Towards an Infrared Photon Based Calibration of Super Cryogenic Dark Matter Search (SuperCDMS) Detectors

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Supervisor: Prof. Wolfgang Rau

Muad Ghaith

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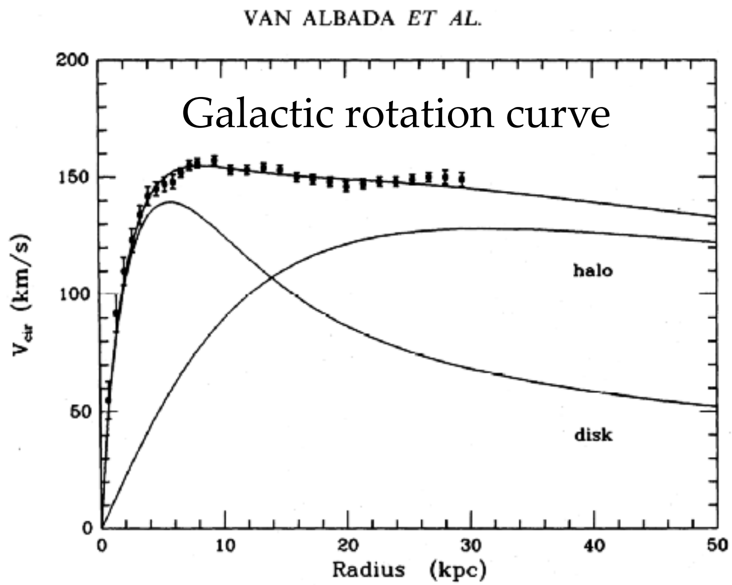
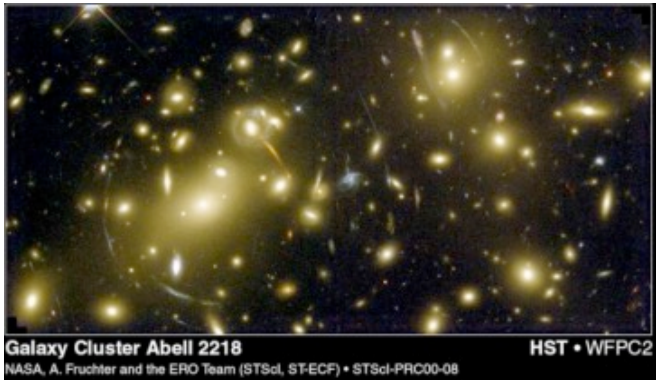
Introduction – Dark Matter

- We know that dark matter exists from its effects on normal "luminous" matter.
  - It drives formation and dynamics of galaxy.
  - It interacts weakly with luminous matter.
- Examples for evidence for dark matter:
  - Galactic rotation curves
  - Gravitational lensing
- Dark matter makes up ~80 % of the matter in the universe, but we don't know yet what it is.

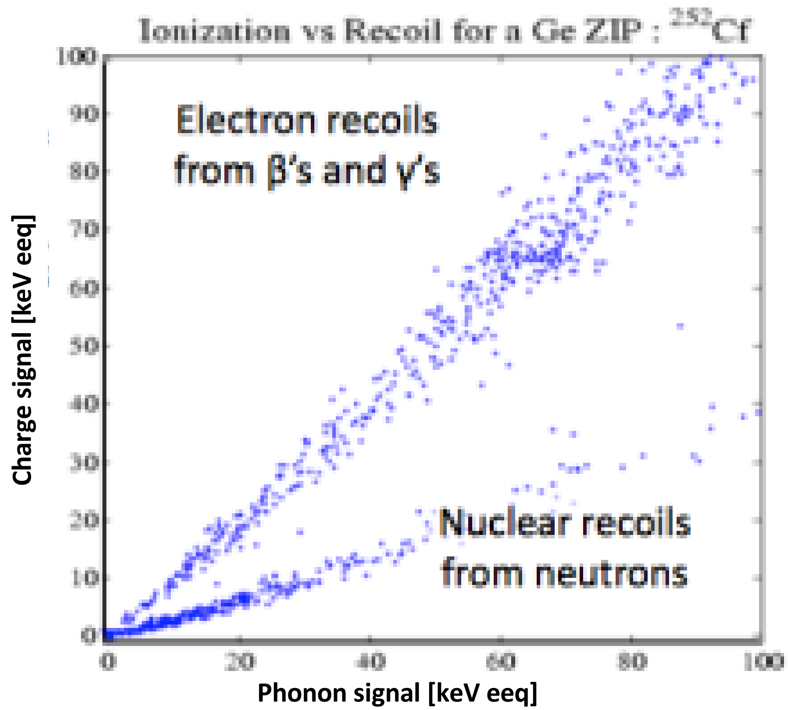




SuperCDMS Experiment

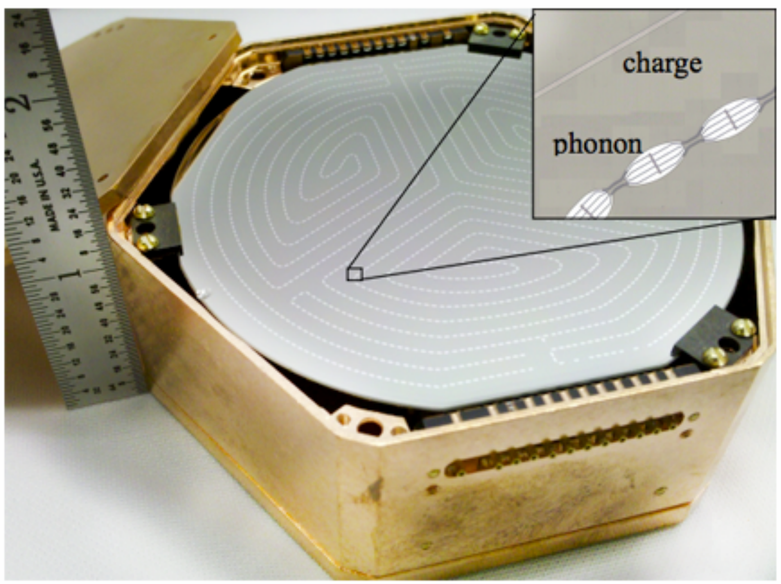
- SuperCDMS uses ultra-pure Ge and Si detectors to search for Weakly Interacting Massive Particles (WIMPs), a well motivated dark mater candidate particle.

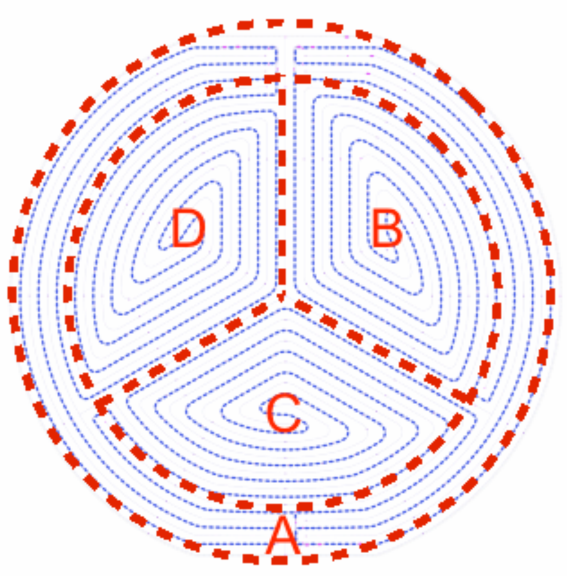
- Two signal types of signals are recorded in SuperCDMS:
  - Phonon signal (lattice vibrations); main information about interaction energy.
  - Charge signal; allows the identification of interaction type (electron recoils or nuclear recoil).



SuperCDMS iZIP detector

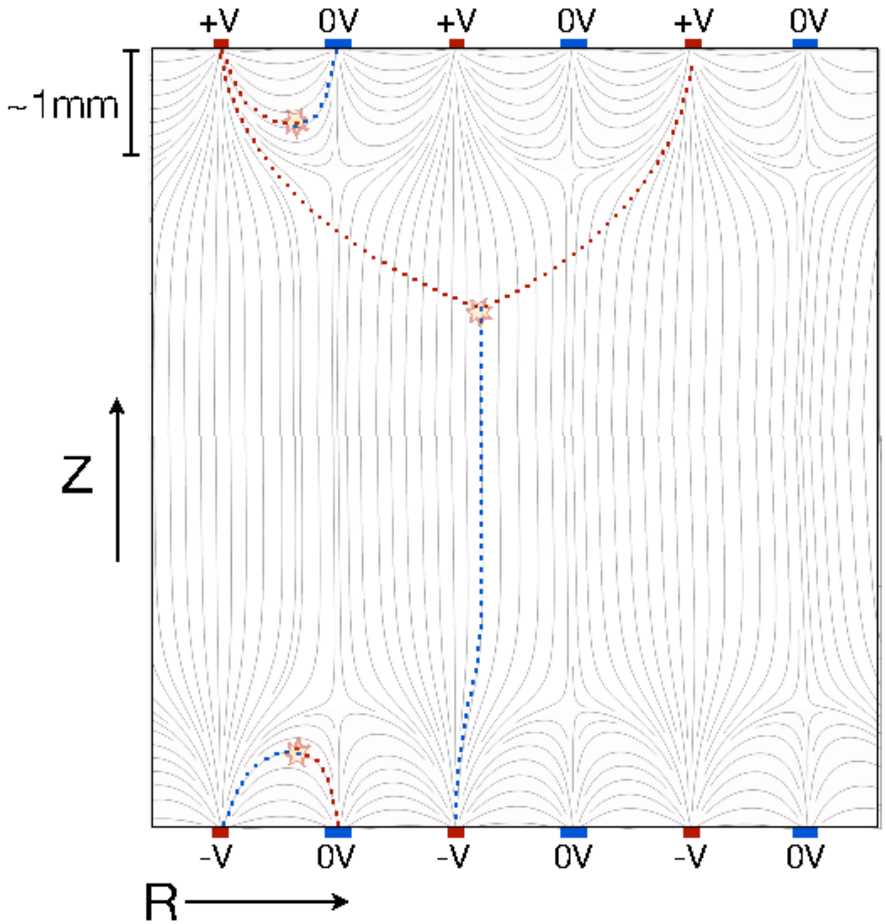
- The detector used in this measurement is a typical interleaved Z-sensitive Ionization Phonon (iZIP) detector.
- It has 4 phonon channels interleaved with 2 charge channels on each of the two sides.





Electric Field Configuration

- Phonon channels are grounded while charge channels are biased.
- Field geometry: surface events produce charge signal only on one side, bulk event on both sides.
- Surface field ~ 1 mm.

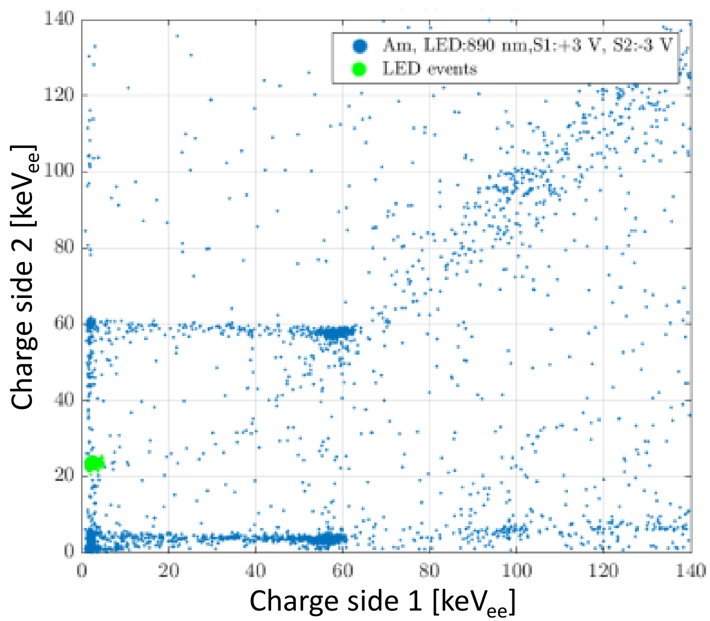


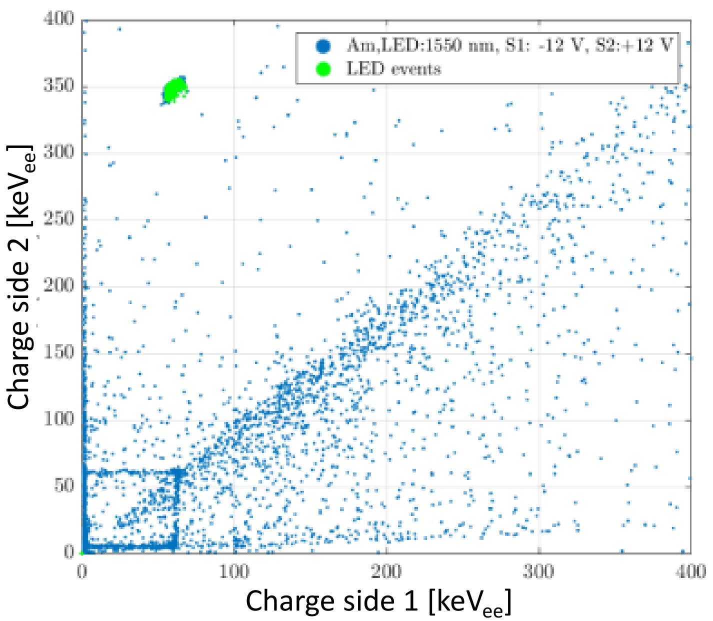
Main Goal

- The new generation of SuperCDMS at SNOLAB will be sensitive to the lower WIMP mass scale (below ~10 GeV/c^2). Hence, a lower background and lower energy threshold is needed.
- This in turn requires detector calibration at lower energy.
- Energy calibration for SuperCDMS is traditionally done with radioactive gamma sources. However, low energy gammas cannot penetrate the cryostat.
- Therefore we explore the use of IR photons for the calibration of the new SuperCDMS low-mass dark matter detectors.

Test with Optical Fiber

- First test: use IR LEDs at room temperature; transmit light to detector via optical fiber.
- Use different wavelength LEDs (890 nm and 1550 nm), compare to 60 keV gammas (partial surface, partial bulk) from ^{241}Am.
- 890 nm: absorbed at surface (few μm); 1550 nm penetrates partially through the surface field (~1 mm).





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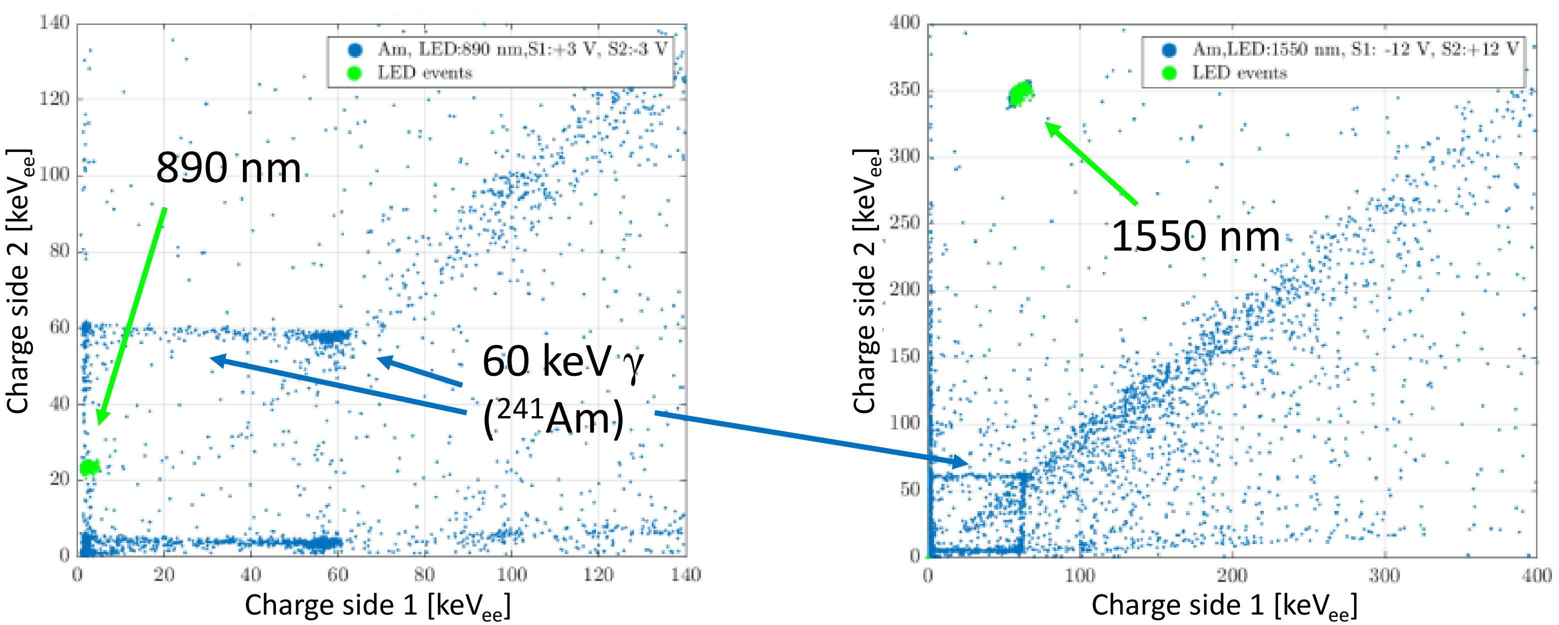
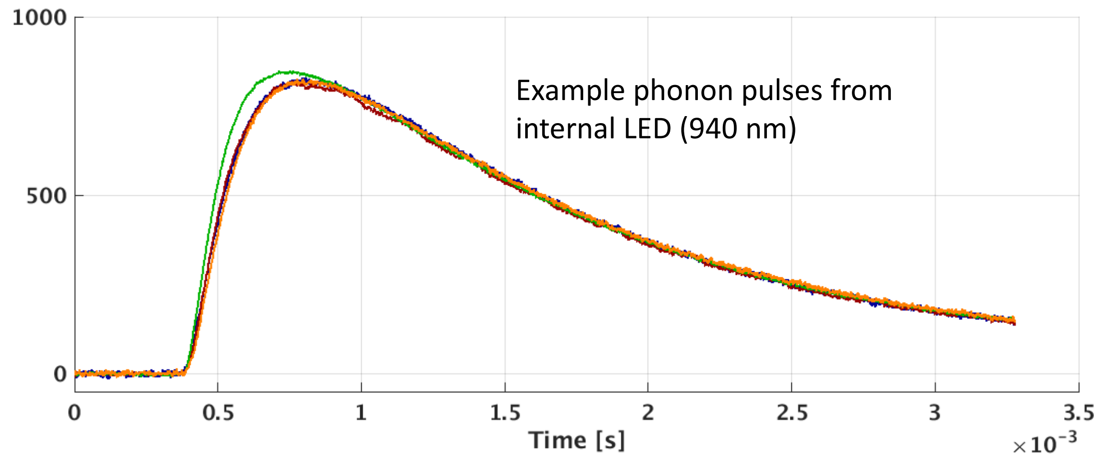
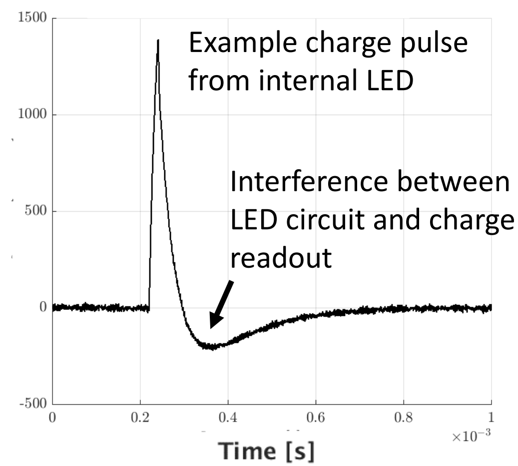
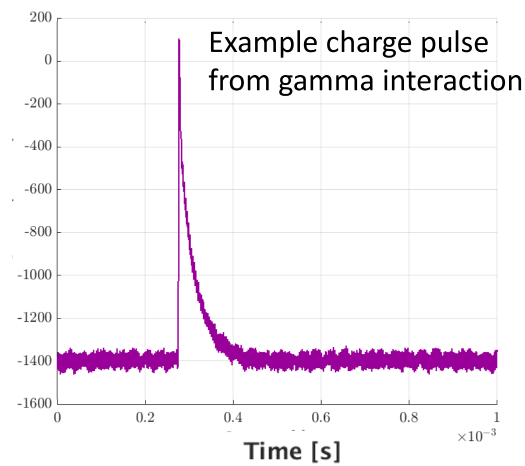


First attempt with internal (cold) LED

- Also tried to use internal LEDs (usually used to condition detectors).
- Can see LED induced pulses without heating detector.
- BUT: standard LED circuit interferes with charge readout.
- Success with internal LED and operational issues ascribed to the use of the fiber led to second experiment with internal LEDs.

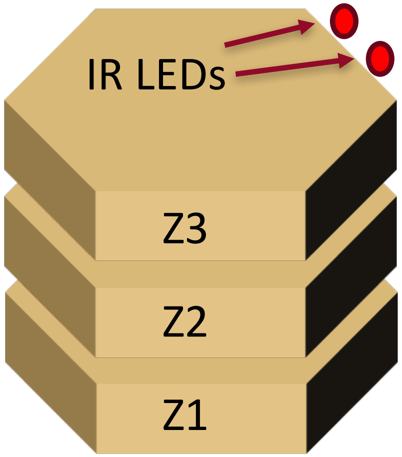


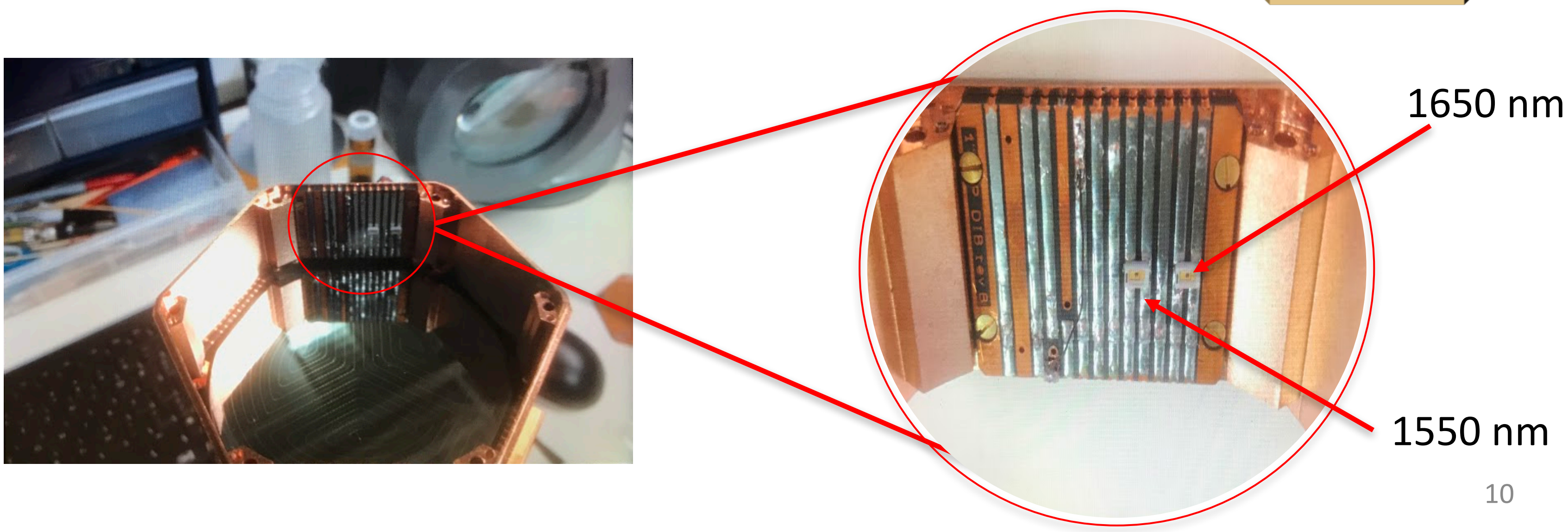




Measurements with Internal LEDs

- 2 LEDs (wavelengths 1650 nm & 1550 nm)
- Stack of three detectors (Z1, Z2, Z3) mounted; two (Z1, Z3) used for measurements
- LEDs closer to Z3
- ^{241}Am – source (60 keV) used to calibrate the energy scale

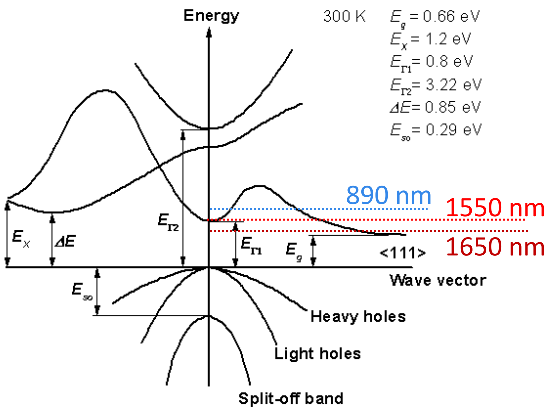


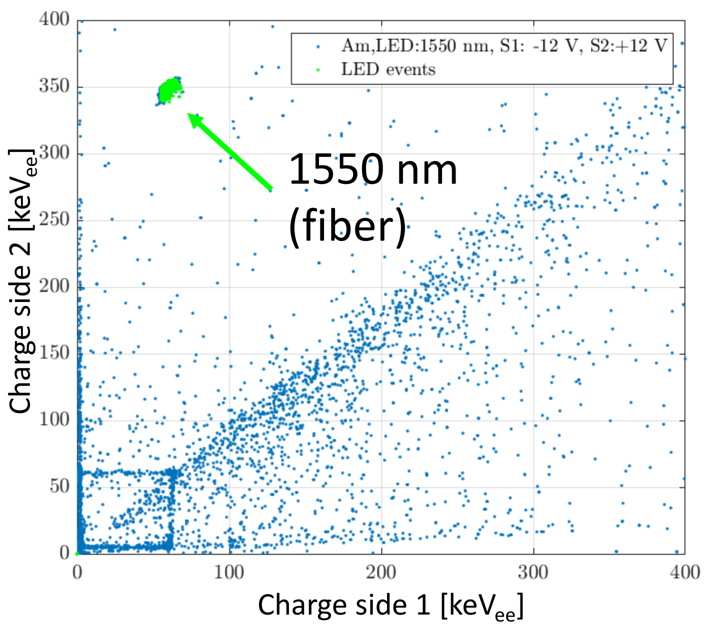


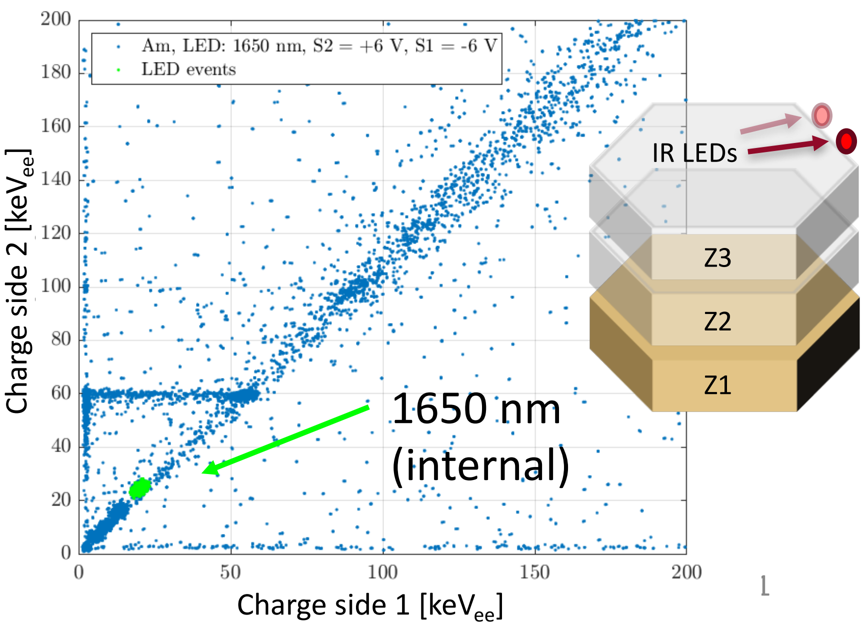
IR photon penetration depth in Ge crystal

Band structure of germanium:

- 1550 nm (0.80 eV): produces near-surface events (very close to direct band gap)
- 1650 nm (0.75 eV) produces bulk interactions (energy well below direct band gap: low interaction probability)

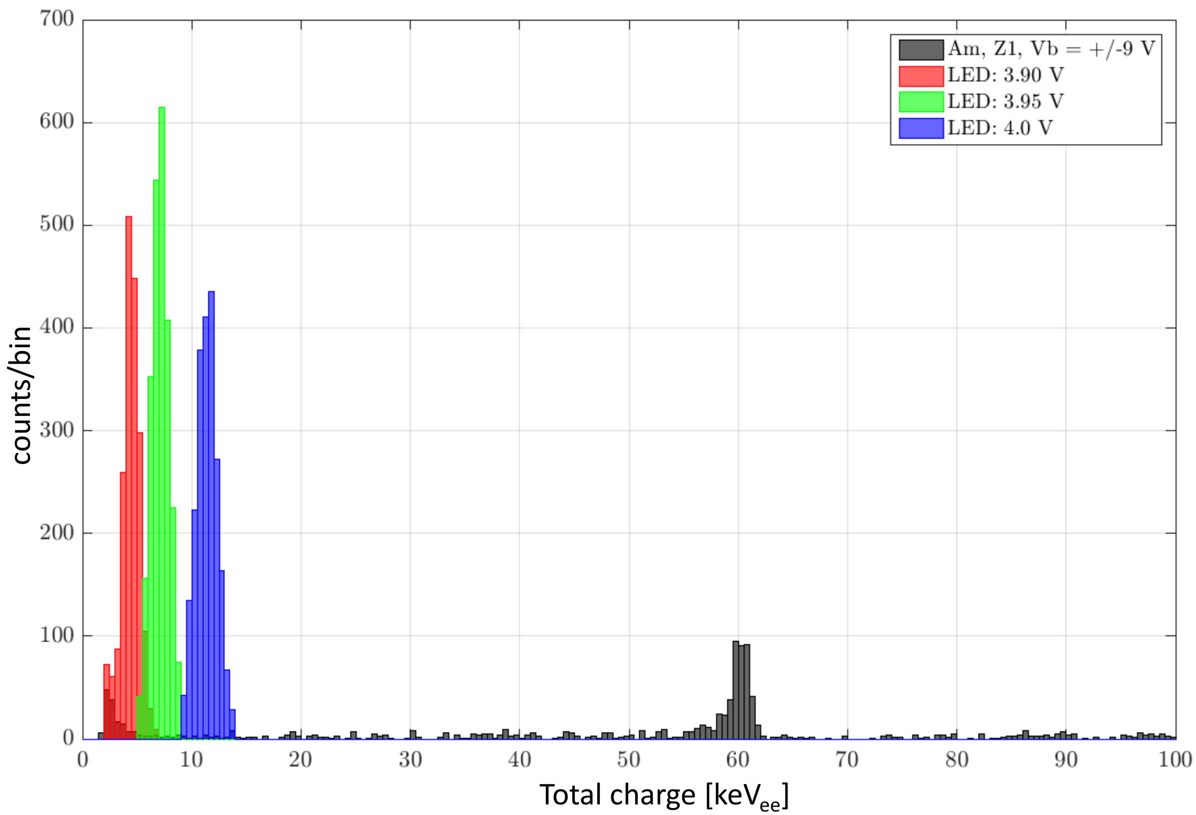






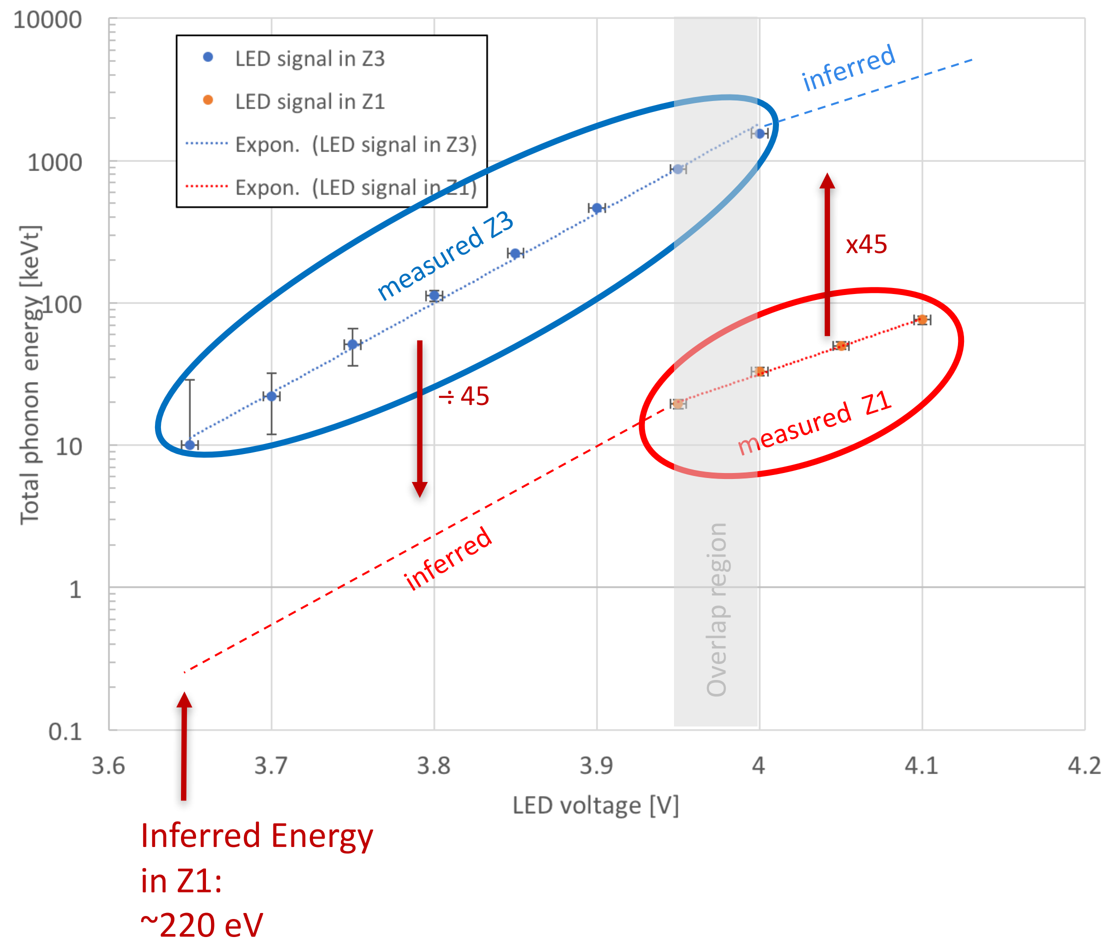
Infrared Photon - Energy Calibration

- The x-axis represents the number of e/h pairs resulting from the interaction between photons and target atoms.
- The energy of the IR photons can be controlled by changing the LED operating voltage.



Measure/Calibrate Low Energies

- Lowest stable operation of LED produces ~10 keV in near detector (Z3)
- Much fewer photons reach Z1
- Measure ratio between Z1 and Z3 signal at high LED voltage
- Z1/Z3 ratio should be constant (probability for photon to reach Z1 depends on geometry)
- Infer energy in Z1 at lowest LED setting (though cannot be measured with present detector/electronics)



Conclusion

- The LED signal is relatively stable over time and measurements are repeatable within uncertainty
  $\rightarrow$ can use internal LED for stability control (faster and easier than use of radioactive source)
- Possible to tune the LED signal to a very low energy scale
  $\rightarrow$ promising as method for very low energy calibration
- Further tests needed to better understand the behavior of IR photons in our Ge detectors.

THANK YOU

Questions?

BACKUP SLIDES

IR photon penetration depth in Ge crystal

TABLE 1. Characteristics of the infrared LEDs.

LED reference	L8245	L7850	L7866
Emission wavelength (μm)	1.65	1.45	1.30
Photon energy (eV)	0.75	0.86	0.95
Absorption length in Ge (μm) [9,10]	1.7e5	400	1

http://dx.doi.org.proxy.queensu.ca/10.1063/1.3292341