DArk Matter In CCDs at Modane (DAMIC-M)

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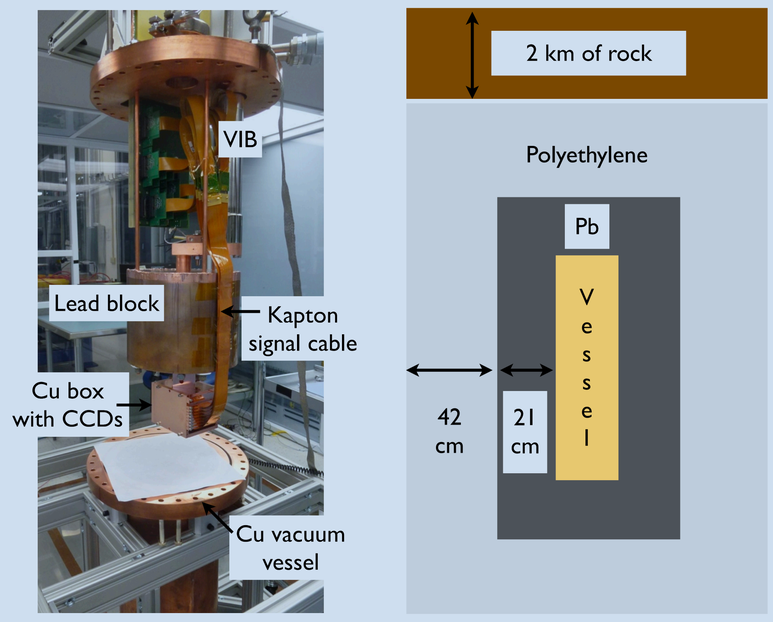
Introduction[1]

- The DArk Matter in CCDs (DAMIC) experiment utilizes the silicon target of multiple Charge Coupled Devices (CCDs) to search for nuclear and electronic recoils induced by the Dark Matter (DM) candidates.
- DAMIC-M aims to improve on the design of the current DAMIC-100 experiment by:
  1. Reducing the electronic noise by a factor of 10 by utilization of skipper CCDs.
  2. Lowering the radio-impurity by a factor of 10 by a more careful selection of detector components.
  3. Increasing the mass of silicon target by a factor of 10 by manufacturing thicker CCDs.

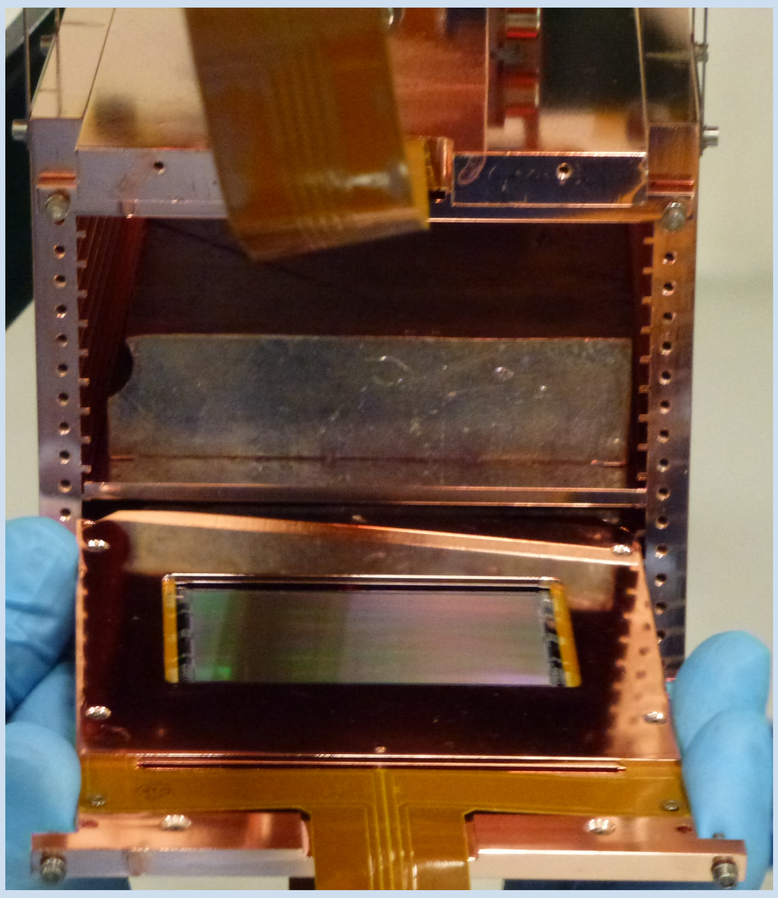
DAMIC-100[2, 3]

DAMIC-100 is the current phase of DAMIC, consisting of a 100-gram silicon target located in the SNOLAB underground laboratory in Canada.



DAMIC-100 outline[2]

The experiment utilizes eighteen 5.5g, 650μm thick, 16MPixel CCDs produced by LBNL which are operated in a 10^{-7}Torr and 133 Kelvin environment. These detectors were calibrated using the photopeaks from ^{137}Cs and ^{55}Fe sources before being shielded by copper, lead and polyethylene.



The modular copper vessel of DAMIC-100

The DAMIC-100 experiment has an electronic read-out noise of 6.5eV$_{ee}$, a leakage current of $10^{-3}e^{-}\text{pix}^{-1}\text{day}^{-1}$ and radio-impurity levels of approximately 5 DRU (events $\text{keV}^{-1}\text{kgray}^{-1}\text{day}^{-1}$)[3].

Dark matter candidates[4]

DAMIC-M will search for different types of dark matter candidates with a wide range of masses (m_χ)

1. Weakly Interacting Massive Particles (WIMPs) (500 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).

Particle tracks in CCDs[4, 1, 2]

To observe such particle collisions with such low-energy particles, the DAMIC experiment measures the interaction between incoming dark matter particles and either the nucleus or electrons of the silicon target of the CCD.

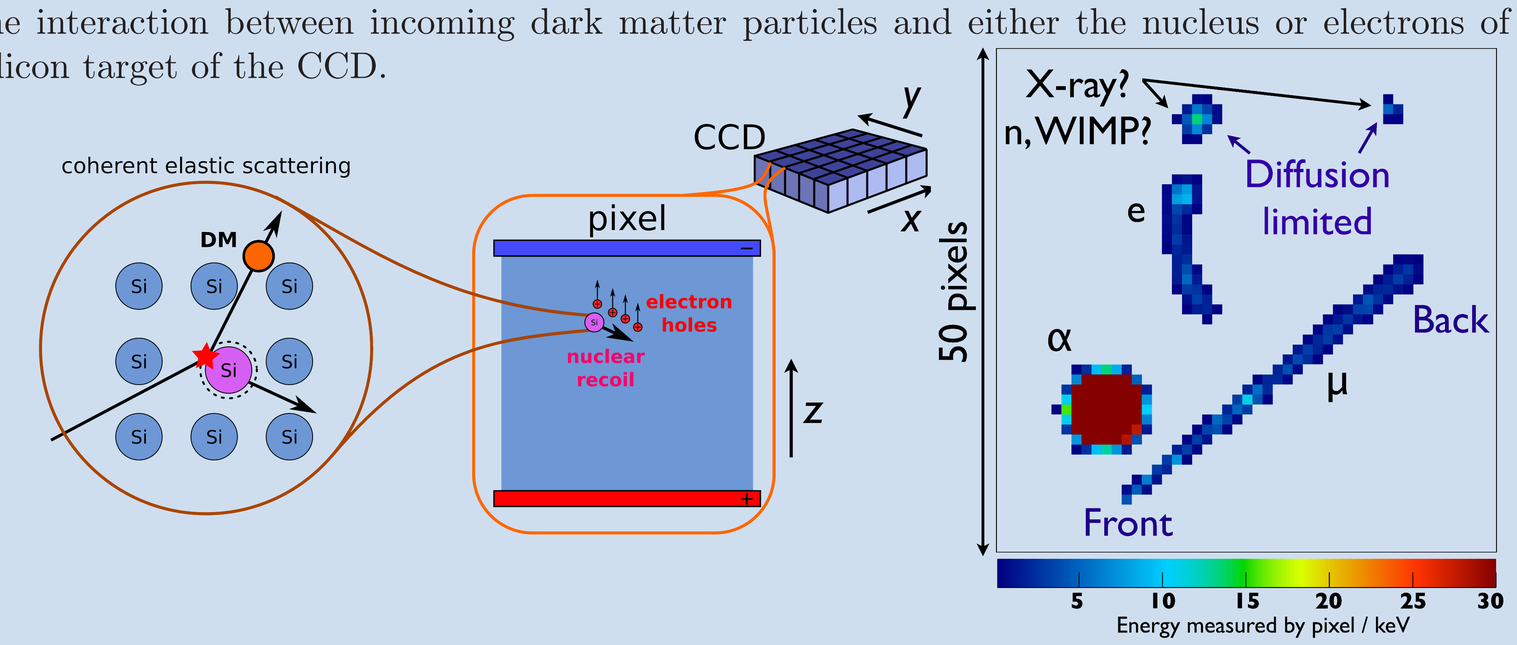
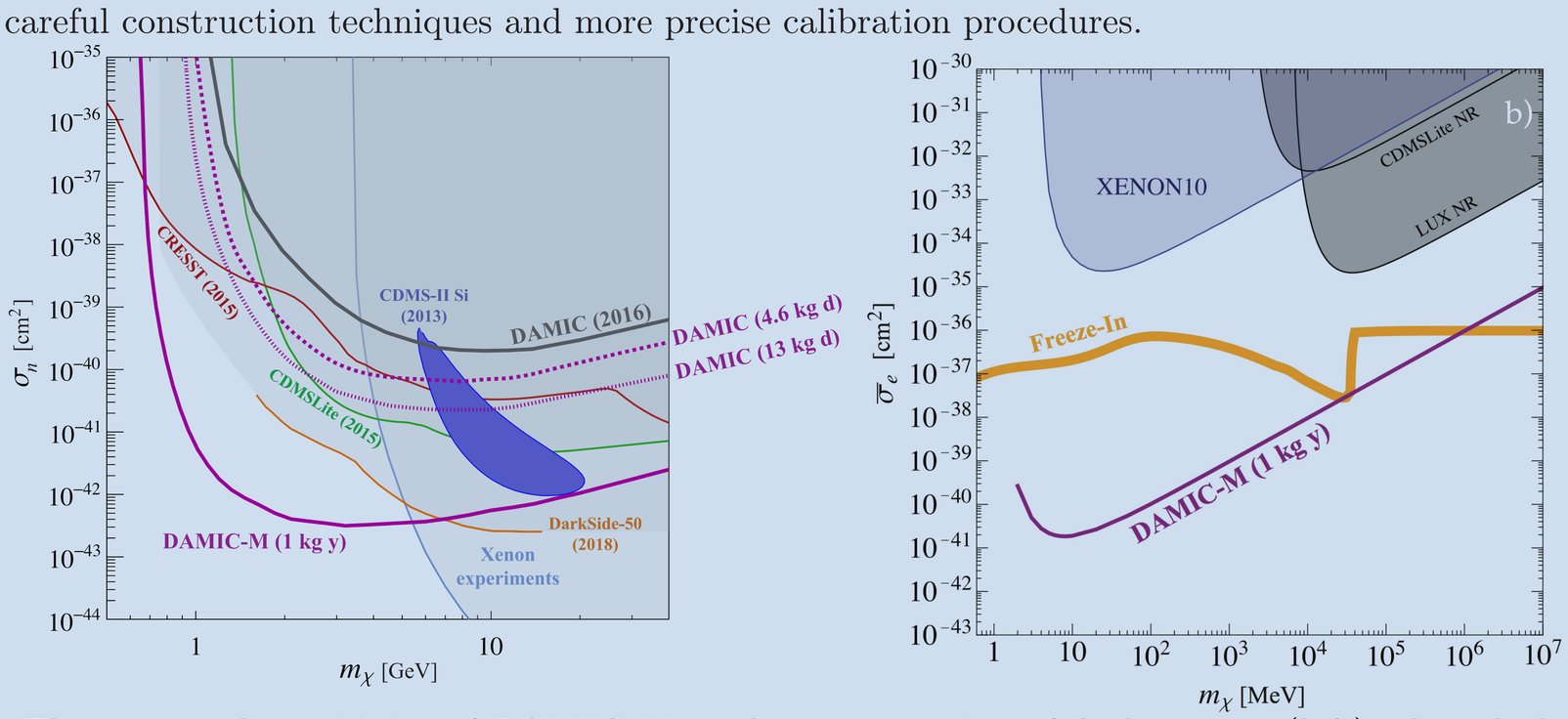


Illustration of nuclear recoil induced by dark matter in silicon bulk of CCDs (left) and (right) reconstructed particle tracks observed by DAMIC CCDs[2].

The minimum ionizing energy in an intrinsic silicon bulk is 3.62eV. However, due to thermal and electrical properties of material, electronic noise dominates the signal in an uncontrolled environment. By controlling the environmental condition of the CCD and by performing a careful analysis, particle tracks can be reconstructed, and dark matter collisions could be observed.

The expected performance of DAMIC-M [3]

DAMIC-M will improve upon DAMIC-100 by utilizing new detector readout technology, using more careful construction techniques and more precise calibration procedures.



The expected sensitivity of DAMIC-M to the cross section of dark matter (left) when dark matter is a WIMP or (right) when the dark photon is a light mediator ($\ll$keV) of dark matter interactions[3].

References

[1] The University of Chicago. (Accessed on 15 Oct. 2018) DAMIC-M Dark Matter In CCDs at Modane. [Online]. Available: https://damic.uchicago.edu/

[2] A. E. Chavarria *et al.*, "DAMIC at SNOLAB," *Phys. Procedia*, vol. 61, pp. 21–33, 2015.

[3] Settimo, Mariangela, "The DAMIC experiment at SNOLAB," in *53rd Rencontres de Moriond on QCD and High Energy Interactions (Moriond QCD 2018) La Thuile, Italy, March 17-24, 2018*, 2018.

[4] Junhui Liao, "Low Mass WIMP Detection with CCDs," Ph.D. dissertation, Universtät Zürich, 2016.