

PHYSICS GRADUATE STUDIES

UNIVERSITY OF NOTRE DAME



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NOTRE DAME

COLLEGE OF SCIENCE

MESSAGE FROM THE CHAIR

Choosing the right graduate physics program can be a difficult decision. An ideal graduate school blends world-class facilities, renowned faculty who are thoughtful teachers and mentors, and opportunities for professional development. The University of Notre Dame combines all of these. We offer the research opportunities of a large university coupled with a smaller, tight-knit community of graduate students working together to push forward the front lines of modern physics research.

The Department of Physics prides itself on its collaborative and interdisciplinary environment. Our department consists of 44 tenured and tenure-track faculty, 17 research professors, and more than 100 doctoral students. Our faculty includes 15 fellows of the American Physical Society, eight American Association for the Advancement of Science (AAAS) fellows, two winners of major American Physical Society (APS) prize fellowships, and a co-awardee of the 2015 Breakthrough Prize in fundamental physics.

Recently, U.S. News and World Report ranked Notre Dame's Department of Physics as the fourth strongest in the world for international collaboration. Our nuclear physics program, with its three research accelerators, is also ranked among the top in the nation. Notre Dame's high-energy physics group was involved with the 2012 discovery of the Higgs boson, and our astrophysics, network science, condensed matter, biophysics, atomic physics, and theoretical groups play major roles in advancing our understanding of the universe.

I encourage you to learn more about our programs through this brochure, our website, physics.nd.edu or by calling us at (574) 631-6386. We hope you'll consider joining our thriving research community.



Peter Garnavich, Department Chair, Professor



GRADUATE PROGRAM AT A GLANCE



Graduate students are an indispensable part of the Notre Dame Department of Physics, contributing to and energizing research in a wide range of experimental and theoretical physics. During a typical year, over 100 graduate students collaborate with the 60 faculty members and 20 post-doctoral researchers who comprise ND Physics.

- All admitted students receive a funding package including full tuition support, a competitive stipend, and a full medical insurance subsidy.
- Beginning doctoral students typically work as teaching assistants (~15 hours/week) during the academic year. TAs also receive a parking waiver.
- Additional grants, combined with a low cost of living index, enable our students to focus on their academic program.
- During the summer, most students hold research assistantships. The majority of advanced students work as research assistants funded by external research grants during the academic year.
- Applicants with strong academic records are automatically considered for fellowships.
- On average, 25 percent of our doctoral students are women and 29 percent are international students.
- The Graduate Physics Society (GPS) offers community, academic and professional support.
- Student support is also provided by Grad Student Life, Graduate Career Center, and Graduate Professional Development.

All admitted students receive **full tuition** support and a stipend



29% of our **doctoral students** are international, and 25% are **women**

During a typical year...

100 graduate students collaborate with

60 faculty members, and

20 post-doctoral researchers



FACULTY

ASTROPHYSICS

Dinshaw Balsara, Professor, Theoretical Astrophysics/ Computational. Concurrent Professor, Department of Applied and Computational Mathematics and Statistics (Ph.D., University of Illinois Urbana-Champaign, 1990)

Timothy Beers, Professor and Notre Dame Chair in Astrophysics (Ph.D., Harvard University, 1983)

Jeffrey Chilcote, Assistant Professor, Observational Astrophysics Instrumentation (Ph.D., University of California, Los Angeles, 2014)

Jonathan Crass, Research Assistant Professor, Astrophysics (Ph.D., University of Cambridge, 2014)

Justin R. Crepp, Associate Professor, Observational Astrophysics Instrumentation (Ph.D., University of Florida, 2008)

Keith Davis, Concurrent Assistant Professional Specialist, Director, Digital Visualization Theater (Ph.D., Clemson University, 2017)

Peter Garnavich, Department Chair, Professor, Observational Astrophysics/Cosmology (Ph.D., University of Washington, 1991)

J. Christopher Howk, Professor, Observational Astrophysics (Ph.D., University of Wisconsin, 1999)

Nicolas Lehner, Research Professor, Observational Astrophysics (Ph.D., Queens University of Belfast, 2000)

Grant Mathews, Professor, Theoretical Astrophysics/ Cosmology (Ph.D., University of Maryland, 1977)

Lara Arielle Phillips, Research Assistant Professor, Theoretical Astrophysics/Cosmology (Ph.D., Princeton University, 2003)

Vinicius Placco, Research Assistant Professor, Astrophysics (Ph.D., University of Sao Paulo, 2010)

Terrence Rettig, Professor, Observational Astrophysics (Ph.D., Indiana University, 1976)

In-Saeng Suh, Concurrent Research Associate Professor, Theoretical Astrophysics/Computational (Ph.D., Hanyang University, 1997)

CONDENSED MATTER PHYSICS

Badih Assaf, Freimann Assistant Professor, Experimental (Ph.D., Northeastern University, 2014)

Bruce Bunker, Professor, Experimental (Ph.D., University of Washington, 1980)

Malgorzata Dobrowolska, Associate Dean for Undergraduate Students, College of Science, and the Rev. John Cardinal O'Hara, C.S.C. Professor, Experimental (Ph.D., Polish Academy of Science, 1980)

Morten Eskildsen, Professor, Experimental (Ph.D., University of Copenhagen, 1998)

Jacek Furdyna, Marquez Professor, Experimental (Ph.D., Northwestern University, 1960)

Kenjiro K. Gomes, Freimann Assistant Professor, Experimental (Ph.D., University of Illinois Urbana-Champaign, 2008)

Boldizsár Jankó, Professor, Theoretical (Ph.D., Cornell University, 1996)

Marasu Kuno, Concurrent Professor, Nanoscale Materials (Ph.D., Massachusetts Institute of Technology, 1998)

Xinyu Liu, Research Associate Professor, Experimental (Ph.D., University of Notre Dame, 2003)

Kathie Newman, Professor, Theoretical (Ph.D., University of Washington, 1981)

Steven Ruggiero, Professor, Experimental (Ph.D., Stanford University, 1981)

Zoltán Toroczkai, Professor, Theoretical. Concurrent Professor, Computer Science and Engineering (Ph.D., Virginia Polytechnic Institute, 1997)

Dervis Can Vural, Assistant Professor, Computational Models, Dynamics & Reactions, Networks & Interactions (Ph.D., University of Illinois Urbana-Champaign, 2011)

BIOPHYSICS

Jeffrey Peng, Concurrent Associate Professor, Dynamics & Reactions, Networks & Interactions (Ph.D., University of Michigan, 1993)

Sylvia Ptasinska, Associate Professor, Imaging & Structure (Ph.D., University of Innsbruck, 2004)

Steven Ruggiero, Professor, Imaging & Structure (Ph.D., Stanford University, 1981)

Carol Tanner, Professor, Biophysics & Experimental Atomic Physics (Ph.D., University of California Berkeley, 1985)

Zoltán Toroczkai, Professor, Networks & Interactions (Ph.D., Virginia Polytechnic Institute, 1997)

Dervis Can Vural, Assistant Professor, Computational Models, Dynamics & Reactions, Networks & Interactions (Ph.D., University of Illinois Urbana-Champaign, 2011)

HIGH ENERGY PHYSICS

Antonio Delgado, Professor, Theoretical (Ph.D., Universidad Autonoma de Madrid, 2001)

Michael Hildreth, Professor, Experimental (Ph.D., Stanford University, 1995)

Colin Jessop, Professor, Experimental (Ph.D., Harvard University, 1993)

Christopher Kolda, Professor, Theoretical (Ph.D., University of Michigan, 1995)

Kevin Lannon, Associate Professor, Experimental (Ph.D., University of Illinois Urbana-Champaign, 2003)

John LoSecco, Professor, Experimental (Ph.D., Harvard University, 1976)

Nancy Marinelli, Research Associate Professor, Experimental (Ph.D., University of Bari, 1997)

Adam Martin, Tom and Carolyn Marquez Assistant Professor of Physics, Theoretical (Ph.D., Boston University, 2007)

Randal Ruchti, Professor, Experimental (Ph.D., Michigan State University, 1973)

Jonathan Sapirstein, Professor, Theoretical Atomic Physics & High Energy Physics (Ph.D., Stanford University, 1979)

Mitchell Wayne, Professor, Experimental (Ph.D., University of California, Los Angeles, 1985)

NUCLEAR PHYSICS

Tan Ahn, Assistant Professor, Experimental (Ph.D., Stony Brook University, 2008)

Ani Aprahamian, Freimann Professor, Experimental (Ph.D., Clark University, 1986)

Dan Bardayan, Professor, Experimental (Ph.D., Yale University, 1999)

Georg Berg, Research Professor, Experimental (Ph.D., University of Cologne, 1974)

Maxime Brodeur, Ortenzio Family Assistant Professorship in Applied Medical and Nuclear Physics, Experimental (Ph.D., University of British Columbia, 2010)

Mark Caprio, Associate Professor and Director of Graduate Studies, Theoretical (Ph.D., Yale University, 2003)

Philippe Collon, Professor, Experimental, Director of Undergraduate Studies (Ph.D., Universität Wien, 1999)

Manoel Couder, Assistant Professor, Experimental (Ph.D., Université Catholique de Louvain, 2004)

James deBoer, Research Assistant Professor, Experimental (Ph.D., University of Notre Dame, 2011)

Stefan Frauendorf, Professor, Theoretical (Ph.D., Technical University of Dresden, 1971)

Umesh Garg, Professor, Experimental (Ph.D., Stony Brook University, 1978)

Joachim Görres, Research Professor, Experimental (Ph.D., University of Munster, 1983)

Micha Kilburn, Assistant Professional Specialist, Physics Education (Ph.D., Michigan State University, 2011)

Jay LaVerne, Concurrent Professional Specialist, Radiation Laboratory (Ph.D., University of Nebraska, 1981)

Khachatur Manyukan, Research Assistant Professor, Experimental (Ph.D., Yerevan State University, 2006)

Patrick O'Malley, Research Assistant Professor, Experimental (Ph.D., Rutgers University, 2012)

Graham Peaslee, Professor, Experimental (Ph.D., SUNY Stony Brook, 1987)

Daniel Robertson, Research Associate Professor, Experimental (Ph.D., University of Notre Dame, 2010)

Anna Simon, Assistant Professor, Experimental (Ph.D., Jagellonian University, 2010)

Edward Stech, Professional Specialist, Experimental (Ph.D., University of Notre Dame, 2004)

Rebecca Surman, Professor, Theoretical (Ph.D., University of North Carolina at Chapel Hill, 1998).

Wanpeng Tan, Research Associate Professor, Experimental (Ph.D., Michigan State University, 2002).

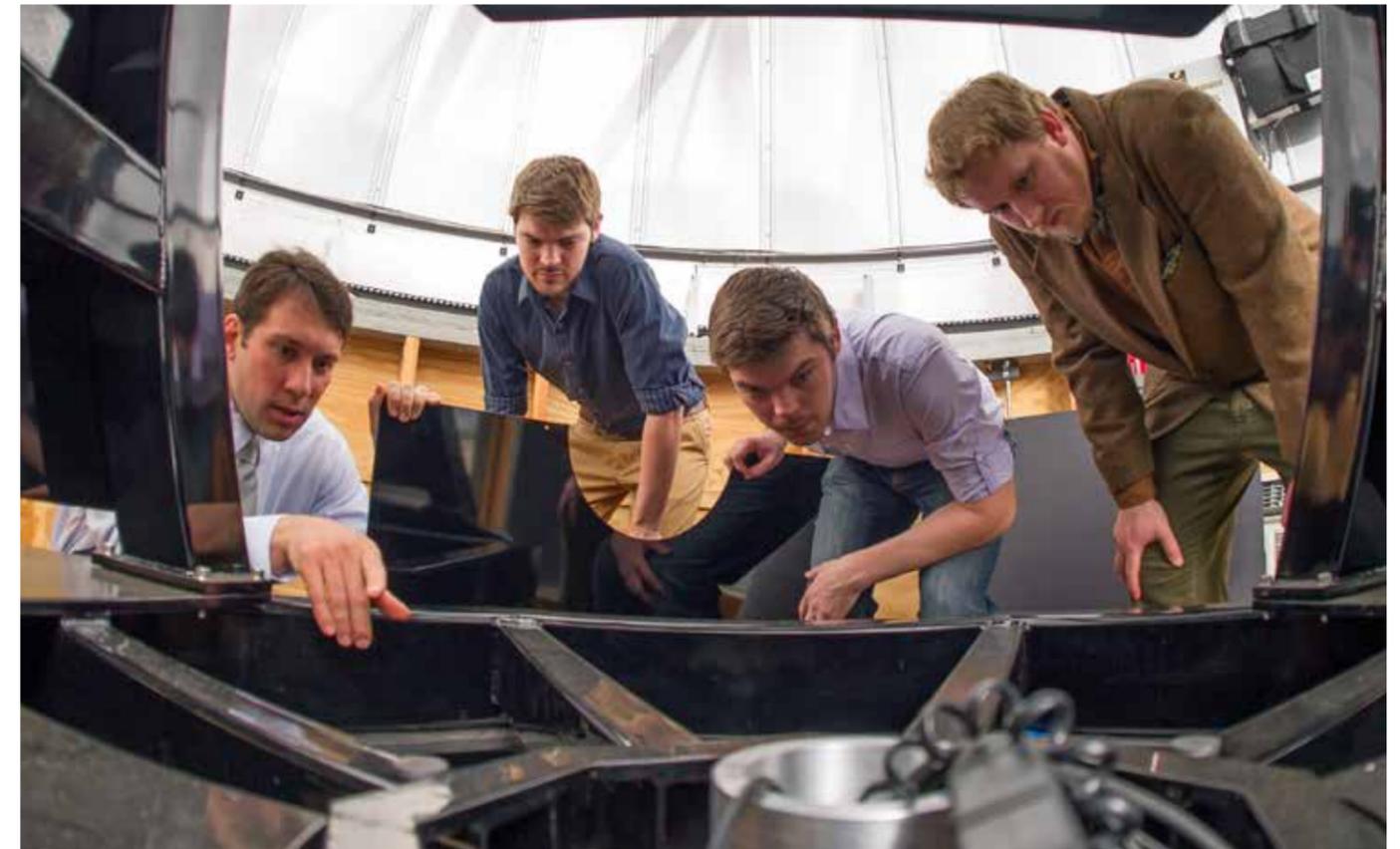
Michael Wiescher, Freimann Professor, Experimental (Ph.D., University of Munster, 1980)

ASTROPHYSICS

From the detection of exoplanets orbiting other stars, to unlocking the secrets of dark matter and dark energy, Notre Dame astrophysicists are working to answer some of the most fundamental questions about how the universe operates. Our faculty have been recognized for codiscovering the acceleration of the universe's expansion (dark energy), the oldest known star in the galaxy (HE 1523-0901), and the first Earth-like planet in a star's habitable zone (Kepler-62e). They make use of the Hubble Space Telescope, participate in the Sloan Digital Sky Survey, and are partners in the Large Binocular Telescope in Arizona and the Keck Observatory in Hawaii, some of the largest and most advanced telescopes in the world. Research at Notre Dame

includes work on a wide variety of both theoretical and observational projects, including: studies of the Big Bang, extra dimensions, the origin of galaxies, stellar evolution, supernova explosions, black holes, neutron stars, brown dwarfs, circumstellar disks, extrasolar planets and many other topics. We are a world leader in the field of nuclear astrophysics, studying the processes inside stars that produced the elements that we see around us. And we are fast becoming a leader in the new field of "galactic archaeology", in which astronomers use the oldest known stars to probe conditions soon after the Big Bang. Major ongoing research is being conducted to establish observational constraints on the astrophysical site of the rapid neutron-capture process, responsible

for the production of roughly half of the elements in the lower half of the Periodic Table. In addition, observations of the distinctive elemental abundance patterns in carbon-enhanced metal-poor stars arising from the very first stars born in the universe are deepening our understanding of early chemical evolution, and the assembly history of the galactic halo. Notre Dame has also recently developed two experimental astrophysics labs to build cutting-edge instruments for telescopes that operate at visible and near infrared wavelengths. These instruments facilitate the next generation of scientific discoveries including allowing for unprecedented accuracy in detecting and studying planets orbiting other stars.

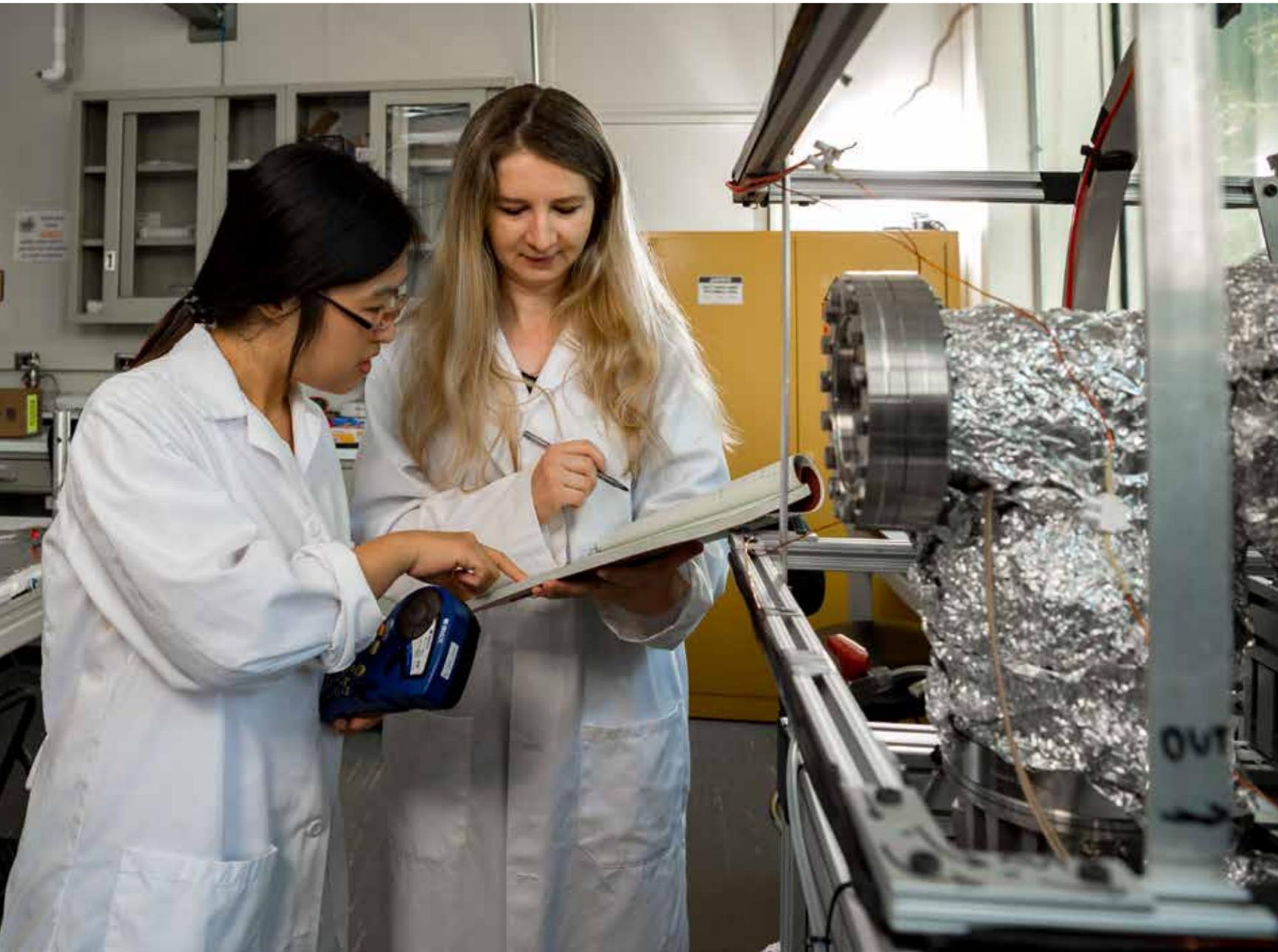


BIOPHYSICS

Our expanding research in biophysics involves experimental and theoretical effort geared toward understanding how biology works at the molecular level. The biophysics group comprises faculty from the Physics, Chemistry and Biochemistry, and Applied Mathematics departments. We study the geometry,

electronic structure, and interactions of such biological systems as DNA, proteins, bacteria, viruses, and liposomes. In order to tackle these challenges our laboratories are equipped with state-of-the-art instrumentation for laser transmission spectroscopy, photoelectron spectroscopy, and nuclear magnetic

resonance. In theoretical biophysics, mathematical and computational tools are applied to bio-complexity problems, including the development of new techniques for early detection of cancer and its treatment, in collaboration with the Harper Cancer Research Institute at Notre Dame.



COMPLEX SYSTEMS

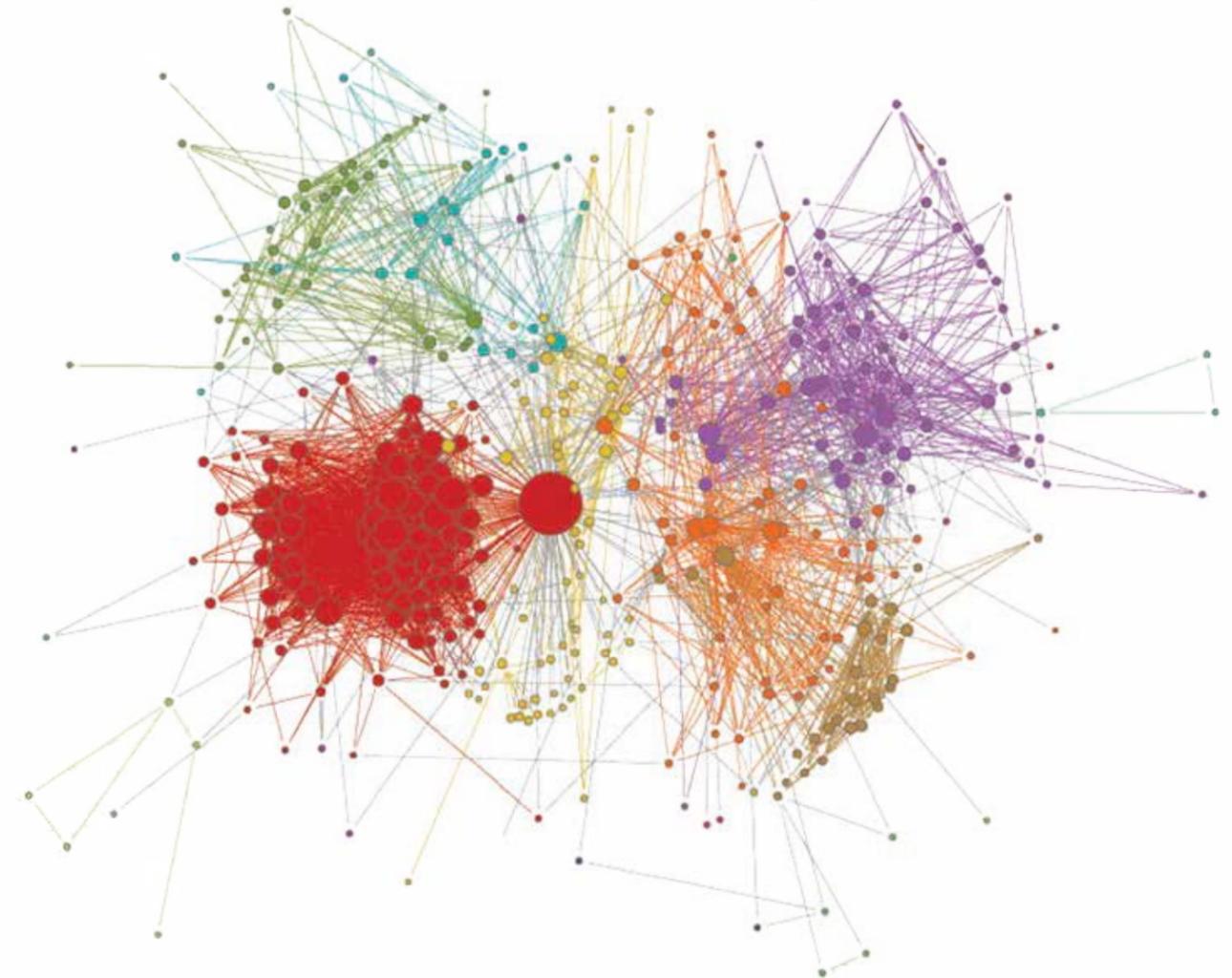
Modern network science was born at Notre Dame with the invention of scale-free (or power-law) networks and the discovery that they were ubiquitous in both natural and man-made systems. Our group continues to work in complex networks, studying the many-body behavior of physical

and biological systems in which disorder and strong interactions play an important role. Examples include disordered solids, social and biological networks, population genetics and evolution, inverse problems, reliability theory, swarms and active matter, and various foundational questions in quantum many-body theory.

This research is driven by three fundamental questions:

- (1) Universality:** To what extent do microscopic laws uniquely determine macroscopic behavior?
- (2) Statistics:** How should microscopic laws be transformed to give macroscopic ones?
- (3) Inversion:** Can microscopic laws be determined from macroscopic observations?

The work is highly interdisciplinary, involving collaborations with applied mathematicians, biologists, engineers and computer scientists, and is funded by the NSF, NIH, and DARPA.

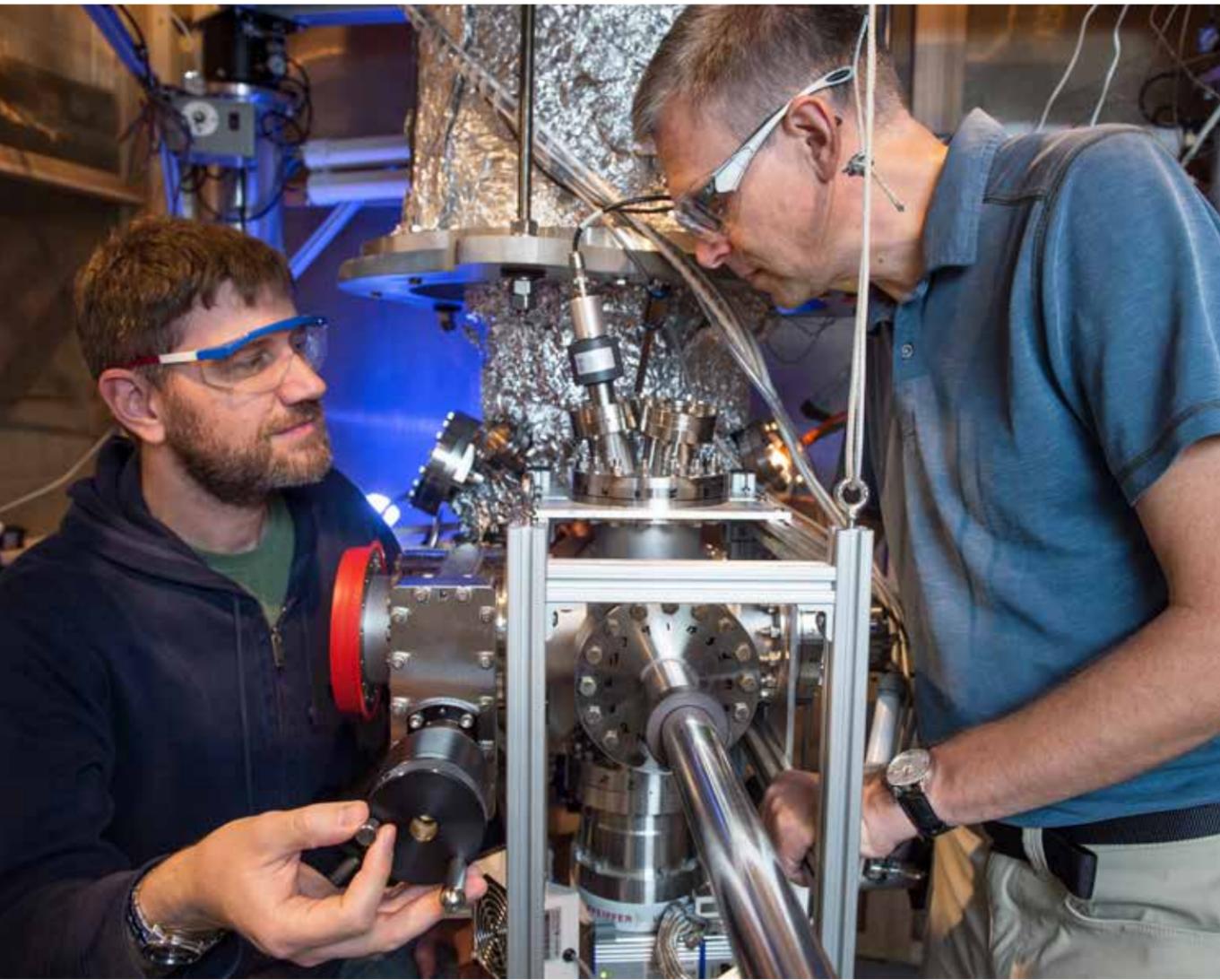


CONDENSED MATTER PHYSICS

In our experimental condensed matter program, students and faculty fabricate nanoscale materials (such as self-assembled quantum dots and nanowires) and study them using facilities on campus and at national laboratories. New materials investigated also include wide-bandgap hetero-structures and ferromagnetic semiconductors with possible spintronic applications. Graphene, topological insulators, and other low-dimensional systems are

studied for fundamental electronic properties. Scanning tunneling microscope (STM) spectroscopy and small-angle neutron scattering are used to explore the structure and dynamics of magnetic vortices in superconductors. At even smaller length scales, researchers manipulate individual atoms on surfaces using an STM to study quasicrystals and organic superconductors. The resulting artificially engineered atomic

structures are used to investigate fundamental properties of quantum electronic systems. Interdisciplinary research involves collaborations with chemists, biologists, and electrical, chemical, and environmental engineers. Theorists work on topics including the interaction of superconductors with magnetic materials, superconducting mesoscopic devices, and theoretical underpinnings of electrostatic behavior in molecular dynamics simulations.

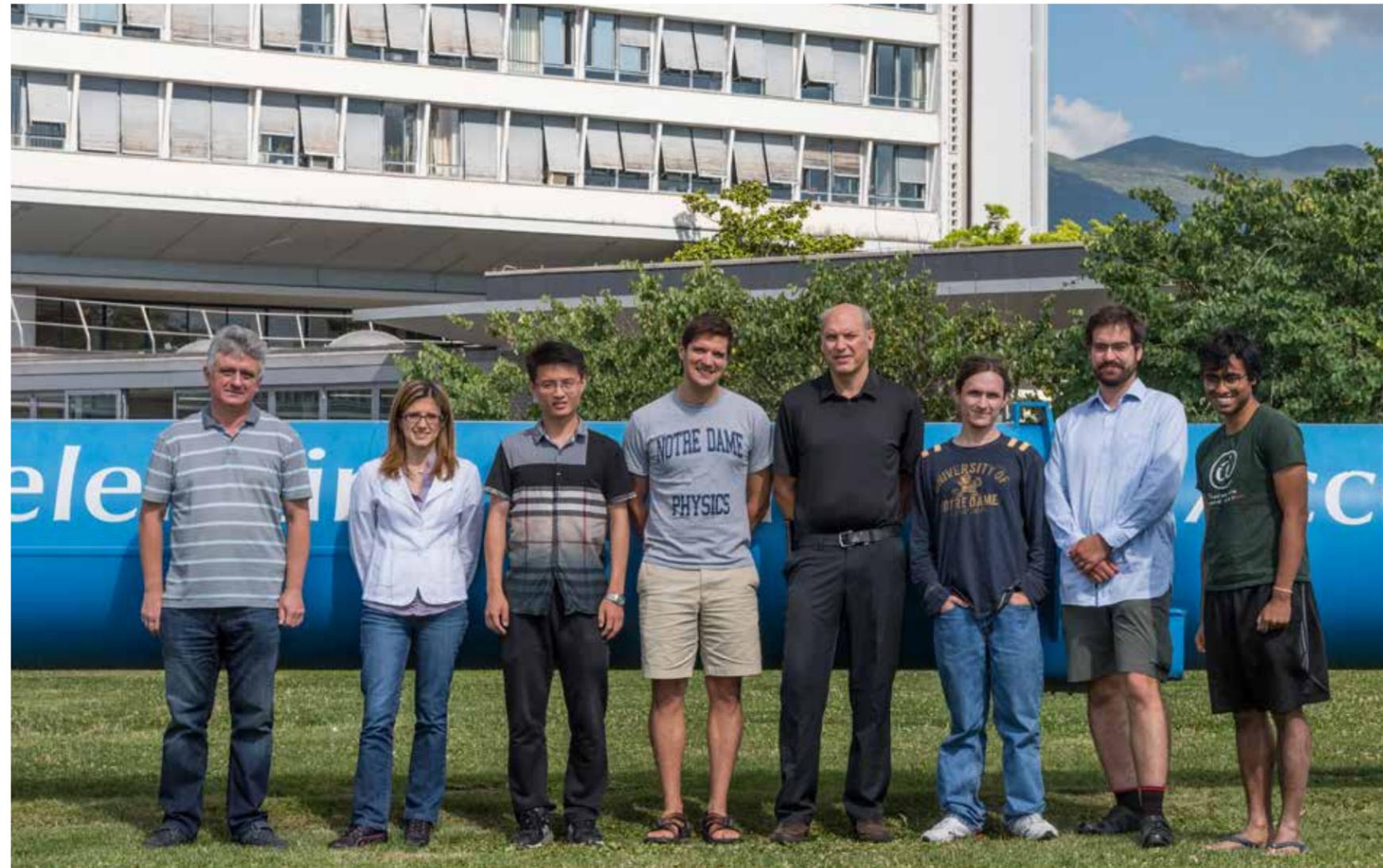


HIGH ENERGY PHYSICS

Researchers in elementary particle physics at Notre Dame play major roles in the CMS experiment at the CERN Large Hadron Collider (LHC), leading major instrumentation, computing, and analysis efforts. The goal of the LHC program is the elucidation of the fundamental laws of nature, including electroweak symmetry breaking, the generation of particle mass, CP violation,

and the hierarchy problem. In 2012, the Notre Dame team played a key role in the discovery of the Higgs boson at the LHC and is now embarking on the measurement of the coupling between the Higgs boson and the top quark, as well as major detector upgrades. Notre Dame also participates in the DUNE neutrino oscillation experiment at Fermilab and the Sanford Underground

Research Facility in South Dakota, hoping to elucidate the mass hierarchy among the neutrinos and their CP-violating phases. The theoretical efforts at Notre Dame focus on physics beyond the standard model, including how signals of novel particles or phenomena would manifest at the LHC, flavor physics and CP violation, dark matter, and cosmology.



NUCLEAR PHYSICS

The Nuclear Science Laboratory at Notre Dame is the longest continuously operating accelerator lab at any U.S. university, and its nuclear physics program is ranked among the strongest in the nation. Our research is built around a broad program in experimental and theoretical low-energy nuclear physics, including nuclear astrophysics, nuclear structure, nuclear reactions with radioactive ion beams, and accelerator mass spectroscopy. The recent addition of a third accelerator marks the beginning of an applied nuclear physics program, where ion beam analysis techniques

are used to search for trace chemicals in environmental samples. The lab's fourth accelerator is focused on high-sensitivity astrophysics studies and is located a mile underground at CASPAR, a low-background accelerator laboratory at the Sanford Underground Research Facility in South Dakota.

We encourage the participation of our students in every aspect of the research program, while the laboratory, with its three accelerators and recently installed next-generation mass separator, provides an extensive and invaluable hands-on experience.

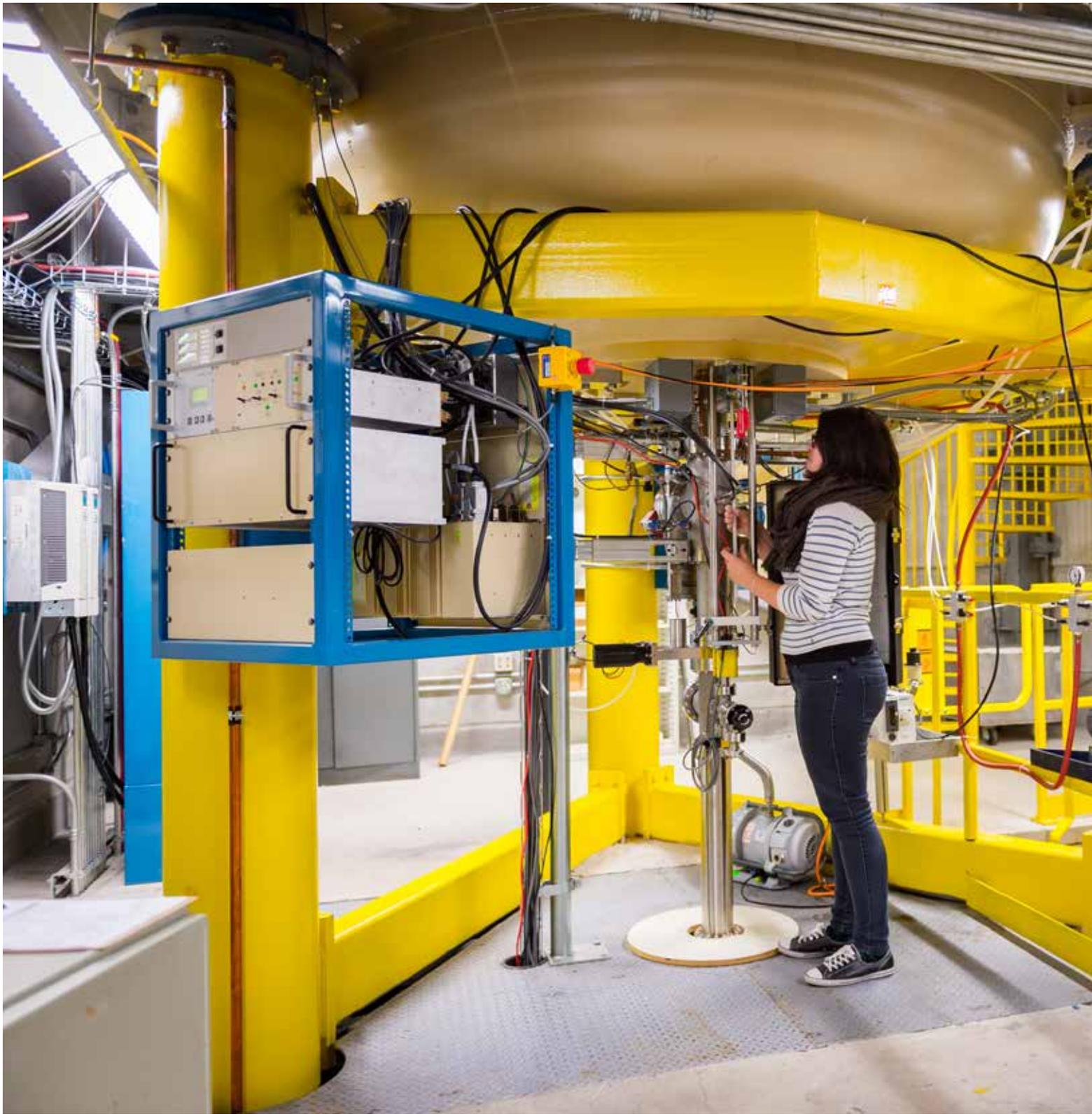
The experiments we conduct at Notre Dame and at facilities worldwide are complemented by a theoretical program that includes modeling efforts in nuclear structure and nucleosynthesis, and the use of supercomputing to explore the physics of light nuclei. Notre Dame is a founding member of the Joint Institute for Nuclear Astrophysics, one of only ten NSF-funded Physics Frontier Centers in the nation, and continually hosts visiting researchers from around the world who come to collaborate with our group and to use our facilities.



OUTREACH

Notre Dame's Physics Department has long emphasized the vital importance of public outreach as part of the mission of scientists, and graduate students are core contributors to the department's exceptional range of outreach programs. Members of the department run camps and workshops, lead physics activities in local and regional schools, and involve high school students and teachers in research. The QuarkNet program was founded at Notre Dame and Fermilab and now involves more than 50 universities across the country and nearly 600 high school teachers who are learning physics by participating in real world experiments. The Art2Science Camp integrates reading, writing, and a variety of art forms with math and the physical sciences. Members of the physics department also share their love of physics with the local community through a Physics Demo team led by physics graduate students. The department hosts one of the nation's largest and longest-running Research Experiences for Undergraduates programs.





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