Contribution ID: **42** Type: **Poster Communication**

Magnetic resonance spectroscopy and imaging in the CASPEr dark matter experiment

Wednesday 6 September 2023 19:15 (20 minutes)

An overview of our experimental program to detect QCD axions and axion-like-particles (ALPs) as possible candidates for dark matter (DM) using NMR techniques within the cosmic axion spin precession experiment (CASPEr) is presented [1]. ALPs are hypothetical particles that could also solve the strong CP violation problem, and it is predicted that the axion field would behave as a classical field: it would oscillate at a mass-dependent frequency. ALPs also have derivative interactions with the SM fields. Nuclei that are interacting with the background axion DM acquire time-varying CP-odd nuclear moments such as an electric dipole moment (EDM). In analogy with NMR, these moments cause spin precession in a material sample induced by coupling between the ALP field and the axial nuclear current, in the presence of an electric field. Precision magnetometry can be used to look for such a precession. The signals from these particles will be very weak so all possibilities for signal enhancement need to be considered and for that, the chosen nuclei are 129-Xe that are hyperpolarized using the spin-exchange optical pumping (SEOP) technique inside a large optical cell. In this method, polarization is transferred to the Xenon via Fermi contact interactions with an optically pumped alkali metal, Rubidium. Especially for investigations of the nuclear spin resonance of liquid Xe as a fundamental physics experiment, a non-metallic variable temperature insert (VTI) is needed. This VTI should be suited for immersion in liquid helium. The sapphire sample holder is to hold on a level of 165 K ±1 K by a gaseous flow of temperature-stabilized nitrogen. Xenon has a much higher spin density when it is liquid, thus it has to be kept in that narrow temperature range. The hyperpolarized Xenon is then to be placed in an external magnetic field that will be swept from ultra-low field up to 14.1 T looking for the resonance with the axion field, while the Xenon nuclei undergo precession due to the gradient interaction. The first-generation experiments explore many decades of ALP parameter space beyond the current astrophysical and laboratory bounds. It is anticipated that future versions of the experiment could ultimately cover the entire range of masses up to ˜µeV, complementary to cavity searches.

[1] Derek F. Jackson Kimball, et al. "Overview of the Cosmic Axion Spin Precession Experiment (CASPEr)." In Microwave Cavities and Detectors for Axion Research, edited by Gianpaolo Carosi and Gray Rybka, 105–21. Springer Proceedings in Physics. Cham: Springer International Publishing, 2020.

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Session Classification: Poster Session