Contribution ID: **126** Type: **not specified**

The first high-temperature superconducting cavities for axion dark matter search

Superconducting radiofrequency (SRF) technology has played an essential role in advancing precision measurements in particle physics experiments, over the past decades, and is expected to be so in the search for dark matter axions. The axion haloscope requires high quality (Q) factor superconducting cavities immersed in multi-tesla magnetic fields for sensitive searches, which can be achieved using high-temperature superconducting (HTS) materials. Biaxially-textured rare-earth barium copper oxide (ReBCO) tapes, possessing strong vortex pinning capabilities in high magnetic fields, serve as an optimal material choice for realizing high Q cavities. The Center for Axion and Precision Physics Research has successfully demonstrated the technology by fabricating several cavities using commercially available ReBCO tapes. In this talk, we present the progress in next-generation cavities over the initial prototype. We detail the development of a large-volume GdBCO-tape cavity and two EuBCO-tape cavities, achieving Q factors of half-million, 3.5 million, and 13 million, respectively, at an 8 T magnetic field. These advancements have resulted in two-orders-of-magnitude improvement in Q factors compared to traditional copper cavities used in axion haloscopes, highlighting a major breakthrough in the field. Moreover, we discuss the first results of an axion dark matter search employing an HTS cavity with frequency tuning achieved by a sapphire rod. The experiment exhibited an order-of-magnitude increase in scanning speed compared to prior laboratory conditions.

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Session Classification: Parallel: Dark Matter 4