Dear SURF Readers,

Welcome to the March 2015 Sanford Underground Research Facility (SURF) monthly newsletter. The newsletter is posted online; a pdf copy is available as well. You can read recent and archived newsletters at our website -- www.sanfordlab.org. We are glad to receive your input on news, links to news articles, upcoming workshops, conference notices, scientific updates, information concerning SURF, employment opportunities, and other highlights relevant to underground science.

Important Dates

May 18-22: Conference on Underground Science at SURF - South Dakota School of Mines and Technology, Rapid City, SD

June 8-9: Berkeley Workshop on Dark Matter Detection – LBNL, Berkeley, CA – To register or for more details, see page 3

CUBED Research Activities

Dr. Dongming Mei, Physics Professor at the University of South Dakota, Michelle While, Chris Chiller, and Angela Chiller of the **C**enter for **U**ltra-low **B**ackground **E**xperiments in the **D**akotas (CUBED) have been installing equipment for the Low Background Counting facility (LBC) at the Davis Campus at SURF. The LBC began in 2012, led by researchers at the University of South Dakota in collaboration with others at Black Hills State University and SURF. Eleven institutions are members of the CUBED collaboration.

Experiments are located deep underground to minimize background cosmic-radiation, and also demand low radiation counts of the materials from which they are constructed. Material assays, screening, and low background counting capabilities are critical to the success of the planned SURF experiments. CUBED installed an n-type semiconductor germanium detector in the Davis Campus at SURF. The initial data predict ~ 100 mBq per kg sensitivity to ^{232}Th and ^{238}U with 7-day long assays.

More shielding is needed for this level of sensitivity than the mile of rock overburden (4300 m.w.e) on the Davis Campus. The detector is shielded by 10-cm of OFHC copper inside a stainless steel nitrogen purge chamber (radon mitigation). A 15-cm lead shield further reduces environmental gammas. Lead corrosion inhibition was accomplished through low-activity silica blasting and borated paraffin coating, which slows thermal neutrons and guards against human contact.

The CUBED low-background counting station has been counting backgrounds and CUBED researchers have been training students since March 2014. The CUBED counting station has a large cavity walled with copper bricks (shown in Figures 1-2). It is particularly useful for screening large objects, such as PMTs.

Figure 1: The cavity of the CUBED low-background counting station

Figure 2: The entire CUBED low-background station

Its recent background rate without LN purging was 0.12 Hz, achieved by rebuilding the lead shield with Mylar sheets that sealed the shield better. (Thanks to LBNL Senior Physicist / SURF Operations Head Kevin Lesko and LBNL Staff Scientist Vic Gehman for their help.) With an appropriate LN purging system, which has been built and awaits approval, a factor of 2 lower background rates can be achieved. Since the CUBED detector is an N-type, its threshold is as low as 12 keV, which has achieved sensitivity for counting 46.5 keV gamma rays from ^{210}Pb at a level of 2.5 mBq/cm^2. CUBED anticipates improving

this sensitivity at least by a factor of 2 once the designated LN purging is implemented.

This spring brought a new season to the CUBED low-background station at SURF. CUBED researchers replaced the preamplifier, which required moving 4.5 tons of borated paraffin lead bricks from around the germanium crystal. Once this was accomplished, they returned the copper and lead bricks surrounding the detector and applied a layer of Mylar to enhance the removal of radon via nitrogen gas purge (see Figure 3). Special thanks to Ryan Martin (USD), Kevin Lesko (LBNL), Jason Stock (SDSMT), Daniel Moore (SDSMT), Oren Loken (SURF) and Robyn Varland (SURF) for their efforts associated with the project.

The CUBED team will be implementing its Liquid Nitrogen Purge Dewar this month, and will begin sampling LZ components soon after.

Figure 3: Left: The final shield around CUBED is a Mylar screen; Right: Vic Gehman and Kevin Lesko place a brick on the reconfigured shield

NASA researches underground

When people think of NASA, they typically envision images of rockets, rovers, and stunning photographs of deep space. However, NASA is also involved with research on Planet Earth. Greg Wanger, Assistant Professor in Earth Sciences at the University of South California (USC), is participating in research funded by the NASA Astrobiology Institute (NAI). The group is interested in the study of 'intraterrestrials', microbes that inhabit the deep subsurface. On earth, microbes inhabit all the physical space that provides the minimum requirements for life as we know it. If there is life elsewhere in our solar system, it most likely resides below the surface. Understanding earth's intraterrestrials helps constrain the environments on other planetary bodies where life may be hiding. The multi-disciplinary team, led by Jan Amend at the USC, also hosts researchers from the California Institute of Technology, the Jet Propulsion Laboratory, Rensselaer Polytechnic Institute, and the Desert Research Institute. They are developing field, laboratory, and modeling approaches aimed at detecting and characterizing microbial life in the subsurface (see Figure 4).

Figure 4: SURF Team Members Maggy Osbourn, Brandy Reese, and Yamini Jangir on the 4850L near 17 ledge conducting water chemistry and taking microbial samples

Figure 5: Deep UV Fluorescence Scanner (predecessor to the Mars 2020 SHERLOC instrument) on the 4850L scanning a core sample collected during the LBNE drilling efforts

SURF has played a significant role in this research. With its dedication to scientific endeavors, SURF has granted the group tremendous access to the depths. With access and logistical support from the SURF staff, the researchers have been able to deploy several long-term experiments that until now have been very difficult or even impossible to undertake. Last year, they deployed a deep-UV laser fluorescence scanner to map core samples as they were extracted during the LBNE drilling operations (see Figure 5). This instrument is predecessor to one currently being developed at JPL for the Mars 2020 rover called SHERLOC (Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals) shown in Figure 6. SHERLOC, attached to an arm of the Mars rover, will use a special spectroscopy—wavelengths of light—to determine whether there are organics or other chemicals on the planet.

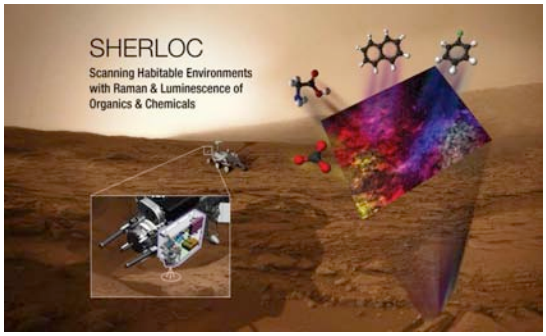

Figure 6: SHERLOC has been selected as one of seven investigations for the payload of NASA's Mars 2020 rover mission (Image credit: NASA/JPL-Caltech)

At Sanford Lab, researchers also have access to the technology they need and they can allow experiments to incubate. It helps considerably that the Sanford Lab underground has well-characterized geology and access to several levels, allowing 3-D windows into the subsurface. The greatest challenges are the extreme temperature swings on Mars, as much as 80-90 degrees each day, whether there will be enough light for the rover arm, and the amount of radiation SHERLOC can endure.

Meanwhile, the group focuses on life underground. "Studying life in extreme environments may help us identify those forms on other planets," Wanger said.

LZ (LUX-ZEPLIN) Review

A Department of Energy critical decision (CD) review of the LUX-ZEPLIN (LZ) Project took place on March 11-13 at Lawrence Berkeley National Laboratory (see Figure 7). Reviewers evaluated the readiness of the LZ Project for CD-1 (Approve Alternative Selection and Cost Range) and CD-3a for long-lead procurement of critical photomultiplier tubes. An experienced committee reviewed all aspects of the LZ Project design and cost and schedule based on presentations and extensive documentation provided by the LZ collaboration. A final committee report is under preparation. The outcome of the review will be described in more detail in next month's newsletter.

Figure 7: Panorama view of the LZ meeting held on March 11-13. LZ spokesperson Harry Nelson of UCSB speaks to the group

Name chosen for LBNE

The neutrino experiment formerly known as LBNE has transformed. Since January, its collaboration has gained about 50 new member institutions, elected two new spokespersons, and chosen a new name: Deep Underground Neutrino Experiment, or DUNE. To read more, see *Symmetry* (March 25).

Register for Workshop!

Berkeley Workshop on Dark Matter Detection, LBNL, June 8-9, 2015. Sponsored by LBNL's Institute for Nuclear and Particle Astrophysics (INPA) and UC Berkeley's BEPP Center (Berkeley Experimental Particle Physics). Theme for the 2015 workshop will be Dark Matter detection beyond G2-new ideas and directions. For contributions for presentations on new ideas, please contact: Kevin Lesko KTLesko@lbl.gov, Kathryn Zurek, KMZurek@lbl.gov, or Peter Sorensen pfsorensen@lbl.gov
To register: Melissa Barclay mbarclay@berkeley.edu
Website:
https://indico.physics.lbl.gov/indico/conferenceDisplay.py?confId=191

Reports/Papers Available

The Sanford Underground Research Facility at Homestake. (Jaret Heise, January 16, 2015, Cornell University Library, http://arxiv.org/abs/1503.01112.)

P5 report (Print quality) The full Particle Physics Project Prioritization Panel report as accepted by the High Energy Physics Advisory Committee

For news, *twitter* updates, and other features see the SURF website: www.sanfordlab.org
Like SURF on Facebook:
http://www.facebook.com/SURFatHomestake

SURF IN THE NEWS

Symmetry: The dawn of DUNE (Jennifer Huber, Kathryn Jepsen, March 25)
10 unusual detector materials (Troy Rummler, February 15)

Today at Berkeley Lab: *Dark Matter Experiment Completes First Reviews* (March 23)

BBC Radio 5 Live: Chamkaur Ghag discussing Dark Matter (February 13)
The Naked Scientists: Detecting dark matter (February 13)

Fermilab Today: New spokespersons named for experiment at Long-Baseline Neutrino Facility (March 13)
Fifty years of neutrinos (Constance Walter, March 11)
The Majorana Mysteries (Constance Walter, March 5)

Quantum Diaries: *ELBNF is born* (Joe Lykken, February 3)
A day in the life of a Black Hills WIMP hunter (Sally Shaw, February 3)

NC1 (CBS): Sanford Lab Set to Make History with New Experiment (Alyssa Terry, February 28)

KEVN: Science drama reading at Homestake Opera House (Staff, February 25)

Rapid City Journal: Sanford Lab inspires unique learning experiences for BHSU students (March 20)
Black Hills projects get state money (Bob Mercer, March 12)
Sanford Lab future is bright (Gov. Dennis Daugaard, March 2)
Homestake Visitors Center construction on track (Tom Griffith, February 26)
$5M Lead visitor center on track for June 1 opening (Tom Griffith, February 26)
Homestake (photos of the week, Josh Morgan, February 24)

Black Hills Pioneer: The Future of the Sanford Underground Research Lab (Gov. Dennis Daugaard, February 27)
8th Lead-Deadwood Winterfest begins Thursday (Adam Hurlburt, February 25)
Science + Arts: Sanford Lab & Homestake Opera House Theater Drama Reading of the Play "Background" (February 24)
L-D schools to propose math, science curriculum changes (Jaci Conrad Pearson, February 24)

DURA News

To comment on DURA, please contact its chair Richard Gaitskell (Richard_Gaitskell@brown.edu). For Bio-Geo-Engineering matters, contact Bill Roggenthen (William.Roggenthen@sdsmt.edu).
For further information on DURA, see: http://sanfordlab.org/dura

SANFORD UNDERGROUND LABORATORY NEWS

Golden Anniversary

Fifty years ago, in 1965, Ray Davis began building his neutrino experiment deep underground in the Homestake mine, with the goal of detecting neutrinos. Using a 100,000-gallon tank filled with perchloroethylene (dry cleaning fluid), Davis surmised that when neutrinos interacted with the chlorine atoms, they would change into argon atoms, which could be detected (see Figure 8). Davis's research eventually led to a shared Nobel Prize in Physics, awarded in 2002 "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos."

Figure 8: Ray Davis inspects his neutrino experiment tank during construction (Courtesy of Anna Davis)

The South Dakota portion of his research had already been preceded by nearly twenty years of similar experimentation at Brookhaven's Graphite Research Reactor in New York, the Savannah River Plant in South Carolina, and an 2300-foot deep underground limestone mine in Akron, Ohio.

In South Dakota, Davis launched a full-scale experiment underground. Currently, the LUX (Large Underground Xenon) experiment is located where Davis conducted his research, although the cavity was enlarged to make way for LUX. His former data room is used for LN2 (Liquid Nitrogen) storage. The

4850 Level Davis Campus derives its name from Ray Davis.

By the mid-70s, Davis began to see signs of neutrinos in the tank, but he consistently found only one-third of the neutrinos predicted by his collaborator, astrophysicist John Bahcall, leading to a dilemma referred to as the "solar neutrino problem."

"The solar neutrino problem caused great consternation among physicists and astrophysicists," Davis wrote. "My opinion in the early years was that something was wrong with the standard solar model; many physicists thought there was something wrong with my experiment."

Other scientists researched the solar neutrino problem, following up on Davis's research and questions. Eventually, the Sudbury Neutrino Observatory (SNO) in Ontario, Canada solved the question. As they travel through space, neutrinos oscillate, or change flavors, between electron, muon, and tau neutrinos. The SNO detector is sensitive to all flavors, while Davis's experiment detected only the electron type.

In 2002, Davis wrote, "a whole new field of neutrino physics has developed in directions I never imagined in the Homestake days." Some of this research is taking place at Sanford Lab.

This year, Sanford Lab will celebrate the golden anniversary with special guests and events.

Dr. Michael Cherry, Roy P. Daniels Professor at Louisiana State University, who worked with Ray Davis at Homestake for eight years, will discuss his experiences at a public presentation on Thursday, April 16. The event will be held at the Homestake Opera House in Lead, South Dakota.

July 11 is annual Neutrino Day, also held in Lead. This year, scientists from Fermilab will talk to visitors about the experiments taking place there. Ray Jayawardhana, Dean of Science at York University in Toronto, will be the keynote speaker. Author of *Neutrino Hunter* and *Strange New Worlds*, which was the basis for a television documentary, Jayawardhana has won numerous awards for his research and writing.

Other speakers include John Wilkerson, Principal Investigator with the MAJORANA collaboration (who also worked with Ray Davis), and Harry Nelson, spokesperson for LUX-LZ, the next generation dark matter experiment.

Info on Travel to Lead

Please be aware of possible travel delays to and from Lead starting Monday, April 6. Temporary signals will replace a four-way stop sign, and traffic will be reduced to one lane on some streets. You are encouraged to take the Central City route to and from Sanford Lab instead of Highway 85.

EDUCATION AND OUTREACH

Science and the Arts

The Sanford Lab Education and Outreach Department organized a *Science and the Arts* event - a staged reading of the play *Background*, by Lauren Gunderson - in February for the Lead community, held at the Historic Homestake Opera House. The play explores the life of cosmologist Ralph Alpher, who published the first predictions of the cosmic microwave background (CMB) in 1948 in the famous (among physicists) Alpher-Bethe-Gamow (αβΥ) paper. (Alpher's thesis advisor, George Gamow, added Hans Bethe's name as a joke.) Alpher was not acknowledged for his contribution when the CMB was discovered, or later when Penzias and Wilson were awarded the Nobel Prize in 1978 "for their discovery of cosmic microwave background radiation."

The event started with a reception, a science introduction by SURF Experimental Support Scientist Mark Hanhardt, and finally the reading of the play by local actors, including Sanford Lab Communications Director Constance Walter. The evening was supported in part by an NSF grant through the Center for Science and Performing Arts at the Graduate School of the City University of New York.

K-12 Outreach

Staff of the Sanford Lab Education and Outreach Department travel many miles to reach classrooms

across the state, sometimes literally and other times virtually.

Recently, E&O initiated efforts with Little Wound High School located on the Pine Ridge Reservation in Kyle, South Dakota. The school's principal and science teachers were excited to have Sanford Science and Education Center staff share personal experiences and career ideas, as well as the cutting edge science being performed at the Sanford Lab with their students. SURF Science Education Specialist Tom Campbell visited David West's high school chemistry class. The school is eager for science content in Chemistry and Biology, and also in Earth and Space Science.

Campbell presented to four chemistry sections at Little Wound using a practical Earth Science approach focusing on the alkali and alkaline earth elements. Some of these include what are affectionately termed by geochemists as large-ion lithophile elements (LILE). These are characterized as being somewhat incompatible during many geochemical processes due to their large ionic radius and +1 valence state (e.g., K, Rb, Cs). Other elemental oddballs include what are known as high field strength elements (HFSE) like Ta, Nb, U, Th, and the rare earth elements (REEs). It just so happens that all of these elements (along with Li, Na, Ca, and Be) are prevalent in what geologists refer to as "granite pegmatites," numerous in the Black Hills of South Dakota. These are right in the students' backyard. Pegmatites are essentially coarse-grained igneous rocks of granite composition that may contain an abundance of many Group 1 and Group 2 elements among the other elements referred to above. Campbell used an engaging combination of slides and discussion, and also asked a lot of questions.

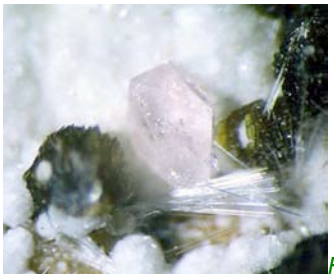

Figure 9: Pahasapaite (pink) from the Tip Top pegmatite near Custer, South Dakota. It is a lithium calcium potassium beryllophosphate hydrate. Field of view is 6mm.

The presentation was loosely based on Black Hills pegmatites and pegmatite occurrences throughout the world, which gave the students some idea of diverse geologic ages as well as a geographic perspective. The students became familiar with the concept of how atomic size and charge affect behavior of elements in an "earthly" context, such as Cs vs. Na. Campbell used common household objects such as a basketball and a golf ball for size analogies. He indicated how Cs was so large that it doesn't easily fit into the structure of most common rock-forming minerals and forms its own unique minerals like rhodizite, londonite, and pezzottaite.

He also related his personal research experience with pegmatites in his discovery of three minerals new to science from a pegmatite in South Dakota. He explained the analytical procedures involved in characterizing them, and how he subsequently named one of them Pahasapaite, for Paha Sapa, the Lakota word for the Black Hills (see Figure 9). All of the students appreciated the story and the naming of the mineral.

Campbell concluded his presentation with a short discussion of the CASPAR (Compact Accelerator System Performing Astrophysical Research) project at SURF, and how the accelerator will mimic nuclear fusion in stars and assist in understanding how many of the elements in the universe (and the Periodic Table) originated. This was a segue into plans for a star party at the school in April.

Wessington Springs is a rural community in the heart of South Dakota, approximately five hours from Lead. The science teacher at the Wessington Springs Middle School, James Kruse, is a regular attendee at teacher professional development workshops given by Sanford Lab E&O staff. In 2014, Kruse attended the *Underground STEM* workshop led by SURF Science Education Specialist Julie Dahl, and learned about the LUX and MJD experiments. His eighth-grade students recently completed a unit on dark matter and neutrinos, during which they piloted an engineering design activity that Julie has been developing, building models of the MJD lead shield so that no particles could get through the cracks (see Figure 10).

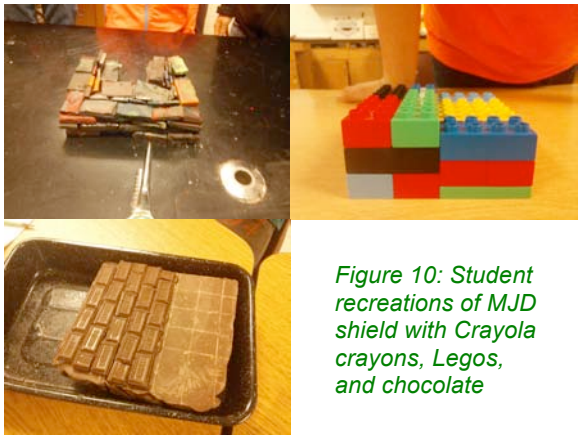

Figure 10: Student recreations of MJD shield with Crayola crayons, Legos, and chocolate

Students in Group 1 melted Crayola crayons in test tubes in boiling water, and then formed bricks. Once the finished bricks were completed, they arranged them in a small-scale model of the MAJORANA shield. Students in Group 2 collected and used Legos to build a shield. Students in Group 3 decided to make an edible MAJORANA shield. Their first attempt was to make a solid wall. When told this could not be done on the real shield, they modified it, made bricks, and etched a wall. The result took several builds.

The unit culminated in a videoconference to the Davis Campus, during which the students heard from SURF E&O Deputy Director Peggy Norris, Experiment Support Specialist Mark Hanhardt, and several graduate students from the MJD group. The middle school students were a little shy until they actually saw a corner of the lead shield on the camera in the MJD clean room. They then opened up with a lot of questions for the graduate students about the design. Photos of student designs are provided, courtesy of James Kruse.

ENVIRONMENT, HEALTH & SAFETY

Gardening Safety

- Always wear sun protection (a hat, long sleeves, and sunscreen).
- Take care when using lawnmowers and other garden equipment.
- Use potting mix carefully as it can cause Legionnaires' disease. Also, some plants are toxic.
- Always supervise children or pets in the garden; keep equipment and chemicals locked away and out of their reach.

Underground Lab Space Available

For use by Summer 2015 at the Waste Isolation Pilot Plant (WIPP). Formerly used by LANL researchers, space with four air-conditioned storage/office conexes (over 475 sq. ft. total) and one cleanroom (over 400 sq. ft.) is available (see insert photo). The cleanroom is plumbed for liquid nitrogen and has routinely operated as class 1000. Located in the northwestern part of WIPP, 667m below the surface, the cavity is mined in Halite.

More information about doing science at WIPP and radiologic characteristics is available at: http://www.wipp.energy.gov/science/UG_Lab/UG_LabNew.html.
For inquiries, please contact Roger Nelson at the DOE Carlsbad Field Office (575-234-7213) (roger.nelson@wipp.ws).

UPCOMING CONFERENCES AND WORKSHOPS

South Dakota Academy of Science 100th anniversary meeting, Cedar Shore Resort and Conference Center, Oacoma, SD, April 10-11, 2015. Symposium on 100 years of Physics in South Dakota. http://sdaos.org

APS April meeting, Baltimore, MD, April 11-14, 2015. Physicists and students in astrophysics, gravitational physics, nuclear physics, and particle physics will share new research and insights. http://www.aps.org/meetings/april/

Conference on Science at the Sanford Underground Research Facility (CUSSL), South Dakota School of Mines and Technology, Rapid City, May 18-22, 2015. Topics will include science carried out at Sanford Laboratory: Neutrino Physics, Proton Decay, Nuclear Astrophysics, Dark Matter, Neutrinoless Double Beta Decay, Materials Science for Nuclear and Particle Physics, Geology, and Biology.
http://meetings.undergroundphysics.org/indico/conferenceDisplay.py?confId=0

12th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2015), Vail Marriott Mountain Resort, Colorado, May 19-24, 2015. Focus on elementary particle physics, nuclear physics, astrophysics, particle astrophysics, nuclear astrophysics, and cosmology. Bonnie Fleming, cipanp2015_questions@yale.edu
http://cipanp2015.yale.edu

Neutrinos and Dark Matter in Nuclear Physics (NDM15), Jyväskylä, Finland, June 1-5, 2015. Gathering of scientists in fields of neutrino physics, astrophysics, and dark matter physics.
https://www.jyu.fi/en/congress/ndm15

Weak Interactions and Neutrinos Workshop (WIN2015), MPIK, Heidelberg, Germany, June 8-13, 2015. Examine crucial issues in neutrino physics and related fields.
http://www.mpi-hd.mpg.de/WIN2015/

Conferences for Undergraduate Women in Physics, Rapid City, South Dakota area, January 15-17, 2016. If you are associated with any of the physics experiments taking place at Sanford Lab or planned for the future, and wish to be involved in the planning process for the 2016 conference, please contact Peggy Norris at pnorris@sanfordlab.org.

JOBS

Research Associate, University College, London. Three-year post, research on Dark Matter, especially the LUX-ZEPLIN (LZ) experiment. Deadline: 3/25/15. Queries: Cham Ghag, c.ghag@ucl.ac.uk.
http://www.hep.ucl.ac.uk/positions/lz_ra_feb2015.shtml

Lecturer/Assistant Professor, Lancaster University (UK). Research in experimental particle physics, T2K collaboration, and the future ELBNF. Deadline: 3/31/15 Contact: Peter Ratoff, p.ratoff@lancaster.ac.uk
http://hr-jobs.lancs.ac.uk/Vacancy.aspx?ref=A1169

Associate Research Scientist, Fermilab. Work on Liquid argon TPC design and construction. Deadline: 4/3/15.
https://academicjobsonline.org/ajo/jobs/5401

Postdoctoral position, LLNL. Work on the WATCHMAN experiment, a low energy neutrino project-reactor, supernova neutrinos, and nuclear non-proliferation in the Nuclear and Chemical Sciences Division. Job ID: 12836.
https://careers-prd.llnl.gov/psp/careers/EMPLOYEE/HRMS/c/HRS_HRAM.HRS_CE.GBL?Page=HRS_CE_JOB_DTL&Action=A&JobOpeningId=12836&SiteId=1&PostingSeq=1

Associate Professor, Kamioka Observatory, ICRR, University of Tokyo. Conduct research at Super-Kamiokande and other future projects. Deadline: 4/27/15. Queries: Prof. Masayuki Nakahata, nakahata@icrr.u-tokyo.ac.jp
Applications: application@icrr.u-tokyo.ac.jp

Postdoctoral position, Texas A&M University. Work on SuperCDMS at SNOLab. Opportunities in detector development, cryogenic testing, data analysis, research project management. Position will remain open till filled. mahapatra@physics.tamu.edu
https://physics.tamu.edu/about/openpositions.shtml

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