SUPERCDMS LOW-ENERGY DATA RELEASE

This guide describes the public data released in support of the recent SuperCDMS search for light WIMPs. The data provided in this package should be sufficient to allow you reproduce the limit in arXiv:1402.7137, provided that you follow the steps proscribed here. Questions about the data or limits should be directed to supercdms_publications@fnal.gov.

1. Description of Data

SuperCDMS at Soudan consists of 15 detectors each with a mass of approximately 600 g. Each detector has its own trigger threshold, which is set to a unique value based on its noise level. For this analysis, seven detectors had significant sensitivity to the low-energy recoils characteristic of WIMPs < 10 GeV. Although only recoils in these seven detectors are used to set the limit, the other eight detectors are used to veto events that scatter in multiple detectors ("single-scatter" requirement) because a WIMP is unlikely to produce such an event topology.

This data release consists of three types of files: candidate files, efficiency files, and the charge model file.

1.1. Candidate data.

The files in the `candidates` directory contain the actual data from the seven detectors used in the analysis. This analysis uses a number of event selections, summarized in the paper, to remove events that are unlikely to be WIMPs. There are four tiers of selection criteria:

(a) *quality cuts*: removes periods of noisy data and poorly reconstructed events
(b) *trigger requirement*: the detector of interest must have issued a trigger
(c) *preselection requirements*: a combination of the single-scatter requirement, ionization fiducialization requirements to remove events on faces and sidewalls, phonon-based nuclear recoil (NR) consistency requirements, and 3σ NR band in ionization vs. total phonon energy
(d) *boosted decision tree (BDT)*: optimized final selection of nuclear recoils using the phonon energy, ionization energy, phonon radial partition, and phonon z partition

For simplicity, the data release only contains events that pass all requirements of the first three tiers (a)-(c), *except* that the 3σ NR band requirement in (c) is not applied.

Each text file in the `candidates` directory contains four columns that correspond to the following information:

(1) total phonon energy (keV)
(2) ionization energy (keVee)
(3) boolean indicating whether an event passes the 3σ NR band selection
(4) boolean indicating whether an event passes the (BDT) selection

In other words, the 11 candidate events reported in the paper will correspond exactly to those events with a 1 in the fourth column of the candidate files.

Detector	Exposure [kg-d]
T1Z1	80.2
T2Z1	82.9
T2Z2	80.9
T4Z2	87.4
T4Z3	83.8
T5Z2	82.7
T5Z3	79.2

TABLE 1. Exposures for each detector.

1.2. **Efficiencies and Exposures.** The efficiency files include the final WIMP efficiency for each detector as a function of total phonon energy, after applying all selection criteria (a)-(d). The first column of each file lists the total phonon energy, while the second column lists the actual efficiency of all selection criteria. The efficiencies for each detector have additionally been combined in an exposure-weighted sum, to give the analysis efficiency for all detectors when added together (`efficiency_total.txt`). The exposures for each detector are listed in Table 1.

1.3. **Charge models and nuclear recoil energy scale.** SuperCDMS measures the "total phonon energy" produced by each event. The total phonon energy is the sum of the recoil energy of the event and the Neganov-Luke phonon energy, produced in proportion to the charge energy. In symbols,

$$E_p = E_r + E_{Luke}$$
$$E_{Luke} = \frac{E_Q}{3\text{ eV}} e\Delta V,$$

where $\Delta V = 4$ V is the bias voltage across the detectors. Because WIMP spectra are predicted in recoil energy (E_r), we need a way of translating between the recoil energy and total phonon energy (E_p) for nuclear recoils. To do this, the mean charge energy for nuclear recoils was measured as a function of total phonon energy using ^{252}Cf calibration data and parameterized with the following functional form

$$E_Q = f(E_p) = \alpha_1 + \alpha_2 E_p + 10^{\alpha_3}\text{erf}\left(-\frac{E_p}{10^{\alpha_4}}\right).$$

The parameters α_1, α_2, α_3, and α_4 are listed in the files in `charge_models.txt`, and a unique charge model is fit for each detector individually. The recoil energy of each event is then obtained by simply subtracting off the Luke phonon contribution from the total measured phonon energy

$$E_r = E_p - \frac{E_Q}{3\text{ eV}} e\Delta V.$$

2. Reproducing the Limit

The following steps outline the procedure to reproduce the limit reported in the paper.

(1) **Prepare data:** Figure 1 shows data from all detectors overlaid, labeled by the selection criteria the events pass. The analysis presented in the paper sums data from all detectors together, treating the seven detectors as a single monolithic detector.

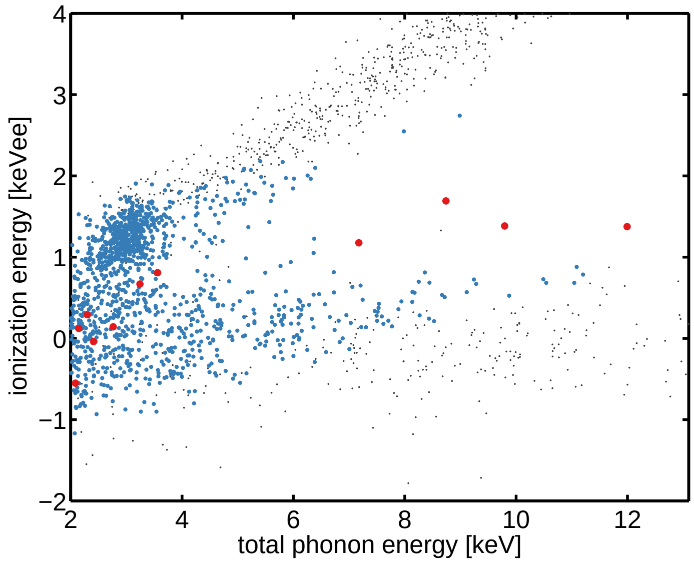


FIGURE 1. Data summed over all detectors. Black points are all data passing selection criteria (a)-(c) except the 3σ NR band selection, blue points also pass the NR band, and red points pass all criteria (a)-(d).

(2) **WIMP spectrum:** Computing an upper limit on the WIMP-nucleon from the data requires an expression for the energy spectrum of the WIMP signal, such as that given in [1]. Spectra are given as a rate per *recoil energy* (dR/dE_r), while the data are in terms of *total phonon energy* (E_p). We can either convert the data to recoil energy or the WIMP spectrum to total phonon energy. The latter is simpler, and can be obtained by the change of variables given by

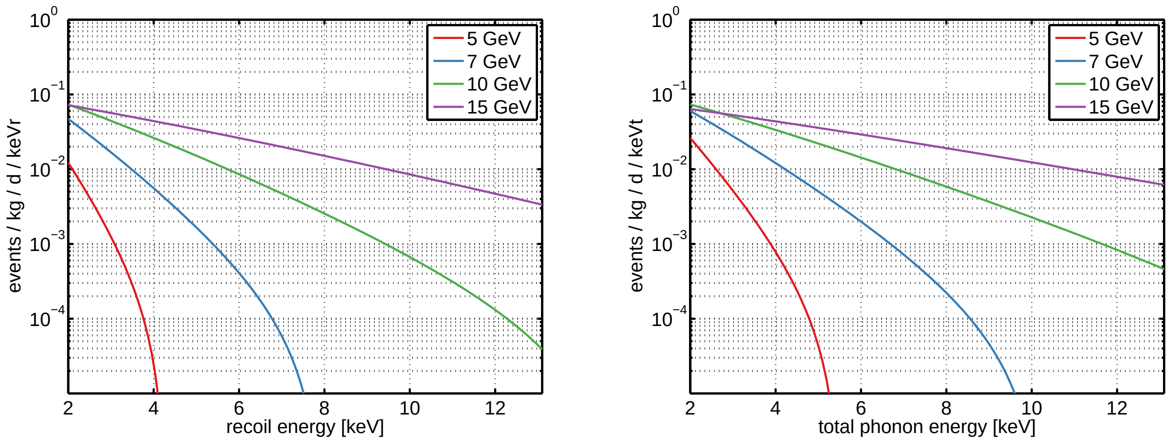
$$\frac{dR}{dE_p} = \frac{dR}{dE_r}(E_r(E_p)) \times \frac{dE_r}{dE_p}(E_p)$$

$$E_r(E_p) = E_p - f(E_p) \times \frac{\Delta V}{3\text{ eV}}$$

$$\frac{dE_r}{dE_p}(E_p) = 1 - f'(E_p) \times \frac{\Delta V}{3\text{ eV}}.$$

Since there is one charge model per detector, the total phonon energy spectrum expected from WIMPs is slightly different for each detector. The total spectrum expected in the experiment is an exposure- and efficiency-weighted sum of the spectra for each detector.

(3) **Compute limit:** The limit can be computed using a variety of techniques. For the analysis presented in the paper, we computed the 90% C.L. upper limit using the optimal interval method, described in [2]. For convenience, the directory `OI_code` contains fortran code that computes the limit with the optimal interval method, using the correct events and efficiencies, summed across detectors, after the BDT cut. Comments in the header of `SCDMSUpper.f` describe how to compile the code, which should run correctly out of the box and reproduce the limit from the paper. The



(a) Spectrum per recoil energy

(b) Spectrum per total phonon energy (T2Z1 charge model)

FIGURE 2. Differential spectrum for WIMP-nucleon scattering on Ge, in terms of each energy units, for a WIMP-nucleon cross section of 10^{-42} cm^2.

input files already contain the prepared data, efficiency, and spectral information, so steps (1) and (2) are not necessary in order to use this limit code. The code produces an output file called `UL_output`, the first two columns of which are the limit on the cross section and the WIMP mass. The limit calculated by this code differs slightly from the limit published in the paper ($<$ 2% above 4 GeV, but as much as 10% below 4 GeV). This effect occurs because the limit here is computed using a single efficiency curve, while the limit in the paper is the median over many realizations of the systematic uncertainty. The two limits therefore differ at the lowest WIMP masses, where the systematic uncertainty is largest.

REFERENCES

[1] J. Lewin and P. Smith, Astropart. Phys. **6**, 87 (1996).
[2] S. Yellin, Phys. Rev. D. **66**, 032005 (2002).

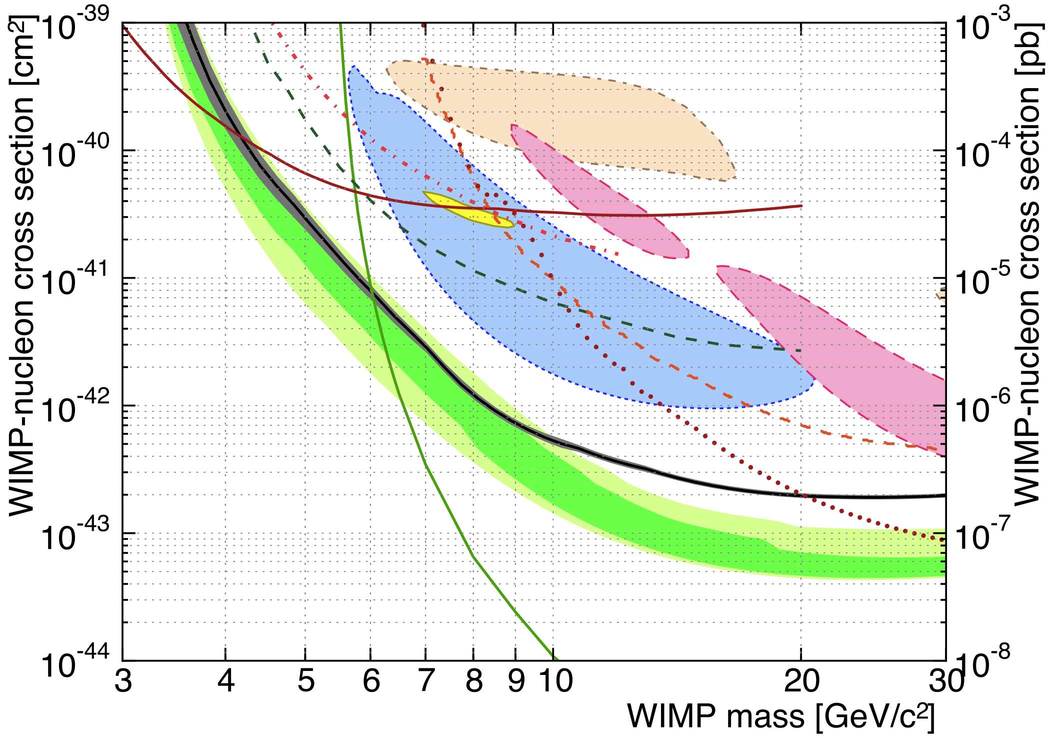


FIGURE 3. The 90% C.L. upper limit obtained from the optimal interval method, shown in solid black.