NEWS FOR MICHIGAN STATE UNIVERSITY ALUMNI AND FRIENDS

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MSUToday

BIG SCIENCE

MSU powers breakthrough discoveries and world-changing technologies

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MSUToday

NEWS FOR MICHIGAN STATE UNIVERSITY ALUMNI AND FRIENDS

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This issue of *MSUToday*, which focuses on big science at MSU, comes to you with the support of President Lou Anna K. Simon, Provost Kim Wilcox, and others throughout the campus community.

For up-to-date news, visit the MSU News Web site at **news.msu.edu**.

Your comments are welcome: write to *MSUToday*, Michigan State University, 302 Olds Hall, East Lansing, MI, 48824-1047; call (517) 355-7505; or e-mail msutoday@msu.edu.

Tell us what you think

We'd like your feedback on *MSUToday* magazine and other communications from MSU. We'll be sending a brief survey via e-mail to a randomly selected sample of *MSUToday* recipients. If you receive a survey, we encourage you to take a few minutes to complete and return it. We value your input and thank you in advance for sharing your thoughts.

On the cover:
The National Superconducting Cyclotron Laboratory's miniball charged-particle detector allows for the simultaneous detection of many charged particles and for experimenters to determine the energy of a nuclear collision.

FSC logo

FROM THE PRESIDENT

December 11, 2008, was a great day for science. On that day, the U.S. Department of Energy announced that the Facility for Rare Isotope Beams would be established at Michigan State University—a decision that will lead to an exceptional nuclear science user facility that will serve the nation's and the world's top scientists and build on MSU's half-century commitment to accelerator-based experimental nuclear science.

This is big science, and at MSU, our land-grant roots mean we work hard to translate big science into big impact. We're making breakthrough discoveries and developing innovative technologies that help solve the world's most pressing problems and improve quality of life for millions, providing clean and affordable energy, access to education, safe and plentiful food, and good health.

At MSU we are not only powering big science but also building a pipeline and capacity for big science in the future. We are providing opportunities for students to work side by side with faculty researchers and to participate in industry-sponsored projects—in Michigan and as far away as Tanzania. We're helping prepare not only the next generation of scientists but also the next generation of science professors.

This issue of *MSUToday* highlights some of MSU's big breakthroughs and impacts—from world-leading nuclear science to evolutionary automotive technology and revolutionary biofuels, from pollinator research to protect the world's food supplies to collaborative milestones in physics and astrophysics that are making scientific history—and much more.

Please read on to learn more about how Michigan State University is not only a place to discover but also to learn, to apply, to achieve, to dream, and to fulfill dreams.

Sincerely,

Lou Anna K. Simon
President

MSU researchers nab 'doubly magic' isotope

Daniel Bazin, senior physicist at the National Superconducting Cyclotron Laboratory, is among those who helped develop the equipment that has enabled measurements of several rare nuclei.

With help from newly developed equipment designed and built at MSU, university researchers have been able to make first-of-a-kind measurements of several rare nuclei, one of which has been termed a "holy grail" of experimental nuclear physics.

The discoveries—made at MSU's National Superconducting Cyclotron Laboratory (NSCL) using an isotope purification device—will help refine theoretical models about how elements are created in the cosmos. Until now, this was beyond the technical reach of nearly all of the world's nuclear science facilities.

"Tin-100, in particular, has been sort of a holy grail of experimental nuclear physics," NSCL senior physicist Daniel Bazin says of one of the isotopes. The isotope—described in a paper published in December in *Physical Review Letters* detailing how the researchers were able to measure the nuclei of tin, cadmium, and indium—possesses 50 protons and 50 neutrons.

Within nuclear science, the number 50 is considered "magic" because it's one of a handful of numbers associated with extra stability. Other magic numbers are 2, 8, 20, 28, 82, and 126.

It takes a magic number of protons or neutrons to fill the nested energetic shells that form the nucleus like Russian matryoshka nesting dolls. To understand the concept, consider that each carved doll similarly has a magic number of marbles that precisely and completely fill the hollow interior. And, just as a doll full of marbles neatly packed together is probably sturdier than one that's only half or a quarter full, a closed-shell nucleus is more stable than its counterparts.

Tin-100 is one of the few "doubly magic" nuclei with magic numbers of both protons and neutrons. Such nuclei are generally far more stable than other particles, especially at the fleeting, shape-shifting edge of nuclear existence. Because of this stability, doubly magic nuclei serve as useful semipermanent signposts for rare isotope researchers who troll the unexplored terrain of the nuclear landscape seeking to answer basic questions about the structure of nuclear matter and processes that create chemical elements inside stars.

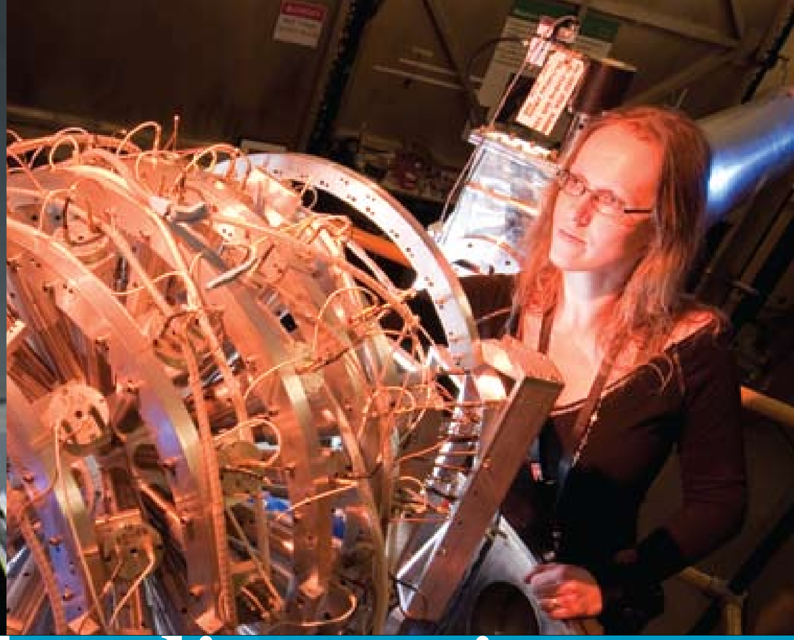
A new experimental device, the radio frequency fragment separator, provides at least a hundredfold boost to NSCL's ability to filter out the few exotic isotopes from the vast sea of other particles produced by its coupled superconducting cyclotrons and downstream magnets. Funding for the equipment was provided by the National Science Foundation.

This newfound filtering ability resulted in the first production and measurement in North America of tin-100, which has been eagerly pursued by experimentalists since at least the mid-1990s. GSI in Germany and GANIL in France are the only other nuclear science facilities in the world to have successfully produced and studied the rare, proton-rich isotope of tin, an element extensively used for thousands of years in everything from ancient spears and knives to cars and modern electronics.

In their paper, Bazin and his collaborators also report the measurement of the half-lives of the cadmium-96 (48 protons and 48 neutrons) and indium-98 (49 protons and 49 neutrons) isotopes.

The announcement of the observation of the three rare isotopes builds on recent NSCL success in creating nuclear matter that otherwise only exists in extreme environments in space, including exploding stars. In fall 2007, the laboratory reported the discovery of three neutron-rich isotopes of magnesium and aluminum in the journal *Nature*, a finding that received considerable media attention in the science and mainstream press.

The laboratory currently is undertaking a major MSU-funded upgrade, the centerpiece of which is a new low-energy reaccelerator that will be used to conduct astrophysical research. When this upgrade is completed in summer 2010, NSCL will be the only facility in the world capable of offering experimentalists the chance to conduct research with fast, stopped, and reaccelerated beams of rare isotopes.



ADVANCING KNOWLEDGE through world-leading science

Daniela Henzlova, research associate at the National Superconducting Cyclotron Laboratory, installs the miniball charged-particle detector in a vacuum chamber. The miniball detects charged particles such as protons and heavier nuclei. Together with two large neutron walls placed outside the chamber, the miniball can be used to simultaneously study both the neutrons and protons emitted in a nuclear collision.

By Geoff Koch

> It is not in the stars to hold our destiny but in ourselves.
>
> – Shakespeare

The U.S. Department of Energy's announcement that Michigan State University had been selected to design and establish the Facility for Rare Isotope Beams was good news not only for MSU but also for countless others, including the best scientific minds around the world.

Imagine for a moment you're an astrophysicist. You care about stars—and not just for the beauty they add to a cloudless night sky. Your job is to determine how they form, what makes them shine, and how they eventually die, sometimes in spectacular fashion.

Or maybe you're a nuclear physicist studying the dense knot of protons and neutrons at the center of the atom. You wonder just how these particles interact and how the elements they help to create—like iron, nickel, and tin—are formed.

Perhaps you work in national security, building detectors for screening luggage at airports or shipping containers in seaports—or at a hospital, treating patients with cancer. Or, you're a U.S. citizen who's worried about national competitiveness in science and technology.

Maybe you're a student, unafraid of numbers and itching for a chance to work around a one-of-a-kind machine that can help answer timeless questions about the origins of the universe.

For you and countless others, December 11, 2008, was a good day—the day that the U.S. Department of Energy (DOE) Office of Science announced that Michigan State University had been selected to design and establish the Facility for Rare Isotope Beams (FRIB).

After a decadelong pursuit of a secure future for MSU's experimental nuclear science program, the news was sweet for all who bleed Spartan green, but it was also good news for numerous constituencies who understand the importance of the decision and the value of its impact.

The proposed $550 million facility will bring together an international community of top scientists to advance understanding of rare nuclear isotopes, fleeting bits of matter created primarily in the super-extreme environment of stars.

Although these short-lived atomic nuclei can't be seen or felt, research to produce and study them at MSU is making an enormous impact in the world of science. It's an impact that translates to benefits for everyday lives around the globe as it helps unlock the mysteries of nature and the universe and fuels breakthrough applications for medicine, national security, and the environment.

"The opportunities to advance human knowledge through science and the potential for scientific discoveries to improve the human condition are tremendous," says MSU National Superconducting Cyclotron Laboratory (NSCL) Director Konrad Gelbke, who was tapped to lead FRIB. "This will be a transformational facility—not just for MSU but for the best scientific minds around the world."

Experimental game changer

FRIB will build on MSU's half-century commitment to accelerator-based experimental nuclear science and, says Gelbke, allow the university to expand a role for which it is known and valued around the world—"facilitator of the best ideas." A national user facility, FRIB will enable anyone with an interesting scientific question and a strong plan for answering it in an experiment to submit a proposal to an independent review committee for "beam time" at the leading-edge facility.

For years, MSU has operated a user program at the National Science Foundation–funded NSCL, a world-class rare isotope research facility that has served 700 researchers from 100 institutions in more than 30 countries. FRIB is expected to increase the quality and quantity of research opportunities for approximately 1,000 university and laboratory scientists, postdoctoral associates, and graduate students around the globe.

The main advantage—and attraction for researchers—is FRIB's beating heart, a high-energy linear accelerator that will be nothing less than an experimental game changer.

Like NSCL, FRIB will forge isotopes by first speeding up a mass of everyday nuclei; focusing the horde into a beam the width of a thin, pencil-drawn line; slamming that beam into a thin target material; and then sorting and making sense of the many different particles that fly out the other side. Some of these particles are rare isotopes.

The advantage of FRIB's accelerator is not measured in speed. Like the existing superconducting cyclotrons at NSCL, the new accelerator will launch nuclei down a beam line at roughly half the speed of light—fast enough to travel around Earth four times each second. But FRIB's accelerator will hurl dramatically more nuclei per second. This technical capability is important because many of the most sought-after rare isotopes pursued by scientists are unimaginably elusive.

"Some of the rare isotopes we're most interested in are produced only one in every billion billion collisions at the target," says Brad Sherrill, University Distinguished Professor of physics at MSU, "so your chances of making one are about the same as flipping a coin 52 times and turning up heads each time."

The accelerator at FRIB won't change those odds but will, in effect, allow the rate at which the coin can be flipped to increase

"This is a great day for science. We are grateful for the Department of Energy's commitment to address this critical priority for the nation's physical sciences research infrastructure, and we are proud to have been selected as a partner. We are deeply dedicated to working with the Department of Energy's Office of Science to develop an exceptional user facility serving the needs of national and international scientists. This is the first step on the journey."

– MSU President Lou Anna K. Simon, speaking on the day it was announced that the Facility for Rare Isotope Beams would be located at MSU

Chris Magsig (left), research and development engineer, and Philip Voss, graduate student, at the National Superconducting Cyclotron Laboratory, are seen through the A1900 quadropole triplet—magnets that will be used for momentum compression for ReA3, the new reaccelerator.

John Popielarski, engineer at the National Superconducting Cyclotron Laboratory, works on the superconducting coaxial resonator, which accelerates particles toward detectors.

exponentially—enabling production of certain exotic isotopes at the edges of the known nuclear map that are, for all practical purposes, otherwise off limits.

Discovery potential and impact

FRIB will assist astrophysicists, the scientists who are helping to piece together the chemical evolution of the universe—or, more precisely, to explain how we got from the hydrogen, helium, and lithium produced in the Big Bang to the 90 or so naturally occurring elements that sprawl across the periodic table today, approximately 14 billion years later.

"In a sense, we study galactic chemical evolution, and FRIB is the machine that will decipher the DNA of this process, which is the quantum structure of nuclei," says Hendrik Schatz, MSU professor of physics and coprincipal investigator of the Joint Institute for Nuclear Astrophysics, supported by the National Science Foundation. "By understanding the chemical history of the galaxy, we understand our origins; there is definitely a time-machine aspect here."

For Sherrill, who also is the NSCL associate director for research and designated FRIB chief scientist, the nucleus itself is the site of a host of unanswered questions worth pursuing. Most fundamentally, even though it's been more than a half century since the discovery of the proton and neutron—the building-block particles that compose nuclei—researchers still can't predict exactly how these particles interact with each other to form all the matter that we see around us.

But advances in experimental nuclear science are changing things. The ability to produce increasing numbers of exotic nuclei will "enable myriad experimental possibilities that collectively will advance and possibly even transform nuclear theory," wrote Sherrill in an April 2007 *CERN Courier* article, which he coauthored with Florida State University's Kirby Kemper and University of Notre Dame's Michael Wiescher.

Although the full impact of the discovery potential won't be known for another 10 to 20 years, experimental nuclear research already has made possible technologies that are making the world a better and safer place.

Consider the case of Don Sackett, who did his doctoral research at NSCL in the early 1990s. His dissertation experiment involved detecting the faint energetic echoes of fleeting nuclear events with an array of wall-sized detectors. More than a decade later, he is CEO of Massachusetts-based Innov-X Systems, which produces high-precision handheld devices for detecting a host of potentially nasty elements, from specks of lead paint on children's toys to traces of an aluminum alloy used only in nuclear weapons production in shipments of allegedly innocuous steel pipes.

"The experience [at NSCL] of having to run your own independent project is a lot like the real working world," said Sackett in an August 2008 audio interview published on the NSCL Web site. Sackett says his success at Innov-X, whose detectors also are used by soldiers in Iraq to inspect for potential security threats, would not have been possible without his MSU training.

Advances in accelerator technology used in nuclear and high-energy particle physics also are leading to advances in proton therapy, which is showing promise in treating certain types of cancer.

Several years ago, MSU technical staff consulted on the design of medical cyclotrons now sold by California-based Varian Medical Systems, one of the world's leading medical-device manufacturers. The December 2008 issue of *symmetry* magazine features an article about the many past and present contributions of U.S. DOE Office of Science–funded national labs aimed at reducing the cost or increasing the effectiveness of this treatment. Indeed, it was the DOE's Fermi National Accelerator Laboratory in Illinois that helped to spawn this treatment option in the 1980s when it built a proton accelerator for Loma Linda University Medical Center in Southern California.

Education and economic benefits

FRIB is expected to provide economic benefits as well. The science infrastructure investment will bring an estimated billion dollars in economic activity to Michigan over two decades.

And as an investment in U.S. competitiveness, the decision to site the facility on a university campus is a clear win for nuclear science education, a foundational STEM (science, technology, engineering, and mathematics) discipline.

Countless reports from government, academia, and the media have urged investment in STEM-related fields to help ensure future U.S. competitiveness in science. MSU already is home to the nation's No. 2–ranked graduate program in nuclear physics, according to *U.S. News & World Report*, and the university helps train 10 percent of all U.S. nuclear science doctoral students.

One of the strengths of NSCL—the nation's only nuclear science flagship facility based on a university campus—is the access it provides students at all postsecondary levels to cutting-edge tools of nuclear science not often readily available to students. FRIB is expected to continue and to enhance such opportunities for student research while energizing would-be researchers.

The kind of excitement that big, experimental science generates is evidenced in the response to the "Large Hadron Rap" on YouTube. The educational, entertaining, and very campy video—which explains the technology and science of the world's most powerful accelerator, the Large Hadron Collider in Geneva Switzerland—has been viewed more than four million times. Its creator—MSU physics graduate Katie McAlpine—has been interviewed about her video by major news outlets including the *New York Times*, National Public Radio, and the Associated Press and is now working on a rap about rare isotope research.

While the journey to make FRIB a reality has only just begun, the U.S. Department of Energy's selection of MSU as its site is a significant

"The Department of Energy's new Facility for Rare Isotope Beams at Michigan State University promises to vastly expand our understanding of nuclear astrophysics and nuclear structure. This capability will allow physicists to study the nuclear reactions that power stars and stellar explosions, explore the structure of the nuclei of atoms and the forces that bind them together, test current theories about the fundamental nature of matter, and play a role in developing new nuclear medicines and techniques."

– Acting Associate Director of the Office of Science for Nuclear Physics Eugene Henry

ECONOMIC IMPACT FOR MICHIGAN

The proposed Facility for Rare Isotope Beams (FRIB) could bring an estimated billion-dollar impact to Michigan over two decades, including:

- Estimated $550 million in construction costs
- Creation of about 400 full-time jobs: about 180 jobs at FRIB and 220 jobs in related industries
- Increased business for the local hospitality industry associated with attracting researchers from around the nation and world to MSU
- $187 million in state tax revenue

– Source: Anderson Economic Group

milestone in the history of nuclear science and long-awaited good news for the international science community.

Currently, senior MSU administrators and scientists are focused on completing the cooperative agreement for FRIB, beginning the environmental review of the proposed site, and continuing to build a relationship with the U.S. DOE Office of Science.

Until the next-generation facility is completed, a substantial upgrade to NSCL is ensuring that today's finest scientific minds—and the next generation of nuclear scientists—have uninterrupted opportunities for research that can capture the imagination and transform the world.

More news is on the way, but until then, you might pause and turn your eyes skyward when the nighttime viewing conditions are good. The sight might have new meaning given the prospect of a powerful new tool for unraveling some of the mysteries of the stars above.

Without a doubt, the spectacle remains a prime example of nature's beauty—something appreciated through the ages and expressed well by Johannes Keppler, the first scientist to discern the laws of planetary motion more than 300 years ago: "The treasures hidden in the heavens are so rich that the human mind shall never be lacking in fresh nourishment."

DOE DECISION

MSU and the University of Chicago/Argonne National Laboratory LLC submitted proposals for the Facility for Rare Isotope Beams (FRIB) in response to a May 20, 2008, Funding Opportunity Announcement (FOA) from the U.S. Department of Energy.

The proposals were subject to a merit review process conducted by a panel of world-renowned experts from universities, national laboratories, and federal agencies. The appraisal included rigorous evaluation of the proposals based on the merit review criteria described in the FOA, presentations by the applicants, and visits by the merit review panel to each applicant's site.

MSU's application was judged to be superior based on the merit review criteria and the program policy factor contained in the FOA, including provision of a proposed budget that is reasonable and realistic, giving substantial confidence that MSU can establish the FRIB within the cost limitations of the FOA. MSU also offered a direct cost share to the project.

Graduate student researcher Jill Berryman is gaining hands-on experience at the National Superconducting Cyclotron Laboratory. "That experience is really rare," she says, "and sometimes I have to take a step back and just realize how much I am doing here."

RESEARCH AND EDUCATION SYNERGY

- MSU's graduate program in nuclear physics is ranked second in the nation, according to *U.S. News & World Report*.
- The university helps to train 10 percent of all U.S. nuclear science doctoral students.
- The National Superconducting Cyclotron Laboratory (NSCL) is the nation's only nuclear science flagship facility based on a university campus.
- Today, approximately 100 MSU undergraduate and graduate students work at NSCL in a variety of capacities, from work-study employees to research associates.
- One of NSCL's strengths is the access it provides students at all postsecondary levels to leading-edge tools of nuclear science that are not often readily available to university students.
- Each year, NSCL welcomes thousands of visitors, most of them in school groups, and hosts a summer camp that provides high school students and science teachers with opportunities to work with MSU faculty and to conduct their own research.

MSU SCIENTISTS COLLABORATE IN BREAKTHROUGHS

MSU contributions make CERN spin

When the world's most powerful particle accelerator kicked into high gear last fall, MSU students and faculty were on hand to watch scientific history being made.

Meanwhile, other faculty and alumni were paying close attention, knowing they had played roles—or will play future roles—in the success of the project.

"This is the dream of every physicist—to be present when a new energy regime opens up, potentially offering answers to some of the most important scientific questions of our time," says Joey Huston, MSU professor of physics and astronomy, who was involved in the construction of detectors installed at the accelerator site.

Known as the Large Hadron Collider, the accelerator is located within the European Centre for Nuclear Research—or CERN, as it is known by its French acronym—in Switzerland. Scientists predict the accelerator's very-high-energy proton collisions will yield extraordinary discoveries about the nature of the physical universe.

"We have a variety of questions we'd like to undertake," says Raymond Brock, MSU professor of physics and astronomy, who has spent much of his time the past several years working on the accelerator. "They all pretty much boil down to understanding the earliest bits of time in the universe."

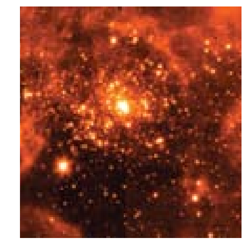
For more than 15 years, MSU has been working on the design and construction of what's known as the ATLAS project, a massive detector located at CERN that will collect and measure the subatomic debris resulting from collisions of the protons. Specifically, MSU has constructed a significant portion of the 2,000-ton Tilecal hadron calorimeter, which consists of detectors within the ATLAS project designed to measure the energies of the particles produced in the high-energy collisions. In all, as many as 50 MSU faculty, postdoctoral fellows, and graduate and undergraduate students have spent time at CERN.

MSU will be one of a number of sites around the country that will be charged with analyzing the mountains of data that will flow from the accelerator.

"This is unknown territory," Huston adds. "We're expecting the answers to some of our most pressing scientific questions, but we're also hoping and expecting to be surprised by something completely new."

Spartan camera captures first light

Among the first images captured by the Spartan Infrared Camera—MSU's contribution to the specialized instruments mounted on the SOuthern Astrophysical Research (SOAR) telescope in Chile—is one of R136, a massive star cluster at the center of the 30 Doradus nebula in the Large Magellanic Cloud, which is more than 160,000 light years away.



Since its arrival in Chile last October, the Spartan Infrared Camera has been undergoing tests to ensure it's ready for the world-class research being conducted using the SOAR telescope, a joint venture of MSU, the University of North Carolina at Chapel Hill, the country of Brazil, and the National Optical Astronomy Observatories.

The camera was built by a team headed by Edwin Loh, an MSU professor of physics and astronomy. Due to its infrared capabilities, the $2.1 million piece of equipment is able to capture images of distant stars and galaxies with much more detail than possible in the past.

"MSU is proud of Professor Loh's progress in making this world-class imager a reality," says Paul Hunt, associate vice president for research and graduate studies. "Ed's vision and perseverance are coming to fruition, and both MSU and external astronomers stand to benefit greatly."

MSU scientists help lead top-quark discovery

MSU scientists and colleagues around the world took a step closer to understanding the universe with the discovery of a fundamental building block of nature. The recent detection of a single top quark at the U.S. Department of Energy's Fermi National Accelerator Laboratory near Chicago is a major breakthrough in understanding matter and energy.

"The discovery of a single top quark production fills in a major piece of the puzzle in particle physics and solidifies our understanding of the basic components of matter," says Reinhard Schwienhorst, assistant professor of physics at MSU.

Quarks are believed to be the smallest bits of matter and interact to form particles such as protons. Previously, top quarks were known to be produced only in pairs. By producing a single top quark, scientists have recorded the most massive of elementary particles and perhaps have paved the way for discovery of the Higgs boson.

Sometimes referred to as the "God particle," the Higgs boson is the theoretical building block of the Standard Model of the universe and could explain how massless elementary particles acquire mass.

Chien-Peng Yuan, MSU professor of physics, pioneered study of heavy top quarks and their relationship to the Higgs boson. He proposed the relevant strategies for discovering single top quarks in 1989. Since then, Yuan has continued to theorize about top quarks, collaborating closely with MSU colleagues.

Scientists involved in the Fermilab project worked in two groups, each exceeding 600 physicists, and MSU was one of a handful of institutions with faculty on both. Schwienhorst was coleader of the DZero team, and MSU doctoral student Jorge Benitez was active in that group. Kirsten Tollefson, MSU associate professor of physics, led a group of nearly 150 Collider Detector team physicists.

"For the last three years, the two groups have been in direct competition with each other over which experiment would be the first to see single top quarks," Tollefson says. "It was pretty amazing that we each came out with confirmation from two experiments."

"The discovery of a single top quark production marks a milestone in physics," Schwienhorst says. "We anticipate upcoming research at the Large Hadron Collider in Europe to take these findings to the next step and either evolve our understanding of particle physics or overturn the model completely."