gauge

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We propose a novel  $R_\xi$  gauge in the five-vector (5V) framework within the Abelian Higgs model. In the Cartesian basis of the complex Higgs field, the 5V  $R_\xi$  gauge ensures non-divergent tree-level amplitudes for each Feynman diagram in the high-energy limit. This framework pinpoints the origin of high-energy divergences in tree-level amplitudes for each diagram, providing a criterion for quantifying the degree of divergences from other gauges. The 5V description necessitates treating the Goldstone field as the fifth gauge-field component, offering deeper insight into the dynamics of massive gauge bosons, particularly its longitudinal mode. The impact of this framework is demonstrated by rigorously comparing tree-level amplitudes from the 5V  $R_\xi$  gauge with those from the conventional 4V  $R_\xi$  gauge and the Feynman diagram gauge, the latter of which exhibits no gauge cancellation, similar to the 5V  $R_\xi$  gauge.

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