Softly shifting away from direct detection: reviving the Higgs portal DM

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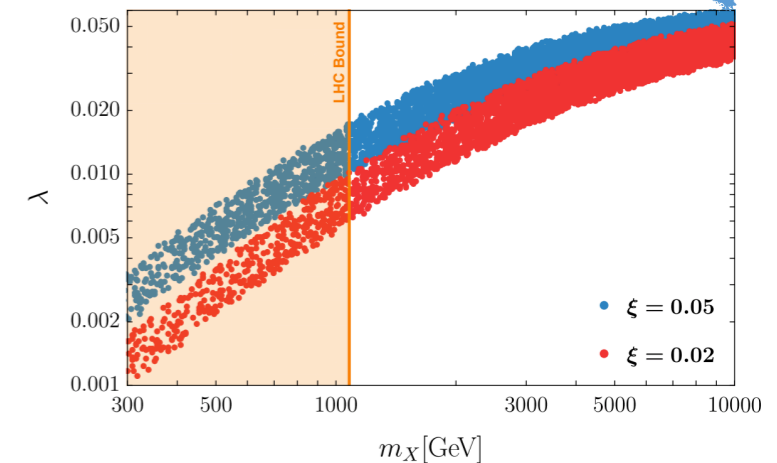1) <u>Motivation:</u> assuming Higgs-DM are PNGBs, calculable scalar potential

$\mathcal{O}_1 = \dfrac{1}{f^2}\partial_\mu(H^\dagger H)\partial^\mu(\eta^2)$

arising from NLSM; energy-sensitive; dominating in DM annihilation

$\mathcal{O}_2 = \lambda H^\dagger H \eta^2$

arising from calculable scalar potential; energy-insensitive; dominating in direct detection

NDA value when X decouples; hard-breaking

2) <u>Implementation of soft breaking mechanism: a proof-of-concept example</u>

$\Sigma = \dfrac{1}{f}(0,0,0,h,\eta,\sqrt{f^2-h^2-\eta^2})^T$

$\Psi_L = \dfrac{1}{\sqrt{2}}(ib_L, b_L, it_L, -t_L, 0, 0)^T,$

$\Psi_R = (0,0,0,0,X_R,t_R)^T.$

Shift symmetry: SO(2) rotation

$\Sigma \to \mathcal{R}\Sigma, \quad \Psi_{L,R} \to \mathcal{R}\Psi_{L,R}$

which is only broken by

$\mathcal{L} \supset m_X \bar{X}_L X_R + \text{h.c.}$

3) Dark Matter Phenomenology

NDA value

New parameter space by implementing soft breaking mechanism