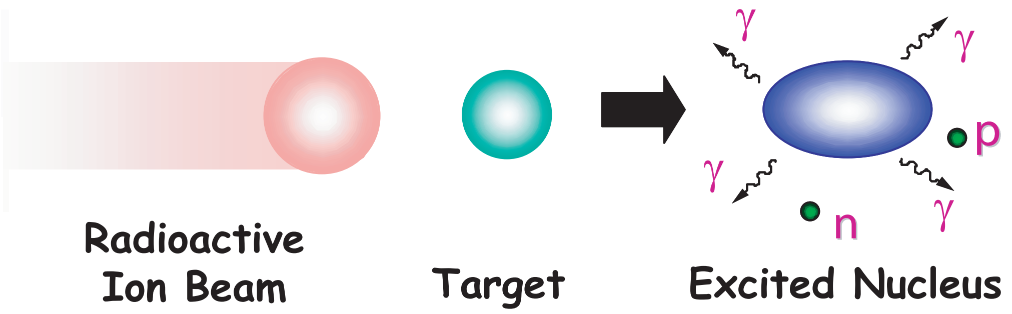
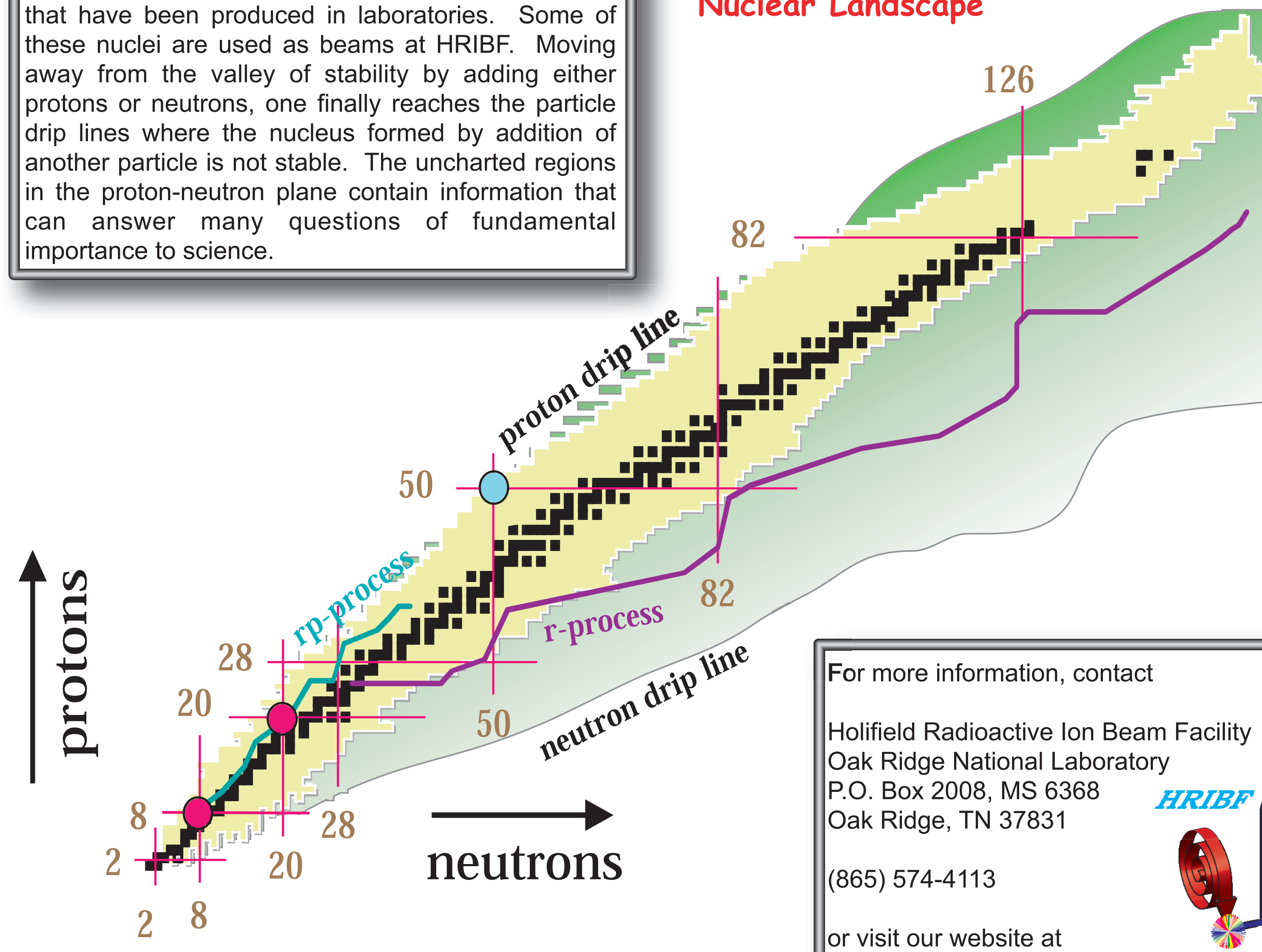
Physics Research at HRIBF



Research at the HRIBF involves the study of nuclear collisions initiated by beams of unstable nuclei. The products of these collisions are examined by complex detector systems to provide information about the quantum states created during the collision and about the collision itself. The experiments are designed to collect information especially critical to the understanding of nuclear structure and astrophysics.

Of the 3,000 nuclei believed to exist, less than 300 are stable. The stable nuclei exist in what is referred to as the "valley of stability" on the nuclear landscape chart (indicated by black squares, below). The yellow region indicates radioactive, short-lived nuclei that have been produced in laboratories. Some of these nuclei are used as beams at HRIBF. Moving away from the valley of stability by adding either protons or neutrons, one finally reaches the particle drip lines where the nucleus formed by addition of another particle is not stable. The uncharted regions in the proton-neutron plane contain information that can answer many questions of fundamental importance to science.

Nuclear Landscape



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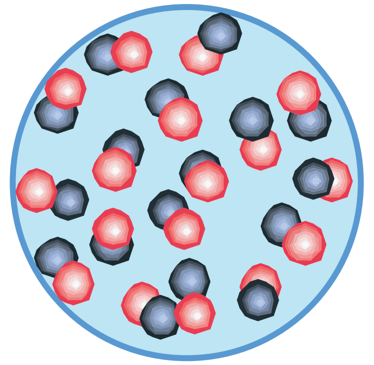
HRIBF

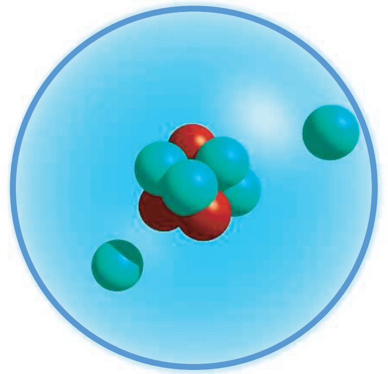


Nature of Proton- and Neutron-Rich Matter

HRIBF is the only facility in the world that provides accelerated beams of medium-mass, short-lived, neutron-rich nuclei. Such beams are used to explore the structure of exotic nuclei employing various spectroscopic techniques. The resulting information provides crucial input for nuclear theory that strives to develop a unified description of the nucleus. This work, augmented by reaction studies, illuminates the nature of proton and neutron motion in nuclei. Reactions with neutron-rich accelerated beams help us understand how to synthesize heavy and superheavy nuclei.

Exotic Magic Nuclei

Some nuclei (with Z or N equal to 2, 8, 20, 28, 50, 82, and 126) are very tightly bound relative to their isotopic neighbors and are referred to as "magic." They are closed-shell systems analogous to the noble gases. The knowledge of their structure is very important for understanding how the nucleus works. While the doubly-magic nuclei ^{16}O, and ^{40}Ca (indicated by red dots on the nuclear landscape diagram, left) are stable, the exotic doubly-magic ^{100}Sn (blue dot, right) is radioactive. Experiments at HRIBF investigate proton-rich nuclei around ^{100}Sn.



Detector Systems

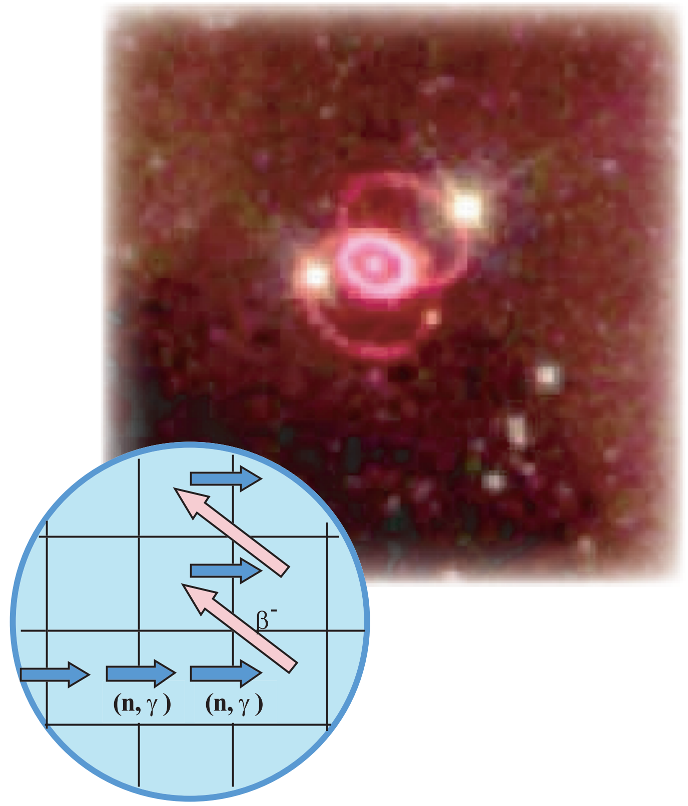
Detector systems at HRIBF are highly efficient for the study of nuclear reactions. Typically, this efficiency is achieved by surrounding the target with several layers of radiation detectors; charged particle detectors must be contained within the vacuum system while gamma ray detectors can be located outside the thin aluminum chambers. Most detectors are comprised of a material which interacts with the radiation and produces electrons or light. In the case of light, the light strikes a photoelectric material which also produces electrons. In either case, the electrons are gathered and multiplied so that a signal is generated in electronic circuits and processed to provide information such as the energy of the radiation and even the time at which the reaction occurred.

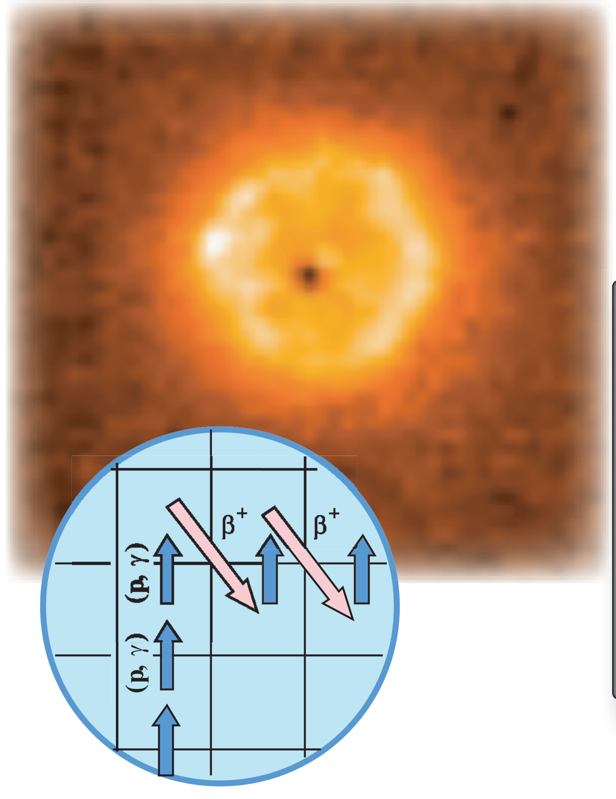
Limits of Nuclear Existence

Nuclear structure research at HRIBF provides insight into the nature of the force that clusters protons and neutrons into a nucleus. HRIBF tests the limits of nuclear stability using intense beams above the Coulomb barrier and new techniques for detecting the shortest-lived, proton-rich nuclei. These nuclei have exotic decay modes such as one- and two-proton emission.

How Do Stars Explode?

HRIBF produces beams of radioactive nuclei with low, easily variable energies and intensities sufficient to allow some of the first direct measurements of the nuclear reactions that power novae, X-ray bursts, and other stellar explosions. HRIBF's unique combination of high-quality radioactive beams with experimental equipment optimized for astrophysics experiments has enabled high-precision measurements of stellar reactions with radioactive beams.





Origin of the Elements and Cosmic Gamma Rays

The unique capabilities of HRIBF allow the determination of how rapidly some isotopes are created in stellar explosions, and how quickly they may be destroyed, through direct measurements of reactions with radioactive beams. These measurements are required to reduce the large uncertainties in the prediction of the synthesis of many nuclides, including those that comprise our world as well as long-lived radioisotopes. Better predictions of the origin of these important sources of gamma rays in the cosmos are needed to decipher the observations from astronomical observatories such as CHANDRA, HUBBLE, and INTEGRAL.

Theory

The major challenge for nuclear theory is to develop a comprehensive microscopic description of the nucleus. Nuclear theorists associated with HRIBF develop models that help us understand nuclear structure, nuclear reactions, and the way nuclei behave in cosmic explosions. Much of this theoretical work involves advanced computing.