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Hyperchargeless Scalar Triplets and the Price of Minimalism

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We study the most minimal scalar extension that offers a tree-level violation of the custodial symmetry, while containing a dark matter (DM) candidate. A hypercharge-less scalar triplet that obtains a small vev breaks the custodial symmetry, which translates to the charged component $T^{\pm} \to ZW^{\pm}$ decay. Adding an inert singlet to this extension as a stable DM also opens up the fully invisible decay of the neutral triplet scalar, $T^0 \to SS$. Associated production of these charged and triplet scalars via vector boson fusion at a muon collider is studied, where the invisible decay mode aids the signal discernibility via large missing energy contribution. The parameter space reach in terms of discovery projection is presented at both the 3 TeV and 10 TeV muon colliders, with BDT-enhanced signal extraction for the former.

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