2. CDMS-II Experiment

The Cryogenic Dark Matter Search (CDMS-II) experiment consisted of an array of 19 germanium (250 g) and 11 silicon (100 g) particle detectors operated at cryogenic temperature (~50 mK) [11, 12]. Each detector was a cylindrical disk, 7.6 cm in diameter and 1 cm thick. The detectors are grouped into five towers, each tower containing six detectors. Detectors are identified by their tower number (T1-T5) and their position within that tower (Z1-Z6). Particle interactions in a detector generated ionization as well as athermal phonons. An electric field across the detector separated the resulting electrons and holes which were collected on electrodes patterned on the flat faces, producing an ionization energy measurement. Phonons were collected in four superconducting thin-film absorber circuits and the energy was read out using tungsten transition-edge sensors (TESs) coupled with superconducting quantum interference devices (SQUIDs). A direct line of sight between adjacent detectors in a tower allows identification of events scattering between detectors.

The ionization yield, or the ratio of charge to phonon energy depositions, provided the primary discrimination between electron recoils and nuclear recoils to better than $10^{-3}$ misidentification rate. For events within 10 μm of a detector surface, charge collection was suppressed and ionization yield was reduced. Additional discrimination was obtained from the promptness of phonon pulses; surface events had faster pulses than bulk events. Combining ionization yield and phonon timing, bulk electron recoils were rejected to better than $10^{-5}$ misidentification rate and surface electron recoils to better than $10^{-2}$. This is illustrated in Fig. 1 using...
In order to suppress ambient photons and radiogenic neutron rates, the entire experimental apparatus was surrounded by layers of lead and polyethylene. Finally, the experiment was situated at the Soudan Underground Mine at a depth of 2000 m.w.e. to suppress muon flux. An active plastic scintillator veto further tagged remaining incident muons which interacted in the apparatus to generate cosmogenic neutrons [11].

3. Results

We report results from the final WIMP-search data acquired between July 2007 and September 2008. At regular intervals during data acquisition, as well as collectively afterwards, detector performance was characterized by automated checks of detector neutralization (required for full ionization collection) and Kolmogorov-Smirnov tests on various parameter distributions including charge and phonon pulse characteristics. All 30 detectors (Ge and Si) were used to identify particle interactions, but only optimally performing Ge detectors were used to search for WIMP scatters, leading to 612 kg-days of net WIMP-search exposure.

To prevent bias, the definition of physics cuts, calculation of their efficiencies, and characterization of detector response was done only using calibration data from $^{133}$Ba and $^{252}$Cf sources, or events in WIMP-search data outside the signal region. 356 keV $\gamma$-rays from $^{133}$Ba were used to calibrate the ionization and phonon energy scales of the detectors. The validity and linearity of this calibration were verified at WIMP-scatter energies of interest using $^{133}$Ba and $^{252}$Cf neutrons [11]. All leading to 612 kg-days of net WIMP-search exposure.

Figures 2 and 3 illustrate the signal and background suppression resulting from various cuts applied to the data. Figure 2 shows the signal criteria efficiency versus recoil energy. Each line represents the cumulative effect of the criterion combined with the ones above it.

mean ionization yield of calibration-neutron events and having failed a surface event cut based on phonon pulse timing. The efficiency of these criteria were measured as a function of energy and are plotted in Fig. 2. The WIMP-spectrum-averaged equivalent exposure for a WIMP of mass 60 GeV/c$^2$ was 194 kg-days.

Prior to unblinding, we also estimated the expected contribution of various background sources. The cosmogenic neutron background was estimated to be 0.04±0.04(stat.) by Monte Carlo simulations of muon-induced particle showers and subsequent neutron production. The radiogenic background was estimated to be between 0.03 and 0.06 events based on counting of shielding and detector material samples. The expected background contribution from surface events was 0.6±0.1(stat.), estimated using pass-fail ratios of the surface-event cut, measured on calibration surface events and WIMP-search events outside the signal region.

With the analysis finalized, the blind signal region was unmasked on November 5, 2009. We observed two events in the WIMP-acceptance region at recoil energies of 12.3 keV and 15.5 keV. These are marked in Fig. 3.
The candidate events occurred in periods of ideal experimental performance, separated in time by several months, and in different detectors in the apparatus. However, a detailed study revealed degraded surface event rejection for a small fraction of events with ionization energy below \( \sim 6 \text{ keV} \), due to misconstrued event timing. Accounting for this effect, the surface background estimate stood revised to 0.8 \pm 0.1 \text{(stat.)} \pm 0.2 \text{(sys.)}.

Combining this with the estimated neutron background, the probability to observe two or more background events is 23%. The solid black line shows the combined limit for the full data set recorded at Soudan. The dotted line indicates the expected sensitivity for this exposure based on our estimated background combined with the observed sensitivity of past Soudan data. Prior results from CDMS [12], EDELWEISS II [13], XENON10 [14], and ZEPLIN III [15] are shown for comparison. The shaded regions indicate allowed parameter space calculated from certain Minimal Supersymmetric Models [16, 17] [Right] The shaded blue region represents WIMP masses and mass splittings for which there exists a cross section compatible with the DAMA/LIBRA [18] modulation spectrum at 90% C.L. under the inelastic dark matter interpretation [19]. Excluded regions for CDMS II (solid-black hatched) and XENON10 [20] (red-dashed hatched) were calculated in this work using the Optimum Interval Method. Reproduced from Ref. [10].

These data were also analyzed under the hypothesis of WIMP inelastic scattering [19], which was proposed to explain the DAMA/LIBRA data [18]. We computed DAMA/LIBRA regions allowed at the 90% C.L. following the \( \chi^2 \) goodness-of-fit technique described in [23], without including channeling effects [24]. Limits from our data and that of XENON10 [20] were computed using the Optimum Interval Method [22]. Regions excluded by CDMS and XENON10 were defined by demanding the 90% C.L. upper limit to completely rule out the DAMA/LIBRA allowed cross section intervals for allowed WIMP masses and mass splittings. The results are shown in the right pane of Fig. 4.

4. Current Status

CDMS-II ended operations in March 2009, and is being upgraded to SuperCDMS Soudan. CDMS-II detectors are being replaced with new ones, 2.5 times more massive than the old ones and with phonon sensors redesigned for better surface event rejection. The first tower of new detectors has already been deployed and is taking data at Soudan. By Summer 2010, 15kg of Ge detectors will be deployed in SuperCDMS with the goal of probing WIMP-nucleon cross-sections of \( 5 \times 10^{-45} \text{cm}^2 \) [25].

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