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the Advanced Axion Dark Matter detector

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An upgrade to the Axion Dark Matter eXperiment (ADMX) will extend its high sensitivity search for QCD axions up to axion masses of 40 μeV. Axions are especially significant as dark matter if their mass is of order 2–40 μeV. They would then make up the dark-matter halos of galaxies. These halo axions may be detected by the Sikivie process, by which they decay to photons through the $\mathbf{E} \cdot \mathbf{B_0}$ interaction in a tunable high-Q microwave cavity permeated by a strong external magnetic field B_0. The corresponding resonant frequencies are in the microwave part of the electromagnetic spectrum: 0.5–10 GHz.

At present, ADMX uses near quantum-limited SQUID-based amplifiers and a 200 ℓ volume, 7.6 T magnet. Both cavity and amplifier are operated at ultralow temperatures (below 0.1 K). Generation-2 ADMX has demonstrated the sensitivity to detect even the most weakly-coupled QCD axions, the so-called DFSZ limit. Over the next 2–3 years, ADMX will search the 2–9 μeV range at the DFSZ limit.

As the search moves to higher axion masses, and therefore also to higher photon frequencies, the size of the cavities, typically half of the wavelength in two dimensions and 4–8 times the wavelength in the third, becomes smaller. To maintain B_0^2V, one may employ multiple cavities or very elaborate resonant structures. (The number increases more or less as the cube of the axion mass.) Clever microwave engineering can support the growth in cavity complexity to some extent, but there is a substantial cost of such intricate resonant structures and the supporting bits and pieces.

A proposed alternate approach is to increase the magnetic field substantially and decrease the volume. To the extent that the product B_0^2V is maintained, the cavity configurations used over 0.5–2.2 GHz can continue to be used. Ultrahigh-sensitivity superconducting electronics are also required.

A conservative, two phase process is proposed to build the Advanced Axion Dark Matter detector. For the Phase-1 detector, we specify a 19 T, 15 cm diameter magnet based on Nb\sb3Sn and NbTi technology, temperatures in the 60–80 mK regime, and continued use of the ADMX-style Josephson parametric amplifiers. In Phase 2, we add a high-temperature superconducting insert coil to provide $>$30~T in a 6.5 cm diameter. The operating temperature of the smaller and higher-resonant-frequency cavity is expected to be below 50 mK. Because the thermal emission from the cavity is negligible at these temperatures, Phase 2 will employ quantum-limited single-photon detectors.

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