Status of DAMIC at SNOLAB

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DAMIC at SNOLAB

- Si CCD as WIMP target.
- Progressive program with increasing target masses (current ~5 g).
- Sub-keV$_r$ threshold.
- Energy reconstruction.
- Position reconstruction.
- Signal/background characterization based on patterns of charge collected on CCD plane.

CCD for ionization detection

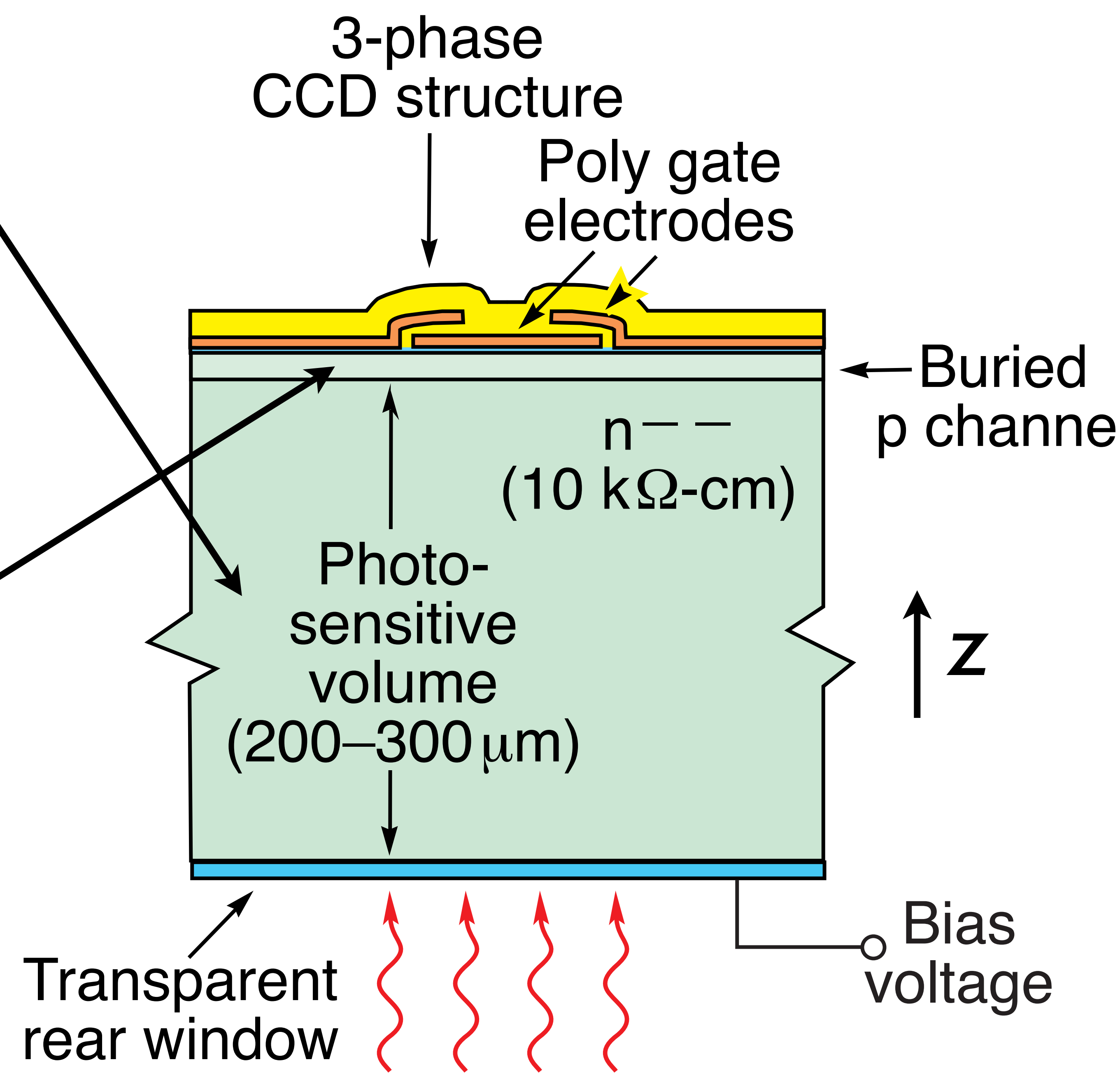
Electrons / Nuclear recoils deposit energy in the CCD bulk

Ionized electrons promoted to conduction band (3.62 eV per e⁻h pair)

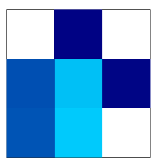
Electrons collected and held at the gates

Charge read out after some exposure time

A CCD pixel



15 µm x 15 µm pixels

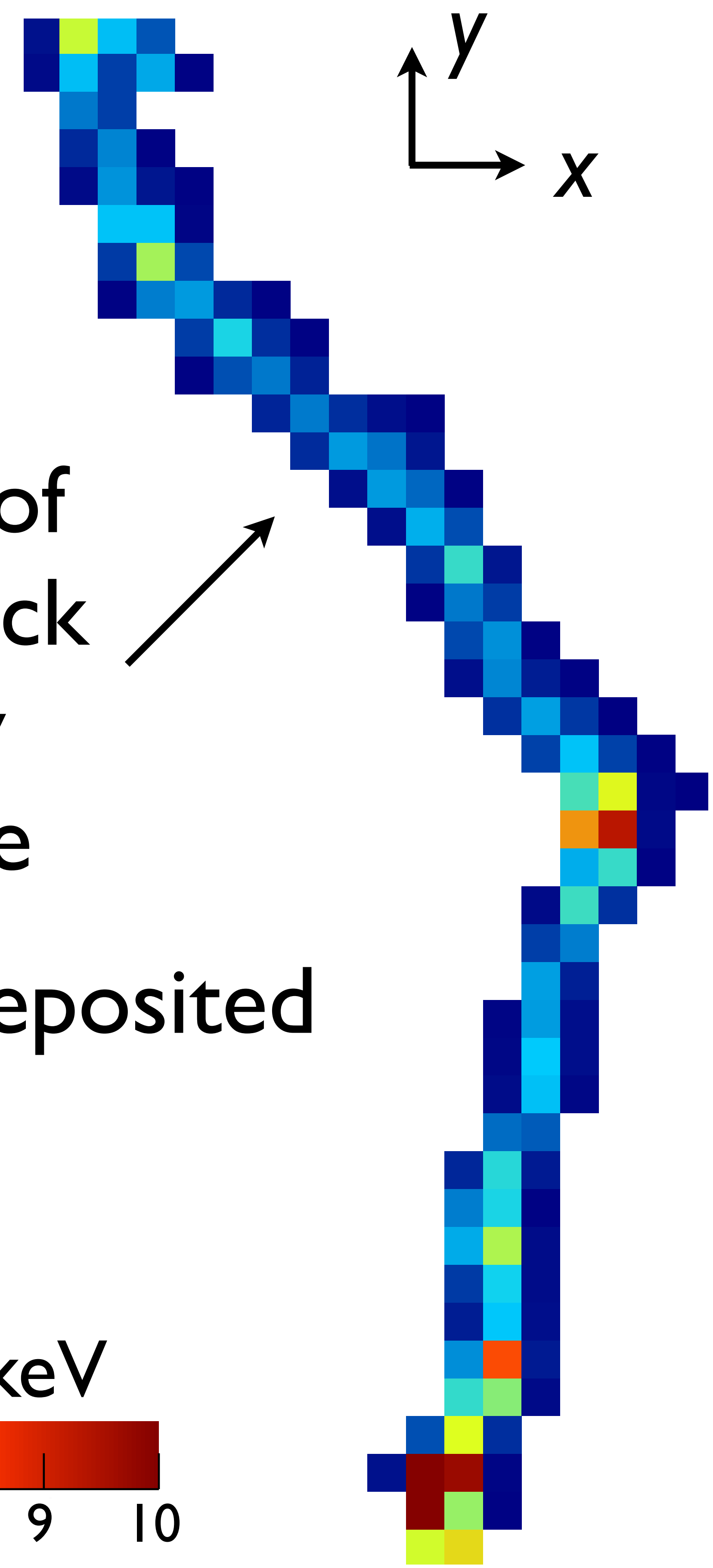


9 keV event

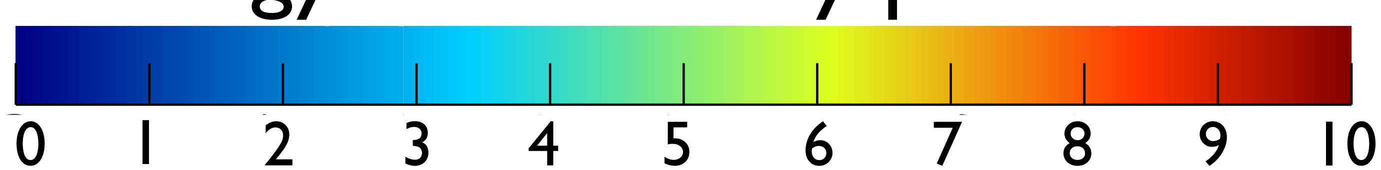
Energy spread over many pixels due to charge diffusion (~0.2 µm²/µm RMS)

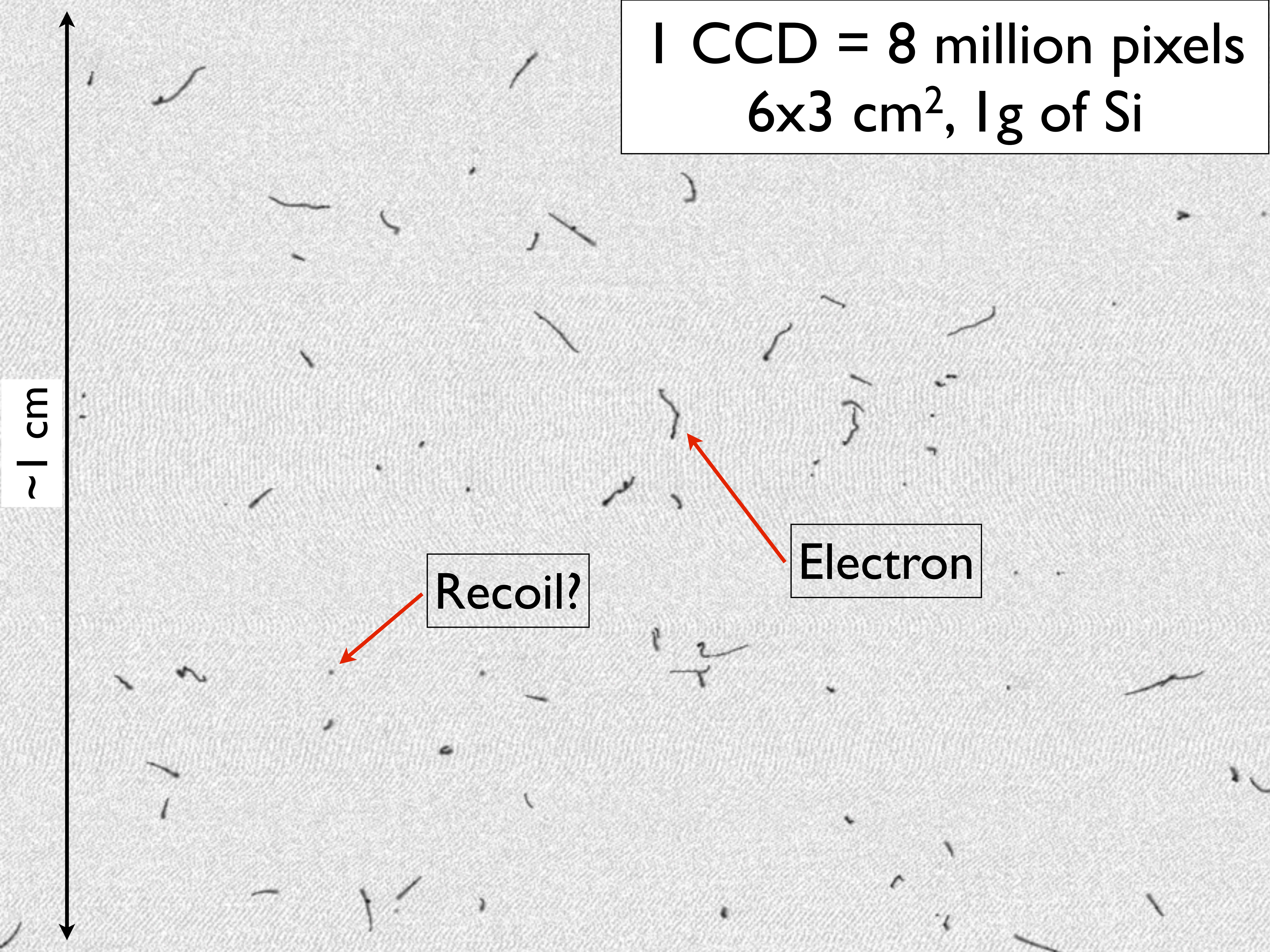
Projection of electron track on the *x*-*y* CCD plane

260 keV deposited



Energy measured by pixel / keV



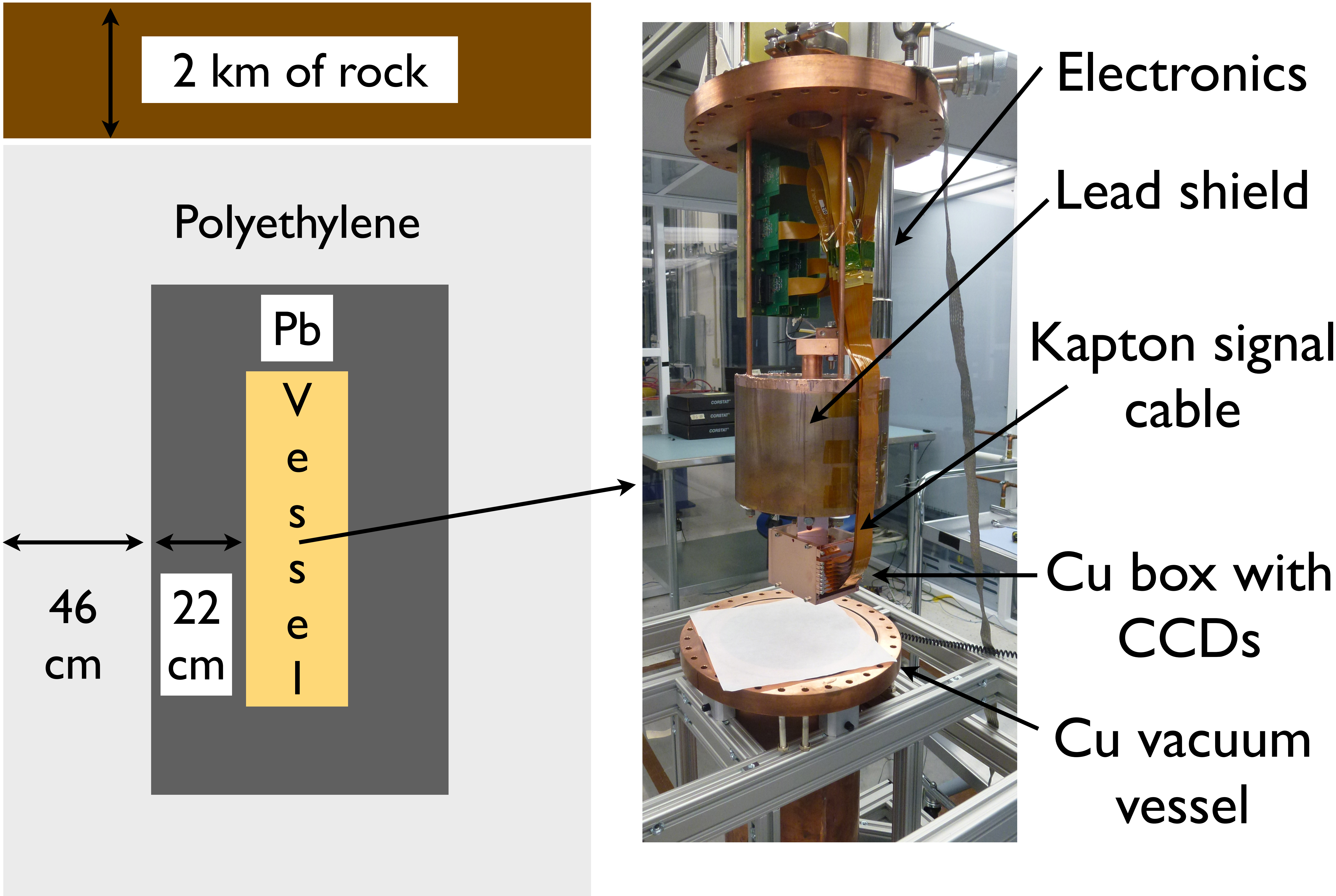

1 CCD = 8 million pixels
6x3 cm^2, 1g of Si
~1 cm
Electron
Recoil?

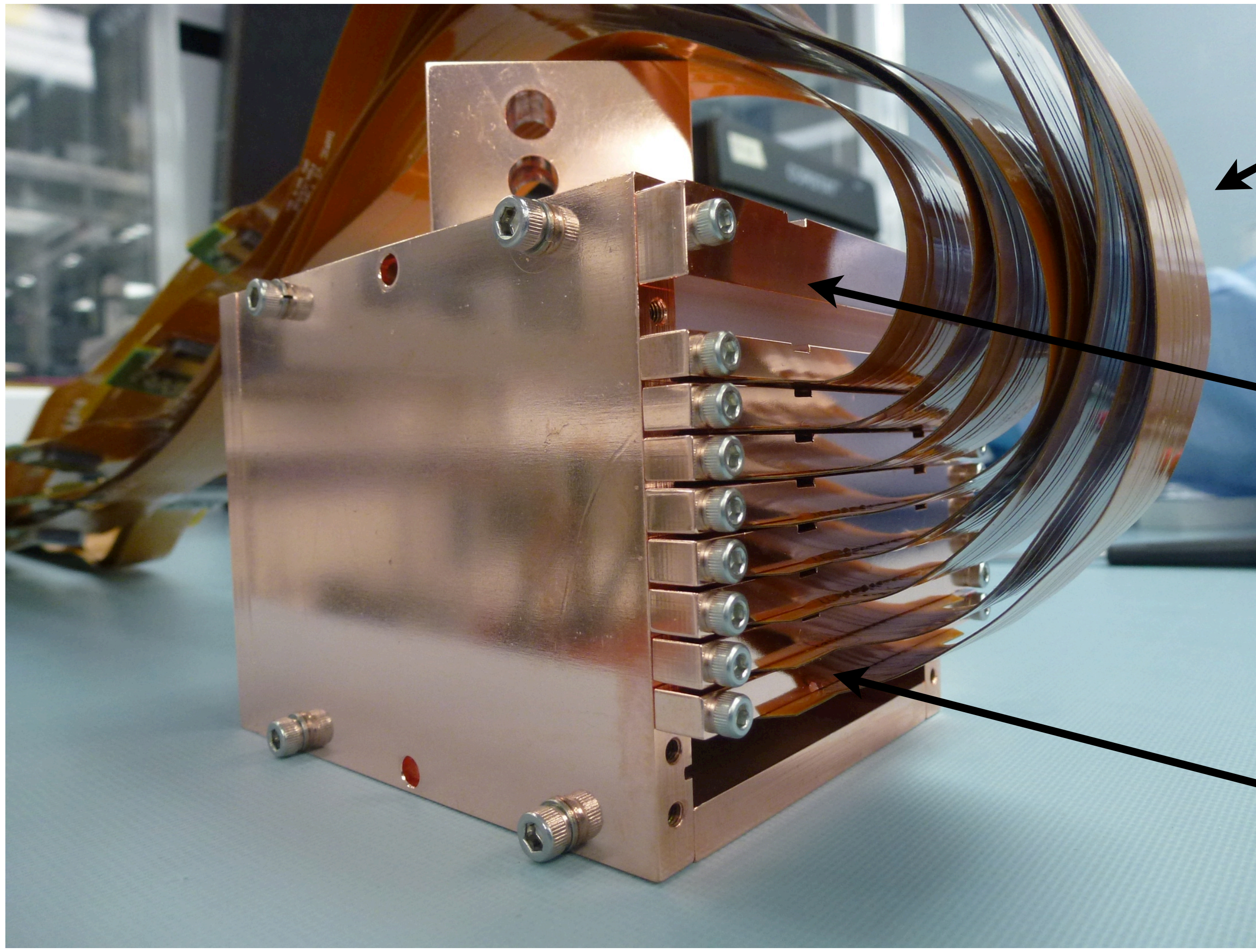
SNOLAB installation

Installation completed at J-Drift in Dec 2012

Two people in the picture but many more involved

Shielding


2 km of rock
Polyethylene
Pb
Vessel
46 cm
22 cm
Electronics
Lead shield
Kapton signal cable
Cu box with CCDs
Cu vacuum vessel



Cu box with 8 CCDs
6 250 μm thick
2 850 μm thick

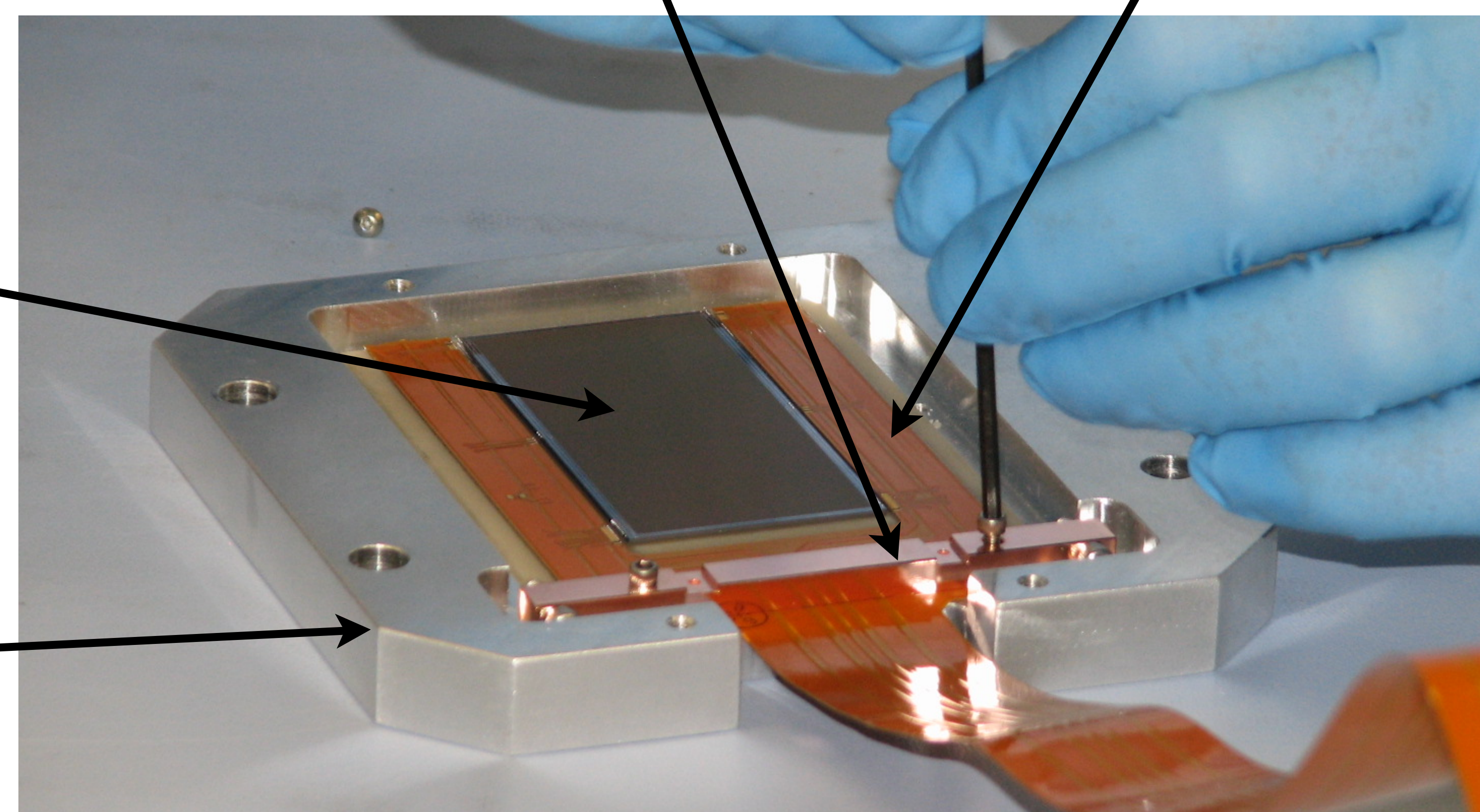
^{10}B film under poly slide to measure n background via (n,α) with CCD #1

Cu frame

Kapton cable

CCD on AlN support

Holder for assembly



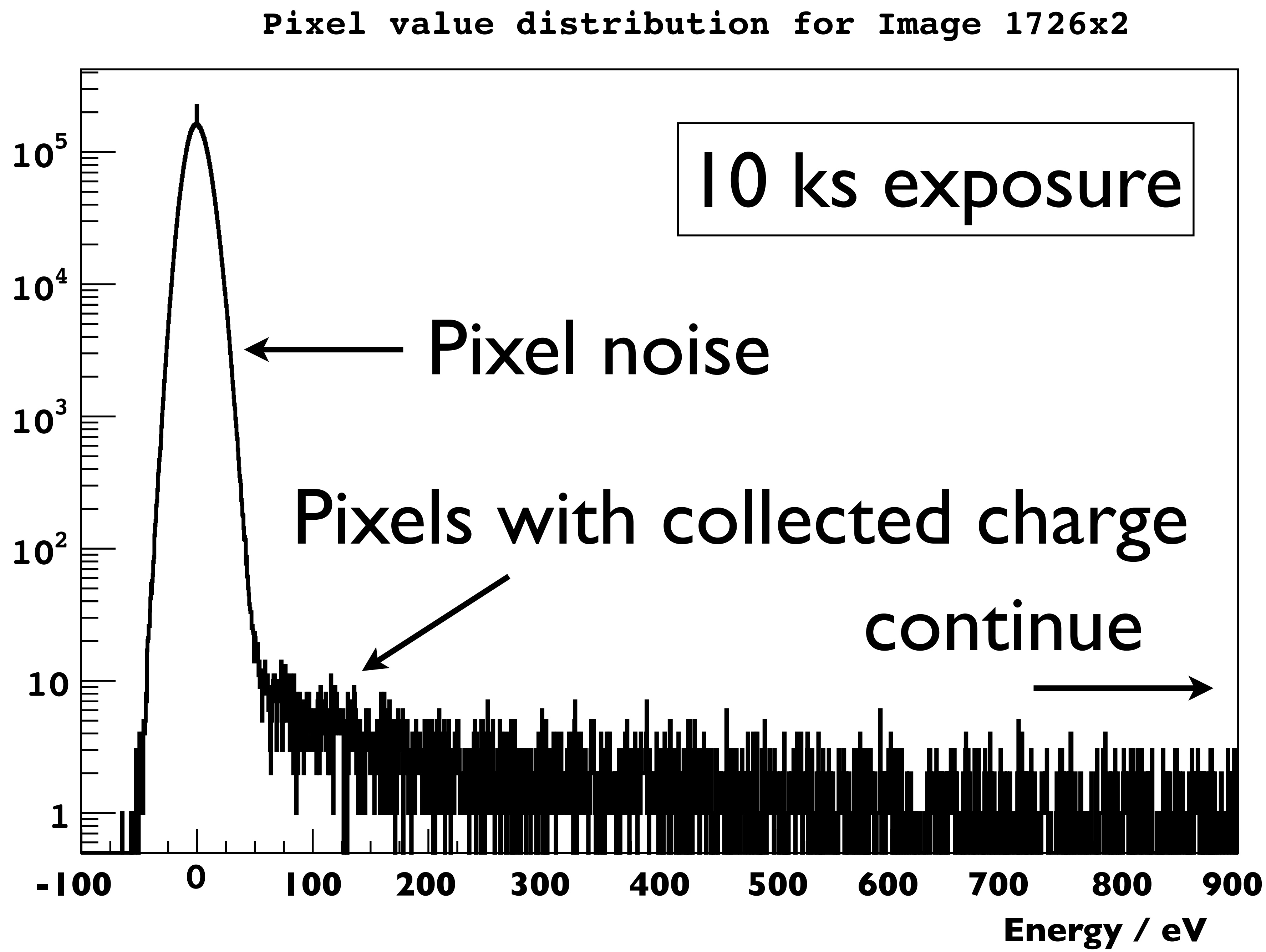
Status

- Had trouble reading CCD #4.
- CCD #6 broke on Jan 15 (defect in Si lattice).
- In order turn off bias of CCD #6 had to also turn off CCD #5.
- Continued operating CCDs 1-3 and 7-8 successfully.
- Good noise performance.
- Found unexpected background.

Energy threshold

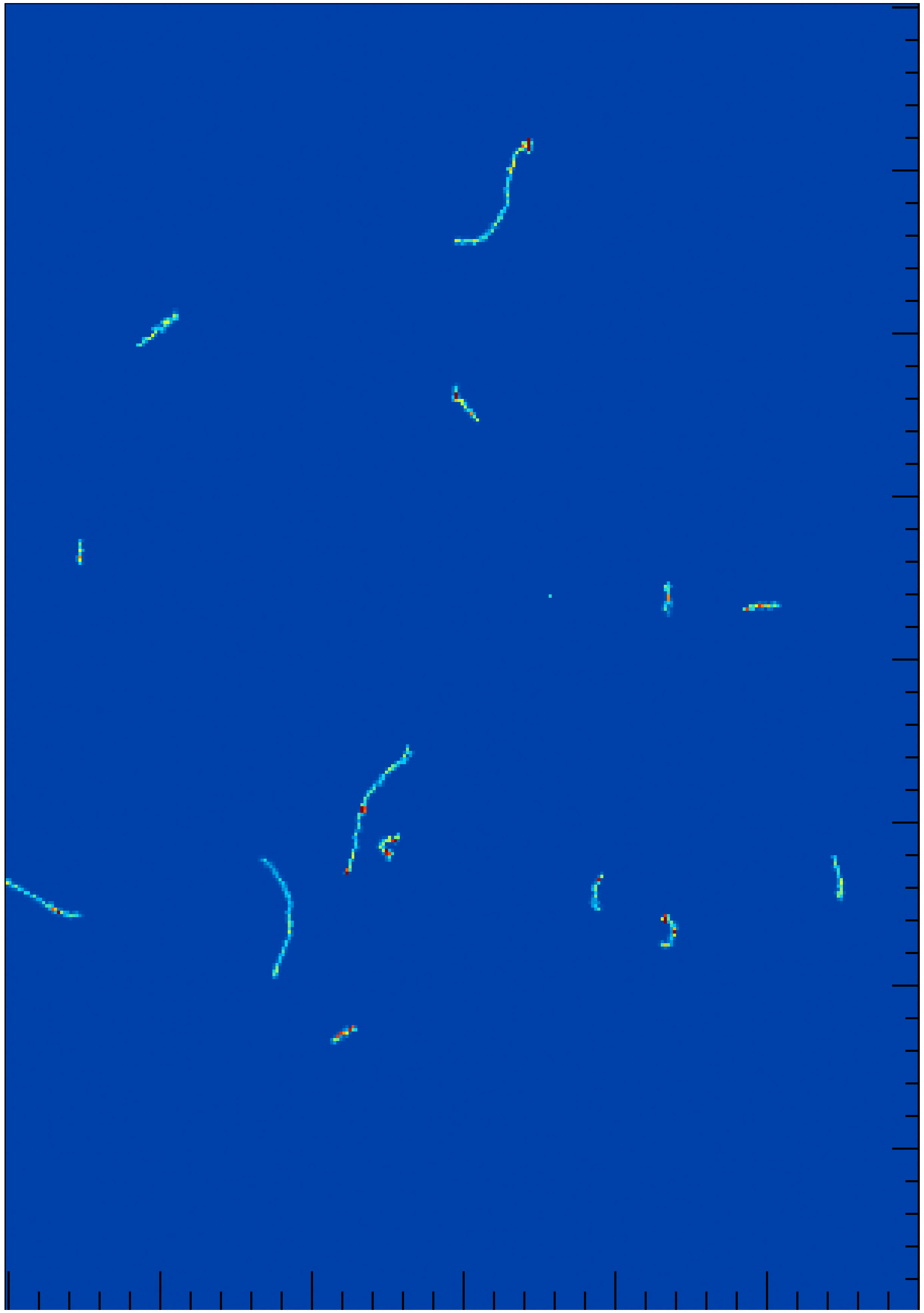
- DAMIC CCDs are operated at 130 K.
- The dark current is ~0.01 e^-/pix/day.
- Low noise electronics allow for a read out noise ~2 e^- RMS = 7 eV (Gaussian white noise on the pixel values).
- Number of single pixel values above threshold due to noise is proportional to number of CCD reads.
- This sets the nominal 40 eV_{ee} threshold.

Distribution of pixel values in an image

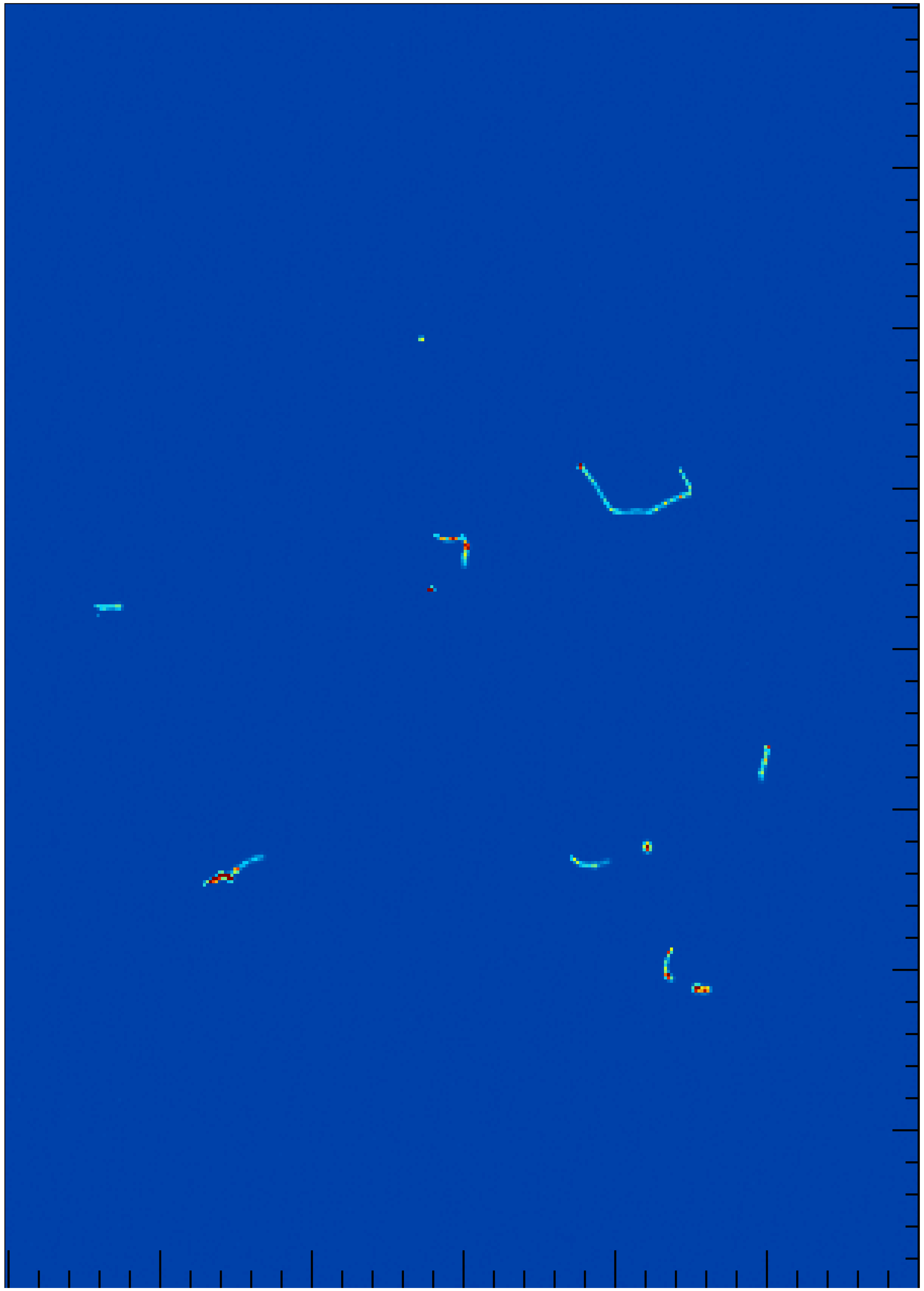


MCNPX Simulation

- We have started a DAMIC simulation based on MCNPX.
- Given a particle source, we get energy deposits in a mesh the size of the CCD image.
- We also store the mean x, y and z positions of the deposits in the cell.
- We use this information with some noise + diffusion models to construct fake image.



Simulated βs



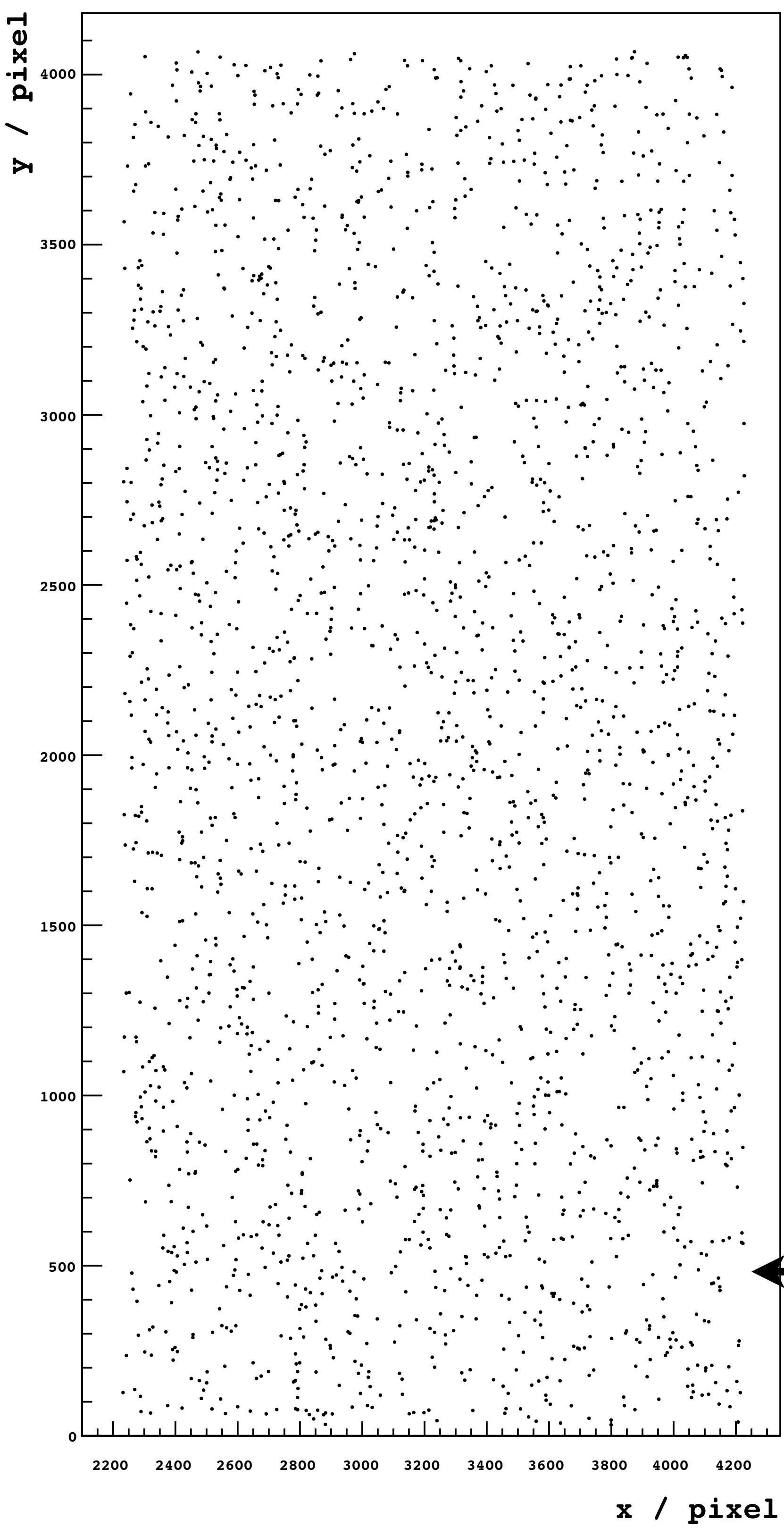
Data

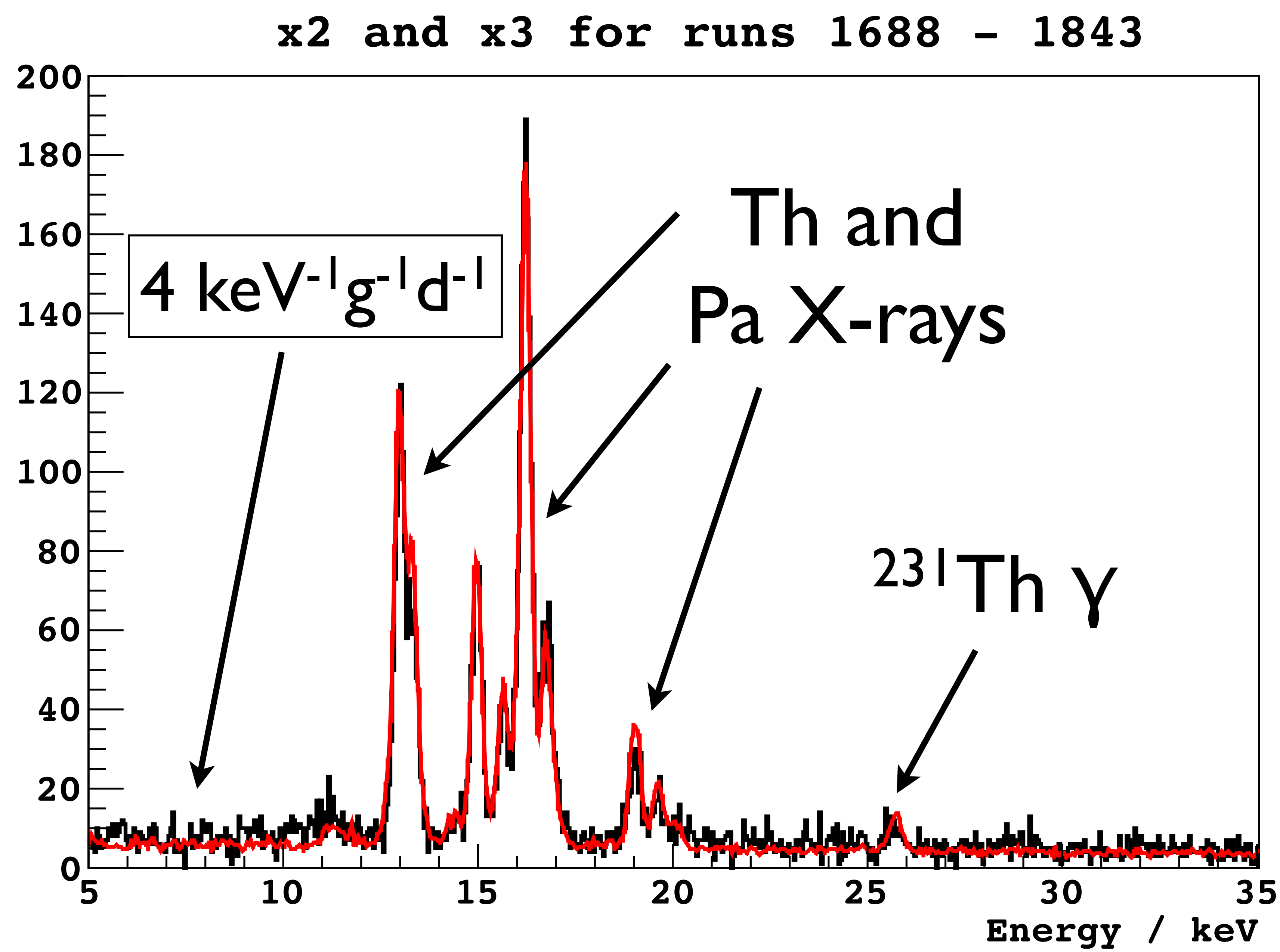
Energy spectrum

- We produced the following energy spectra by simply finding clusters of adjacent pixels 4 σ above the noise.
- We excluded those clusters that were on the edge of the image.
- We excluded clusters >20% of pixels saturated the ADC (pixel with > 30 keV_{ee}).
- Same treatment to data and simulation.

DAMIC spectrum

Spatial distribution

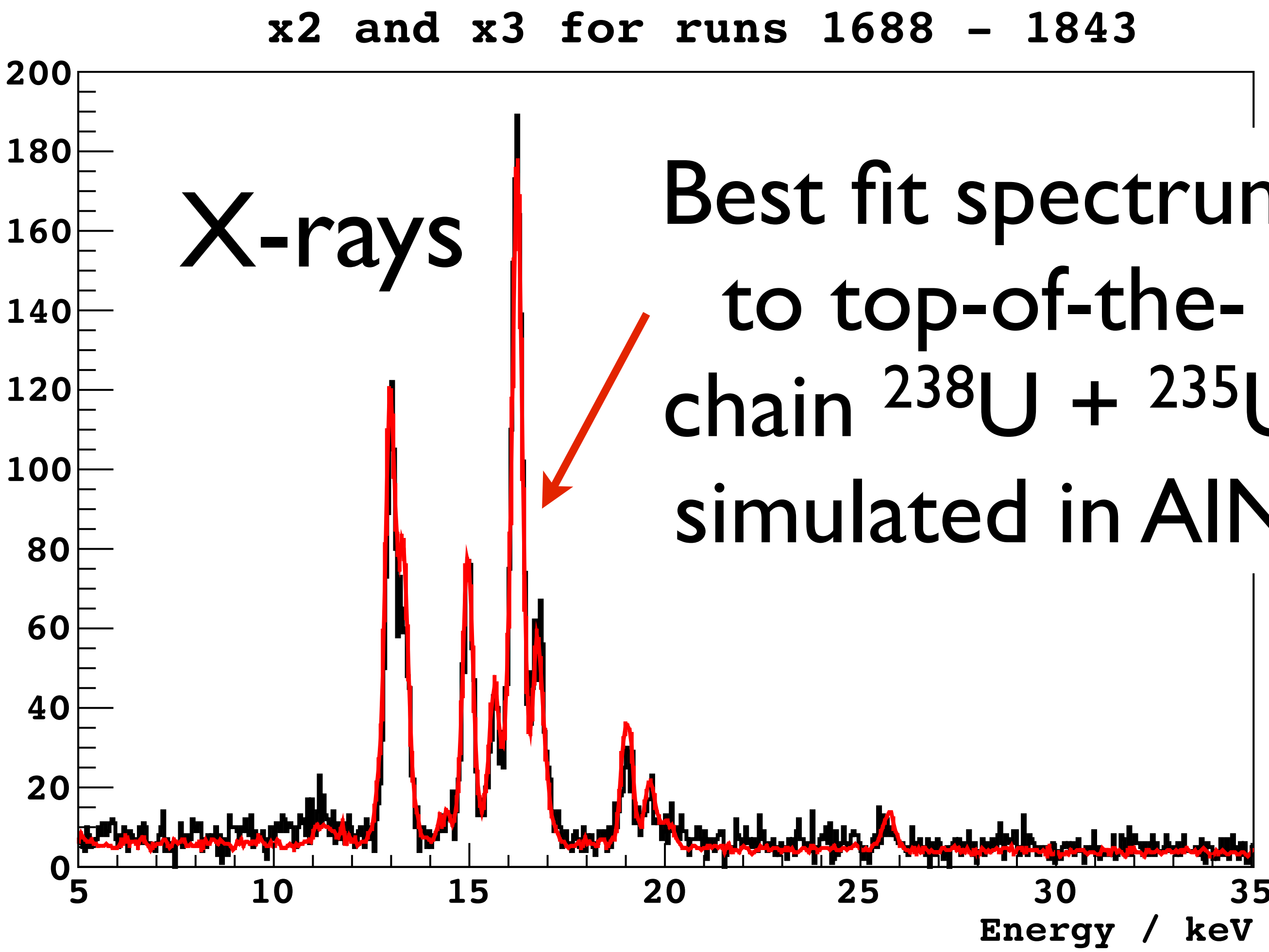


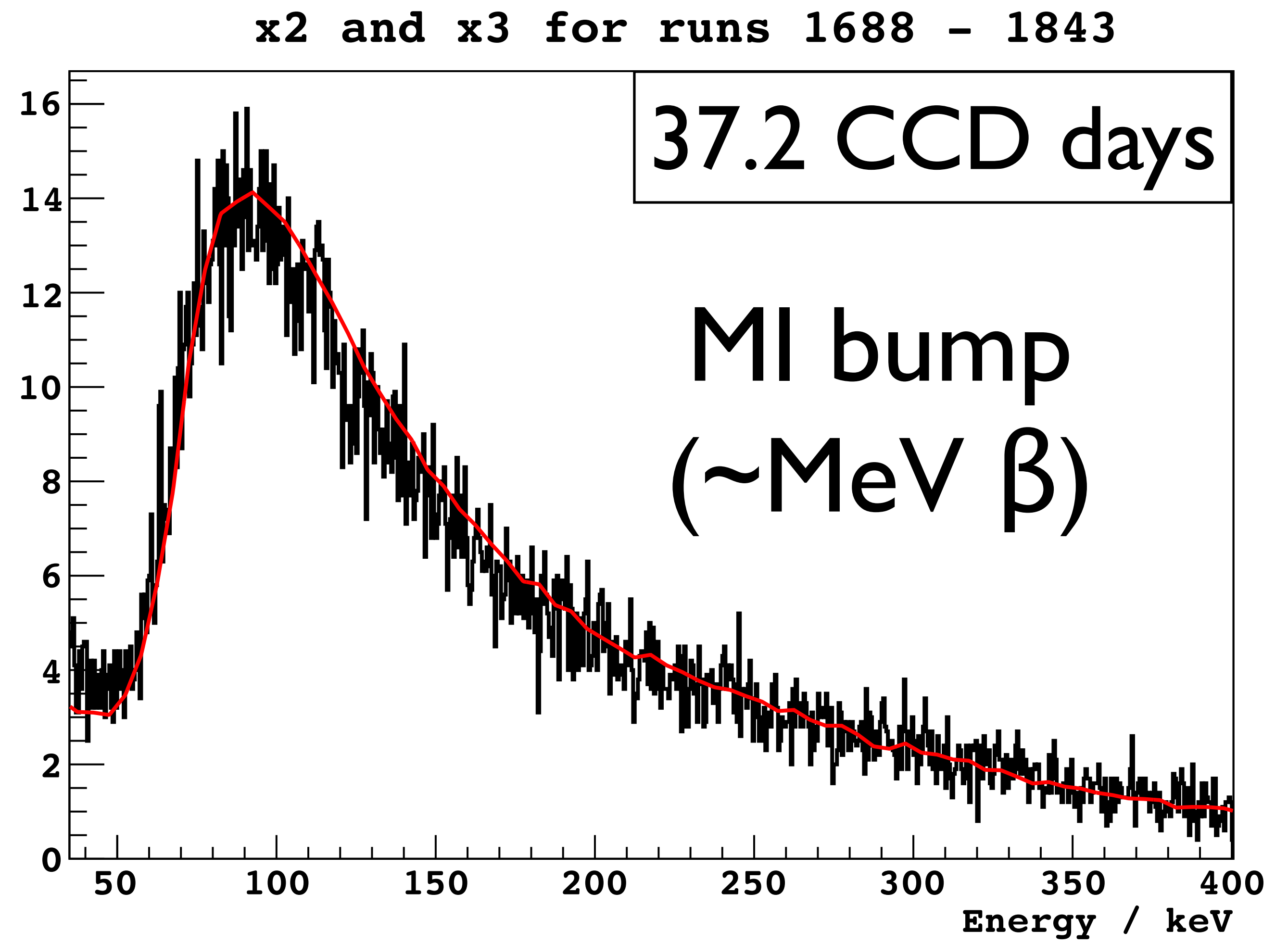


Uniform distribution in CCD

The background is at the same level as DAMIC at NuMi

DAMIC spectrum





	Bq / kg
^{235}U	330 ± 30
^{238}U	4110 ± 530
^{226}Ra	42 ± 9
^{232}Th	32 ± 8

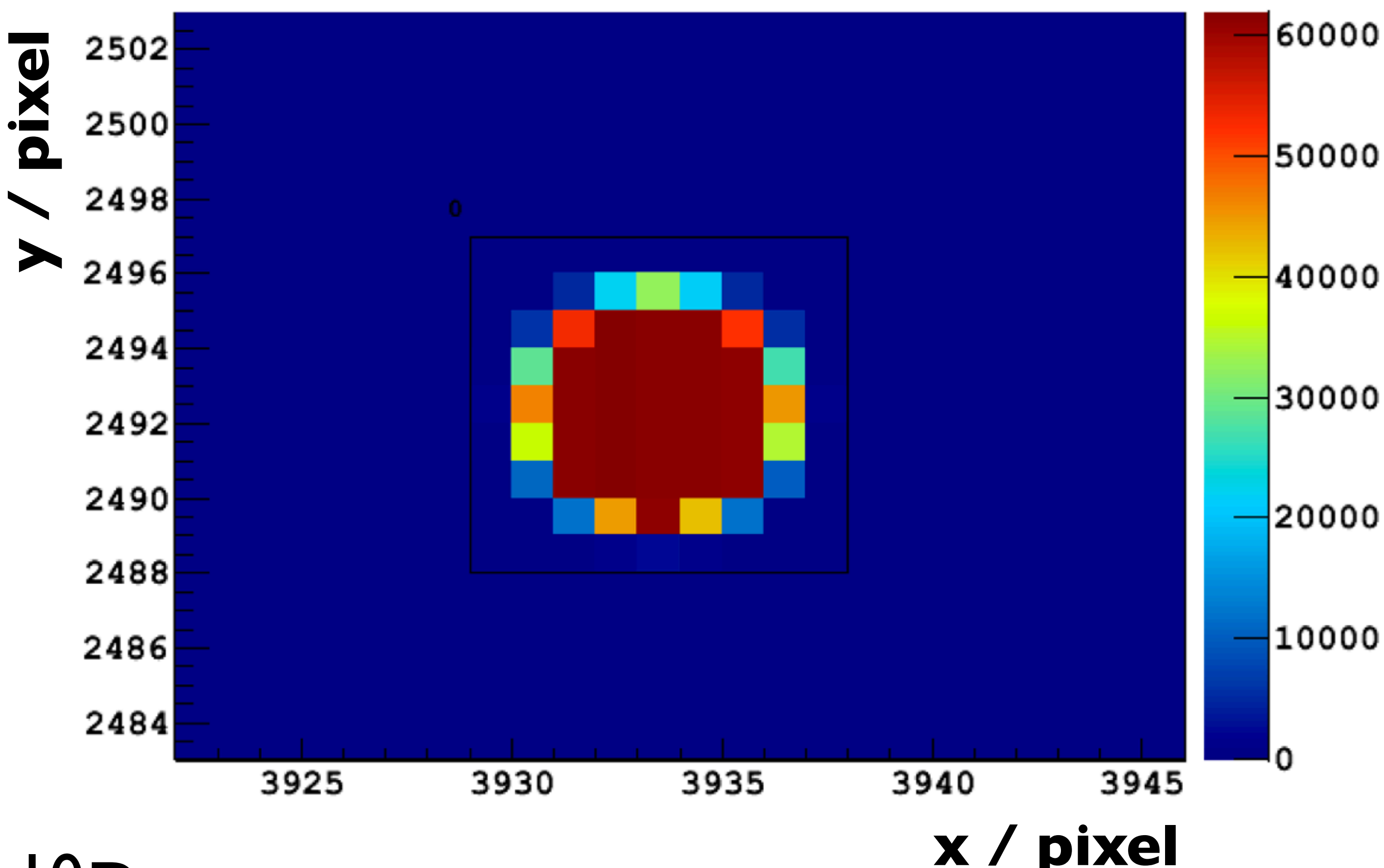
SNOLAB γ-ray measurement of AlN

} ppb levels

U is very dim in γ but very bright in X-rays.

α-particle background

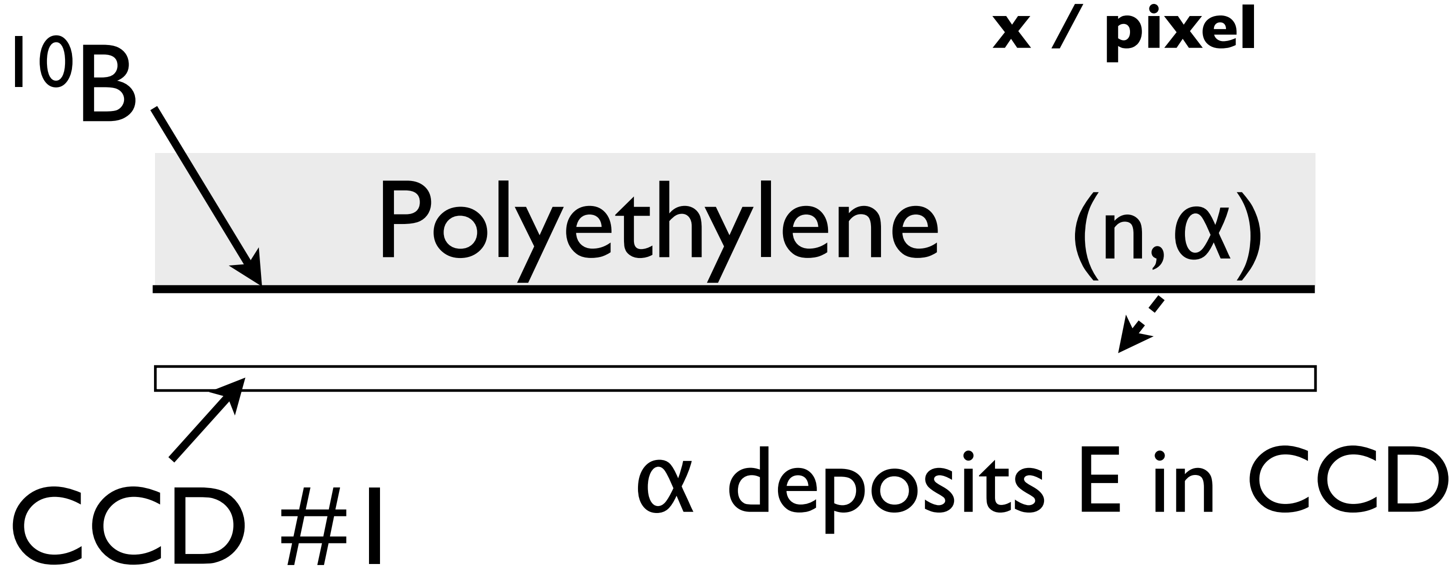
An α in DAMIC



αs travel tens of μms

Either from radioactive contamination in the bulk or surface contamination

~1/4 day^{-1}CCD^{-1}



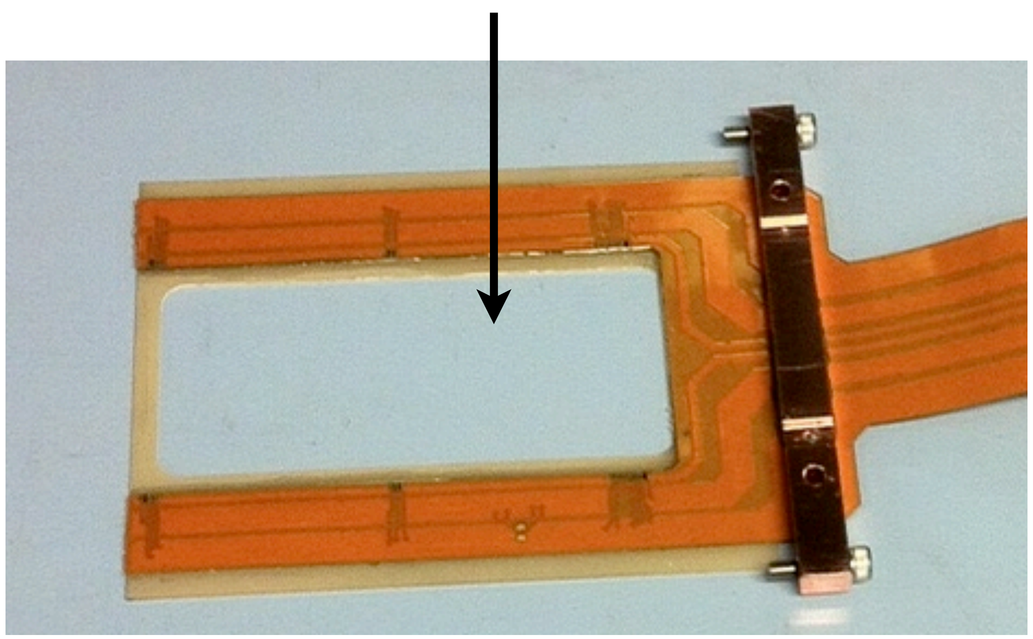
For CCD #1 α may also come from ^{10}B layer above it

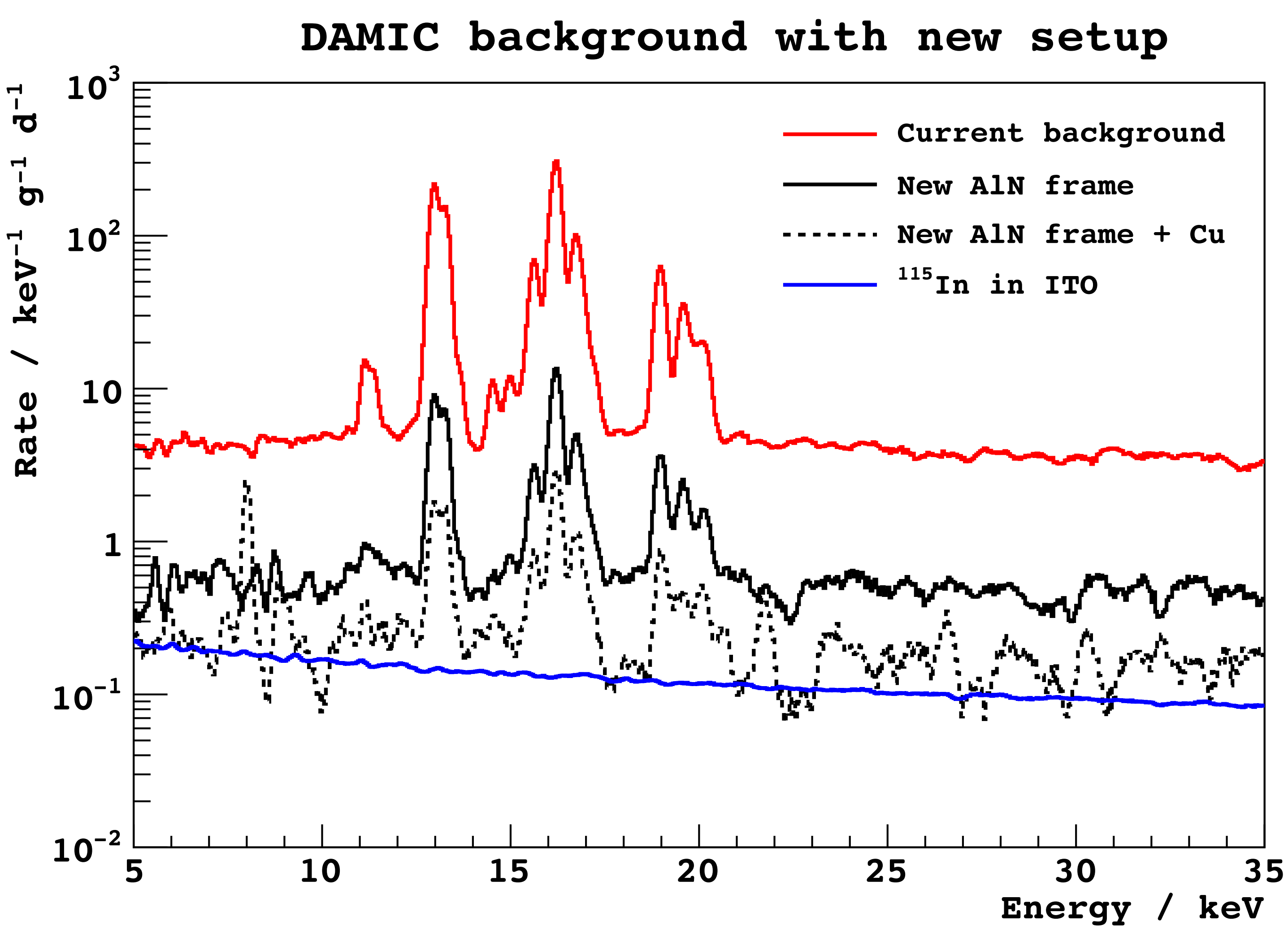
New AlN frame

AlN is needed to support CCD (too thin)

Unnecessary with next gen CCDs (~1 mm)

Temporary solution: Cut a hole in the AlN





new background: fraction of keV^{-1}g^{-1}d^{-1}

10x less background

Outlook

- Will upgrade setup at SNOLAB in May with ~3 new CCDs (grams).
- Residual background from ITO and AlN will be from the back and edges of the CCD, so fiducialization will decrease the background substantially.
- Will uncover spectrum <0.5 keV_{ee} down to ~0.1 $keV^{-1}g^{-1}d^{-1}$.
- ~10x improvement over NuMi measurement.

The Future

- From first run at SNOLAB we have found no deal breakers for DAMIC.
- α contamination, if from the bulk, sets a worst case limiting background of 10^{-4} - 10^{-3} keV^{-1} g^{-1} d^{-1}.
- We will aim for the use of thick, self-supporting CCDs for next version of DAMIC (~1 mm).
- Only high-resistivity Si with Kapton cables inside a Cu box.
- With thicker, larger CCDs (~8 g each), we could fit ~100 g of Si in current SNOLAB setup.

Goal

Achieve lowest possible background within Cu box

↓

Remove non-physical events by patterns of charge on pixels

↓

Remove surface events, i.e. fiducialize

↓

Measure bulk, external γ-ray and neutron backgrounds by exploiting particle identification above tens of keV

↑

+ in-situ measurement of n background with ^{10}B layer

↑

Estimate background at low energies

↑

Compare to observed spectrum

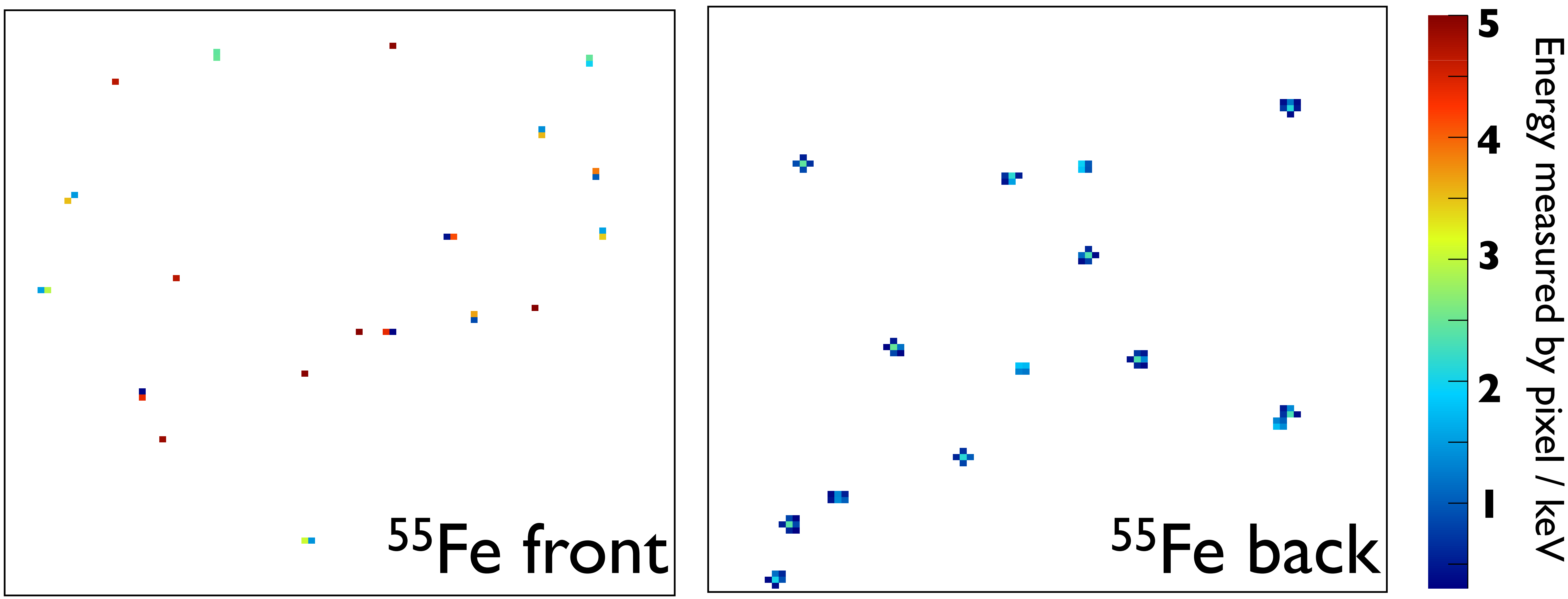
Calibration program

- What is the best way to reject non-physical background and surface events and what is the efficiency?
- What is the exact size of the fully depleted Si region, i.e. the active target mass?
- How well can we discriminate electrons from recoils and down to what energy?
- What is the nuclear recoil energy scale?

Calibration sources

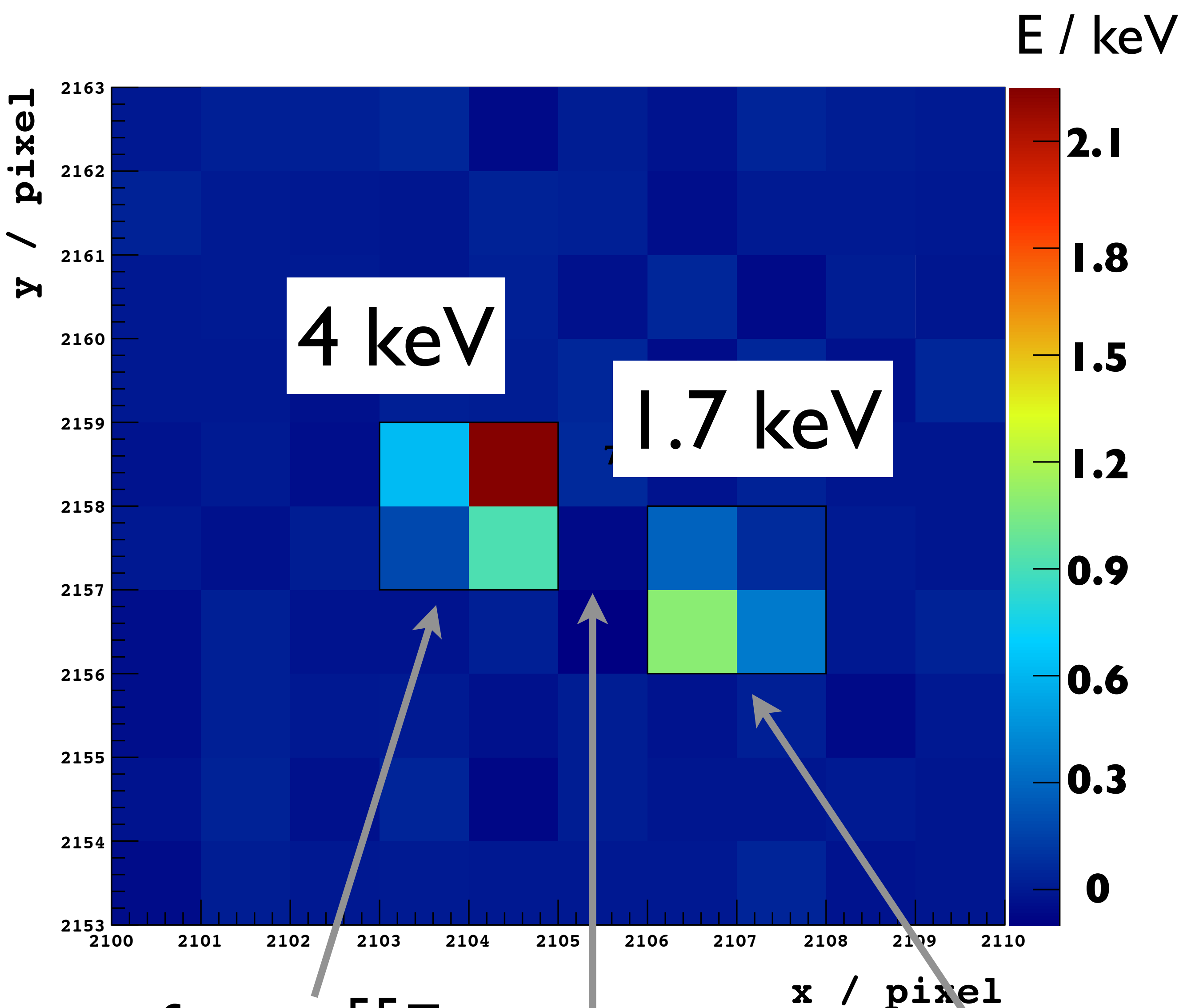
We have exposed DAMIC CCDs to ^{55}Fe (X-ray), ^{252}Cf (n) and ^{60}Co (γ) sources

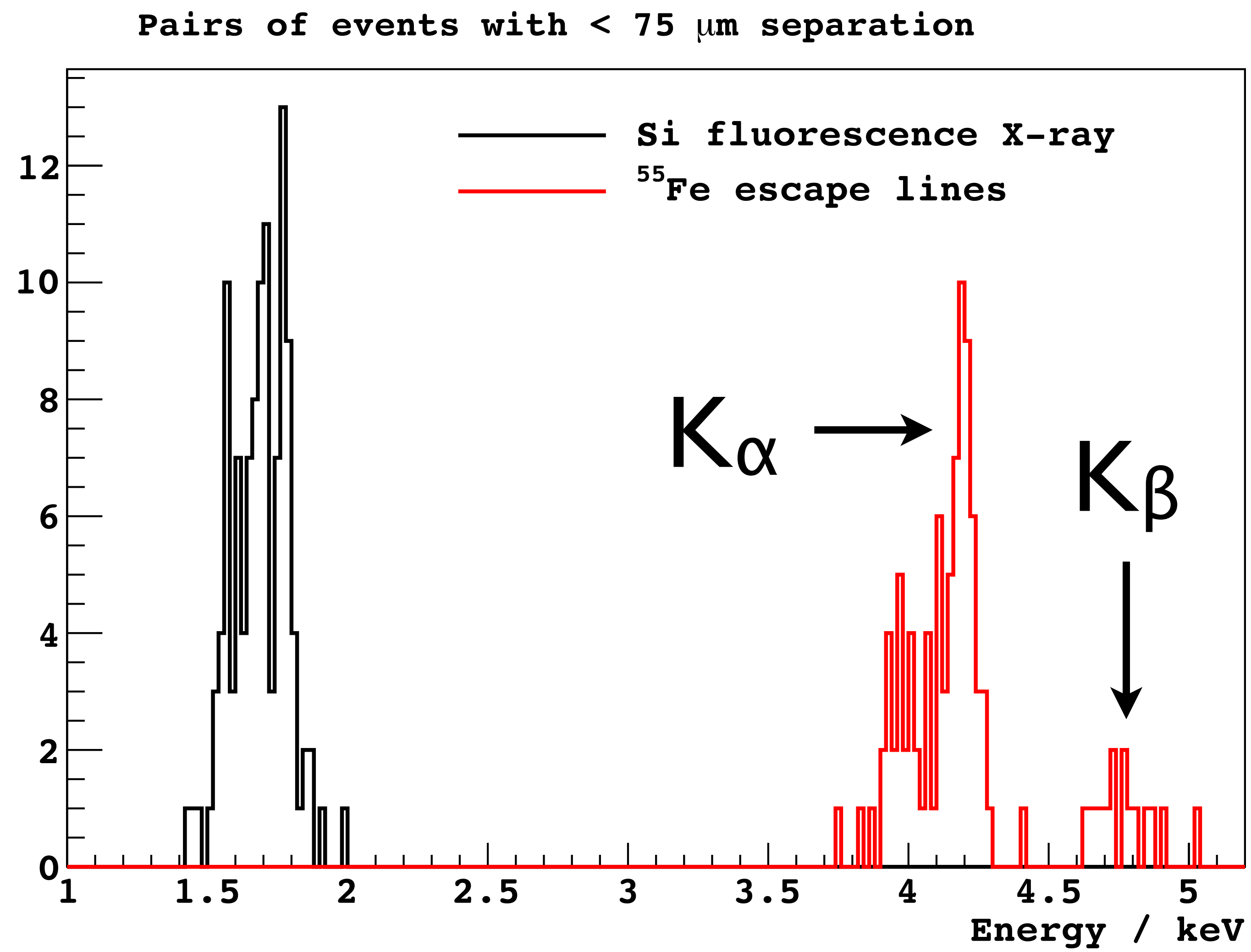
Studies still in progress



5.9 keV (Mn K_α) and 6.5 keV (Mn K_β) X-rays

Spatial correlation in ^{55}Fe





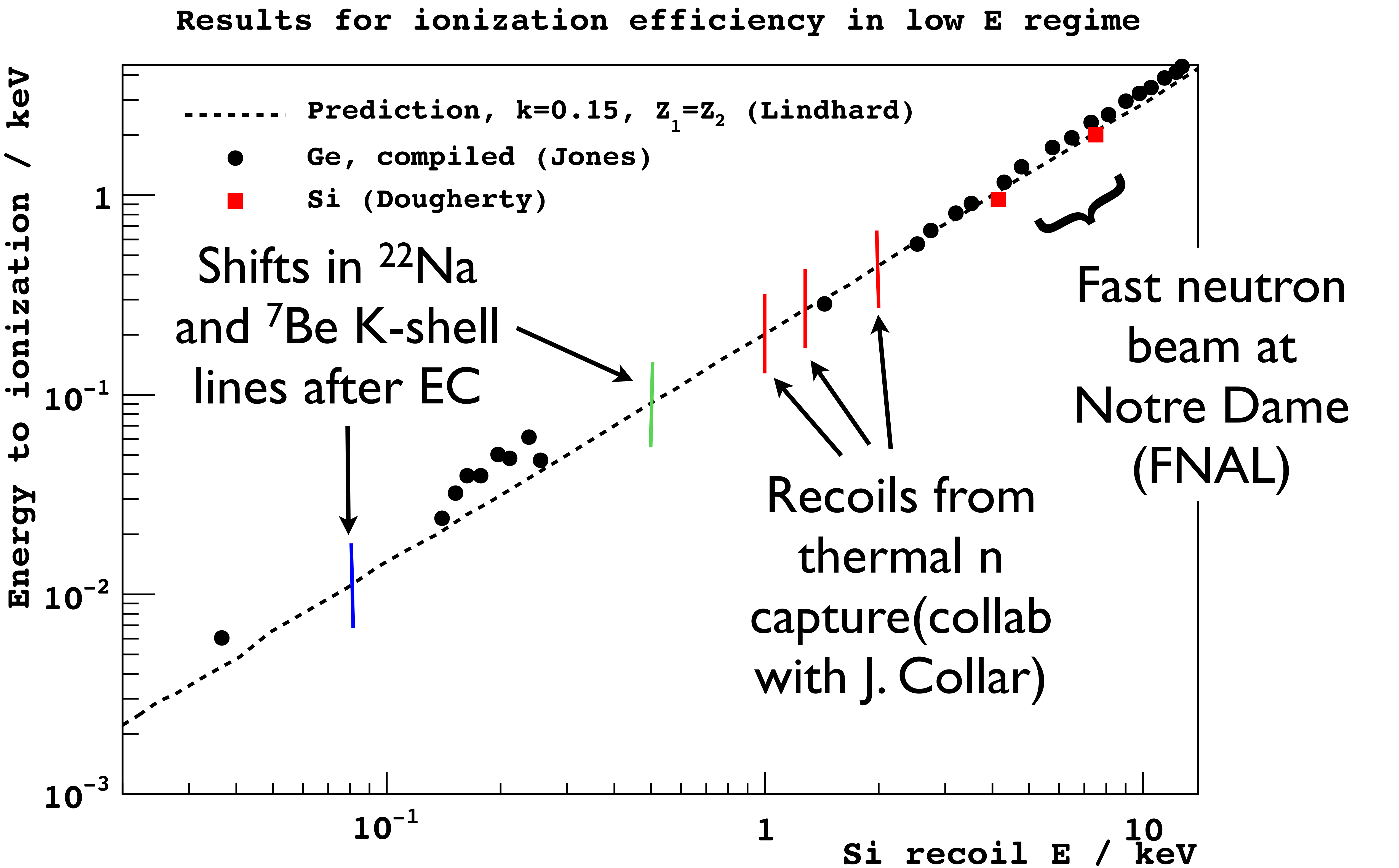
pe from ^{55}Fe X-ray absorption

fluorescence X-ray travels tens of μm

pe from Si fluorescence X-ray absorption

Spatial correlation between fluorescence X-rays and ^{55}Fe lines

Calibration of E_r scale



Conclusion

- No unsurmountable problem identified by running at SNOLAB.
- Unforeseen U background in AlN.
- Will upgrade setup at SNOLAB in May to improve by ~x10 result from NuMi.
- Aiming for a 100 g setup with ~1mm thick CCDs with no AlN nor ITO (10^{-4} keV^{-1}g^{-1}d^{-1}).
- Strong calibration program to take advantage of the low threshold and unique background characterization features of DAMIC.

Thank you!