J Low Temp Phys (2008) 151: 818–823
DOI 10.1007/s10909-008-9740-7

Present Status of the SuperCDMS program

D.S. Akerib · C.N. Bailey · D.A. Bauer · P.L. Brink · R. Bunker · B. Cabrera · D.O. Caldwell · J. Cooley · P. Cushman · F. DeJongh · M.R. Dragowsky · L. Duong · E. Figueroa-Feliciano · J. Filippini · S.R. Golwala · D.R. Grant · J. Hall · R. Hennings-Yeomans · D. Holmgren · M.E. Huber · K.D. Irwin · R. Mahapatra · N. Mirabolfathi · H. Nelson · L. Novak · R.W. Ogburn · M. Pyle · X. Qiu · E. Ramberg · W. Rau · A. Reisetter · T. Saab · B. Sadoulet · J. Sander · R.L. Schmitt · R.W. Schnee · D.N. Seitz · B. Serfass · K.M. Sundqvist · A. Tomada · S. Yellin · J. Yoo · B.A. Young

Received: 22 July 2007 / Accepted: 15 September 2007 / Published online: 25 January 2008

P.L. Brink for the SuperCDMS Collaboration.

S.R. Golwala
California Institute of Technology, Pasadena, CA, USA

D.S. Akerib · C.N. Bailey · M.R. Dragowsky · D.R. Grant · R. Hennings-Yeomans · R.W. Schnee
Case Western Reserve University, Cleveland, OH, USA

D.A. Bauer · F. DeJongh · J. Hall · D. Holmgren · E. Ramberg · R.L. Schmitt · J. Yoo
Fermi National Accelerator Laboratory, Batavia, IL, USA

E. Figueroa-Feliciano
Massachusetts Institute of Technology, Cambridge, MA, USA

K.D. Irwin
National Institute of Standards and Technology, Boulder, CO, USA

W. Rau
Queen's University, Kingston, Ontario, Canada

B.A. Young
Santa Clara University, Santa Clara, CA, USA

P.L. Brink (✉) · B. Cabrera · J. Cooley · L. Novak · R.W. Ogburn · M. Pyle · A. Tomada · S. Yellin
Stanford University, Palo Alto, CA, USA
e-mail: pbrink@stanford.edu

J. Filippini · N. Mirabolfathi · B. Sadoulet · D.N. Seitz · B. Serfass · K.M. Sundqvist
University of California at Berkeley, Berkeley, CA, USA

R. Bunker · D.O. Caldwell · R. Mahapatra · H. Nelson · J. Sander
University of California at Santa Barbara, Santa Barbara, CA, USA

Abstract The expected final reach of the Weakly Interacting Massive Particle (WIMP) search experiment CDMS-II by the end of 2007 is a WIMP-nucleon cross-section sensitivity of 2.1×10^{-44} cm^2. To proceed further in our search, we have proposed the SuperCDMS Phase A project that would deploy 42 1-inch thick Ge detectors, at a site deeper than the location of CDMS II, and reach a desired sensitivity goal of 1.3×10^{-45} cm^2. These cross-sections are of interest and are complementary to Supersymmetry searches at the Large Hadron Collider (LHC) and future linear colliders.

Keywords Dark Matter · Cryogenic detectors

PACS 14.80 Ly · 95.35 +d

1 Introduction

The expected WIMP-search sensitivity by the end of the presently running Cryogenic Dark Matter Search (CDMS) II experiment [1] will begin to explore the region of WIMP-mass nucleon cross-section parameter space motivated by some Supersymmetric extensions beyond the Standard Model of Particle Physics (see Fig. 1). However the small mass and potential backgrounds of CDMS II will probably prevent much further progress than that indicated in Fig. 1 for "CDMS II 2007". Thus, a few years ago we proposed a Roadmap [2, 3] for the CDMS technology that would allow deployment of larger mass detectors and address potential background issues to allow a push to even greater WIMP sensitivity.

The first goal of the SuperCDMS program, a 25 kg Ge experiment, would utilize 7 SuperTowers (ST) of detectors, each containing 6 Ge detectors of mass 640 g, compared to the 19 Ge detectors of CDMS II of mass 240 g each. As indicated in Fig. 1, the projected WIMP sensitivity of this SuperCDMS Phase A experiment would be 1.3×10^{-45} cm^2 at 60 GeV/c^2 WIMP mass. This sensitivity would be sufficient to investigate some split-supersymmetry models [4, 5] and benchmarks from the Linear Collider Cosmology (LCC) study [6], along with a significant fraction of mSUGRA models [7]. Performing this experiment at the present CDMS-II site, the Soudan Mine, Minnesota, would likely encounter a background due to muon-induced neutrons. Thus we proposed conducting the SuperCDMS program at a deeper site, the new SNOLAB facility in Canada. A shorter term Detector Development Project whose goal is to operate 2 SuperTowers of 25 mm-thick Ge detectors in the present CDMS II cryogenic facility at Soudan has recently been approved.

M.E. Huber
University of Colorado at Denver and Health Sciences Center, Denver, CO, USA

T. Saab
University of Florida, Gainesville, FL, USA

P. Cushman · L. Duong · X. Qiu · A. Reisetter
University of Minnesota, Minneapolis, MN, USA

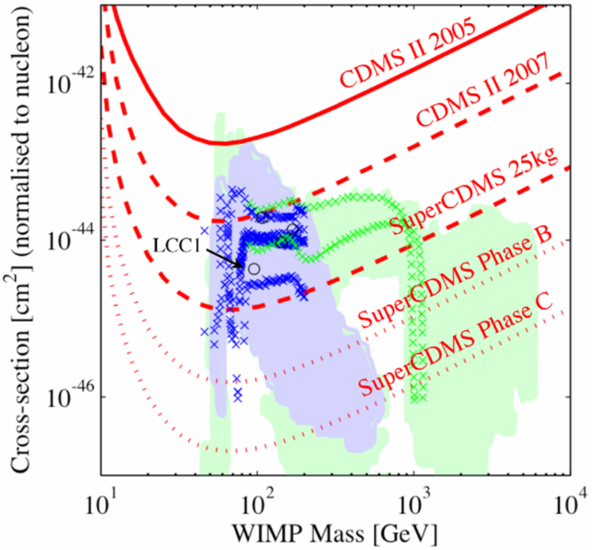

Fig. 1 (Color online) Present (*solid curves*) and projected (*dashed curves*) WIMP exclusion limits for present CDMS II and proposed SuperCDMS experiments. The two lower *fine-dashed curves* indicate the expected sensitivity of the SuperCDMS Phase B (145 kg) and Phase C (1000 kg) experiments. The *light* (*green*) [4] and *dark* (*blue*) [5] *crosses* are theoretical predictions from split supersymmetry models. The (*black*) *circles* are the constrained MSSM benchmarks from the Linear Collider Cosmology (LCC) study [6]. The *shaded regions* are mSUGRA theoretical models [7], all with WMAP constraints on the relic density. The *darker grey* (*blue*) *shaded region* also imposes a 1-sigma constraint from the muon g-2 measurement [7]

This paper provides an update on our present activities on the SuperCDMS program. We have refined our estimates for background contributions, further validating the need to move to a deeper site. The first SuperCDMS detectors have been successfully fabricated and are undergoing evaluation [8]. The improvements in detector performance required appear to be within reach.

2 Background Contributions in Direct Wimp Search

To perform a WIMP search experiment whose sensitivity increases linearly with time requires the search to be background free, with no events that could mimic the nuclear-recoil of interest [2]. Generally, for CDMS-style experiments, site selection and shield design around the cryostat determine the nuclear-recoil background due to neutrons; whereas detector design and surface contamination determine background contributions due to electron recoils.

Table 1 contains a summary of our best estimates for all known background contributions to the CDMS experiments, ongoing [1] or planned. We anticipate revisions to our backgrounds budget as further Monte Carlo simulations are performed and more data become available, both from our present detectors at Soudan and neutron data from deeper sites. However, the following conclusions and goals are not expected to change significantly as we go forward.

Table 1 Backgrounds expected in 10–40 keV nuclear recoil energy interval during the CDMS II five-Tower and SuperCDMS Detector Projects, and the future SuperCDMS 25 kg Experiment. Event Rates, and number of events {No.}, "before veto" include events that scatter in multiple detectors. Event rates and number of events for all other categories are for single-scatter events only. The event rates, in units of Events/kg-day, are computed assuming a fiducial volume of 70% of the total mass and a signal efficiency of 70%. The raw exposures assume a 68% duty cycle

Background events	All scatters before veto		Single scatters after veto		Leakage	Not rejected singles	
	Rate	{No.}	Rate	{No.}		Rate	{No.}
CDMS II Towers 1-5 at Soudan 4.5 kg × 485 days (raw 1300 kg-d)							
Gammas	n/a	{n/a}	147	{1.3E5}	2.0E-6	4.2E-4	{0.25}
Betas	n/a	{n/a}	0.4	{370}	2.1E-3	1.2E-3	{0.75}
Neutrons:							
radio-nuclides	n/a	{n/a}	2.0E-5	{0.01}	1	2.0E-5	{0.01}
muon-induced	1.1E-2	{7}	1.5E-4	{0.09}	1	1.5E-4	{0.09}
SuperCDMS ST 1-2 at Soudan 7.5 kg × 550 days (raw 2800 kg-d)							
Gammas	n/a	{n/a}	147	{2.9E5}	1.0E-7	2.1E-5	{0.03}
Betas	n/a	{n/a}	0.16	{320}	2.5E-4	5.8E-5	{0.08}
Neutrons:							
radio-nuclides	n/a	{n/a}	2.0E-5	{0.03}	1	2.0E-5	{0.03}
muon-induced	1.1E-2	{15}	1.5E-4	{0.20}	1	1.5E-4	{0.20}
SuperCDMS ST 1-7 at SNOLab 25 kg × 1100 days (raw 18 tonne-d)							
Gammas	n/a	{n/a}	68	{8.6E5}	1.0E-7	1.0E-5	{0.09}
Betas	n/a	{n/a}	0.16	{2000}	2.5E-4	5.8E-5	{0.51}
Neutrons:							
radio-nuclides	n/a	{n/a}	1.5E-5	{0.13}	1	1.5E-5	{0.13}
muon-induced	6.8E-5	{0.6}	4.5E-7	{4E-3}	1	4.5E-7	{0.004}

2.1 Nuclear Recoil Backgrounds

The present Soudan CDMS-II veto shield is 94% efficient at identifying muon-induced neutrons interacting with a single detector, with 80% coming from muon tagging, the remainder from detecting associated shower fragments. As indicated in Table 1, we anticipate that muon-induced, fast, neutrons will be the dominant source of background for running the first two SuperTowers at the 2080 meter water equivalent (m.w.e.) deep Soudan site.

Figure 2 shows a conceptual sketch for the cryostat and shielding appropriate to conduct a SuperCDMS experiment. At a deep site like SNOLab (6000 m.w.e.), neutrons from fission in the lead shield are expected to be the dominant source of nuclear recoil events, due to radio-nuclides assumed to be present at the 0.1 ppb level (see Table 1).

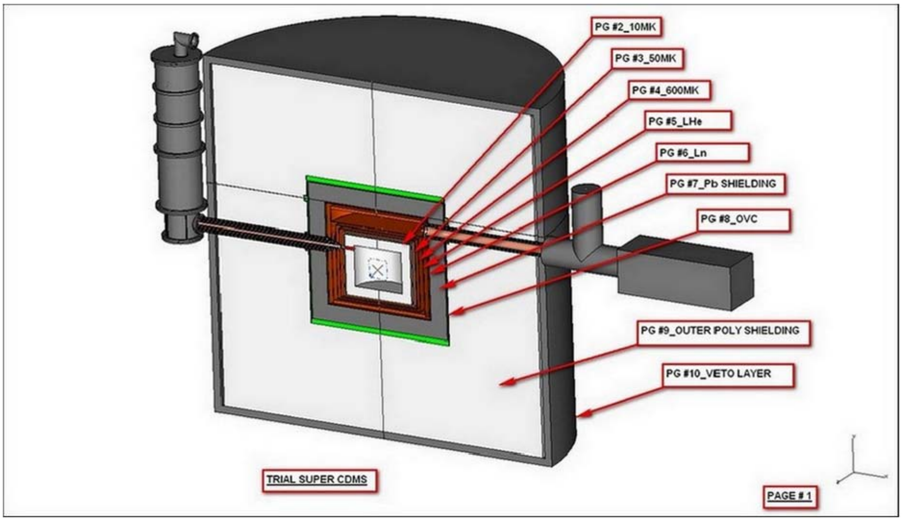

Fig. 2 (Color online) Conceptual sketch of SuperCDMS cryostat and shield. The detector volume is 289 liters, surrounded by several copper cans, the lead shield, the Al vacuum can, the (outer) polyethylene and the active muon veto

2.2 Electron Recoil Backgrounds

In order to protect the lead shield shown in Fig. 2 from radon gas and its associated plate-out daughters (a significant gamma background contribution at Soudan) we are considering installing the lead shield inside the outer vacuum chamber of the detector cryostat. Not only does this protect the lead from radon during operation, but the vacuum chamber wall can then be fabricated of aluminium rather than radio-pure copper.

As indicated in Table 1, the majority of background events detected by the CDMS detectors are due to gammas or betas. However the CDMS detector technology [1] allows us to reject the majority of these events in our search for true nuclear-recoil events. The detector leakage factor is worse for events classified as betas. These are electron recoil events within a few microns of the detector surface. The increase in detector thickness for SuperCDMS from 10 mm to 25.4 mm is treated as a reduction in the beta rate per unit mass in Table 1.

The remaining factor of 8 required in reducing the number of beta events will come from 4 sources [2]. Surface contamination due to radon-plate has dropped considerably for CDMS II Towers 4 and 5 compared to Towers 1 and 2 due to improved radon mitigation measures; the phonon sensor design has been re-optimized to increase the surface area coverage [8]; hydrogenation of the amorphous-Si electrodes is also being investigated with some promising results [8]. Finally, analysis of the pulse shapes had already extracted a factor of 3 improvement during the course of CDMS II [9], and we expect further improvements with sensor redesign closely coupled to simulation results and analysis of data.

3 SuperCDMS Outlook

With the funding of the Detector Development Project, the successful fabrication of the first 25 mm-thick Ge detectors and ongoing characterization results, we are confident that the background goals of both the Detector Development Project and the 25 kg Ge experiment can be accomplished.

References

1. N. Mirabolfathi et al., J. Low Temp. Phys., these proceedings, doi:10.1007/s10909-008-9741-6
2. R.W. Schnee et al., SuperCDMS Collaboration, astro-ph/0502435
3. P.L. Brink et al., SuperCDMS Collaboration, astro-ph/0503583
4. G.F. Giudice, A. Romanino, Nucl. Phys. B **699**, 65 (2004)
5. A. Pierce, Phys. Rev. D **70**, 075006 (2004)
6. E.A. Baltz et al., Phys. Rev. D **74**, 103521 (2006), hep-ph/0602187
7. E.A. Baltz, P. Gondolo, J. High Energy Phys. **0410**, 052 (2004)
8. C.N. Bailey et al., J. Low Temp. Phys., these proceedings, doi:10.1007/s10909-007-9645-x
9. D.S. Akerib et al., Phys. Rev. D **73**, 011102 (2006). CDMS Collaboration