Driving innovation by unraveling the mysteries of matter and energy



The University of Notre Dame was among the first U.S. universities to begin conducting nuclear physics research. In the 1930s, a Notre Dame professor and a graduate student built the University's first electrostatic particle accelerator. A second accelerator, designed to be the most powerful in the world at the time, was used by researchers working with the Manhattan Project during the Second World War.

In subsequent decades, the University continued to expand its research program. Today, it includes the Notre Dame Nuclear Science Laboratory (NSL), situated within the Institute for Structure and Nuclear Astrophysics (ISNAP), a Notre Dame research center. The NSL focuses on low- and medium-energy experimental nuclear physics, and nuclear astrophysics. In addition, Notre Dame's Radiation Laboratory offers opportunities for collaborative basic research into the fundamental chemical processes induced by ionizing radiation.
Together, these research hubs unite faculty and students around a core mission: to yield benefits for the common good by answering fundamental questions about the nature of matter and energy.

Learn More

isnap.nd.edu

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Facilities

The NSL operates three accelerators on Notre Dame's main campus. The **FN Pelletron accelerator** is primarily used for the nuclear structure and astrophysics program, as a driver for the TriSol radioactive beam facility, and for Accelerator Mass Spectrometer (AMS). A **5MV single-ended (5U) NEC Pelletron accelerator** hosts an experimental program in low-energy nuclear astrophysics for both light ion and heavy ion beams as well a source for intense neutron beams. The **3MV Pelletron tandem** is used for applied nuclear physics work, including Proton Induced X-ray Emission (PIXE) measurements for material analysis.

Complementing the three on-campus accelerators is a fourth Notre Dame-operated accelerator for research focused on high-sensitivity astrophysics studies one mile underground at the **Sanford Underground Research Facility in South Dakota**.

Notre Dame's Radiation Laboratory (NDRL), located near the University's iconic Hesburgh Library, offers unique irradiation facilities and opportunities for worldwide collaborative investigation. The Laboratory studies the effects of ionizing radiation on the molecular decomposition of water and various organic materials, including polymers.

NUCLEAR PHYSICS AT NOTRE DAME

Research Partnerships

ISNAP is a founding member of the International Research Network for Nuclear Astrophysics (IReNA) along with Michigan State University, the University of Washington, Arizona State University, and Central Michigan University. An NSF AccelNet Network of Networks, IReNA connects nine interdisciplinary research networks across 4 continents to foster collaboration, complement and enhance research capabilities in the US and abroad, and thus greatly accelerate progress in science.

Nuclear physics faculty at the University are also actively involved in research and development projects through collaborations with the Argonne National Laboratory and at the Facility of Radioactive Ion Beams (FRIB) at Michigan State University.

Workforce Development

Notre Dame's nuclear physics research projects offer graduate students a comprehensive research experience that includes hands-on work with experimental equipment, operating accelerators, designing instruments, analyzing data, developing and carrying out calculations for the nuclear quantum many-body problem on high-performance computers, performing calculations of nuclear reaction networks in astrophysical environments, and publishing scientific articles. The NSL also actively engages in several educational and outreach programs and products that reach students of middle school age and up.

Research Areas

- Experimental Programs: The experimental program uses the accelerator facilities of the NSL and completes low-energy nuclear astrophysics experiments with light and heavy ion beams, Accelerator Mass Spectrometry (AMS), nuclear reaction and scattering studies, and radioactive beam studies.
- Nuclear Theory: Notre Dame's Nuclear Theory group is motivated by the needs of the NSL's experimental program. It has been instrumental in developing new phenomenological methods for interpreting nuclear reaction mechanisms and identifying key nuclear parameters that need to be studied. Understanding multi-messenger probes from unique astrophysical events is also a primary driver.
- Nuclear Astrophysics: NSL researchers are working to understand low-energy nuclear reactions and decay processes in quiescent and explosive stellar burning processes. They define the conditions and timescales for these processes, identify their role and contribution in the chemical elements' origin, and identify characteristic features or signatures in astrophysical observables.
- Nuclear Structure Physics: Research in this area at the NSL is concerned with the emergence of collectivity in the evolution of structure from closed shells and single-particle states to mid-shells and beyond in nuclei.
- Nuclear Applications: This emerging research area complements the fundamental research activities of ISNAP. Accelerator Mass Spectrometry is used to identify the smallest products of critical reactions in supernova explosions and to identify long-lived radioactive depositions from stellar explosions in lunar, meteoritic, and deep-ocean samples.
- Fundamental Symmetries: This NSL research project aimed at answering whether the fundamental interactions that are basic to the structure of matter are fully understood. Precision measurement of nuclear beta decay is one of the probes used to test the Standard Model of the electroweak interaction.
- Radiation Research: The NDRL conducts basic research into the fundamental chemical processes induced by ionizing radiation. Current projects investigate energy deposition and transport following the absorption of ionizing radiation, the structure and properties of the radiolytic species, basic science for the management and further development of safe and efficient energy sources, and excited state dynamics in semiconductor quantum dots, metal nanoclusters, and hybrid architectures to improve photoconversion efficiencies in photocatalysis and solar cells.

