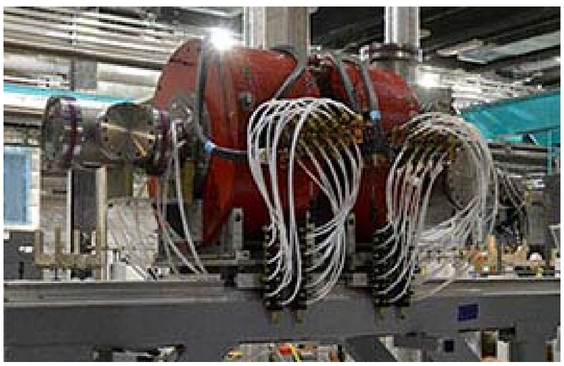
FRIB LABORATORY UPDATE for USERS

January 2017

## FRIB makes first beam from ARTEMIS ion source



*On 14 October, the first FRIB ion beam was produced from the Advanced Room-TEMperature Ion Source (ARTEMIS). Above, ARTEMIS is shown on the platform at the time of its installation in April 2016.*

*Above is an updated photo of the same area in October 2016 that shows ARTEMIS behind fencing and shielding as it undergoes testing.*

The FRIB Project reached a new milestone in October: the extraction of the first ion beam from its Advanced Room-TEMperature Ion Source (ARTEMIS). On 12 October, FRIB staff turned on ARTEMIS for the first time, and the successful testing resulted in the first ion beam produced on 14 October.

ARTEMIS is FRIB's first accelerator component to be installed, which took place back in April. It is one of two electron cyclotron resonance (ECR) ion sources that FRIB will use to produce ions from elements. One room-temperature ECR (ARTEMIS) will support general-purpose operations and one superconducting ECR (SC-ECR) will provide high intensity for all elements including heavy ion beams like uranium.

In the ion source, neutral atoms are vaporized into a hot plasma, which knocks electrons off the atoms and ionizes them. The resulting ions are contained with electric and magnetic fields and extracted into the FRIB front end.

Now that ARTEMIS is installed and is being successfully tested, the next step is to complete the installation of the FRIB front end to receive and transport the extracted beam of ions for further acceleration.

# FRIB installs first cryomodule into linear accelerator tunnel

*The FRIB Project installed the first of 48 cryomodules into its linear accelerator tunnel on 29 September.*

On 29 September, the FRIB Project installed the first of 48 cryomodules into its linear accelerator tunnel.

This installation involved the β=0.085 cryomodule, which is FRIB's first completed and tested cryomodule. It is approximately 20 feet long and weighs approximately 26,000 pounds.

The β=0.085 cryomodule contains eight superconducting radiofrequency (SRF) β=0.085 quarter-wave resonators, three superconducting focusing solenoids and three beam-position monitors.

[Watch a video of the installation.]

# Civil construction progress allows FRIB to advance several technical installation milestones

*On 27 October, the 4.5 Kelvin lower cryogenic cold box was delivered to FRIB from Oklahoma. Weighing in at 100,000 pounds, the 39-foot-wide cold box was placed horizontally in FRIB's cold box room.*

As civil construction advances ahead of schedule, FRIB Project team members managing technical work are preserving this schedule float and delivering their scope to ensure the baseline is delivered with a high likelihood of success.

In addition to the milestones highlighted above (FRIB makes first beam from ARTEMIS ion source, and FRIB installs first cryomodule into linear accelerator tunnel), there are several other significant technical achievements to report:

On 27 October, the 4.5 Kelvin (K) lower cryogenic cold box was delivered to FRIB from the supplier in Oklahoma. Weighing in at 100,000 pounds, the 39-foot-wide cold box was placed by the construction manager horizontally in FRIB's cold box room. It joins the vertical upper cryogenic cold box, also weighing 100,000 pounds, that was delivered to FRIB in August. The two cold boxes will be connected to cool helium to an extremely low temperature, which will make the cavities within the cryomodules superconducting in FRIB's linear accelerator tunnel.

The upper cold box lowers the temperature of the helium from 300 degrees K to 60 K. The lower cold box serves as the second step in the helium-cooling process, dropping the temperature from 60 K to 4.5 K. When the cavities are superconducting, there is no resistance, which means there will be virtually no heat loss with an electrical current, making FRIB more energy-efficient as it accelerates rare isotope beams.

The FRIB baseline schedule calls for both coldboxes to be installed in October 2017; it now looks possible to have the installation done earlier and to make liquid helium in 2017.

*The 85,000-pound wedge vessel was delivered in October and is currently being tested in the ReA12 highbay. After testing, the wedge vessel will be installed in the target area.*

Other technical installation milestones include:
• FRIB's Conventional Facilities and Infrastructure Division assisted in the installation of the radio frequency quadrupole (RFQ), which weighed approximately 30 tons. The RFQ, which prepares the beam for acceleration in FRIB's superconducting linear accelerator, is currently being assembled.
• The 85,000 pound wedge vessel was delivered on 28 October and is currently being tested in the ReA12 highbay. After testing, the wedge vessel, which houses focusing magnets and a wedge assembly for beam momentum compression, will be installed in the target area in mid-December.
• With the completion of the RFQ assembly, the air-handling units for the front end and the tunnel have been turned on.
• Magnets have been delivered and are being stored in the linac tunnel, with several installed along the beamline.

Additionally, civil construction work is ongoing. Raised-access flooring in the surface building is now complete, and electrical panels are being mounted on the south equipment racks. Piping is being installed to storage tanks in the chemical treatment room. In the compressor room and the cold box room, warm-side piping installation is ongoing. Ductwork is being installed for the lower second floor mechanical room, and roofing continues on the west side of the building.

The turnover of the front-end area occurred in December, when all conventional utilities became operational. Looking ahead to 2017 and another significant project milestone, all civil construction is slated for beneficial occupancy in March.

## DOE Office of Project Assessment review held 6-8 December

The DOE-SC Office of Project Assessment's (OPA) review of FRIB was held 6-8 December. The main focus of the review was to assess overall FRIB Project progress since the last review in June 2016, with a focus on our technical progress.

The review committee was organized into five subcommittees and FRIB staff gave 53 presentations.

The OPA assessed all aspects of the FRIB Project – technical, cost, schedule, management, and environmental safety and health – and found that FRIB is overall making appropriate progress toward completion. The review committee answered all charge questions affirmatively.

DOE has tentatively scheduled the next review for 27-29 June.

## SAC met at FRIB 8-9 December

*The FRIB Scientific Advisory Committee (SAC) met on 8-9 December at Michigan State University.*

The FRIB Scientific Advisory Committee (SAC) met on 8-9 December at Michigan State University. The SAC reviewed the laboratory plans for realizing a successful day-one FRIB scientific program.

Included in their charge was a request to review the current state of preparation of the FRIBUO equipment working groups and FRIB Theory Alliance, and comment on any actions the laboratory could take to assist in their efforts. The FRIB User Organization Executive Committee Chair, Heather Crawford, presented the status of the equipment working groups based on input from the groups. The SAC also heard presentations on the status of the High Rigidity Spectrograph and a project to study radioactive decay called the Decay Station. The SAC submitted their report on 22 December.

Present members of the SAC are: David Dean (chair), Ani Aprahamian, Klaus Blaum, Rolf Ent, Katherine Grzywacz-Jones, Robert Janssens, Augusto Macchiavelli, Gail McLaughlin, Michael Ramsey-Musolf, Heather Crawford, and Witek Nazarewicz.

## NSF awards MSU funding to operate NSCL until 2021

A cooperative agreement between Michigan State University and the National Science Foundation (NSF) awarded in November will fund continued operation of NSCL for the user community. The agreement will allow forefront research in nuclear and accelerator science and maintain NSCL as one of the world's flagship nuclear science research facilities. It provides much needed funds to allow ReA3 to be operated as a user facility.

"We are extremely happy and grateful. This cooperative agreement from the NSF allows researchers to continue enabling cutting-edge scientific research into the nature and origin of atomic nuclei," said Brad Sherrill, University Distinguished Professor of physics and NSCL director. "We are excited about what this means for our users." It is anticipated that the funding will run about 3,000 hours of approved experiments each year.

As one of the nation's major user facility providing beams of rare isotopes for nuclear science, NSCL provides unique, hands-on learning opportunities for the next generation of nuclear scientists. It offers the opportunity for forefront science and for users to develop programs that will continue when FRIB is completed.

The Physics Division of the National Science Foundation has supported NSCL operation at MSU since the mid-1980s. The new funding will cover continued operation until 2021. "It is incredibly important to both the nation's leadership in nuclear science and to our scientific user community that rare isotope research continue in a strong way at NSCL until FRIB," said Thomas Glasmacher, University Distinguished Professor of physics and FRIB Laboratory director.

In addition to continuing to fund the operations of NSCL cyclotrons, the agreement also will provide funding to operate the newly built ReA3 program that will allow researchers to perform experiments with re-accelerated rare isotopes at 3 to 5 MeV/u. A separate proposal will be submitted to the NSF to enable research at higher energy from 6 to 12 MeV/u by, so called ReA6. If funded this will expand NSCL operation to include above Coulomb barrier, reaccelerated, rare-isotope beams. This capability should be available sometime in 2019.

## NSCL users discover bubble nucleus

Research conducted at NSCL, headed by a research group from IPN Orsay, France, has shed new light on the structure of the nucleus.

The work, detailed in Nature Physics, found that the distribution of the protons in silicon-34 has a bubble-like center, something scientists had suspected for some time, but hadn't been able to prove so far. Interestingly, the distribution of neutrons does not exhibit a bubble. Usually, the protons and neutrons that make up a nucleus are distributed fairly uniformly throughout. So the scientists, as well as the scientific world, took notice when this central depletion of protons was discovered.

Reactions to the Nature Physics article included online articles published on PhysOrg, Science Newsline, Science Bulletin, and ChemEurope, and several others. In addition, several aggregator websites posted links to the online articles.

## MSU member of science and security consortium

Michigan State University continues to be a member of the Nuclear Science and Security Consortium (NSSC) which recently successfully competed for an additional five years of support.

The National Nuclear Security Administration (NNSA) awarded the support to the NSSC, which consists of eight universities and five national laboratories. The other universities of the consortium, which is led by the University of

California, Berkeley, are the University of California, Davis; University of California, Irvine; University of Nevada, Las Vegas; George Washington University; Texas A&M University; and the University of Tennessee, Knoxville. The five national laboratories are Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, and Sandia National Laboratories.

The mission of the NSSC is to support the nation's nuclear security agenda, recruiting and training students in relevant nuclear disciplines in preparation for research and leadership roles in the national laboratories. The NSSC draws students and scholars together in unconventional ways, replacing the boundaries that separate disciplines with a more inclusive science-technology policy interface.

"I am confident that more basic research efforts in academia will complement the applied efforts of the national laboratories and industry in supporting the critically important national security goals of our country," said Anne Harrington, NNSA deputy administrator for defense nuclear nonproliferation, in an NNSA press release announcing the award.

The consortium will carry out cutting-edge research and development in four technical areas: nuclear and particle physics; radiochemistry and forensics; nuclear engineering; and nuclear instrumentation and radiation detection. In order to accomplish this goal, four crossover areas were added: nuclear data, modeling and simulation, nuclear security policy, and education and training.

Since 2011, the NSSC has trained about 350 students and postdoctoral scholars through a multidisciplinary program that provides hands-on training in nuclear science, technology, and policy. Students and scholars spent considerable time working at partnering national laboratories through collaboration with more than 60 lab scientists.

## New highly sensitive Single-Ion Penning Trap will allow FRIB to determine precise masses of rare isotopes

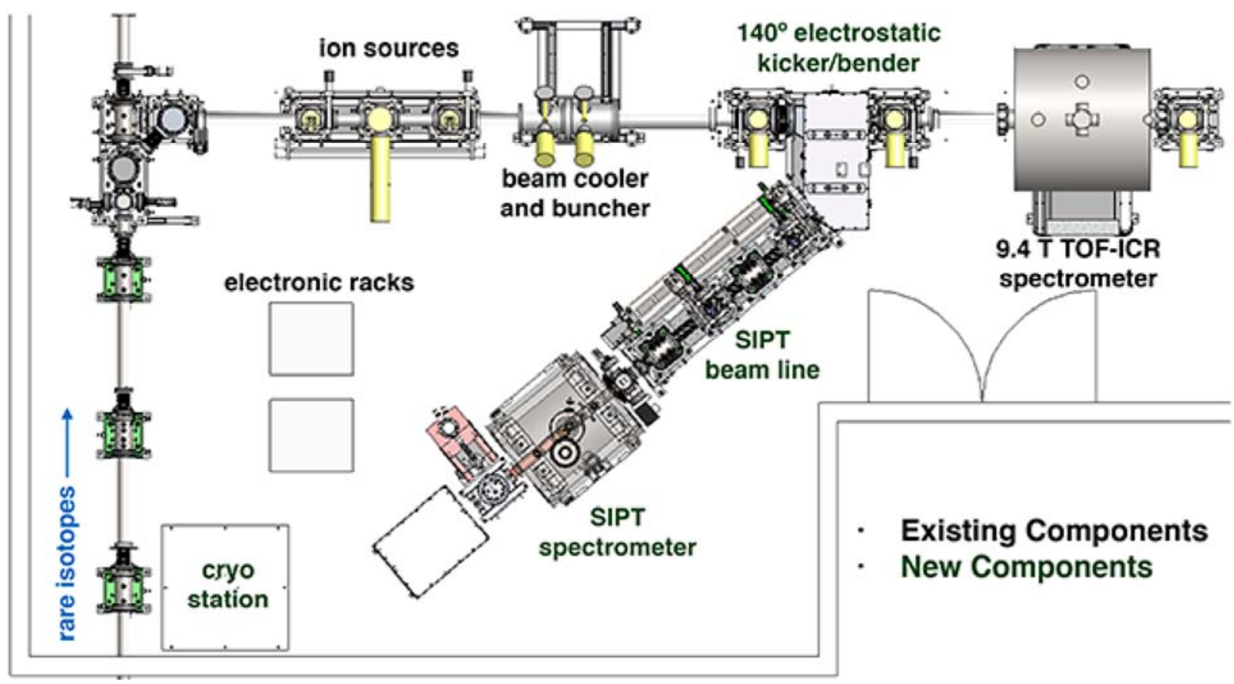


*Figure 1: Schematic overview of the Low Energy Beam and Ion Trap (LEBIT) facility with the new Single-Ion Penning Trap (SIPT) system.*

Over the last few decades, advances in radioactive beam facilities like the Coupled Cyclotron Facility at NSCL have made short-lived, rare-isotope beams available for study in various science areas. New facilities, like FRIB, will provide even more exotic rare isotopes. Determining the masses of these rare isotopes is of utmost importance since masses define the binding energy of the nucleons in the atomic nucleus. Nuclear masses contribute to a broad spectrum of physics topics, including those that will be the focus of study at FRIB, like nuclear structure and reactions, nuclear astrophysics, fundamental interactions, and metrology. As FRIB will provide the broadest range of rare isotopes in the world, it is the ideal location for a highly sensitive and precise mass spectrometer for short-lived isotopes.

The Low Energy Beam and Ion Trap (LEBIT) facility at NSCL uses ion traps to manipulate and perform mass measurements on rare isotopes. In particular, the LEBIT facility uses a Penning trap to confine the atomic nucleus in a strong magnetic field and probe its mass using externally applied electric fields. In order to obtain a measurement, usually 100-300 total ions are required. This limits the experimental reach of the science program because a measurement of a rare isotope that is delivered at a rate of a few ions per day would require too much experimental beam time.

To overcome this limitation and to handle the specific challenges posed by rare isotopes, we have built a dedicated Single-Ion Penning Trap (SIPT) mass spectrometer at NSCL.

These challenges, which include short half-lives and extremely low production rates, are dealt with by employing the narrowband FT-ICR detection method under cryogenic conditions. SIPT has been integrated into the existing LEBIT facility, as shown schematically in Figure 1.

SIPT has achieved its first major commissioning milestone and measured a signal of multiple ions in the trap. A beam of $^{39}K^{+}$ ions was produced with a stable ion source. The beam was subsequently cooled and converted into bunches of ions. The ion bunches were transported through the new SIPT beam line and captured in the Penning trap. After the ions were captured, a radio frequency field was applied to the ions to drive their motion in the trap. The ion motion produced a signal on the trap electrodes, which was then amplified. The frequency of the measured signal can be used to determine the mass of the ions.

The next major milestone will require installation of the cryogenic amplifier circuitry and demonstrating single-ion sensitivity, which is required for rare-isotopes mass measurements.

Once complete, and used in concert with the original Penning trap mass spectrometer, the new SIPT system will ensure that the LEBIT mass measurement program at MSU can make optimal use of the wide range of rare isotope beams provided by FRIB.

## Contributors this issue

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# LOOKING AHEAD

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| **24 March** | ReA Solenoidal Spectrometer Projects meeting to be held at Argonne National Laboratory (ANL) |
| **12-14 April** | NSCL Site Visit |
| **1-5 May** | Experimental Systems Advisory Committee (ESAC) Review of FRIB (tentative) |
| **3-4 May** | NSCL Program Advisory Committee (PAC) 41 (proposals due 1 March) |
| **28 May – 2 June** | ARIS 2017 - The third international conference on Advances in Radioactive Isotope Science |
| **30 May - 1 June** | Accelerator Systems Advisory Committee (ASAC) Review of FRIB |
| **27-29 June** | DOE-SC Office of Project Assessment Review of FRIB (tentative) |
| **3-4 August** | 2017 Low Energy Community Meeting at Argonne National Laboratory (ANL) |

The FRIB Laboratory Update for Users is published by the FRIB Laboratory and distributed via email.
Please email questions, comments, and contributions to communications@frib.msu.edu.

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*Michigan State University is establishing FRIB as a scientific user facility for the Office of Nuclear Physics in the U.S. Department of Energy Office of Science.*