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Bound state formation effects for dark matter beyond WIMPs

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Bound state formation can have a large impact on the dynamics of dark-matter freeze out in the early Universe, in particular for colored co-annihilators. We study their effect for dark-matter freeze out beyond the WIMP paradigm, i.e. for very weak dark-matter couplings. In this case, chemical decoupling is initiated by the break-down of efficient conversions between the co-annihilators and dark matter. This scenario has been dubbed conversion-driven freeze out or co-scattering. It provides a prolonged process of chemical decoupling rendering bound state formation particularly relevant. We investigate the importance of next-to-leading order bound state effects in this scenario and find that corrections to the bound state decay rate have the largest impact on the relic density – around 30%. Bound state excitations and corrections to the ionization rate are subdominant, potentially leading to an effect around 5% and below 1%, respectively. We reevaluate the cosmologically viable parameter space which extends significantly due to the corrections. As the scenario leads to the prominent signature of long-lived particles it provides great prospects to be probed by dedicated searches at the upcoming LHC runs.

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