Dark Matter and collider phenomenology in the IHDM and Scotogenic model

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The Scotogenic Model [1] is an appealing candidate to solve some of the problems of the Standard Model (SM), since it includes radiatively induced neutrino masses and a WIMP-like Dark Matter (DM) candidate. However, in the scalar sector, the Scotogenic model includes the features contained in the Inert Higgs Doublet Model [2] (IHDM).

IHDM and the Scotogenic model

In IHDM and the Scotogenic model an extra Z_2 symmetry and a scalar doublet field η are introduced. Furthermore, in the Scotogenic model we add three singlet fermionic fields N_i (i=1,2,3).

The η^0 neutral particles and the N_i particles of the model will contribute to the neutrinos masses at one loop.

$$M_{\nu,ij} = \frac{h_{ik}h_{jk}}{32\pi^2} M_k \left[\frac{m_R^2}{m_R^2 - M_{N_k}^2} \log\left(\frac{m_R^2}{M_{N_k}^2}\right) - \frac{m_I^2}{m_I^2 - M_{N_k}^2} \log\left(\frac{m_I^2}{M_{N_k}^2}\right) \right].$$

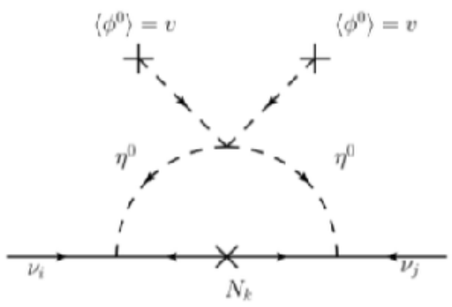

Figure 1. Radiative seesaw mechanism.

$$SM \rightarrow even$$
$$\eta \rightarrow odd$$
$$N_i \rightarrow odd$$

Setting $\lambda_5 < 0$ implies choosing η_R as the lightest particle in both models: this will be our DM candidate.

In order to find a possible observable that helps us to discriminate between IHDM and Scotogenic model, we performed a study about the DM abundance in the two frameworks. Results are shown in Figure 2.

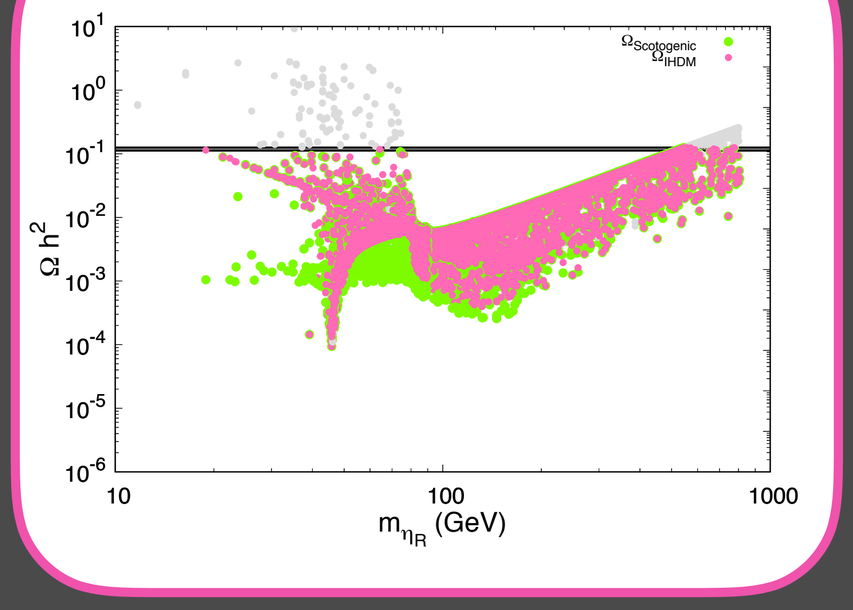

Figure 2. Relic density for the Scotogenic (green) and the IHDM (pink) calculated by micrOMEGAs.

$$\lambda_5 = [10^{-9}, 1]$$
$$m_{\eta_R} = 493.07411\ GeV$$
$$MN_i = [900, 10000]\ GeV$$

Table 1. Main parameters of the BSP.

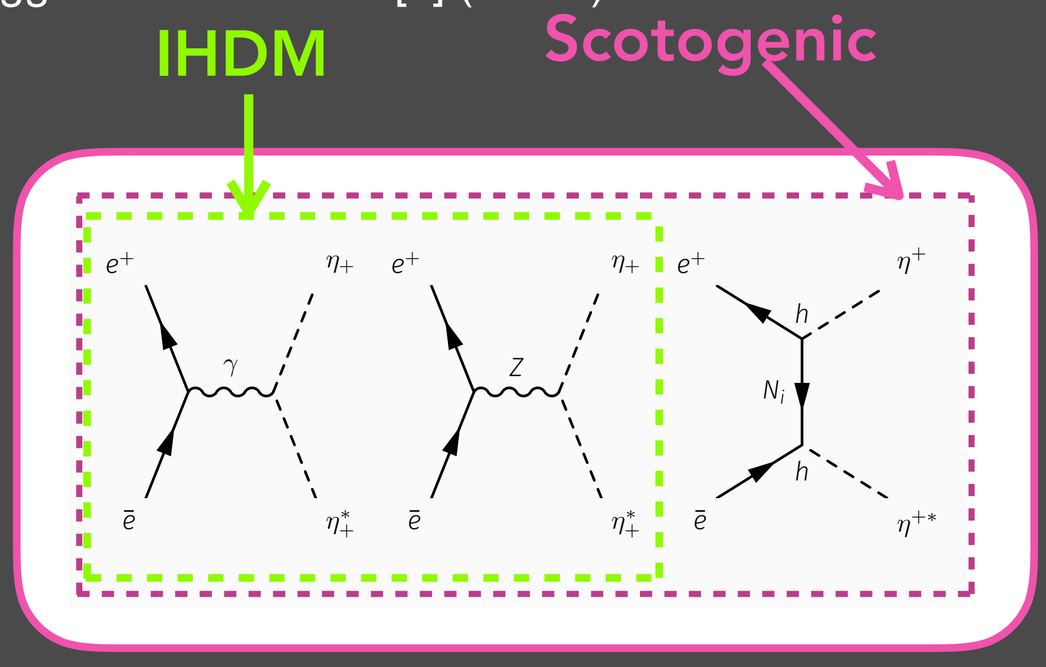

Figure 3. Feynman diagrams for each model: Scotogenic model (magenta dashed line), IHDM (green dashed line).

The cross section $e^+e^- \longrightarrow \eta^+\eta^-$ was calculated using MadGraph [3]. The benchmark point (BSP), in agreement with the relic density measured by Planck [4] and with LFV constraints, is shown in Table 1. The Feynman diagrams that contribute to the process are described in Figure 3.

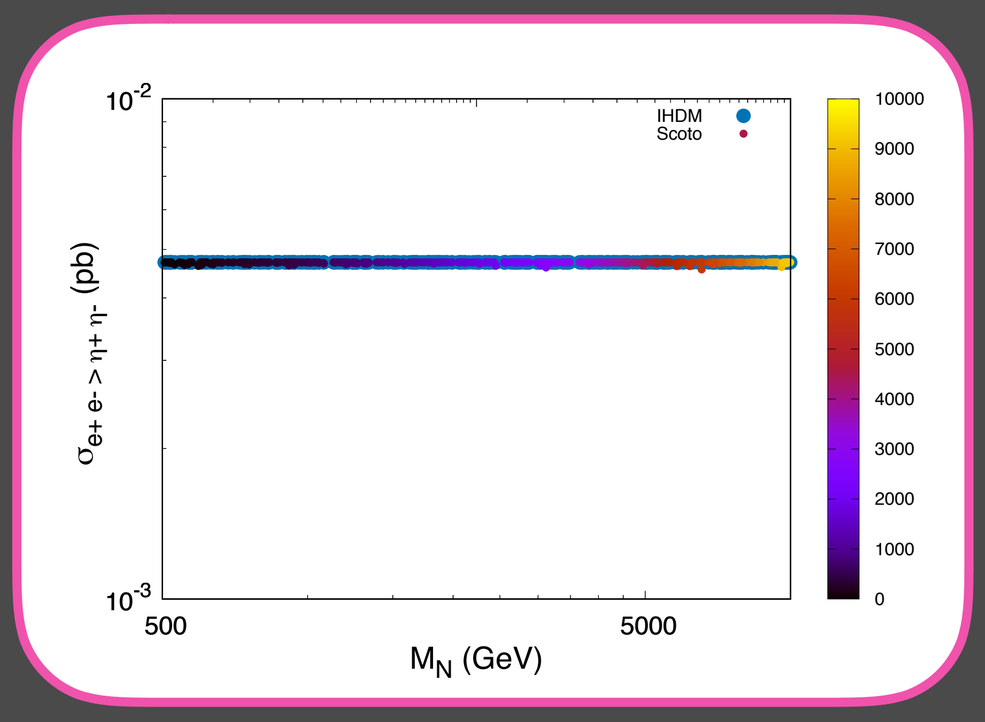

Figure 4: Cross section for IHDM (blue dots) and Scotogenic model (color dots).

Figure 4 shows the mass of the lightest fermion N_1 versus its respective cross section calculated for each point. The colorbar represents the difference of mass between two particles, m_{η_R} and M_{N_1}. Considering the same DM candidate in both models, when the difference in mass is large or small, the contribution coming from the extra Scotogenic model diagram is not enough to enhance significantly of the cross section. However, if we assume the DM candidate to be fermionic, such contribution might in principle increase.

Acknowledgments:

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References

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[2] M. A. Diaz et al, Advances in High Energy Physics, 8278375 (2015).

[3] MadGraph 5: Going Beyond. JHEP1106(2011)128

[4] M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D 98, 030001 (2018).