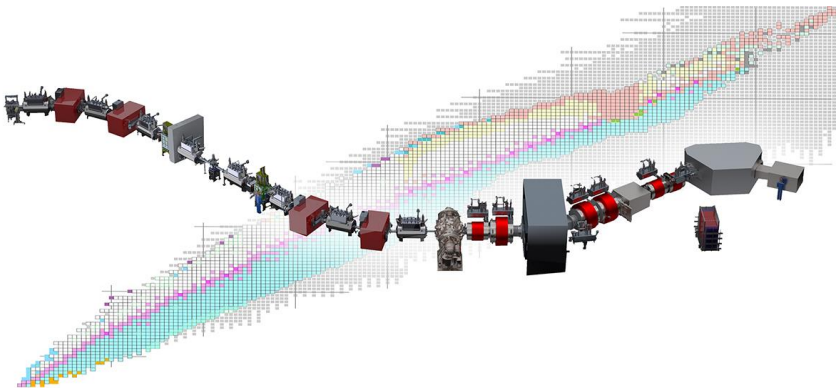
FACILITY FOR
RARE ISOTOPE BEAMS

June 2024

High Rigidity Spectrometer (HRS)



Broadening FRIB's Scientific Impact

The High Rigidity Spectrometer (HRS) will substantially increase FRIB's scientific reach and productivity. "A New Era of Discovery: The 2023 Long Range Plan for Nuclear Science," by the Nuclear Science Advisory Committee (NSAC), a federally chartered advisory committee to the U.S. Department of Energy and National Science Foundation, identified HRS as a key instrument for FRIB.

HRS is the first major addition to FRIB's experimental facilities. It consists of two segments: the High-Transmission Beam Line (HTBL) and the Spectrometer Section (SPS). HTBL transports rare-isotope beams from the Advanced Rare Isotope Separator (ARIS) fragment separator to the reaction target stationed at the entrance of SPS. ARIS delivers specific rare-isotope beams (RIBs) to the fragment separator focal plane. From there, RIBs are delivered to experimental areas including HRS.

At SPS, reaction products created at the target are analyzed. HRS is used to analyze the fact charged reaction products. A wide variety of ancillary detector systems developed by the nuclear science community for experiments at FRIB will be used in combination with HRS, such as the Gamma-Ray Energy Tracking Array (GRETA) and the Modular Neutron Array (MoNA-LISA).

Science HRS Will Enable

HRS will enable scientists to characterize the properties of isotopes that are created in rare-isotope reactions produced at about 50 percent of the speed of light. With the ability to measure properties such as the mass, charge, and velocity of rare isotopes produced in those conditions, HRS will be a centerpiece experimental instrument of FRIB's fast-beam program that will substantially increase FRIB's scientific reach and productivity.

HRS is designed to also accommodate FRIB's scientific program after the envisioned FRIB400 energy upgrade (frib.msu.edu/FRIB400) that will double FRIB's beam energy to 400 MeV/nucleon and further expand the scientific impact by increasing the yield of many rare isotopes tenfold.

Learn more at frib.msu.edu

HRS Collaborations

The scientific user community has worked together to develop the scientific case for and the design of HRS. The FRIB Users Organization HRS working group meets regularly to ensure HRS meets the requirements for a broad scientific program. Member institutions include:

- 20 U.S. universities and colleges: Augustana College, Bucknell University, Central Michigan University, Davidson College, Florida State University, Hope College, Indiana University, Indiana Wesleyan University, Kalamazoo College, Michigan State University, Ohio University, Ohio Wesleyan University, Rutgers University, Texas A&M University, University of North Carolina/TUNL, University of Notre Dame, University of Tennessee, Washington University in St. Louis, Ursinus College, Wabash College
- 5 U.S. national laboratories: Argonne National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Oak Ridge National Laboratory
- 4 international institutions: GSI/FAIR (Germany), Radioactive Isotope Beam Factory (RIBF) at RIKEN (Japan), TRIUMF (Canada), University of Surrey (United Kingdom)

Sponsor

The U.S. Department of Energy, Office of Science Office of Nuclear Physics

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How It Works

HRS will transmit with near 100-percent efficiency isotopes that are travelling at velocities for which the rare-isotope production rate is optimal. In addition, at the higher velocities, the foils in the rare-isotope production target—in which reactions between isotopes take place—can be much thicker, greatly increasing the chances that a desired isotope reaction will occur.

The combined effects of a higher rare-isotope beam intensity and the use of thicker target foils will greatly increase the sensitivity of the scientific program at FRIB. This will be beneficial in particular for experiments with the most neutron-rich isotopes that have the highest potential for discovery. HRS will thus extend FRIB's scientific reach to neutron-rich isotopes by up to a factor of about 100.

The increase will enable forefront experiments not otherwise possible anywhere in the world, such as detailed studies of calcium-60. Calcium-60 has 12 more neutrons than the heaviest stable isotope of calcium found in nature. It is of particular interest to understand the forces that bind neutrons and protons into nuclei.

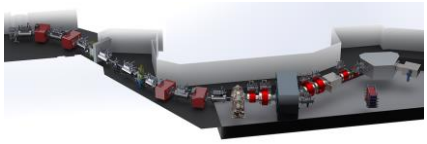
Nuclear Science Community Support

- A user community of over 500 scientists for the HRS is expected.
- "A New Era of Discovery: The 2023 Long Range Plan for Nuclear Science," by the Nuclear Science Advisory Committee (NSAC), a federally chartered advisory committee to the U.S. Department of Energy and National Science Foundation, identified HRS as a key instrument for FRIB.
- HRS will address the overarching intellectual challenges from the 2015 Nuclear Science Advisory Committee (NSAC) Long Range Plan and the National Research Council Decadal Study.
- Eleven of the 17 NSAC Rare-Isotope Beam Taskforce benchmarks, which were introduced to characterize the scientific research of a rare-isotope facility, require the use of fast beams at FRIB and benefit from the experimental program that will be performed at HRS.

Status

The HRS project scope includes the design, procurement, installation, and commissioning of the technical elements including the magnets and associated diagnostics, controls, power supplies, and cryogenic ancillary systems. The HRS design incorporates the implementation and use of state-of-the-art experimental instruments developed by the FRIB scientific user community.

- In September 2023, the U.S. Department of Energy Office of Science (DOE-SC) awarded $115 million for the HRS project.
- In August 2021, a Preliminary Design Report was issued with input from the HRS working group.
- On 16 September 2020, the DOE-SC Office of Nuclear Physics approved Critical Decision 1 (CD-1: Approve Alternative Selection and Cost Range) for the HRS project.
- In November 2018, HRS achieved Critical Decision 0 (CD-0) as part of DOE's staged project approval process. CD-0 documents that a mission need, such as a scientific goal or a new capability, requiring material investment exists.
- In December 2014, the FRIB scientific user community wrote and published a whitepaper that detailed the scientific motivations for HRS.



About FRIB

- FRIB started scientific user operation in May 2022, and published results are available at frib.msu.edu/publications.
- FRIB supports a community of 1,800 scientific users from 126 U.S. colleges and universities, 13 U.S. national laboratories, and 53 countries.
- FRIB provides researchers with a vast unexplored terrain of more than 1,000 new rare isotopes never before produced on Earth — more than double what was previously possible.
- FRIB has delivered more than 270 rare isotope beams to experiments.
- FRIB will make the United States the world leader in rare isotope nuclear science research.
- U.S. companies in fields, such as homeland security and nuclear medicine, would have an advantage in commercializing FRIB's discoveries in the United States.
- FRIB is a component in training the next generation of nuclear physics researchers.
- FRIB was delivered on budget and a few months early.

For More Information

Learn more about HRS at hrs.lbl.gov