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Search for Dark Matter ALPs Through Photon Couplings in Atomic Systems

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Axion-like particles (ALPs) have emerged as a compelling portal to the dark sector, offering unique experimental signatures through their coupling to photons. In recent years there has been remarkable progress in the physics of axions and ALPs in several directions. In this work, we investigate the feasibility of detecting dark matter ALPs via inverse Primakoff (IP) scattering process, where ALPs convert into photons through interactions with atomic electromagnetic fields. The primary contribution of our study is two-fold: firstly, we perform detailed cross-section calculations for IP inelastic channels of atomic excitation and ionization, incorporating realistic atomic charge and current distributions using state-of-the-art many-body atomic physics methods. Secondly, expanding the parameter space in (m_a, $g_{a\gamma\gamma}$) for laboratory-based investigations into DM-ALPs. We derive experimental sensitivities at 90% CL using data from the surface-level TEXONO [1, 2] experiment using high-purity germanium detector and the underground XENONnT [3] experiment using liquid xenon, both featuring low-threshold electromagnetic detectors. Dark matter ALP detection is constrained by the requirement of ALP stability over cosmological timescales. The lifetime of ALPs has to be longer than the age of the Universe in order for the dark matter ALP to reach and be observable in terrestrial experiments. This leads to the finding that part of the (m_a, $g_{a\gamma\gamma}$) parameter space is not accessible by the current direct experimental searches. However, we outline a path forward: future low-threshold, high-exposure detectors could extend sensitivity up to MeV-scale ALPs by exploiting the inelastic IP process. This work has been published in Physical Review D (Ref [4]) and it opens new laboratory-based opportunities to explore the ALP dark matter landscape beyond the reach of traditional searches.

References

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Collaboration you are representing

TEXONO

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