Dear SURF Readers,

Welcome to the March 2016 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

April 26-28: LZ CD-2/3b Independent Project Review – LBNL, Berkeley

May 19-22: DUNE Collaboration meeting – SDSMT, Rapid City

CASPAR Installation - Progress

In January 2016, the Compact Accelerator System for Performing Astrophysical Research (CASPAR) facility reached a long anticipated milestone with the installation of its 1 Megavolt Van de Graaff accelerator column (Figures 1-2). This final equipment placement completes the first stage of installation at SURF. Researchers working at the CASPAR facility will study the processes in stars that create the heavier elements in the universe. Researchers, led by Frank Strieder, Associate Professor of Physics at South Dakota School of Mines and Technology, and CASPAR's Principal Investigator, began installing the system last fall.

Figure 1: Overview of the CASPAR accelerator with its tank closed and the first section of the beamline with a magnetic quadrupole doublet lens

Available equipment, e.g. accelerator and magnets, had to be refurbished and tested at the University of Notre Dame, new equipment, e.g. beamline components and support structures, were designed and integrated into the existing system, and a control system was developed.

The CASPAR accelerator consists of a source of ions and some means of producing electrical fields to accelerate them. The characteristics of the ion source determine to a great extent the limit on performance of an accelerator system. In general for nuclear astrophysics, it is important that the ion source produces a high particle current, which allows measurements to extend to lower beam energies. The ion species is very important; experiments involving light ions such as hydrogen and helium are usually of particular interest. The size of the source's ion-emitting area is also important, since it determines the minimum spot size to which the resulting ion beam can be focused at the experimental end station. It is desirable that the energy distribution of the ions emitted by the source be at a minimum.

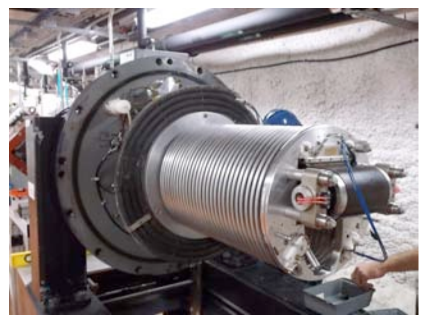

Figure 2: A close-up of the CASPAR Van de Graaff accelerator column. The belt to transport charge to the terminal is visible on the right-hand side. The ion source will be mounted below the belt on this end. The acceleration tube is inside the column, while rings outside ensure a homogeneous electrical field.

CASPAR uses a so-called RF-ion source, a plasma source using an electrodeless discharge produced by a radio-frequency (RF) field. Gas, either hydrogen or helium, is enclosed in a glass tube, and an RF field is produced inside the tube by exterior coils. The RF field causes naturally present electrons to oscillate in helical orbits through the gas, thus ionizing the gas atoms. The ions are extracted from an exit channel by a superimposed electrical field with a voltage of about 20 kV.

The Van de Graaff accelerator is modeled on a concept which was developed in the early 1930s. The high accelerating voltage is produced by mechanically transporting positively charged particles on a rotating belt made of insulating material that is driven by a motor, from the ground to the insulated high-voltage terminal.

Usually there are two pulleys, one at the base of the machine and one in the terminal. The surface of the belt is charged near the base pulley, using a set of sharp-pointed needles powered by a standard transformer-rectifier system, called the sprayer.

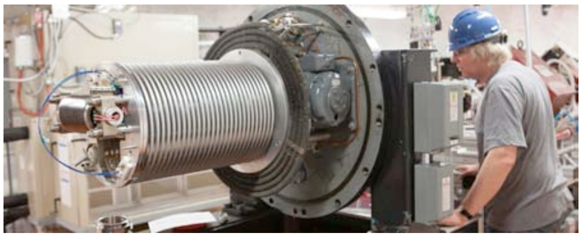

Figure 3: Frank Strieder, CASPAR Principal Investigator, inspects the CASPAR accelerator column

To maintain a desired voltage at a constant level, the transported charge must be in equilibrium with the charge losses. Charge is lost via the accelerated ion beam, leakage through the supporting insulators, and current flow through the chain of high resistances connecting the terminal with the ground. An increase in the belt current raises the terminal voltage, and an increase in the current losses lowers the voltage. The desired voltage is established predominantly by applying the correct sprayer voltage, and the extractable beam current is limited by the amount of charge that can be transported by the belt. The belt pulley also drives a generator (located inside the terminal), which is needed to power the various components of the ion source.

After production in the ion source, the ions enter the accelerating tube, which is kept at high vacuum to reduce discharging in the residual gas. The tube also must be able to hold the entire high voltage between the terminal and the ground, and is made up of insulating sections separated by metallic electrodes. These electrodes are connected to a resistor chain, producing a nearly-uniform voltage drop and ion acceleration along the column. The electrodes act as a succession of electrostatic lenses of long focal length providing some focusing properties. As a result, the ion beam at the exit of the accelerator usually has a diameter of less than a few millimeters. In order to improve the stability of the high voltage, the electric field along the belt and the tube should be as uniform as possible. For this reason, the whole structure is enclosed in a type of cage consisting of metallic circular rings enclosing the belt and the tubes. The rings are placed at equal distances along the axis of the accelerator and are connected to the resistor chain. The radius of curvature of all high-potential surfaces is kept as large as possible to reduce field gradients and thus discharges. The entire accelerator structure is contained in a tank filled with the electrically insulating gas at high pressure, a CO_2/N_2 mixture at 200 psi.

Figure 4: The accelerator column after installation

With the accelerator as well as the beamline now reassembled and the ion source to be installed soon, a final push is underway toward full-system commissioning prior to the projected start of beam tests in late spring. Accelerator operations will make CASPAR the deepest underground accelerator facility in the world--the first of its kind in the US--and lead to reaction studies significant for neutron sources for the s-process responsible for the production of about half of the chemical elements heavier than iron.

CASPAR Accelerator System: Some Facts (Figure 5)

1. *Turbo molecular pumping system*: Used to evacuate the beamline of air. Transporting particles within a vacuum tube reduces energy loss and scattering that can happen in collisions with gas.

2. *Beam profile monitors*: These intercept the beam periodically, providing information on beam shape, size, and position.

3. *Quadrupole magnet doublet*: Electromagnetic focusing elements in CASPAR's beamline used to confine the beam and deliver a focused beam to the target.

4. *Faraday cup system*: This can be inserted into the beamline, when required, to intercept the beam and measure the amount of particles per second which is being worked with.

Figure 5: The CASPAR accelerator

5. *4-jaw slits*: Slit systems are used to define a desired region to tune the beam of particles through, to help define the beam shape and size.

6. *Accelerator tank*: The accelerator is confined within a steel pressure vessel at ~200 psi of insulating gas to help maintain the voltage of the accelerator independent of room conditions.

7. *Dipole analyzing magnet*: This is an electromagnetic dipole bending magnet used to deflect ions 25 degrees. It ensures that only those particles with the right energy are directed to the target in CASPAR's beamline.

Recent SURF Publications

The MJD collaboration group published their first paper involving data collected at SURF. "Muon Flux Measurements at the Davis Campus of the Sanford Underground Research Facility with the MAJORANA DEMONSTRATOR (MJD) Veto System" is available at: http://arxiv.org/abs/1602.07742.

Another LUX paper that has been recently published, "First spin-dependent WIMP-nucleon cross section limits from the LUX experiment," is available online at: http://arxiv.org/abs/1602.03489.

REPORTS/PAPERS AVAILABLE

Forward Momentum 2025, a 5-year strategic plan based on a 10-year vision for SURF: *www.sanfordlab.org/sites/sanfordlab.org/files/.../Forward_Momentum.pdf*

All four volumes of the Deep Underground Neutrino Experiment (DUNE) for Conceptual Design Report DUNE/LBNF are now available on arXiv: Vol. 1. Overview 1601.05471. Vol. 2. Physics 1512.06148, Vol. 3. LBNF 1601.05823, Vol. 4. DUNE detector 1601.02984. http://arxiv.org/

The Sanford Underground Research Facility at Homestake (SURF). (K.T. Lesko, Phys.Procedia 61 (2015) 542-551.)

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 Sanford Lab Visitor Center on Facebook: https://www.facebook.com/sanfordlabhomestake/

SURF IN THE NEWS

Fermilab Creative Services: Why I love neutrinos (Mike Headley, February 18)

Science Springs: Majorana wins big with 'second string' (Constance Walter, February 29)

Forbes Magazine: Ten amazing things astrophysics says about you (Brian Koberlein, March 12)

YouTube: Season 1 Episode 2: Gravitational Waves with Mark Hanhardt from Sanford Lab (Junky Chunks, February 25)

KOTA Territory: School of Mines hosts regional conference for student physicists (Staff, March 13)
Children First: Reaching students with STARBASE (Scott Gross, February 29)

NewsCenter 1: Pi day; *Pi Day Art* (Monica Davis, March 14)

Prairie Business: Education: Learning Opportunities for All Ages (Tom Jackson, Jr., February 26)

BHSU news: BHSU students mentor middle schoolers during underground competition at Sanford Lab (Staff, March 8)
Sanford Lab inspires unique learning experience for students (Staff, March 6)

SD Mines News: Mines Hosts Student Physicists (Staff, March 11)
Physics Senior Takes Underground Research to the Capitol (Staff, March 1)

Mitchell Daily Republic: Van Driel: Undergrad goes underground (Kella Rodiek, March 5)

Rapid City Journal: Women in Science Conference encourages interest in STEM fields (Josh Morgan, March 9)

Black Hills Pioneer: Sanford Lab Homestake Visitor Center hosts first Pi Day celebration (Adam Hurlburt, March 15)

DURA

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

Underground Robotics competition

On March 4, 16 middle-school students from Belle Fourche and Spearfish participated in the Robotics competition at the 4850 Level of Sanford Lab (Figure 6). Coordinators included Brianna Mount, Research Assistant Professor at BHSU, and BHSU students Tonia Robinson (pre-optometrist major) and Krystal Nelson (pre-med major) who served as mentors for the middle-school teams.

Figure 6: Brianna Mount focuses the camera on one of the LEGO robots as it navigates the obstacle course. Krystal Nelson, BHSU student who mentored the winning team, looks on.

The students, who could see and hear the robots through a live internet connection, worked in eight groups of two, using LEGO Mindstorm kits, designing a robot able to navigate an obstacle course that included tunnels, a bridge, and tight turns.

"This competition really engages middle-school students in science, technology, engineering, and math (STEM) because it's hands-on learning," Mount said. "They construct and program the LEGO robots, and then get to see the results of their work. It's educational and fun."

EDUCATION AND OUTREACH

Education & Outreach Curriculum: Beyond the Pilot

Last summer, Education and Outreach at Sanford Underground Research Facility developed six science curriculum units—two each for grades 3-5, 6-8, and 9-12. These curriculum modules provide K-12 teachers with tools to share the science of Sanford Lab with their students in a way that is aligned with South Dakota's science education standards. Each unit includes a materials kit and inquiry-based lessons in which students ask questions and test theories. The units span one to two weeks of instructional time and are delivered to the classroom by an E&O staff member.

The Education and Outreach team has been working with teachers across South Dakota this academic year to pilot test the curriculum units. During the pilot, each teacher is assigned a support person. Teachers agree to use the curriculum units in their classrooms and provide feedback about how their students connected, or did not connect, with the lessons. Teachers are also asked for suggestions to improve the units. So far, the E&O staff has received detailed feedback from more than a dozen teachers. Feedback from teachers is a crucial component and will be used to refine the units.

Additionally, E&O has enlisted the assistance of an outside evaluator. The evaluator will conduct short phone interviews with this year's teachers to gain further insight into the implementation of the curriculum units. The evaluator will also help the E&O team evaluate pre- and post-student data to measure student growth.

The goal is to have all six of the current curriculum units fully revised and formalized for broader dissemination next fall.

Figure 7: Students explore the concept of dark matter in the universe

This summer, approximately 20 teachers at each grade band will attend professional development connected to the units. During the weeklong teacher training (June 27-July 1), each teacher will have the opportunity to explore two curriculum units. Next school year, these teachers will have access to all of the curriculum units for use within their classrooms.

National Pi Day

To celebrate "National Pi Day," Sanford Lab, in partnership with the Sanford Lab Homestake Visitor Center and the Lead Deadwood Arts Center, hosted the first Lead Pi day at the Visitor Center in Lead. Dan May, Assistant Professor of Mathematics from Black Hills State University, explained the concept of Pi and how it relates to the science and engineering taking place at Sanford Lab. Events featured hands-on activities and Albert Einstein birthday card art contest for area students. (Pi Day is also Albert Einstein's birthday.) Pizza Lab in Central City provided "Dark Matter" and "Neutrino" pizza pies, and the Hearst Library in Lead sold pies as a fundraiser for the Library. Pi Day is celebrated March 14 in honor of the constant number, representing the ratio of a circle's circumference to its diameter: briefly 3.14.

Deep Talks

A Deep Talks meeting takes place the second Thursday of each month at the Sanford Lab Homestake Visitor Center, and will continue through May. Over 60 people attended on March 10 to hear Vince Guiseppe, Assistant Professor at the University of South Carolina, and Cabot-Ann Christofferson, MAJORANA liaison to Sanford Lab and chemistry instructor at South Dakota School of Mines, speak on "Nuggets, acids, and plates: The underground production and installation of the purest copper in the world." A reception preceded the talk, with sample craft brews from Crow Peak Brewery, as well as light refreshments.

ENVIRONMENT, HEALTH & SAFETY

Earth Day: April 22

- Think globally, act locally.
- Recycle; reuse; replenish; reduce; restore
- Plant a tree! (#Trees4Earth)
- To participate in events where you live: http://www.earthday.org/

STAFF NEWS

Markus Horn joined Sanford Lab as a research scientist. He has been part of the Large Underground Xenon (LUX) collaboration since 2012. He will continue to work with LUX, and then transition to LUX-ZEPLIN (LZ), the next generation dark matter. In his new role, Horn will support current and future science experiments and help review potential new experiments.

Charles Maupin, a mechanical engineer, will be working with David Taylor, SURF Senior Project Engineer, to design the LZ cryogenic system. Maupin is a graduate of South Dakota School of Mines and Technology, and previously worked at *Spencer Fluid* in Gillette, Wyoming.

New infrastructure technicians who will be working in the Ross Shaft include: Mike Mergen, Max Voorhees, and Mike Johnson.

UPCOMING CONFERENCES AND WORKSHOPS

Cosmology 2016 Rencontres de Moriond Conference, La Thuile (Valle d'Aosta, Italy), March 19-26, Topics devoted to Cosmology and dark matter. For registration and more details:
http://moriond.in2p3.fr/J16

APS April meeting 2016, Salt Lake City, April 16-19. **The Cold Universe**, April 25-July 15, UC Santa Barbara.
http://www.aps.org/meetings/calendar.cfm

PhysStat2016 workshop, Kavli IPMU University of Tokyo, May 30-June 1**.** A second workshop will follow at Fermilab, September 19-21.
http://indico.ipmu.jp/indico/conferenceDisplay.py?confId=82

Neutrino 2016, **London, England**, July 4-9. Programs on neutrino physics, the impact of neutrino physics on astronomy and cosmology, and future development.
http://neutrino2016.iopconfs.org/home

Geoneutrino summer school, Gran Sasso, Italy, July 11-21. Bring together nuclear/particle physicists and geologists, with the aim to contribute and build up a new geoscience community.
https://agenda.infn.it/conferenceDisplay.py?confId=10519

ICHEP 2016 Chicago: 38th International Conference on High Energy Physics, August 3-10, Chicago. Physicists will share latest advancements in particle physics, astroparticle physics, cosmology, and accelerator science.
http://ichep2016.org/

NuFACT 2016, Quy Nhon, Vietnam, August 21-27. Workshop on neutrino physics beyond the PMNS matrix.
http://vietnam.in2p3.fr/2016/nufact/

JOBS

Postdoctoral Fellow (Nuclear Science), LBNL. Work on experiments to search for lepton number violation and to probe the absolute neutrino mass scale. Contact: Alan Poon, awpoon@lbl.gov. Closing: 3/30/16.
https://lbl.taleo.net/careersection/2/jobdetail.ftl?lang=en&job=82113

Postdoctoral position, Univ. of Michigan. Research with neutrino group. Opportunities to work on JSNS2 experiment in Japan, SBND, and MicroBooNE experiments at Fermilab. Contact: Joshua Spitz, spitzj@umich.edu. Closing: 7/15/16.
http://inspirehep.net/record/1423248

Postdoctoral Research Fellow, Queen's University. Research with PICO Dark Matter experiment at SNOLAB. Contact: Tony Noble, potato@snolab.ca. Review begins: 3/1/16.
https://www.snolab.ca/employment/2016-02-02-post-doc-position-queens-university

Postdoctoral Position, Brown University. Research on LUX-ZEPLIN (LZ) in Astroparticle Physics group led by Rick Gaitskell. Review begins: 2/6/16. Contact: richard_gaitskell@brown.edu
https://academicjobsonline.org/ajo/jobs/6834

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