Dark Matter Search Results from DAMIC at SNOLAB

On Behalf of the DAMIC Collaboration

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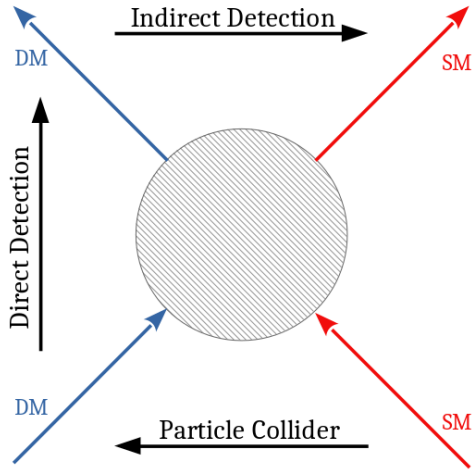
The Dark Matter Problem

Cosmological evidence of dark matter:

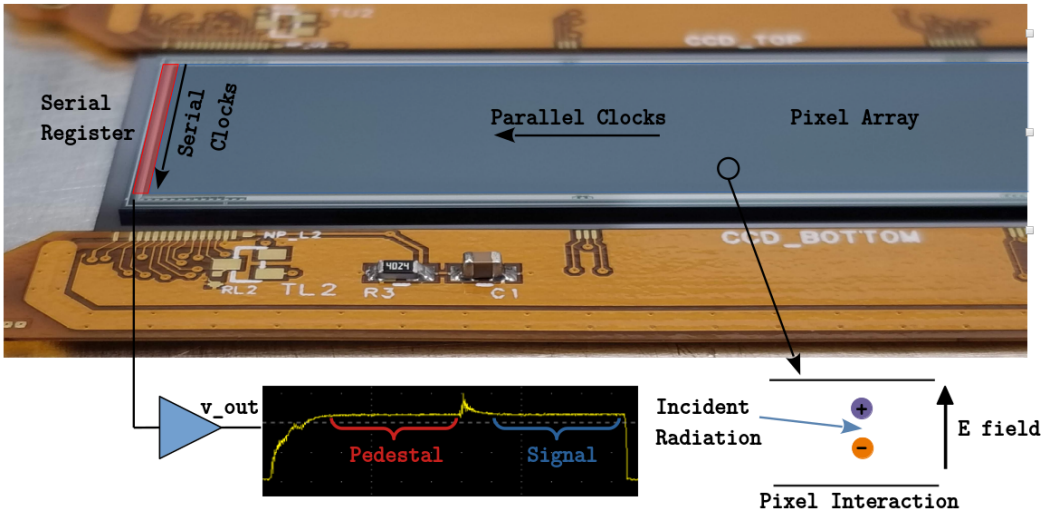
- CMB Power Spectrum
- Galaxy rotation curves
- Gravitational lensing
- Galaxy formations

Aim to measure interactions with matter:

- Elastic scattering off nuclei (standard WIMP scenario)
  - m_χ = 1-1000 GeV c^{-2}
- Inelastic scattering off electrons (dark sector coupling)
  - m_χ = 1-1000 MeV c^{-2}

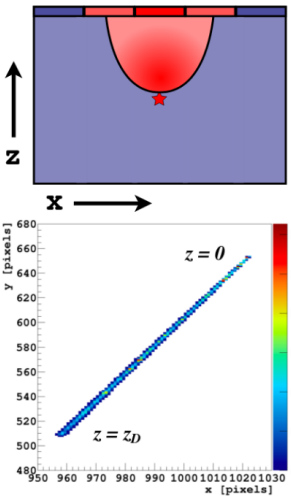


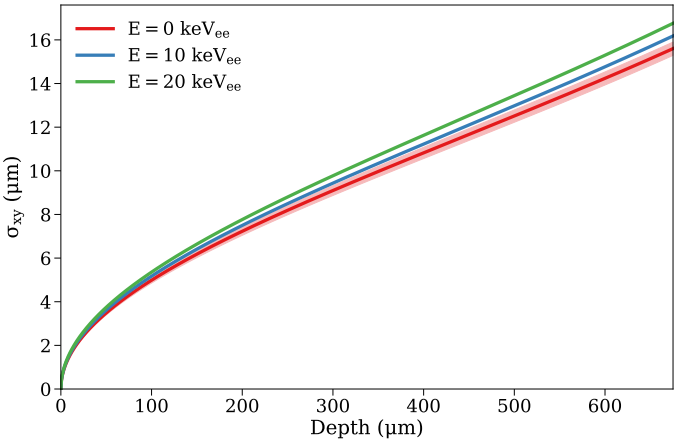
CCD Operation–Charge Collection



CCD Operation–Charge Diffusion

Thermal diffusion causes charge to spread out as it drifts–use muons to calibrate

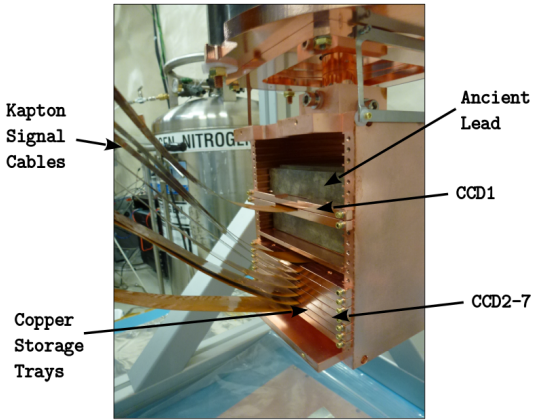




Diffusion follows: $\sigma_{xy}(z, E) = \sqrt{-A \ln(1 - bz)}(\alpha + \beta E)$

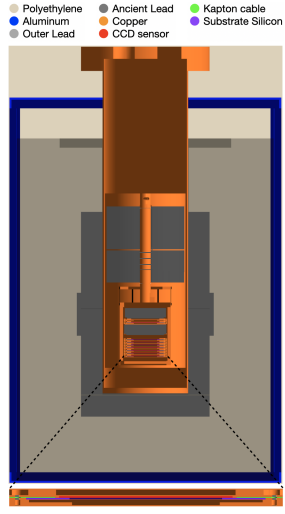
DAMIC at SNOLAB

- Located at SNOLAB ($\sim$ 6000 M.W.E) in Sudbury, Ontario
- Array of 7 CCDs (6.0 g, 16 megapixel) cooled to $\sim$ 140 K
  - Low noise (< 2 e$^-$)
  - Extremely low leakage current (2×10^{-22} Acm^{-2})
- 50 eV$_{ee}$ analysis threshold (10% reconstruction efficiency)
- Total background rate of 10 counts / kg / day / keV$_{ee}$
- 10.6 kg day exposure of Si target for final WIMP analysis



Background Model Methodology

- Simulate full detector geometry and radioactive contaminants in Geant4
- Group simulations into 49 templates
- Perform template fit assuming Poisson statistics in E-σ_x space for $6 < E < 20$ $\mathrm{keV_{ee}}$
  - Using data > 6 $\mathrm{keV_{ee}}$ has minimal impact to WIMP mass we are most sensitive
  - Amount of contaminants constrained by radioactive assays of detector components
- Assemble weighted templates and extrapolate down to low energy to use in WIMP search

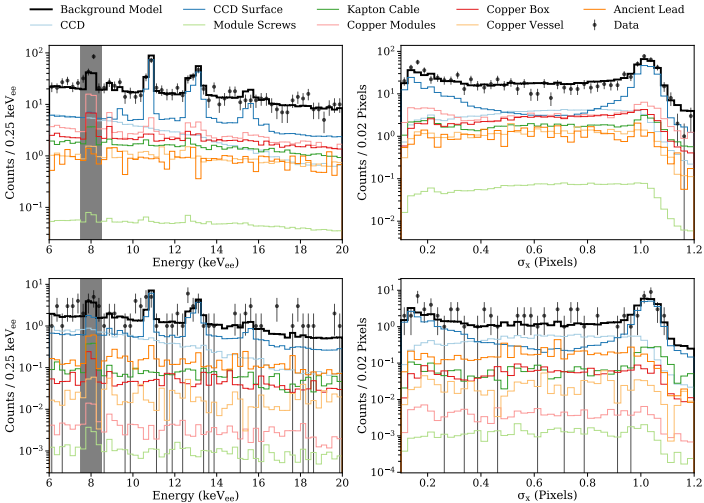


Geant4 detector geometry

Background Model Fit Results–Fit

CCD2-7. 2D template fit in E-σ_x space

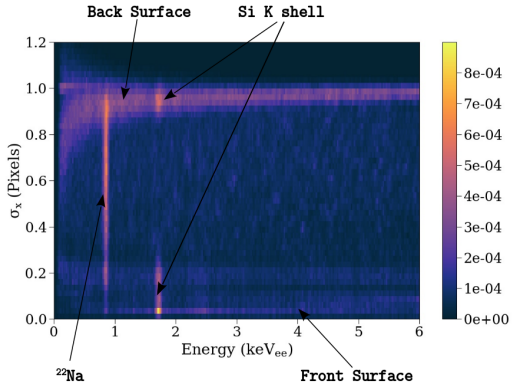
CCD1. Not a fit! Based on CCD2-7 result



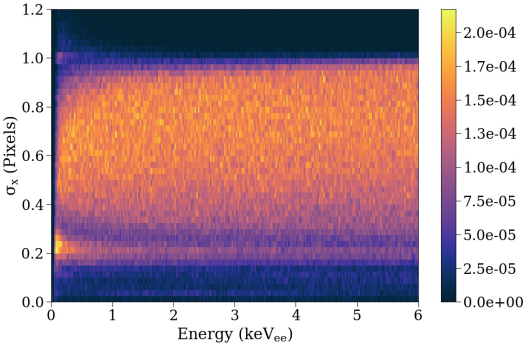
Publication coming soon!

Background Model Fit Results–Low Energy

From the background model fit, we sample the low energy ($E \in [0, 6]$ keV$_{ee}$), apply detector response, and run through reconstruction algorithm



Background model low energy extrapolation

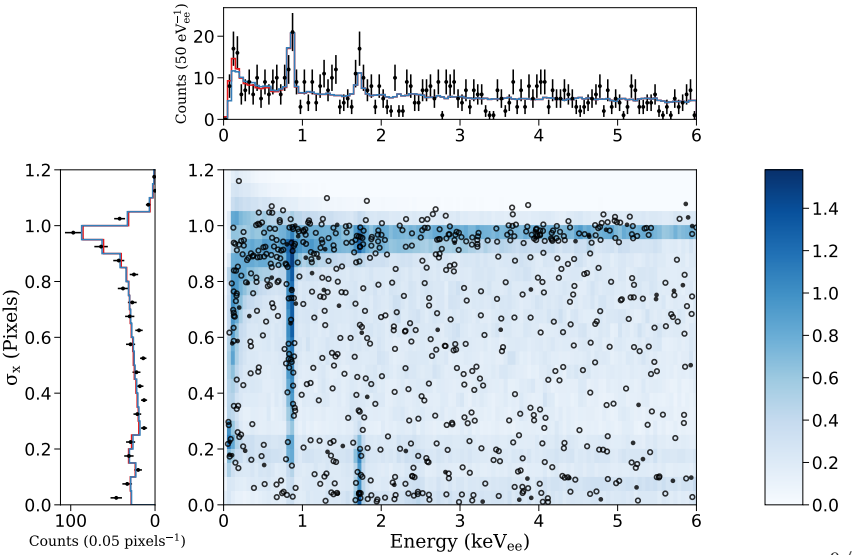


Uniform E-z template

WIMP Likelihood Search Results

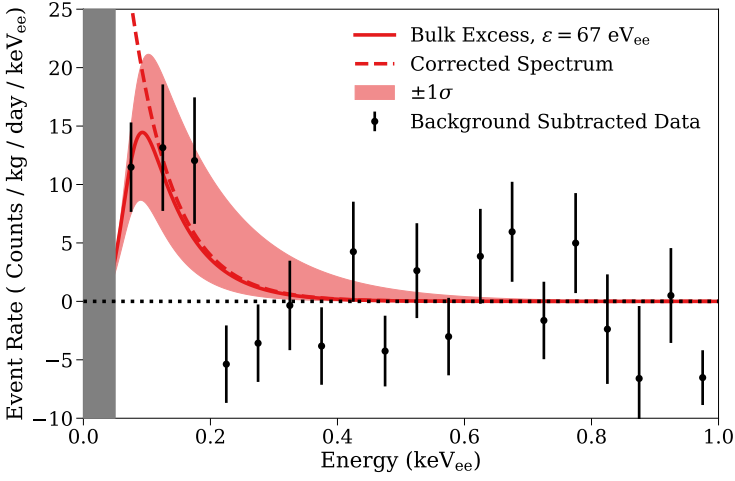
Perform an extended likelihood fit in 2D (E-σ_x)

Above 200 eV_{ee} there is good agreement between background model and data

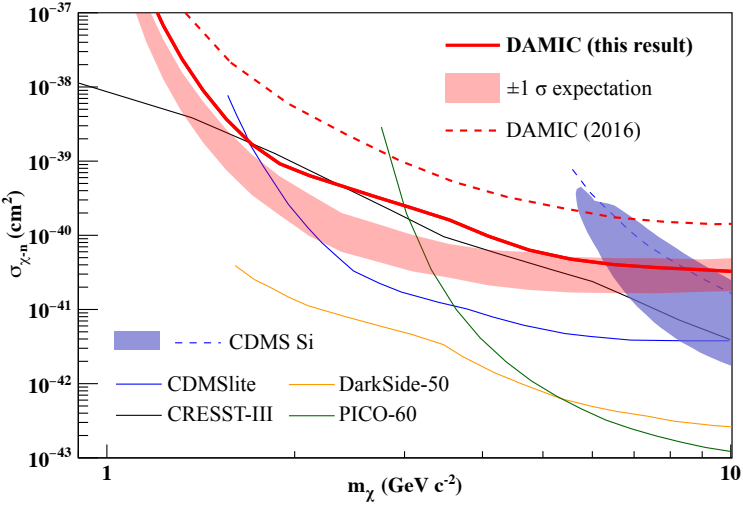


WIMP Likelihood Search Results–Low Energy Excess

Low energy excess can be described by a decaying exponential with 67 eV_{ee} decay length with a 3.7σ significance.

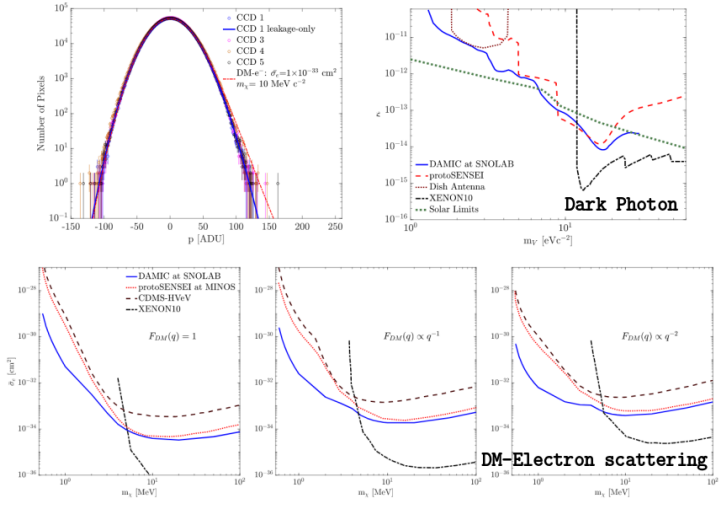


WIMP-Nucleon Cross Section Limits



Aguilar-Arevalo, A., et al. PRL 125(24): 241803

Light Dark Matter Limits

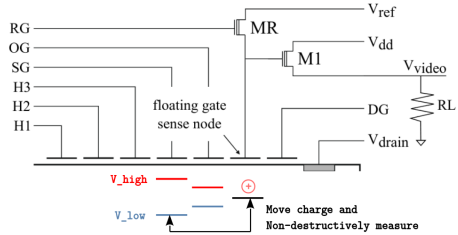


Aguilar-Arevalo, A., et al. PRL 123(18): 181802

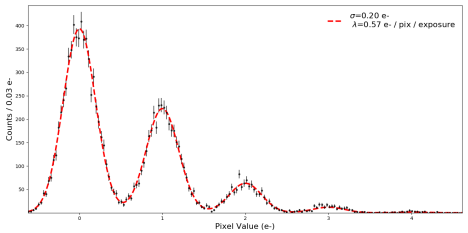
Future Work–Skipper CCDs

Skipper CCDs offer a mechanism for vast noise suppression to < 1 e$^-$. Several future CCD experiments will employ these devices:

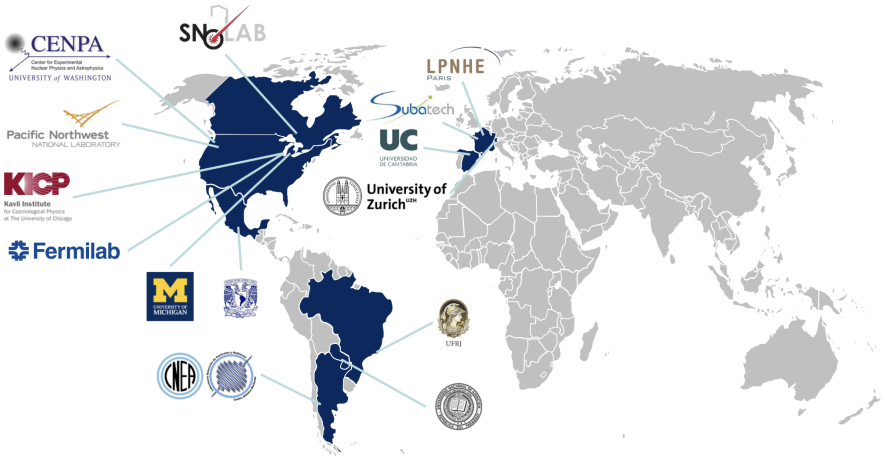
- DAMIC at SNOLAB Upgrade (2021)
- Low Background Chamber in Modane (2021)
- DAMIC-M (2023)
- OSCURA (2025)



Tiffenberg, Javier, et al. PRL 119(13): 131802



Questions?


DAMIC Collaboration
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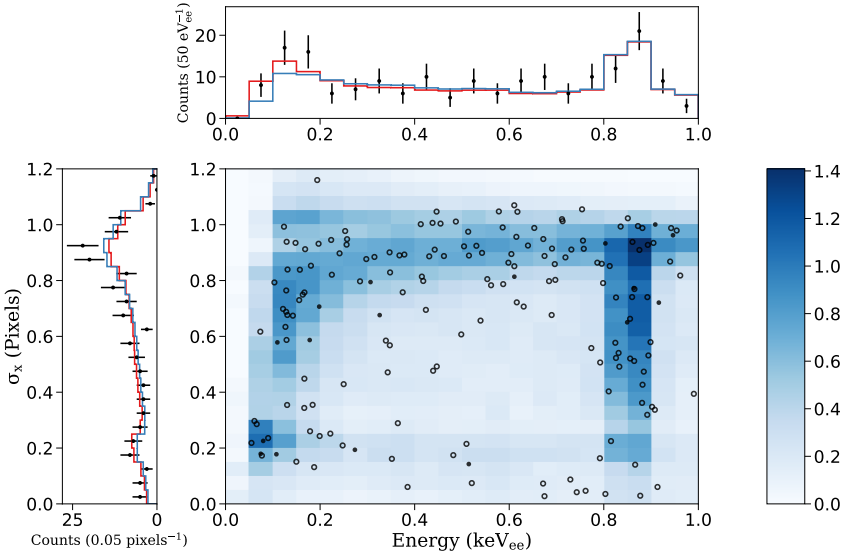
University of Zurich
UNIVERSITY of MICHIGAN
UFRJ
CNEA

Backup Slides

WIMP Likelihood Search 0-1 $\mathrm{keV_{ee}}$