PERFORMANCE AND BACKGROUND MEASUREMENTS OF THE CDMS II TOWER I DETECTORS AT THE STANFORD UNDERGROUND FACILITY

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The CDMS II experiment deployed a set of 6 ZIP (Z-dependent Ionization and Phonon) detectors at the Stanford Underground Facility (SUF) shallow depth site in the fall of 2001. With a payload consisting of 4 Ge (250g ea.) and 2 Si (100g ea.) ZIPs, the run demonstrated the simultaneous operability of multiple ZIPs. Excellent discrimination between electron and nuclear recoil events of 99.99%, between 5–100 keV, was established in addition to rejecting over 90% of surface electron recoils, while establishing a recoil threshold down to 5 keV. This presentation will report on the performance of the ZIPs as well as the measured background rates at SUF, their last stop before being deployed at the deep site in Soudan.

1. Introduction

Beginning in December 2001, the CDMS experiment accumulated low background data for a period of roughly 6 months along with several weeks of gamma and neutron calibrations. The goal of the run was twofold : the accumulation of low background data with the aim of improving upon the current CDMS limit [1], and the full characterization and calibration of the detectors in preparation for their installation at the Soudan deep site. The 6 detectors used in this data run consisted of 4 250 g Ge and 2 100 g Si ZIPs arranged in a vertical stack, with a 2 mm seperation between detectors and no intervening material. An extensive description of the Stanford Underground Facility (SUF) can be found in [2].

2. Results From the CDMS 2001 Run

2.1. *Response of the Phonon and Ionization Channels*

One of the important characteristics of the detector performance is the baseline noise. Figure 1 shows the phonon versus ionization noise resolution for

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a Ge ZIP. The FWHM resolution of the phonon (ionization) channels are $\sim$ 320 (870) eV, well below the design specifications, with similar performance seen on the other detectors. Such a noise resolution meant that full trigger efficiency was achieved by $\sim 5\,\mathrm{keV}$ recoil energy.

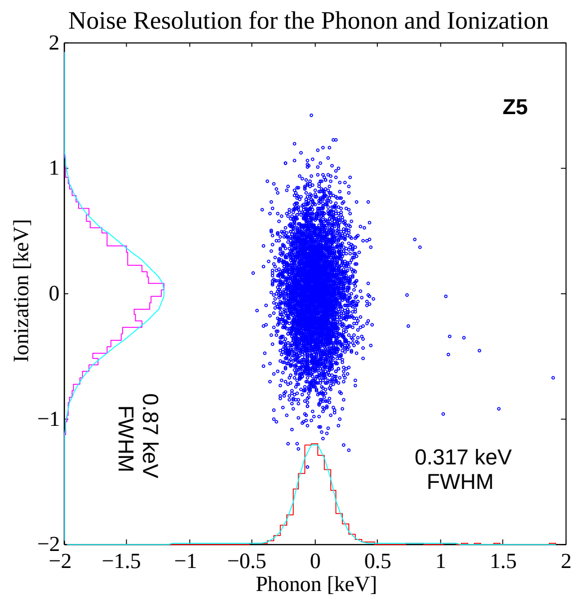

Figure 1. Baseline (or zero energy) noise resolution for a Ge detector. The phonon and ionization responses are plotted on the x and y axes respectively. A projection onto either axis is fitted to a Gaussian shape in order to obtain the noise resolution.

Calibrating the energy response of the detectors was done primarily with three gamma line sources : $662\,\mathrm{keV}$ gamma rays from an external ^{137}Cs source and ^{71}Ga $10.3\,\mathrm{keV}$ x-rays and ^{73m}Ge $66.7\,\mathrm{keV}$ gamma rays from internal radioactivity. Figure 2 shows the response of the ionization channel of a Ge ZIP to the three signals. With this data the linearity of the phonon and ionization responses can be established to be within 1% over the 0–662 keV range.

2.2. *Electron/Nuclear Recoil Discrimination*

The 2σ electron and nuclear recoil bands, shown in Figure 3, are determined from data with ^{60}Co and ^{252}Cf sources, respectively. The discrimination capability of the detectors is then determined by the number of electron

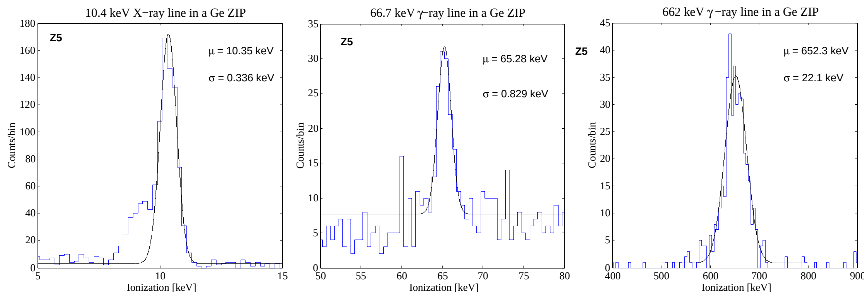

Figure 2. Ionization channel response to the 10.3, 66.7, and 662 keV gamma rays in a Ge ZIP. This data establishes both the scale and linearity of the energy response.

recoil events (from a ^{60}Co calibration) falling within the 2σ nuclear recoil band. Table 1 lists the 90% confidence level electron recoil rejection ability of the 6 detectors for various energy bins. Over the energy range 5–100 keV most of the detectors are able to reject $\sim$ 99.95% of electron recoils. The electron recoil rejection is further illustrated in Figure 4 which shows histograms of the discrimination parameter for several energy bins. The electron calibration data, well fitted by a gaussian over several orders of magnitude, are quite distinct from the nuclear recoil regions, indicated by vertical lines.

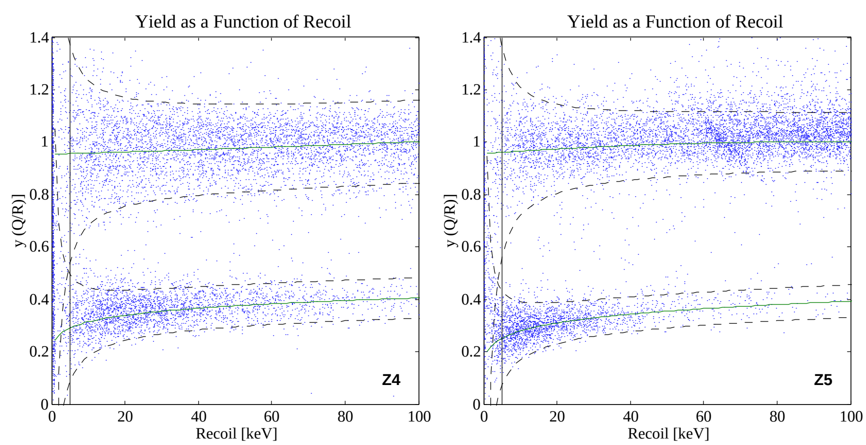

Figure 3. Electron and nuclear recoil bands, defined in the recoil-yield plane, of a Si (left) and Ge (right) ZIP detector. The bands are determined from data taken with ^{60}Co and ^{252}Cf sources.

Table 1. Electron recoil discrimination, at 90% confidence level, in the ZIP detectors as a function of energy. Discrimination is defined as the fraction of electron recoil events that appear within the $\pm 2\sigma$ nuclear recoil band. The final column shows the discrimination obtained by summing up the events in the inner four detectors. Overall, the values listed in this table indicate that fewer than 1 electron recoil event out of 1000 is misidentified.

	Detector						
Energy [keV]	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**	**Z6**	**Z2-Z5**
0–5	2.68%	1.50%	1.84%	1.56%	0.95%	1.23%	0.36%
5–10	2.21%	0.47%	0.82%	0.90%	0.19%	0.66%	0.30%
10–20	0.66%	0.13%	0.28%	0.15%	0.088%	0.30%	0.053
20–30	0.44%	0.13%	0.16%	0.16%	0.088%	0.25%	0.032
30–40	0.17%	0.13%	0.17%	0.35%	0.090%	0.13%	0.072
40–50	0.14%	0.13%	0.17%	0.16%	0.090%	0.15%	0.033
5–100	**0.23%**	**0.023%**	**0.060%**	**0.069%**	**0.0087%**	**0.12%**	**0.022**

2.3. *Event Rates*

The muon anti-coincident electron recoil rates measured during the run ranged from 1–3 evetnts/kg/keV/day below 100 keV for the various detectors. These values are quite consistent with those measured in previous runs [2]. Surface electron recoil events appear to be present at a rate of ∼0.1 evetnts/kg/keV/day below 100 keV. Electrons from the decay of ^{210}Pb, as determined by the rate of 5.3 MeV α particles from the subsequent ^{210}Po decays, appear to account for a fraction of the surface electron recoil rate. Monte Carlo studies are currently being pursued in order to identify the source of the surface events and determine whether that background can be reduced for future detectors.

3. Conclusion

The SUF Run 21 has demonstrated the electrical, thermal, and mechanical operation of a fully equipped CDMS II tower consisting of 4 Ge and 2 Si ZIPs, with detector performance meeting, and in several cases exceeding expectations. In addition to calibrating the detectors, a low background data set of ∼ 120 live days was accumulated. Further details on the analysis of the accumulated data can be found in [3].

Acknowledgments

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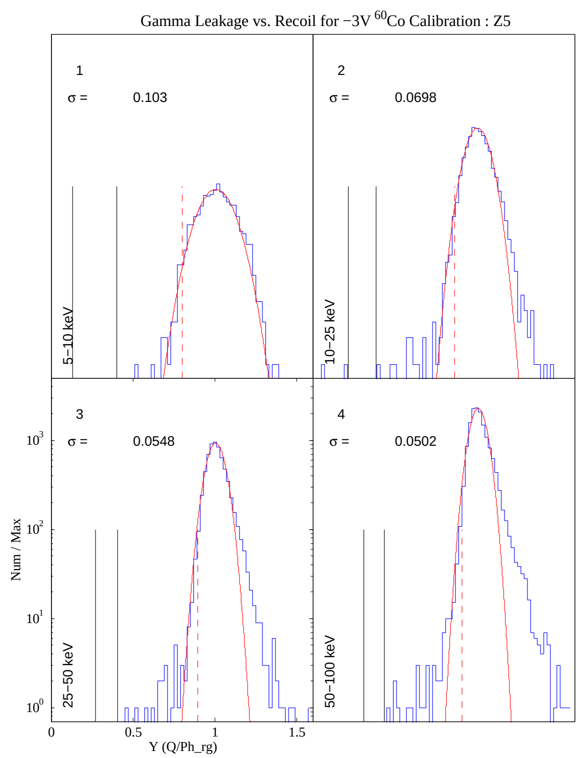

Figure 4. Histograms of the discrimination parameter, the ration of ionization to phonon signal, of a Ge ZIP for several energy bins. The electron calibration data, well fitted by a gaussian over several orders of magnitude, are quite distinct from the nuclear recoil regions, indicated by vertical lines.

References

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