

Dear SURF Readers,

Welcome to the September/October 2016 (and FINAL) issue of the 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. Over the past eight years, we have enjoyed receiving your contributions highlighting underground science. Please read Kevin Lesko's article below on the history and evolution of SURF.

Important Dates

November 15-17: LZ CD-3 Director's Review – LBNL, Berkeley

December 5-6: Dark Matter Workshop - LBNL, Berkeley (Please see page 9)

A Brief History of the Underground Laboratory Efforts at Homestake

Kevin T. Lesko

This newsletter began in November 2008, almost 100 issues ago, and this issue marks our last publication, as management of SURF transitions from Berkeley Lab to Fermilab. On this occasion, I would like to share my personal memories of the history behind the establishment of the first and only major U.S. underground laboratory, by collecting some of the events and milestones that resulted in the formation of the Sanford Underground Research Facility, or SURF. This short article pulls together some of the major milestones over the past 16 years on the road to the establishment of this major physics focus for the U.S. and indeed, the world physics program. It reflects my personal views, seen primarily through the lens of my own involvement throughout this endeavor.

Today, at the 4850 Level, SURF houses the world-leading dark matter experiment, LUX (Figure 1), and is preparing to install the LUX-ZEPLIN (LZ) experiment with thirty times the sensitivity of LUX. The MAJORANA DEMONSTRATOR is online and collecting data in which researchers hope to find evidence of neutrinoless double-beta decay (Figure 2). And the CASPAR collaboration is installing its nuclear astrophysics facility at SURF's 4850 Level. The Black Hills Underground Campus houses four of

the world's most sensitive low background assay devices and is preparing to install an additional four in the coming year. A collection of biology and earth science experiments are making increasing use of the Sanford Facility's underground infrastructure including a significant effort by kiSMET.

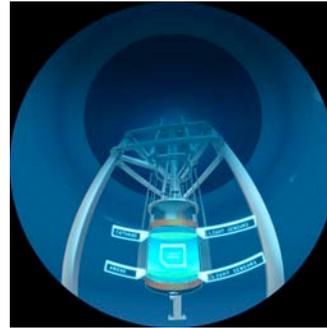


Figure 1: A scene from the planetarium show: A view of the LUX detector at the Homestake Mine in South Dakota. (Image courtesy of planetarium show "Phantom of the Universe")



Figure 2: The MAJORANA DEMONSTRATOR team moves Module 2 into the shield. Right: Module 1 has been operating in the shield for a year. Module 2 began collecting data in August.

Very importantly, Lead, South Dakota has just hosted its 8th annual neutrino day (early forms of neutrino day date back to 2001). In the past month, Fermilab's Long Baseline Neutrino (LBNF) was awarded DOE's CD-3a for advanced acquisition, and is preparing for the cavern excavation required for that massive experiment. Indeed, the Long Baseline Neutrino program has become the most ambitious domestic physics effort since the SSC. Recognizing the importance of SURF to this program, on 1 October 2016, the management of SURF transfers from Berkeley Lab to Fermilab.

The efforts to create an underground research facility in the U.S. date back to at least the 1980s¹ with the first reference I found being a report showing detailed concepts for an underground physics laboratory. Al Mann, of the University of Pennsylvania, one of the authors of this report, was decades ahead of the rest of us. While the early efforts were ultimately unsuccessful, they laid out a vision that would come to fruition many years later.

I became involved in the Homestake efforts in the fall of 2000. Wick Haxton, then at the University of Washington, was organizing a neutrino working group session in preparation for the Nuclear Physics Long Range Plan. Wick requested that I organize and chair a session considering options for a U.S. underground laboratoryⁱⁱ. It was at this meeting that Ken Lande, of the University of Pennsylvania, announced that the Homestake Mine, long the home of Ray Davis's seminal Homestake Chlorine solar neutrino experiment, was closing and the facility would be donated to science. At this pre-meeting, the momentum for a U.S.-based underground laboratory began to gather. It was here that Princeton Professor Frank Calaprice advised us to "go deep". The primary conclusion from this meeting was:

Recommendation #1:

...

- *To satisfy the background requirements of new solar/supernova neutrino and double beta decay experiments, the nuclear physics community should spearhead an effort to create a deep underground multipurpose laboratory. Because this national facility could also serve the needs of dark matter and nucleon decay experiments, it is important to involve colleagues from particle and astrophysics. The urgency of one of the proposals (Homestake) requires that the community move now to define the merits and attributes of such a facility.*

To understand better the spectrum of physics experiments that would benefit from an underground laboratory, as well as the biology, geology, and engineering uses, the Bahcall Committee was established in late 2000, which I co-chaired with John Bahcall. The committee included many notable physics leaders including Barry Barish, Janet Conrad, Wick Haxton, Kem Robinson, Marvin Marshak, Peter Doe, and Tom Glasser. The committee generated a detailed examination of the science options as well as technically evaluating six sitesⁱⁱⁱ. The technical evaluation report proved useful over the intervening 16 years. This committee issued its report in March 2001, unanimously recommending the Homestake site for a National Underground Scientific Laboratory (NUSL).

Under Wick Haxton's leadership, a proposal was submitted to the National Science Foundation (NSF) and plans for the State of South Dakota and the NSF developing the Homestake site for an MREFC project advanced for several years. In 2002, a major workshop on Neutrino and Subterranean Science (NESS) was convened by the White House Office of Science and Technology Policy to examine the physics programs possible at a deep underground laboratory and at the South Pole. Barry Barish's report on the NRC^{iv} study figured prominently in this workshop. During this period, I served on the NUSL Executive Advisory Board, until the NUSL efforts halted in 2003.



Figure 3: Historic sign from the Homestake Mining era



Figure 4: May 2009 underground photo – the water level had finally reached the 4850 Level. The Davis Cavern, mostly below the 4850 Level, still had to be pumped dry.

In 2004, Michael Turner, then Director of the NSF's Math and Physical Sciences Division, took steps to re-examine the case for a deep underground, multidisciplinary laboratory. An informational meeting was held at the NSF on 29 March 2004 in which a set of solicitations from the NSF was detailed to provide the agencies with the information needed for such a large undertaking. The NSF created Solicitation-1 (S-1) to generally define the requirements for an underground lab and associated

infrastructure in a site-independent manner. S-2 funded four sites to develop concepts for a laboratory. S-3 was the down-select between these sites. Later, S-4 funded R&D science-related activities for long-term needs such as advanced technology or background control and mitigation. Bernard Sadoulet (UC Berkeley) was the PI for the S-1 effort with Gene Beier (University of Pennsylvania), Hamish Robertson (University of Washington), Charles Fairhurst (University of Minnesota), T.C. Onstott (Princeton), and James Tiedje (Michigan State University). They generated the Deep Science Report⁵.

I submitted the proposal for the Homestake Site with UC Berkeley as the lead institution, together with Bill Roggenthen as co-PI from South Dakota School of Mines & Technology (SDSM&T). We received S-2 funding in September 2005 to create a detailed report for Homestake. Between 2005 and 2007, Bill and I formed the Homestake Collaboration and forged strong ties to the South Dakota Office of the Governor. The South Dakota Science and Technology Authority (SDSTA) was formed, and established a Program Advisory Committee, soliciting letters of interest from scientific collaborations interested in working at Homestake. SDSTA also created a Cultural Advisory Committee, and made strong connections to the local communities. Demonstrating the strong interest in underground science, we received 85 letters of interest from collaborations seeking space in the underground for their experiments. The Homestake Conceptual Design Report was completed in January 2007, one of four site-specific reports submitted to the NSF.

The steadfast and strong support from the State of South Dakota throughout this process cannot be overstated. Working with the State Legislature, Governor Rounds secured \$46M for the conversion of the former Homestake gold mine to a world leading science facility. In June 2006, South Dakota philanthropist T. Denny Sanford donated \$70M (!) for the creation of the facility, primarily interested in the impact that the scientific and educational created by the Sanford Laboratory would have on the students of South Dakota. A strong collaboration was forged among the state, private, and NSF teams around the Deep Underground Science and Engineering Laboratory (DUSEL). Then Governor and now-Senator Rounds deserves the lion's share of credit for establishing SURF. I have worked with

three Governors of South Dakota, five executive directors of the SDSTA, and all of the South Dakota Congressional delegation for the past decade. Although they have all been important to the process and have played key roles, no individual has maintained a clearer picture of the impact of an underground research facility on his state nor worked harder to achieve a world-class facility than Mike Rounds.



Figure 5: Governor Mike Rounds, Kevin Lesko, and Bill Roggenthen tour the Hearst Mining Building at UC Berkeley, which was dedicated to the memory of California Senator George Hearst, founder of the Homestake Gold Mine in Lead, S.D. (June 2009)



Figure 6: January 2009 photo of reviewers, participants and observers in front of the Faculty Club, UC Berkeley

In June 2007, the NSF site selection process chose Homestake as the site for DUSEL. We received funding to develop a full Technical Design over the following three years. These years were a period of intense activity and productivity. We forged strong ties with our experimental collaborations, which spanned physics (neutrino oscillations, neutrinoless double beta decay, dark matter, nuclear astrophysics, low background counting) biology, earth sciences, and engineering. Special advisory committees were established to understand the limits of large span cavities within rock formations at depth--the Large Cavity Advisory Board. The

Infrastructure Advisory Board assisted with access and general facilities infrastructure, and an exceptionally talented and critical Environment Health and Safety Oversight Committee aided us in developing a safe working environment. The DUSEL Experiment Development Committee kept us in line with the experimental requirements across a wide spectrum of interested users. We were faced with the simultaneous challenge of converting the former mine to science uses, installing an Early Science Program supported by the SD Funds, and developing the longer-term plans for DUSEL.



Figure 7: Inside the Large Underground Xenon dark matter detector, arrays of photomultiplier tubes can detect a single photon of light

Of course, there were many reviews during this time: annual reviews by the NSF, internal reviews by the project and UC Berkeley, and proposal reviews, to name some of them. Each year saw the project team become stronger and more experienced with help from Ed Temple's annual improvement plans, which some interpreted as "beatings," in a light-hearted way. Our Preliminary Design Report (PDR)^{vi}, was completed in May 2011 and reviewed in July 2011, receiving very high marks from the NSF's independent review panel. Throughout this period, Jon Kotcher, David Lissauer, Steve Meador, and Joe Dehmer at the NSF made sure that we were on track with the agency requirements and progressing rapidly enough. The DUSEL team numbered somewhere around 100, and many of those individuals still form the core of SURF's staff today. While all made significant contributions, I especially wish to recognize contributions from Dick DiGennaro, Graham Fleming, Gil Gilchriese, Mike Headley, Dianna Jacobs, Mandy Knight, Bob Lanou, Don Medley, Kem Robinson, David Vardiman, Ron Wheeler, and Josh Willhite. They deserve recognition for their efforts in crafting the DUSEL studies and reports and establishing the Sanford Laboratory.

In December 2010, the National Science Board (NSB), abruptly decided to stop funding the NSF

efforts to steward DUSEL. The decision came just months the scheduled completion of the PDR and planned PDR reviews. This created a difficult situation for the science collaborations and the other funding agencies who were relying on the formation of DUSEL to host experiments. In particular, the DOE was depending on DUSEL to host neutrino, double beta decay, and dark matter experiments. The NSF and DOE, in late 2010, had already solicited the National Research Council (a research arm of the National Academy of Sciences) to assess the science program proposed for DUSEL. The NSB decision occurred days before the first NRC committee meeting. Barry Barish, the physics consultant of the NSB, presented the Board's decision to the NRC's committee and the DUSEL team at this meeting. Fortunately (in my opinion) the committee still completed their work. Then, in February 2011, the DOE Office of Science asked Jay Marx and Mark Reichanadter to convene a study of options and alternatives^{vii}. The NRC committee integrated the conclusions of the Marx committee^{viii} into their report. I am particularly proud that the DUSEL team was able to maintain their focus, completing the PDR, and performing exceedingly well in presenting the Preliminary Design to the NSF's review panel in July 2011.

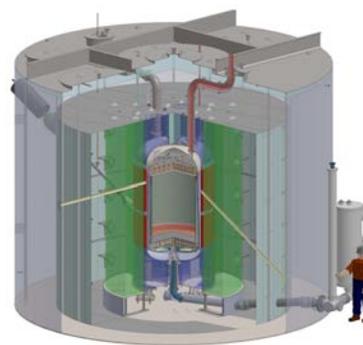


Figure 8: The LUX-ZEPLIN (LZ) Facility is currently under construction with an anticipated opening date of 2020

With DOE support, the Sanford Underground Research Facility kept its doors open. Two major experimental users of the facility--MAJORANA DEMONSTRATOR and LUX—were installed underground. LUX soon achieved and maintained world leadership searching for Dark Matter (Figure 7), and just last month completed its data taking. The international LZ collaboration is planning to install a new dark matter experiment 30 times larger in place of LUX (Figure 8), and has already passed its CD2 and CD3A/B milestones as well as obtaining significant international support. The plans for the U.S.-led Long Baseline Neutrino Facility (LBNF)

have rapidly advanced in the past several years, with strong leadership from FNAL. The DUNE physics program, with broad participation from the world's neutrino community, will fully characterize the neutrino oscillation matrix, search for CP violation in the lepton sector, determine the neutrino mass hierarchy, and search for new physics with a long baseline neutrino beam reaching from Chicago to Lead^{ix}. The refurbishment of the Ross Shaft has nearly reached the 4000-foot level, which will provide modern, robust, and high-speed access to the 4850 science level. So the physics program laid out in our efforts to design a Deep Underground Scientific and Engineering Laboratory has been realized. The biology, geology, and engineering efforts are growing.

For the past eight years, Melissa Barclay has published and distributed this newsletter, first to the DUSEL community, and then to the SURF community, a readership that exceeded 2000. I wish to acknowledge and thank Melissa Barclay for her assistance through the years, as well as Willi Chinowsky for his years of editorial assistance. Those wishing to continue to learn about SURF are invited to subscribe to the SDSTA's newsletter, DEEP THOUGHTS at:

<http://www.sanfordlab.org/newsletters>.

This is my version of the history. I am certain that I have neglected events that figure prominently in others' recollection. I cannot properly recognize all the individuals who played important roles in establishing the U.S. premiere underground research facility, and I apologize for any errors or omissions. I look forward to seeing you on the 4850.

[References on page 10 at end of newsletter]

Phantom of the Homestake Mine

4850 feet below the surface, the search for a phantom continues. A new planetarium show is previewing the discovery of this phantom--Dark Matter--at SURF, as well as in astrophysics and at the Large Hadron Collider (LHC).

This new show stars Academy Award winner Tilda Swinton as narrator, with sound effects from an Academy Award winning team at Skywalker Sound, and guidance from Nobel Laureate George Smoot. The director is head of the Media Lab at CERN.

The title "Phantom of the Universe" reflects dark matter's presence everywhere in the universe from galaxies to deep underground.

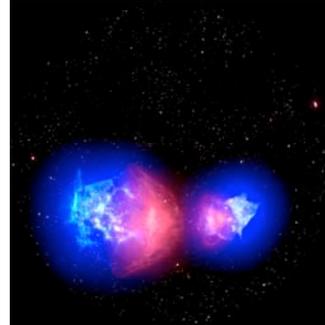


Figure 9: A scene from the planetarium show: The Bullet Cluster showing evidence of dark matter (blue). (Image courtesy of planetarium show "Phantom of the Universe")

(These images from "Phantom of the Universe" are a projection of the planetarium show onto a flat surface. Therefore the images are circular and have distortions. The bottom of the circle corresponds to the front of the planetarium.)

Three years in the making, the show will be distributed for free to planetariums worldwide. It is expected to premiere in several cities including London (date to be determined) and Vienna in mid-October.

The show reveals the first hints of dark matter's existence through the eyes of Fritz Zwicky, the scientist who coined the term "dark matter." It describes the astral choreography witnessed by Vera Rubin in the Andromeda galaxy.

We learn how scientists around the world are collaborating to track down the constituents of dark matter. It plunges deep underground to see the LUX dark matter detector.



Figure 10: Tilda Swinton and Mike Barnett in the recording studio

The production includes camera footage taken at SURF, including a ride on a rail car through a 4850-foot-deep tunnel.

From there, it journeys across space to the LHC at CERN, speeding alongside particles before they collide in visually stunning explosions of light and sound.

The collaboration that created “Phantom of the Universe” included Lawrence Berkeley National Lab, University of Texas Arlington, and Michigan State University. The production was supported by the Department of Energy, the National Science Foundation, the ATLAS Experiment, and others.

REPORTS/PAPERS AVAILABLE

Special DUNE News: 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](#). Jaret Heise, J.Phys.Conf.Ser. **606** (2015) no. 1, 012015; [arxiv: 1503.01112](https://arxiv.org/abs/1503.01112) (2015)

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

[The Sanford Underground Research Facility at Homestake \(SURF\)](#). (K.T. Lesko, Phys Procedia **61** 542 (2015)

[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

Nature: [Dark matter: What's the matter?](#) (Jeff Hecht, September 29)

Scientific American: [Physics confronts its heart of darkness: Cracks showing in dominant explanation for dark matter](#) (Lee Billings, September 1)

Phys.org: [Researchers moving forward with neutrino experiments](#) (Staff, August 24)
[Elusive neutrinos and hypothetical 'dark sector' particles could hold answers to cosmic mysteries](#) (SLAC communications, August 4)

PhysicsWorld.com: [Flash Physics: Europa's plumes, reflective atoms, LUX-ZEPLIN goes ahead](#) (Hamish Johnston, September 27)

News.FNAL.gov: [Joint proclamation of support for LBNF and DUNE from Illinois and South Dakota](#) (Staff, September 9)
[LBNF/DUNE update: Much more than a hole in the ground](#) (Chris Mossey, August 1)

LBNL News Center: [Construction of World's Most Sensitive Dark Matter Detector Moves Forward](#) (Glenn Roberts Jr., September 26); Also in: *Phys.org* (September 27); *Cryogenicsociety.org*: [Construction Moves Forward on Next-Gen Dark Matter Detector](#) (September 27)

Live Science: [Dark Matter Just Got Murkier](#) (Don Lincoln, September 9)

Astronomisch Nieuws: [Diep, dieper, diepst](#) (Arie Nouwen, July 24)

Yibada.com: [Scientists currently building best technology for detecting dark matter](#) (Mateo Altamirana, July 25)

USD.edu: [Physics Graduate Students Working in Underground Lab](#) (Carson Walker, August 10)

newswise: [Neutrino Experiments Utilize ORNL Experts, Equipment to Explore the Unknown](#) (ORNL, August 23)

energy.gov: [What is a Neutrino Horn?](#) (Molly Olmstead, Fermilad, August 29)

SLAC: [Physicist Trio Amplifies SLAC Research on Mysterious Forms of Matter](#) (SLAC staff, August 2)

NIU Newsroom: [Mysterious matter](#) (Tom Parisi, August 15)

Live Science: [Dark Matter Just Got Murkier](#) (Don Lincoln, September 9)

Space Daily: [T2K CP Violation Results Help Explain Workings of Universe](#) (LSU Staff, 9/7)

Only in your state.com: [Underneath This Mine In South Dakota Lies A Creepy Yet Amazing Laboratory](#) (Leah, August 20)

House Beautiful: [40 American Towns You Haven't Heard of But Should Visit ASAP](#) (Lauren Smith, July 29)

The Plainsman: [Finding life, deep below the Black Hills](#) (Michael Mornard, September 5)

Argus Leader: [Four S.D. colleges earn research innovation grants](#) (Megan Raposa, August 23)

Northern Star: [NIU joins DUNE project](#) (Samantha Malone, September 12)

CG Partners: [Sanford Lab Homestake Wins 2016 SEGD Global Design Award](#) (Clive Roux, September 19)

Top Examiner: [LUX-ZEPLIN dark matter detection ambition to become a reality](#) (Ravi Mandalia, September 27)

DNA India: [World's most sensitive dark matter detector construction plans move forward](#) (September 28)

Rapid City Journal: [Top of the class](#) (Staff, August 21)

[Tributes honor longtime legislator Jim Dunn of Lead, who died at 89](#) (Tom Griffith, August 13)
[Steampunk ball slated August 20](#) (August 8)

Black Hills Pioneer: [CASPAR models the hearts of stars](#) (John Higgins, September 13)
[Massive Sanford Lab experiment warrants transportation discussions](#) (Jaci Conrad Pearson, August 18)

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

Yates Tunnel

As of September 7, moving equipment to the Yates Shaft will be easier. Over the past several years, Sanford Lab has been working to rehabilitate 192 feet of the Yates Tunnel, which stretches more than 200 feet.

“Before this project was completed, no one could use the tunnel,” said Andrew Brosnahan, SURF Facility Engineer. “Now we can get work done more efficiently and safely.”



Figure 11: During the backfilling process, the tunnel was reinforced with supports

Traditional ground support techniques, which involve the use of rock bolts and mesh, were not an option on this project because of the low overburden above the tunnel and the broken ground, said Bryce Pietzyk, Underground Access Director. The solution came in the form of a steel archway system, using prefabricated steel archway sections, and was developed in partnership with True North Steel,

Donovan Construction, W-D Masonry, the South Dakota School of Mines and Technology Mining Department, RESPEC, and Sanford Lab.

Working from the outside of the ramp, crews from *Donovan* removed old timber sets and other debris—8 feet at a time. As each section was cleared, they installed 8-foot long, 4-foot tall corrugated steel bases on either side of the tunnel, then placed two 4-foot sections of angle-iron steel archways that span the tunnel on top of the base (Figure 11).

Next, a team from *W-D Masonry* backfilled the void above the section with concrete, pumping it upward through taps in the rib of the tunnel. In the end, 47 steel archways and 24 steel bases were installed, with nearly 700 cubic yards of concrete poured. The tunnel, now 10 feet tall and 10 feet wide, will provide safer access from the shop yards to the ramp.

EDUCATION AND OUTREACH

Field Trips to Sanford Lab

Summer often brings diverse groups of visitors to the Black Hills. In August, the Education and Outreach (E&O) Department hosted two groups that fall into that category:

Students from the Box Elder Job Corps camp visited Sanford Lab for a day to learn about research and jobs. They learned about research best practices, did a water filtration engineering activity, and toured the Waste Water Treatment Plant (WWTP) and hoistroom. They finished the day talking to Research Scientist Markus Horn and Project Engineer David Taylor about how science and engineering teams work together to make a project like LZ happen. The group, ranging from 16-25 years of age, included a number of refugees from a variety of countries who have relocated to South Dakota.

On August 22, a group of high school students from various Caribbean nations—in the country on a State Department-sponsored Ambassadors program—spent a day at Sanford Lab. They toured the WWTP and hoistroom, did a water filtration engineering activity, and had a videoconference to the Davis Campus with Experiment Support Scientist Dana Byram.

Student Researchers

In April, Black Hills State University (BHSU) received a grant of more than \$250,000 from the National Science Foundation to support students participating in undergraduate science research at SURF. The funds will be used over three years to provide 21 college level students with a 10-week hands-on research experience. Six students participated this summer (Figure 12).



Figure 12: Left to right: Dana Harvey, Joseph Barnes, Patrisse Vasek, Madeline Alisa Valentin, Pauline Dredger, and Kingsley Vincent Chow

The program director, Brianna Mount, an assistant research professor at BHSU, said the program gives student researchers opportunities to engage in research related to important physics experiments—searching for dark matter and investigating properties of the neutrino—as well as research in other scientific fields, specifically chemistry and biology.

Students supported by the grant funds lived on campus and worked with BHSU faculty mentors at the BHSU Underground Campus (BHUC) at SURF. In addition to their summer research projects, students worked with BHSU faculty and staff on career mentoring, including professional development sessions on selecting graduate schools and applying for jobs in scientific industries.

South Dakota State Fair

As summer wound down, Sanford Lab went to the South Dakota State Fair in Huron, SD. The first two days of the fair—September 1-2—were designated Education Days, with classes visiting from schools around the east-central part of the State. We had a table with kids' activities in the Arts and Education Building, and gave a *Day in the Life of a Sanford Lab Scientist* presentation for students (and

interested adults) once each day. In addition, Communications Director Constance Walters gave a public presentation on Thursday evening.

Fall Presentations

Now that the school year has begun, requests for classroom presentations at schools are flowing in. We have three new presentations for this school year, in addition to three that were developed last year:

Particle Accelerators - Smashing Science: Students are introduced to the Deep Underground Neutrino Experiment (DUNE). They will have an opportunity to dig into science concepts behind the particle accelerator that makes this experiment possible. *Recommended for grades 3-5*

Dark Matter - It's A Matter of Gravity!: Students are introduced to dark matter, a mystery particle that is much more abundant than anything in the universe, but that has not (yet) been detected because it does not emit light. Students will apply their understanding of gravity to examine the evidence for dark matter and draw their own conclusions about its existence. They will learn how scientists are attempting to detect these elusive particles in experiments at Sanford Lab. *Recommended for grades 6-8*

What Can We Learn From A Borehole?: Students are introduced to the microenvironments of the Sanford Underground Research Facility through examination of one of its many boreholes, looking at the interactions between geology, water chemistry, biology, and human intervention. Scientists have determined that deep in some parts of this former gold mine, ancient water has been trapped inside the rock for 10,000 years. How do the fields of biology, geology, chemistry, physics and engineering intersect in this environment, and what interesting careers could it lead to? *Recommended for grades 9-12.*

ENVIRONMENT, HEALTH & SAFETY



LBNL video on Slips, Trips and Falls

<http://today.lbl.gov/2016/09/15/video-offers-tips-on-how-to-prevent-slips-trips-and-falls/>

UPCOMING CONFERENCES AND WORKSHOPS

The **3rd Berkeley Workshop on the Direct Detection of Dark Matter** will be held December 5-6, 2016, at LBNL. The purpose of the workshop is to focus on ideas towards and challenges of future dark matter search experiments. To register or for more info:

<https://indico.physics.lbl.gov/indico/conferenceDisplay.py?confId=311>

APS17 Mini-symposium on Detecting Neutral Particles with Low-Energy Threshold. January 28-31, 2017, Washington, DC. Topics: fundamental symmetries, neutrinos, and dark matter.

<http://www.aps.org/meetings/meeting.cfm?name=APR17>

WIN2017, Workshop on Weak Interactions and Neutrinos, June 19-24, 2017, Irvine, CA.

<http://www.physics.uci.edu/WIN2017/>



JOBS

Postdoctoral Fellow, Lawrence Berkeley National Lab. Research in Neutrino Physics, search for lepton number violation and probe absolute neutrino mass scale. Contact: Alan Poon, awpoon@lbl.gov. Job #: 82899

<http://jobs.lbl.gov/positions.html?jobcode=abc&jobfield=60>

Postdoctoral Research Assistant, Queen Mary, University of London. Particle Physics Research Centre (PPRC) research in SNO+ group. Contact: Jeanne Wilson, j.r.wilson@qmul.ac.uk. Closing: 10/22/16.

<https://webapps2.is.qmul.ac.uk/jobs/job.action?jobRef=QMUL9463>

2017 KICP Fellowships. Three-year fellowship in KICP-supported research in astroparticle physics or cosmology. Closing: 10/31/16.

<http://kicp-fellowship.uchicago.edu/>

Assistant Professor, University of Tennessee, Knoxville. Tenure-track position in field of Experimental Low Energy Nuclear Physics. Closing: 11/15/16.

<https://apply.interfolio.com/36687>

Dunlap Postdoctoral Fellowship, University of Toronto. Research in Astronomy and Astrophysics. director@dunlap.utoronto.ca. Closing: 11/1/16. <http://www.dunlap.utoronto.ca/postdoctoral-position/>

Postdoctoral researchers, Yale. Two openings in Experimental Nuclear and Particle Physics. David Moore, david.c.moore@yale.edu. Closing: 11/18/16. <http://inspirehep.net/record/1481910>

NERSC Data Postdoctoral Fellow, LBNL. Support high-energy experiments, esp. LUX-ZEPLIN (LZ) software development/deployment. <https://lbl.taleo.net/careersection/2/jobdetail.ftl?lang=en&job=82724>

AIP State Department Fellowship, Washington DC. Contribute scientific and technical expertise and raise awareness of the value of scientific input. One year fellowship. Closing: 11/1/16. <https://www.aip.org/policy/fellowships/sdf>

Two postdoctoral positions, University of Alabama. Research in Nuclear Physics group on EXO-200 neutrinoless double-beta-decay. Andreas Piepke, andreas@ua.edu. Indicate "EXO" in the subject line. Closing: 10/1/16. <https://facultyjobs.ua.edu/postings/38770>

Research Associate Physics, Brookhaven National Lab. Research with Electronic Detector Group (EDG) on DUNE, ProtoDUNE, Daya Bay and other experiments. Job ID: 771 <https://jobs.bnl.gov/job/upton/research-associate-physics/3437/2658641>

Newsletter Editor: Melissa Barclay

Contributors: Kevin Lesko; Constance Walter (Sanford Lab news); Kevin Lesko (A Brief History of the Underground Laboratory Efforts at Homestake); Mike Barnett (Phantom of the Homestake Mine); June Apaza, Peggy Norris (Education & Outreach)

Photo Credits: Figs. 1,9: Phantom of the Universe Planetarium Show; Fig. 2: John Wilkerson; Figs. 3,4: Bill Harlan; Fig. 5: Robert Saunders, UC Berkeley; Fig. 6: Roy Kaltschmidt, LBNL; Figs. 7,11: Matt Kapust; Fig. 8: LZ Collaboration

Lawrence Berkeley National Lab
Kevin T. Lesko: 510-486-7731
KTLesko@lbl.gov
Melissa Barclay: 510-486-5237
mbarclay@berkeley.edu

SDSTA/Sanford Lab
Mike Headley, Executive Director
Mandy Knight, 605-722-4022
MKnight@sanfordlab.org
<http://www.sanfordlab.org/>

BERKELEY OFFICE

SURF Project Office
Lawrence Berkeley National Lab (LBNL)
One Cyclotron Road
MS 50B-5239
Berkeley, CA 94720

ⁱ Preliminary Site Selection and Evaluation for a National Underground Physics Laboratory LA-UR-82-556
R.R.Sharp, Jr. *et al.*

ⁱⁱ <http://arxiv.org/pdf/nucl-th/0011014v2.pdf>

ⁱⁱⁱ <http://www.sns.ias.edu/~jnb/>

^{iv} <https://www.nap.edu/catalog/10583/neutrinos-and-beyond-new-windows-on-nature>

^v <http://www.sanfordlab.org/publications/reports>

^{vi} [arXiv:1108.0959](https://arxiv.org/abs/1108.0959)

^{vii}

http://science.energy.gov/~media/np/pdf/review_of_underground_science_report_final.pdf

^{viii} <https://www.nap.edu/catalog/13204/an-assessment-of-the-science-proposed-for-the-deep-underground-science-and-engineering-laboratory-dusel>

^{ix} <http://www.dunescience.org>