Status of the CDMS search for WIMPs.

Andrew Sonnenschein
(for the CDMS collaboration [1])

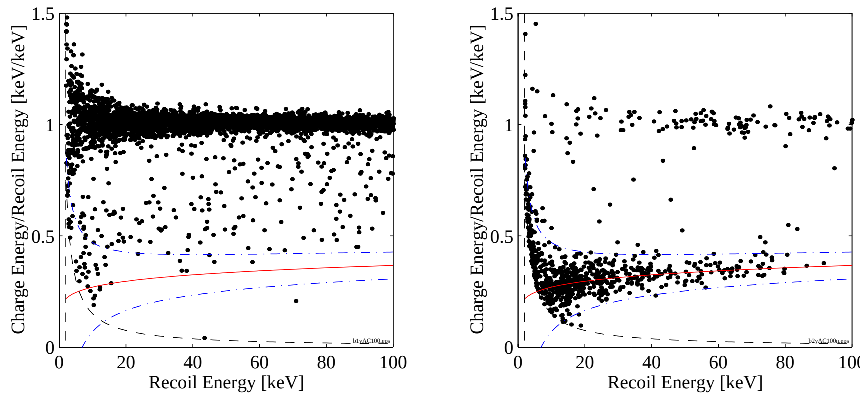
Abstract. The Cryogenic Dark Matter Search (CDMS) experiment uses germanium and silicon detectors cooled to 20 mK to attempt to detect weakly interacting dark matter particles in our galactic halo. We discuss recent results obtained with an array of two 165 g germanium detectors and a 100 g silicon detector after a 33 live-day exposure.

I THE CHALLENGE OF WIMP DETECTION.

One possible solution to the famous "dark matter problem" is that the dark matter is in the form of weakly interacting massive particles (WIMPs), which could be, for example, the neutralinos predicted by supersymmetry [1]. These particles should have masses in the range $10^1 - 10^3$ GeV. Large numbers of them could have been produced in thermal equilibrium in the early Universe. Today, they would be present in the dark halo of the Galaxy, which is known to have a local density of $\simeq 0.4$ Gev/cm^3. If the halo mass is dominated by WIMPs of mass m, they should have a local flux of $(m/1\ GeV) \times 10^7 cm^{-1} s^{-1}$ and might be detected via interactions with detectors on Earth. Unfortunately, the small interaction cross sections on atomic nucleii imply very low event rates (<0.01 event/kg-day) and the energy transferred to the nucleus is also low (~ 10 keV).

[1] The CDMS collaboration: D.S. Akerib[a], P.D. Barnes Jr.[b], D.A. Bauer[c], A. Bolozdynya[a], P.L. Brink[d], B. Cabrera[d], D.O. Caldwell[c], J.P. Castle[e], R.M. Clarke[d], P. Colling[d], M.B. Crisler[f], A. DaSilva[b], A.K. Davies[d], R. Dixon[f], S. Eichblatt[f],, R.J. Gaitskell[g], S.R. Golwala[g], E.E. Haller[h], J. Hellmig[g], M.E. Huber[i], K.D. Irwin[j], J. Jochum[g], F. Lipschultz[e], J. Martinis[j], S.W. Nam[d], B. Neuhauser[e], H. Nelson[c], T.A. Perera[a], R.R. Ross[h], T. Saab[d], B. Sadoulet[g], R.W. Schnee[a], T. Shutt[k], A. Smith[h], A. Sonnenschein[c], A.L. Spadafora[g], W.K. Stockwell[g], S. Yellin[c], B.A. Young[l] [a]*Case Western Reserve University, Cleveland, OH.* [b]*Lawrence Livermore National Laboratory, Livermore, CA.* [c]*University of California, Santa Barbara, CA.* [d]*Stanford University, Stanford, CA.* [e]*San Francisco State University, San Francisco, CA.* [f]*Fermi National Accelerator Laboratory, Batavia,IL.* [g]*Center for Particle Astrophysics and Department of Physics, University of California, Berkeley, CA.* [h]*Lawrence Berkeley National Laboratory, Berkeley, CA .* [i]*University of Colorado, Denver, CO.* [j]*National Institute of Standards and Technology, Boulder,CO.* [k]*Princeton University, Princeton, NJ.* [l]*Santa Clara University,Santa Clara, CA.* Address inquiries to Andrews@slac.stanford.edu.

FIGURE 1. Demonstration of nuclear recoil discrimination in a 165 g thermistor-instrumented Ge detector. The ratio of the ionization and thermal signals is plotted as a function of recoil energy for exposure to a Co-60 gamma ray source (left) and a Cf-252 neutron source (right).



The main challenge for WIMP detection is to achieve low background counting rates at low energies in a detector that incorporates at least a few kg of target material. One approach to solving this problem is to build detectors that can discriminate between WIMP scattering events and background events. Nuclear scattering produces less ionization in semiconductor targets per unit energy deposited than scattering on electrons. Since gamma rays, which are the dominant background source for dark matter searches, interact with electrons via compton and photoelectric scattering, while WIMPs make ionization only through the recoil of a target nucleus, a measurement of the ratio of ionization to deposited energy permits discrimination between the two types of interaction. At low temperatures. it is possible to measure both the heat deposited by an ionizing event and the amount of ionization, making this type of discrimination technologically feasible.

II THE CDMS DETECTORS AND SHIELDING.

The Cryogenic Dark Matter Search (CDMS) collaboration has built germanium and silicon detectors which operate at a temperature of 20 mK. Energy deposition is measured with two different technologies, (1) Neutron-transmutation-doped germanium thermistors capable of measuring temperature changes of less than 1 μK in an attached target crystal [2], and (2) Tungsten superconducting transition-edge sensors (TES), which respond to the initial high-energy phonon burst associated with a particle interaction [3]. Both types of detector have a noise threshold of $\sim$3 keV in recoil energy. In the TES devices, the shapes and arrival times of pulses at a grid of 4 sensors contain information about the location of the event inside the detector.

Ionization is read out with conventional JFET charge amplifiers. There are charge-trapping effects which lead to a suppression of the the ionization signal for events occurring near the crystal surfaces [4]. This leads to a degradation of the capability to discriminate nuclear scattering events from surface events, such as those caused by external β emitters. In the TES devices, this problem can be overcome by imposing a cut on the pulse rise times, which are faster for surface events.

The setup and operation of the CDMS experiment has been described before in eg. Ref. [5]. The site of the CDMS I experiment is a tunnel on the campus of Stanford University, with a 17 meters water-equivalent overburden. A low-radioactivity cryostat installed in the tunnel is designed to be filled with 42 detectors, or about 20 kg of total detector mass. The cryostat is shielded from gamma rays by 16 cm of low radioactivity lead and from neutrons by 25 cm of polyethylene moderator. A set of plastic scintillator veto counters surrounds the apparatus and is used to tag events caused by neutrons made in the shielding by the fraction of cosmic ray muons which penetrate the overburden.

A new cryostat and shield are being prepared for an extension of our experiment called CDMS II, which will be located at the Soudan iron mine (2200 meters water-equivalent) in Tower, MN, USA. Detectors will be transferred to the new site when the irreducible neutron background at the shallow site from neutrons that leak through the shielding becomes the limiting factor in sensitivity.

III RECENT RESULTS.

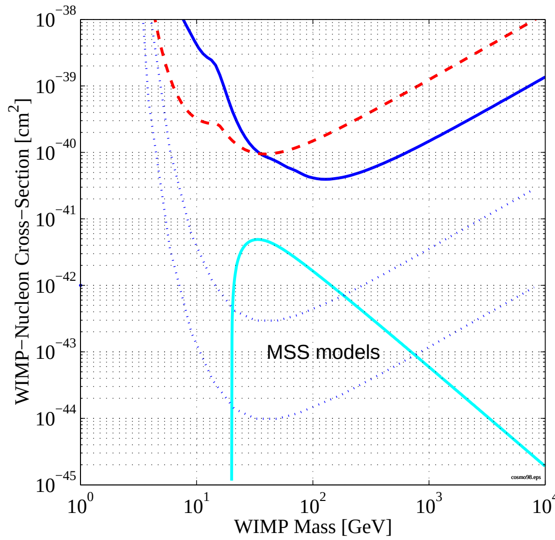
Figure 2 shows our 90% CL limits on the masses and cross sections of WIMPs that might populate our galactic halo after a 33 live-day exposure of an array of two 165g thermistor-instrumented Ge detectors and a 100g Si TES detector. Currently, the thermistor-instrumented devices are limited by contamination of the packaging materials with β emitters, including ^3H below the 18.6 keV endpoint and unidentified others at higher energy. The TES devices are nearly background-free above the $\sim$ 20 keV threshold where the risetime-based rejection of surface events is efficient.

In the future, we expect to improve these limits by reducing the background counting rates through reduction in β contamination, reduction in surface charge trapping, the use of self-shielding detector arrays, and further implementation of our TES technology. The TES sensors have recently been successfully transferred to Ge target crystals. Currently, we are collecting data from an array of 6 thermistor-instrumented Ge detectors with improved charge collection and an array of 6 Ge TES detectors is in preparation. The anticipated sensitivity of the experiment after these improvements is indicated in Figure 2.

ACKNOWLEDGEMENTS.

This work is supported by the Center for Particle Astrophysics, an NSF Science and Technology Center operated by the University of California, Berkeley, under

FIGURE 2. Limits (90% CL) on masses and cross sections for coherent scattering of halo WIMPs assuming a halo density of 0.3 GeV/cm^3 and a velocity dispersion of 220 Km/s. Current results are shown for Si (dashed line) and Ge (solid line). Also shown are a set of MSSM predictions for the neutralino [1] and the expected ultimate CDMS I and II sensitivity.



Cooperative Agreement No. AST-91-20005, and by the DOE under contracts DE-AC03-76SF00098, DE-FG03-91-ER40618 and DE-FG03-90ER40569.

REFERENCES

1. G. Jungman, M. Kamionkowski, K. Griest, Phys. Rep. 267, 195 (1996).
2. N. Wang *et al.*, *Phys. Rev.* **B41** 3761 (1990). T. Shutt *et al., Phys. Rev. Lett.* **69**, 3452 and 3531 (1992). A. Sonnenschein *et al.*, Proceedings of the International Conference on the Identification of Dark Matter (IDM98), 1998, Buxton, UK (ed. N. Spooner), in press.
3. K.D. Irwin *et al., Rev. Sci. Instrum.* **66**, 11 (1995). R.M. Clarke *et al.*, IDM98.
4. T. Shutt *et al.*, Proceedings of the VIIth International Workshop on Low Temperature Detectors, 1997, Munich, Germany (ed. S. Cooper) 221.
5. T. Shutt et al., Nucl. Phys. B (Proc. Suppl.) 51B (1996) 318-322. R.W. Schnee et al., NIM S.