The DAMIC Experiment at SNOLAB

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For the DAMIC Collaboration

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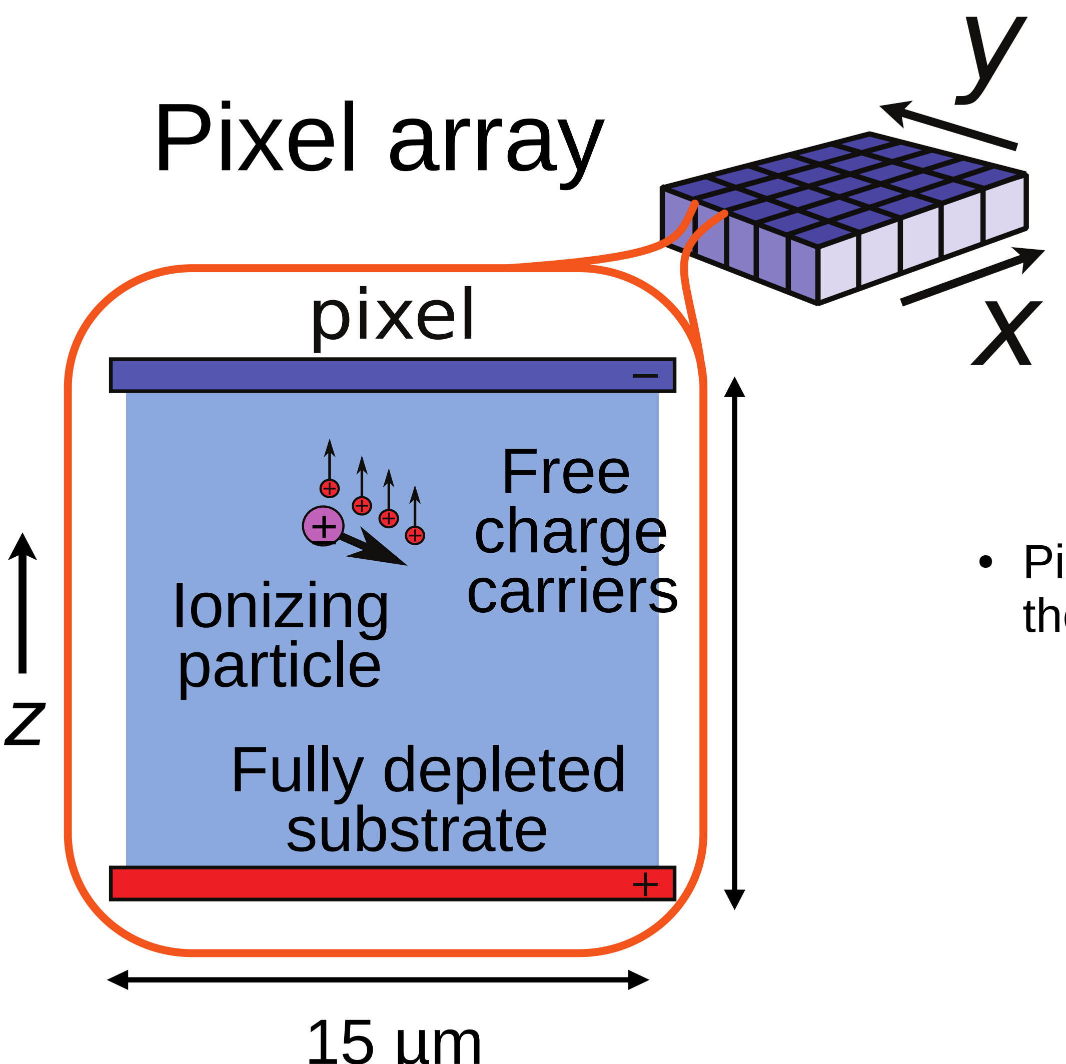
Outline

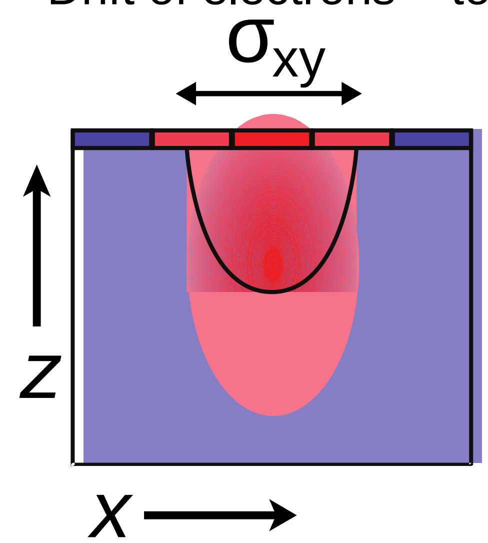
- Charge Coupled Devices (CCDs) as particle detectors.
- DAMIC at SNOLAB.
- Background discrimination.
- Low mass dark matter search results.
- Future of the DAMIC program.

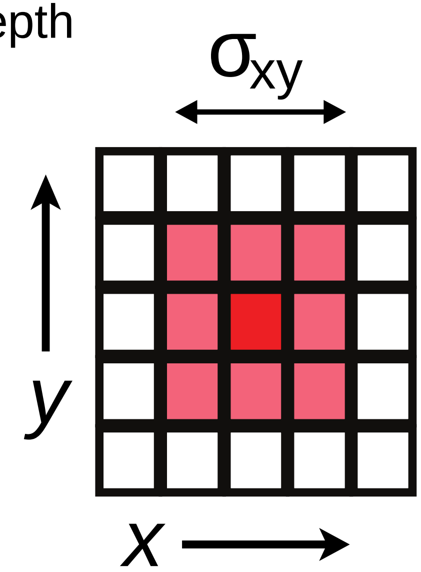
CCD Principles

- Particle produces ionization which drifts to surface of CCD

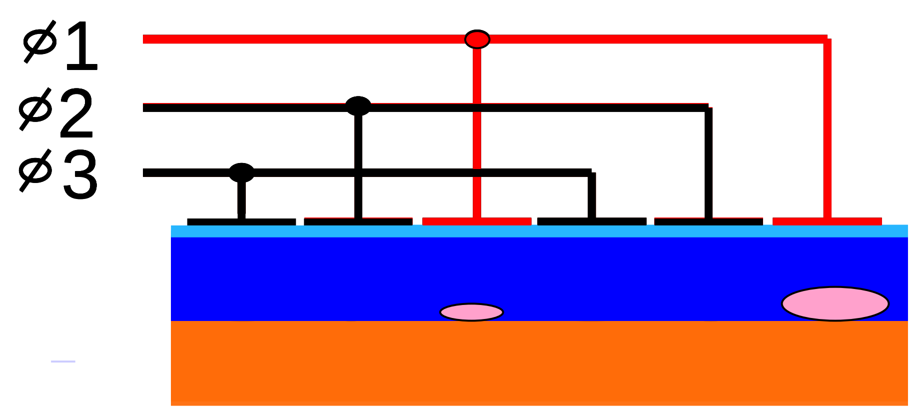


- Drift of electrons ~ to depth

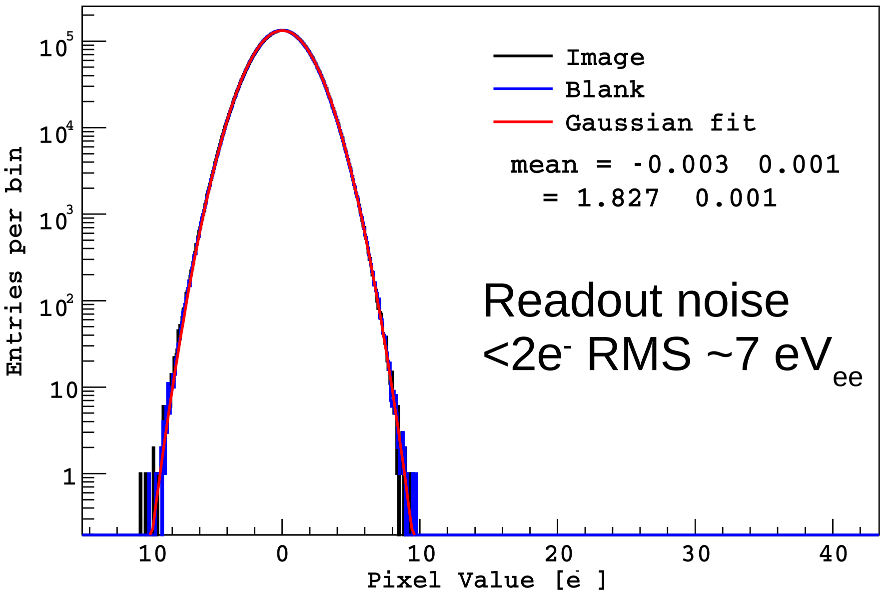


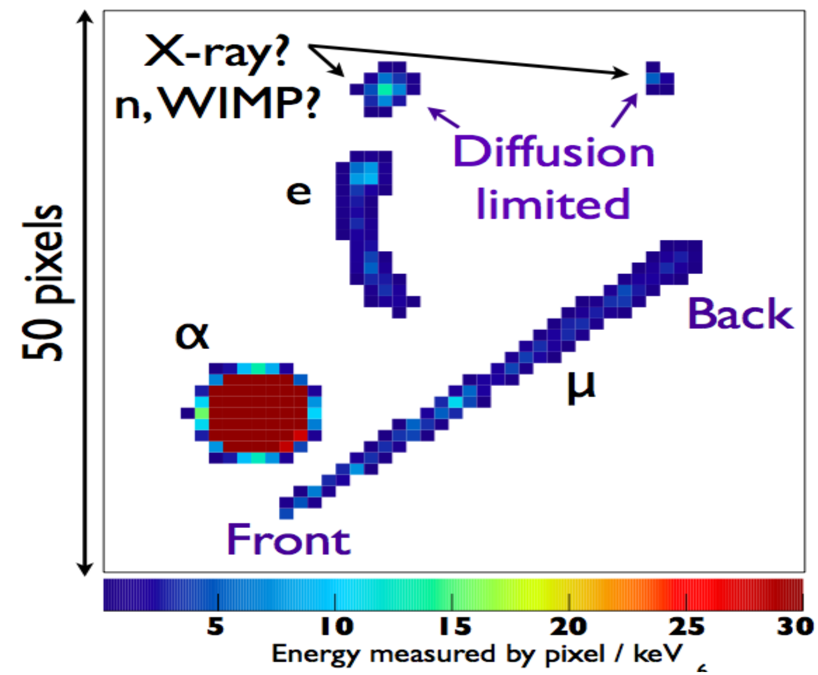


- Pixels are “exposed” for long periods of time and then shifted pixel-by-pixel to amplifier for readout

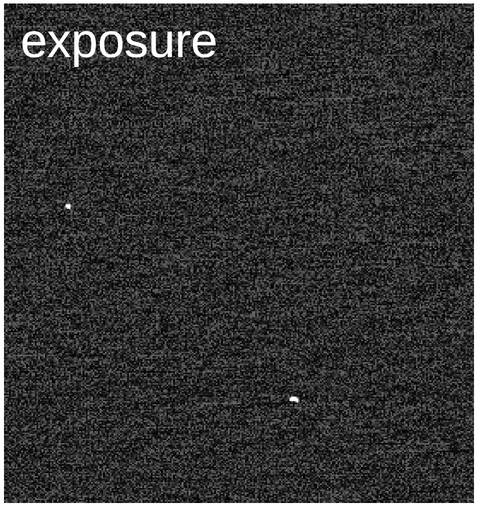


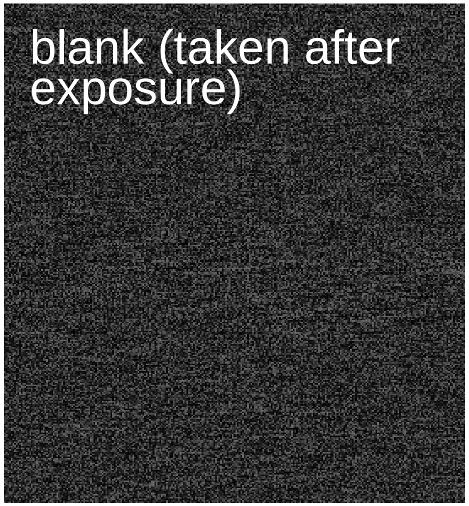
CCD Performance





- Negligible (<0.001 e/pixel/day) dark current @ 120 K

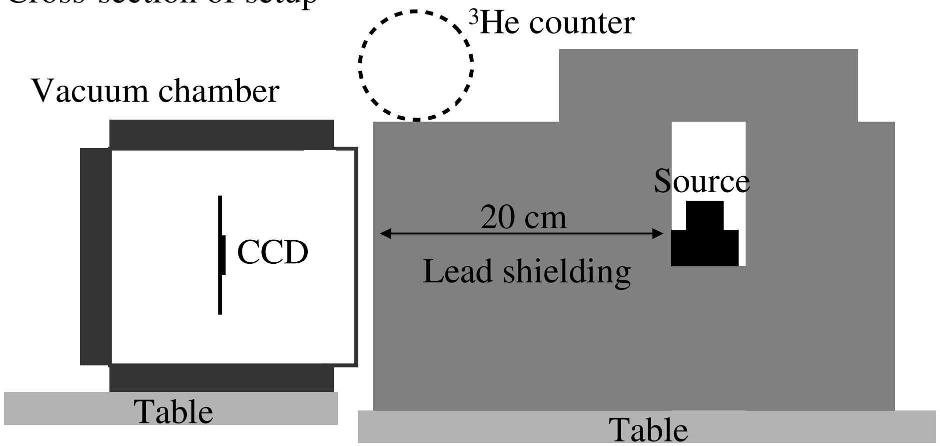




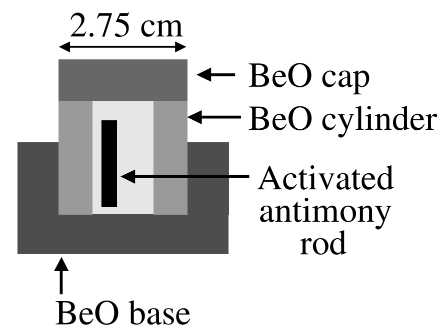
- “Worms”: electrons
- Straight tracks: minimum ionizing particles
- MeV blobs: alphas
- Point-like clusters: low-energy X-rays, compton scatters, nuclear recoils

Nuclear Recoil Calibration

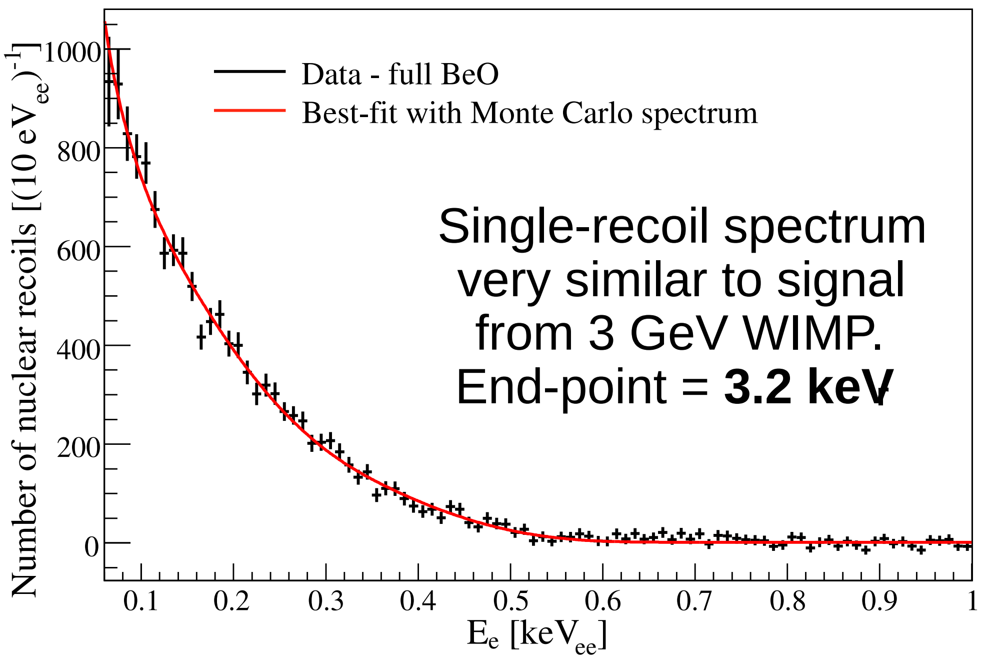
a) Cross-section of setup



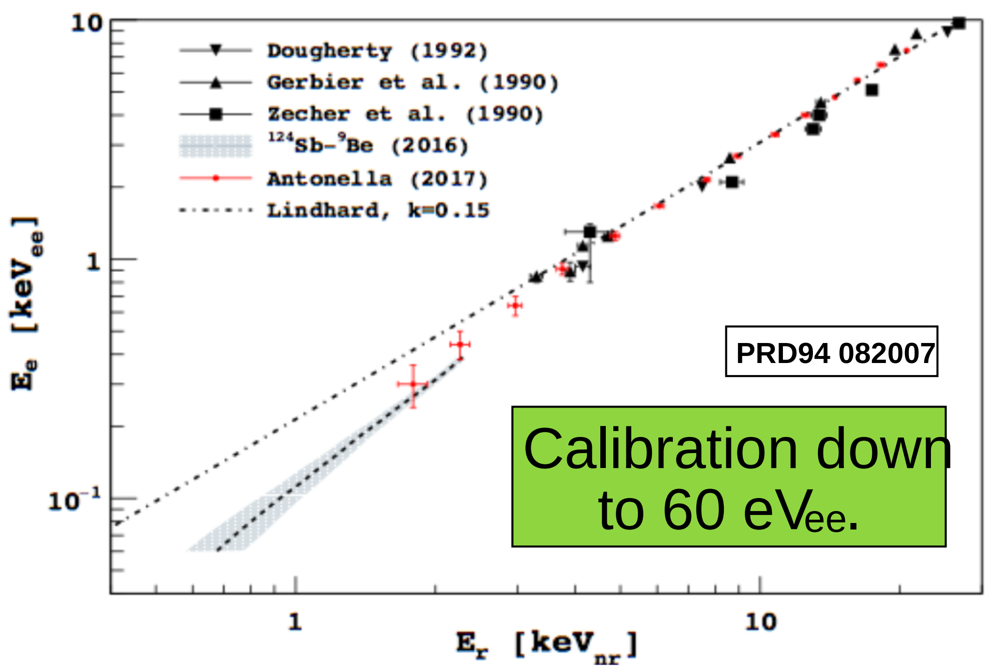
b) ^{124}Sb-^{9}Be source detail



24 keV neutrons from ^{9}Be(γ,n) reaction



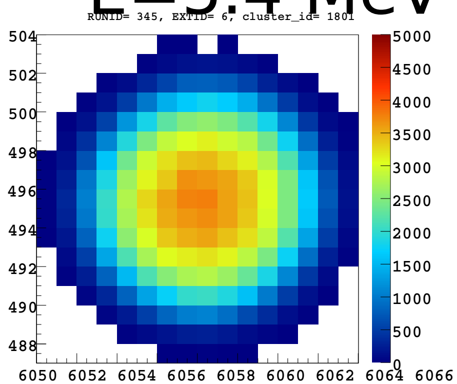
Single-recoil spectrum very similar to signal from 3 GeV WIMP. End-point = **3.2 keV**



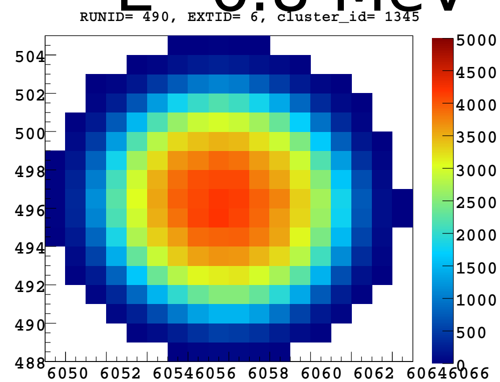
Calibration down to 60 eV$_{ee}$.

Background Suppression

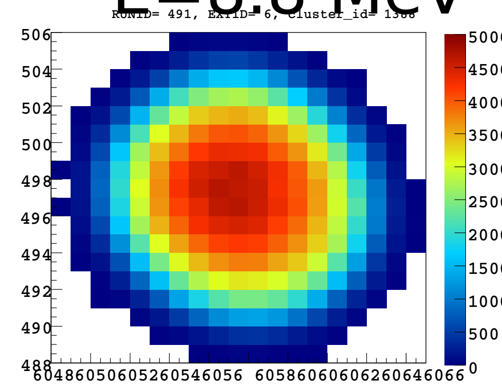
E=5.4 MeV



E=6.8 MeV



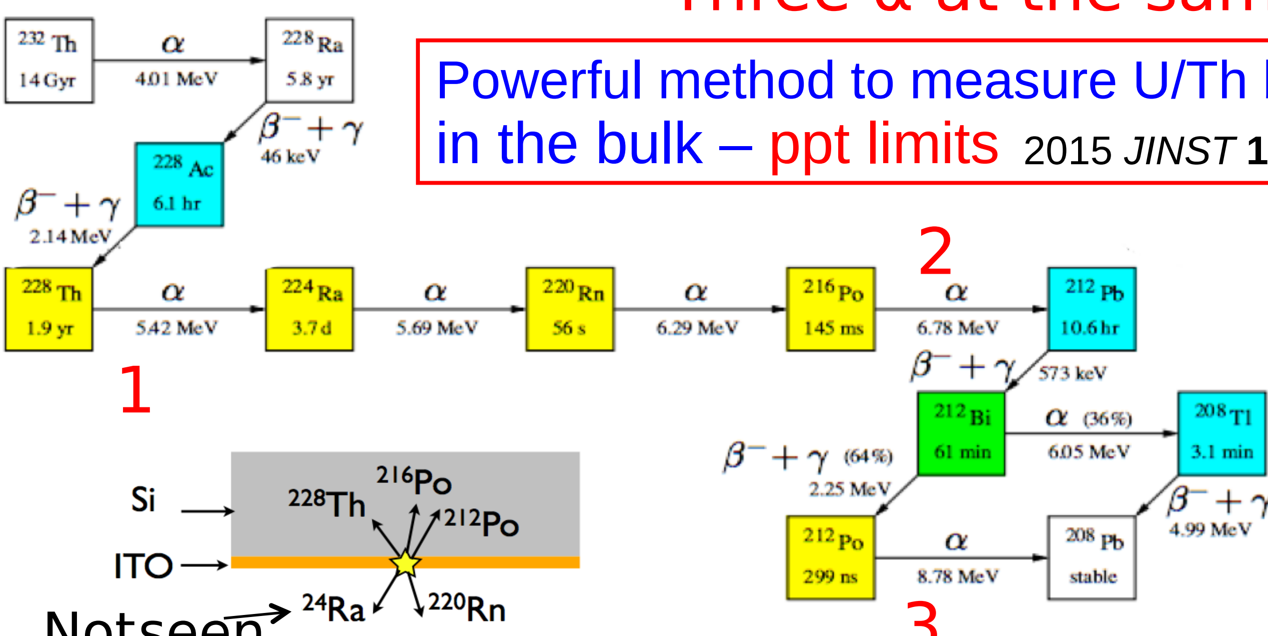
E=8.8 MeV



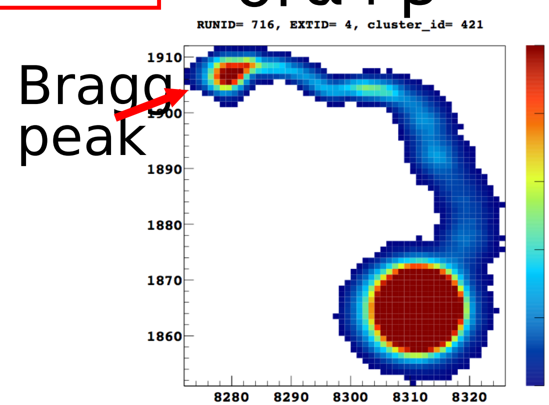
1 Δt=17.8d 2 Δt < 5.5h 3

Three α at the same location!

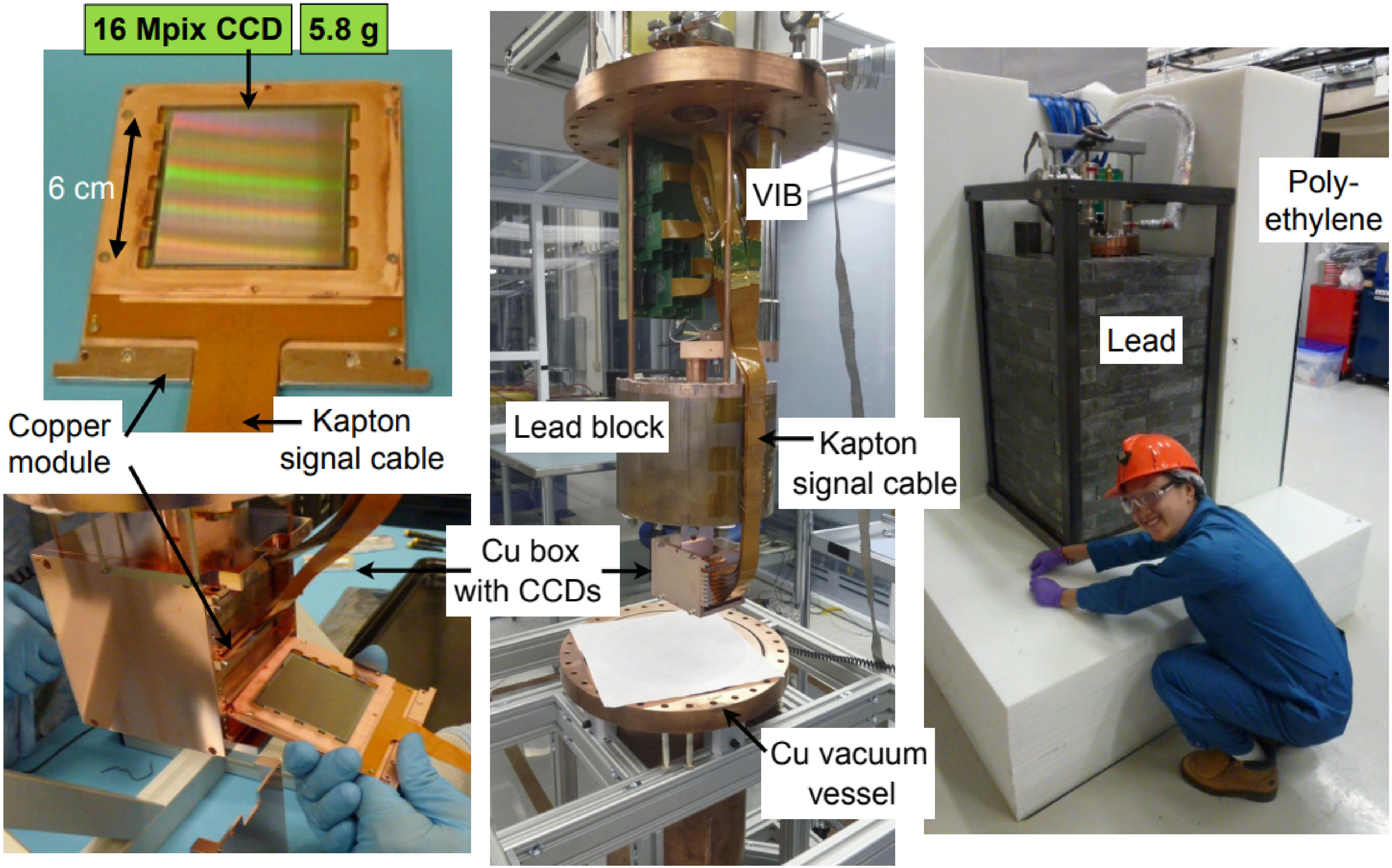
Powerful method to measure U/Th bkg in the bulk – ppt limits 2015 *JINST* **10** P08014



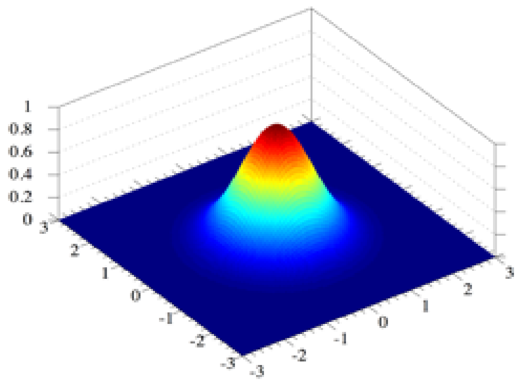
Example of α+β



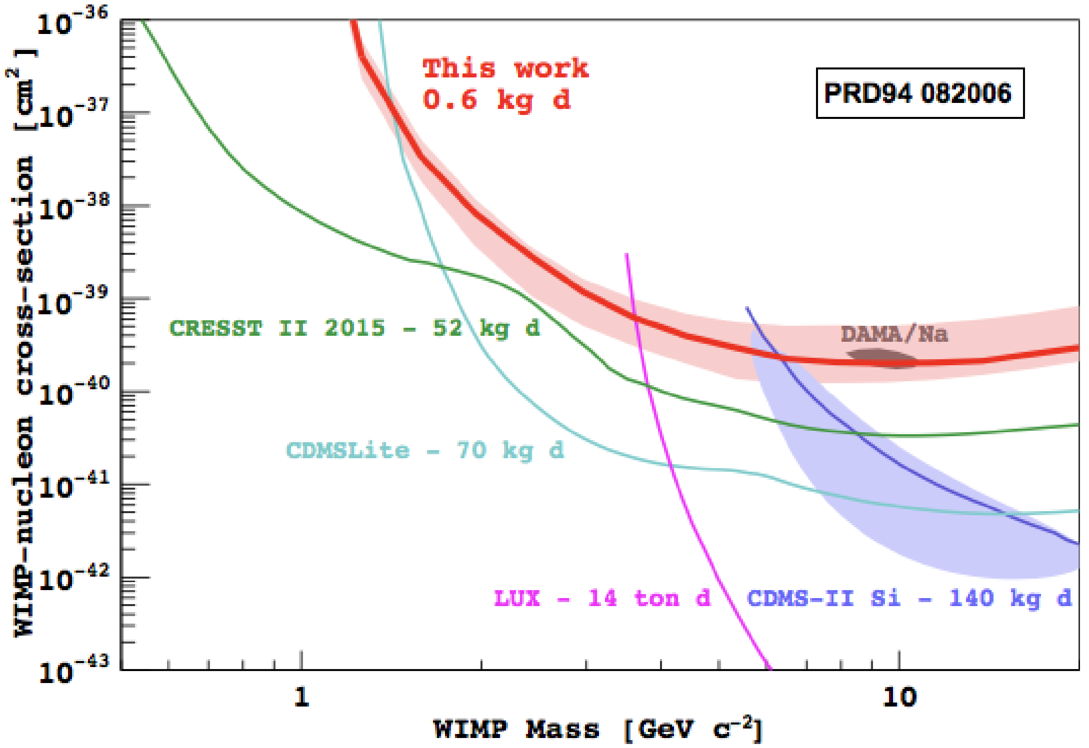
DAMIC at SNOLAB



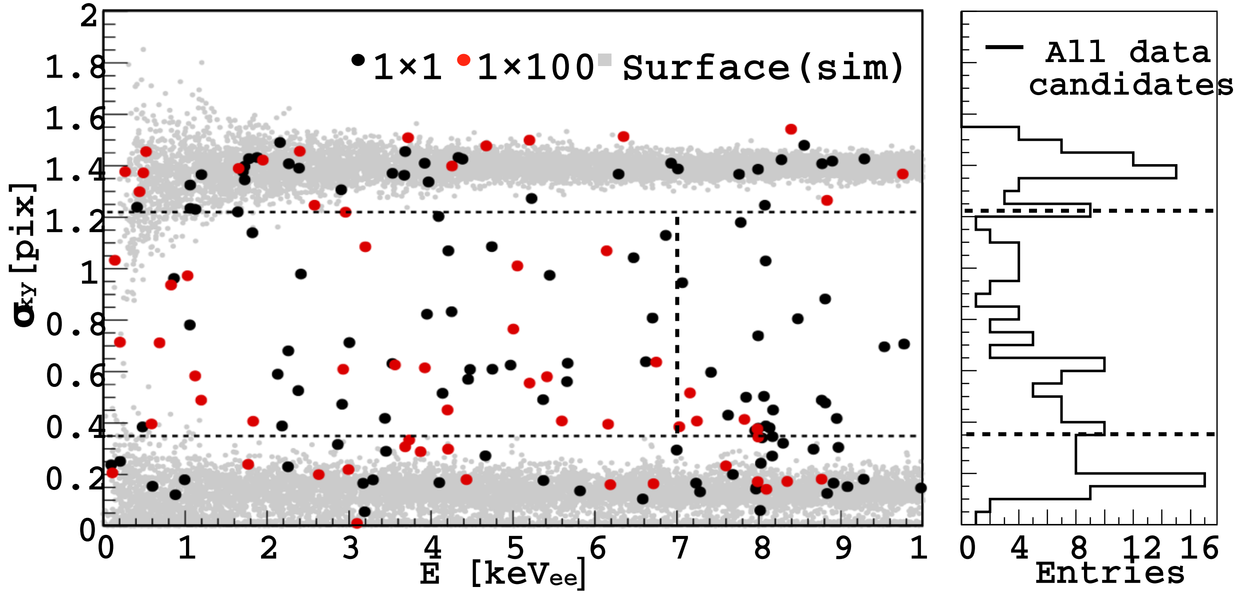
WIMP Search



2D Gaussian distribution of free charge in pixel array.



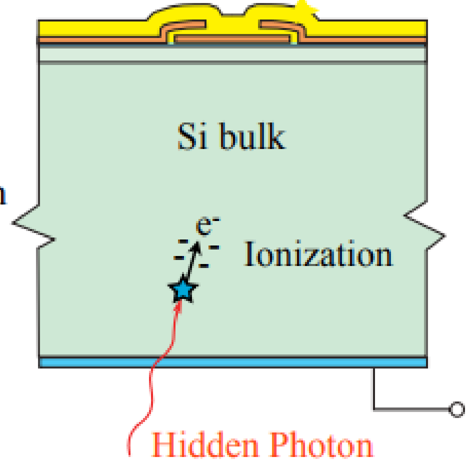
Measure E and σ_{xy} for every event



0.6 kg days of data with test devices at SNOLAB
~30 dru of background

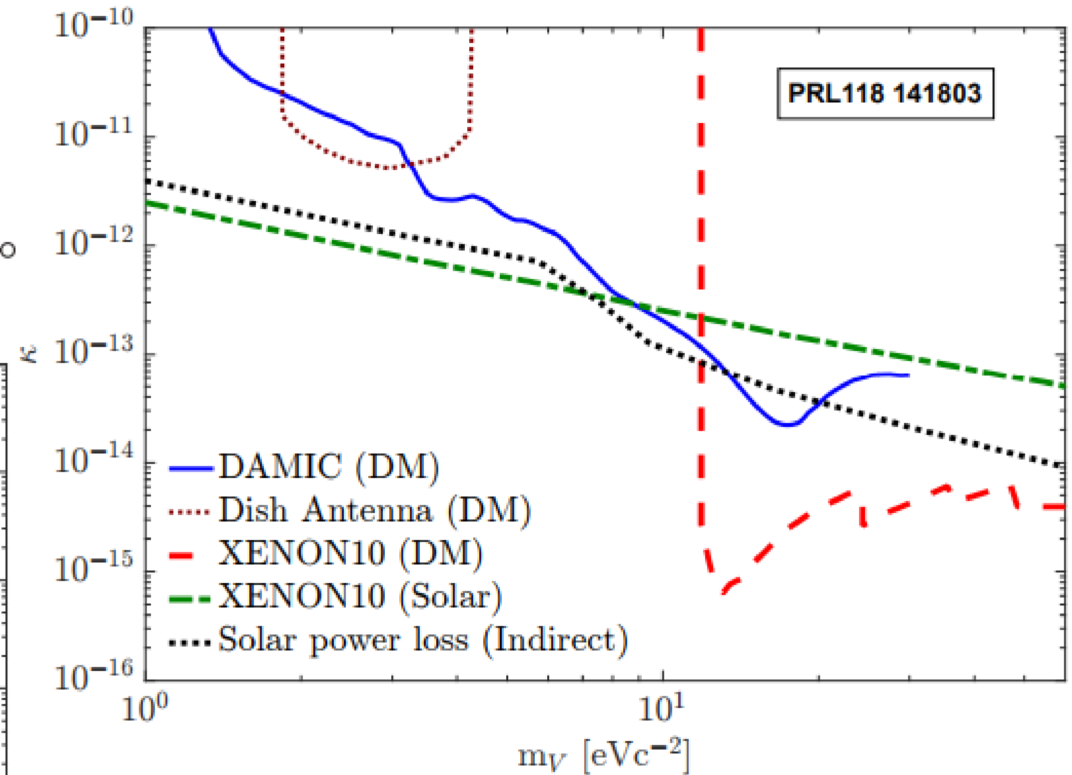
Hidden Photon Search

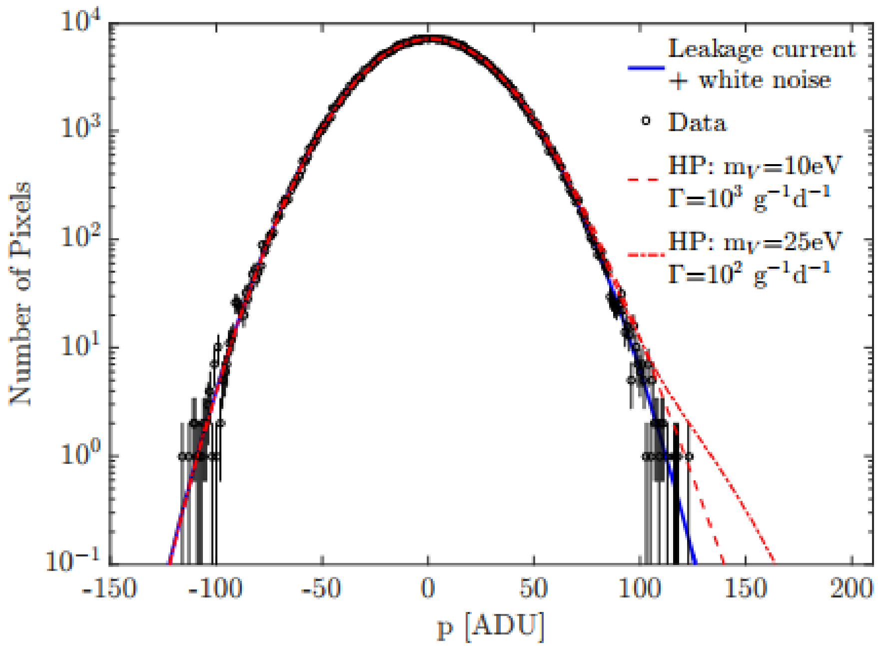
Absorption of hidden-photon dark matter.



~1 week of data with 1 CCD.

Leakage current **4 e$^-$ mm^{-2} d^{-1}**.





Pixel distribution consistent with white noise + uniform leakage current.

DAMIC100

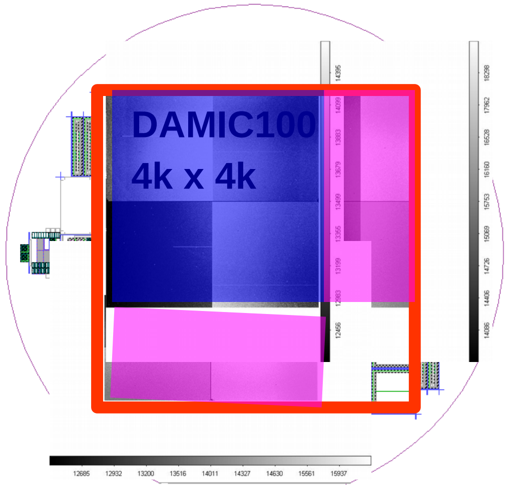
- Seven CCDs (~40 g) running at SNOLAB since Jan 2017.
- Currently ~6 kg-day of data with 5-15 dru total background.

DAMIC-1K

- A 1kg detector built with the existing technology.
- Sub-e^- resolution, 2 e^- (~7 eV_{ee}) threshold.
- Background improvement to 0.1 dru:
  - Improved design
  - Strict handling
  - Baking to remove ^3H

6k x 6k pixels, 1 mm thick
≈ 20 g / CCD
≈ 50 CCDs / 1 Kg

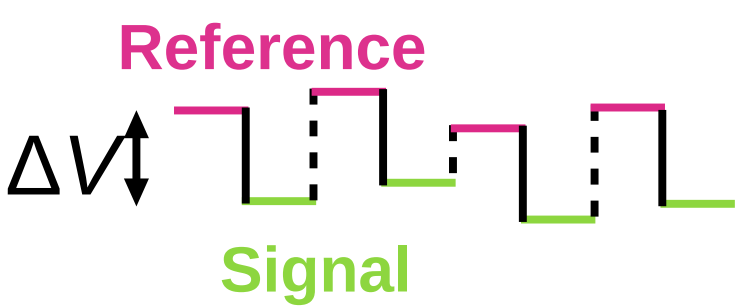
Silicon wafer



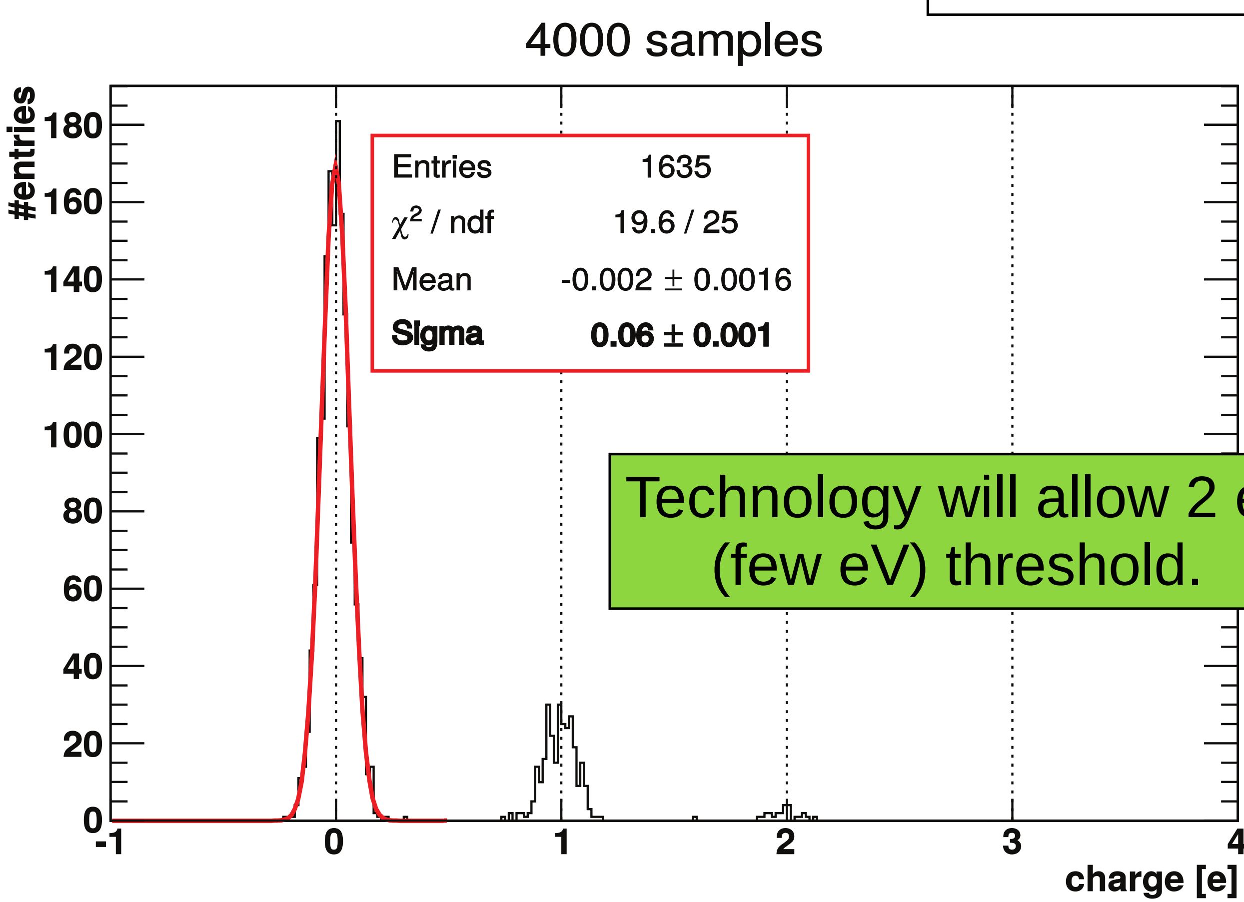
SENSEI

LDRD at Fermilab (PI Tiffenberg): Skipper CCDs (LBNL design) successfully tested with sub e- noise.

Non destructive "skipper" readout: Perform N uncorrelated measurements of the same pixel for ~1/√*N* noise reduction



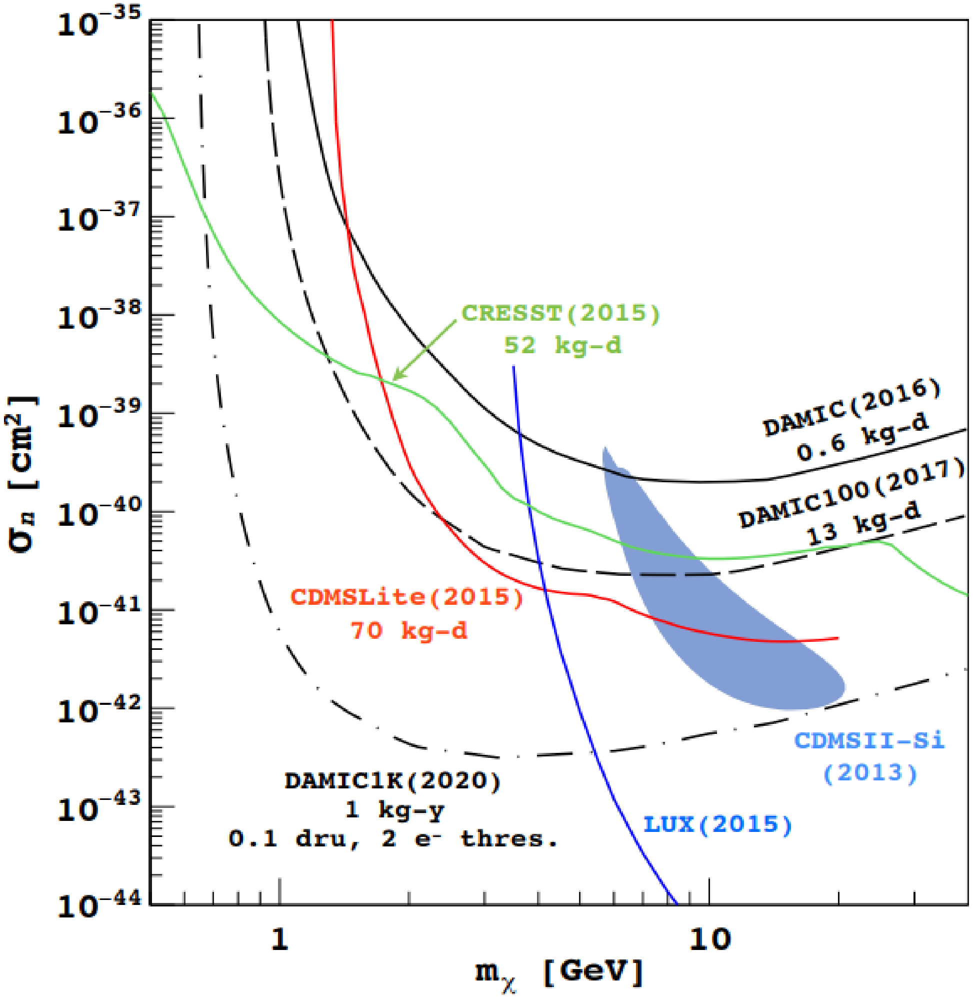
arXiv:1706.00028



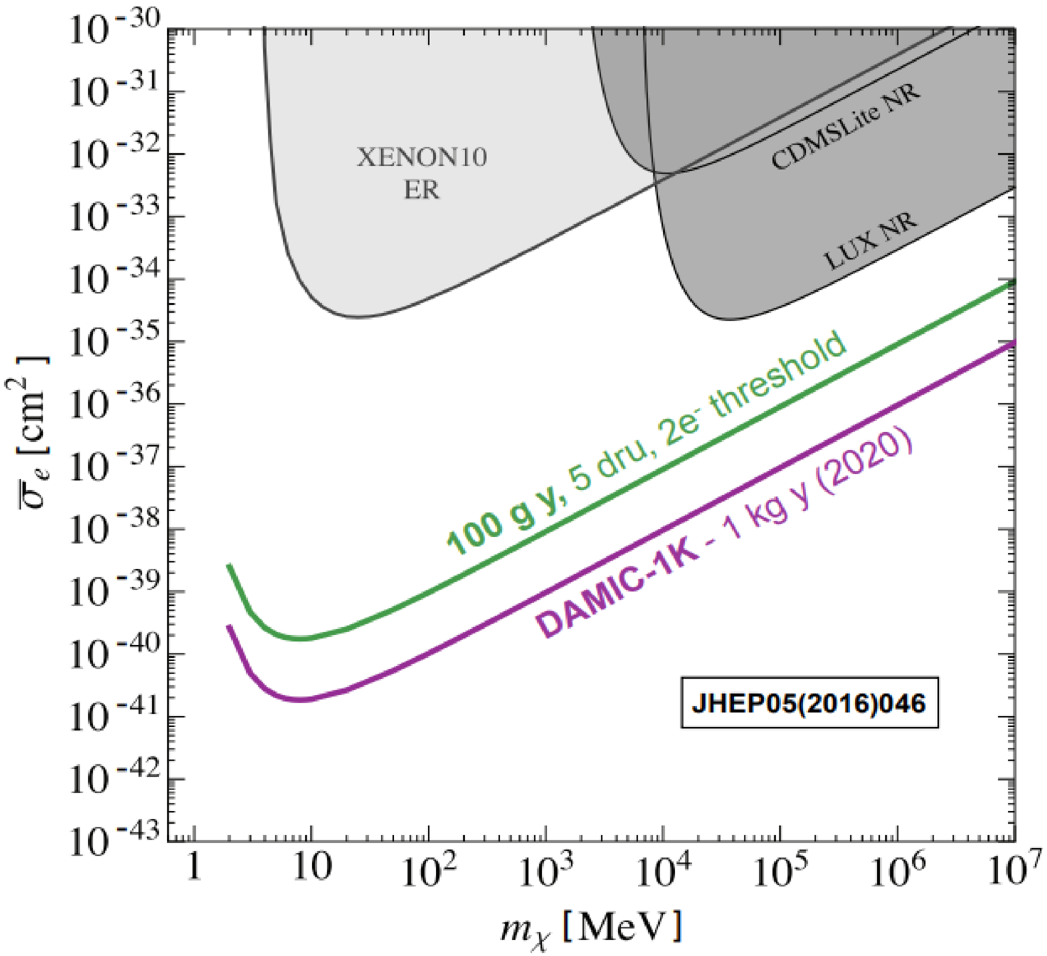
Technology will allow 2 e- (few eV) threshold.

DAMIC Program

DM-nucleus SI coherent scattering



DM-e Scattering via Ultra-light Hidden Photon



Conclusion

- CCDs offer low-noise, low-background detectors with high-resolution position reconstruction.
- DAMIC has already placed competitive dark matter search results (WIMP & hidden photon) with early development detectors.
- Developed discrimination techniques to measure and suppress backgrounds.
- Can build kg scale detector with 2 e^- (7 eV_{ee}) threshold.