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# SuperCDMS Cold Hardware Design

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**Abstract** We discuss the current design of the cold hardware and cold electronics to be used in the upcoming SuperCDMS Soudan deployment. Engineering challenges associated with such concerns as thermal isolation, microphonics, radiopurity, and power dissipation are discussed, along with identifying the design changes necessary for SuperCDMS SNOLAB. The Cryogenic Dark Matter Search (CDMS) employs ultrapure 1-inch thick, 3-inch diameter germanium crystals operating below 50 mK in a dilution cryostat. These detectors give an ionization and phonon signal, which gives us rejection capabilities regarding background events versus dark matter signals.

**Keywords** SuperCDMS · Dark mater · Low temperature detectors · Cold hardware · Cosmology · Particle astrophysics · LTD-14 · Sadoulet group · UC Berkeley · Cryogenic · Soudan · SNOLab · Phonon · WIMP · Galaxy

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## 1 CDMS

The Cryogenic Dark Matter Search (CDMS) uses ultrapure 1-inch thick, 3-inch diameter germanium crystals operating below 50 mK in an attempt to directly detect dark matter in the form of Weakly Interacting Massive Particles (WIMPs). Each detector produces ionization and phonon signals and is equipped with 2 charge collection electrodes and 4 transition edge sensor arrays (TES). The ratio of ionization to phonon signal gives us the ability to distinguish between electron and nuclear recoils, thus allowing us to distinguish between background events and a WIMP signal. The cold hardware aspect encompasses all assemblies within the cryostat. These assemblies include the physical support, detector packaging, interconnections, and biasing and preamplification components [1]. To reduce background, the interleaved geometry promises to reject surface events with high efficiency, which has been so far the limiting factor in CDMS. Each detector is equipped with 8 SQUIDs, 2 JFET cards, and 4 near infrared Light Emitting Diodes (940 nm), which all connect to the cold electronics. Striplines connect the cold electronics from inside the dilution fridge, which is at 50 mK, to the warm electronics at 300 K.

## 2 iZip Detectors

SuperCDMS Soudan plans to deploy 15 iZIP (interleaved Z-sensitive Ionization and Phonon) detectors ($\approx$10 kg). These iZIP detectors measure the charge ionization and athermal phonons resulting from particle interactions within the crystal. The setup consists of the hexagonal tower, containing a stack of 3 detector assemblies. These detector assemblies are wired to Detector Interface Board (DIB) cards and LEDs, which are integrated in the housing assemblies. The individual stages of the tower are thermally isolated at 4 K, 600 mK, 50 mK and 10 mK to achieve minimal heat load on the detectors. The tower floor is isolated by a hollow graphite cylinder in order to ensure sufficient thermal isolation and provide mechanical support. Each detector is equipped with 4 ionization electrodes and 10 athermal phonon sensors. Each ionization electrode is connected to a low-noise JFET operating at 150 K, which acts as the input node of the charge amplifier. The cross section of this assembly is shown in Fig. 1.

## 3 Ionization and Phonon Signals

The ionization signals are preamplified by InterFET IF4501 JFETs [1]. The FET card carries the FET window and is made up of a flex circuit, which allows the JFETs to operate at 150 K within the SQUET assembly. The SQUET card is housing both, SQUIDs and Filed Effect Transistors (FET). SQUID is an acronym for Superconducting Quantum Interference Device. The FET window is mounted within the FET gusset, which encompasses a copper enclosure that absorbs IR emitted by the JFETs. In order to properly reach operating temperature, a resistor is mounted on the window near the JFETs. Power dissipation combined with the thermal impedance of the

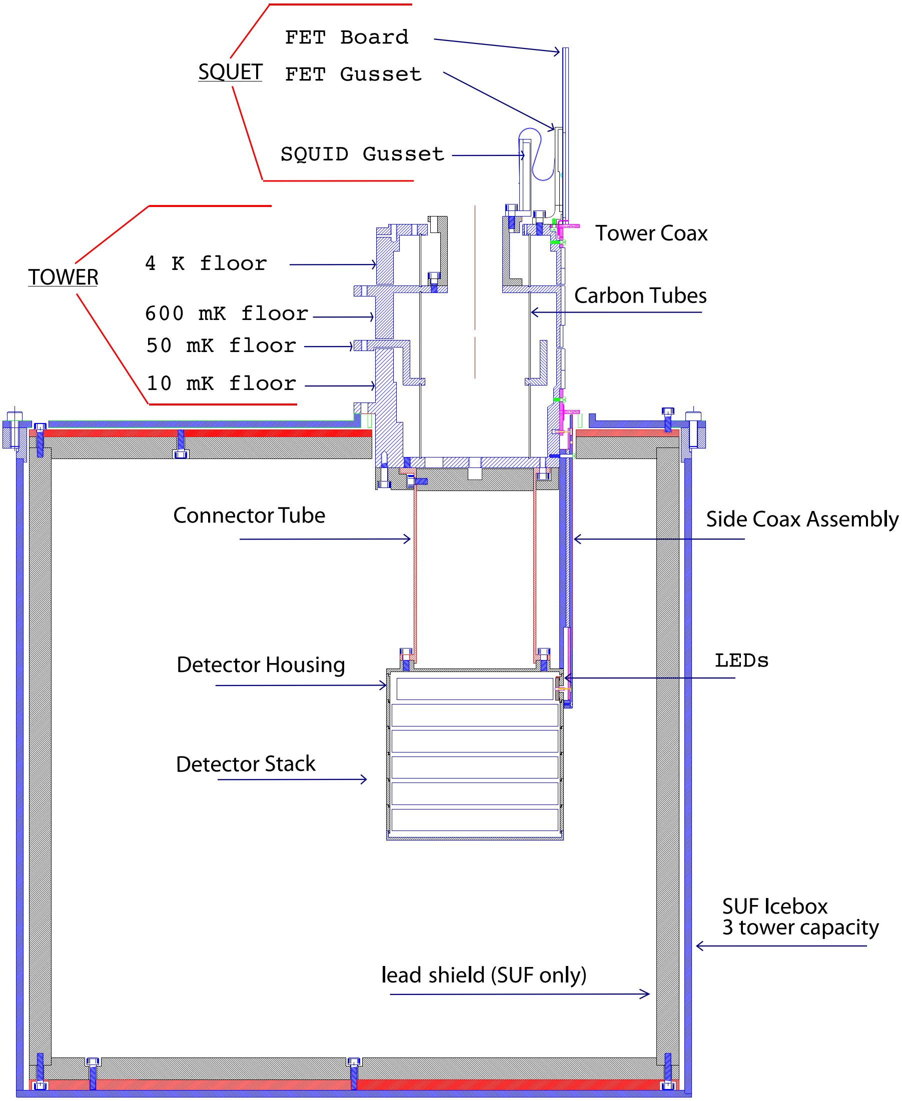

**Fig. 1** (Color online) Stack assembly cross section

window keeps them at 150 K. The Stripline connects the cold electronics on the 4 K stage of the dilution fridge and carries the bias, JFET drain, feedback, and source connections to the warm electronics at 300 K [1].

The phonon signals are produced by low impedance Transition Edge Sensor (TES) arrays ($R < 0.2\ \Omega$) and are preamplified by SQUIDs operating at 600 mK. The SQUID amplified has a power dissipation of $<1\ \mu$W. The TES signal and return lines are in vacuum coaxes, which go between the detector and the FET card. The superconducting flyover cable, which consists of twisted pair ribbon cable, passes to

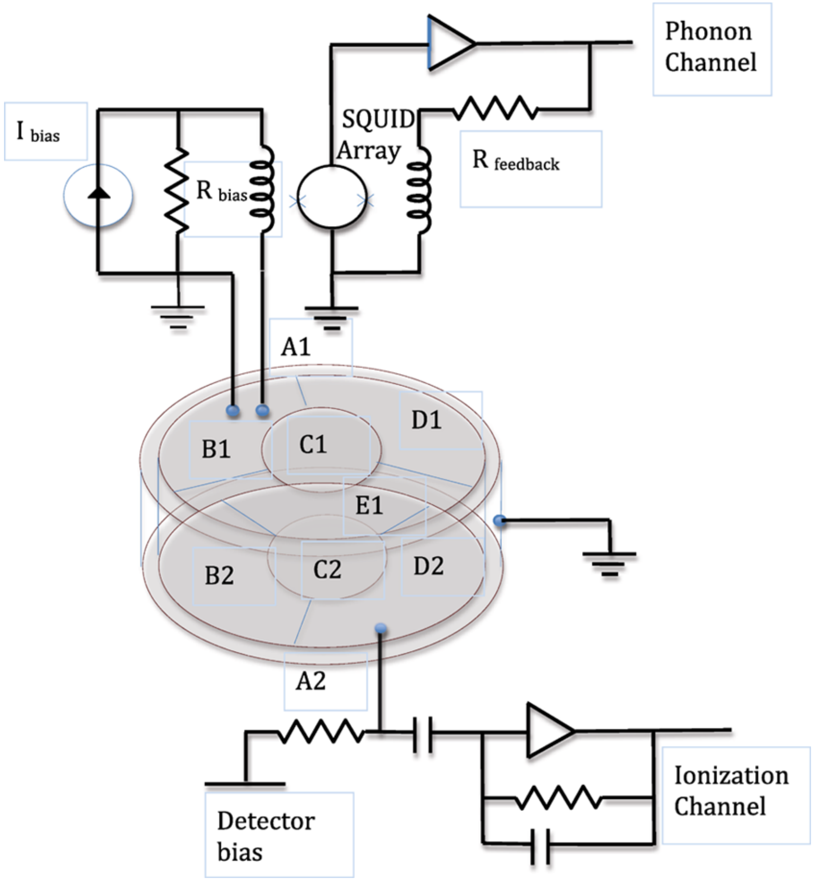

**Fig. 2** (Color online) Readout schematics of CDMS detector with cold hardware integration

the SQUID card, which houses the cold electronics. The SQUIDs operating at 1 K, well below their superconducting transition, must be shielded from magnetic flux. At the end of the tower, the side coax connects to the SQUET card. The side coax connects the DIB to the tower at 40 mK and passes signals to the 4 K stage of the tower while maintaining thermal isolation. Figure 1 shows a cross section of the stack assembly. Figure 2 shows the readout schematics of phonon and ionization channels.

## 4 Purity

Radioactive background creates a number of constraints on our selected materials, the storage of these components and our shipping methods. Oxygen-free high conductivity (OFHC) copper is the primary material used in the cold hardware. OFHC provides high thermal conductivity, while providing low intrinsic radioactivity. Each

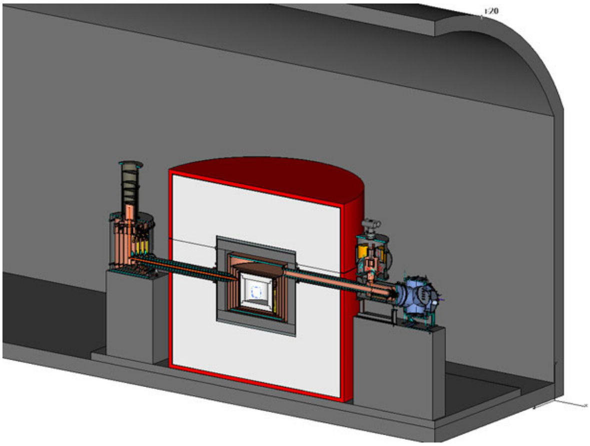

**Fig. 3** (Color online) Conceptual design of SNOLAB fridge (Source: Fermi Lab)

copper component is acid-etched to remove surface contamination prior to any installation or integration. To avoid intrinsic radioactivity of fiberglass, circuit boards are fabricated from copper-clad polyimide. To minimize contamination, solder is made from low activity lead and assemblies are constructed under clean room conditions. Parts are stored in a nitrogen purge to prevent contamination by radon. The towers are transported via ground shipping sealed in specially designed aluminum vessels under 15 psi of pressure. The vessels are placed in thick wall Polyethylene containers.

## 5 Engineering Challenges

The CDMS cold hardware operates at low temperatures ranging from 10 mK to 300 K. This requires minimal power dissipation and thermal load from the wires. Minimizing the intrinsic noise due to electromagnetic or microphonic pickup is necessary for optimal signal sensitivity. Radioactive backgrounds picked up by the detectors pose equally significant challenges. To reduce background radiation, CDMS runs in the Soudan Underground Laboratory at a depth of 2,341 feet, with PTFE and lead shielding surrounding the detectors and cold hardware [2]. Similarly, this requires that material used for the hardware is low in background. The ionization signals, preamplified by JFETs, have a high impedance gate wire, which is sensitive to noise pickup. This alters the setup, requiring that the JFETs be mounted within inches of the detectors, despite the face that they must be operated at higher temperatures (100 K). For the phonon channels, the interconnect resistances must be low in order to avoid reduced sensitivity due to thermal noise [3].

## 6 SNOLAB

SuperCDMS SNOLAB plans to deploy 100 kg of low temperature germanium detectors. Modifications of the existing Soudan cold hardware design are necessary to account for the increase in the number of detectors projected to run. The towers will be required to mechanically support a stack of 12× one kg detectors, while maintaining thermal isolation of the individual temperature stages. With the SuperCDMS Soudan design, the heat load from the FETs required to run 12 detectors is too high to efficiently maintain operating temperature. We are currently in the process of redesigning the cold hardware to meet these challenges. The conceptual design of SNOLAB is shown in Fig. 3.

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## References

1. D. Seitz et al., J. Low Temp. Phys. **1185**, 143 (2009)
2. Z. Ahmed et al., Science **327**, 1619 (2009)
3. Z. Ahmed et al., Phys. Rev. Lett. **RL 106**, 131302 (2011)