Abstract.
There is ample evidence that visible matter cannot account for a large component of the mass in the universe. Weakly Interacting Massive Particles (WIMPs) are one popular hypothesis to account for the missing mass. The Super Cryogenic Dark Matter Search (SuperCDMS) experiment is designed to directly detect WIMPs through interactions with a nucleus in a target crystal. The SuperCDMS detectors are instrumented with phonon and charge sensors, enabling excellent rejection of electron-recoil backgrounds. Approximately 3000 kg-days of exposure have been collected with the SuperCDMS Soudan experiment. We will describe the search for WIMPs with masses between 10-100 GeV and work towards the SuperCDMS SNOLAB experiment.

1. Introduction
The properties of dark matter is currently one of the big open questions in physics. One hypothesis is that the missing mass is due to a yet to be discovered massive particle that interacts very weakly with ordinary matter. Direct detection experiments rely on observing interactions in terrestrial targets initiated by WIMPs in our galactic halo. The expected number of WIMP-induced events is small which drives the need for sensitive detectors with low background rates.

SuperCDMS is a cryogenic crystal based experiment that relies on ionization and phonon information to discriminate between electron and nuclear recoils. The current experiment in Soudan has ended its physics running and is in the process of analyzing data with an analysis optimized for WIMPs with masses above 10 GeV. A new generation of the experiment will be based at SNOLAB and is expected to have excellent sensitivity to low mass (<10 GeV) mass WIMPs.

2. SuperCDMS Soudan High Threshold Analysis
SuperCDMS Soudan is located in the Soudan Underground Laboratory in Soudan, MN which provides 2090 m.w.e. of shielding. The experiment utilizes the shielding and cryostat from the CDMS-II run. Instead of a mix of germanium and silicon crystals, the target is 15 instrumented germanium crystals, each with a mass of approximately 0.6 kg. The detectors arranged into five towers of three detectors each within a cryostat that maintains a temperature around 50 mK.

The crystals are instrumented as interleaved Z-sensitive Ionization and Phonon (iZIP) detectors. Each iZIP detector is instrumented on both faces with four phonon channels and
two ionization channels. A 4 V bias is applied across the crystal through the ionization channels which are kept at ± 2 V. The phonon channels are grounded which creates field lines between the channels near the surface. This causes charge produced near a detector face to be collected on just one side as shown in Fig. 1. By requiring the charge signal to be symmetric on both detector faces, it is possible to achieve a surface event rejection factor better than $1.3 \times 10^{-5}$ in the WIMP search signal region [1].

![Image](image.png)

**Figure 1.** The combination of biased charge channels and grounded phonon channels cause distortions of the field near the crystal surface which trap charge created near the surface on one side. The asymmetry caused by this allows for powerful rejection of surface events.

Despite the powerful rejection capability of the iZIP technology, backgrounds are still a major concern. Decays of radioactive contaminants in the detector, cryostat and shielding can produce background events that can fall within the signal region. Gamma induced events are largely rejected based on the ratio of charge to phonon energy since they are more ionizing than nuclear recoils. This separation is less definite at lower energies where resolution becomes important. Modeling of this background can be accomplished using data collecting from $^{133}$Ba calibration runs. Two Si wafers were exposed to a Rn source to create $^{210}$Pb calibration sources. One wafer was placed above a detector face on top of tower 3 and the other was placed below the face of the bottom iZIP in the same tower. These sources provide valuable information about the detector response to backgrounds originating from $^{210}$Pb. The absolute $^{206}$Pb rate can be inferred from the observed $^{210}$Po alpha decay rate.

Around 500 days of exposure has been collected between 2012 and Summer 2014. The accumulated exposure as a function of time is shown in Fig. 2. The projected sensitivity is shown in Fig. 3. We expect to improve upon the previous CDMS II result by approximately an order of magnitude. The final analysis technique is yet to be determined but we are exploring techniques such as boosted-decision trees, a profile likelihood and a traditional cut-and-count approach. We plan to release results in 2016.

### 3. SuperCDMS SNOLAB Project

SuperCDMS SNOLAB was one of the proposals selected by the funding agencies to go forward as part of the second generation of direct detection dark matter experiments. The project will be a newly built experiment based at SNOLAB in the Creighton Mine in Sudbury, Canada. SNOLAB operates as a class 2000 clean room beneath 6010 m.w.e. of overburden. Space in one of the ladder labs has been set aside for the new experiment.

In addition to germanium, silicon detectors will also be deployed. The crystal sizes will be increased to 33 mm thickness and 100 mm diameter. Each Ge detector will have a mass of 1.39 kg and each Si detector will have a mass of .6 kg. The target payload will incorporate a new generation of iZIP technology. The granularity of the phonon channels will increase from four
Figure 2. This plot shows the collected raw live time of the Soudan run as a function of time.

Figure 3. We show projected sensitivity for the SuperCDMS Soudan high threshold WIMP search. The width of the band has been derived from varying the parameters of the analysis.

In addition to recoil phonons, charges drifting through a crystal produce phonons through the Neganov-Trofimov-Luke effect[2][3][4]. The contribution of additional phonon energy is linearly proportional to the bias across the crystal in the form of $N_e/hV_b$, where $N_e/h$ is the number of electron-hole pairs, $e$ is the electron charge and $V_b$ is the applied voltage bias. By increasing the voltage to high values, the ionization signal is amplified through the phonon channels which effectively lowers the experimental threshold. The penalty is that the original phonon signal can not be recovered and discrimination between electron and nuclear recoils is not possible. This technique has been applied successfully to individual detectors at Soudan with biases around 70 V[5][6]. The goal for SNOLAB is to run a large fraction of detectors in high voltage (HV) mode biased at 100 V.

The experimental configuration will consist of five towers of six detectors each. One tower will be devoted to HV detectors running with four Ge detectors and two Si detectors. The other

to six channels. A fabricated test crystal and the phonon channel map are shown in Fig. 4 and Fig. 5. Both sides will be fabricated and will have two charge channels each.
towers will be a mix of Ge and Si iZIP detectors. Optimization of the payload and arrangement is under study. The towers will be housed in a Cu cryostat that has a 31-tower capacity to allow for future payload upgrades. Layers of polyethylene shielding will surround the cryostat to absorb neutrons emitted by radiogenic contaminants. This inner polyethylene layer will be surround by a layer of low activity lead, which will be surrounded by another layer of higher activity lead, to block external gammas. The lead layers will be surrounded by water tanks on a base of polyethylene to shield from external neutrons. The experiment will rest upon a seismic isolation platform to protect it from seismic events caused by mining activities. A diagram of the shielding configuration is provided in Fig. 6.

Figure 4. This figure is a picture of a SuperCDMS SNOLAB iZIP crystal inside its Cu housing. The phonon sensors are easily visible and the interleaved charge channels are more difficult to see.

Figure 5. The right figure shows the read-out configuration for the phonon channels.

Figure 6. This figure shows the configuration of the proposed SNOLAB shield and cryostat. The configuration is similar to the shielding design deployed at SuperCDMS Soudan.

The initial payload will consist of 25kg of iZIP Ge, 4.1 kg of iZIP Si, 5.6 kg of HV Ge and 1.4 kg of HV Si detectors. The HV detectors provide sensitivity to low mass (<5 GeV) WIMPs while the iZIP detectors have superior sensitivity in intermediate mass ranges due to the electron
recoil background rejection capability. We estimate the majority of our background rates using a Geant4 based simulation framework with estimates of contamination rates taken from literature [7][8]. The projected sensitivity for a five year exposure is shown in Fig. 7. SuperCDMS SNOLAB will be a leading experiment in low mass searches due to the HV detectors. The project has recently undergone U.S. Department of Energy Critical Design Phase-1 review and expect to begin collecting data in a few years.

![Graph showing projected sensitivity for a five year run of SuperCDMS SNOLAB.]

**Figure 7.** We show projected sensitivity for a five year run of SuperCDMS SNOLAB.

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