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Quantum sensors for RADES haloscopes

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The RADES collaboration has been exploring different haloscope designs to improve the sensitivity to relic axions in certain masses. From multicavities, to increase volume at higher frequencies, to superconducting tapes, to achieve high quality factors, several technologies are being tested in order to increase the reach of conventional haloscope strategies.

One of the most promising technologies under development is the quantum sensing. Haloscope sensitivity is limited by the standard quantum noise in the amplifiers. This noise floor is unavoidable even reducing further the temperature so a new scheme is needed in order to speed up searches. Making use of quantum sensors, a single photon counter can be developed. This sensor, instead of measuring power, measures the number of photons in the cavity, which allows going beyond the standard quantum limit.
Single photon counters in the GHz regime have been applied for different purposes, like measuring spins (Wang, Z. et al. Single-electron spin resonance detection by microwave photon counting. Nature, 2023). For haloscope experiments, first proof of concept was done in 2020 (Dixit, A. et al. Searching for Dark Matter with a Superconducting Qubit, Phys. Rev. Lett., 2021). In this work the feasibility of the technology was demonstrated using superconducting qubits called transmons in a haloscope without magnetic field.

The RADES collaboration is following their path and during last year, with the help of new collaborators with expertise in quantum research, we have had the opportunity to test different configurations improving both the cavity and the transmon design. These efforts have been supported recently with an ERC Synergy grant awarded for the DarkQuantum project, from professors I.G. Irastorza (U. Zaragoza), T. Kontos (ENS Paris), S.Paraoanu (Aalto U., Helsinki) and W. Wernsdorfer (KIT, Karlsruhe), which will also boost the development of RADES haloscope for BabyIAXO magnet.

Here, first measurements of quantum sensors developed for future RADES haloscopes are presented: experimental setup, measuring protocol, limitations and future steps, as well as current design and first prototype for RADES BabyIAXO haloscope.

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