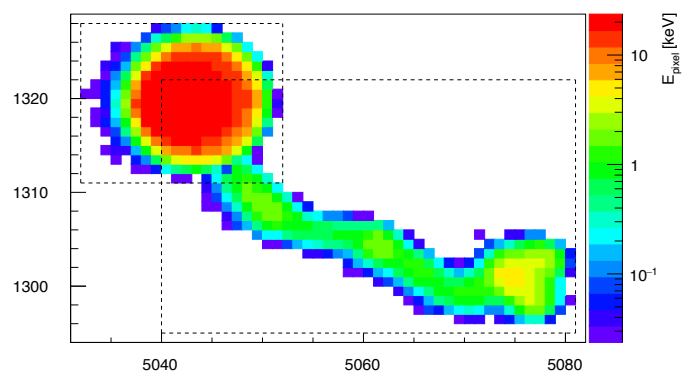


Dark Matter Direct Detection with DAMIC

A brief overview of CCDs as detectors for particle Dark Matter

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Dark matter remains one of the most important scientific mysteries

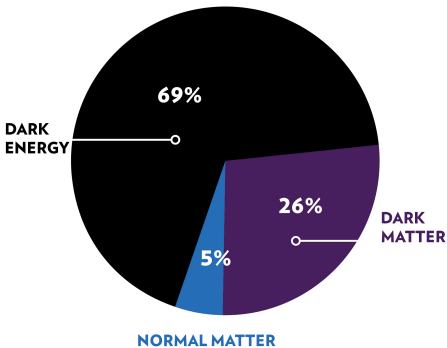
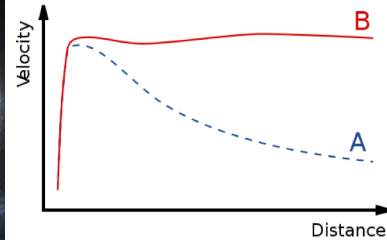
Overwhelming astrophysical evidence:



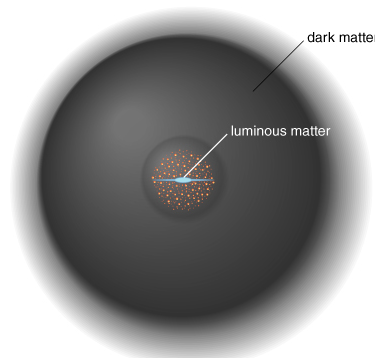
$$K + U = E$$

$$K + U = \frac{1}{2}U$$

$$2K + U = 0$$



Dark Matter



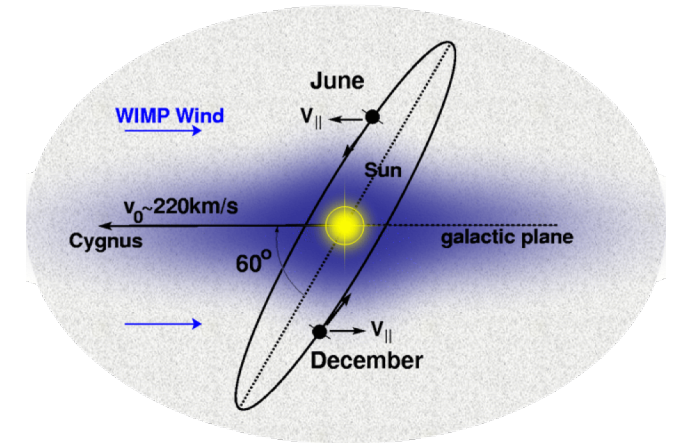
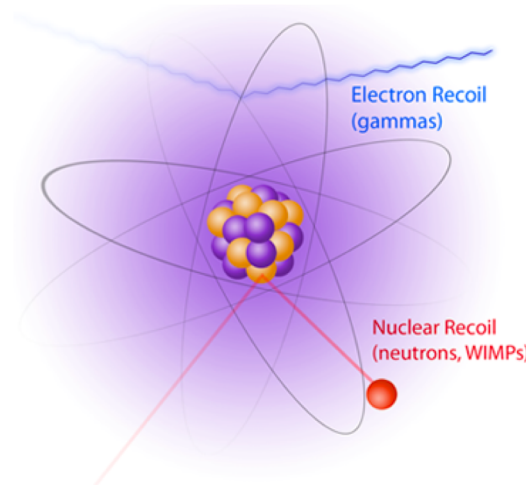
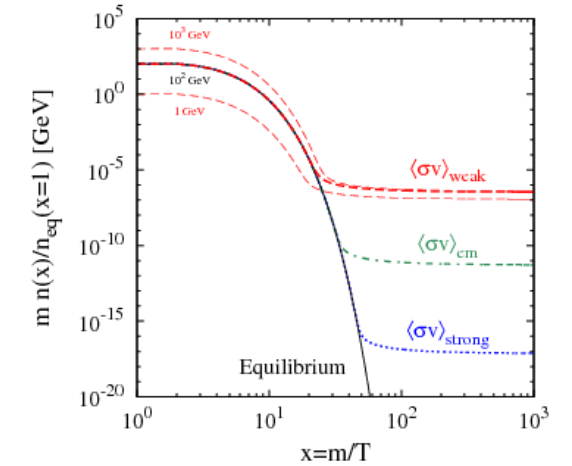
Cosmic Structure

WIMPs, an attractive paradigm for BSM physics:

- Created in early universe
- Predicted mass $O(100 \text{ GeV})$

Principle of Detection

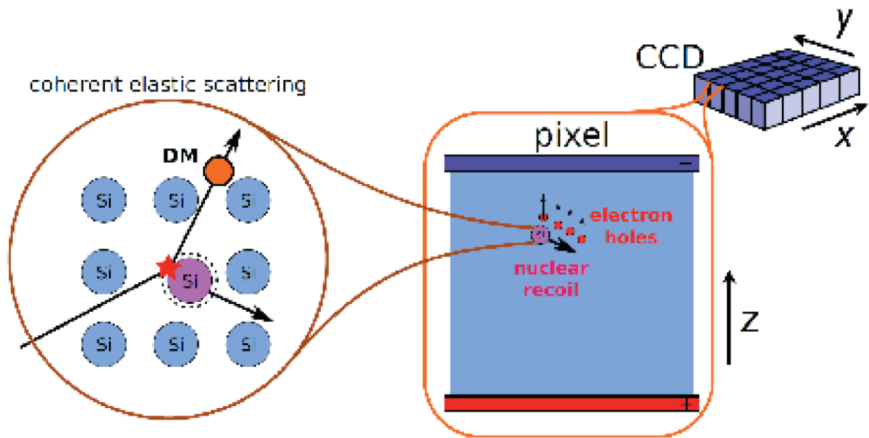
- Recoil interactions $O(\text{keV})$
- Need sub-keV thresholds!



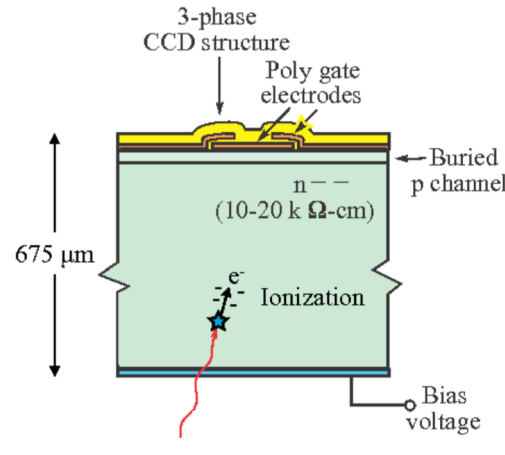
Motivation to probe low-mass WIMPs ($< 20 \text{ GeV}$) and dark sector candidates via electron recoils

DAMIC employs the bulk-silicon of thick, scientific-grade CCDs to detect DM-nucleus/electron coherent elastic scattering

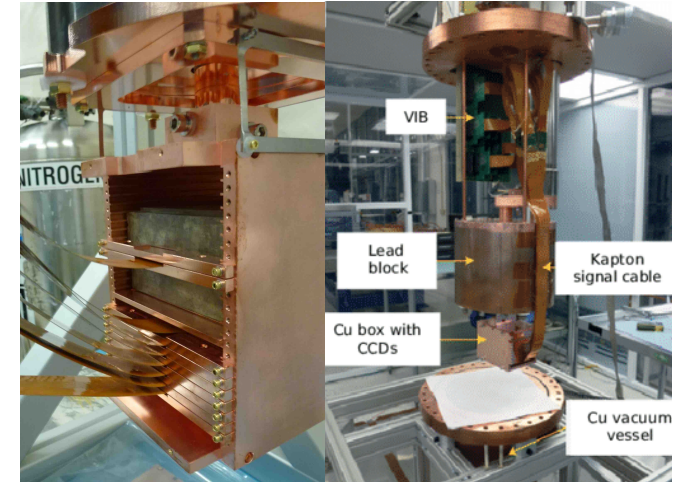
WIMP Detection Principle in a CCD



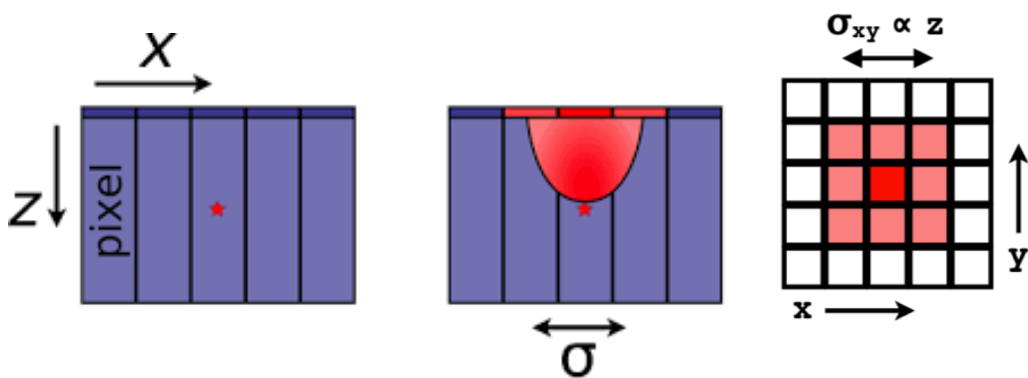
MOS Pixel



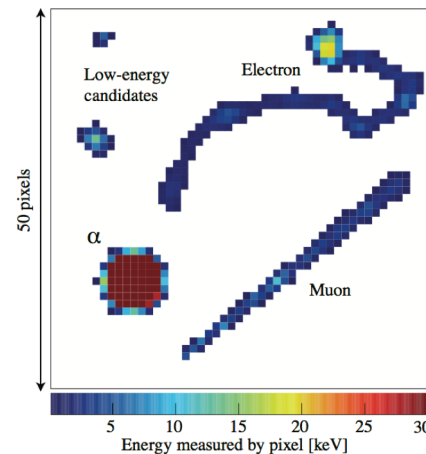
Setup at SNOLAB



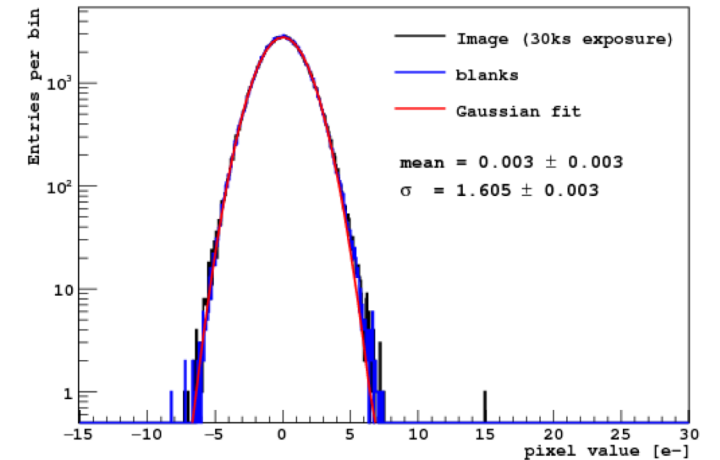
Exquisite Spatial Reconstruction



Particle ID

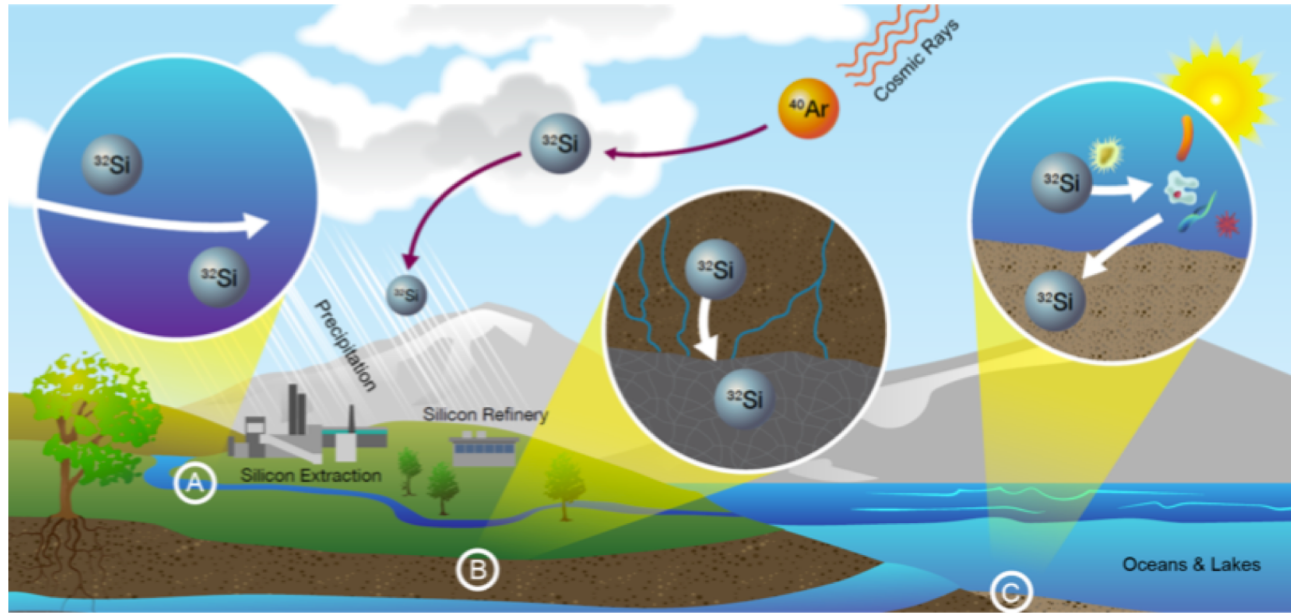


Excellent Charge Resolution

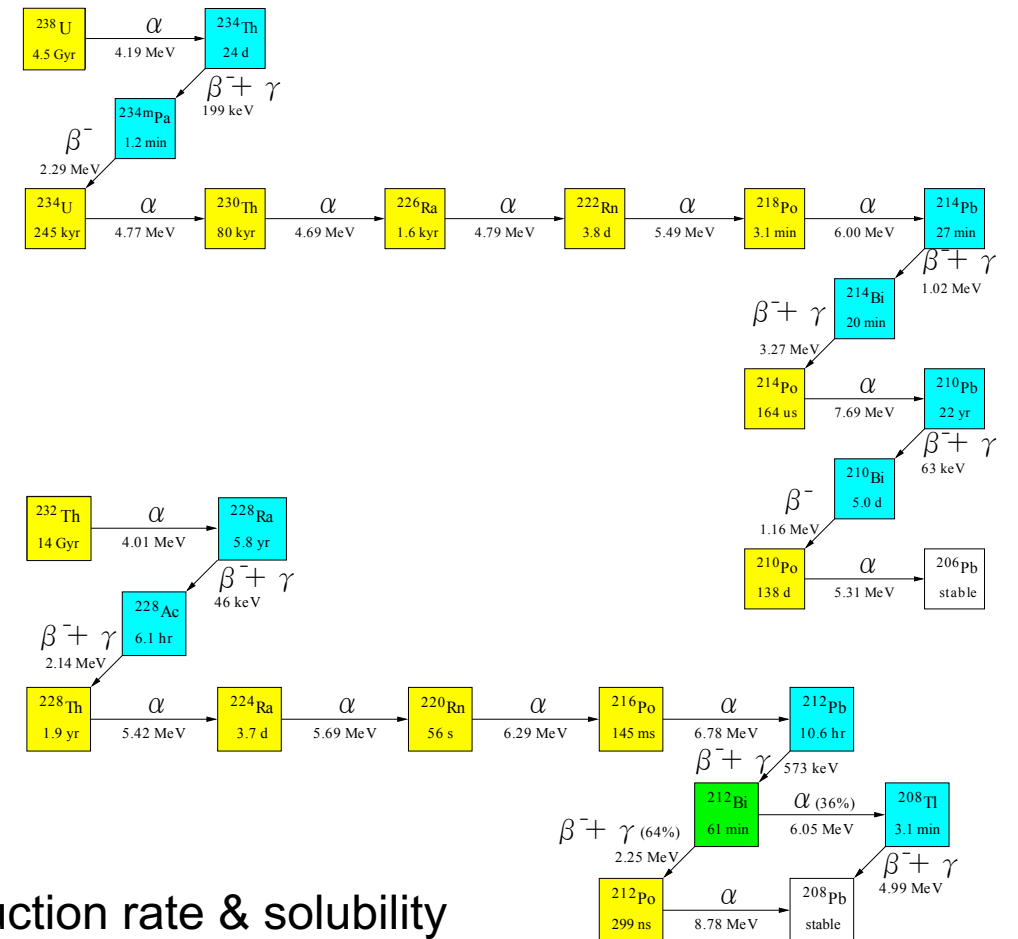


The sensitivity of direct-detection experiments is determined by the ability to identify & mitigate radioactive backgrounds

Cosmogenic isotopes



Natural Radioactivity

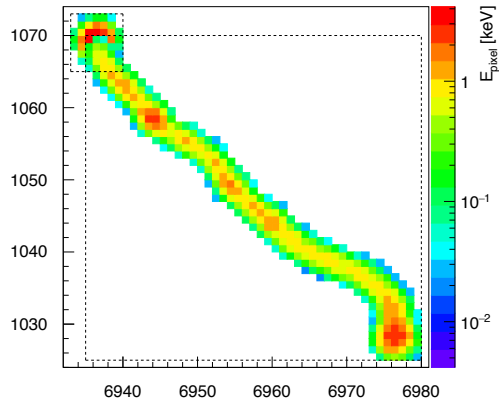


Of particular concern...

- ^{32}Si due to cosmic ray spallation → **bulk contamination**
- ^{210}Pb , a daughter of radon decay → **surface contamination**
- ^3H due to cosmic ray spallation: ongoing R&D to measure production rate & solubility

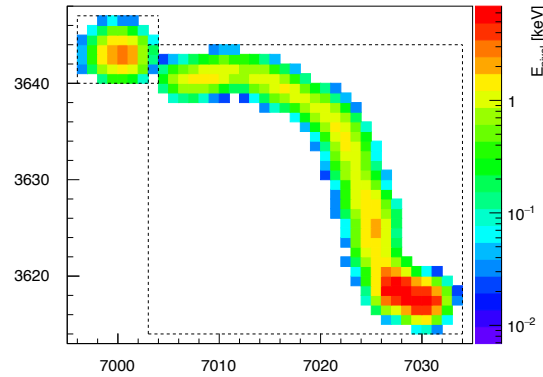
Contamination measured by identifying spatially-correlated decays

$^{32}\text{Si } \beta_1\text{-}\beta_2$



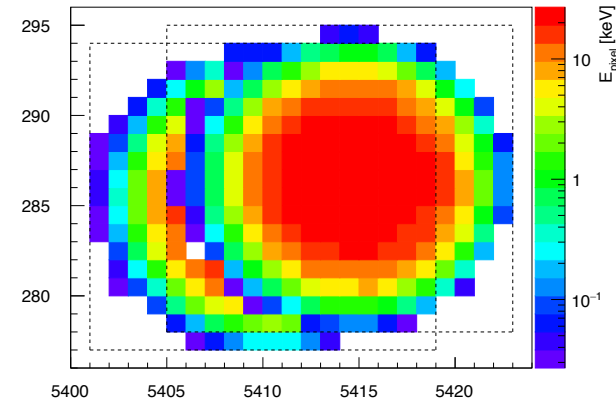
- $E_{\beta_1} = 110 \text{ keV}$
- $E_{\beta_2} = 361 \text{ keV}$
- $\Delta t = 11.7 \text{ d}$

$^{210}\text{Pb } \beta_1\text{-}\beta_2$



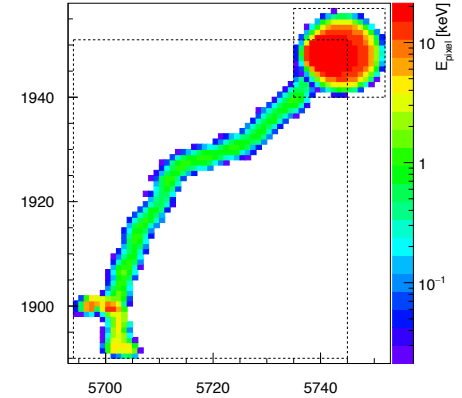
- $E_{\beta_1} = 57 \text{ keV}$
- $E_{\beta_2} = 376 \text{ keV}$
- $\Delta t = 1.4 \text{ d}$

$\alpha\text{-}\alpha$



- $E_{\alpha_1} = 4.3 \text{ MeV}$
- $E_{\alpha_2} = 3.8 \text{ MeV}$
- $\Delta t = 5.2 \text{ d}$

$^{210}\text{Pb } \beta_1\text{-}\alpha$



- $E_{\beta_1} = 717 \text{ keV}$
- $E_{\alpha} = 3.62 \text{ MeV}$
- $\Delta t = 32.3 \text{ d}$

^{32}Si

- $133.3 \pm 27.8 \text{ } \mu\text{Bq/kg}$

^{210}Pb

- $83.1 \pm 11.8 \text{ nBq/cm}^2$

^{238}U

- No $\alpha\text{-}\beta$ sequences
- Upper limit:

0.53/kg/day or 1.5 ppt [95%]

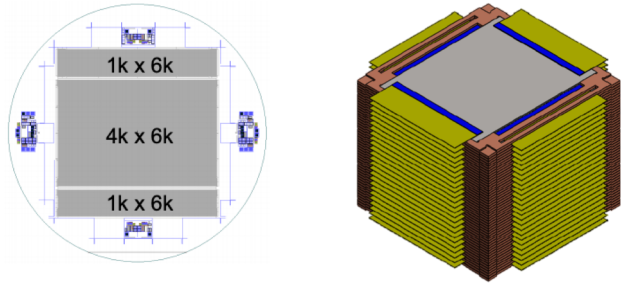
^{232}Th

- No α 's with $E = 18.7 \text{ MeV}$
- Upper limit:

0.35/kg/day or 1 ppt [95%]

DAMIC-M (Dark Matter in CCDs at Modane), a kg-scale detector with record-mass CCDs and novel readout, is being developed

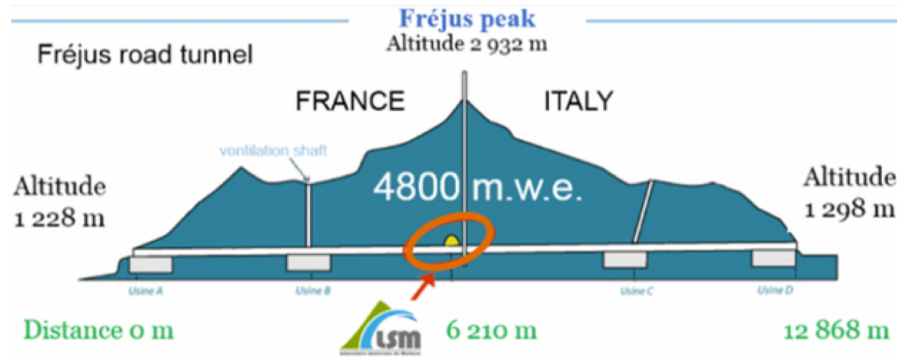
Record-mass CCDs



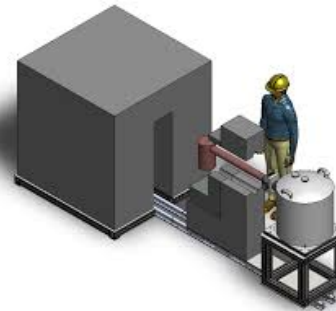
- 50 CCDs x 20g = 1 kg!
- Led R&D of thick detector fabrication at UChicago PNF

Extensive Background Reduction

Laboratoire Souterrain de Modane (LSM)



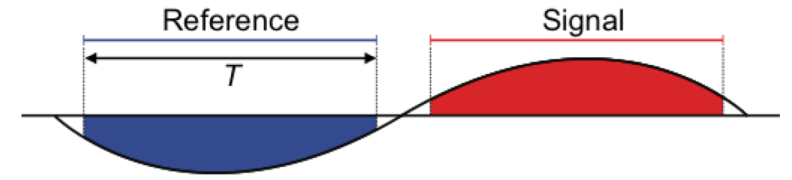
- Radon-trapping facility
- CCD shielding
- Underground packaging



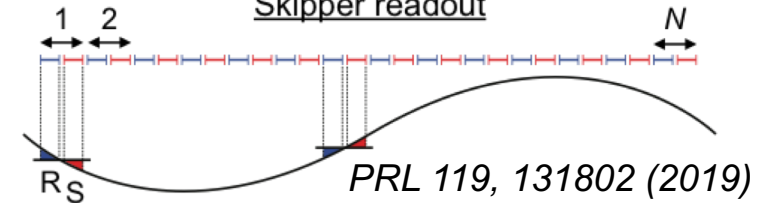
It will be critical to characterize Skipper CCDs and electronics

Novel Readout

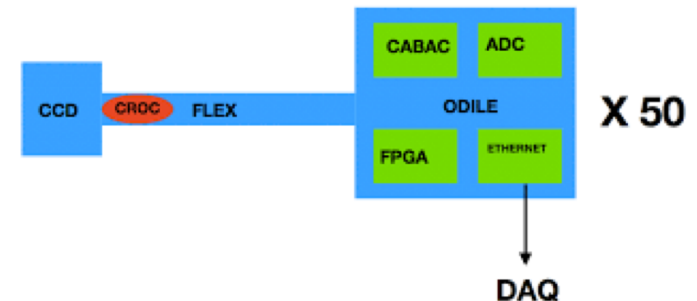
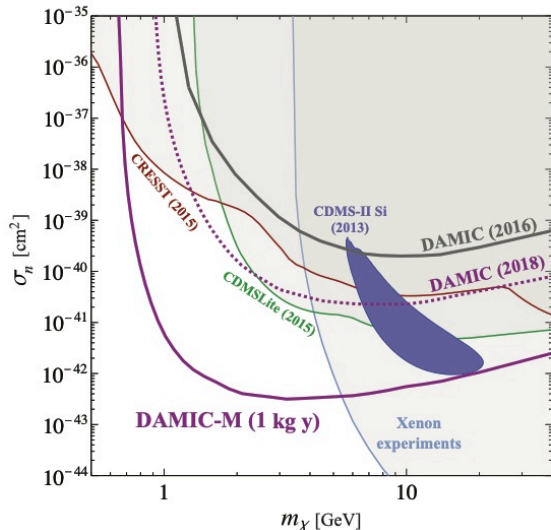
Conventional readout



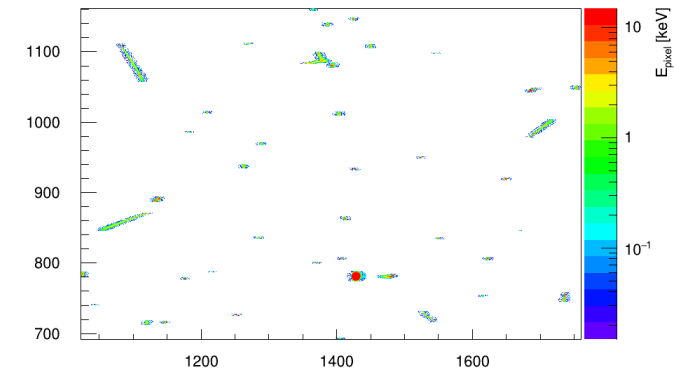
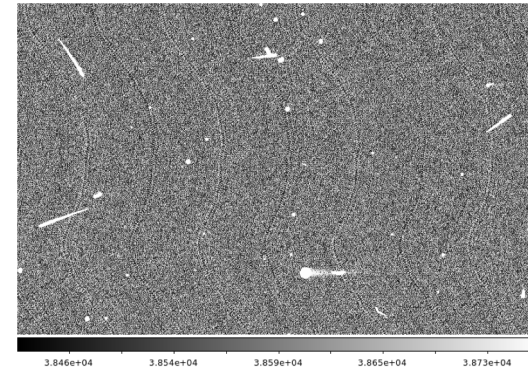
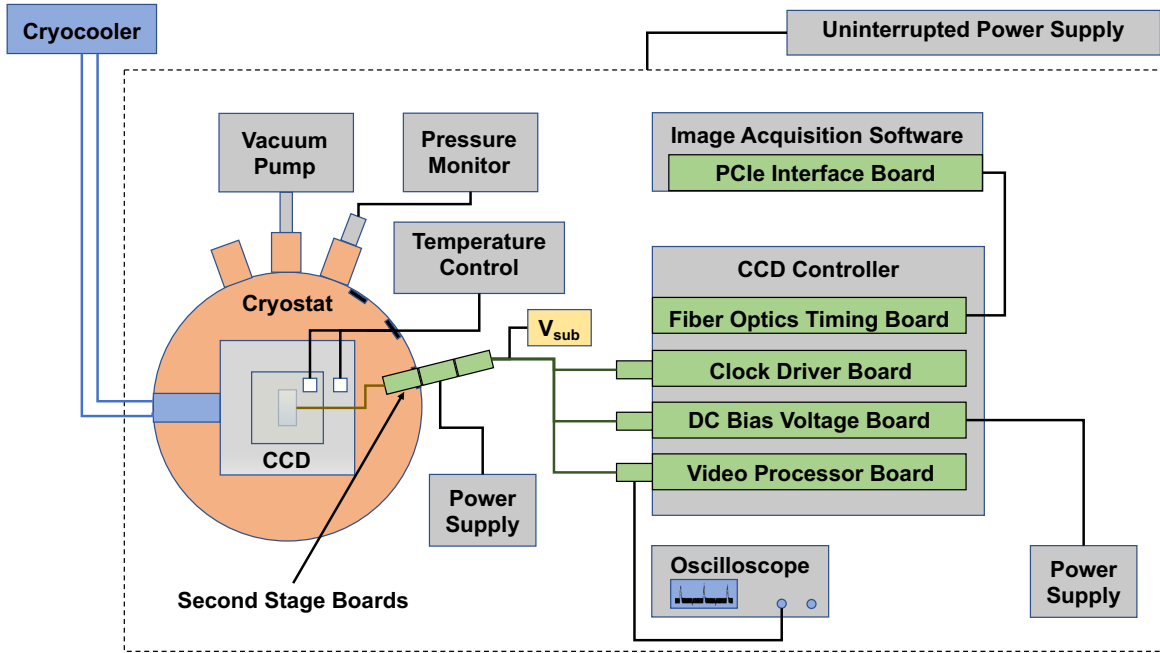
Skipper readout



- Non-destructive, multiple charge measurement, read noise $\sim 1/\sqrt{N}$
- Single-electron sensitivity

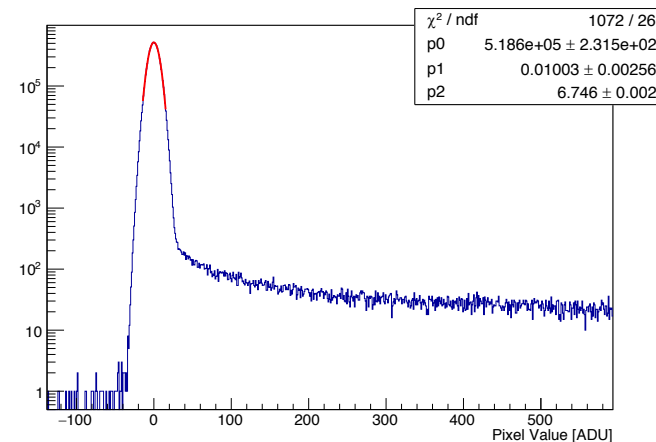
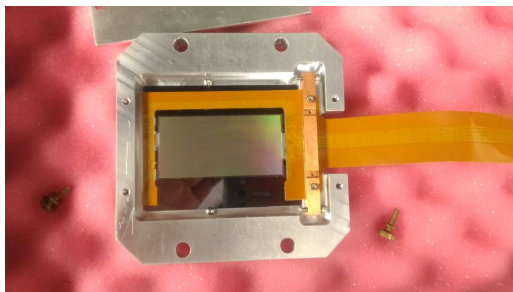


A system for electronics development and CCD calibration

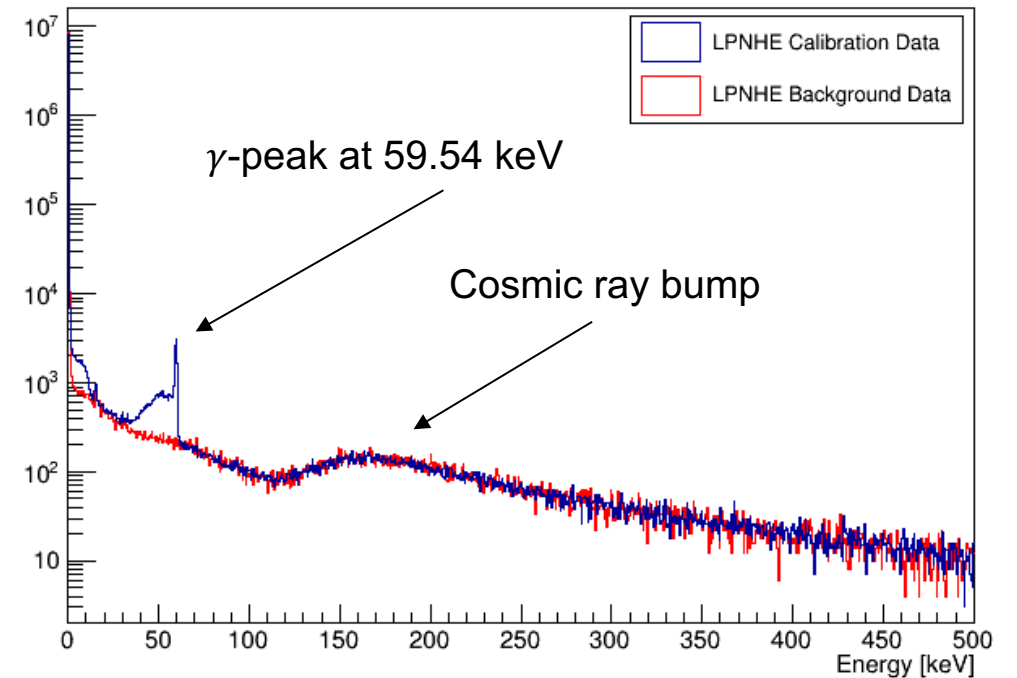


^{241}Am Energy Spectrum

- Modular cryostat in ISO Class 7 cleanroom
- 4k x 2k CCD deployed



➔ Readout noise $\sim 6 e^-$



Acknowledgements



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Cheers!

