Dark Matter search using Radiation Damage (RADAC + DAMIC)

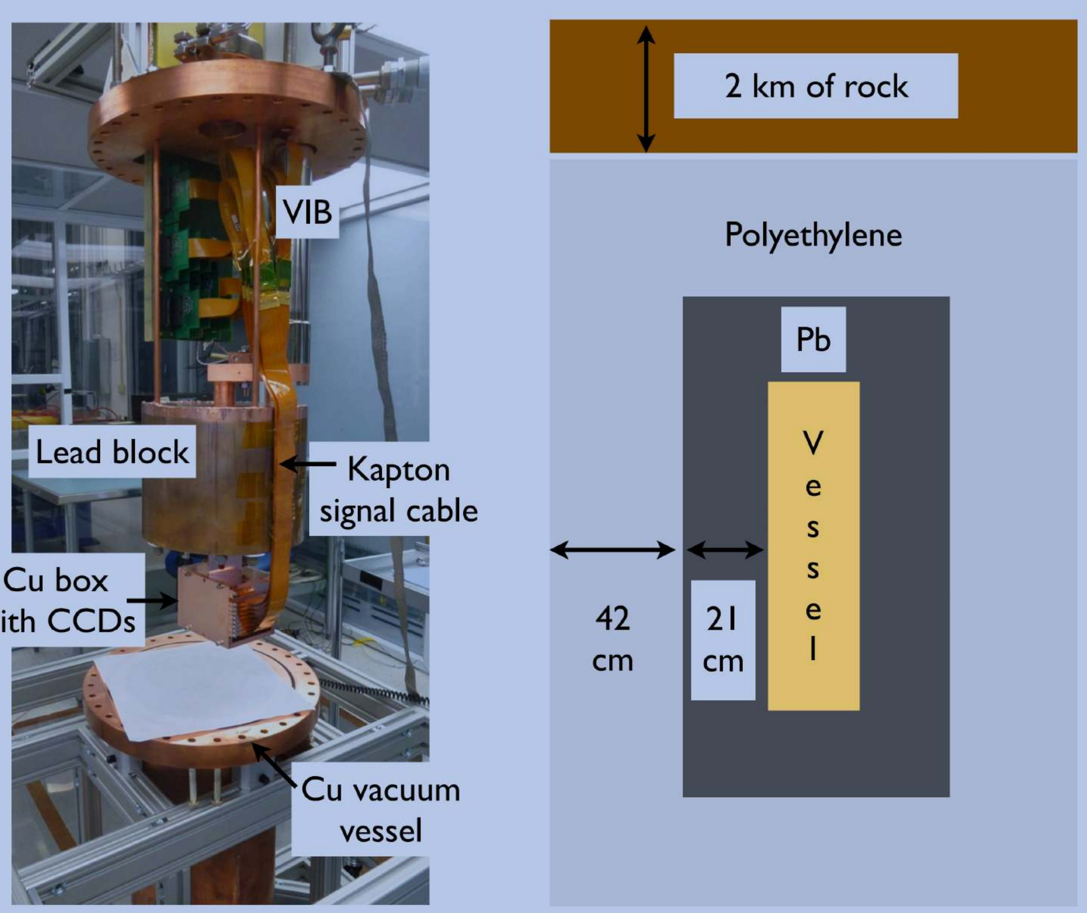
Steven Juhyung Lee,
Prof. Ben Kilminster, Dr. Peter Robmann, Dr. Anna Macchiolo,
Dr. Achim Vollhardt, Daniel Florin, David Wolf
Universität Zürich

Our mostly Dark Universe

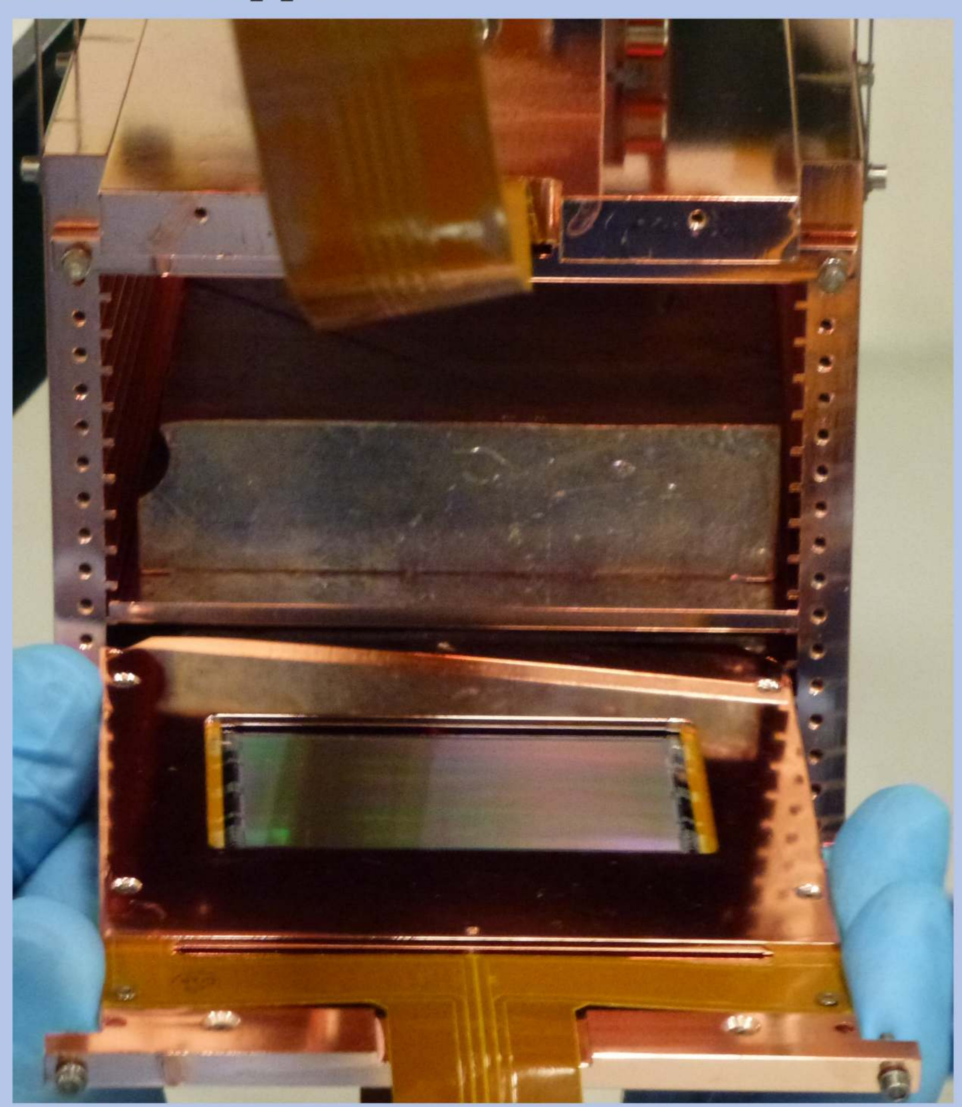
- Our universe is governed by 4 fundamental forces:
  1. Weak (explained by Electroweak theory).
  2. Strong (explained by Quantum Chromodynamics).
  3. Electromagnetic (explained by Quantum Electrodynamics).
  4. Gravitational (explained by General Relativity).
- Electromagnetic forces govern what can be "seen" and dark matter is "dark" because it does not interact electromagnetically.
- Our observable universe contains only 4.9% of ordinary visible matter, 26.8% of Dark Matter and 68.3% of Dark Energy.

DAMIC and CCDs

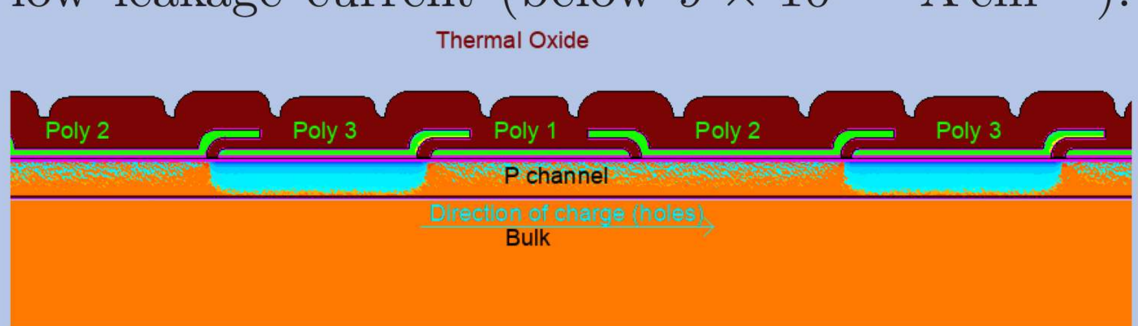
The DAMIC-SNOLAB experiment utilizes ultra-sensitive CCDs to look for dark matter. It is located inside the SNOLAB underground laboratory in Canada.



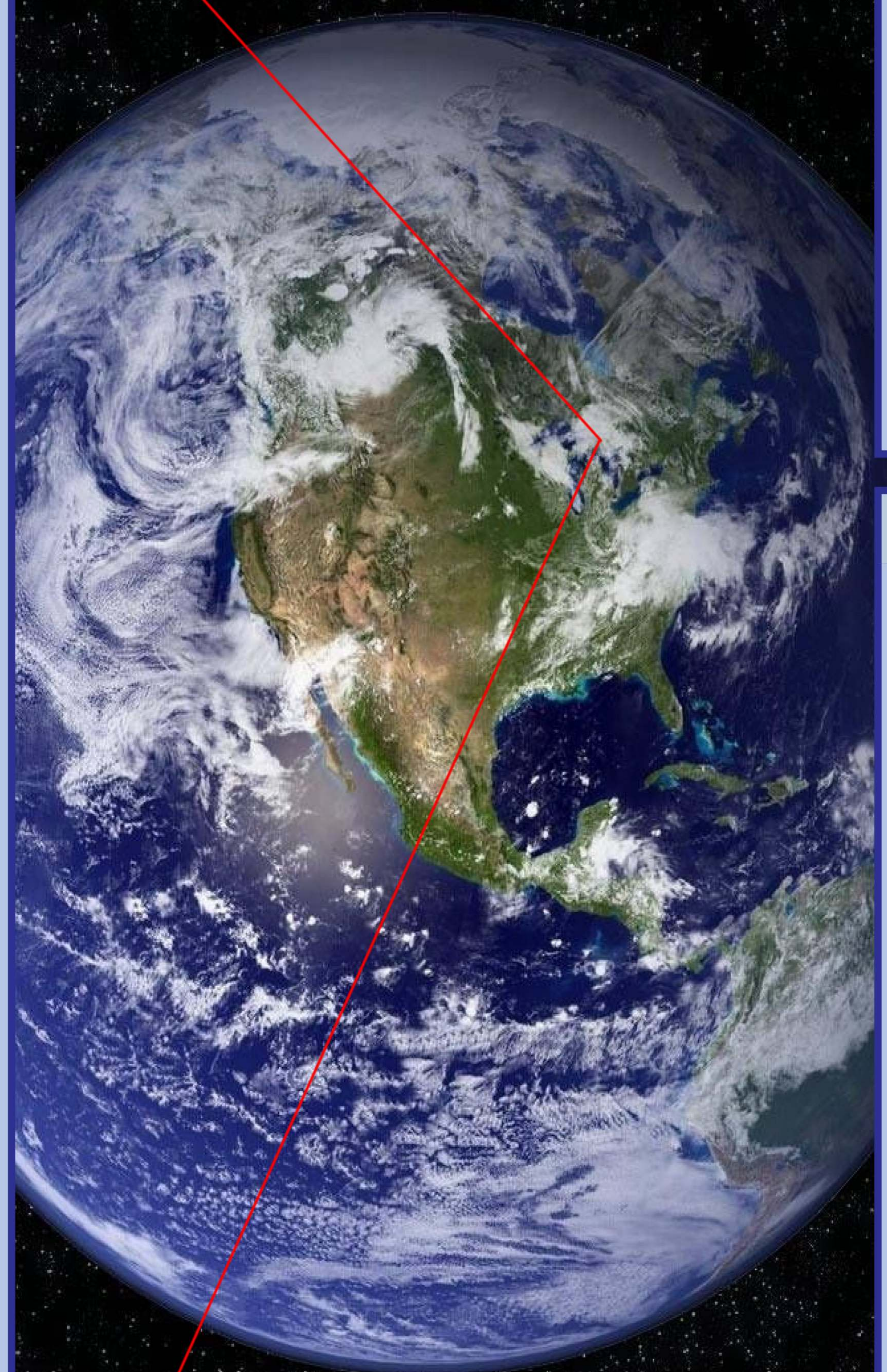
Each of the CCDs is 675 µm thick and has 16 million pixels (approximately 10 cm × 10 cm). There are 8 CCDs installed in DAMIC-SNOLAB and the whole experiment is further shielded using ancient lead and ultra-pure non-radioactive copper.



These large, thick CCDs have a huge advantage over other solid state detectors as the interface to electronics are far from the pixels and therefore each pixel generates very low leakage current (below $9 \times 10^{-22}\,\mathrm{A\,cm^{-2}}$).



In addition, these CCDs use three-stage polysilicon gates, which minimizes the loss of charges generated by particles interacting in their bulk.



Searching for Dark Matter

We currently search for dark matter with the following masses (m_χ)

1. Weakly Interacting Massive Particles (WIMPs) (100 MeV$\leq m_\chi \leq$ 50 GeV)
2. Hidden photons that compose all of dark matter (1 eV $\leq m_\chi \leq 10^4$ eV).
3. Hidden photons that mediate dark matter interactions (1 MeV $\leq m_\chi \leq 10^7$ MeV).

Dark Matter "Cloud"

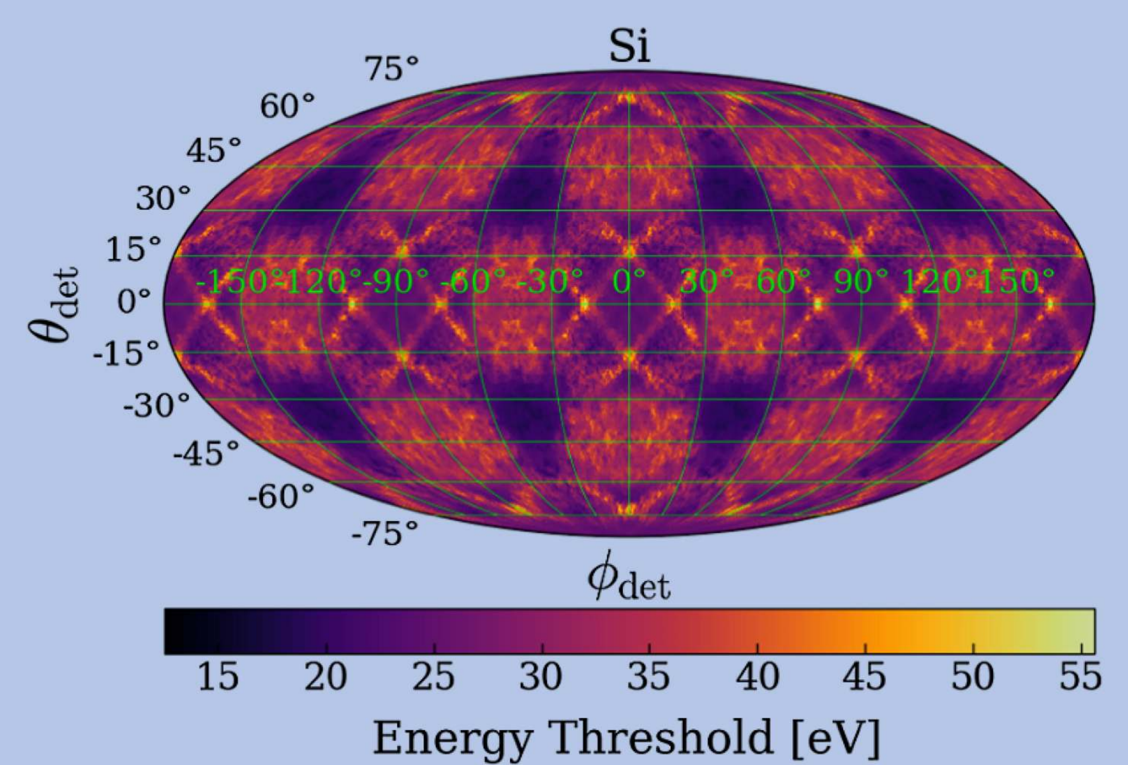
Our galaxy and our planet are travelling through a cloud of dark matter. This means even though the dark matter interacts very infrequently, we can search for it directly anywhere on (or inside) the Earth.

- Setting up dense and massive detectors underground allows us to look for dark matter while shielding them from cosmogenic "ordinary" matter.
- DAMIC currently has a detector 2 km underground with 6 km water equivalent shielding from the "ordinary" matter.
- DAMIC has been collecting images of particles interacting with its Charge-Coupled Devices (CCDs) for over 9 years now.

Radiation Damage and DM

Since the Dark Matter does not interact electromagnetically with matter, it behaves similarly to electrically neutral particles. This can lead to permanent radiation damage in solid state detects such as the CCDs.

- The energy required to produce such damage in silicon is (30 ± 12) eV (Damage threshold damage).
- The threshold energy is a function of the angle between the silicon lattice structure and the incoming particle.



Daily Modulation of Dark Matter induced Radiation Damage

Due to the rotation of the Earth and its relative velocity with respect to the Dark Matter cloud, a stationary silicon detector will have a daily modulation in the rate of radiation damage.