Vibration and EMF Backgrounds at NEXUS

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FERMILAB-POSTER-19-095-AE

Background

NEXUS (**N**orthwestern **EX**perimental **U**nderground **S**ite) is a dark matter detector prototyping and calibration facility at Fermilab. It is part of the SuperCDMS collaboration, which is focused on exploring light-WIMP parameter space. The NEXUS cryostat, typically operated at temperatures of about 10 mK, is located 107 meters underground in the MINOS Near Detector Hall to reduce cosmic ray backgrounds. We characterized the vibrational and electro-magnetic frequency (EMF) backgrounds surrounding the cryostat and investigated how these backgrounds transfer into the detector itself.

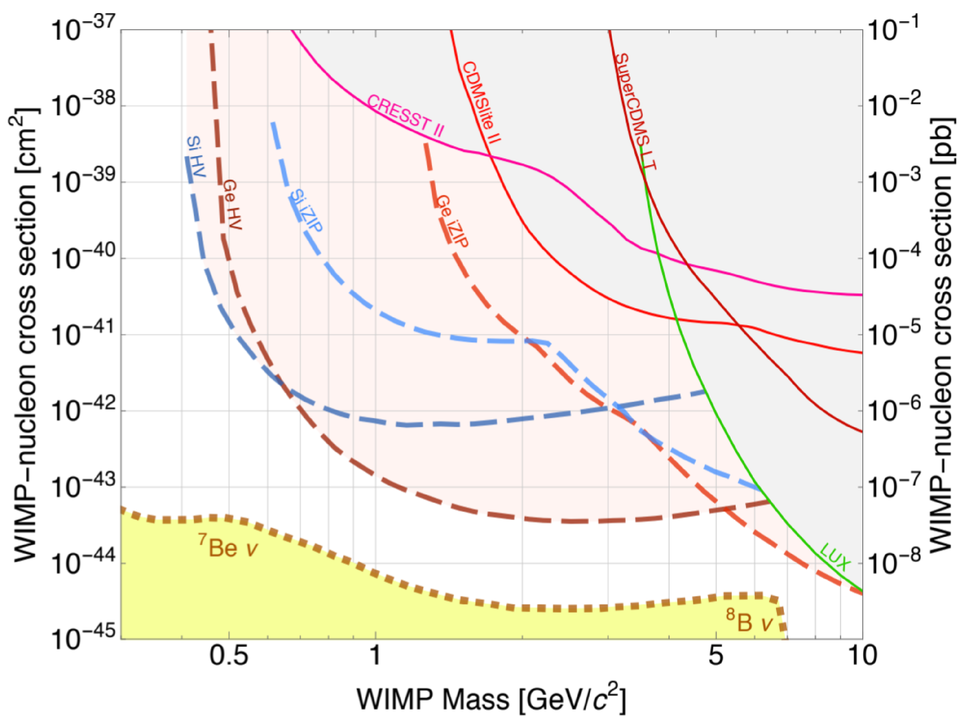

Figure 1. Projected SuperCDMS SNOLAB limits[1].

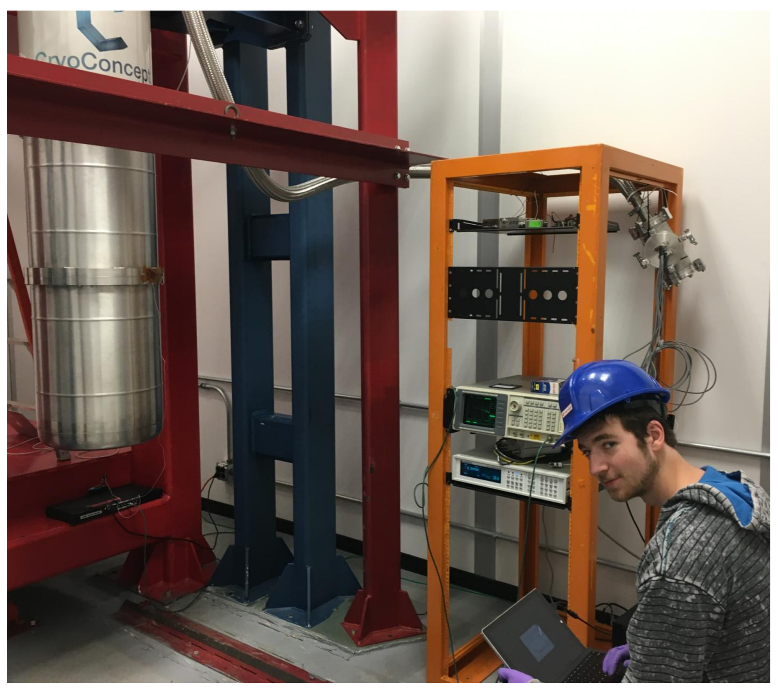

Figure 2. NEXUS cleanroom and cryostat.

Detector Operation

Collisions in the detector payload create electron-hole pairs whose energy is converted to quantized thermal vibrations known as phonons[2]. These phonons heat up the **T**ransition-**E**dge **S**ensors (TES), which respond strongly to small changes in temperature.

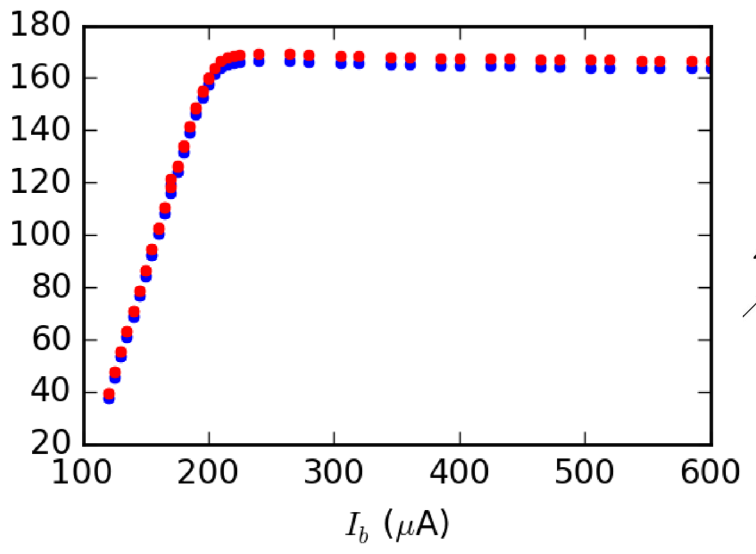

Figure 3. TES response curve[2].

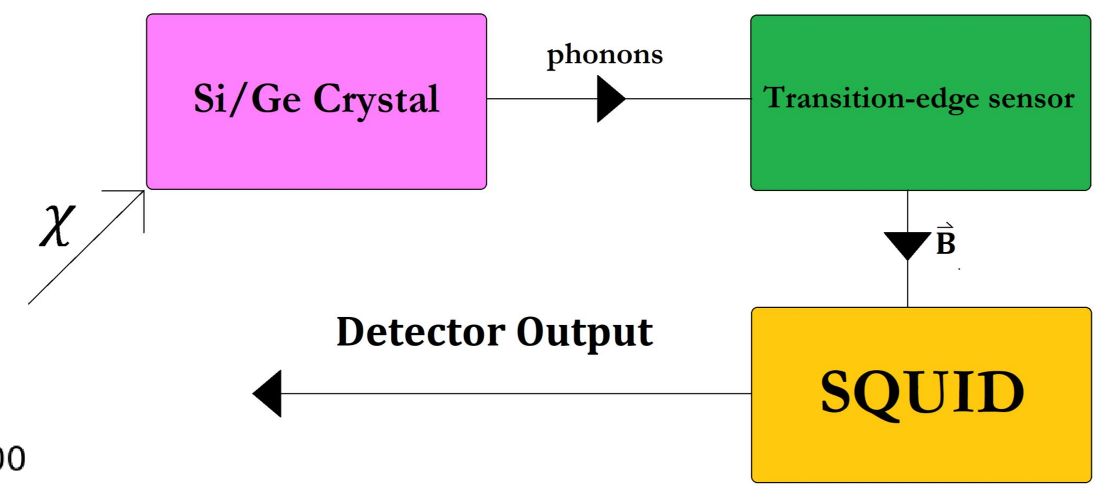

Figure 4. Information flow between different components of a CDMS HV detector.

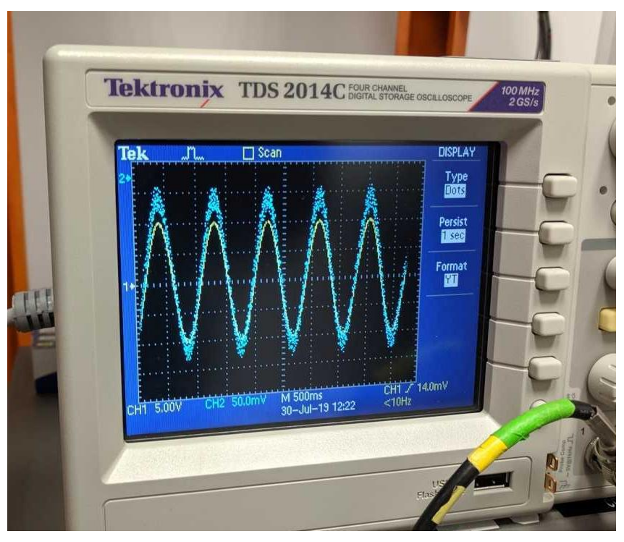

Figure 5. SQUID modulation curves.

The current through the TES is measured by the magnetic field it creates through a **S**uperconducting **QU**antum **I**nterference **D**evice (SQUID). The SQUID output is carried out of the fridge by a chain of temperature-specific wiring that was installed over the course of this investigation.

Measurements

Vibration on and around the cryostat was measured using a piezoelectric transducer. Sets of measurements were taken with fridge equipment in different states, and with mechanical and acoustic excitation of different components. EMF around the cryostat and potential noise sources like computer equipment and lights was measured using a loop of copper wire.

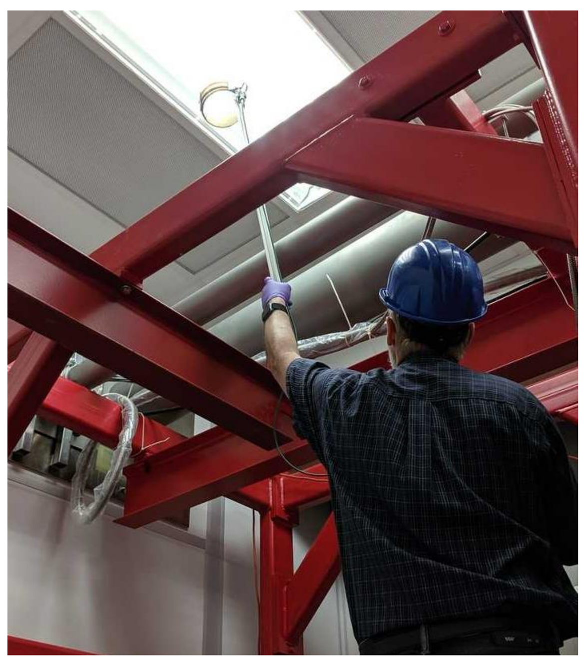

Figure 6. Using the copper wire loop to measure EMF around the cleanroom lights.

Results and Next Steps

The frequency signatures of fridge components and local EMF sources were identified, along with the resonance frequencies of the cleanroom and cryostat.

Noise Source	Noise Type	Primary Frequencies
Fluorescent Lights	EMF	43.5 kHz
Laptop	EMF	2.2 MHz
Lightswitch (AC power)	EMF	60 Hz
Compressor	Vibrational	914 Hz
Pulse Tube	Vibrational	140, 1690 and 1950 Hz
Turbo Fan	Vibrational	820 Hz
Cleanroom resonance	Vibrational	210 Hz
Cryostat resonance	Vibrational	16, 21, 28 and 430 Hz

Table 1. Sources of vibration and EMF noise, along with their primary frequencies.

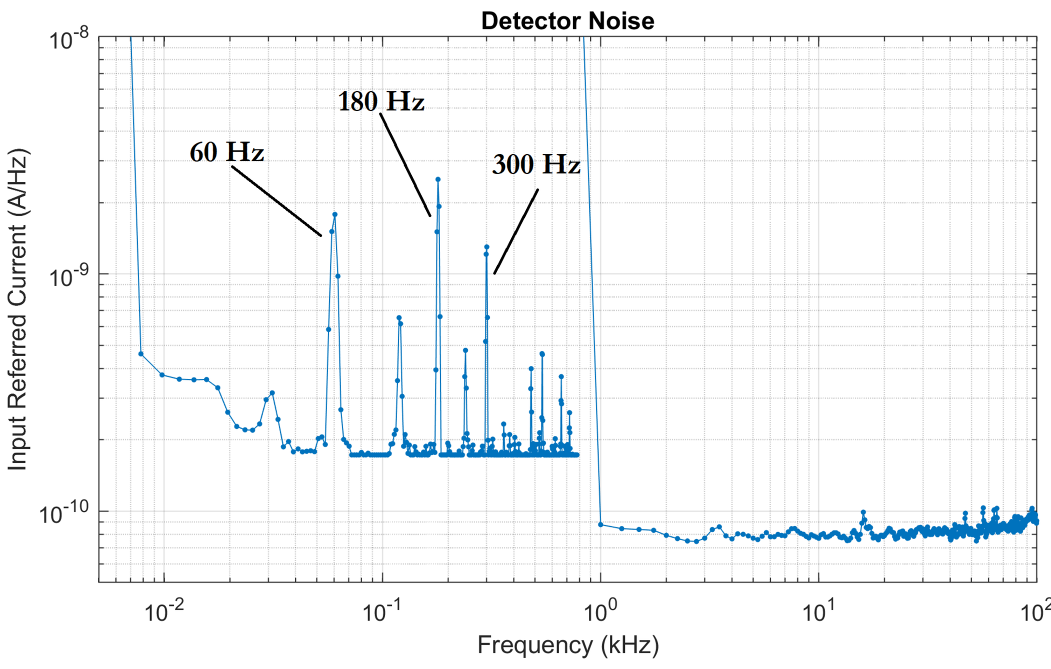

Figure 7. Adjusted SQUID output noise, with two ranges collated.

Detector output noise was dominated by 60 Hz AC power and its harmonics. However, the component of the detector most sensitive to vibration noise, the TES, was not in the desired superconducting state during data-taking. Thus, the full extent of outside vibrational coupling to the detector remains unknown.

Next steps include:

- Measure detector noise with superconducting TES
- Improve adapter cable shielding to reduce 60 Hz noise
- Lower detector readout noise floor

References

[1] R. Agnese *et al.*, "Projected Limits of the SuperCDMS SNOLAB experiment"

[2] N. Kurinsky, "The Low-Mass Limit: Dark Matter Detectors with eV-scale Energy Resolution"

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.