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# Toward design and simulation of superconducting transmon qubits for quantum sensing and computing

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In recent years, significant progress has been made across multiple directions to enhance the properties and performance of superconducting quantum devices, which stand as one of the most promising platforms for quantum computing. This R&D has opened up new opportunities to apply this technology in quantum sensing, particularly for fundamental physics purposes such as the search for weakly electromagnetic coupled dark matter candidates, namely axions and dark photons. Leveraging the high sensitivity to AC fields and Quantum Non-Demolition (QND) measurements, superconducting quantum qubits are promising devices for probing the microwave region in the parameter space of these light dark matter candidates.

This contribution highlights the latest advancements from the National Quantum Science and Technology Institute (NQSTI) Spoke 6 and the National Institute for Nuclear Physics (INFN) in the current state-of-the-art microwave single-photon detection exploiting superconducting quantum technologies. Sample chips were designed, fabricated, and initially measured at the National Institute of Standards and Technology (NIST), followed by comprehensive measurements conducted at the cryogenics laboratory at the University of Milano-Bicocca and the INFN Frascati National Laboratories. These recent measurement campaigns demonstrated a strong agreement between simulations and experimental data, validating all key design parameters and refining our design and simulation workflows.

Currently, our focus is the development and simulation of a two-qubit photon detector which aims to perform coincidence measurements to reduce the dark count rate. A preliminary planar chip layout has been designed exploiting widely-used design software such as Qiskit Metal and KQCircuits while our simulation analysis employs the Lumped Oscillator Model (LOM) and the Energy Participation Ratio (EPR) to extract and optimize Hamiltonian parameters.

These efforts have the potential to significantly enhance superconducting quantum technologies and introduce novel devices and detection schemes to the realm of quantum sensing.

## Title

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