Lepton flavour violation and dark matter in the T1-2A Model

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Introduction and motivation

The Standard Model had made successful predictions over the past years. Nevertheless, it still cannot explain diverse observations. Indeed, in the Standard Model, the neutrinos are massless whereas the existence of neutrino masses has been proven by the discovery of neutrino oscillations. Furthermore, the existence of dark matter cannot be explained within the Standard Model. This is an extensive study of a rather generic model of the scotogenic type [1,2], providing a solution to the dark matter problem while including radiative generation of neutrino masses. After a short introduction to the model, you will find in this poster results based on a Markov Chain Monte Carlo analysis of the associated parameter space in view of numerous constraints from experimental data. Special focus will be given to dark matter phenomenology as well as lepton-flavour violating processes.

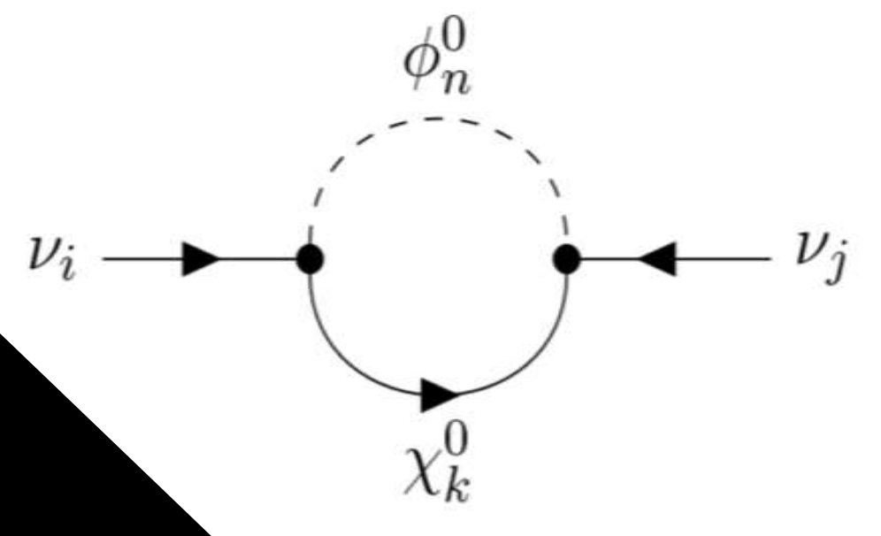
The T1-2A model

	Ψ_1	Ψ_2	F	Φ	S
$SU(2)_L$	**2**	**2**	**1**	**2**	**1**
$U(1)_Y$	-1	1	0	1	0

The Standard Model is extended by both scalar and fermionic doublet and singlet, odd under a $\mathbb{Z}_2$ symmetry. These new particles generate two non-zero neutrino masses and provide three candidates for scalar or fermionic dark matter. The interactions of the new fields with the SM particles are described in the lagrangien with :

$$-\mathcal{L}_{int} = g^i_\Psi \Psi_2 L_i S + g^i_F F L_i \Phi + g^i_R \Psi_1 e^c_{Ri} \Phi^\dagger + \text{h.c}$$

Generation of the neutrino masses



The neutrino masses are generated at one-loop as shown with the diagram. Note that the new fields in the mass basis are named $x^0_{\{1,2,3\}}$, $\phi^0_{\{1,2]}$ and A^0.

In order to obtain the couplings that lead to the correct neutrino masses, instead of randomly selecting them, we use the Casas-Ibarra parametrization [3] as follows:

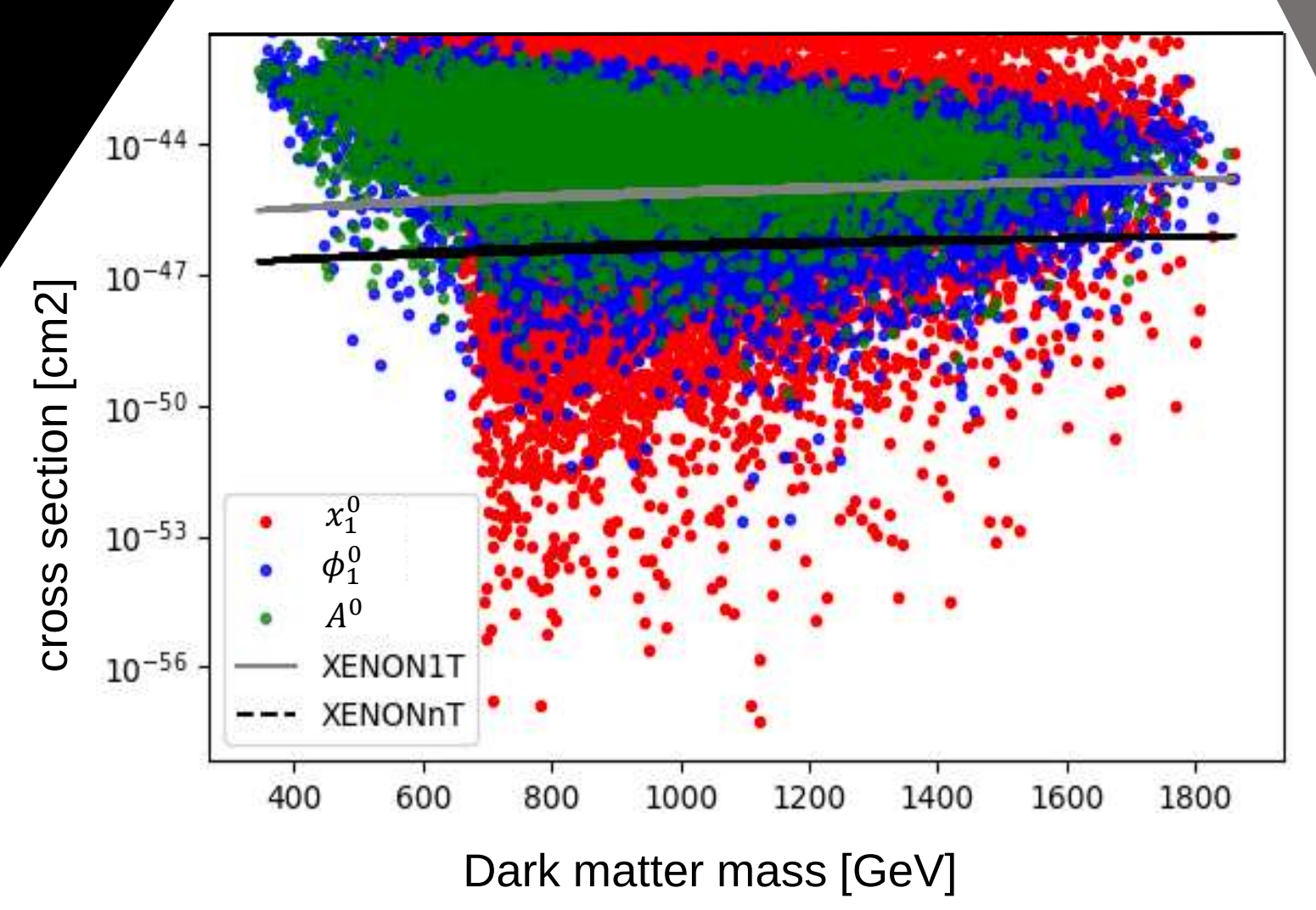
$$\overset{\substack{\textit{Matrix that contains the}\\ g^i_\Psi \textit{ and } g^i_F \textit{ couplings}}}{\mathcal{G}} = \underbrace{\mathrm{U_L\,D_M^{-1/2}}}_{\substack{\textit{This element is}\\ \textit{obtained from the}\\ \textit{loop computation of}\\ \textit{the diagram above}}} \underset{\textit{A Rotation matrix}}{\mathrm{R}} \overbrace{\mathrm{D}_\nu^{1/2}\,\mathrm{V}_\nu^*}^{\substack{\textit{Diagonal matrix containing}\\ \textit{the physical masses of the}\\ \textit{neutrino and PMNS matrix}}}$$

The method

The first step was to implement the model in *SARAH* [4] in order to generate the *Spheno* [5] code allowing to compute the mass spectrum at the one-loop level as well as the relevant lepton-flavour violating observables. Then we produced a *micrOMEGAS* [6] model to compute the relic density and the direct detection cross section of the dark matter. The parameter space scans are based on the Markov Chain Monte Carlo technique. The analysis relies on the likelihood, which confronts the experimental constraints to the predictions obtained for each individual parameter point, taking into account experimental and theoretical uncertainties.

The couplings g_F and g_Ψ are determined using Casas-Ibarra parametrization, while all other model parameters are chosen randomly within preselected intervals.

Direct Detection

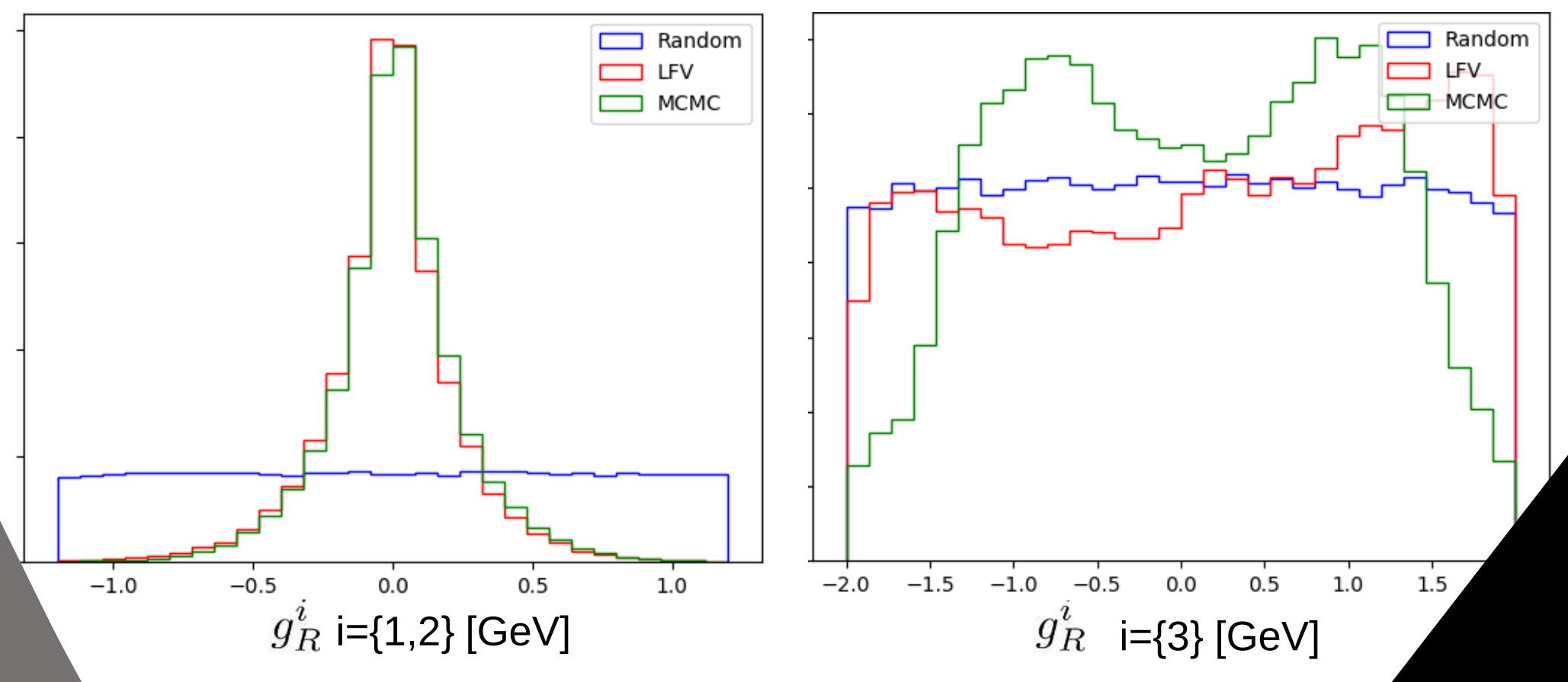


This is the projection of the spin independent cross section on the dark matter mass according to the nature of the dark matter. A large part of the model parameter space connot be tested by the future XENONnT experiment.

Constraints of the Model

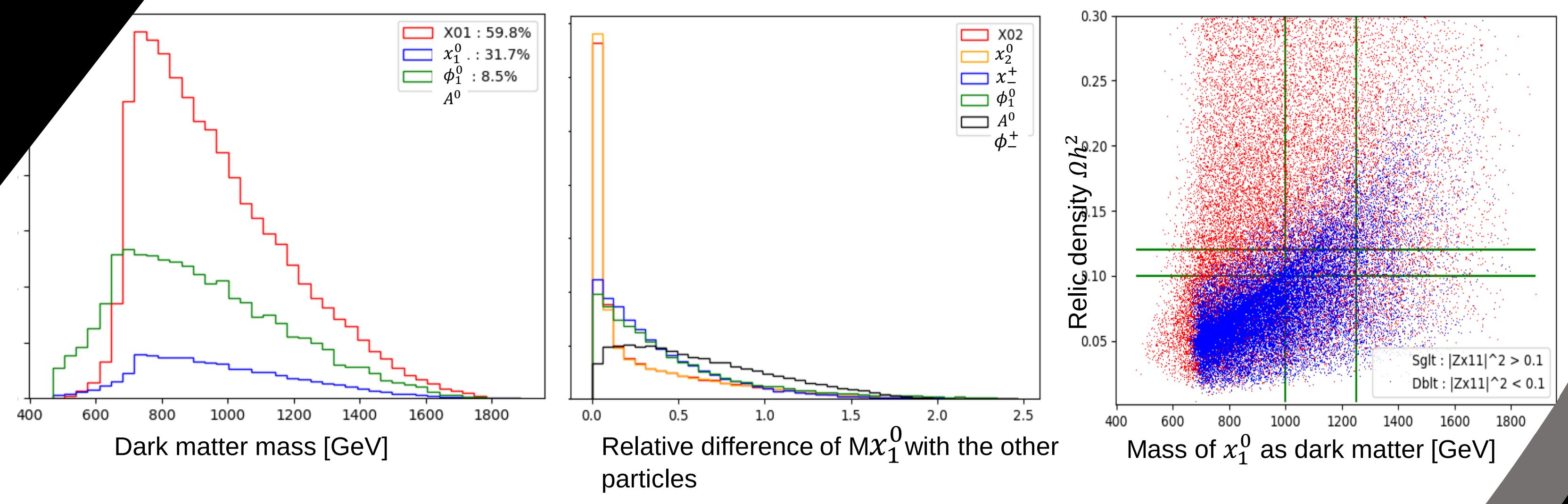
- The Higgs mass at 125 [GeV]
- LFV : The most important constraints are the branching ratios Br($\mu \rightarrow e\gamma$), Br($\mu \rightarrow 3e$), and the convertion rates Cr(Au),Cr(Pb), Cr(Ti)
- Dark matter constraints : relic density, direct detection and a neutral charge for the dark matter
- EDM_e and EDM_μ

Lepton Flavour violation



The g^i_R couplings are constraint by the lepton-flavour violating branching ratios convertion rates. The coupling of the third generation is less constraint.

Dark matter candidates

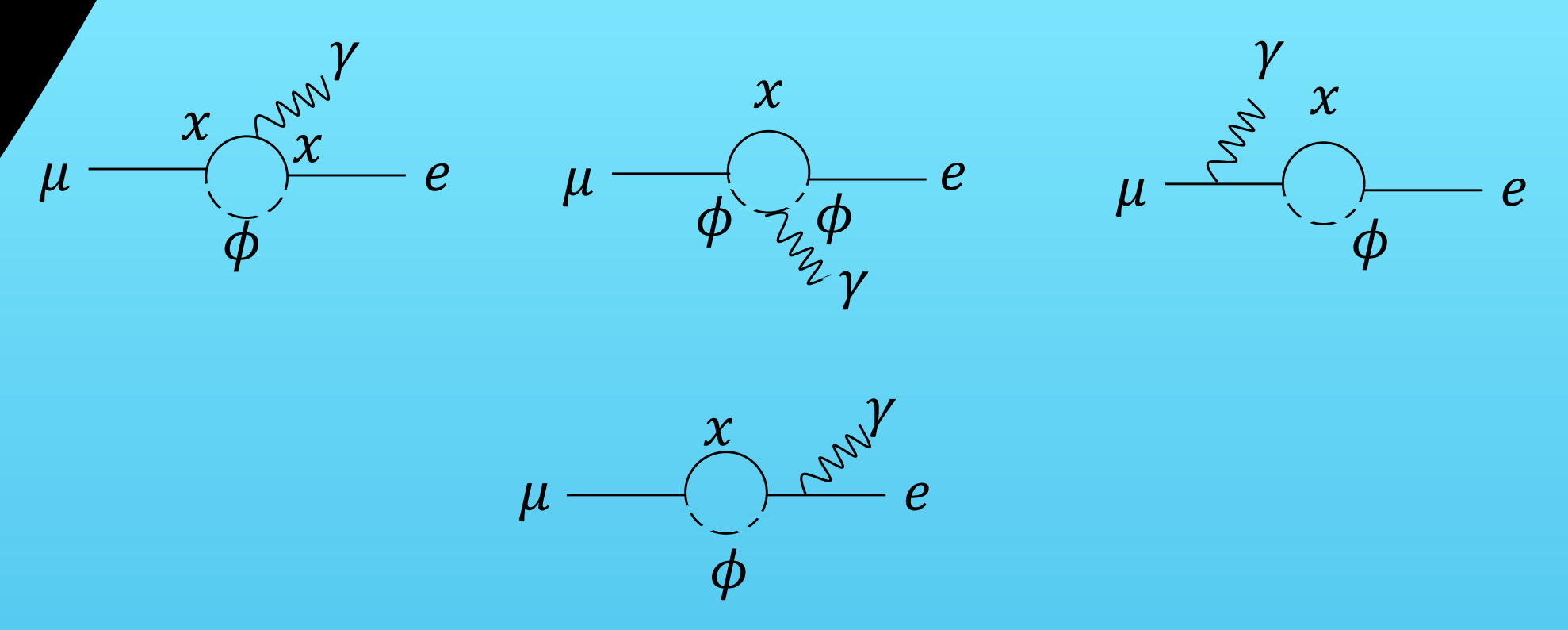


The favorite candidate for dark matter in the T1-2A model is the lightest fermion x^0_1. In this case, there are different coannihilation processes leading to the correctrelic density, e.g. with the second neutral fermion, and most of the time with the charged one. There are also coannihilation processes with the scalar partciles which can occure.

In the third figure, the red dots correspond to the parameter points where the lightest fermion x^0_1 is mainly singlet, the blue dots to those where it is mainly doublet. In most viable configurations, the fermionic dark matter is doublet like. The correct relic density is achieved through coannihilations for a mass between 1 and 1.2 TeV.

Conclusion

We have analysed scalar and fermionic dark matter in the model T1-2A, as well as its doublet or singlet nature. These new particles generate two radiative non zero masses to the neutrinos. Moreover, lepton flavour violation is allowed as for exemple in the decay $\mu \rightarrow e\gamma$:



A large part of the model parameter space survives the direct detection limits from both XENON1T and XENONnT. Beyond the limit of XENONnT it seems that the pseudo-scalar A^0 is not anymore a viable candidate for dark matter. We also saw that the relic density constraint prefers fermionic dark matter with a mass of about 1 to 1.2 TeV. This is due to the coannihilation phenomena which are important due to the predominant doublet nature of the lightest fermion x^0_1.

References

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