The search for dark matter remains one of the most compelling physics goals for HEP.

Recent theoretical work points to a highly constrained range of axion masses that leads to the observed DM abundance, assuming conventional (non-inflationary) cosmology following the Peccei-Quinn transition.

M. Buschmann et al., Nat. Comm. 13 (2022) 1049

The axion, in view of its roots in fundamental physics, is an especially promising dark matter candidate.

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Cavity haloscopes main limitation is that their size is limited by the Compton wavelength, so get too small at high axion masses, have limited tunability and long integration times, limiting the axion search mass region.

A plasma haloscope matches axion and photon masses (plasma frequency), \( m_a = \omega_{\text{plasma}} \). This ameliorates size constraints.

The plasma frequency is given by the effective electron number density and its mass

\[
\omega_p^2 = \frac{n_e e^2}{m_{\text{eff}}} = \frac{2pi}{a^2 \log(a/r)}
\]

We plan to deploy an existing, 13T magnet developed at Helmholtz Zentrum Berlin at Oak Ridge National Laboratory.

ALPHA initial nominal resonator requirements
- Frequency \(~10 \text{ GHz}\)
- Volume \(~4 \times 10^5 \text{ cm}^3\)
- Quality factor \(~10^4\)

Demonstrator Resonator
- 16x16 array of 3.175 mm diameter Cu rods
- Fixed frequency resonator to test simulations
- \(Q > 2000\) at room temperature

The ALPHA tunable plasma haloscope represents a novel technique to perform a broadband axion search, avoiding persistent bottlenecks of cavity-based approaches. It can access the preferred post-inflation axion mass range.