Feasibility Study for an IR-LED Based Calibration System for SuperCDMS Detectors

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ABSTRACT

The Super Cryogenic Dark Matter Search (SuperCDMS) is one of the leading experiments in the direct search for the Weakly Interacting Massive Particles (WIMPs) in the mass range below ~10 GeV/c^2. Particles are detected in cryogenic semiconductor detectors via TES-based phonon sensors and charge collecting electrodes [1]. The next generation of the experiment will be deployed at SNOLAB and aims to further reduce the detection threshold to a few tens of eV by reducing the noise in the readout circuit and improving the design of the phonon sensors [2]. Traditionally, radioactive sources were used to calibrate the energy scale and to monitor detector stability. However, in most cases, it takes a long time to accumulate enough events to identify peaks in the energy spectrum. Moreover, gammas at low energy as would be desired for the lower threshold detectors cannot penetrate the cryostat. This study investigates the possibility of using pulsed infrared LEDs mounted inside the cryostat as alternative calibration sources.

MAIN QUESTIONS

- Can we use pulsed IR LEDs mounted next to the detectors to monitor the detector stability?
- Can we use IR LEDs to establish or to confirm the energy scale at low energies?

EXPERIMENTAL SETUP

- SuperCDMS detector test facility at Queen's: dry dilution fridge (~10 mK base)
- Detector package: 3 Ge iZIPs from SuperCDMS Soudan (Z1-Z3) tower

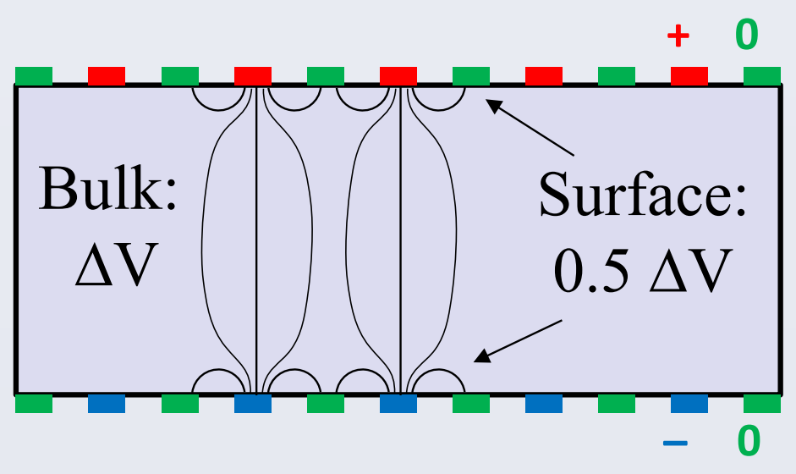


Fig. 1. Electric field map in the iZIP detectors. Interleaved electrodes: identify surface events (charge signal distribution).
Luke amplification: half for surface events (proportional to potential).

- 2 Surface mount LEDs (manufactured by Marubeni) mounted in an empty detector housing next to the top surface of Z3
- Only one (peak wavelength 1650 nm) used for measurements reported here

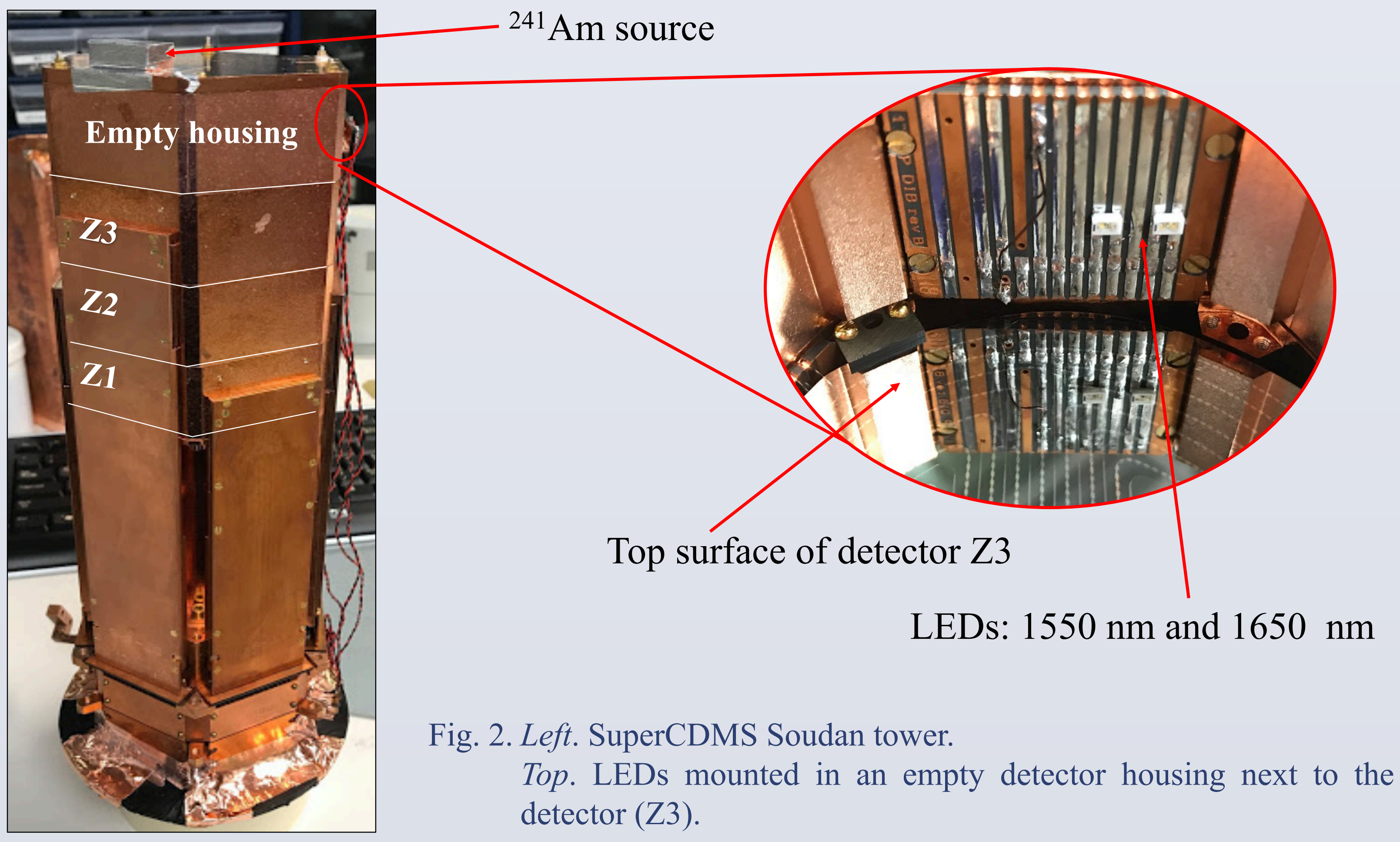


Fig. 2. *Left*. SuperCDMS Soudan tower.
Top. LEDs mounted in an empty detector housing next to the top detector (Z3).

- 1650 nm corresponds to 0.75 eV, well below direct band gap [3] with large penetration depth [4] → can probe bulk properties
- ^{241}Am source for absolute energy calibration (60 keV gammas)

MEASUREMENTS

Stability

- Use Z1; find LED settings (pulse time: 120 μs, f: 16 Hz, I: ~0.05 mA) that produce low-energy pulses
- Take data with LED and ^{241}Am source
- Repeat same measurement the next day

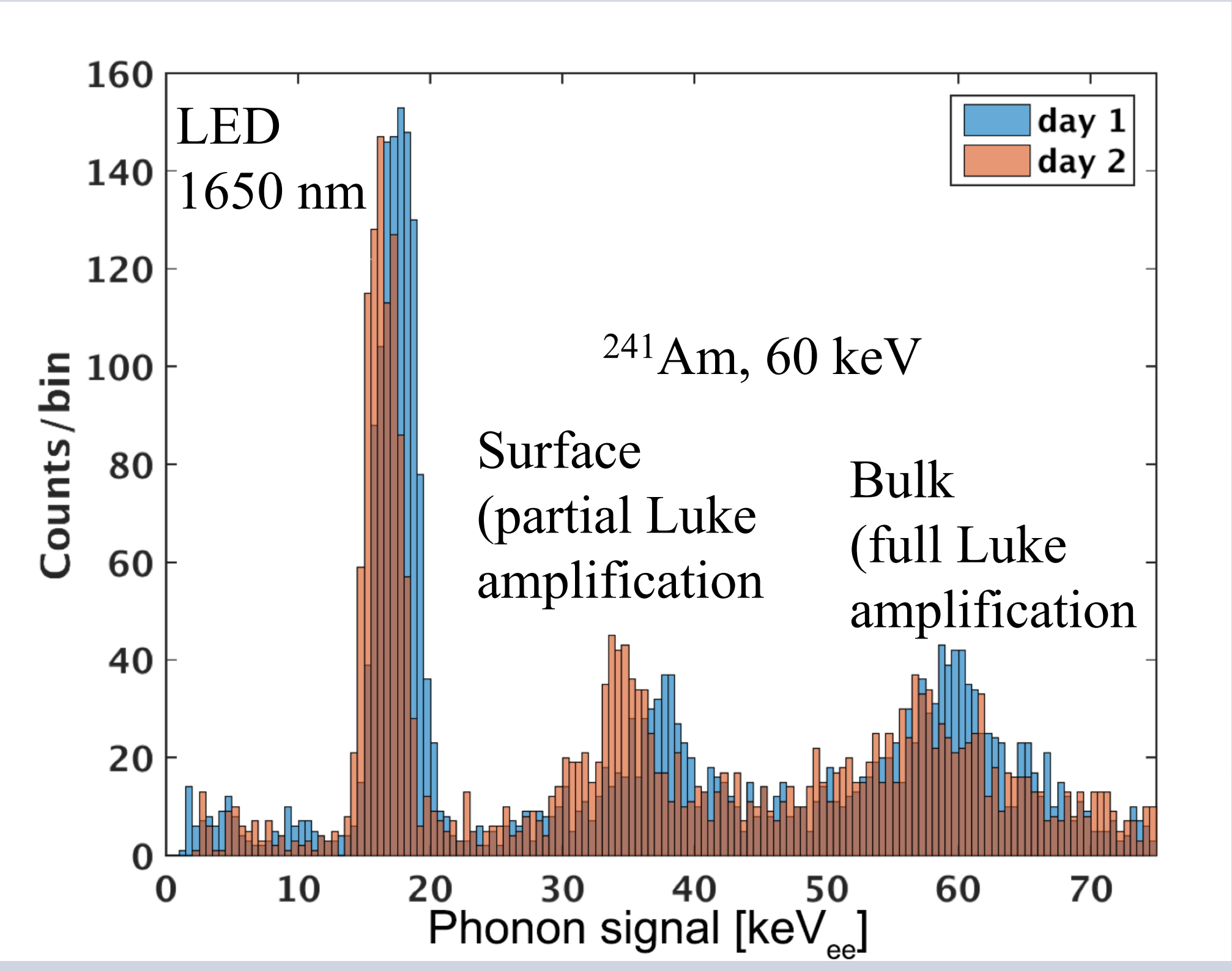


Fig. 3. Comparison of LED pulse amplitudes using the same LED settings acquired at a two consecutive days.

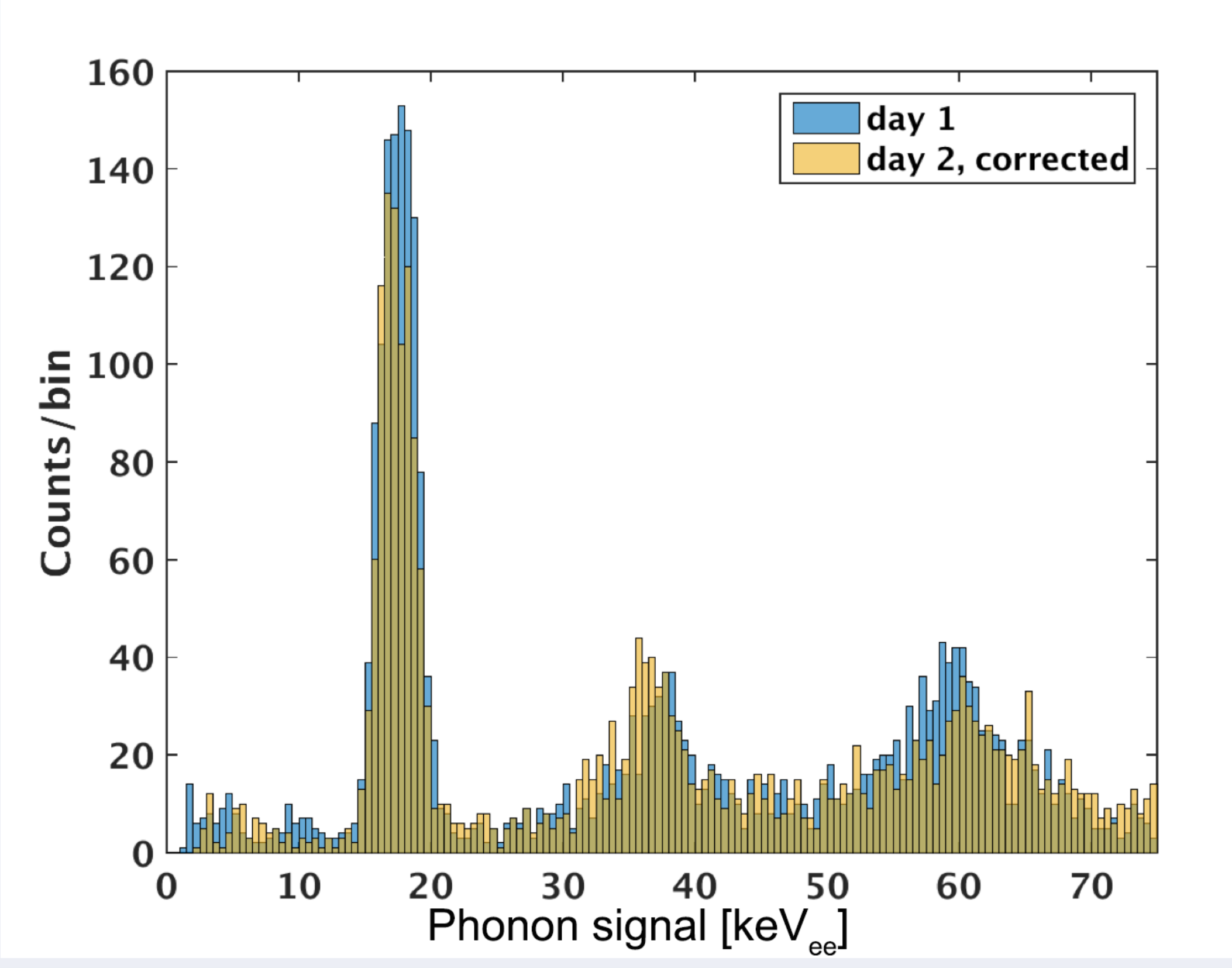
Right peak: 60 keV absorbed in bulk, full Luke amplification.

Middle peak: 60 keV absorbed at surface: half Luke amplification.

Left peak: pulses from IR LED (1650 nm; same settings both days)

- Detector performance clearly worse on day 2 (few percent shift)
- Effect also seen in charge (most likely explanation: detector not properly neutralized)
- Effect stronger for surface events than for bulk (^{241}Am)

Fig. 4. Apply correction to phonon energy scale: LED peak is now lined up; correction factor between factors for surface and bulk correction (consistent with LED pulse being a mix of surface and bulk hits)



Low Energy

- Pulse in detector adjacent to LED very large
- Take advantage of 'shadowing': look at detector farther away from LED
- Can control LED pulses down to a few keV, limited by detector threshold (Queen's setup not optimized for low-threshold measurements)

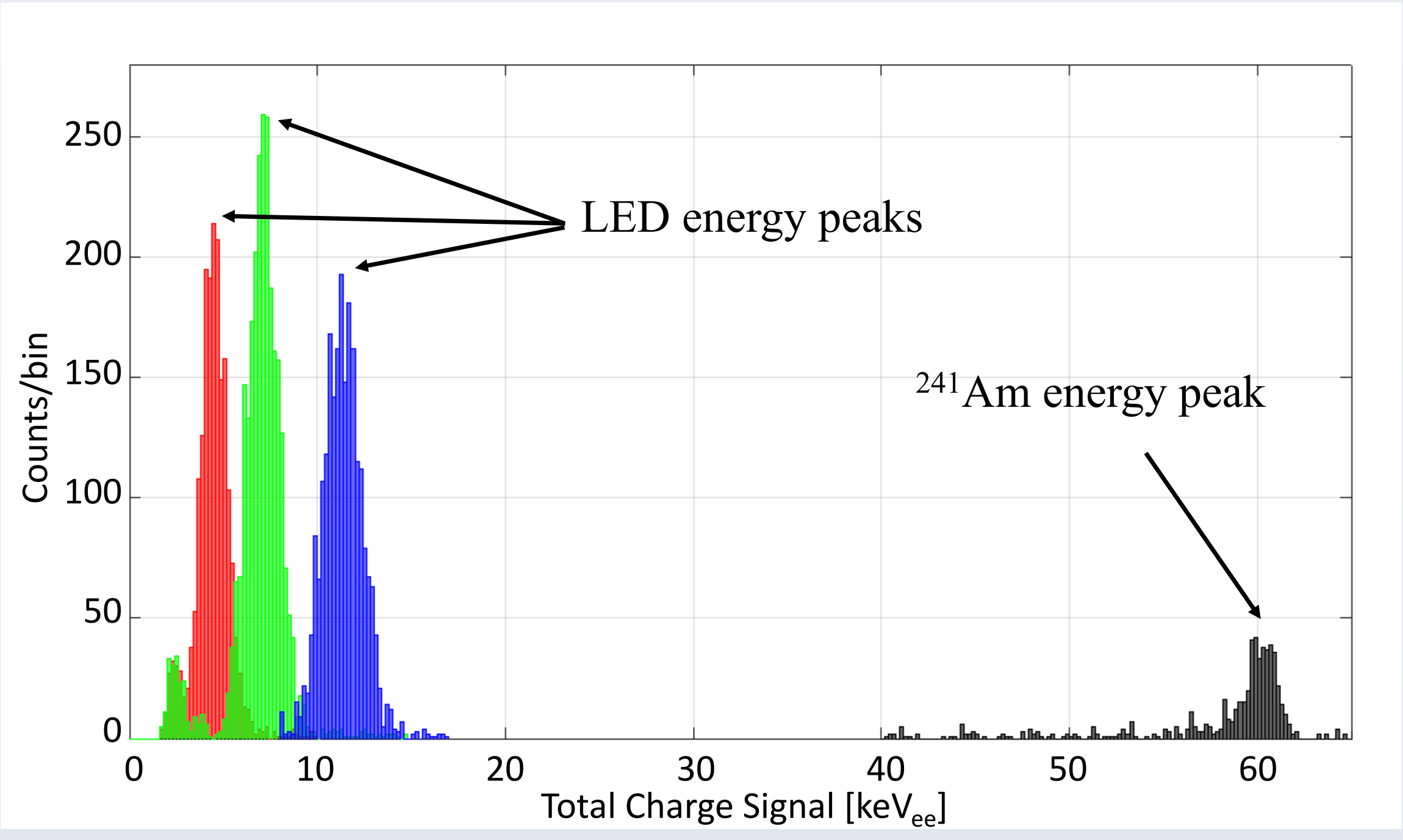
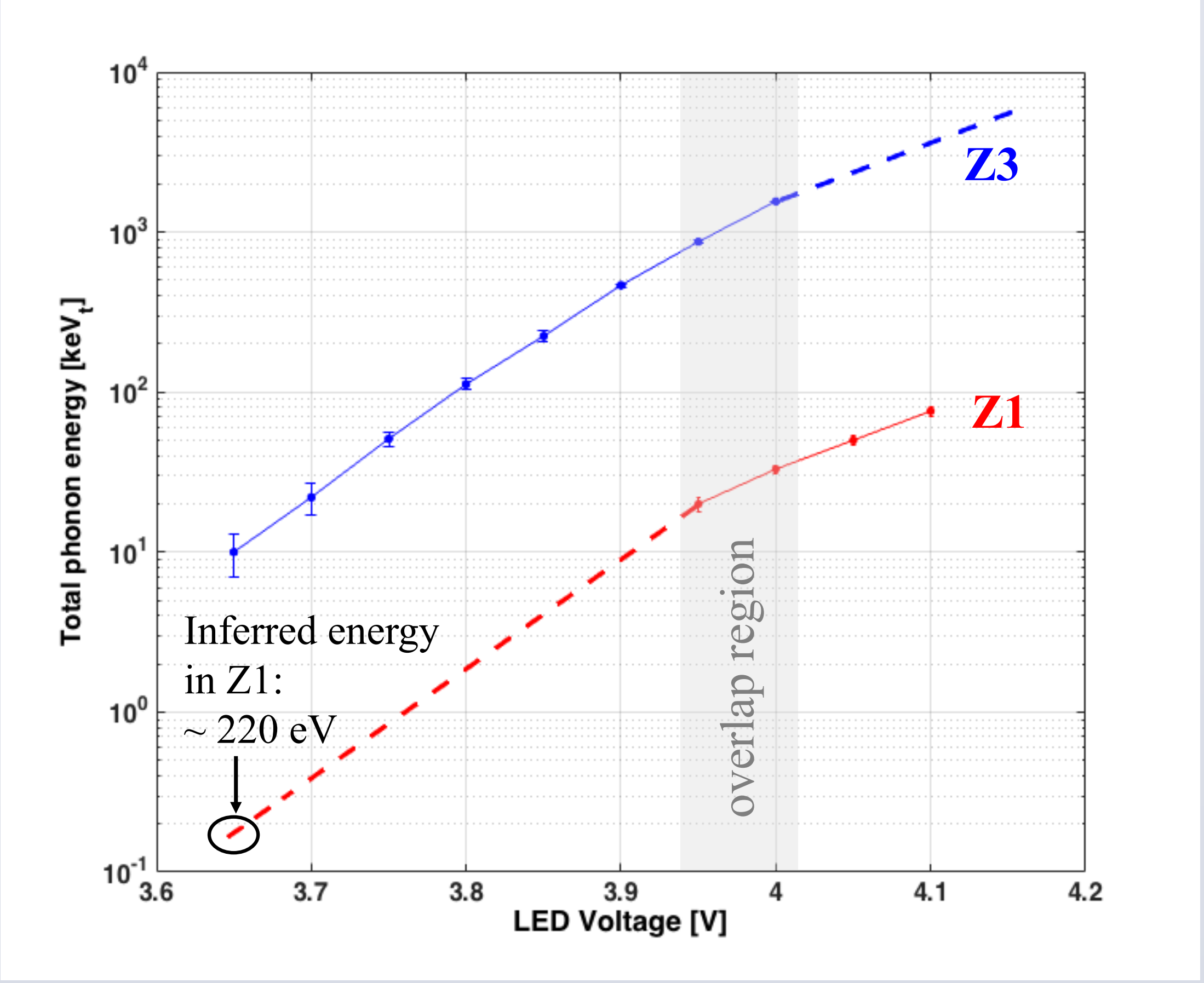


Fig. 5. Low energy IR LED pulse distributions in Z1 (three different LED settings with 60 keV peak from ^{241}Am for reference): good control over LED down to a few keV

- Amplitude ratio in near and far detectors should only depend on geometry
- Measured ratio: 45.3 ± 1.8 (2 settings, above threshold in Z1, below saturation in Z3)
- Reduce pulse amplitude, measure in Z3: good control down to ~10 keV

Fig. 6. Comparison of LED pulse measurements in Z1 and Z3: amplitude ratio measured in 'overlap region': 45.3 ± 1.8; should be independent of energy.

Lowest LED setting with good control: 10 keV in Z3 → inferred energy deposition in Z1: ~220 eV



- Good control over LED pulses down to low energy
- New SuperCMDS detector towers with different geometry and more detectors: shadowing likely stronger
- Promising method to extrapolate energy scale down to energies in the eV range

CONCLUSIONS

In a first set of tests we have shown that IR LEDs mounted right next to SuperCDMS detectors at ~45 mK can be operated consistently generating photon induced pulses in the detectors without adverse effects on the detector performance. The results are encouraging for their application for low energy calibration and stability monitoring. More measurements are being conducted to establish the method and improve our understanding of IR photon interactions at low temperatures.

REFERENCES

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