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Next Generation Quantum Detectors for Low Energy Astroparticle Physics (QuLEAP)

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The challenges of modern fundamental physics lie in low energy phenomena, such as gravitational waves, cosmological inflation and dark matter. Indeed, different phenomena in astronomy (such as radio burst sources, cosmic microwave background, and GHz-peaked radio sources) need the development of sensitive bolometers operating in the GHz-THz bands. Furthermore, low energy particle physics requires single-photon detectors operating in the sub-visible bands down to a few GHz for the detection of dark photons, axions and weakly interacting massive particles. Indeed, state-of-the-art detectors for fundamental physics are mainly based on transition-edge sensors and kinetic inductance detectors. showing a noise-equivalent power (NEP) of ~10^−19 W/Hz^1/2 and an energy resolution of ~500 GHz. Finally, the technologies nowadays in the R&D phase, such as
superconducting qubits are limited to single-photon detection and extremely prone to the external environment.
In this talk, i will present the scientific background and goals of the project QuLEAP funded by the MUR by a FIS2 Consolidator Grant. QuLEAP aims at developing a new cryogenic quantum detection platform pushing the detection sensitivity towards unprecedented levels. To this scope, the project will exploit innovative concepts for the charge and energy management in hybrid mesoscopic superconducting systems. First, the current control of critical temperature of fully superconducting Josephson junctions allows the Josephson escape sensor (JES) to show a record NEP ~10^−25 W/Hz^1/2 and energy resolution of ~2 GHz. Second, the macroscopic phase coherence of superconductors will be exploited to realize a nonlocal superconducting detector (NLSD) with separated sensing and readout elements, thus able to reveal single-photons of frequency down to ~10 GHz. Third, the bipolar thermoelectric response of fully superconducting tunnel junction will be employed to attain single-photon detection in a wide range of frequencies ranging from 10 GHz to 10 PHz.
Concluding, the set of unprecedentedly sensitive detectors developed within QuLEAP operates in synergy with current detection, cold electronics and room-temperature readout technologies, thus enabling new functionalities and filling the existing gaps between the requirements of fundamental physics experiments and the present sensing technologies.

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