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# Quantum Sensor for detection of Dark Matter

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## Introduction

The observable universe is composed of 26% dark matter. So, it is essential to understand dark matter to get a comprehensive description of the universe.

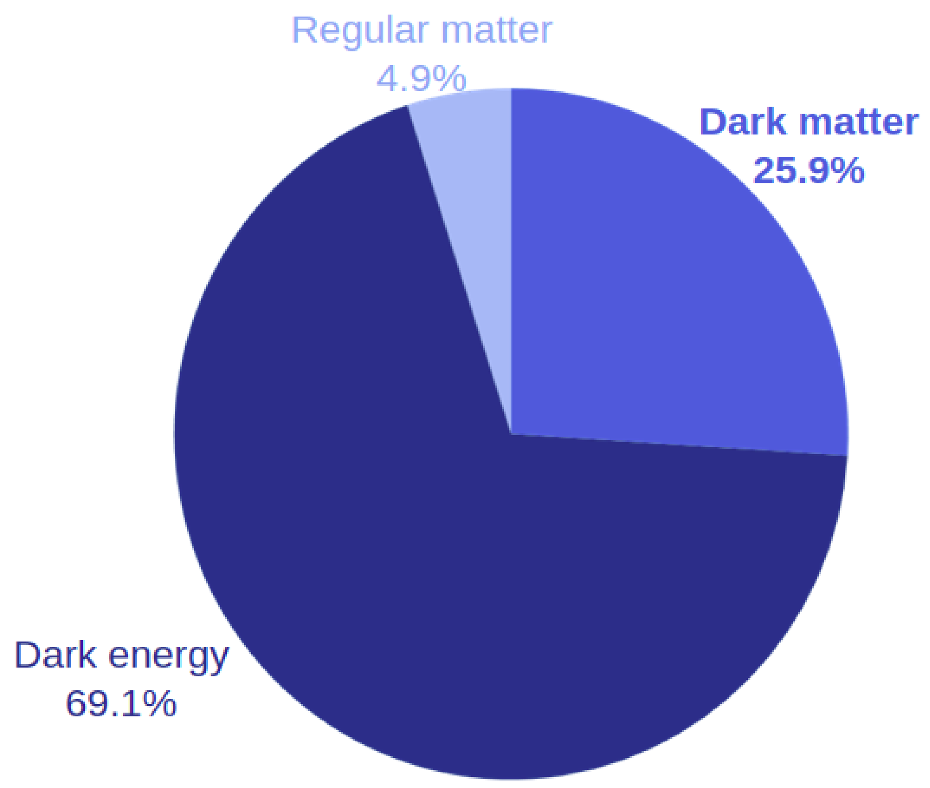



**Fig 1 Composition of Observable Universe. Source: Planck**

## Searching for Dark Matter

It is very difficult to detect such matter since it only reacts through weakest known force. There has been numerous attempt to directly observe dark matter particle but the theoretical bounds for the supposed mass of dark matter is very large.

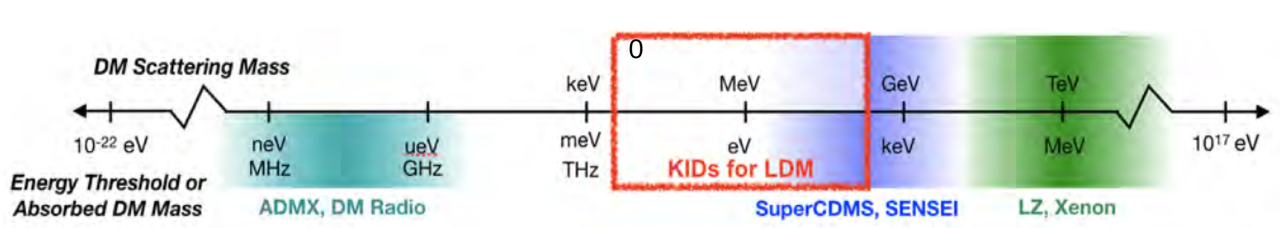
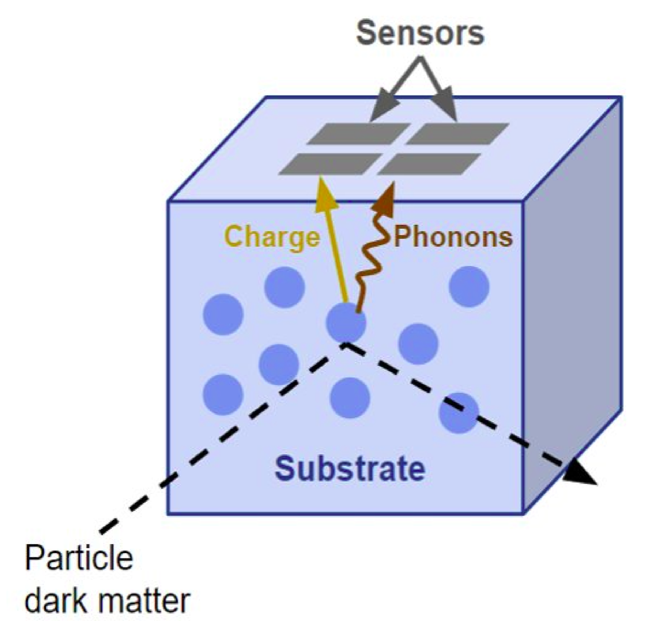



**Fig 2. Current and Future Coverage of LDM Parameter Space**

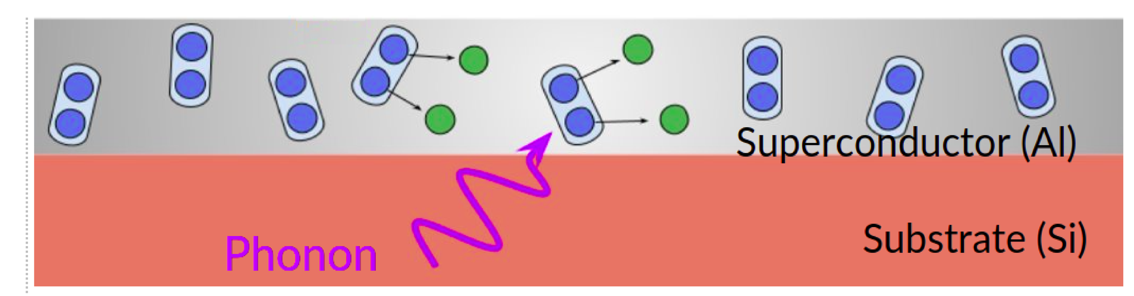
This project aims to look for Light Dark Matter Particles (LDM) which have mass of the order of a few MeV. A quantum sensor is proposed to detect dark matter with this mass range.

## MKID (Microwave Kinetic Inductance Detector)

MKIDs, a kind of quantum sensor, work on the principle that incident energy changes the surface impedance of a superconductor through the kinetic inductance effect. This project aims to deploy the property of MKID to attempt to detect low-energy dark matter particles. It is expected that when dark matter collides with silicon crystal substrate, it will deposit some fraction of its kinetic energy. Sometimes this is enough to create an electron-hole pair and shower of phonons. MKIDs can be used to detect these low-energy phonons.




**Particle dark matter interacts with substrate to create charge hole pair and shower of phonons. Credit: Kelly Stifter**




**MKIDs are composed of superconducting film on top of Semiconductor substrate. The breaking of Cooper pairs within the superconducting film changes their surface inductance. Credit: Gabriel Spahn**

**Fig 3. Operation of the detector**

## Simulating the Detector

Geant4, a simulation software, was used to create and simulate the detector. G4CMP, a library toolkit built on top of Geant4, allows simulating the passage of phonons through silicon crystals. The semiconductor substrate and a layer of a superconductor is modeled to simulate the behavior of the detector.

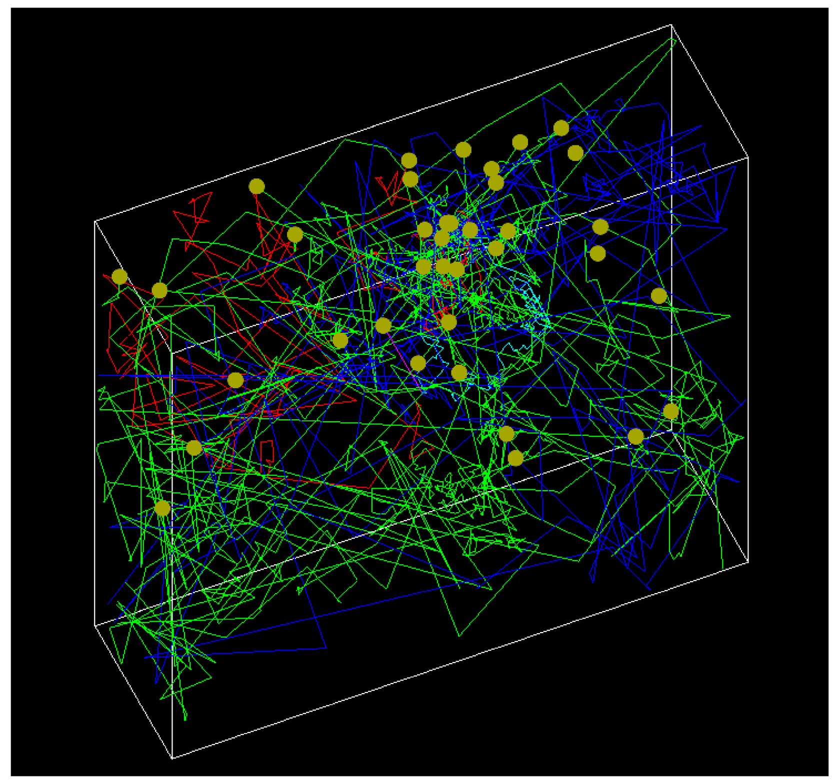


**Fig 4. Phonon generation/propagation. A charge-hole pair is produced with energy of 1e-6 eV in a Silicon Substrate. The image depicts the propagates of different kinds of phonons. The tracks are color coded for different kinds of phonon: Transverse Fast (Blue), Transverse Slow (Green), Longitudinal (Red). The phonon track ends at an electrode which is registered as a hit (yellow circles). Source: Geant4, G4CMP**

## Results and Future Works

The resulting program of this internship project can be used to simulate the collection of phonon generated due to interaction with dark matter. This would allow to create database for varying configuration (energy deposition, position, initial direction) of interaction with dark matter, the results of which can be analyzed to make better decision on design of the detector.

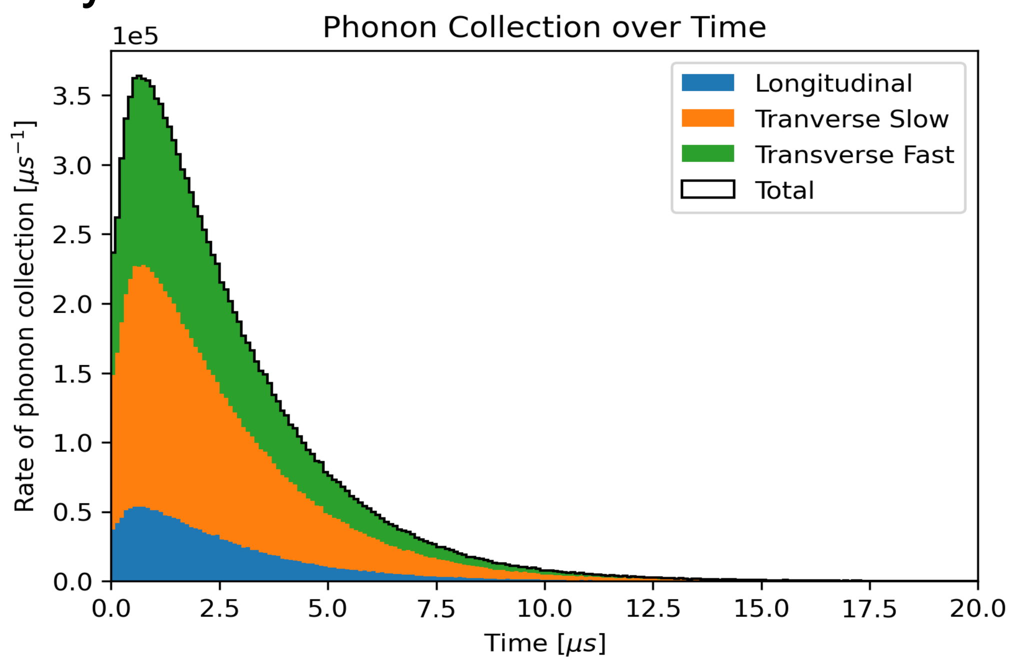



**Fig 6. Phonon Collection over time**

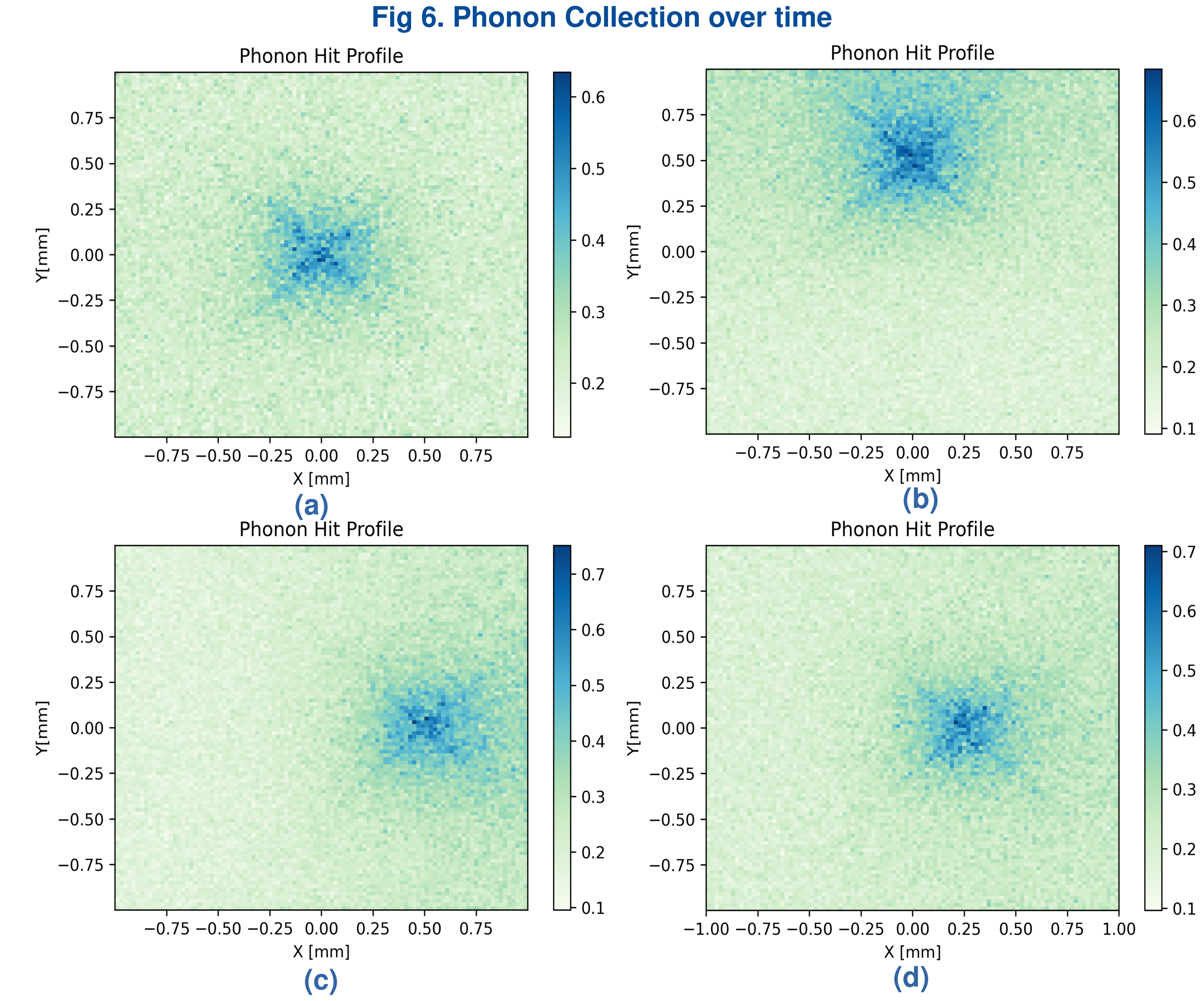



**Fig 7. Phonon Hit profiles for different positions of interaction with dark matter (a) at center, (b) displaced 0.5 mm in Y axis, (c) displaced 0.5 mm in X axis, (d) displaced 0.25 mm in X- axis**

## Acknowledgment

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