

Final Technical Report for DOE Award DE-SC0023877

Project title: Twentieth Exotic Beam Summer School (EBSS2023)

Report Number: DOE-MSU-23877

Date of Report: 9/27/2024

Project period: 6/1/2023 – 5/30/2024

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DOE-SC Program Office: Nuclear Physics

DOE-SC Research Area: Nuclear Structure and Astrophysics

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DOE-SC Award Number: DE-SC0023877

Acknowledgement

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number(s) DE-SC0023877.

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Abstract

The study of unstable nuclei with unusual ratios of protons to neutrons is one of the frontiers of science. Investigating these rare isotopes is critical for understanding the synthesis of the chemical elements in stellar explosions as well as the fundamental nature of the nuclear forces that bind atomic nuclei together. Scientific progress in this field is driven by the development of exotic beams in present and next-generation rare-isotope beam facilities including the Facility for Rare Isotope Beams (FRIB).

Nuclear physics is a broad discipline, influencing our knowledge on subjects as diverse as weakly-bound nuclei, many-body quantum theory, the super heavy elements, and the inner structure of neutron stars. Applications based on nuclear science and technologies include medical diagnostics and therapies, materials science, and national security. The major goal achieved in this project was to hold Exotic Beam Summer School 2023 (EBSS2023), the twentieth installment of EBSS series, July 9-15, 2023 at the Facility for Rare Isotope Beams on the campus of Michigan State University to educate and train the next generation of scientists that will drive research with rare-isotope beams.

FRIB became operational in 2022 and is now providing beams of exotic nuclei that will ramp up to unmatched intensities, exceeding what is available today by orders of magnitude. Beams available at FRIB are facilitating a wide variety of studies in nuclear structure, astrophysics, fundamental symmetries and societal applications. There is a large community of scientists interested in working with rare isotope beams; for example, the FRIB User Organization currently has over 1,700 members. In order to maximize the scientific output of FRIB, there must be a workforce continuously trained in both the physics of exotic beams and in the practical techniques of carrying out an experiment. This summer school series is designed to specifically address this need - to ensure that new generations of scientists from a broad range of institutions and backgrounds is trained, motivated, and equipped to push the field forward to new and important breakthroughs.

Summary of Project Activities

Training of Scientific and Technical Workforce

The twentieth Exotic Beam Summer School was held at the Facility for Rare Isotope Beams on the campus of Michigan State University from July 9 to 15, 2023. 42 students attended the school.

In the morning, students received lectures by established researchers in fields associated with rare isotope beam science. These lectures covered experimental and theoretical aspects of nuclear physics as well as interdisciplinary subjects such as nuclear astrophysics and societal applications.

The lecturers were:

- M. Alcorta (TRIUMF) -- Fundamentals of Radiation Detection
- C. Elster (Ohio U) -- Nuclear Reactions (Theory)
- M. Febraro (ORNL) -- Frontiers of Radiation Detection
- A. Gaiser (MSU/FRIB) -- Isotopes
- R. Garcia-Ruiz (MIT) -- Fundamental Symmetries
- J. Kelley (NCSU) -- Nuclear Data
- M. Kuchera (Davidson U) -- Machine Learning in Nuclear Science
- C. Mueller-Gattermann (ANL) -- Nuclear Structure (Experiment)
- M. Mumpower (LANL) -- Nuclear Astrophysics (Theory)
- W. Nazarewicz (MSU/FRIB) -- Origin of EBSS
- W.-J. Ong (LLNL) -- Nuclear Astrophysics (Experiment)
- R. Orford (LBNL) -- Superheavy Elements
- J. Ressler (LLNL) -- Nuclear Applications
- L. Sobotka (WUSL) -- Nuclear Reactions (Experiment)
- R. Stroberg (U Notre Dame) -- Nuclear Structure (Theory)

In the afternoon, students participated in hands-on activities at the Facility for Rare Isotope Beams, as listed below:

- Rare isotope mass measurement with LEBIT Penning trap
- Nuclear Astrophysics simulations
- GADGET II Time Projection Chamber
- Radioactive Ion Beams with LISE
- Nuclear Theory Calculations
- Nuclear Data Tools
- FRIB Tour

Additional program elements included student poster presentations of their own research to the other students, lecturers, and directors, a dinner Q&A with lecturers and directors focused on careers, preparation of research papers on the results of the LEBIT measurement (including a

feedback session with the directors), a symposium to present the results of the LEBIT measurements, and social events.

The twentieth Exotic Beam Summer School (EBSS2023) was jointly organized by Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Argonne National Laboratory, the Facility for Rare Isotope Beams at Michigan State University, and ARUNA. Currently, ARUNA consists of nuclear accelerator laboratories at Florida State University, Ohio University, Texas A&M University, University of Kentucky, University of Notre Dame, University of Washington, Hope College, Union College, University of Massachusetts-Lowell, James Madison University, Western Michigan University, and Triangle Universities Nuclear Laboratory. The school is funded by these institutions, as well as the US National Science Foundation and Department of Energy.

The EBSS Board of Directors organizing EBSS2023 consisted of:

- C. Wrede (MSU/FRIB) -- local organizer of EBSS2023
- K. Chipps (ORNL)
- J. Gates (LBNL)
- J. Clark (ANL)
- M. Brodeur (Notre Dame/ ARUNA)
- N. Scielzo (LLNL)

The school web site is <https://frib.msu.edu/ebss2023>, which includes links to the presented lecture slides under the “Lecturers” link.