Long-lived particles and non-thermal dark matter (TODO list)

Les Houches 2017 working group

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1 Classification

Volunteer contributors so far: Josemi, José, Andreas, Genevieve, Dipan, Bryan.

Here the idea is to identify all possible interactions of the type:

$$\mathcal{L}_{\rm int} = \lambda \Psi P_{\rm sm} \chi \tag{1}$$

where λ is the coupling, Ψ is the decaying particle, $P_{\rm sm}$ a Standard Model particle, and χ the DM particle. No spins are fixed for the time being, nor the representations under the SM gauge group. However remember that in the setup where Ψ is an $SU(2)_L$ doublet, then $\Psi = (\Psi^0, \Psi^\pm)$, and unsupressed decays like $\Psi^\pm \to \Psi^0 (W^\pm)^*$ will dominate over the DM channel. In order to avoid this, a proposition has been made about an operator where all 3 particles in (1) are $SU(2)_L$-singlets (e.g $P_{\rm sm}$ being a RH fermion), but with Ψ having $SU(3)_c$ charge (thus $P_{\rm sm}$ is a RH quark).

2 Triggers

Possible contributors: Gabriel, Sezen?

We need experimentalists for this :-). We need to check which of the above operators can be studied with existing triggers, or if new triggers should be desinged for that purpose

3 Benchmarks

Volunteer contributors so far: Dipan, José

Useful benchmarks of the parameter space of these models should be identified as for LLP collider studies are concerned. We have been discussing a priori the ranges: 100GeV $\lesssim m_\Psi \lesssim$ 1TeV, and 10keV $\lesssim m_\chi \lesssim m_\Psi/2$. The value of the coupling λ should be extracted as a function of these masses and the desired Ψ lifetime.

4 Cosmology

Volunteer contributors so far: Andre, Andreas, Julia, Genevieve, Sasha, Bryan.

Once the benchmarks are defined, then the task is to find the corresponding cosmological history consistent with the observed DM abundance through out-of-equilibrium production in the early universe. Note that an underabundant DM candidate is not discarded at this stage.

Some examples are already identified from the literature:

- Standard freeze-in [1] by decay, with keV-ish DM, by Ibarra et al [2], in the context of the so-called "scotogenic model".
- (probably) standard freeze-in in the context of type-III Seesaw model [3]
- Freeze-in by decay with low reheating temperature, plus a non-trivial cosmological history, by Hall et al [4].

References

[1] L. J. Hall, K. Jedamzik, J. March-Russell and S. M. West, "Freeze-In Production of FIMP Dark Matter," JHEP **1003** (2010) 080 doi:10.1007/JHEP03(2010)080 [arXiv:0911.1120 [hep-ph]].

[2] A. G. Hessler, A. Ibarra, E. Molinaro and S. Vogl, "Probing the scotogenic FIMP at the LHC," JHEP **1701** (2017) 100 doi:10.1007/JHEP01(2017)100 [arXiv:1611.09540 [hep-ph]].

[3] A. Ghosh, T. Mondal and B. Mukhopadhyaya, "Heavy stable charged tracks as signatures of non-thermal dark matter at the LHC : a study in some non-supersymmetric scenarios," arXiv:1706.06815 [hep-ph].

[4] R. T. Co, F. D'Eramo, L. J. Hall and D. Pappadopulo, "Freeze-In Dark Matter with Displaced Signatures at Colliders," JCAP **1512** (2015) no.12, 024 doi:10.1088/1475-7516/2015/12/024 [arXiv:1506.07532 [hep-ph]].