Demonstration of the CDMS II ZIP technology at a shallow underground site

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Abstract. The most recent CDMS data run (Run 20) was the first run in which multiple ZIP detectors were deployed. Three Si (0.100 kg each) and 3 Ge (0.250 kg each) ZIPs were run with the goals of fully testing such a configuration as well as measuring the γ, β, and n rates simultaneously with Ge and Si detectors. Calibration with γ and n sources established the bulk electron recoil leakage into the neutron band to be less that 0.2%. Low background data taken during the summer of 2000 produced a simultaneous measurement of the muon coincident neutron background with Si and Ge detectors.

INTRODUCTION

The Cryogenic Dark Matter Search (CDMS) experiment utilizes a combination of Si and Ge detectors to search for Weakly Interacting Massive Particles (WIMPs) via their elastic scattering off of the detectors' nuclei. Known as ZIPs (Z-sensitive Ionization and Phonon) the detectors use Si or Ge targets which are instrumented with Transition Edge Sensors (TESs) to measure the recoil energy of interactions, via athermal phonons, and electrodes to independently measure the ionization [1], [2]. The combination of measurements allows for an event by event discrimination between electron recoils (due to γ and β interactions) and nuclear recoils (due to n and WIMP interactions). Surface interactions, which mimic nuclear recoils due to their reduced charge signal, can be discrimninated against based on their phonon pulse shape. Additionally, position determination based on the information from the four phonon channels on each detectors allows for the identification and rejection of any localized sources [3].

The experimental run which began in spring of 2000 (Run 20) was the first time multiple ZIP detectors were operated simultaneously. The combination of 6 detectors and their corresponding low temperature electronics, referred to as a tower, form the unit of what will be put into the Soudan facility. Shown in figure 1 is one of the low

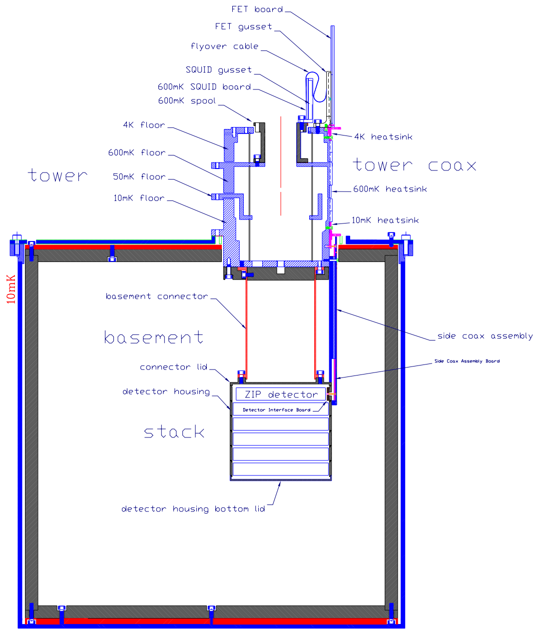

FIGURE 1. Schematic of a ZIP tower showing the 6 detectors at the bottom and the low temperature resout electronics at the top. The detectors are surrounded by 10.7 kg of polyehtylene and 42.6 kg of lead shielding.

temperature electronics readout cards, the various thermal stages of the tower, and the base temperature can (icebox) which houses 10.7 kg of polyethylene and 42.6 kg of Pb shielding, and the six ZIPs stacked on top of each other with a nominal 2 mm separation between each pair.

DETECTOR PERFORMANCE

Noise performance is an important aspect of the electronics design. The electronics, both low and room temperature modules, were custom designed with the goal of meeting noise levels of $10\,\mathrm{pA}/\sqrt{\mathrm{Hz}}$ for the phonon channels and $100\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$ for the charge channels [4]. The phonon noise levels of tens of $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ is entirely TES limited and is flat well below 1 kHz. The charge noise levels correspond are similarly limited by the FET gate noise and exhibit no 1/f noise above 1 kHz. The noise levels achieved during the Run resulted in an energy resolution for the Ge (Si) detectors of $\sim$ 600 (400) eV in the phonon channel and $\sim$ 1000 (1500) eV in the charge channel.

The detectors' response to electron and nuclear recoils was calibrated by exposing them the external γ and neutron sources. A ^{137}Cs source, which produces 662 keV γs was used to establish that the charge collection efficiency was $\sim$ 100% for both Ge and Si detectors as shown in figure 2. This provided an abolute energy calibration for the ZIP detectors. Further calibrations with a γ source (^{60}Co) and a neutron source (^{252}Cf) established a γ rejection of better that 99.8% between 10-100 keV for both the Ge and

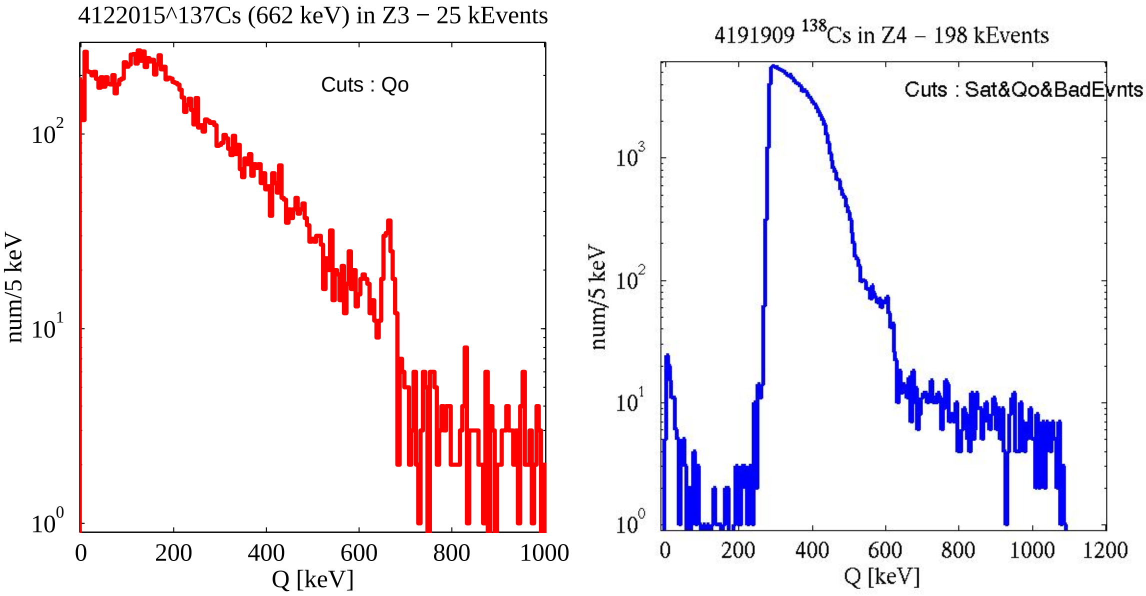

FIGURE 2. Charge yeild (charge/phonon) as function of energy for low background exposure. The left (right) figures show data taken with a 0.241 (0.09) kg-day exposure with a Ge (Si) ZIP. The dots are scattering events that are coincident with a vetoed muon while the square are anti-coincident.

Si detectors. Figure 3 shows the neutron calibration data. The populations of electron recoils (steep slope) and nuclear recoils (shallow slope) are clearly distinguishable to well below 10 kev.

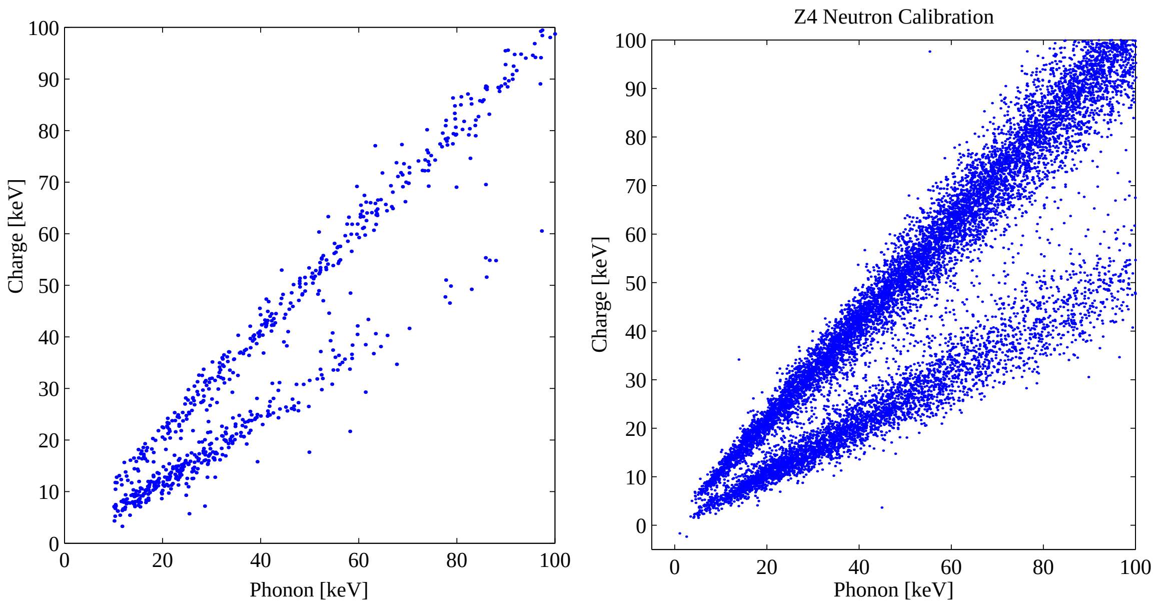

FIGURE 3. The left (right) plots show the charge signal as a function of the phonon signal for electron (steep slope) and nuclear (shallow slope) recoils in a Ge (Si) ZIP. The nuclear recoils were caused by neutrons from a ^{252}Cf fission source while the electron recoils were caused by externally induced γ's.

Low background data, corresposnding to a 0.09 kd-day exposure in a Si ZIP and a 0.241 kg-day exposure in a Ge ZIP are shown in figure 4. In the interval 30-100 keV two muon coincident nuclear recoil events are seen in the Si detector, while 14 are seen in the Ge. This correspond to a rate of less than 60 (58) nuclear recoils per kg-day at a 90% confidence level. No muon anti-coincident events are seen in any of the detectors. Muon anti-coincident γ rates of $\sim$ 6 (3) events/keV/kg-day in the Si (Ge) detectors are consistent with rates measured over the last couple of runs.

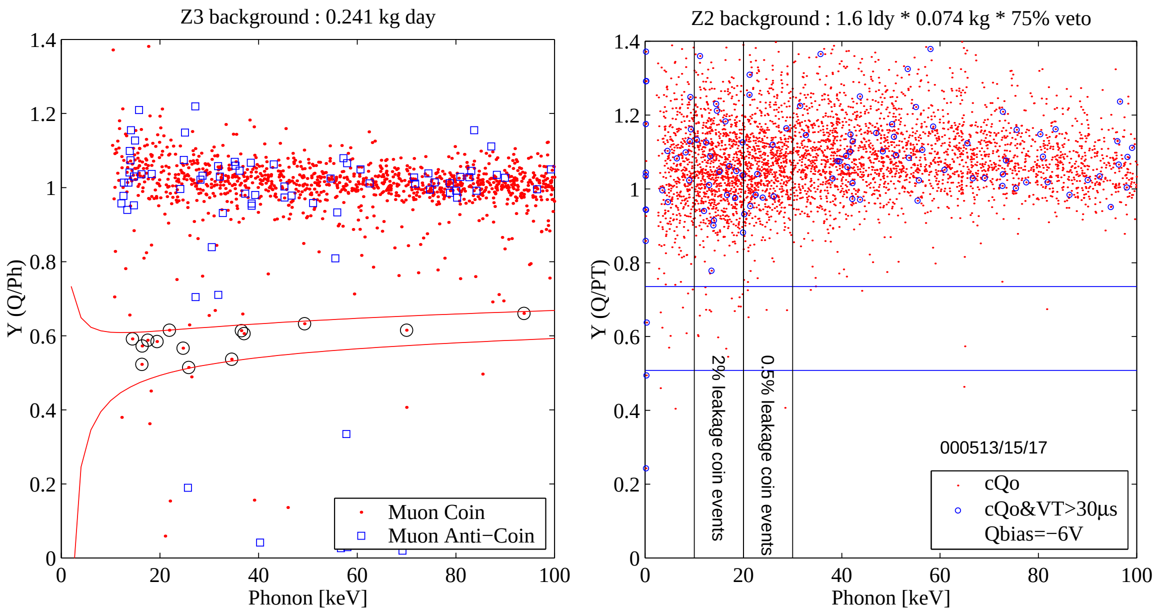

FIGURE 4. Charge yeild (charge/phonon) as function of energy for low background exposure. The left (right) figures show data taken with a 0.241 (0.09) kg-day exposure with a Ge (Si) ZIP. The dots are events that are coincident with a vetoed muon while the square are anti-coincident.

CONCLUSION

The year 2000 run at the Stanford Underground Facility demonstrated our ability to run multiple ZIPs simultaneously and produced a simultaneous measurement of the neutron backgroud in Si and Ge detectors . The performance of the detectors was not affected by being operated within a Tower.

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