Lepton portal dark matter, gravitational waves and collider phenomenology

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The Majorana dark matter χ together with a complex scalar $S^\pm$ can have a lepton portal $\bar{\chi}S^+e_R$, which is an attractive scenario [1], but is very hard to detect via direct and indirect dark matter searches. In this letter, we propose various approaches to probe this model, including space-based gravitational waves experiments, the collider searches from LHC, and the future lepton colliders such as CEPC, FCC-ee.

- The LEP [2] and LHC [3, 4] experiments have already set bounds on the mass of $S^\pm$ via the electroweak Drell-Yan production and then the $\ell^+\ell^- + \not{E}_T$ decay channel. However, there is still rooms for a light $S^\pm$ with mass $\lesssim 100$ GeV. We will work on the projections for the expected reach of the HL-LHC.

- At the LHC, the off-shell Higgs production $pp \to h^* \to S^+S^-$ also influences the production cross section, thus can be used as a probe for the interaction between the complex scalar S and the SM Higgs, i.e. $|S|^2|H|^2$. Provided this coupling is sufficiently large, it can also be probed complementarily by the gravitational waves from a potential strong first-order phase transition.

- The $\bar{\chi}S^+e_R$ portal coupling can be probed by the semi-off-shell Drell-Yan production of $S^\pm$ at the lepton collider, i.e. $e^+e^- \to S^{+(*)}S^- \to \ell^+\ell^- + \not{E}_T$. The Higgs/$Z$ boson exotic decay to $\ell^+\ell^-$ or $\chi\chi$ can probe the scalar couplings as well as the $\bar{\chi}S^+e_R$ portal coupling strength.

References

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