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Complementarity for Dark Sector Bound States

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We explore the possibility that bound states involving dark matter particles could be detected by resonance searches at the LHC, and the generic implications of such scenarios for indirect and direct detection. We demonstrate that resonance searches are complementary to mono-jet searches and can probe dark matter masses above 1 TeV with current LHC data. We argue that this parameter regime, where the bound-state resonance channel is the most sensitive probe of the dark sector, arises most naturally in the context of non-trivial dark sectors with large couplings, nearly-degenerate dark-matter-like states, and multiple force carriers. The presence of bound states detectable by the LHC implies a minimal Sommerfeld enhancement that is appreciable, and potentially also radiative bound state formation in the Galactic halo, leading to large signals in indirect searches. We calculate these complementary constraints, which favor either models where the bound-state-forming dark matter constitutes a small fraction of the total density, or models where the late-time annihilation is suppressed at low velocities or late times. We present concrete examples of models that satisfy all these constraints and where the LHC resonance search is the most sensitive probe of the dark sector.

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