DArk Matter In CCDs at Modane (DAMIC-M)

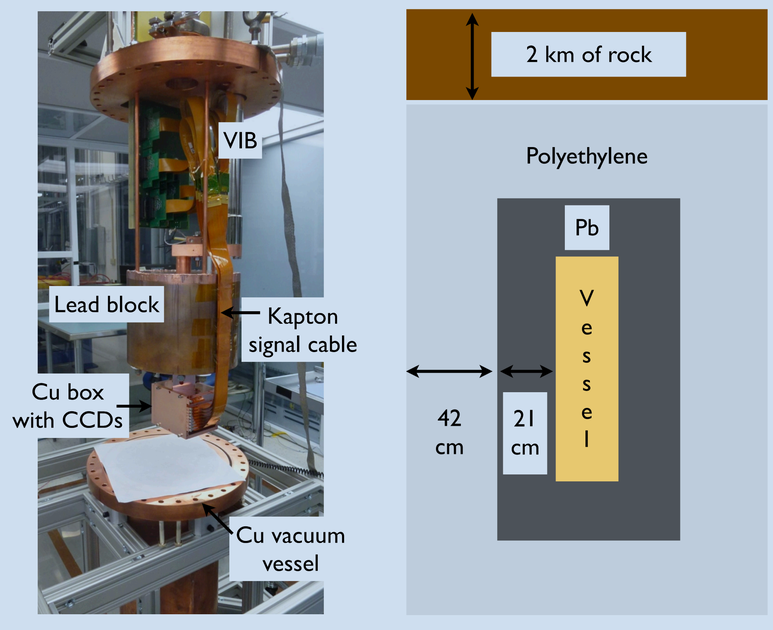
Lukas Ruosch,
Prof. Ben Kilminster, Dr. Anna Macchiolo, Dr. Peter Robmann,
Steven Juhyung Lee, Daniel Florin, David Wolf
Universität Zürich

Introduction[1]

- The DArk Matter in CCDs (DAMIC) experiment utilizes the silicon bulk of multiple Charge Coupled Devices (CCDs) to detect nuclear and electronic recoils induced by Dark Matter (DM) candidates.
- DAMIC@SNOLAB is the current phase of DAMIC located in the SNOLAB underground laboratory in Canada.
- DAMIC-M will improve upon DAMIC@SNOLAB by utilizing new detector readout technology, using more careful construction techniques and more precise calibration procedures. The kg-size detector will be installed at the Laboratoire Souterrain de Modane in France.

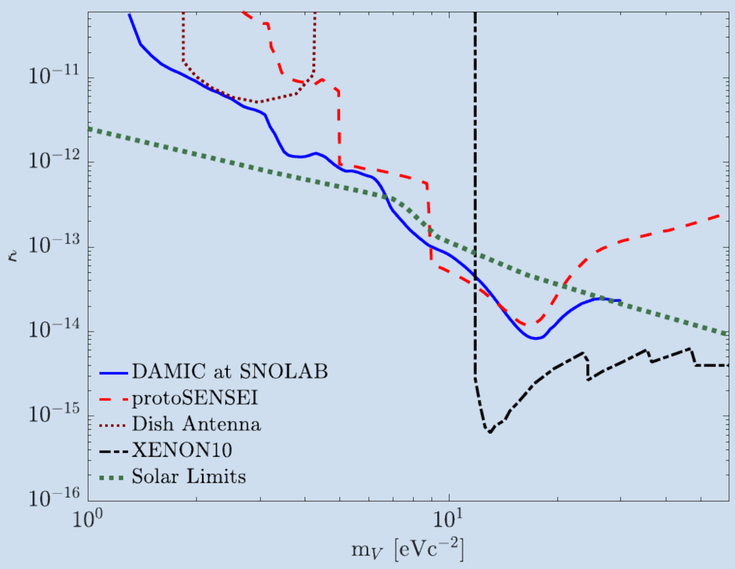
DAMIC@SNOLAB[1, 2, 3]

Since 2014 DAMIC has been collecting data at SNOLAB. The experiment currently utilizes seven 6.0 g, 675 µm thick, 16 Mpixel CCDs produced by LBNL which are operated in a 10^{-7} mbar vacuum environment at 125 K. These detectors were calibrated using the photopeaks from ^{137}Cs and ^{55}Fe sources before being shielded by copper, lead and polyethylene.



Detector outline[2].

Crucial for the very high sensitivity of DAMIC are an electronic read-out noise as low as 6.5 eV_{ee}, a leakage current below 10^{-3} e^-/pix/day and radio-impurity levels of approximately 5 DRU (events $keV^{-1}\,kg^{-1}\,d^{-1}$).



DM kinetic mixing parameter κ as a function of the hidden-photon mass m_V[3].

As of 2019, DAMIC established the best direct-detection limits on dark matter-electron scattering for 0.6 MeV $\leq m_\chi \leq$ 6 MeV and on hidden-photon dark matter of 1.2 eV $\leq m_V \leq$ 9 eV. Further improvements with the SNOLAB apparatus will be explored.

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[2]

To observe 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.

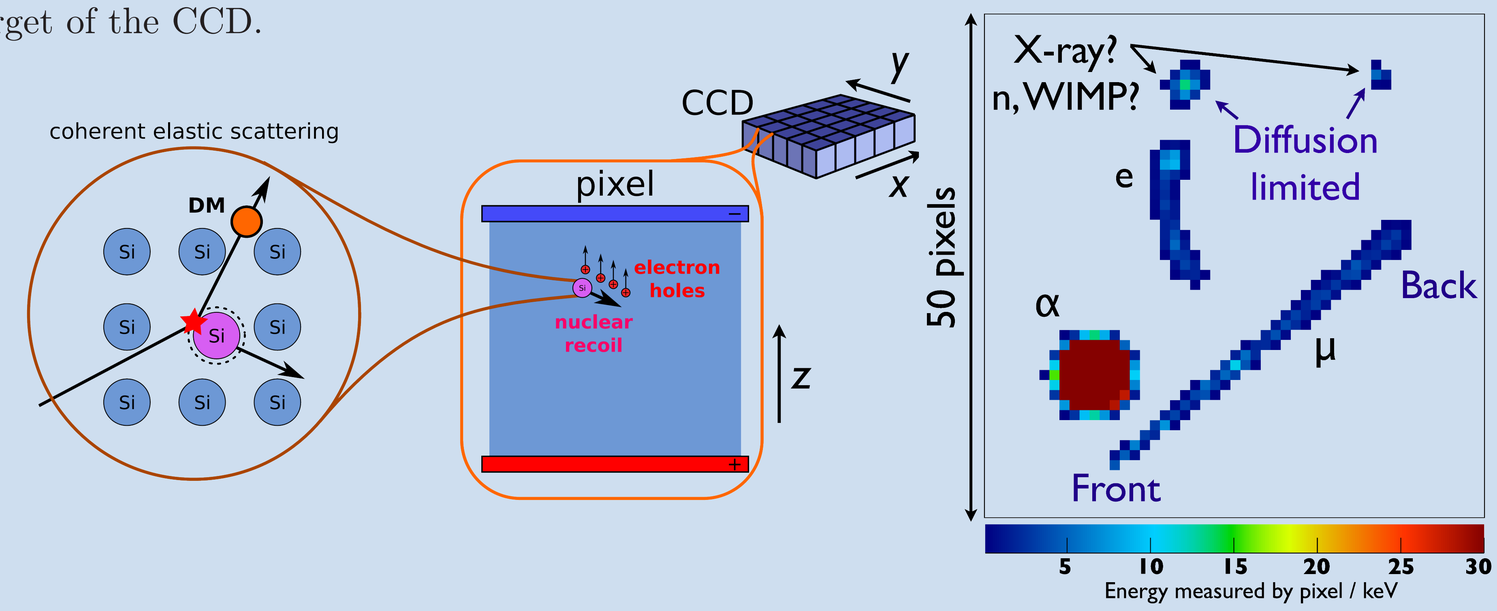
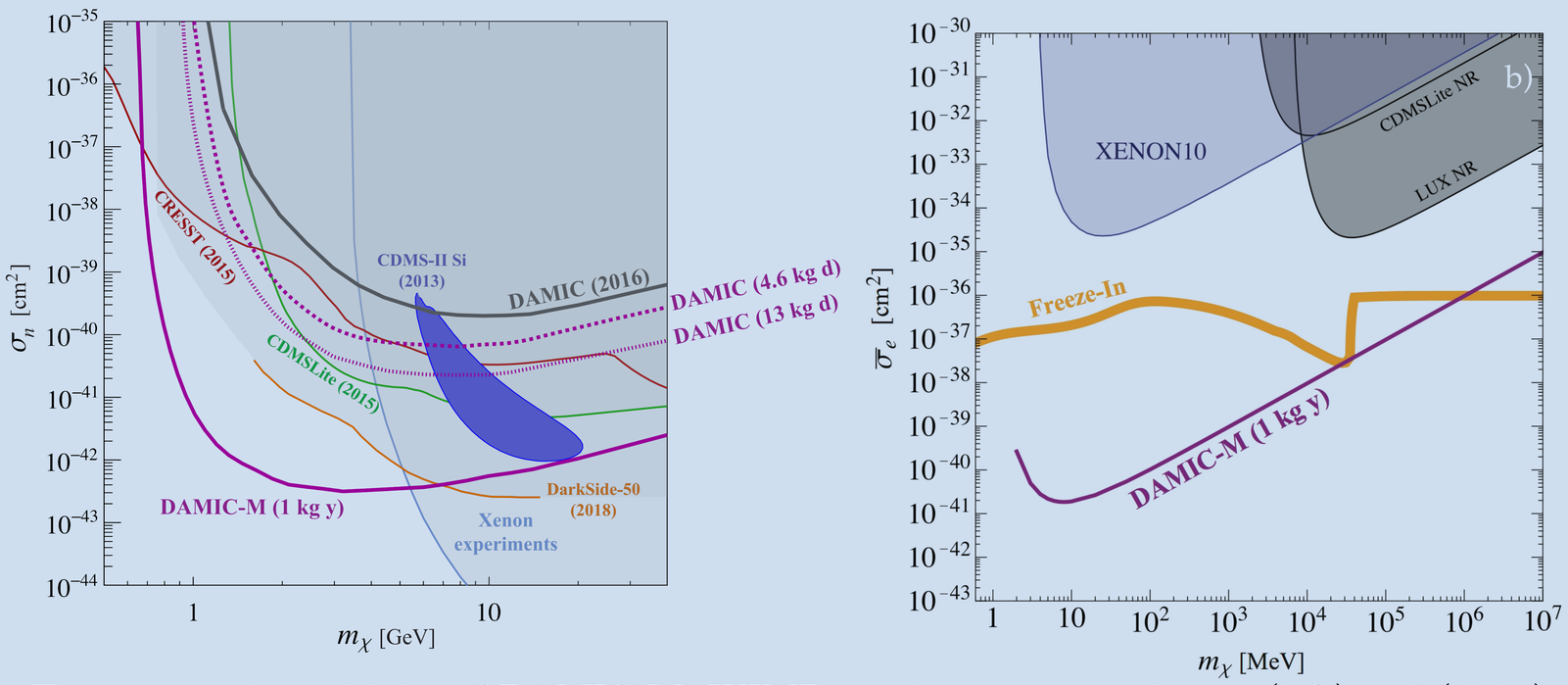


Illustration of nuclear recoil induced by DM in silicon bulk of CCDs (left) and (right) reconstructed particle tracks observed by DAMIC CCDs[2].

The expected performance of DAMIC-M [1, 2]

DAMIC-M aims to improve on the design of the current DAMIC 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 50 by a more careful detector component selection.
3. Increasing the mass of silicon target by a factor of 10 by using larger and more CCDs.



The expected sensitivity of DAMIC-M: WIMPs-nucleus cross section σ_n (left) and (right) DM-electron cross section σ_e for a light mediator as a function of mass m_χ[2].

References

[1] Universtität Zürich. (Accessed on 16 Nov. 2019) The DAMIC experiment at UZH. [Online]. Available: https://www.physik.uzh.ch/en/researcharea/damic.html

[2] 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.

[3] A. Aguilar-Arevalo *et al.*, "Constraints on Light Dark Matter Particles Interacting with Electrons from DAMIC at SNOLAB," *Phys. Rev. Lett.*, vol. 123, no. 18, p. 181802, 2019.

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

UZH contributions

1. Analog to Digital electronics
2. Detector Control Safety system
3. Signal recognition software
4. Detector mechanics
5. Calibration using short-lived isotopes
6. CCD/sensor device simulations