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

2017 CAP Congress – Queen’s University

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May 29, 2017
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 matter 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.
• 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 $\sim 1$ 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 $^{241}\text{Am}$.
- 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)
• 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.
• 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)

Inferred Energy in Z1: ~220 eV
Conclusion

• The LED signal is relatively stable over time and measurements are repeatable within uncertainty → 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 → 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

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

<table>
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<tr>
<th>LED reference</th>
<th>L8245</th>
<th>L7850</th>
<th>L7866</th>
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<tr>
<td>Emission wavelength (µm)</td>
<td>1.65</td>
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<td>Photon energy (eV)</td>
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<td>Absorption length in Ge (µm) [9,10]</td>
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