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Superconducting quantum detectors for applications in direct dark matter search with low-mass and luminosity measurement at FCCee

The detection of individual quanta of light is important for quantum computation, fluorescence lifetime imaging, single-molecule detection, remote sensing, correlation spectroscopy, and more. Thanks to their broadband operation, high detection efficiency, exceptional signal-to-noise ratio, and fast recovery times, superconducting nanowire single-photon detectors (SNSPDs) have become a critical component in these applications.
Initially developed for deep-space communication and quantum information science, SNSPDs possess specific characteristics that make them particularly suited for applications in high-energy physics, in particular, dark matter search [1] and particle detection.

Dark matter search
The QROCODILE experiment [2] uses a microwire-based SNSPDs as a target and sensor for dark matter scattering and absorption, and is sensitive to energy deposits as low as 0.11 eV. We introduce the experimental configuration and report new world-leading constraints on the interactions of sub-MeV dark matter particles with masses as low as 30 keV. The thin-layer geometry of the system provides anisotropy in the interaction rate, enabling directional sensitivity. In addition, we leverage the coupling between phonons and quasiparticles in the detector to simultaneously constrain interactions with both electrons and nucleons.

Luminosity measurement at FCCee
The demonstration of high-efficiency direct relativistic particle detection via SNSPDs opens up a new detector technology for consideration in the FCC. One of the leading potential use cases is the luminosity measurement at FCCee. These detectors are capable of sub-10-ps RMS timing resolution, which will enable collision localization and high-rate background rejection. The energy threshold of the detectors is tunable via their bias current, which can lead to significant energy background rejection.
Furthermore, SNSPDs are also considered for other FCC science cases, such as calorimetry or tracking if coupled to scintillating fibers, long-lived searches, and an ALP detector in the forward region.

[1] Y. Hochberg, I. Charaev, S. W. Nam, V. Verma, M. Colangelo, and K. K. Berggren, Detecting Sub-GeV Dark Matter with Superconducting Nanowires, Phys Rev Lett, vol. 123, no. 15, 2019, doi: 10.1103/PhysRevLett.123.151802.
[2] Laura Baudis and et. al., A New Bite Into Dark Matter with the SNSPD-Based QROCODILE Experiment, arXiv:2412.16279, 2025.

Secondary track

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