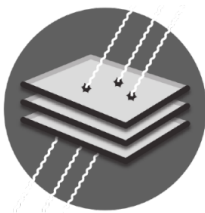


DAMIC (DARk Matter In CCDs) At SNOLAB

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University of Washington
On behalf of the DAMIC Collaboration

July 30, 2019



Outline

Dark Matter Motivation

CCD Detectors

General Operation

DAMIC Detector Performance

DAMIC at SNOLAB

Experimental Setup

Event Selection

Results

Background Model

Expected Sensitivity

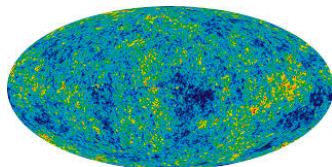
Appendix

Motivation

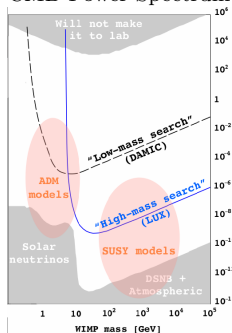
- ▶ Cosmological evidence for DM (CMB, galaxy rotations, etc.)
- ▶ Weakly interacting particle is an attractive candidate (GeV scale mass)
- ▶ DAMIC is interested in low mass models



Galaxy Rotations

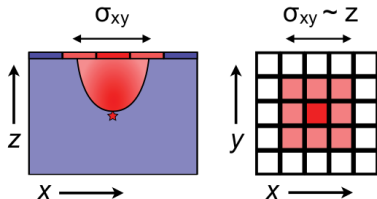
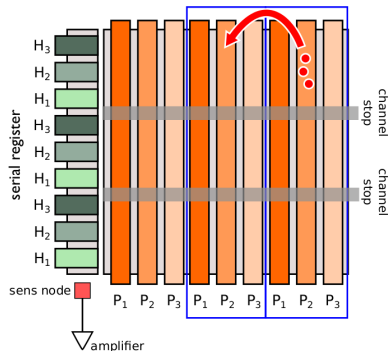
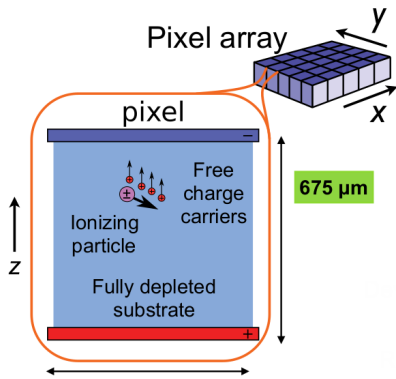


CMB Power Spectrum



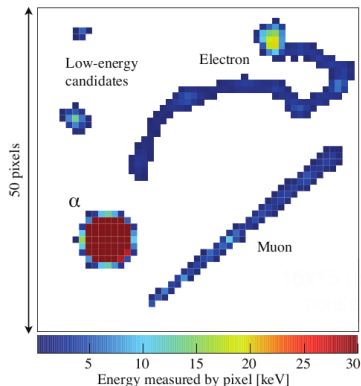
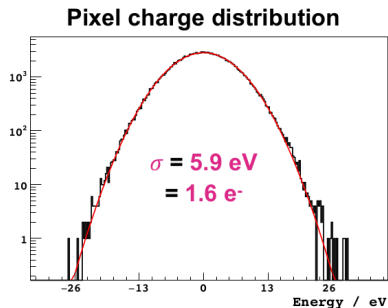
Potential WIMP Parameter Space

General CCD Operations



- ▶ Variable exposure
- ▶ Adjustable readout to minimize noise
- ▶ Well known energy properties
 - ▶ Si band-gap: 1.2 eV
 - ▶ Si W_{ehp} : 3.8 eV

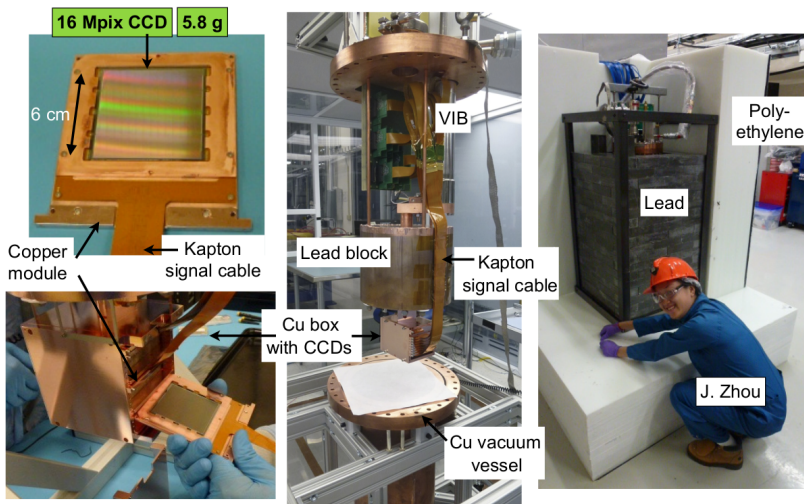
Detector Noise and Measurements



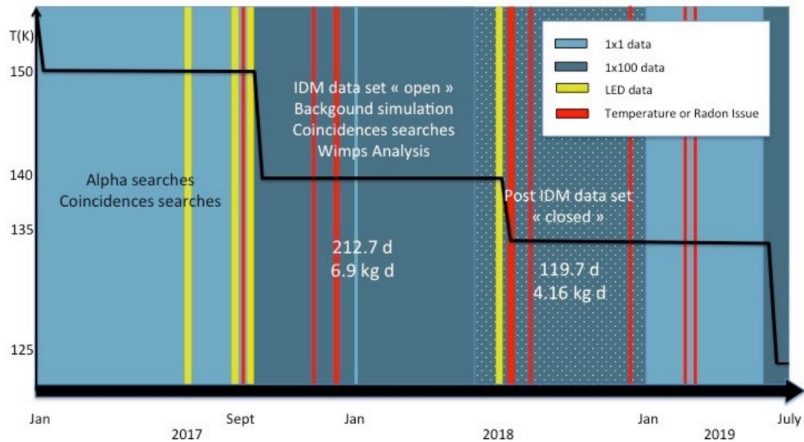
Very low noise and dark current. At 140 K, $I_{DC} = 5 * 10^{-22} \text{ A cm}^{-2}$
or $6 * 10^{-4} \text{ e}^- \text{ pixel}^{-1} \text{ day}^{-1}$

Low energy threshold (due to noise performance) makes DAMIC CCDs sensitive to low mass WIMP interactions

DAMIC at SNOLAB Installation and Setup



DAMIC at SNOLAB Data Runs



WIMP Search Event Selection

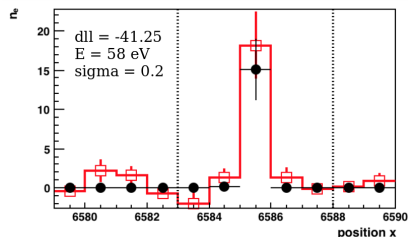
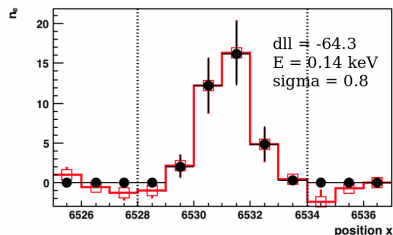
Quality Cuts:

- ▶ Low Radon
- ▶ Stable Temperature
- ▶ Low Dark Current
- ▶ Mask Defects
- ▶ $\Delta\mathcal{L}\mathcal{L}$

$\Delta\mathcal{L}\mathcal{L}$

$\Delta\mathcal{L}\mathcal{L} = \mathcal{L}_{noise} - \mathcal{L}_{noise+gaus}$ is a statistical measure of how different a cluster is from noise.

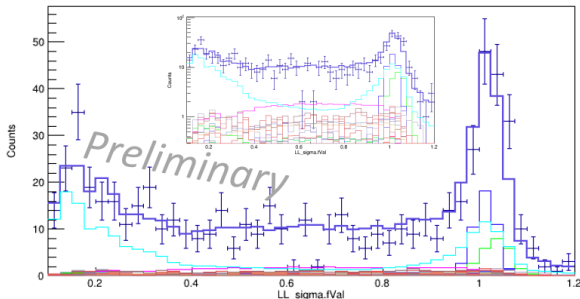
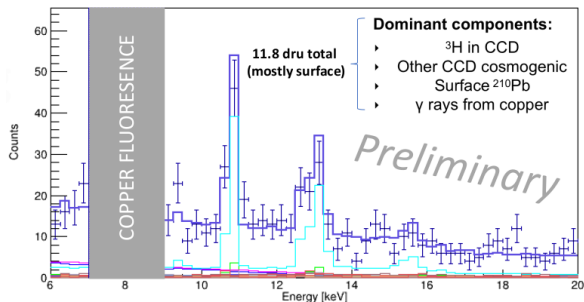
Sample events that passed all cuts shown on the right



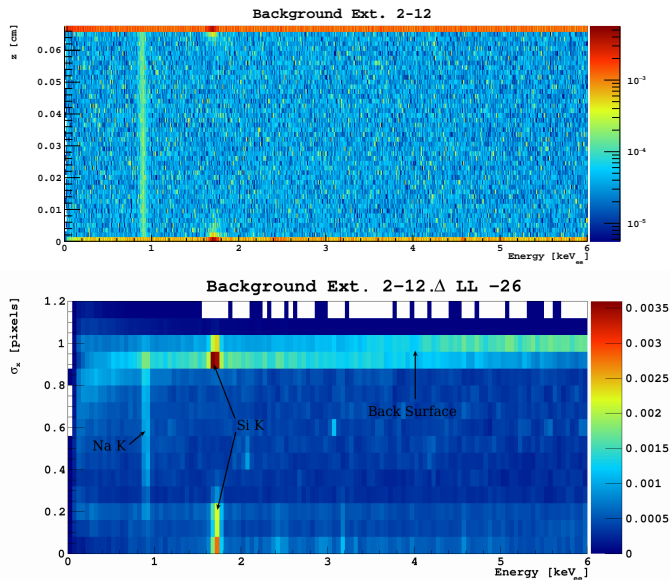
For every event E , σ_x , and $\Delta\mathcal{L}\mathcal{L}$ is extracted

Background Spectral Fit

- ▶ Geant4 Simulation of detector and radio contaminations (bulk and surface)
- ▶ 2D Likelihood fit in (E, σ_x) space of simulation to data
- ▶ Background fit $E > 6$ keV_{ee} (DM search $E < 6$ keV_{ee})
- ▶ Masking Cu fluorescence; have not validated this Geant4 process yet
- ▶ 1D projections show to the right

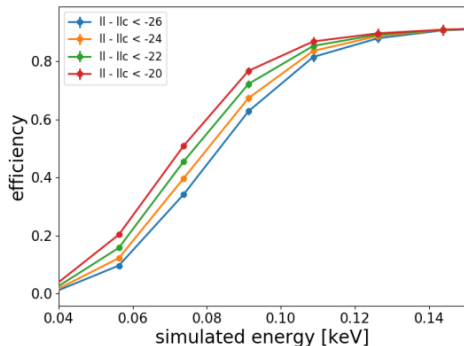


2D Background Model



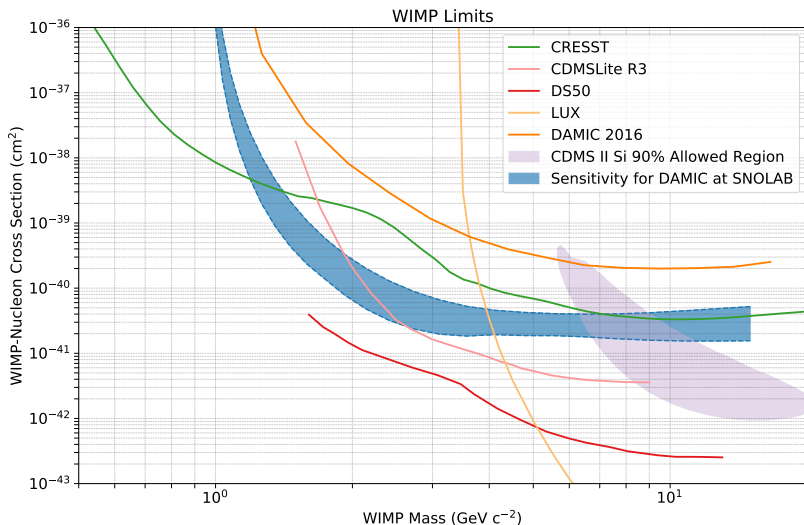
Apply Detector
Response:
Sample from z - E
spectrum
↓
Apply diffusion
model to point
deposition with
random (x, y) and
selected (z, E)
coordinate
↓
Paste event on
image blank
↓
Reconstruct
 $(E, \sigma_x, \Delta\mathcal{L}\mathcal{L})$ to
build detector
background model

Detector Efficiency



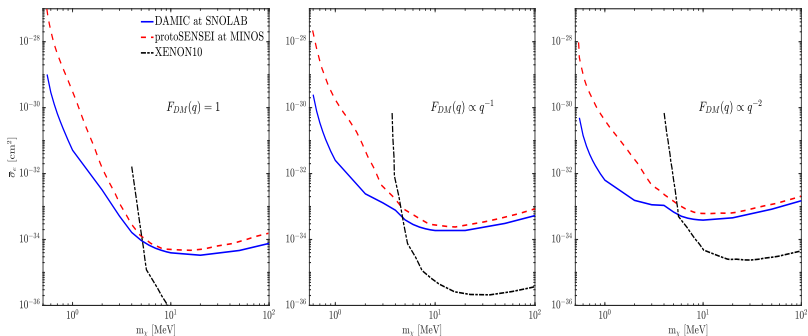
- ▶ Efficiency at low eV_{ee}
- ▶ eV_{nr} (nuclear recoil, energy deposited by WIMP) to eV_{ee} (energy measured by detector) conversion applied
- ▶ DAMIC quenching factor calibrated for the energy range of the experiment

Expected Sensitivity from DAMIC at SNOLAB



Anticipated sensitivity for the 13.3 kg day exposure of DAMIC at SNOLAB

Light Dark Matter: DM-Electron Coupling



Expect paper on the arXiv soon! For more details, attend Karthik Ramanathan's talk on Thursday.

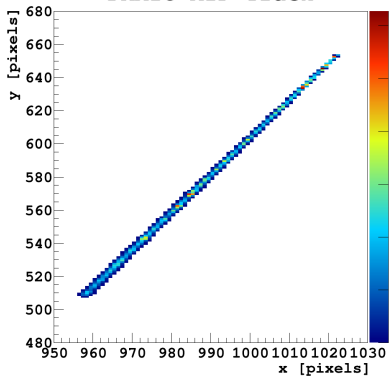
DAMIC Collaboration



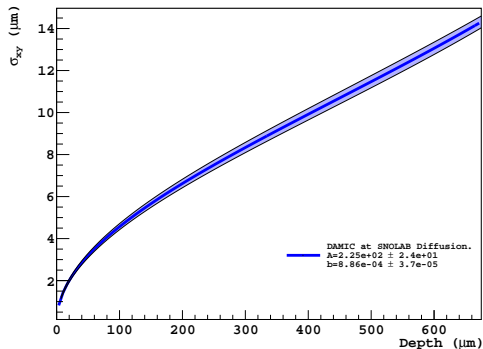
Appendix

Depth Calibration and Diffusion Model

DAMIC MIP Track



DAMIC at SNOLAB Diffusion Model

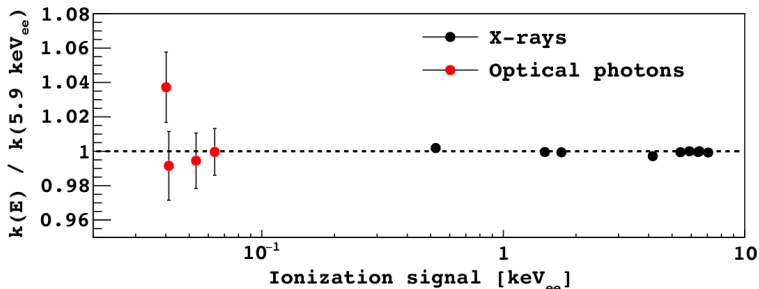


Minimum Ionizing Particles (MIP) used for calibrating the depth of interaction for a set of operating parameters.

$$\sigma_{xy}(z) = \sqrt{-A \ln(1 - bz)}$$

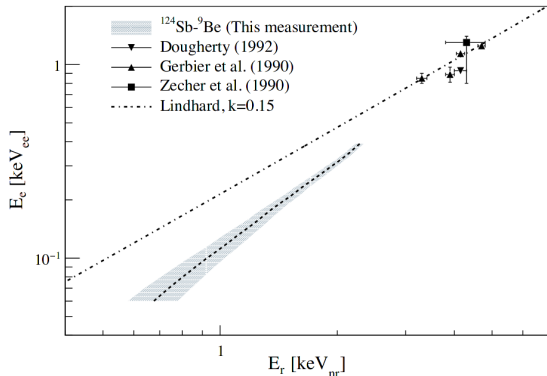
Energy Calibration

- ▶ Amplifiers measure amount of charge in ADU
- ▶ Conversion factor k ($\text{keV}_{\text{ee}}/\text{ADU}$) calibrated using O, Al, Si, Cr, Mn, and Fe x-ray lines
- ▶ k is constant over the energy range we are interested in



arXiv:1607.07410

Nuclear Recoil Ionization Calibration



arXiv:1608.00957

- ▶ DAMIC collaboration performed nuclear recoil measurements on Si targets
- ▶ Calibrated down to 60 eV_{ee} (lowest threshold in Si)