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Extension of the Inert Two-Higgs-Doublet Model with a Real Singlet: Two-Component Dark Matter

The Inert Doublet Model (\emph{IDM}) is extended by introducing a real scalar field S, which is a singlet under the Standard Model gauge group and is stabilized by a second discrete symmetry, Z_2'. The resulting model, known as the \emph{Inert Doublet and Singlet Model}(IDSM), allows for the simultaneous existence of two stable dark matter candidates.

First, the IDM is developed explicitly, including the transformation properties of the fields under $SU(2)_L \times U(1)_Y$, the imposition of the discrete Z_2 symmetry, the construction of the scalar potential, the determination of the electroweak vacuum, the expansion of the fields, and the derivation of the scalar mass spectrum. Based on this development, the conditions under which H^0 can be identified as a dark matter candidate are established, and the relevant theoretical and experimental constraints are presented.

Subsequently, the real singlet and the second discrete symmetry Z_2' are introduced, and the most general scalar potential consistent with $SU(2)_L \times U(1)_Y \times Z_2 \times Z_2'$ is constructed. It is explicitly verified that the vacuum configuration $\langle \eta \rangle = \langle S \rangle = 0$ remains a stationary point. The complete mass spectrum of the model is then derived, and the new mass m_S, together with the interaction portals connecting the singlet, the Higgs boson, and the inert sector, is identified.

Finally, a Monte Carlo scan of 2×10^6 points is performed over the nine-dimensional parameter space of the IDSM, imposing constraints on mass positivity, the inert-sector mass hierarchy, LEP results, perturbativity, vacuum stability, mass ranges, and the Higgs invisible decay width (the channels $h \to H^0 H^0$ and $h \to SS$). A total of 656 points (0.033%) survive these constraints, defining the allowed regions in the (m_{H^0}, m_{A^0}), (m_{H^0}, m_S), and (m_S, λ_6) planes. From this set, a benchmark point is selected for the subsequent study of two-component dark matter phenomenology.

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