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The Cryogenic Dark Matter Search (CDMS II) Experiment - First Results from the Soudan Mine

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The CDMS collaboration has completed its first WIMP search run at the Soudan Underground Laboratory. This run consisted of operating 4 Ge and 2 Si ZIP detectors for 52.6 live days and yields a post-analysis WIMP exposure of 19.4 kg-d for recoil energies between 10-100 keV. Analysis of this data sets the world's lowest exclusion limits on the coherent WIMP-nucleon scalar cross-section for all WIMP masses above 15 GeV/c^2.

Keywords: Dark Matter; SUSY; ZIP

1. Introduction

Most of the dark matter of the universe may consist of Weakly Interacting Massive Particles (WIMPs)[1,2,3]. WIMPs are well motivated predictions from many supersymmetric theories[4,5]. It is possible to detect WIMP dark matter through elastic scattering off of atomic nuclei[6]. These interactions will typically impart a few tens of keV to the recoiling nucleus at a rate of $\lesssim 1$ event per kg per day[7].

The Cryogenic Dark Matter Search (CDMS) collaboration is conducting a WIMP search with a new apparatus in the Soudan Underground Laboratory. The detectors are 4 Ge (250 g) and 2 Si (100 g) ZIP detectors[10] which are surrounded by 22.5 cm of lead and 50 cm of polyethylene. A plastic scintillator enclosure which tags muons with $> 99\%$ efficiency is used to reject events produced by muon activity in the shielding. The muon flux at Soudan is sufficiently low that backgrounds from muon activity in the rock are negligible. The only remaining backgrounds consist of photons and electrons produced by radioactivity inside the shielding. ZIPs can efficiently distinguish these backgrounds from WIMPs since photons and electrons scatter off of electrons while WIMPS scatter off of nuclei.

2. Analysis

From October 11, 2003 until January 11, 2004, we obtained 52.6 live days of exposure using six close-stacked ZIP detectors. Over the course of the run, we performed

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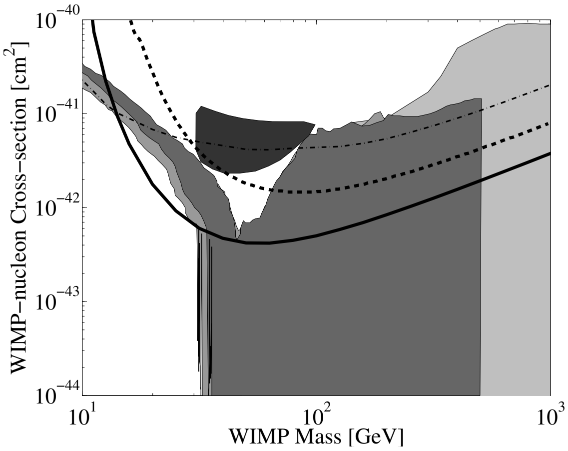

Fig. 1. WIMP-nucleon exclusion plot for spin-independent interactions under the assumptions of a standard isothermal dark matter halo with ρ =0.3 GeV/cm^3 and a mean velocity of 230 km/s. Curves are for EDELWEISS (dashed), CDMS II - SUF (dot dashed), and CDMS II - Soudan (solid). The dark grey heart shaped region is the 3σ DAMA allowed region. The light grey shaded regions correspond to the allowed parameter space for some MSSM models. Plot courtesy of http://dmtools.brown.edu.

several *in situ* calibrations using a ^{133}Ba source (photons only) and a ^{252}Cf source (photons and neutrons). Excellent agreement between data and Monte Carlo simulations for both of the sources indicates that the energy calibration is accurate to within a few percent for both electron and nuclear recoils. The external calibrations also indicate that the experiment is stable to better than 5%.

The analysis of this data is a blind analysis. We did not inspect the nuclear-recoil region of the WIMP-search data until all cuts were finalized making it impossible for our results to bias the analysis. All cuts and their efficiencies are determined from the *in situ* calibrations. For recoils between 10-100 keV, the spectrum-averaged effective exposure for a 60 GeV/c^2 WIMP is 19.4 kg-days. Details of this analysis can be found in a separate paper.[9]

We estimate our only nuclear-recoil background, neutrons produced by muon interactions in the rock, to be 0.05 ± 0.02 events. We estimate our photon misidentification to be $0.18^{+0.43}_{-0.16}$. It is difficult to estimate the misidentification rate of electrons coming from contamination on the detector surface since the external calibrations do not perfectly reproduce the spatial distribution of surface contamination. We estimate a misidentification of 0.4 ± 0.2 electrons, which should be good to within a factor of two.

3. Results

This analysis of the first Soudan CDMS II WIMP-search data set reveals one nuclear-recoil event with a recoil of 64 keV in the 52.6 kg-d raw exposure of our Ge detectors. This rate is consistent with our expected electron-recoil misidentification. Using the optimum interval method [12], these data set an upper limit on the WIMP-nucleon cross-section of 4×10^{-43} cm^2 at the 90% C.L. at a WIMP mass of 60 GeV/c^2 for scalar (spin-independent) coherent interactions and a standard WIMP halo. As shown in Fig. 1, these limits are about a factor of four below the best previous limits set by EDELWEISS [14], and a factor of eight better than our limit with the same detectors at SUF [11], confirmming that events detected by CDMS at SUF and those detected by EDELWEISS were not a WIMP signal.

Under the assumptions of a standard halo model, our new limits are clearly incompatible with the published DAMA signal region [13] if it is due to scalar coherent WIMP interactions. Our new limits significantly constrain supersymmetric models under some theoretical frameworks[5].

Acknowledgments

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