

Final Report

Award: DE-SC0005054

Title: Cosmogenic background and shielding R&D for a Ge Neutrinoless Double Beta Decay Experiment

PI: V.E Guiseppe

Report Date: 1 Oct 2013

Progress Period: 1 Sept. 2011 – 31 Aug. 2013

Accomplishments and Schedule:

The USD Majorana group focused all of its effort in support of the MAJORANA DEMONSTRATOR (MJD) experiment. The PI manages MJD WBS Task 1.09: Mechanical Systems and Integration and coordinates task activities with the MJD Project Office. Task status and progress are regularly reported on collaboration teleconference calls and meetings. Final designs of the shielding subsystems are complete. An overview of the MJD mechanical design was presented at an Independent Safety Review: Shield Structural Safety and follow-up design and assembly plan presented prior to being granted authorization to proceed on shield construction. Construction of the MJD shielding systems at SURF has begun and the proposed activities directly support the completion of the shield systems.

Serving as a task leader, Guiseppe provides scientific and technical leadership over the Mechanical Systems task by: i) guiding the mechanical design to meet the functional requirements of the shield, ii) working with vendors to source ultra-pure Pb and Cu for the shield systems, iii) managing the cleaning of the shield components to meet cleanliness requirements, iv) developing a shield assembly plan, which was used as the basis for authorization to proceed with phase 1 shield assembly at SURF, and v) managing and coordinating all of the shield system construction and activities at SURF.

The PI and the group contribute heavily to the onsite construction activities of the MJD experiment. Since beneficial occupancy of the Davis Campus at SURF, the PI and graduate student N. Snyder spend nearly half time at the lab coordinating much of the task's activities and providing leadership over the lab operations. Postdoctoral Researcher Kirill Pushkin (2012-2013) was stationed permanently at the lab. There, Dr. Pushkin served as a Host Lab Infrastructure deputy task lead in addition to serving as the PI's deputy task lead. Dr. Pushkin provided a broad range of detector construction support while also assisting with the technical needs of shield assembly.

The group led investigations into neutron and neutron-induced backgrounds, shielding effectiveness and design, and radon backgrounds. Previous Postdoctoral Researcher G. Perumpilly (2010-2012) ran MaGe/GEANT4 simulations to provide design support of the MJD project. The results of this work have been used to provide design support of the MJD shield and to set detector and cryostat radon exposure limitations for assembly and the specifications for the assembly glove boxes. Analyses of neutron inelastic scattering on Cu and neutron activation of Pb have been completed; analysis of neutron inelastic scattering Ge-76 continues. Studies of radon progeny surface backgrounds continue with tests underway to understand the detector response to surface alpha decays. The results of these previous background studies will be used in the proposed analysis and the identification of backgrounds in the MJD experiment.

A listing of the key accomplishments during the progress period include:

1. Task Leader. The PI continues to serve as a level-2 task leader of the Majorana Demonstrator (MJD) Project. During the progress period, the PI has maintained and updated the Mechanical Systems and Integration schedule and budget and coordinated the task's activities. Task status and progress are regularly reported on MJ Collaboration teleconference calls and meetings. An overview of the MJD mechanical design was presented at the Preliminary Design Review in November 2010. We drafted a task-wide Failure Mode Effects Analysis. An overview of the MJD mechanical design was presented at the Independent Safety Review: Shield Structural Safety in December 2011. Final designs of the shielding subsystems are nearly complete and reviewed as completed. Construction of the MJD shielding subsystems at SURF has begun. The shield and monolith tables have been installed and the monolith transport system is operational. Outer Cu shielding installation has begun and Pb shield installation will begin shortly. The shield radon purge system is being developed with parts on hand and assembly underway. This system will deliver ultra-pure nitrogen gas to the innermost region of the detector to provide protection from the lab's high radon levels. A similar purge system for the assembly gloveboxes has already operational.
2. Simulation Efforts. Postdoctoral Researcher G. Perumpilly ran MaGe/GEANT4 simulations to provide design support of the MJD project. He completed and reported on MJD's sensitivity to i) external gammas, ii) low energy neutrons and the efficiency of poly shield, iii) radon in the inner volume, iv) external radon, v) Pb-210 backgrounds originating in the Pb shield, and vi) Pb-210 plate-out from radon. The results of i)-v) have been used refine the baseline design of the MJD shield and the results of vi) have been used to set detector and cryostat exposure limitations for assembly and the specifications for the assembly glove boxes. As part of the radon plate

out simulations, new physics were added to MaGe to correctly model the low energy recoils of the radon progeny.

3. **Experiment Operations.** The group has been spending a significant amount of time at SURF contributing to all aspects of laboratory infrastructure and construction activities. Postdoctoral Researcher Kirill Pushkin (2012-2013) was stationed permanently at the lab and served as the WBS 1.03: Host Lab Infrastructure Deputy Task Lead. There, he maintained many of the core day-to-day tasks and activities vital to the operations of the laboratory including daily inspections, managing clean room clothing inventory, coordination of delivery and cleaning of shipments to the lab, and providing guidance to the rotating shift managers. The rest of the group's regular presence (Guiseppe, Snyder) provides expertise and support of other laboratory functions including liquid nitrogen operations, laboratory ventilation measurements and adjustments, clean room protocols, Cu part tracking and labeling, and assistance with the Cu electroforming lab.
4. **BeGe and Detector Activation.** We continue to collaborate with the LANL group on the analysis of an activated BEGe detector to understand internal cosmogenics and pulse shape analysis rejection effectiveness. Also through collaboration with the LANL group, analysis of a neutron-activated semi-coax Ge detector continues to determine the detector response and activation rate of cosmogenics. This pulse shape work and ongoing determination of the cosmogenic isotope production rate is important for predicting the cosmogenic content and pulse shape discrimination of MJD backgrounds.
5. **Neutron Reactions.** We continue to study cosmogenic and neutron-induced backgrounds. Collaborating with LANL, we published the results of neutron activation of an enriched Ge sample that was placed in a neutron beam. When corrected for the cosmic ray flux at the Earth's surface, our work resulted in certain production rates for cosmogenics in enriched Ge. Measurement of neutron activation of Pb has been completed and provides the first evidence of cosmogenic production of Pb shielding. We continue to collaborate on the measurement of potential backgrounds through neutron inelastic scattering in detector materials. After leading the analysis of new measurements of neutron inelastic scattering in Pb, we assisted in the analysis with Cu, Ar, and Ne targets.
6. **Radon study.** In order to understand the backgrounds from radon exposure, we continue to establish a broad program to study progeny deposition and the resulting background contributions. We reported on the deposition rates of radon progeny and the factors that affect the rates. More importantly is to understand the detector response from the energetic decays from surface contaminants. We are modeling the true implantation profile of deposited

radon progeny to establish the primary locations of the originating decays and incorporate the texture (roughness) of the surface to correctly model the track of an energetic particle. We reported on this work and show that simulations are consistent with the measured energy spectrum only when using a depth distribution based on nuclear recoils and a realistic surface texture. This radon work has been reported at the international Low Radioactivity Techniques Workshops and is being prepared for publication.

Cost Status:

Base grant budget period 1-3: 9/1/2010 – 8/31/2013. The following table is an account snapshot as of Oct 1, 2013. Additional postings to the accounts are expected.

	Beginning Balance	Expenditures and Encumbered	Remaining Balance
Salary and Benefits	122400	119,500	2900
Travel	26100	29000	-2900
Indirect	64,500	64500	0
Total:	213,000	213,000	0

During the base budget period, two supplemental grants were funded as subcontracts through ORNL separate from the base grant.

	Beginning Balance	Expenditures and Encumbered	Remaining Balance
FY11	50,000	50,000	0
FY12	75,000	52,500	22,500

The remaining balance on the supplemental grant is expected to be redistributed by ORNL.

Publications :

*V.E. Guiseppe, S.R. Elliott, N.E. Fields, and D. Hixon. "Fast-Neutron Activation of Long-Lived Nuclides in Natural Pb." Submitted to Astropart. Phys. - In Revision (2013). arXiv:1209.4412[nucl-ex].

M. S. Boswell, S. R. Elliott, D. V. Perepelitsa, M. Devlin, N. Fotiades, R. O. Nelson, T. Kawano, and V. E. Guiseppe. "Neutron inelastic scattering in natural Cu as a background in neutrinoless double-beta decay experiments." Accepted by Phys Rev C (2013). arXiv:1210.4800[nucl-ex].

S. MacMullin, M. Boswell, M. Devlin, S. R. Elliott, N. Fotiades, V. E. Guiseppe, R. Henning, T. Kawano, B. H. LaRoque, R. O. Nelson, and J. M. O'Donnell. "Neutron-induced gamma-ray production cross sections for the first excited-state transitions in Ne-20 and Ne-22." Phys Rev C 86, 067601 (2012). arXiv:1210.1189[nucl-ex].

E. Aguayo et al. "Characteristics of Signals Originating Near the Lithium-Diffused N+ Contact of High Purity Germanium P-Type Point Contact Detectors." *Nucl. Instrum. Meth. A* 701, 176–185 (2013). arXiv:1207.6716v1[physics.ins-det].

R.A Johnson, T.H. Burritt, S.R. Elliott, V.M. Gehman, V.E. Guiseppe, J.F. Wilkerson. "Alpha Backgrounds for HPGe Detectors in Neutrinoless Double-Beta Decay Experiments" *Nuc. Instrum. Meth. A* 693, 51 – 58 (2012). arXiv:1201.0165v1[nucl-ex].

S. MacMullin, M. Boswell, M. Devlin, S. R. Elliott, N. Fotiades, V. E. Guiseppe, R. Henning, T. Kawano, B. H. LaRoque, R. O. Nelson, and J. M. O'Donnell. "Partial gamma-ray production cross sections for (n,xng) reactions in natural argon at 1-30 MeV." *Phys. Rev. C* 85, 064614 (2012). arXiv:1202.2141v2[nucl-ex]

C. E. Aalseth et al. "Astroparticle physics with a customized low-background broad energy Germanium detector." *Nucl. Instr. Meth. A* 652, 692–695 (2011). arXiv:1007.3231[nucl-ex].

*S. R. Elliott, V. E. Guiseppe, R. A. Johnson, B. H. LaRoque, and S. G. Mashnik. "Fast-neutron activation of long-lived isotopes in enriched Ge." *Phys. Rev. C* 82, 054610 (2010). arXiv:0912.3748[nucl-ex].

Conference Proceedings:

*G. Perumpilly, V. E. Guiseppe, and N. Snyder. "Modeling surface backgrounds from radon progeny plate-out." *LRT 2013 - AIP Conf. Proc.* (2013).

A. G. Schubert et al. "The MAJORANA DEMONSTRATOR: A Search for Neutrinoless Double-beta Decay of Germanium-76." *J. Phys.: Conf. Ser.* 375, 042010 (2012). arXiv:1109.1567[nucl-ex].

D. G. Phillips et al. "The Majorana experiment: an ultra-low background search for neutrinoless double-beta decay." *J. Phys.: Conf. Ser.* 381, 012044 (2012). arXiv:1111.5578[nucl-ex].

P. Finnerty et al. "The MAJORANA DEMONSTRATOR: Progress towards showing the feasibility of a tonne-scale ^{76}Ge neutrinoless double-beta decay experiment." *IOP Conf. Series* (2012). arXiv:1210.2678[nucl-ex].

*V. E. Guiseppe, S.R. Elliott, A. Hime, K. Rielage, and S. Westerdale. "A Radon Progeny Deposition Model." *AIP Conf. Proc.* 1338, 95–100 (2011). arXiv:1101.0126[nucl-ex]

*V. E. Guiseppe et al. "The Majorana Experiment." *Nucl. Phys. B – Proc. Supp.* 217, 44–46 (2011). arXiv:1101.0119[nucl-ex].

E. Aguayo et al. "The Majorana Demonstrator." DPF-2011 Conference Proceedings (2011). arXiv:1109.6913[nucl-ex].

Presentations:

V.E. Guiseppe, G. Perumpilly, N. Snyder "Modeling surface backgrounds from radon progeny plate-out." Topical Workshop on Low Radioactivity Techniques, Assergi, Italy (2013).

V.E. Guiseppe, "On a Path of Discovery with the Neutrino." Univ. of South Carolina Department of Physics Colloquium, Columbia, SC (2013).

V.E. Guiseppe "The Majorana Demonstrator Neutrinoless Double-beta Decay Experiment" April Meeting of the APS, Atlanta GA (April 2012).

G. Perumpilly, V.E. Guiseppe "Surface alpha backgrounds from plate-out of radon progeny" April Meeting of the APS, Atlanta GA (April 2012).

G. Perumpilly "The MAJORANA DEMONSTRATOR: A Search for Neutrinoless Double-beta Decay" 97th Annual Meeting of the South Dakota Academy of Sciences, Vermillion, SD (April 2012).

V.E. Guiseppe "Investigation of Backgrounds to Rare Event Searches Deep Underground." Los Alamos National Laboratory P-23 Seminar Series, Los Alamos, NM (2011).

V. E Guiseppe, University of North Dakota Physics Colloquium, Grand Forks, ND, "The Nature of the Neutrino Revealed Through Neutrinoless Double-Beta Decay," Invited (September 2011).

V.E. Guiseppe, S.R. Elliott, N. Fields, V.M. Gehman, D. Hixon, and D. Steele. "Neutron activation of long-live isotopes in Ge, Pb, and other metals." DUSEL Cosmogenic Activity and Backgrounds Workshop, Berkeley, CA (April 2011).

V.E Guiseppe. "The motivation and outlook of double-beta decay experiments." 96th Annual Meeting of the South Dakota Academy of Science, Oacoma, SD (April 2011).

D. Hixon, V.E. Guiseppe, S.R. Elliott. "Fast neutron activation of long-live nuclides in natural Pb" April Meeting of the APS, Anaheim, CA (April 2011).

V.E Guiseppe "A radon daughter deposition model for low background experiments." Topical Workshop on Low Radioactivity Techniques, Sudbury, ON (2010).

V.E. Guiseppe for the Majorana Collaboration. "The Majorana Experiment" 2010 Neutrino Oscillation Workshop (NOW), Conca Specchiulla, Italy (Sept. 2010).

Majorana Internal Reports and Presentations

G. Perumpilly, V.E. Guiseppe. "Effect of External Radon in MJ Demonstrator." [M-TECHDOCPHYS-2012-062] Jun. 2012.

G. Perumpilly, V.E. Guiseppe. "Radon in the Inner Volume of MJ Demonstrator." [M-TECHDOCPHYS-2012-061] Jun. 2012.

G. Perumpilly, V.E. Guiseppe. "Low Energy Neutrons: Efficiency of poly shield in MJ Demonstrator" [M-TECHDOCPHYS-2012-060] Jun. 2012.

G. Perumpilly, V.E. Guiseppe. "External Gammas in MJ Demonstrator" [M-TECHDOCPHYS-2012-059] Jun. 2012.

G. Perumpilly, V.E. Guiseppe. "Exposure limit due to Pb-210 plate-out from Rn." [M-TECHDOCPHYS-2011-049] Oct. 2011.

V.E. Guiseppe, E.W. Hoppe, J.A. Detwiler, Y. Efremenko. "Position Paper on Commercial vs. EForm Cu." [M-TECHDOCDDET-2012-139] Sept. 2011.

S. R. Elliott, V.E. Guiseppe, K. Rielage, M. Ronquest. "Rn issues for the Majorana Demonstrator." [M-TECHDOCDDET-2011-129] May 2011.

G. Perumpilly, V.E. Guiseppe. "Simulation of Pb210 Contamination of the Pb shield." [M-TECHDOCPHYS-2011-038] Apr. 2011.

V.E. Guiseppe, Majorana Collaboration Meeting, Lead, SD, "Shield Construction, Overview with Emphasis on Issues" (April 2013).

K. Pushkin, Majorana Collaboration Meeting, Lead, SD, "Rn Purge System" (April 2013).

V.E. Guiseppe, Majorana Collaboration Meeting, Spearfish, SD, "Monolith construction and custom lead bricks, Pb and Cu shield construction" (Oct. 2013).

V.E. Guiseppe, Majorana Collaboration Meeting, Spearfish, SD, "Inner Cu shield and Plastic shield layers" (Oct. 2013).

K. Pushkin, Majorana Collaboration Meeting, Spearfish, SD, "Shield purge systems and Radon" (Oct. 2013).

K. Pushkin, Majorana Collaboration Meeting, Spearfish, SD, "Detector room and glove box status" (Oct. 2013).

V.E. Guiseppe, Majorana Collaboration Meeting, Lead, SD "WBS 1.09 Mechanical Systems" (May 2012).

G. Perumpilly, V.E. Guiseppe, Majorana Collaboration Meeting, Lead, SD "Shield Simulations" (May 2012).

V.E. Guiseppe, Majorana Collaboration Meeting, Seattle, WA, "Gamma rays from the service body and the effectiveness of the shadow shielding (October 2011).

V.E. Guiseppe, Majorana Collaboration Meeting, Seattle, WA, "MJ 1.09 Mechanical Systems" (October 2011).

V.E. Guiseppe, Majorana Collaboration Meeting, Seattle, WA, "Tell-tale Signs of Neutron Interactions: How sensitive can we be to ^{77}Ge " (October 2011).

V.E. Guiseppe, Majorana Independent Safety Review: Shield Structural Safety, "Shield Functional Requirements" and "Assembly Procedures" (December 2011).

V. E. Guiseppe, "Mechanical Systems Overview." MJ Preliminary Design Review, Oak Ridge, TN (November 2010).

H. Salazar, V.E. Guiseppe. "Passive Shield System." MJ Preliminary Design Review, Oak Ridge, TN (November 2010).

D. Steele, S.R. Elliott, V.M. Gehman, V.E. Guiseppe. "Cosmogenic Background & PSA Studies in Donald." Majorana Collaboration Meeting, Oak Ridge, TN, (November 2010).

S. MacMullin, M. Boswell, S.R. Elliott, V.E. Guiseppe, R. Henning, A. Hime, B. Laroque. "Update on measurements of (n,n' gamma) reactions." Majorana Collaboration Meeting, Oak Ridge, TN (November 2010).

M. Ronquest for the MJ Radon Task Force. "The Radon Purge and Other Issues for the Demonstrator." Majorana Collaboration Meeting, Chicago, IL (May 2011).

V.E. Guiseppe, "MJD 1.09: Shield Status and Summary." Majorana Collaboration Meeting, Chicago, IL (May 2011).

G. Perumpilly, V.E. Guiseppe. "Radon Plate Out Simulations." Joint Majorana/GERDA Collaboration Meeting, Chicago, IL (May 2011).

S.R. Elliott, V.M. Gehman, V.E. Guiseppe, B. LaRoque, R. Cooper, D. Radford. "PSA Studies with Neutron-Activated Detectors." Joint Majorana/GERDA Collaboration Meeting, Chicago, IL (May 2011).