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Black Hills State University Underground Campus

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ABSTRACT

The Black Hills State University Underground Campus (BHUC) houses a low background counting facility on the 4850′ level of the Sanford Underground Research Facility. There are currently four ultra-low background, high-purity germanium detectors installed in the BHUC and it is anticipated four more detectors will be installed within a year. In total, the BHUC will be able to accommodate up to twelve detectors with space inside a class 1000 cleanroom, an automated liquid nitrogen fill system, on-site personnel assistance and other required utilities.

1. Introduction

Rare event searches, including direct detection of dark matter and neutrinoless double beta decay, located in underground laboratories around the world require materials with lower and lower concentrations of radioactive elements (Agnes, 2015, 2016; Akerib, 2014; Dell'Oro et al., 2016; Xiao, 2015). These low activities must be quantified both for the selection of materials in underground experiments and to inform simulations for data analysis. Most of the major underground laboratories, such as Boulby Underground Laboratory, Gran Sasso National Laboratory and SNOLAB house low background counting facilities, which are crucial to the success of their large-scale dark matter and neutrino experiments (Lesko, 2015; Lin, 2015; Ghag, 2015). Such a facility has been developed at the Sanford Underground Research Facility (SURF) in the former Homestake mine in South Dakota, which currently hosts low background experiments such as the MAJORANA DEMONSTRATOR (MJD) and the Large Underground Xenon (LUX) experiment, with future experiments being developed over the next several years with LUX-ZEPLIN (LZ) and the Deep Underground Neutrino Experiment (DUNE) (Heise, 2015).

The Black Hills State University Underground Campus (BHUC) is a multidisciplinary facility located on the 4850′ level of SURF with ~4200 m water equivalent (m.w.e.) shielding from cosmic rays. The facility is comprised of two separate cleanroom spaces and an outside staging area for small projects and other research and development activities. 55 m^2 of class 1000 cleanroom space in this facility is reserved for low background counting stations and related equipment. By providing a centralized location in one of the deepest underground facilities in the world, with critical support such as an automated liquid nitrogen (LN_2) system and on-site personnel, the low background facility in the BHUC will support rare event physics experiments as well as other ultra-low background assay needs in the science community. The facility is open to all experimental users, not just those hosted by SURF.

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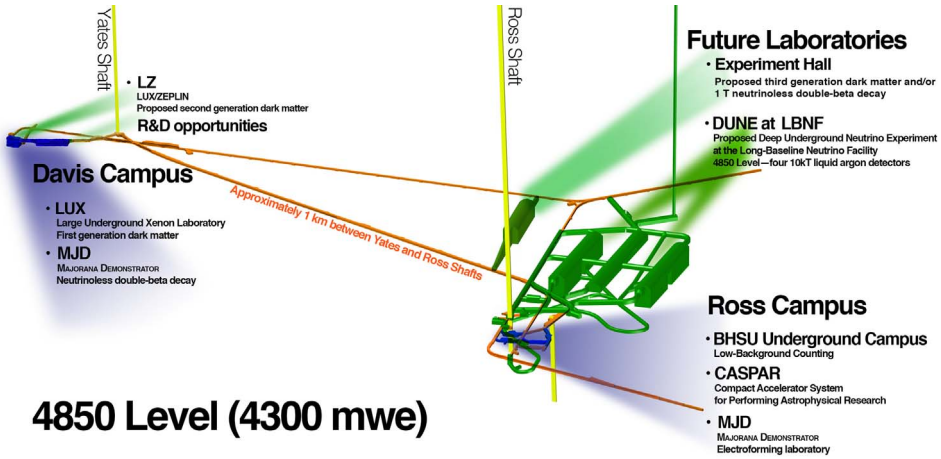

Fig. 1. 4850′ level of SURF. Photography courtesy of SURF.

2. BHUC location and construction

The BHUC is located on the 4850′ level of SURF, the level at which the major physics experiments are housed (see Fig. 1). The BHUC cavern is within the Ross campus, near the Majorana electroforming lab and the location of the CASPAR experiment. No excavation was necessary as the facility is housed in a renovated cavern.

The walls of the former drill repair shop were stabilized with extensive ground support consisting of rock bolts, meshing and shotcrete. Over the shotcrete two coats of Loxon® Masonry Coating Block Surfacer were applied, followed by one coat of Macropoxy® 646 Fast Cure Epoxy. The epoxy was chosen for its ability to act as a radon barrier (Maas, 1997). While the incoming air to the BHUC is not currently radon-reduced, the epoxy layer was applied such that in the future a radon mitigation system might be installed. The cavity sealants will help reduce locally-sourced radon from diffusing into the laboratory airspace. The ambient concentration of Rn in the BHUC varies between 50 and 300 Bq/m^3.

Once the cavern walls and ceiling were completed, a concrete pad for the cleanroom was poured and a layer of the Macropoxy product was applied to the floor of the cavern. The cleanroom was then constructed. It is comprised of modular panels which are each eight feet high. The 18.5 m^2 gowning rooms are soft-walled and the counting room (55 m^2) as well as the biology lab (18.5 m^2) are hard walled. The construction of the BHUC was finished in September of 2015 and the first counting station was installed that November.

3. BHUC counting room

The BHUC counting room is a class 1000 cleanroom. It is anticipated that up to twelve counting stations will be housed in this space. Each station will be supplied with its own dedicated electrical circuit, have access to a ‘star’ ground and be supplied with network connections. Wireless networks are available throughout the BHUC cavern.

Four 180 L dewars outside the cleanroom supply each counting station with liquid nitrogen via vacuum-jacketed piping that runs along three walls of the cleanroom. These liquid nitrogen dewars also supply gaseous nitrogen via their boil-off which is in turn also supplied to each counting station as radon purge gas by stainless steel tubing running along the walls.

The liquid nitrogen flow is operated remotely via solenoid valves controlled through LabVIEW software operating a relay board and LN_2 level sensor instrumentation. Each 180 L dewar sits on a scale and the system can monitor these weights (and thus approximate liquid levels). The system also monitors the counting station dewar levels using an American Magnetics, Inc. (AMI) 286 multi-channel liquid level controller, and can pre-cool the room's piping and fill counting station dewars. The solenoid valves may also be controlled by a set of manual switches.

A purged sample storage system is being developed for the BHUC. Once a sample arrives on site, it is placed in a nearly air-tight container and transported underground. Once the purged sample storage system is constructed, the containers will be connected to and stored in a nitrogen environment supplied by the liquid nitrogen boil-off from the external 180 L dewars. In addition to a shared sample storage system, other support items are shared by users at the BHUC including a well-stocked toolbox, electronics racks with available space and calibration sources.

Black Hills State University (BHSU) faculty and students currently manage and maintain the BHUC, change samples in the detectors and are also available to assist in the installation of detectors underground. BHSU personnel are also available to act as guides for counting room users. Located just 30 km from SURF, it is relatively easy for BHSU personnel to do same or next-day troubleshooting of counting stations while working with remote user groups.

4. Current BHUC counting stations

There are currently four low background counting stations in the BHUC: Morgan, Maeve, Mordred and SOLO (see Fig. 2). Each of these current counting stations are high purity germanium (HPGe) detectors surrounded by Pb and Cu shielding and purged with liquid nitrogen

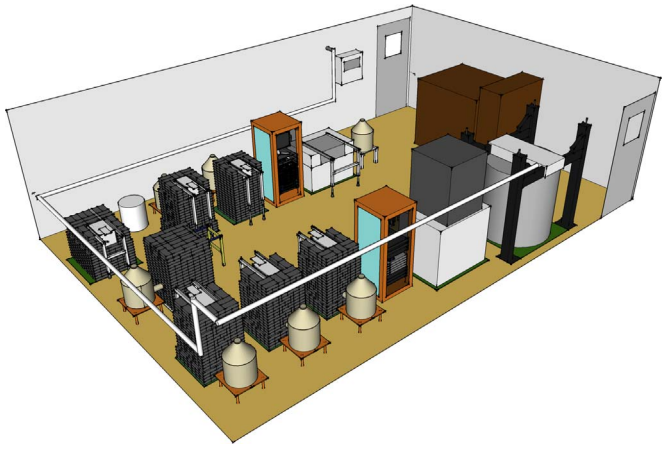

Fig. 2. Current counting stations in the BHUC counting room. From left to right: Mordred, SOLO, Maeve, Morgan HPGe detectors inside their shielding castles. The rack of electronics to the right provides the DAQ and networking for all four detectors. Along the walls of the clean room can be seen the LN_2 and N_2 lines. The LN_2 dewars are located outside the cleanroom to the right of the image.

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