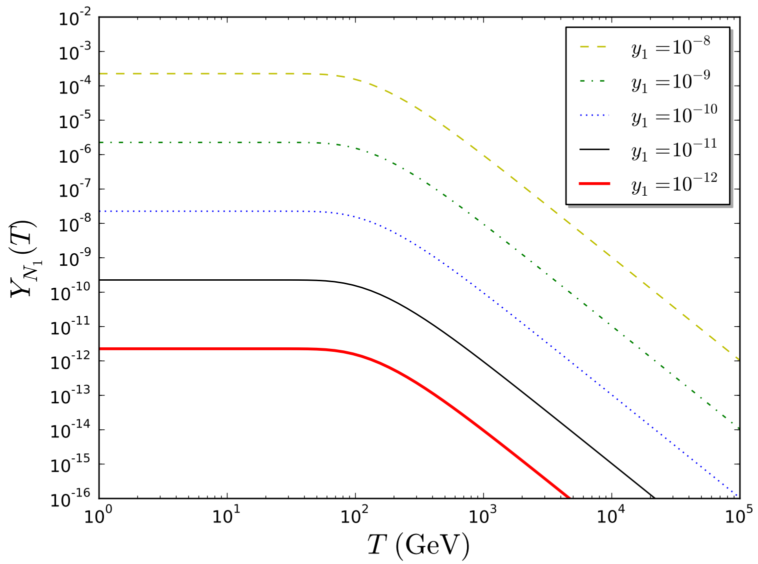
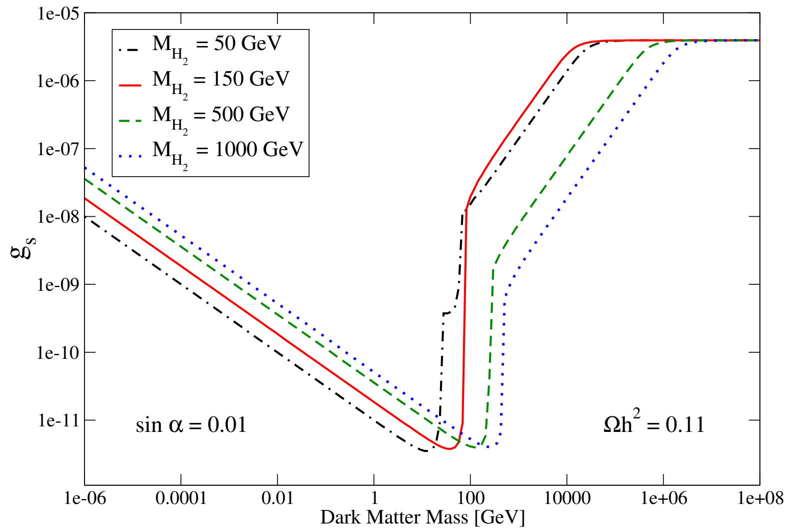
Warm and cold fermionic dark matter via freeze-in





Based on JCAP 1311 (2013) 039 (with M. Klasen)
and arXiv:1405.1259 (with E. Molinaro and O. Zapata)

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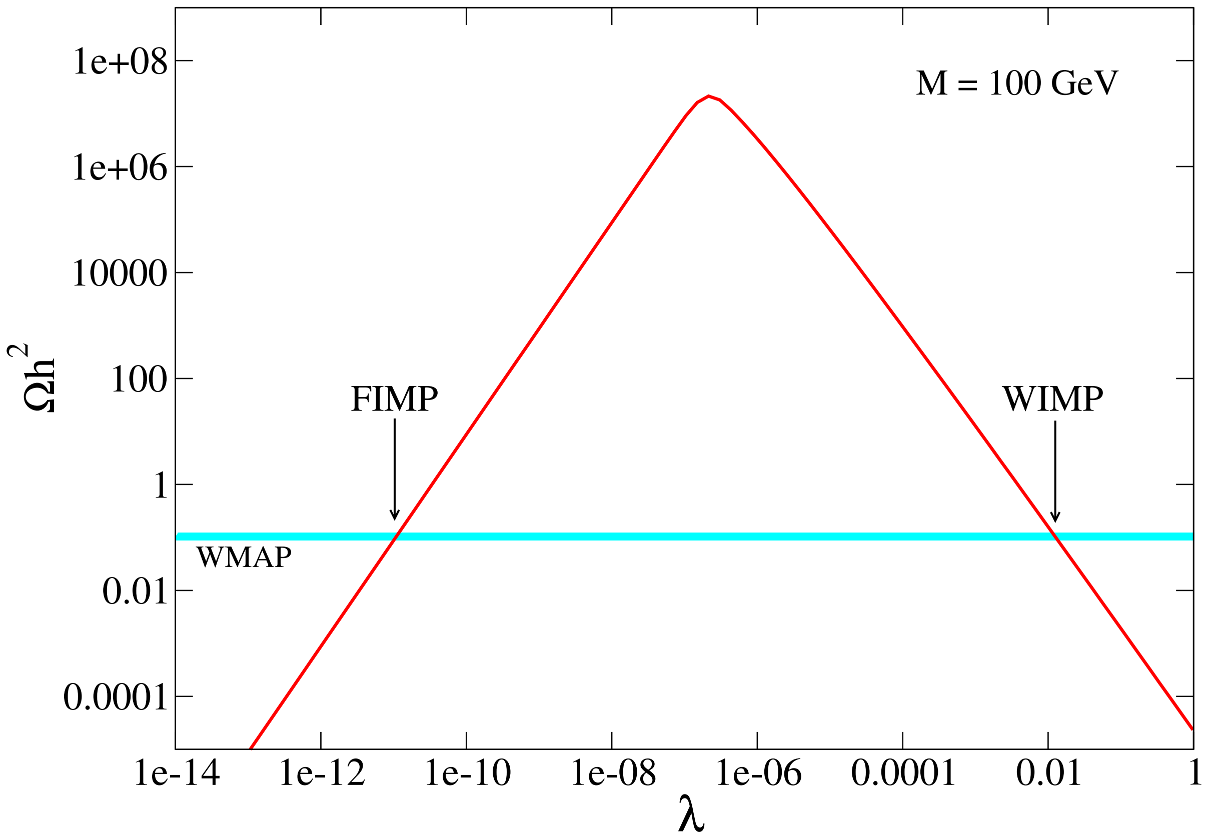
Freeze-in provides an alternative way of satisfying the dark matter constraint

Ω decreases with λ for WIMP-like solutions

For thermal production
$\Omega \to 0$ as $\lambda \to 0$

$\Omega h^2 = 0.1$ is satisfied also for very small λ

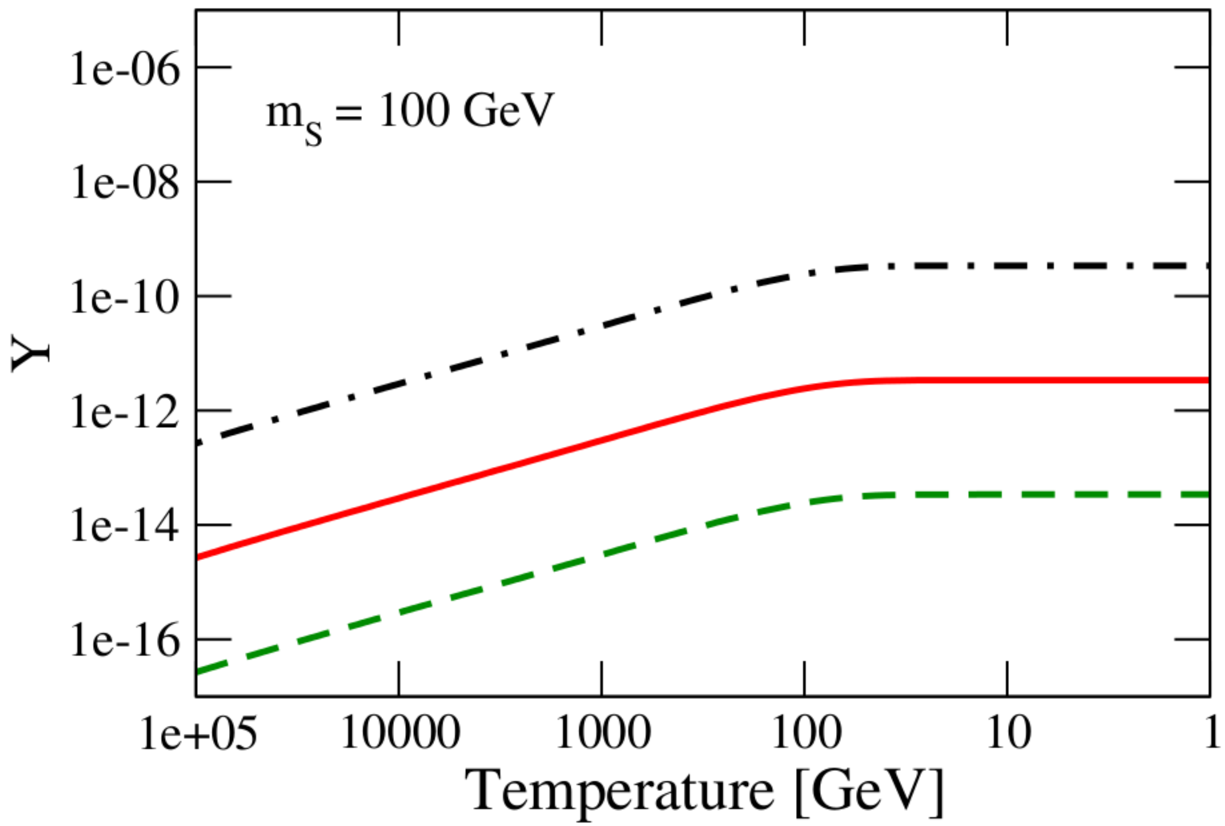


In freeze-in, the dark matter particle does not reach thermal equilibrium in the early Universe

The dm abundance increases with T

Until the freeze-in T is reached

The larger the coupling, the larger Ω



The singlet fermionic model is an extension of the SM that can account for the dark matter

It includes a singlet fermion (χ) and a singlet scalar (ϕ)

$$\mathscr{L} = -\frac{1}{2}\left(M_\chi \bar{\chi}\chi + g_s \phi \bar{\chi}\chi\right) + V(H,\phi)$$

And a Z_2 symmetry to stabilize the dm

χ is odd, ϕ is even

SM fields are even

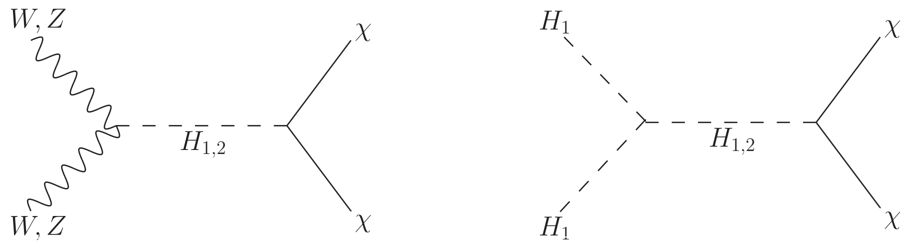
ϕ mixes with the higgs boson $\rightarrow H_1, H_2$

H_1 is higgs-like

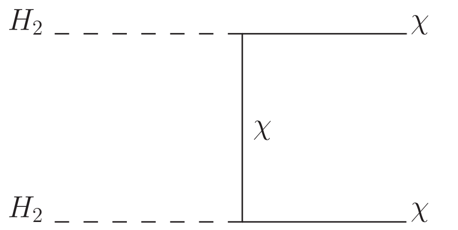
H_2 is singlet-like

Dark matter particles are pair-produced by the annihilation of SM particles

These are H_1- and H_2-mediated processes



$H_2 H_2 \to \chi\chi$ is also important



Y_χ satisfies a simple Boltzmann equation

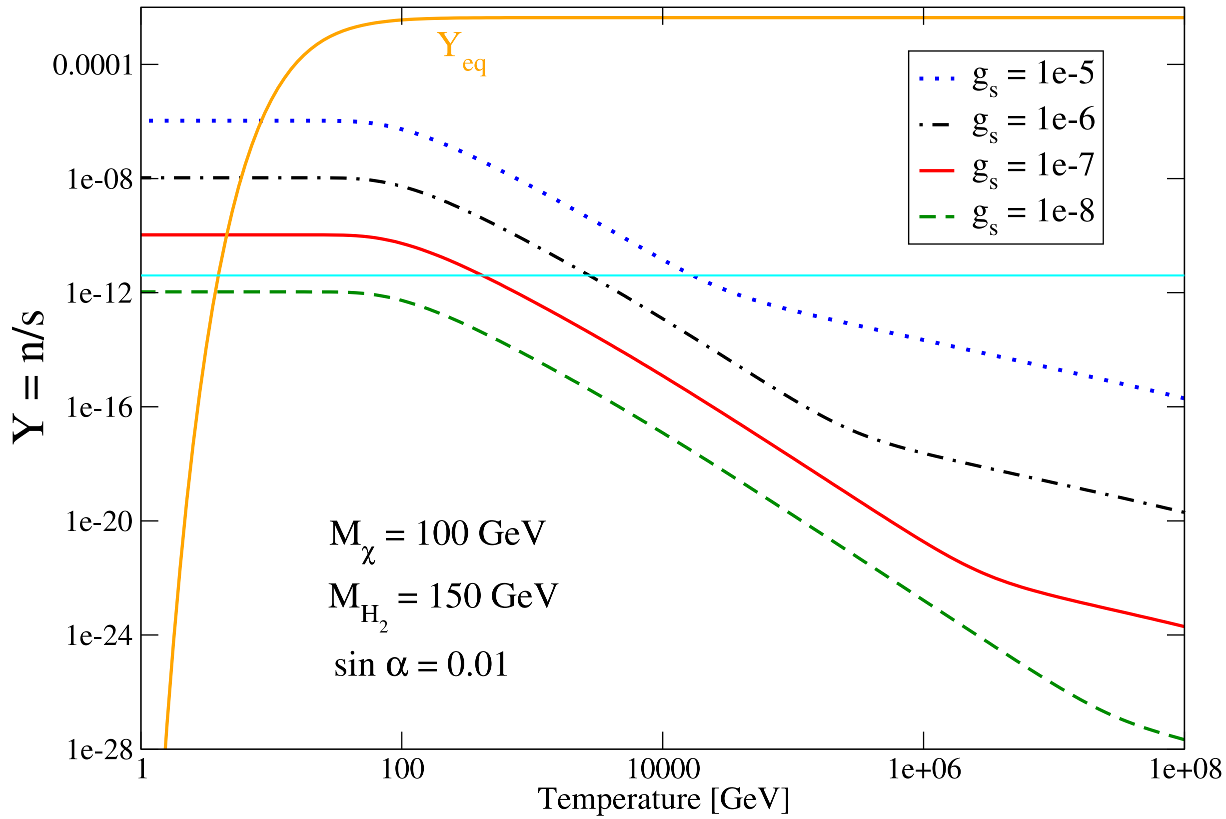
$$\frac{dY}{dT} = -\sqrt{\frac{\pi g_*(T)}{45}} M_p \langle \sigma v \rangle Y_{eq}(T)^2$$

The χ abundance has the typical freeze-in behavior

It increases until $T_{f.i.}$ is reached

$Y(T) \propto g_s^4$ at high temperatures

$Y(T) \propto g_s^2$ at low temperatures

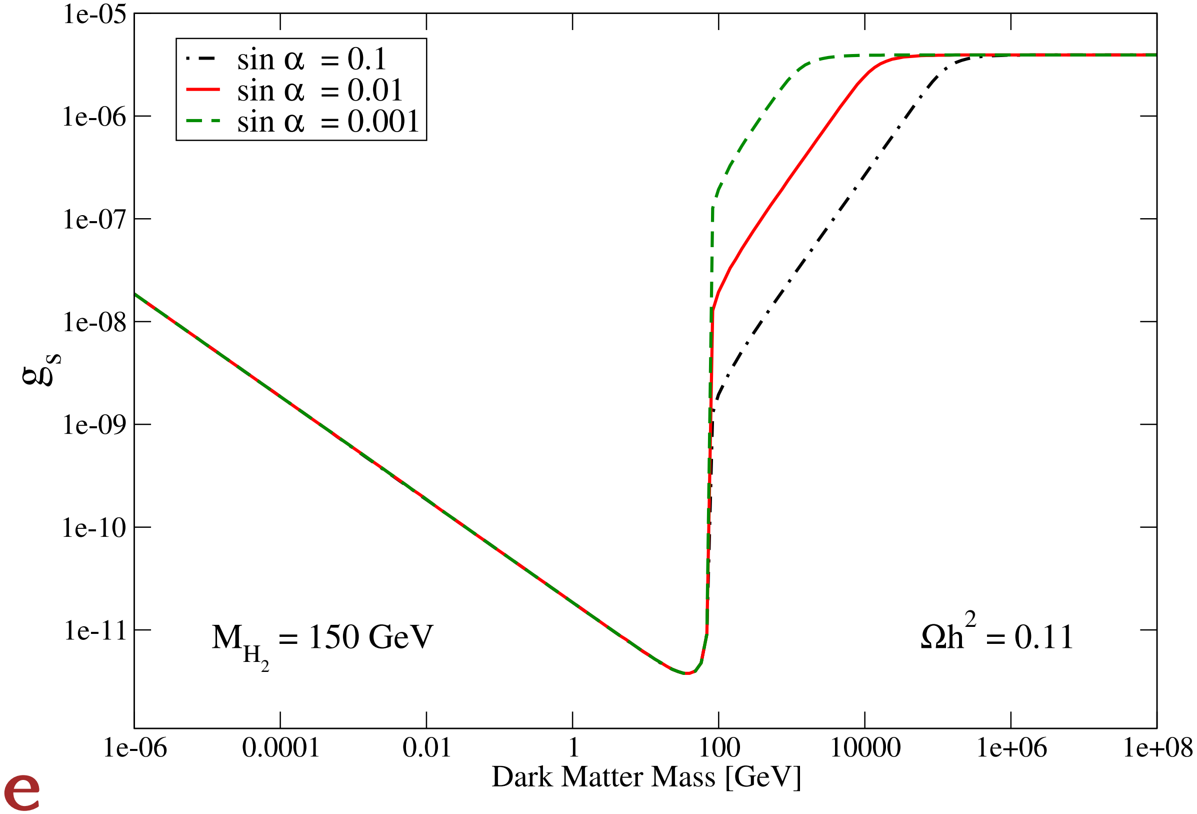


The correct relic density can be obtained over a wide range of dark matter masses

If $M\chi \sim \mathrm{keV}$ g_s should be about 10^{-8}

If $M\chi \gtrsim 10$ TeV g_s should be about 10^{-5}

Close to the H_2 resonance g_s is of order 10^{-11}



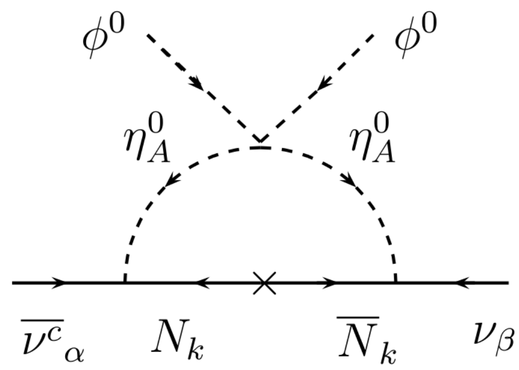
The scotogenic model is an extension of the SM that can explain ν masses and dm

It includes 3 singlet fermions and a scalar doublet

N_i, H_2 odd under Z_2

$$\mathscr{L} \supset Y^{\nu}_{\alpha i} \left(\overline{\nu}_{\alpha L} H_2^0 - \overline{\ell}_{\alpha L} H^+ \right) N_i$$

Neutrinos acquire masses at 1-loop



Two possible dark matter candidates

H^0: WIMP

N_1: WIMP or FIMP

N_1 does not reach thermal equilibrium if its Yukawa couplings are sufficiently small

One light neutrino remains almost massless

N_1 decouples from M_ν

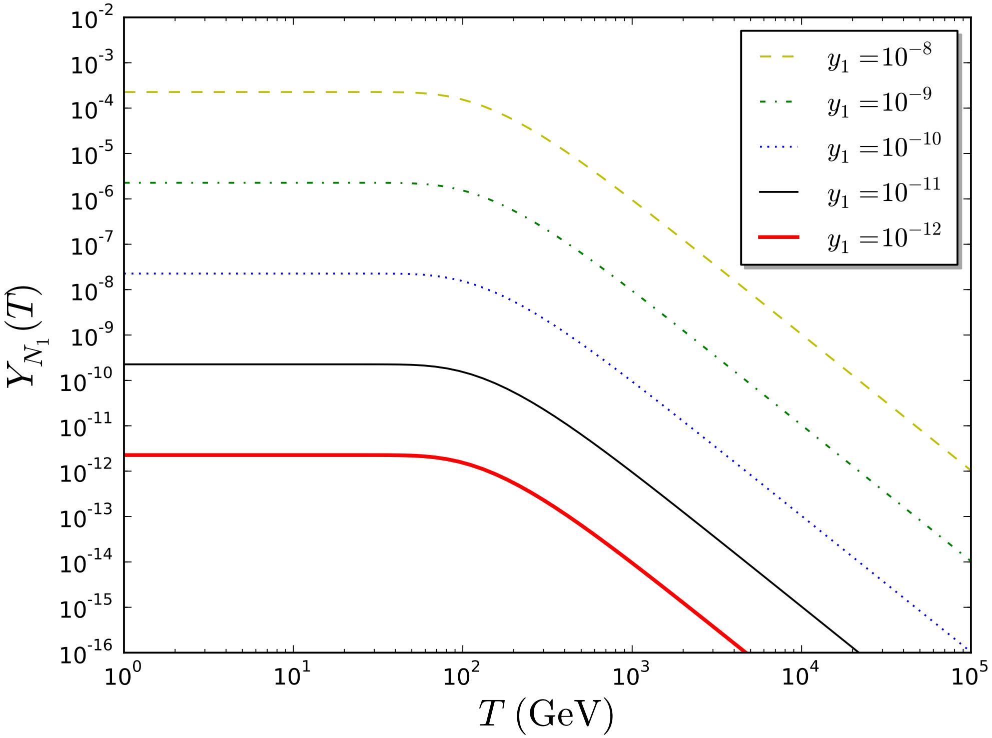
N_1's are produced via decays

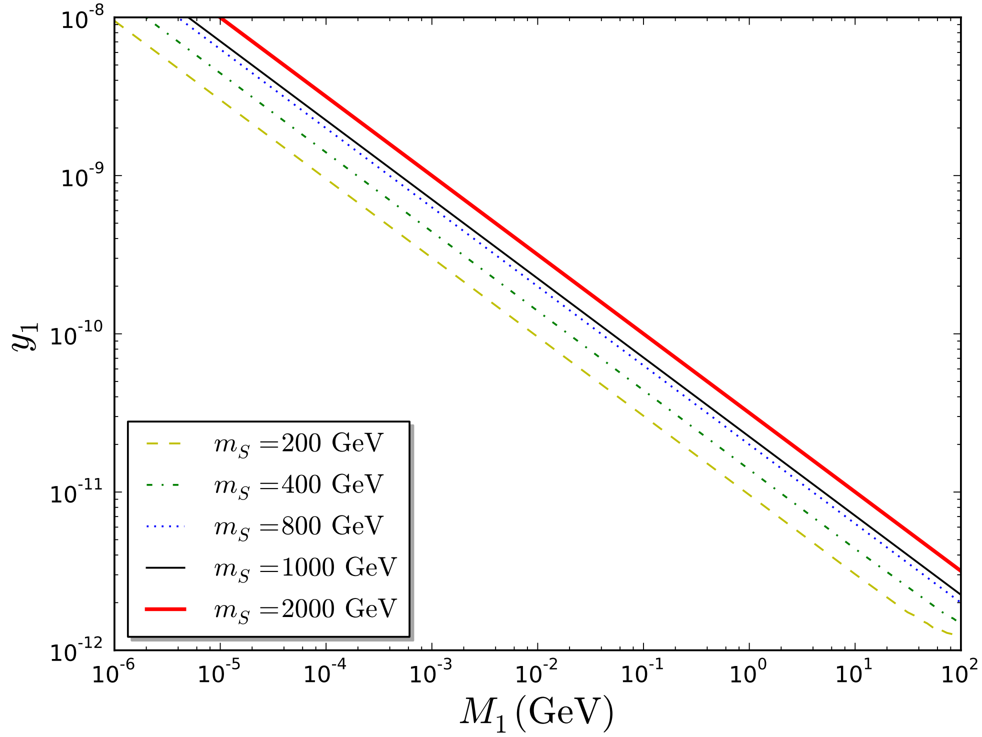
of the heavier odd particles while in equilibrium

The decays of the scalars dominate

$$H^0 \to \nu \, N_1$$
$$H^+ \to \ell^+ \, N_1$$

The correct relic density can be obtained for dm masses between the keV and the TeV scale





The evolution of the dm abundance

The regions consistent with the dark matter constraint

The freeze-in mechanism provides an intriguing alternative to the WIMP framework

It is as simple and predictive

It can explain warm or cold dark matter

It can be tested by dm detection experiments