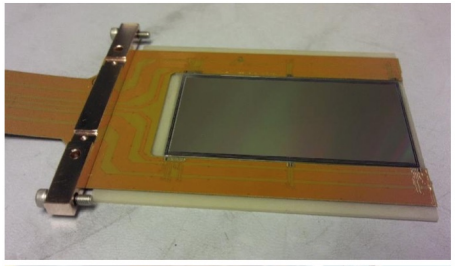
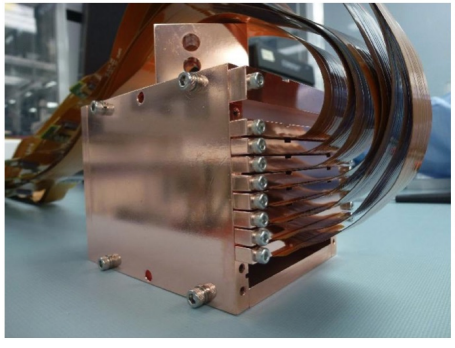
CCD as low energy threshold particle detectors for direct Dark Matter searches, and more...



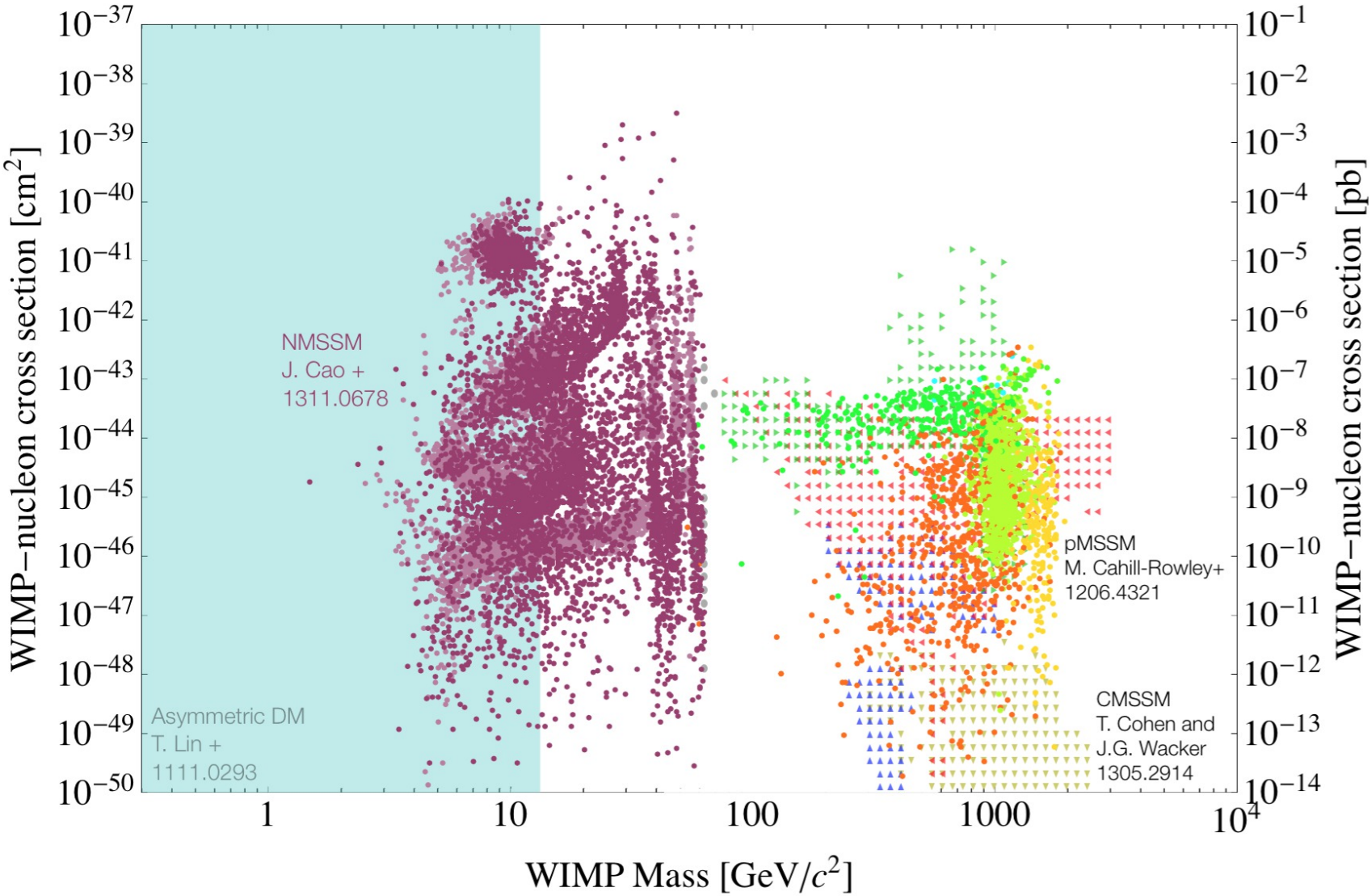


Xavier Bertou

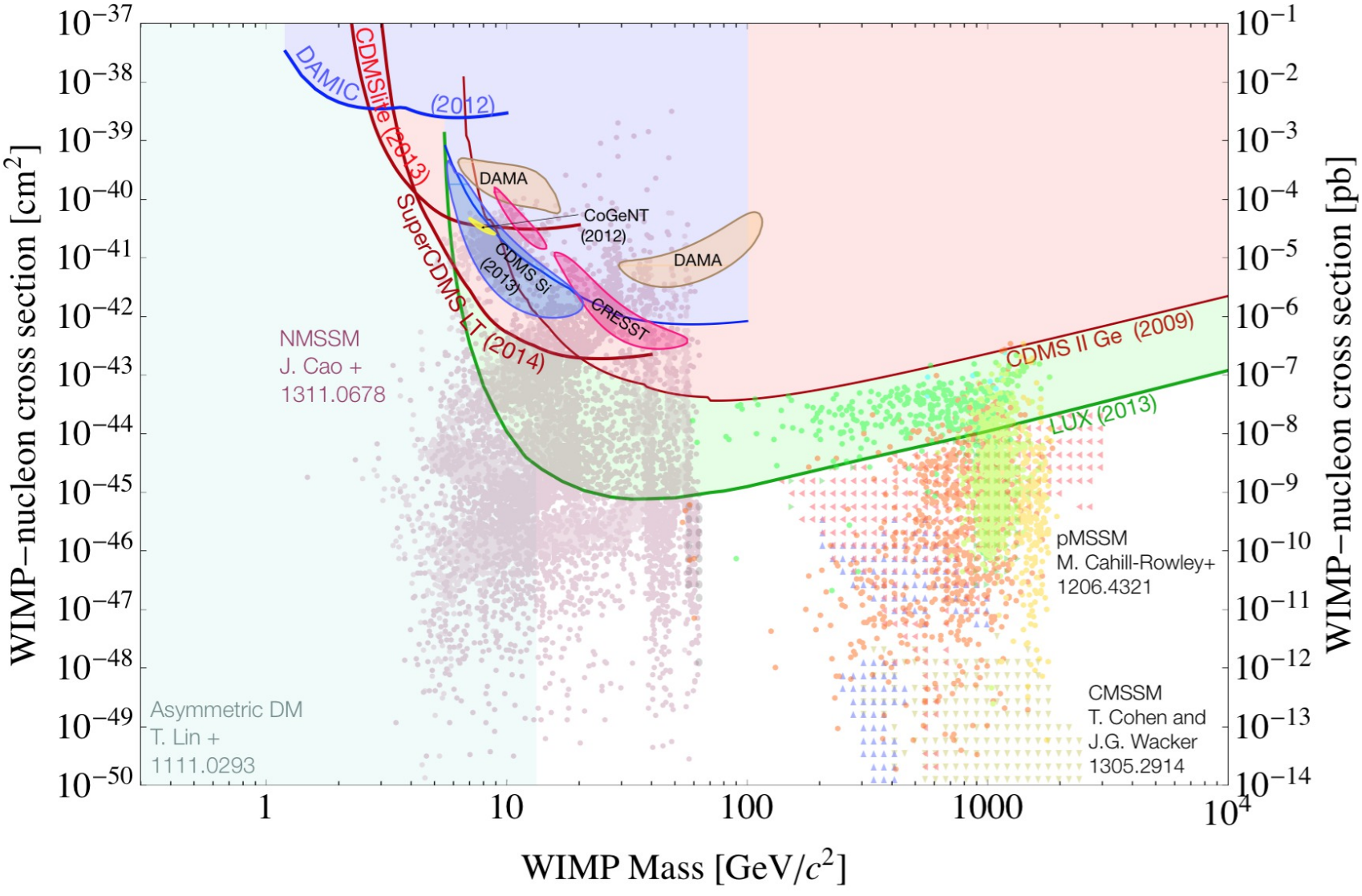
Centro Atómico Bariloche
(CNEA/CONICET)

Dark Matter @ LPNHE
22 September 2014

Low mass WIMP sector



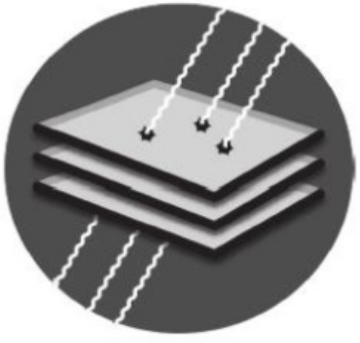
Low mass WIMP sector and experiments



DAMIC: Dark Matter in CCDs

DAMIC Collaboration

International collaboration: 7 institutions from 5 countries

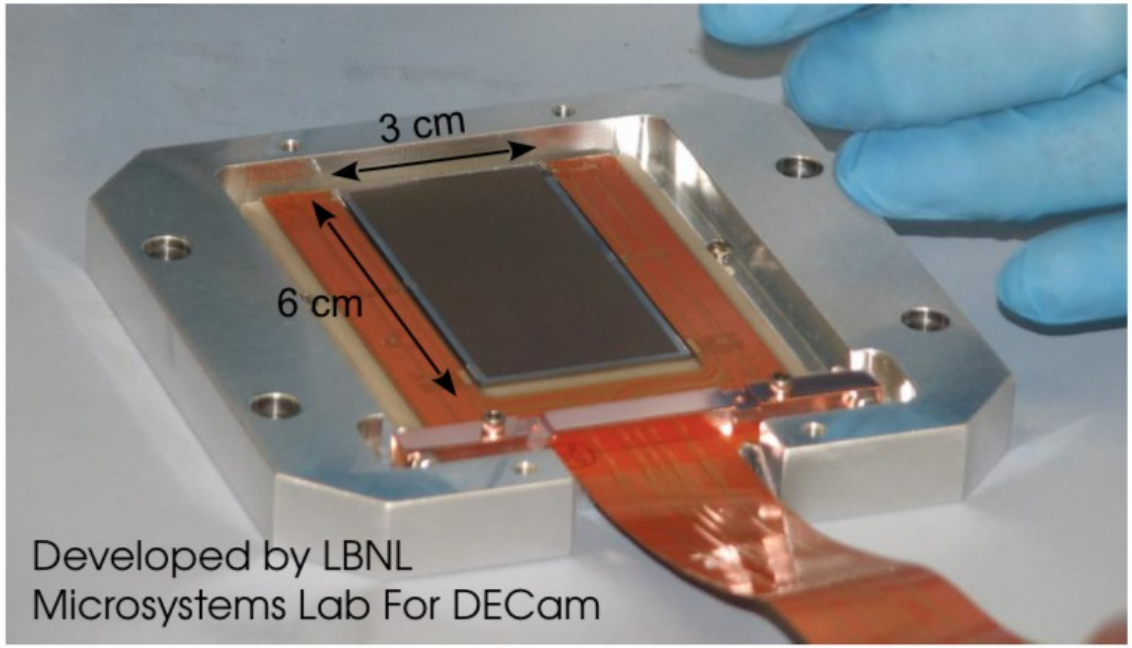


DAMIC

Argentina:	Centro Atómico Bariloche
Mexico:	Universidad Nacional Autónoma de México
Paraguay:	Universidad Nacional de Asunción
Switzerland:	Universität Zürich (UZH)
United States:	Fermilab, U. Chicago, U. Michigan

CCD as low energy threshold particle detectors

Charge-coupled device

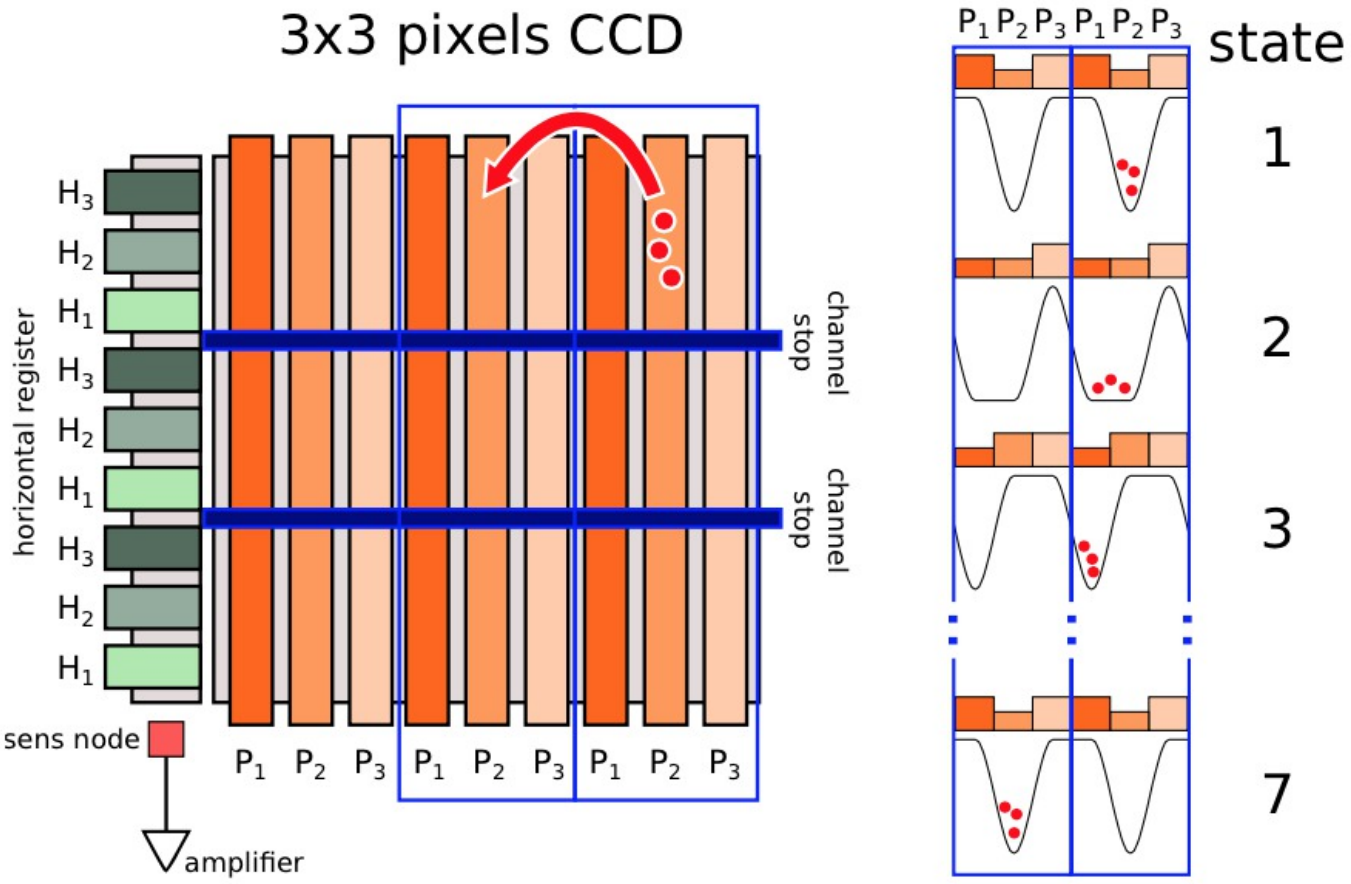


Pixel size: 15 μm x 15 μm
# of pixels: 2000 x 4000
CCD Thickness: 250 μm
CCD Mass: 1 gram
Operation Temp: 150 K

- Readout noise ~ 2.5 electrons RMS
- Detector Threshold < 50 eV_{ee}

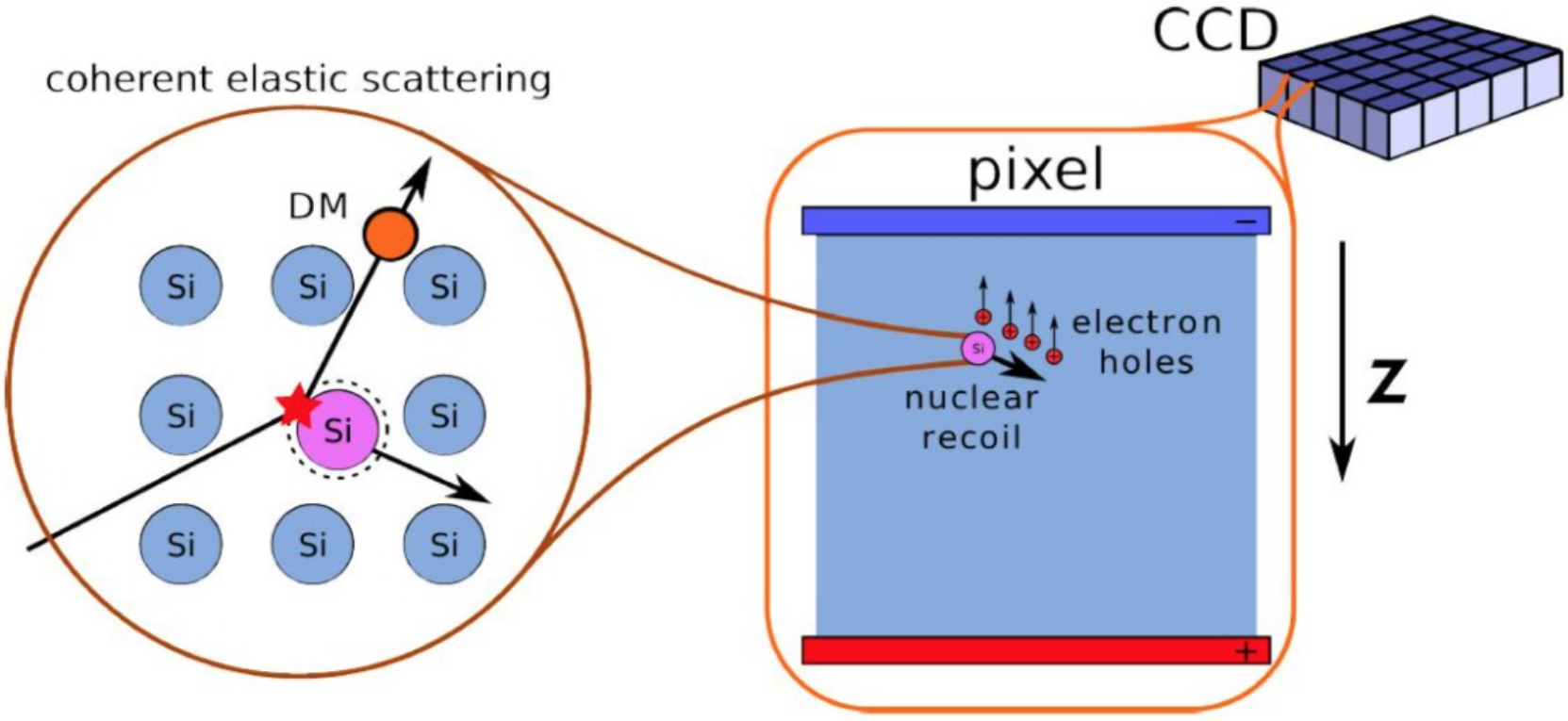
Diffusion → 3D reconstruction
→ surface event rejection

Charge movement and CCD readout



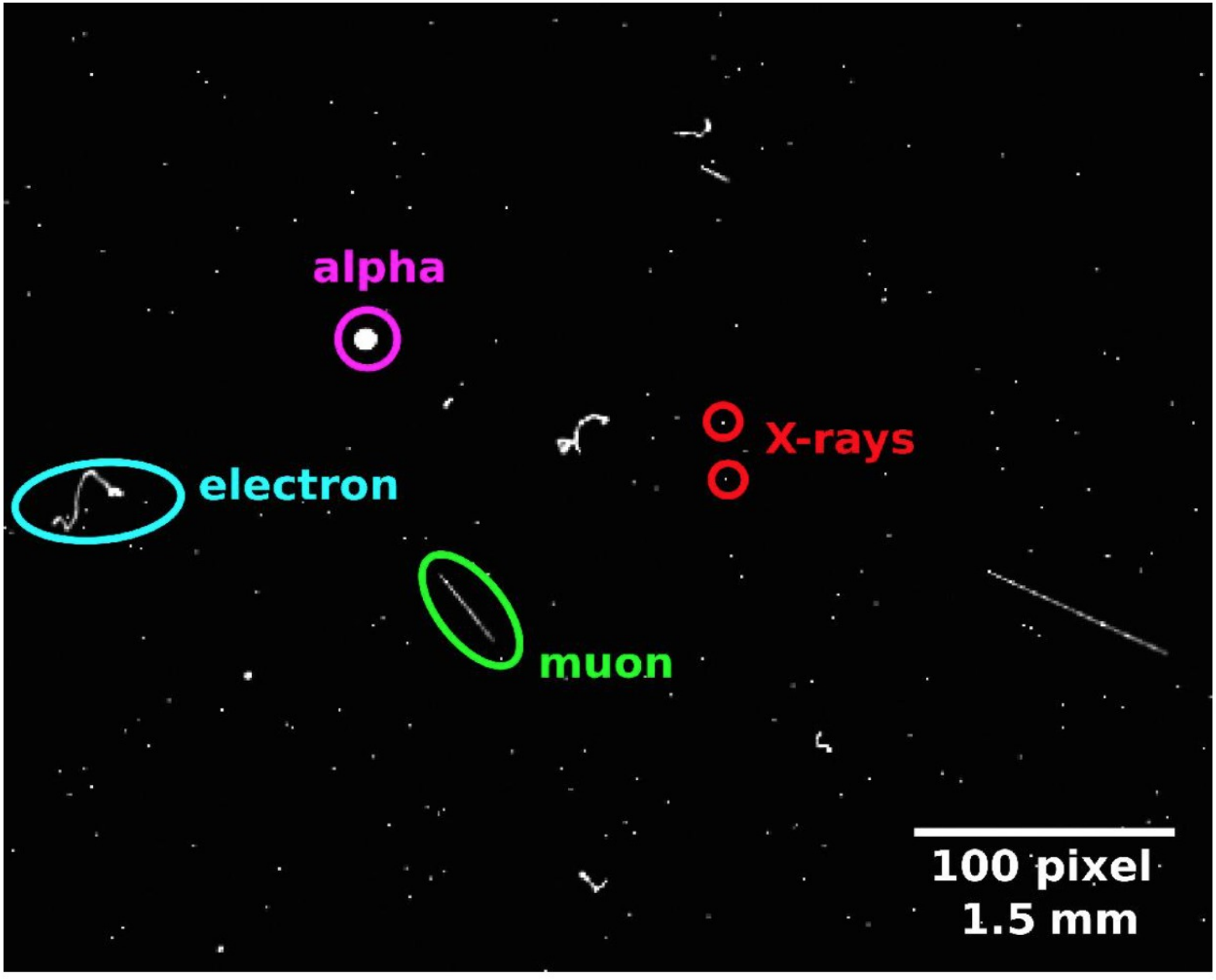
- Charges moved by adjusting P_i (then H_i) voltages
- System capacitance set by the SN: $C = 0.05\,\mathrm{pF} \rightarrow 3\,\mu\mathrm{V/e^-}$

Charge collection in a WIMP interaction

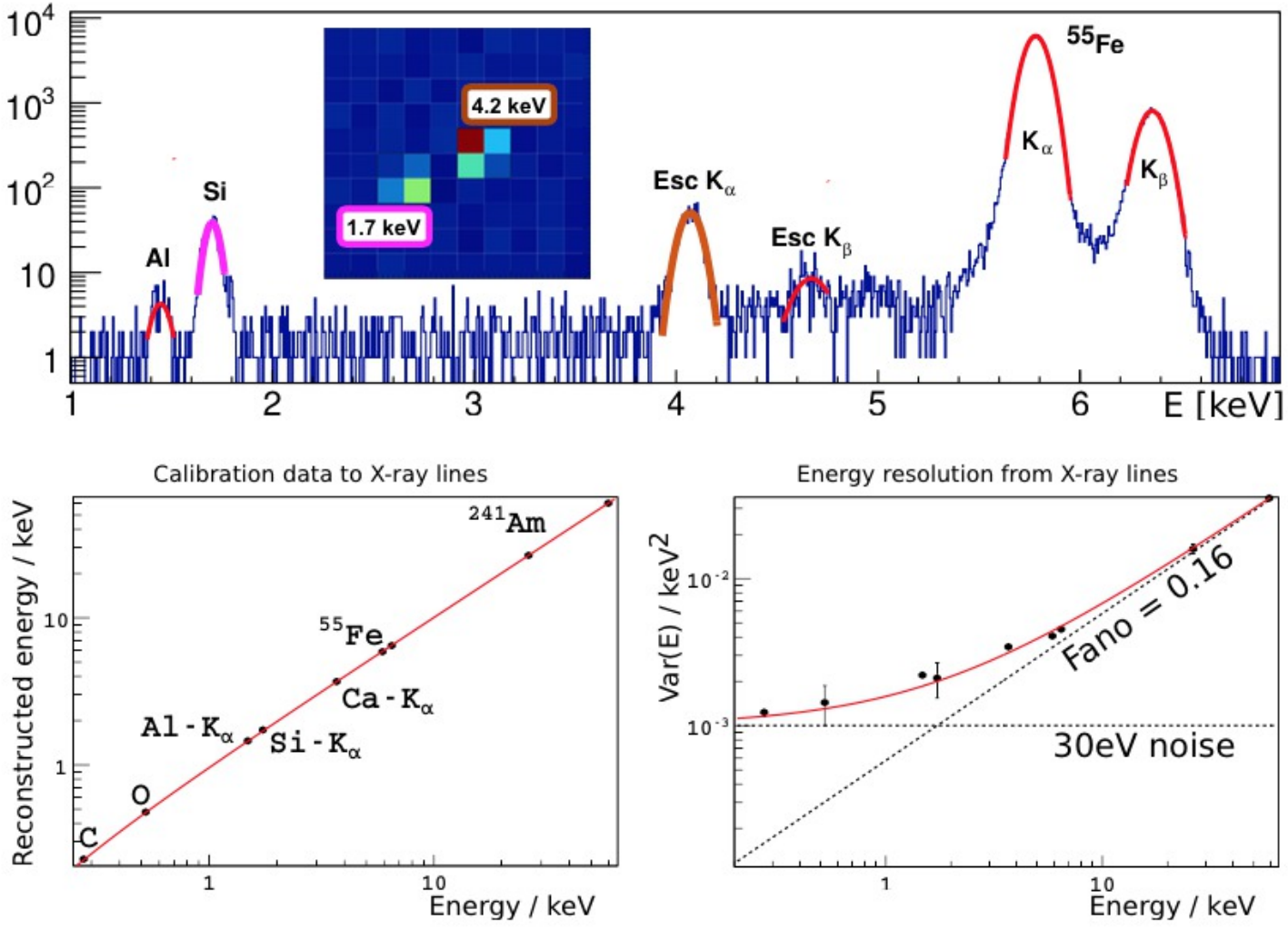


- Fully depleted silicon
- Charge collected in electric potential wells ($15 \times 15 \times 250\,\mu\text{m}^3$)

Typical (surface) CCD image

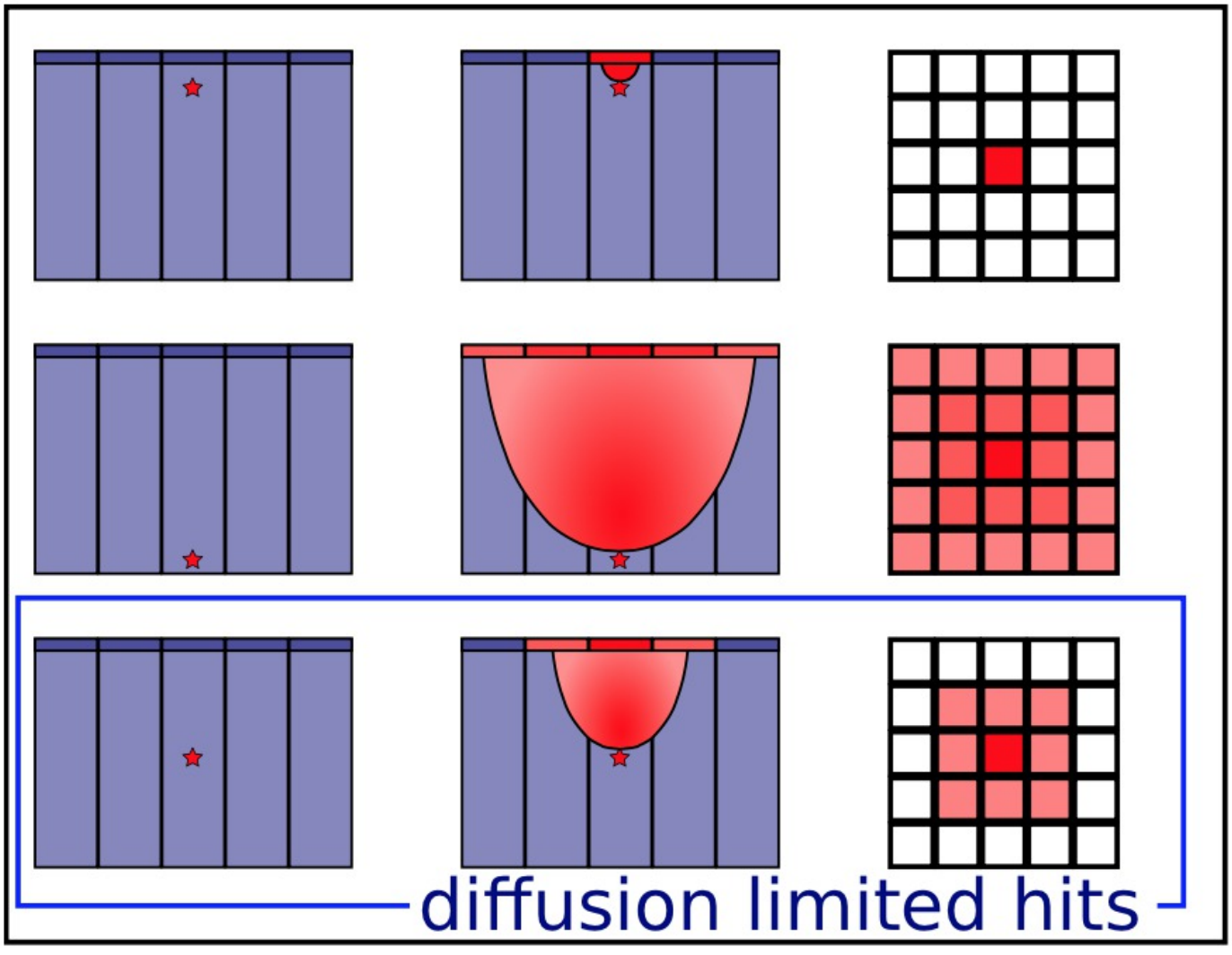


Energy calibration of CCDs



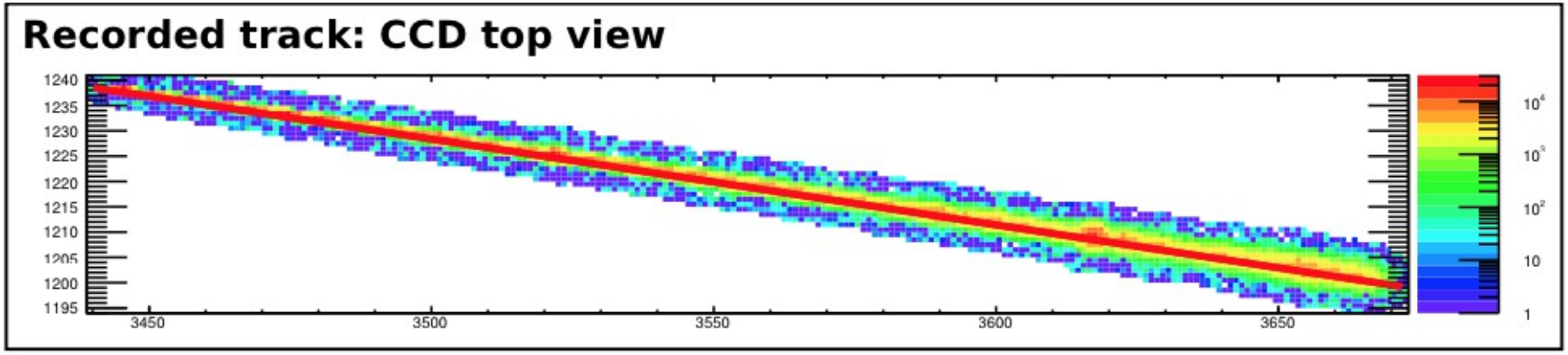
Electron energy scale calibrated down to 280 eV, 63 eV RMS @ 6 keV

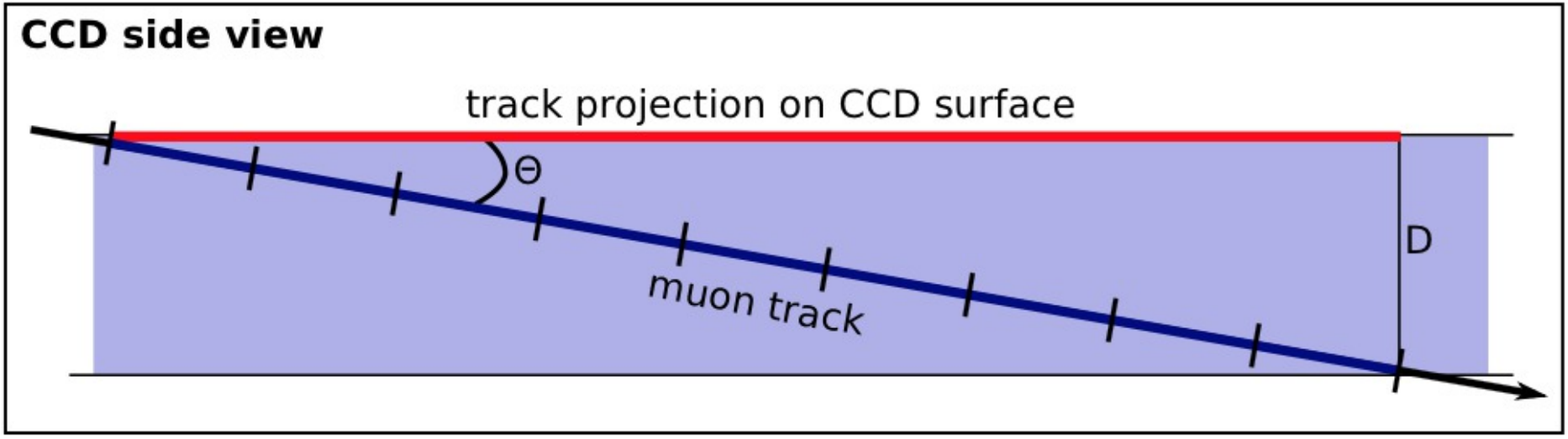
Depth measurement by diffusion



Width of energy deposit gives depth of interaction

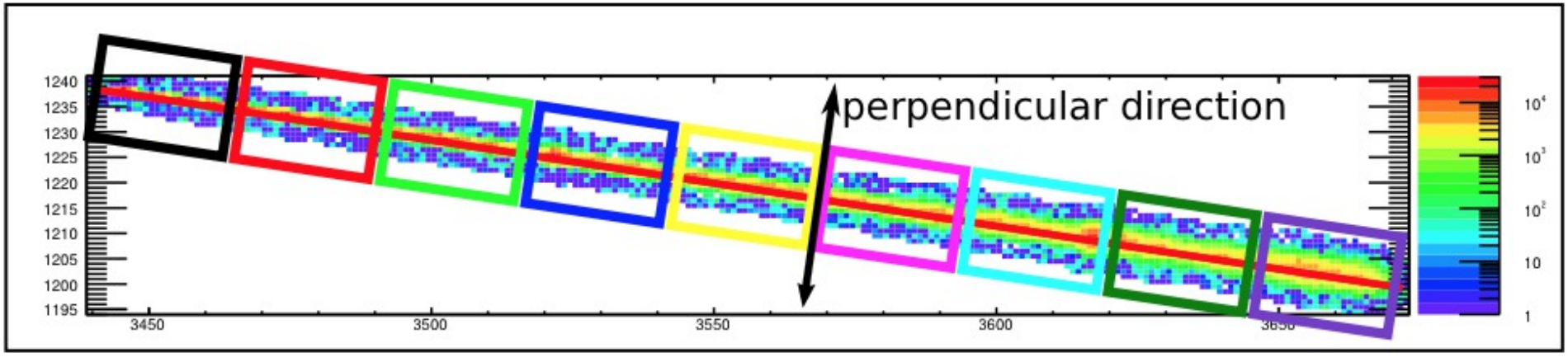
Measuring diffusion with muons

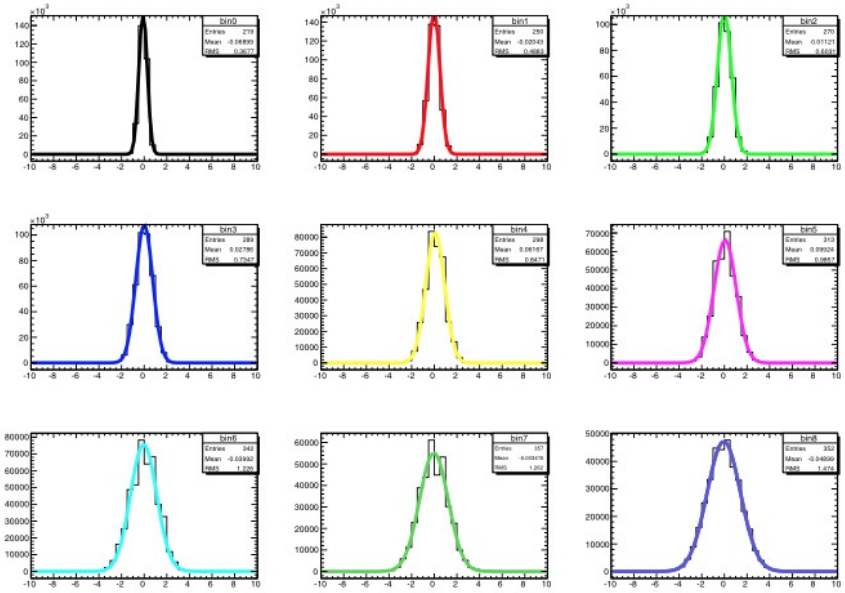


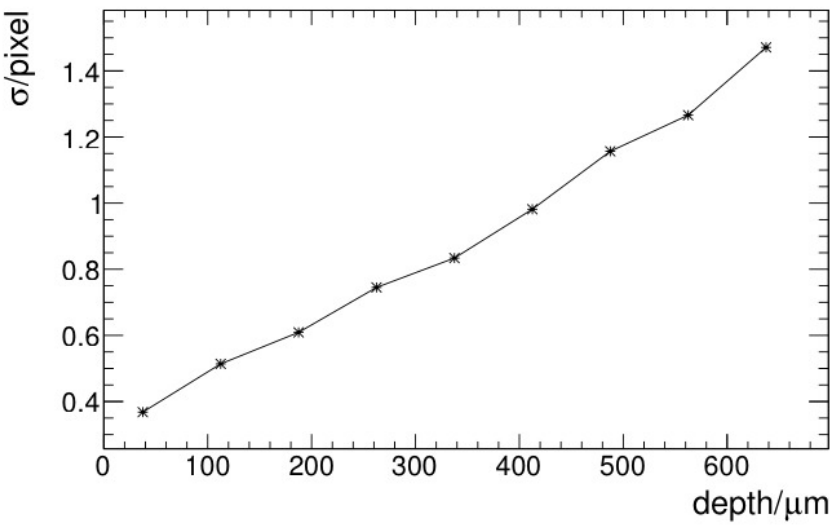


Direct measurement of diffusion effects using muons

Measuring diffusion with muons

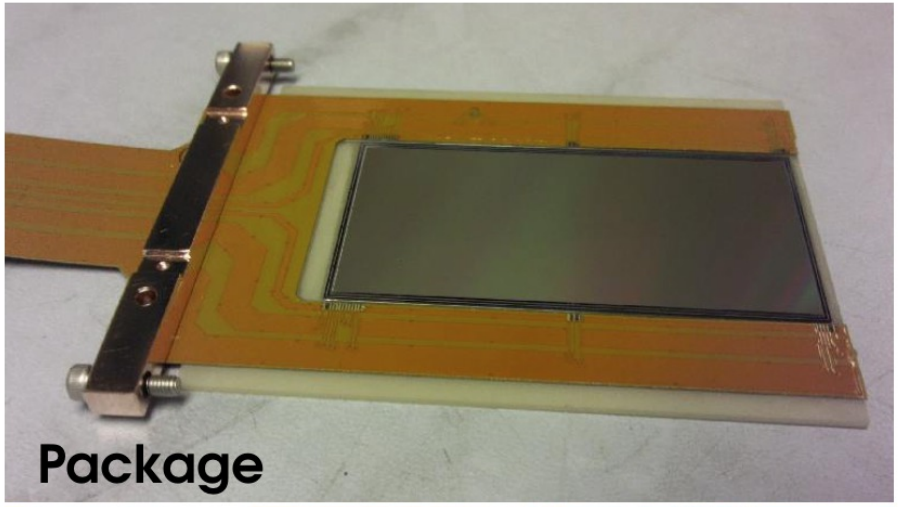


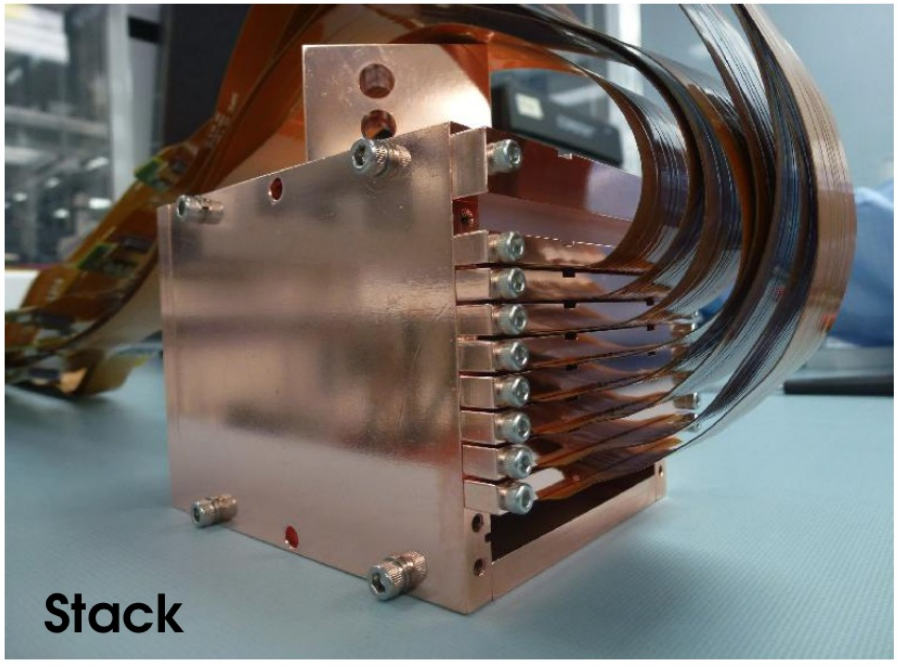


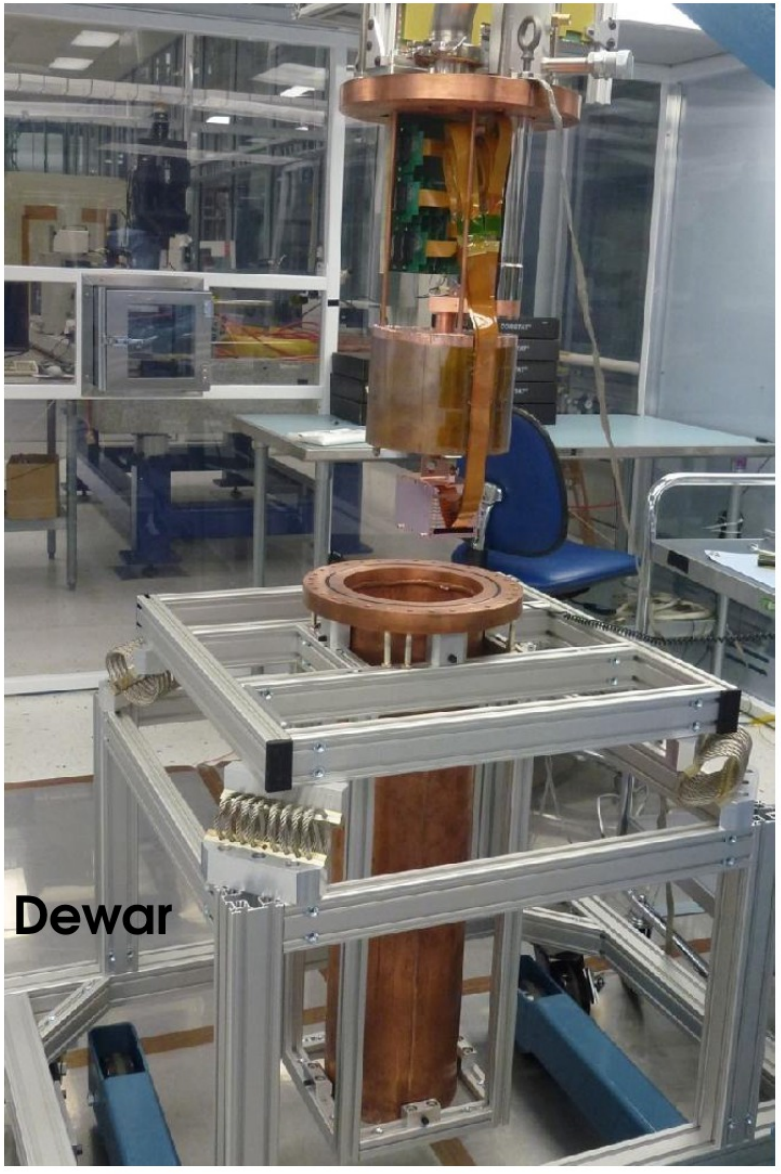


DAMIC in the lab

DAMIC at SNOLAB

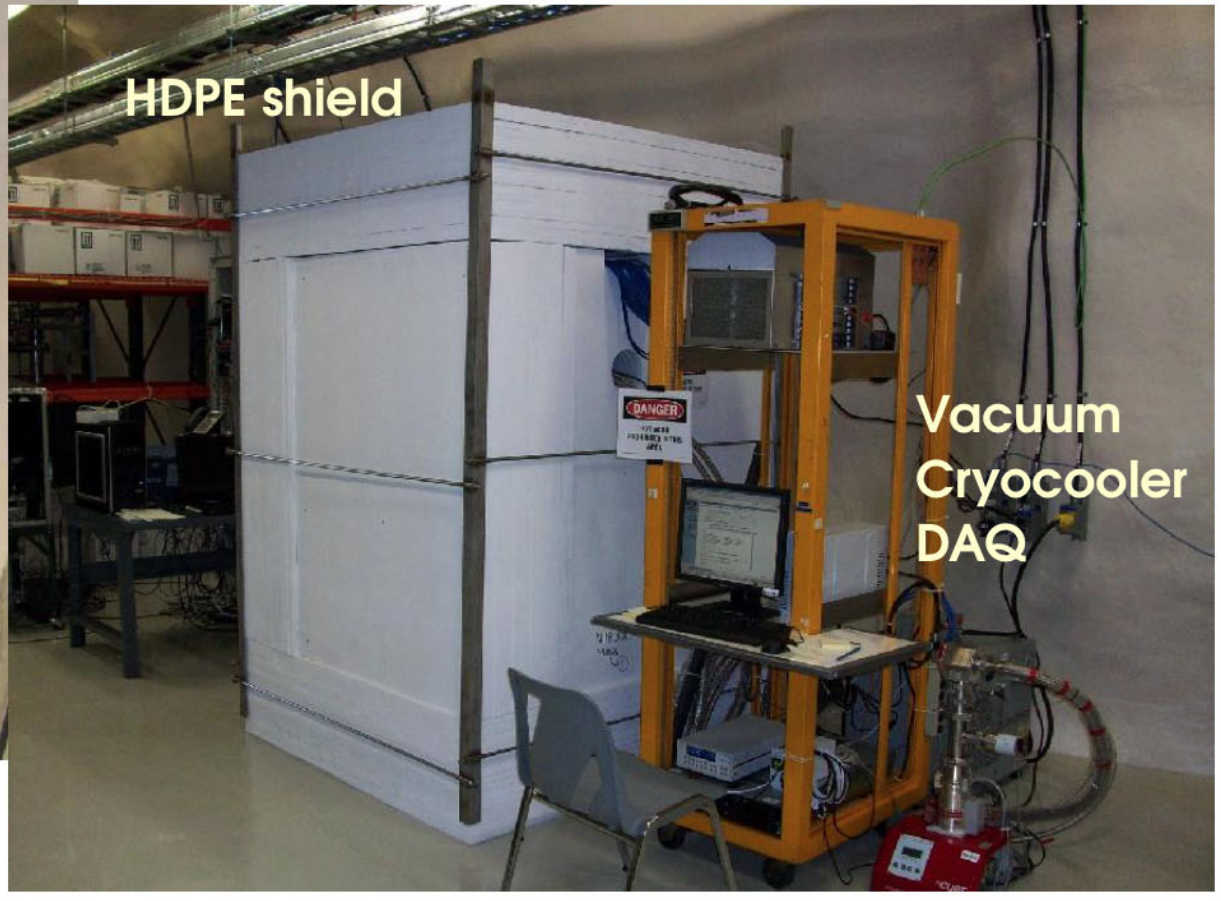




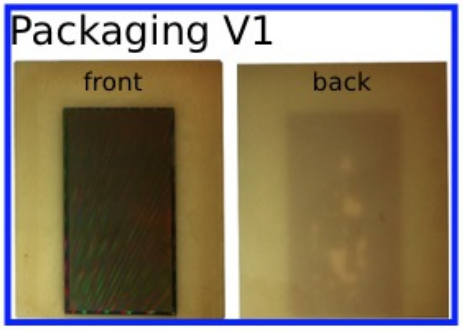


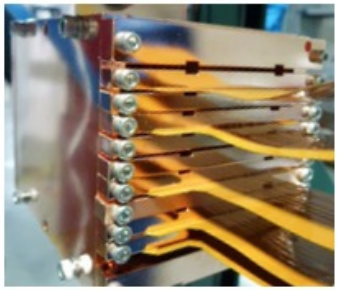
DAMIC at SNOLAB

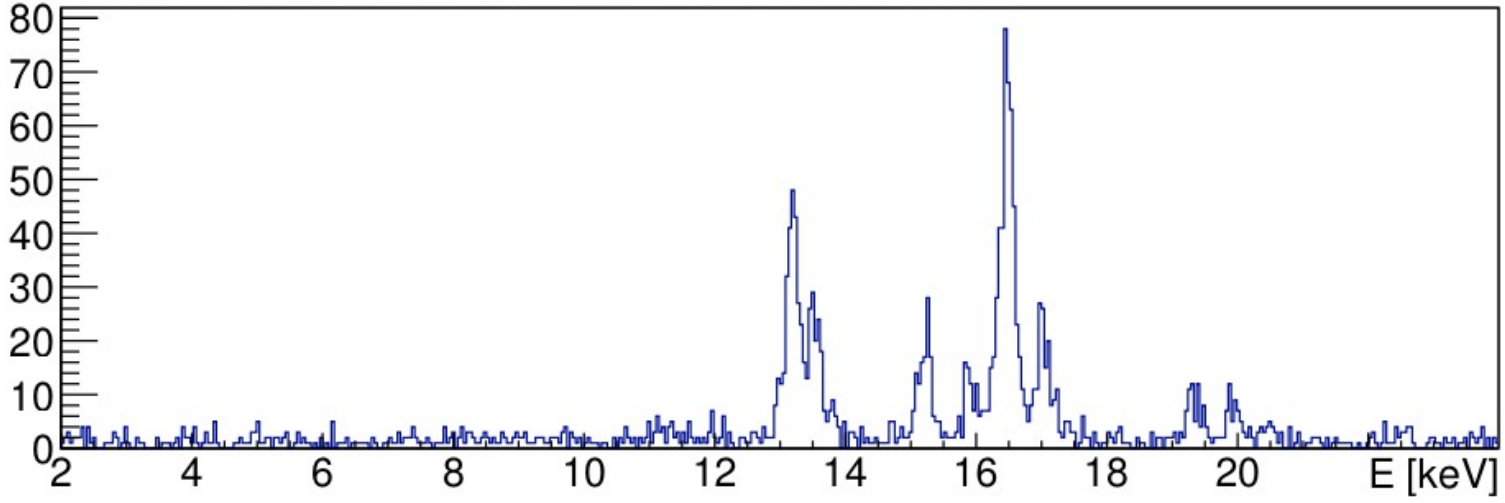
Installed: December 2013



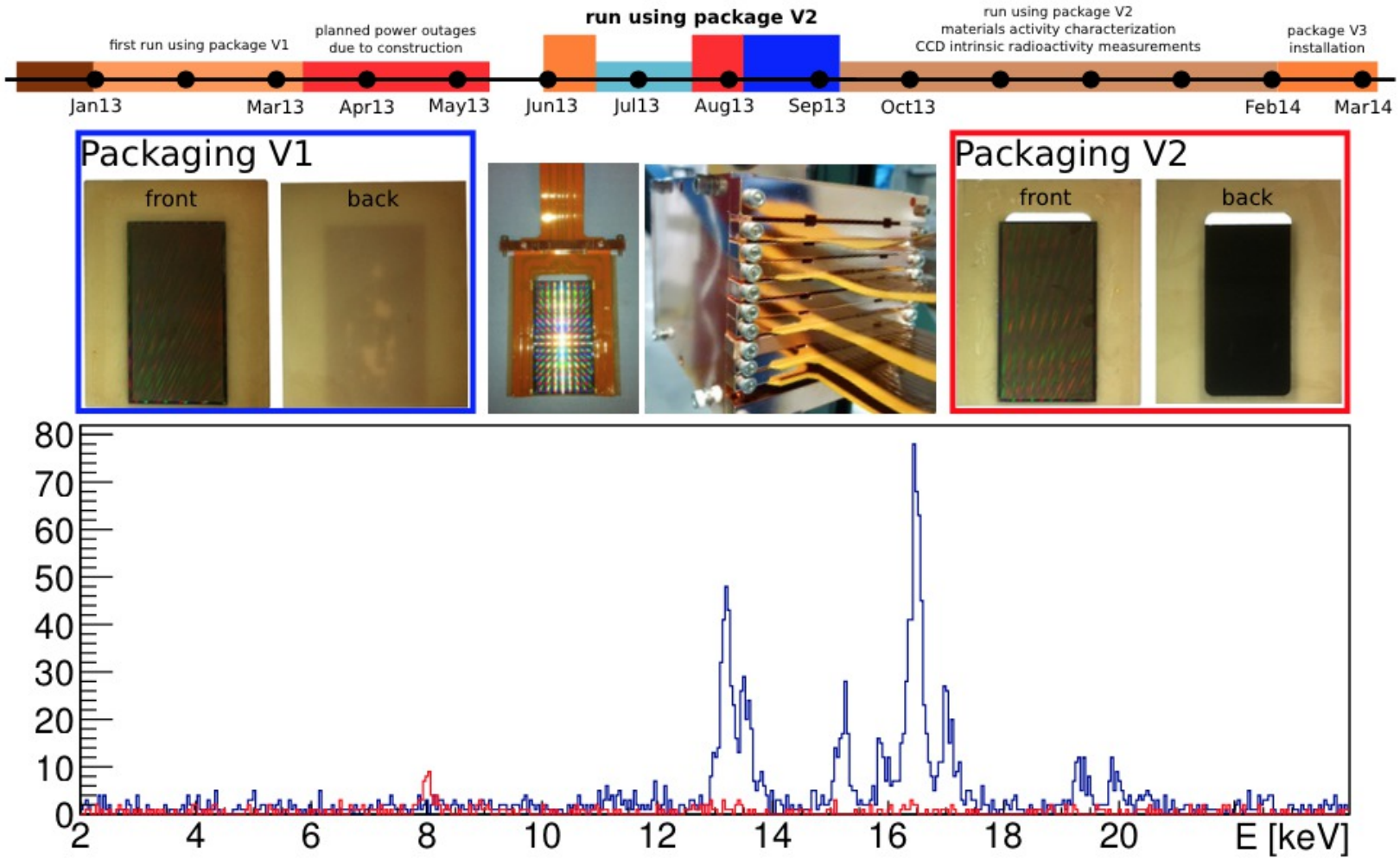
DAMIC background at SNOLAB



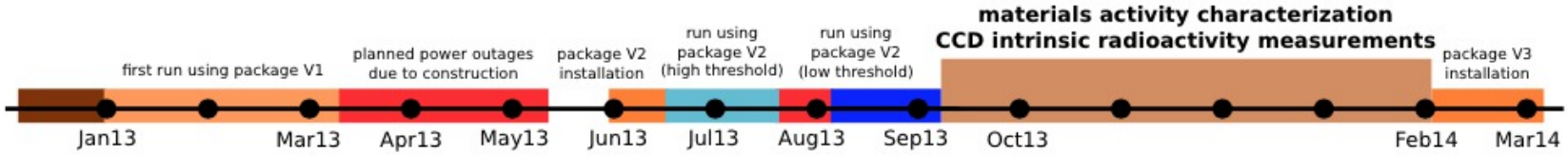




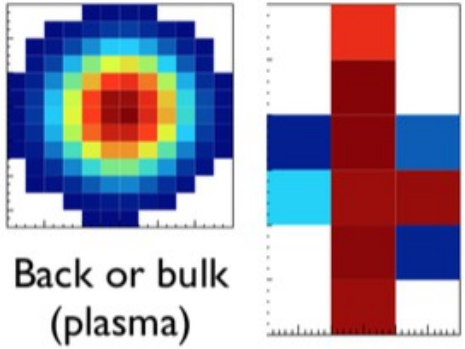
DAMIC background at SNOLAB



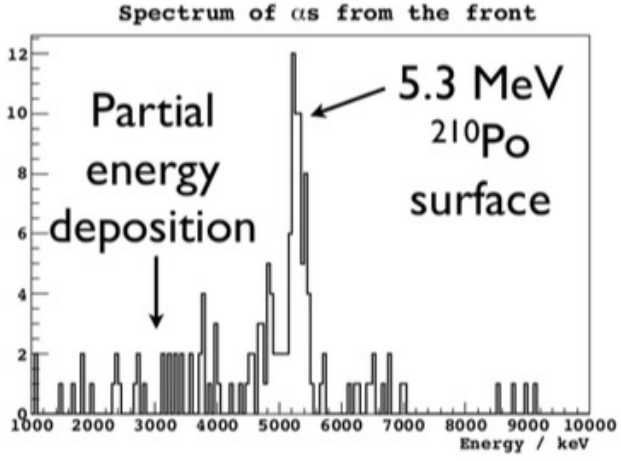
DAMIC background at SNOLAB



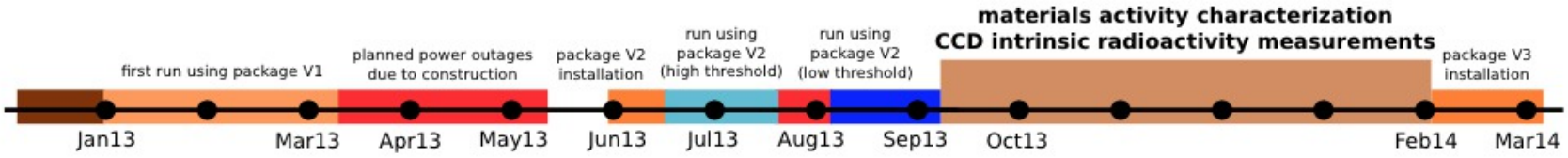
Alpha search



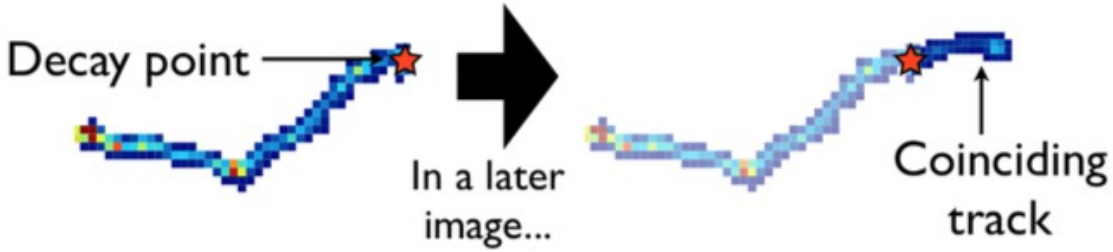
^{232}Th:<0.08 mBq/kg
^{238}U: <0.06 mBq/kg



DAMIC background at SNOLAB



Spatial coincidences



$^{210}Pb \xrightarrow{64\ keV} {}^{210}Bi \xrightarrow{1.2\ MeV} {}^{210}Po$

$\tau_{1/2} = 5$ d

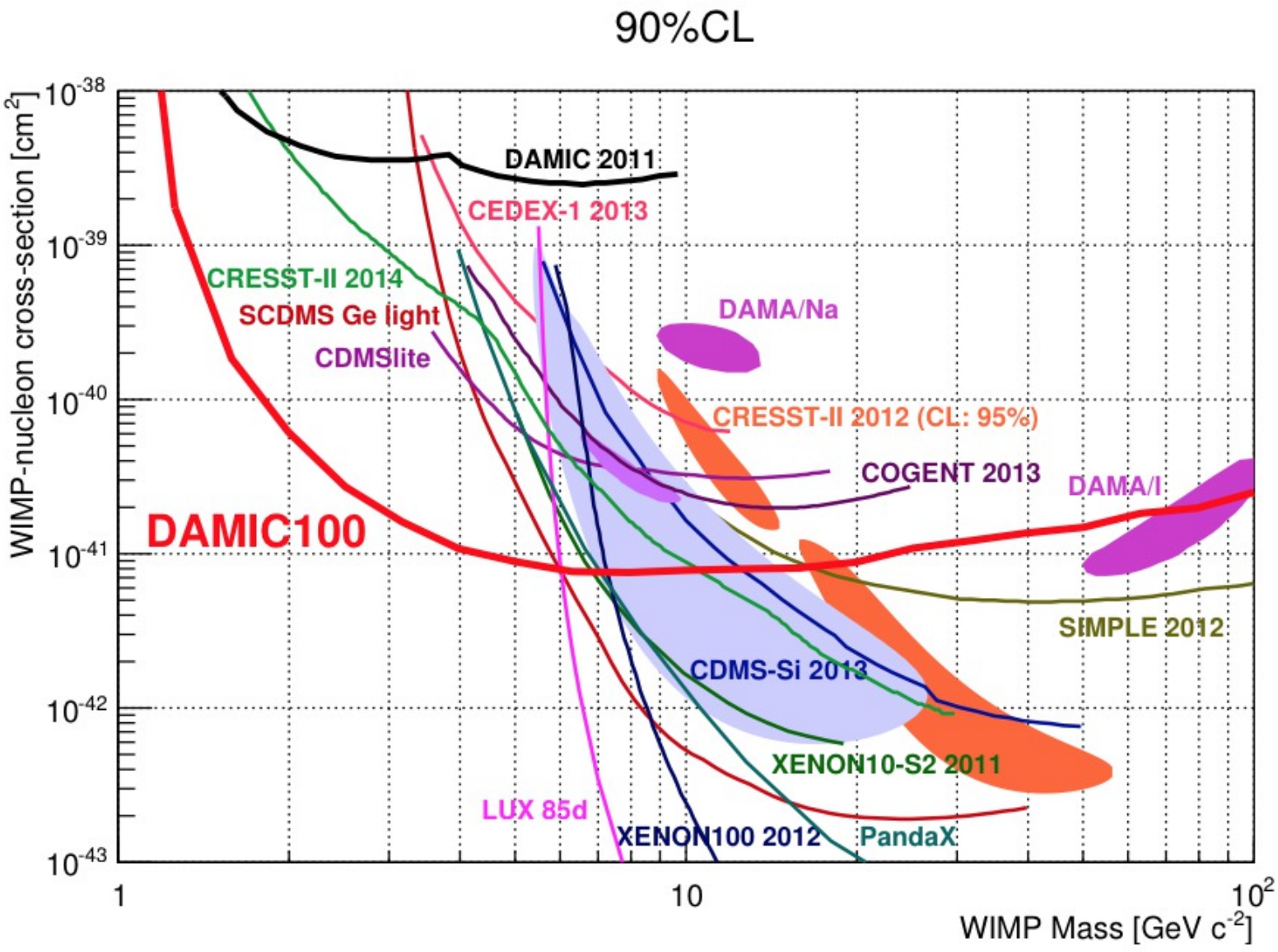
$^{32}Si \xrightarrow{0.22\ MeV} {}^{32}P \xrightarrow{1.7\ MeV} {}^{32}S$

$\tau_{1/2} = 14$ d

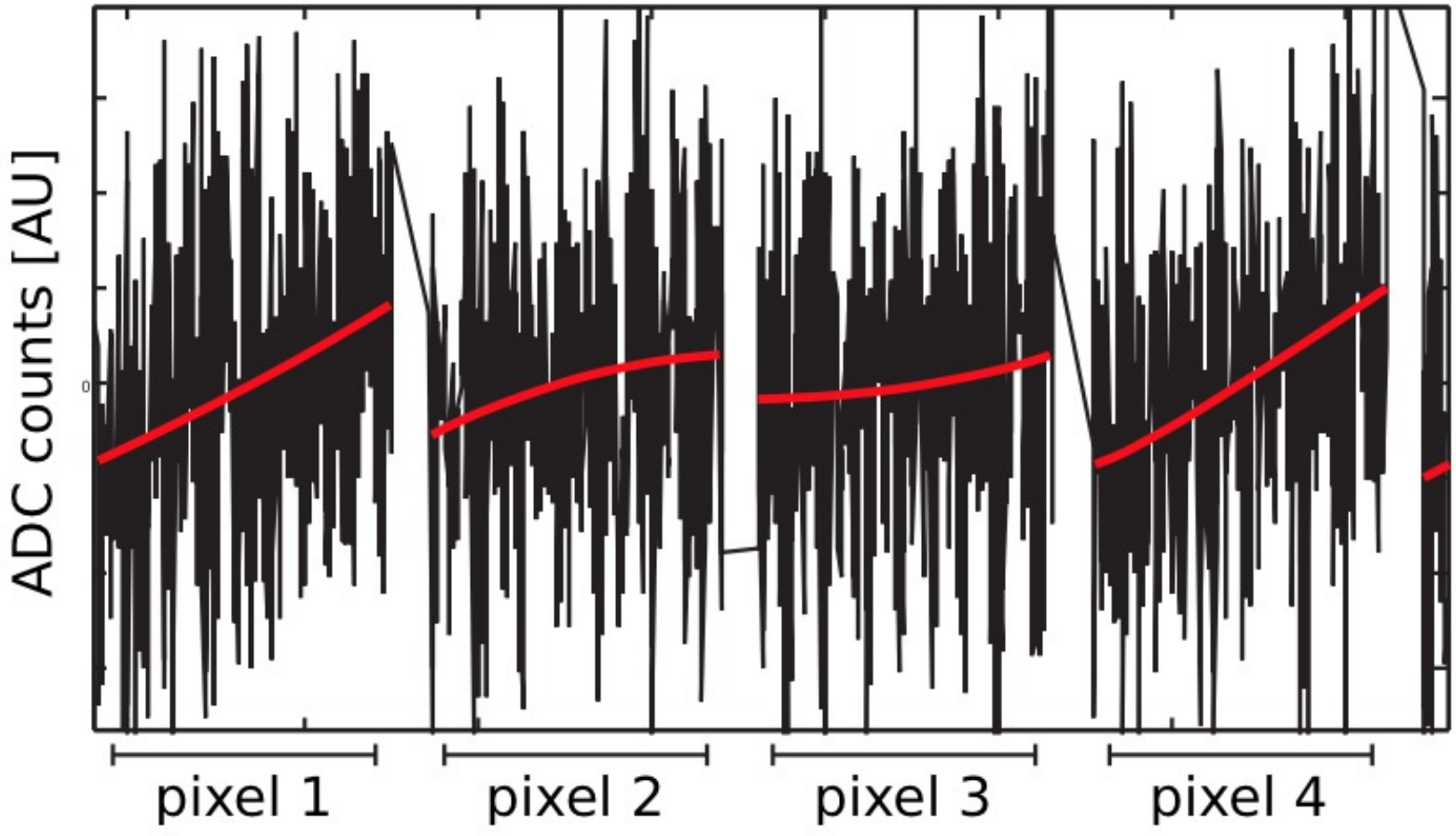
Sequence of βs starting in the same pixel of the CCD in different images

^{32}Si: <2.6 mBq/kg
^{210}Pb: <0.6 mBq/kg

DAMIC-100 expectations



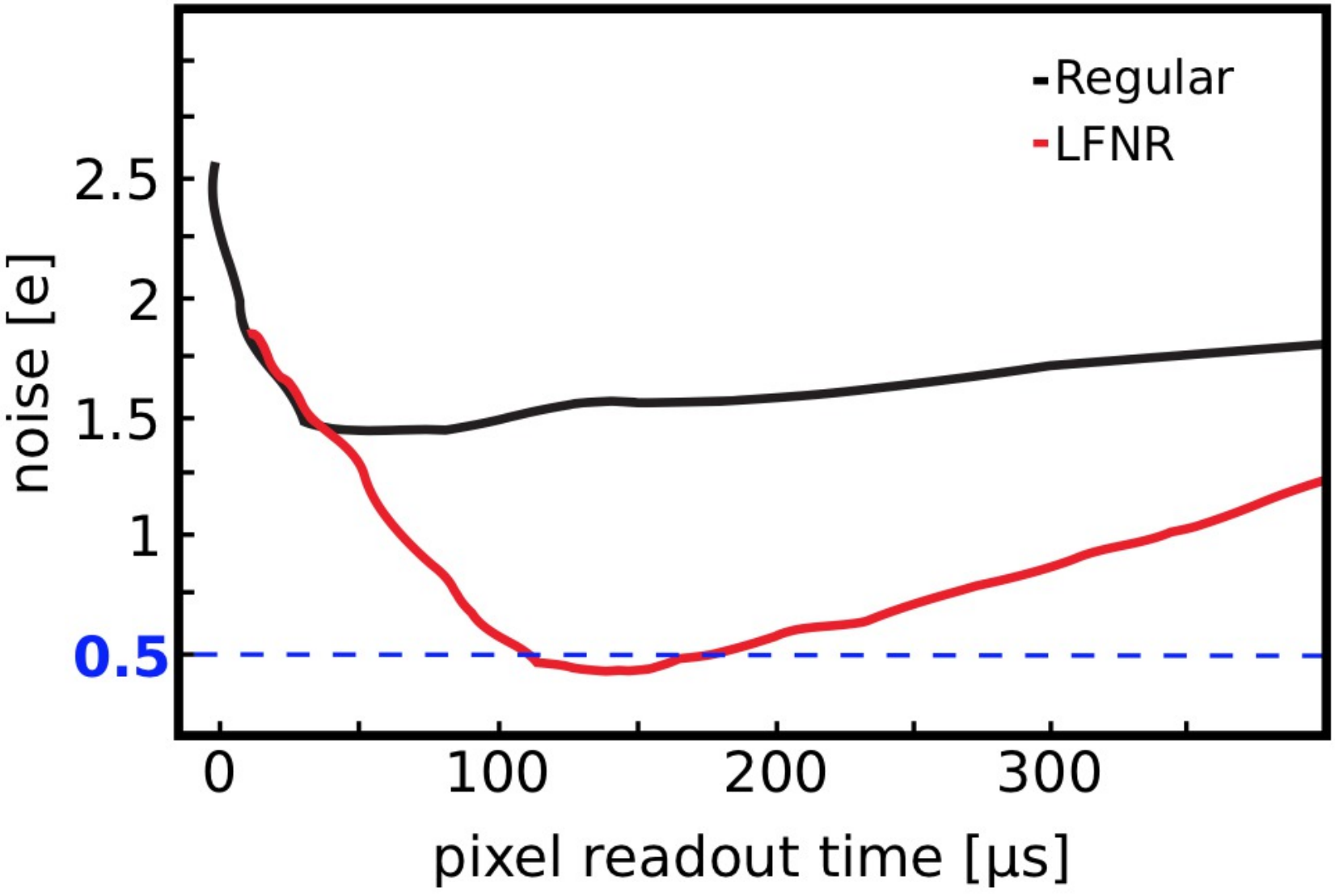
Next step: reduce readout noise (to sub-electron)



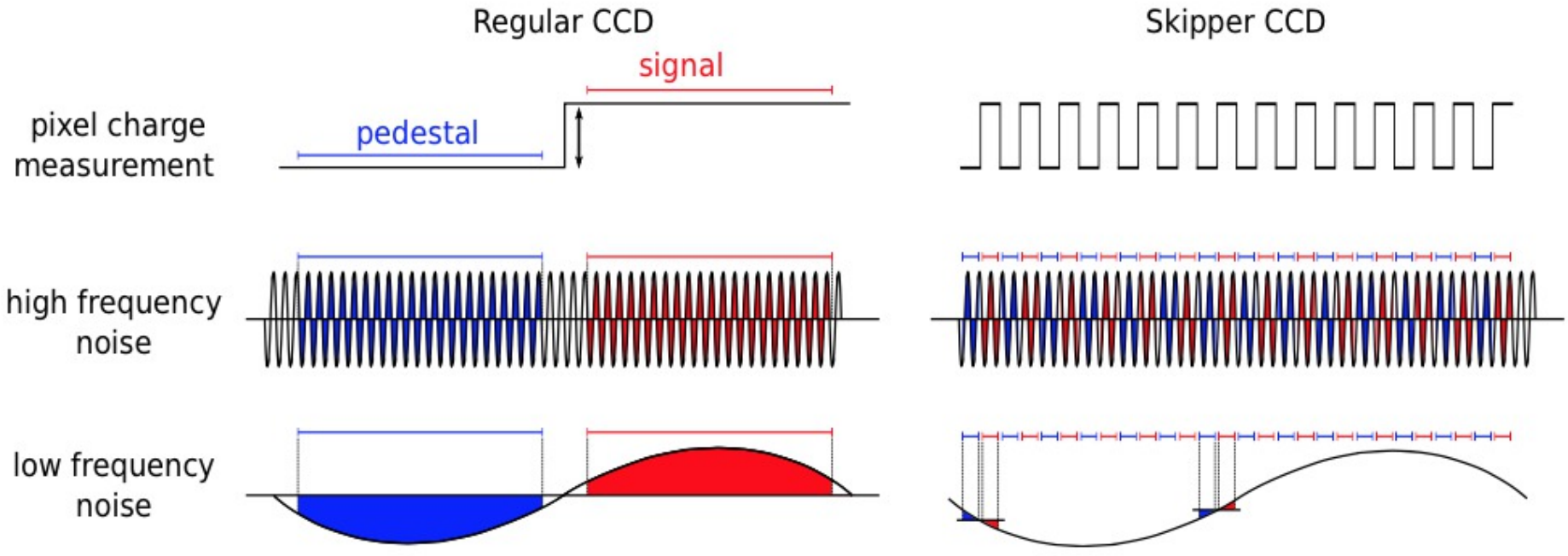
Main (only) remaining source of noise:

low frequency baseline shift in readout

Software: Digital Low Frequency Noise Reduction



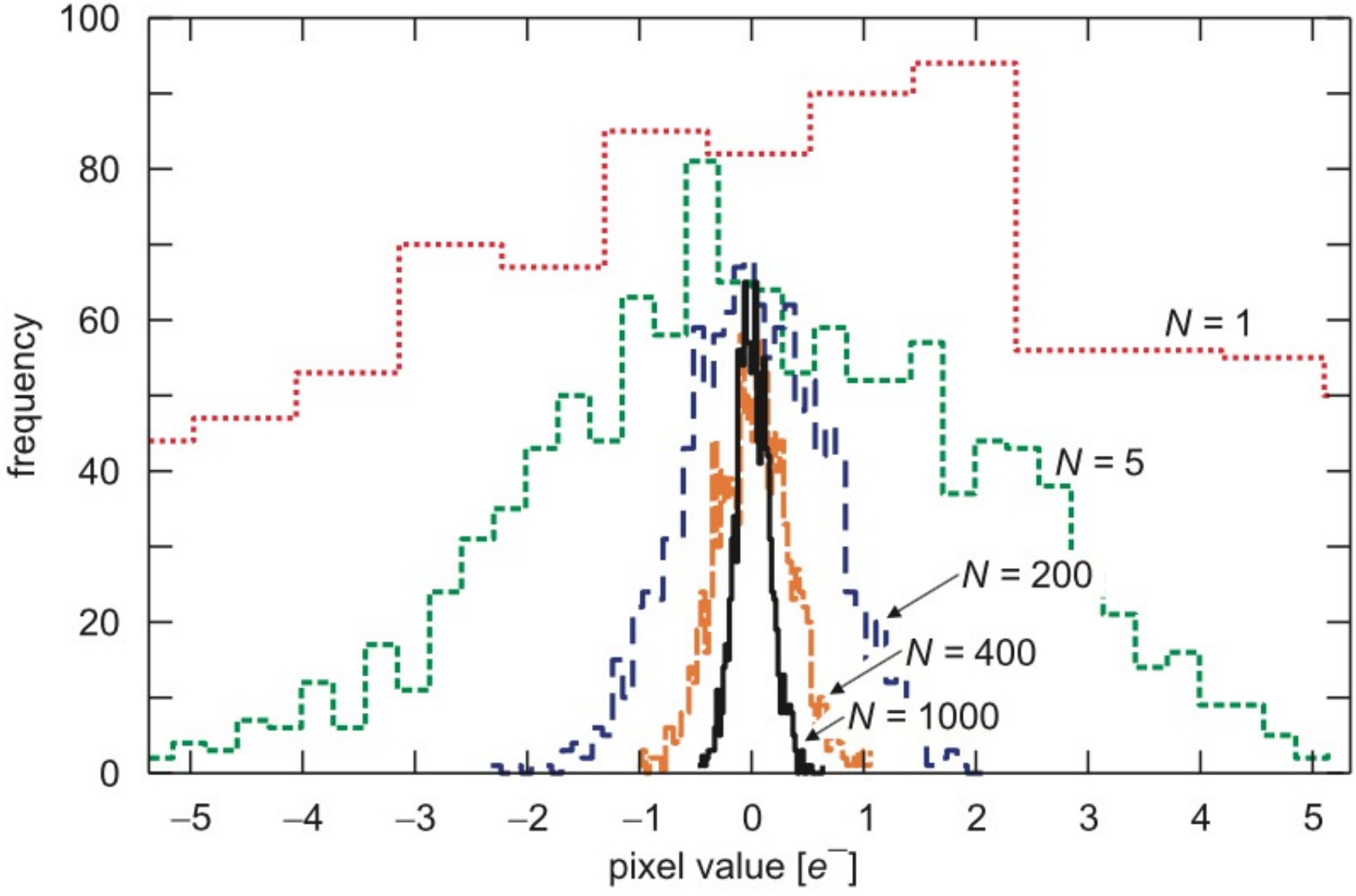
Hardware: Skipper CCD



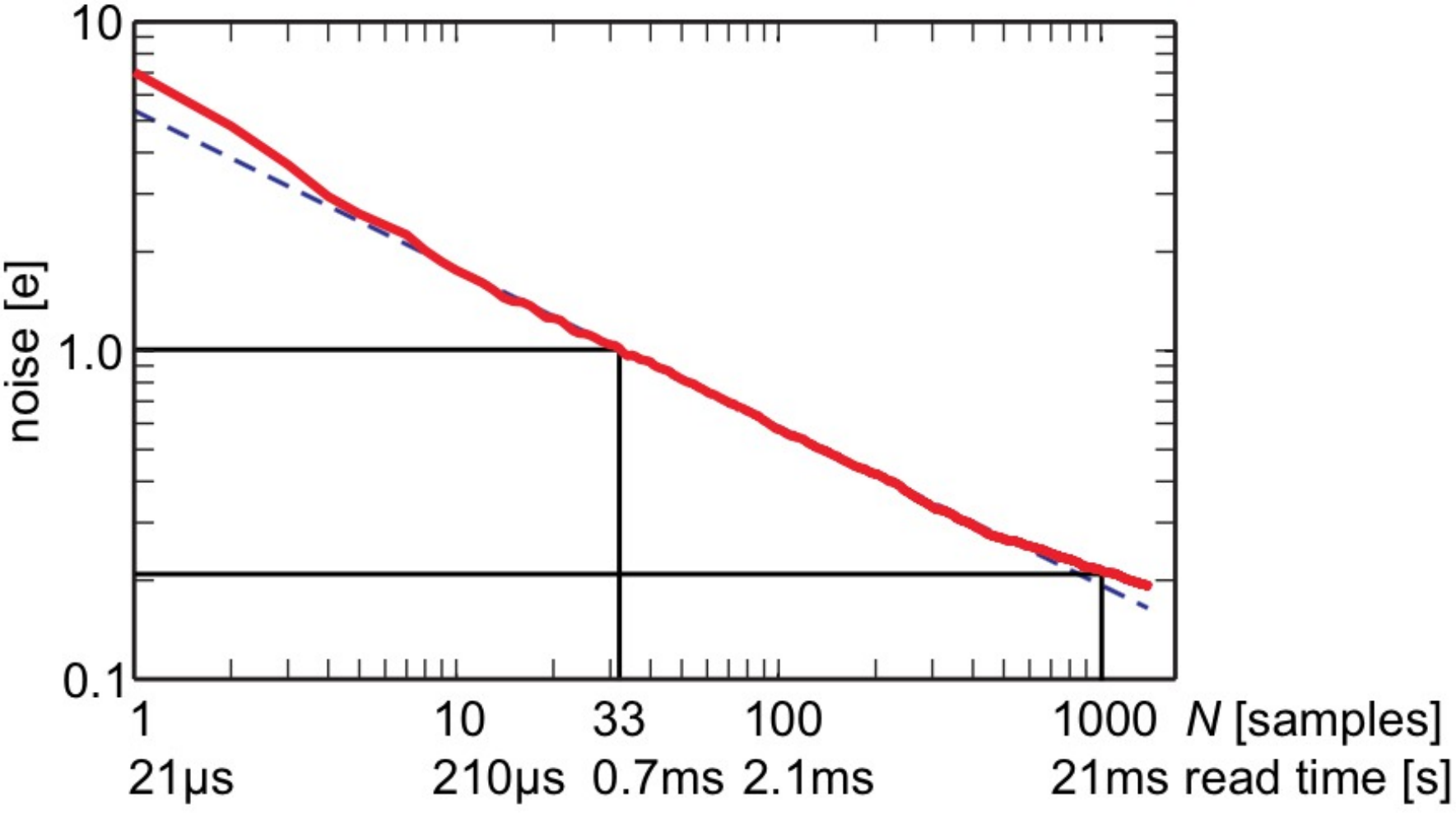
- Baseline is read first
- Then charge is moved to sensor node
- Charge is then read

- Charge is moved back and forth to SN
- Baseline and Charge read in sequence

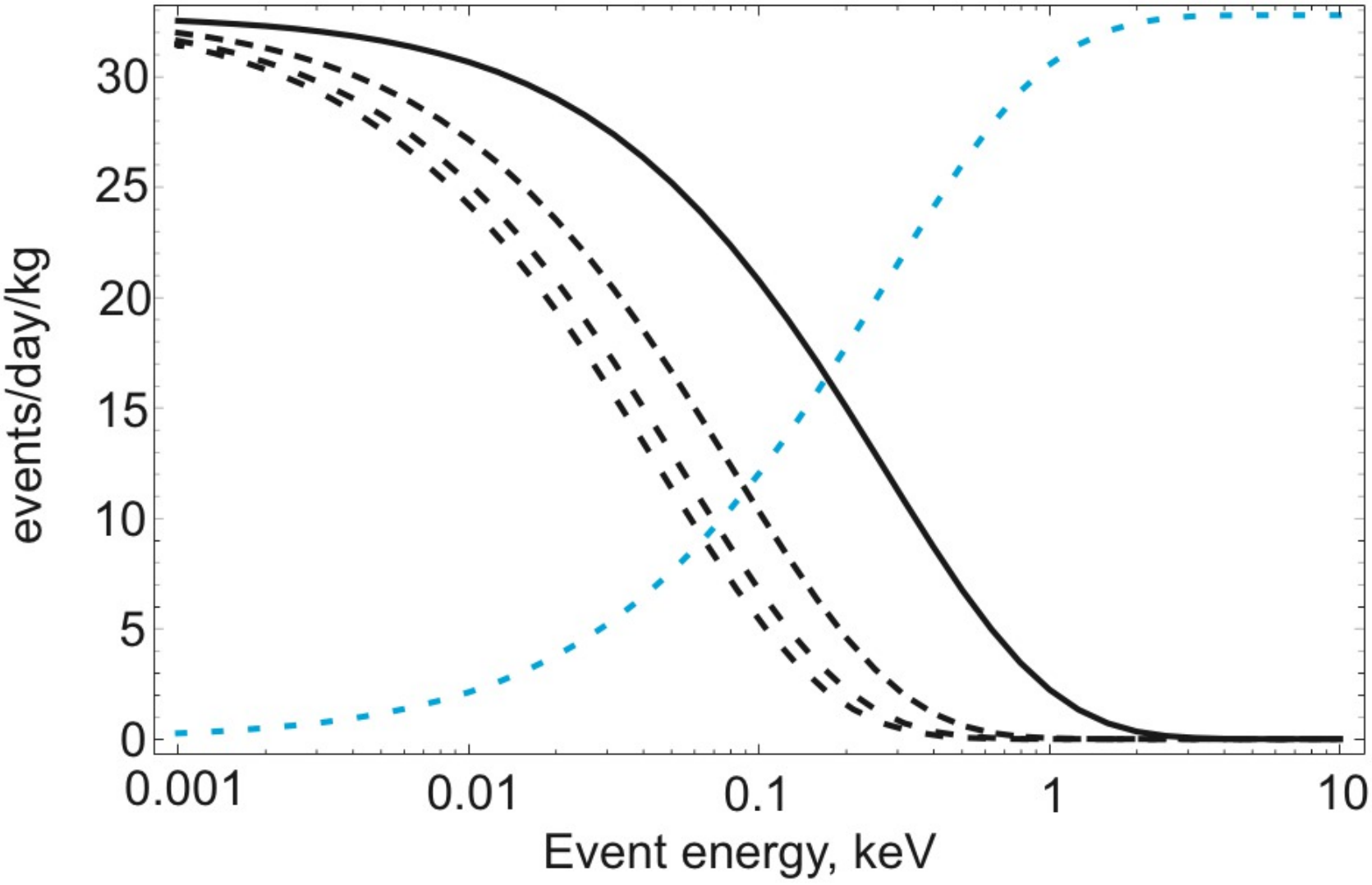
Skipper CCD: noise vs integration time



Skipper CCD: noise vs integration time



Other use: neutrino nucleus coherent scattering



50 g of DAMIC-CCD, 30 m away from Angra, 3.95 GW thermal power

Conclusions

- CCD interesting particle detector for rare events
- current efforts in DAMIC 100, upping the mass
- next effort: going to sub-electron readout noise
- possible use in other experiments (ex:CONNIE)

DAMIC, CONNIE small collaborations, very open to participation

References

- DAMIC: arXiv 1310.6688
- DAMIC-SNOLAB: arXiv 1407.0347
- Skipper CCD: arXiv 1106.1839
- CONNIE: arXiv 1405.576

A busy field → Spin dependent? Directional? Axions?