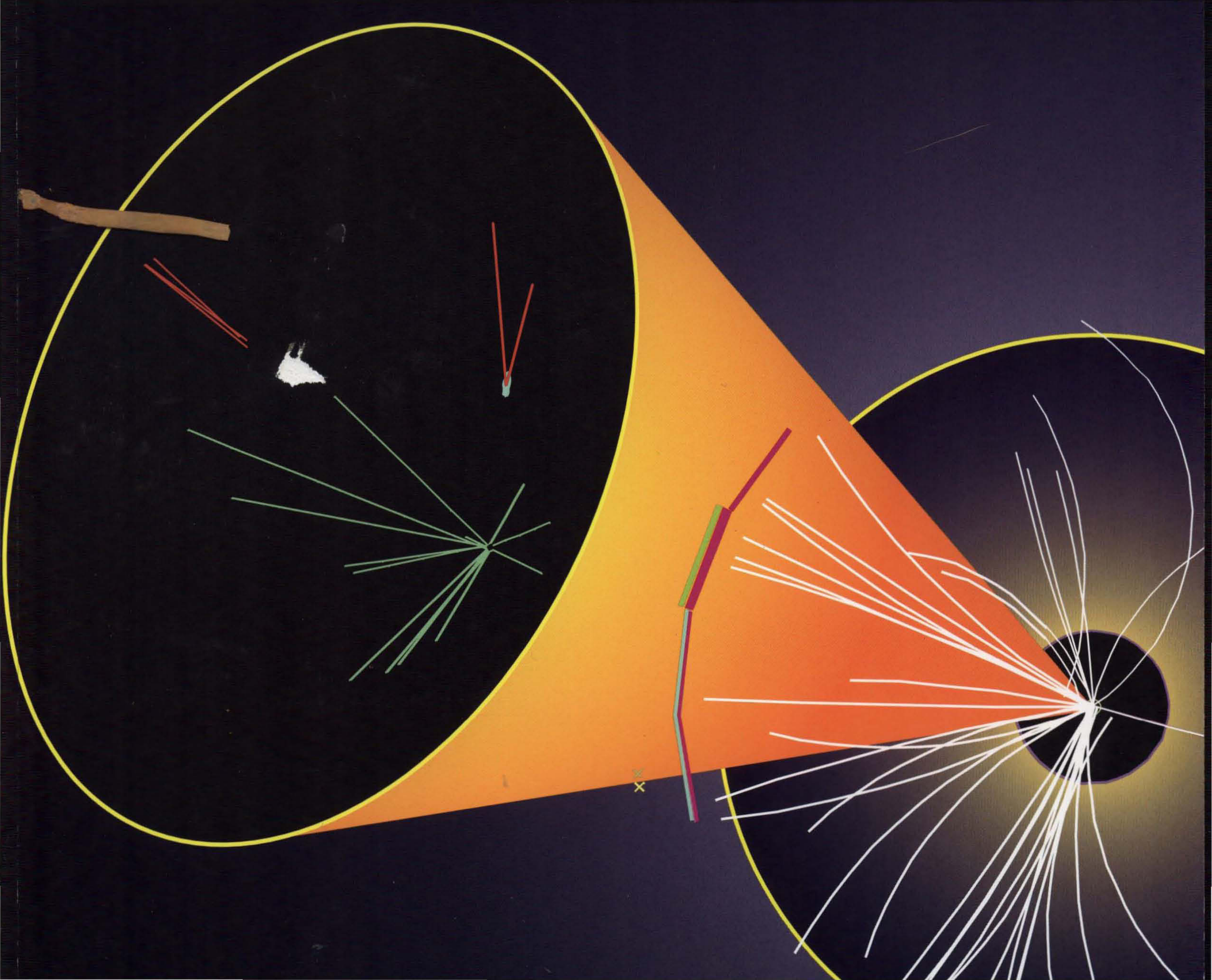
Universities Research Association, Inc.

1999 Annual Report



URA Serves University Scientists

URA IS "an entity in and by means of which universities and other research organizations may cooperate with one another, with the Government of the United States, and with other organizations, toward the support and use of laboratories, machines, and other research facilities, and toward the development of knowledge in the physical and biological sciences."

It was created "...for research, development and education in the physical and biological sciences, including all aspects of the field of high-energy physics, nuclear energy, and their engineering and other applications; and to educate and train technical, research and student personnel in said sciences."

Physicists from 34 states and 24 countries use particle accelerators at Fermi National Accelerator Laboratory in Illinois for forefront research in particle physics.

URA

UNIVERSITIES RESEARCH ASSOCIATION, INC.

Annual Report 1999

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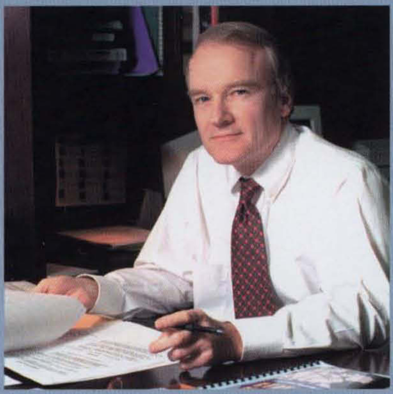
URA is a private not-for-profit corporation. A consortium of research universities, it serves as a contractor to the federal government for the operation of major scientific facilities. This volume —updated annually with new financial and organizational data—provides the historical context for the consortium's structure and mission, as well as highlights of its contributions to science, technology, industry and education.

Message from the URA President


URA President, Frederick M. Bernthal

FOR URA AND ITS 89 MEMBER UNIVERSITIES, this has been a year of passage, with the URA Trustees' appointment of Dr. Michael Witherell, Professor of Physics at the University of California at Santa Barbara, as the fourth Director of Fermilab. The torch was officially passed on July 1, 1999, as now Director Emeritus John Peoples stepped down after ten years of distinguished service to the Laboratory and the nation. Sadly, we must also report that on January 16, 2000, Fermilab's founding Director, Dr. Robert Rathbun Wilson, passed away at his home in Ithaca, New York. A tribute to Bob Wilson and his genius appears in this Annual Report.

This was also a year in which URA, in keeping with our mission of public service in the advancement of scientific research, for the first time in two decades undertook a competitive bid for the operating contract of another major national laboratory. While that particular contract at Oak Ridge was awarded to another group, in keeping with our charter and planning, URA remains ready to respond to other appropriate opportunities to serve the U.S. and international research community.

The pastoral setting of URA's flagship enterprise, Fermilab, combines the qualities of environmental field laboratory, public park, and nature reserve. In that bucolic milieu, the Laboratory is generating new excitement as world leader at the high energy frontier of particle physics. The new Main Injector, Fermilab's key to preeminence in the first decade of the 21st century, is completed and passed all its commissioning milestones on schedule. With assistance from a major infusion of users from around the country and the world, the Laboratory is now working feverishly to bring the upgraded "D-Zero" and "CDF" detectors on-line for the much-anticipated Tevatron Collider Run II, scheduled to begin early in 2001.

The lineup of projects and experiments now planned or underway, and the motivation in physics theory for those experiments, is as exciting as any in the 30-year history of URA. The $136 million Neutrinos from the Main Injector (NUMI) project at Fermilab, an experiment designed to probe whether nature's elusive neutrinos have measurable mass, is in its second year of construction. When this project is completed, neutrinos produced at Fermilab will be seen by a detector to be located deep underground in the former Soudan iron mine in northern Minnesota, a site that is also hosting a UC-Berkeley, Stanford, Case-Western Reserve, and Fermilab collaboration to search for the enigmatic "Cold Dark Matter" in the universe.

The URA paradigm for university-government-

In the spring of 1999, ground was broken in Mendoza Province of Argentina for the southern-hemisphere array of the *Pierre Auger Observatory Project*, the $7.5 million U.S. share of which is jointly funded through URA by DOE and NSF. This $100 million project, under the leadership of Nobel laureate Professor James Cronin of the University of Chicago, involves scientists from some 20 countries, and will study the mysterious origins of cosmic rays of energy 10^{20} eV – 10^{8} times greater than the energy which Fermilab is capable of producing! If all goes as planned, a northern hemisphere component of the observatory will be added in Utah later in this decade.

In another look outward from our planet, Director Emeritus Peoples is now engaged at Fermilab as the new full-time Director of the Sloan Digital Sky Survey. This ambitious project brings Fermilab's advanced information technology to traditional astronomy, and will digitize and analyze all objects observable in a 25% swath of our sky, as seen by the Project's 2.5-meter telescope at Apache Point, New Mexico.

Fermilab scientific, technical, and management talent also continues to lead U.S. participation in the European Large Hadron Collider Project at CERN, where many U.S. scientists will work at the new high-energy frontier of particle physics early in the second half of this decade, participating in experiments that we hope will point the way toward a return of that frontier to the U.S. not long thereafter.

The Annual Meeting of the URA Council of Presidents (our "shareholders") was held in late January this year, with Robert Dynes, Chancellor of the University of California at San Diego, presiding and concluding his year as Chair of the Council. As always, Council business was combined with the annual Policy Forum, this year featuring addresses by Congressman James Sensenbrenner, Chair of the House Science Committee; Dr. Rita Colwell, Director of the National Science Foundation; Dr. Ernest Moniz, Undersecretary of DOE; and Dr. Hans Mark, Director of the Office of Defense Research and Engineering at DOD. Representatives from nearly 60 URA member universities braved the after-effects of a major Washington snowstorm to attend.

URA benefits greatly from the help of many distinguished individuals, who voluntarily provide leadership on our Board of Trustees, on the Fermilab Board of Overseers, and in related oversight activities. Among them, Joe B. Wyatt, for 17 years the Chancellor of Vanderbilt University, continues to serve as Chair of the URA Trustees; Robert Galvin, Chair of the Executive Committee of Motorola, continues to provide his wise counsel to URA as Vice-Chair of the Trustees; and David Shirley, Director Emeritus of the Lawrence Berkeley National Laboratory, serves as Chair of the Fermilab Board of Overseers. Dr. William Marciano of Brookhaven National Laboratory this year chaired the URA Visiting Committee annual review of Fermilab.

As new chapters in the history of URA scientific programs are written, our activities and plans remain grounded in the original URA Articles of Incorporation, key excerpts of which appear on the inside cover of this report. The extraordinary talent that assembles voluntarily from around the country and the world to constitute URA and assist in its undertakings serves to affirm the benefits that derive from this partnership between our national laboratories and our nation's research universities. The URA paradigm for university-government-laboratory partnership has by now been frequently emulated, not only in DOE's activities, but in those of other agencies as well. We look forward to another exciting year of service to our university community and to the American people, as we continue the infinite voyage of scientific discovery.

laboratory partnership

Robert Rathbun Wilson (1914-2000) Founding Fermilab Director

ROBERT WILSON, PHYSICIST, HUMAN-RIGHTS activist, writer, architect, sculptor, artist, spokesman for science, and founder of Fermilab, died January 16, 2000 at the age of 85. As an architect, he envisioned a unique and distinctive headquarters for Fermilab, inspired by the cathedral in Beauvais, France. As an artist, he had the lab buildings painted in bright, primary colors, and he established a herd of American bison at the lab, obtained from a herd in Wyoming, as a symbol of the laboratory's work at the frontiers of physics. As a human-rights activist, he drafted a policy on human rights that was posted throughout the laboratory, stating "Prejudice has no place in the pursuit of knowledge. In any conflict between technical expediency and human rights, we shall stand firmly on the side of human rights. Our support of the rights of the members of minority groups in our Laboratory, and its environs is inextricably intertwined with our goal of creating a new center of technical and scientific excellence".

Wilson at his 80th birthday celebration at Fermilab in 1994.

Robert Wilson may be best known, however, for his answer to a question asked by Senator John Pastore (D-RI) during an appearance before the Congressional Joint Committee on Atomic Energy in 1969. When asked about the value of high-energy physics research in the support of national defense, Wilson replied, "It has nothing to do directly with defending our country, except to make it worth defending".

In the 1960's, Wilson was appointed director of the new National Accelerator Laboratory. There, his concept of cascaded accelerators, moving accelerated particles from one accelerator to another at ever-increasing energies, came into fruition. Timothy Toohig, of the DOE, noted that "Bob Wilson revolutionized the whole accelerator game. Accelerators had been built by experts, in something resembling a closed craft guild. But with Bob, building accelerators became a science".

After Wilson's death, the current director of Fermilab, Michael Witherell, said "Robert Wilson gave our laboratory the distinctive character it possesses today. We inherit from him the tradition of building large and powerful accelerators that open up new ways of exploring the fundamental nature of the universe. In addition, he planned and designed Fermilab's striking physical campus, from the restored prairie to the remarkable architecture, including several of his own sculptures. *(Photographs of Dr. Wilson's sculptures at Fermilab appear throughout this Annual Report.)* He had a vision of the laboratory as a cultural, recreational and educational center for the surrounding community as well as a global research center open to the international community of scientists. He had a profound and unshakable commitment to human rights. Bob Wilson's legacy survives at Fermilab, in the surrounding community, and in the world of science."

Above text adapted from news article in the April 2000 issue of *Physics and Society*, the quarterly newsletter of the Forum on Physics and Society of the American Physical Society

Robert R. Wilson
IN MEMORIAM

Joint Resolution of the
URA Board of Trustees and the
Fermilab Board of Overseers

Robert R. Wilson was a renowned scientist, inspirational leader, innovative accelerator builder, and active humanitarian;

During his tenure as founding director of Fermi National Accelerator Laboratory, Dr. Wilson led the team that created the Laboratory and subsequently established it as one of the world's preeminent research centers;

Dr. Wilson's artistry and aesthetic sensibility are reflected in Fermilab's buildings and grounds, including the distinguished works of sculpture that he created for the Laboratory;

Dr. Wilson served with distinction as a member of the governing boards of Universities Research Association, Inc. from 1985 through 1997, thereby providing URA the benefit of his extensive experience and wise counsel;

THEREFORE, BE IT RESOLVED THAT the URA Board of Trustees and the Fermilab Board of Overseers hereby honor the memory of the late Robert R. Wilson for his dedicated leadership, bold vision, technical mastery, and artistic creativity, all of which have contributed enormously to the unique scientific and educational environment at Fermilab today.

Approved by the
Board of Trustees
April 18, 2000

Approved by the
Fermilab Board of Overseers
April 25, 2000

Robert Wilson wielding a shovel at the groundbreaking for the original Fermilab Main Ring in 1969.

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ALABAMA
University of Alabama-Tuscaloosa

ARIZONA
Arizona State University
University of Arizona

CALIFORNIA
California Institute of Technology
University of California-Berkeley
University of California-Davis
University of California-Irvine
University of California-Los Angeles
University of California-Riverside
University of California-San Diego
University of California-Santa Barbara
San Francisco State University*
Stanford University

COLORADO
University of Colorado-Boulder

CONNECTICUT
Yale University

FLORIDA
Florida State University
University of Florida

HAWAII
University of Hawaii-Manoa

ILLINOIS
University of Chicago
University of Illinois-Champaign/Urbana
Northern Illinois University*
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Iowa State University
University of Iowa

KANSAS
Kansas State University

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Michigan State University
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Wayne State University

MINNESOTA
University of Minnesota

MISSOURI
Washington University

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University of Nebraska-Lincoln

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Princeton University
Rutgers University

NEW MEXICO
New Mexico State University
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State University of New York-Stony Brook
Syracuse University

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University of North Carolina-Chapel Hill

OHIO
Case Western Reserve University
Ohio State University

OKLAHOMA
University of Oklahoma

OREGON
University of Oregon

PENNSYLVANIA
Carnegie Mellon University
Pennsylvania State University
University of Pennsylvania
University of Pittsburgh

RHODE ISLAND
Brown University

SOUTH CAROLINA
University of South Carolina

TENNESSEE
University of Tennessee-Knoxville
Vanderbilt University

TEXAS
University of Houston
University of North Texas
Prairie View A&M University*
Rice University
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Texas A&M University
Texas Tech University
University of Texas-Arlington
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UTAH
University of Utah

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Virginia Polytechnic Institute
University of Virginia
College of William and Mary

WASHINGTON
University of Washington

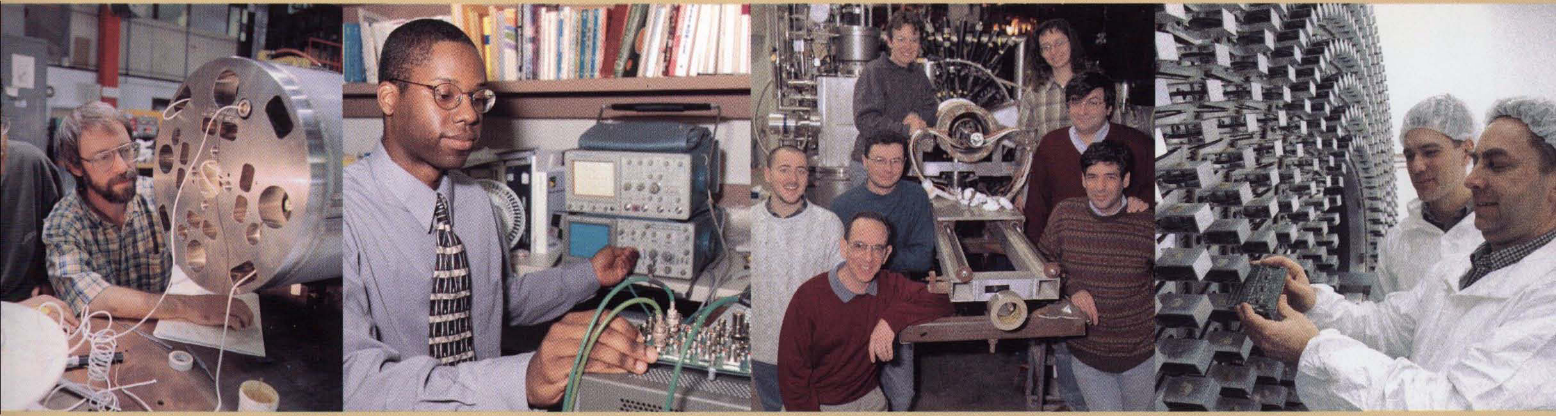
WISCONSIN
University of Wisconsin-Madison

CANADA
McGill University
University of Toronto

ITALY
University of Pisa

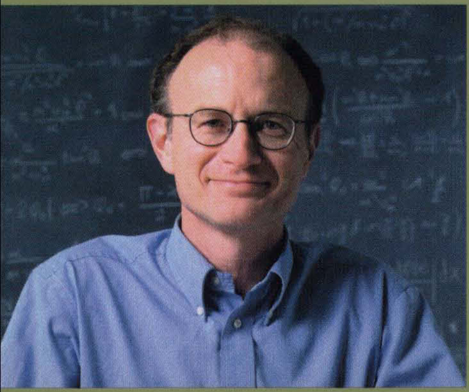
JAPAN
Waseda University

**Associate member institution*



Fermilab users from around the world work with the Laboratory's employees to advance the frontiers of particle physics.

Fermilab



Fermilab Director, Michael Witherell

FERMI NATIONAL ACCELERATOR LABORATORY, 30 miles west of Chicago, is a Department of Energy national laboratory with the primary mission of advancing the understanding of the fundamental nature of matter and energy.

Circling through rings of magnets four miles in circumference, particle beams generate experimental conditions equivalent to those that existed in the first quadrillionth of a second after the birth of the universe. This capability to recreate the energy levels of the Big Bang places Fermilab at the frontier of global particle physics research, providing leadership and resources for qualified experimenters to conduct basic research at the leading edge of high-energy physics and related disciplines. Fermilab is the home of the world's highest-energy particle accelerator, the Tevatron, which can operate as a proton-antiproton collider or as a source of high-energy beams for fixed-target experiments.

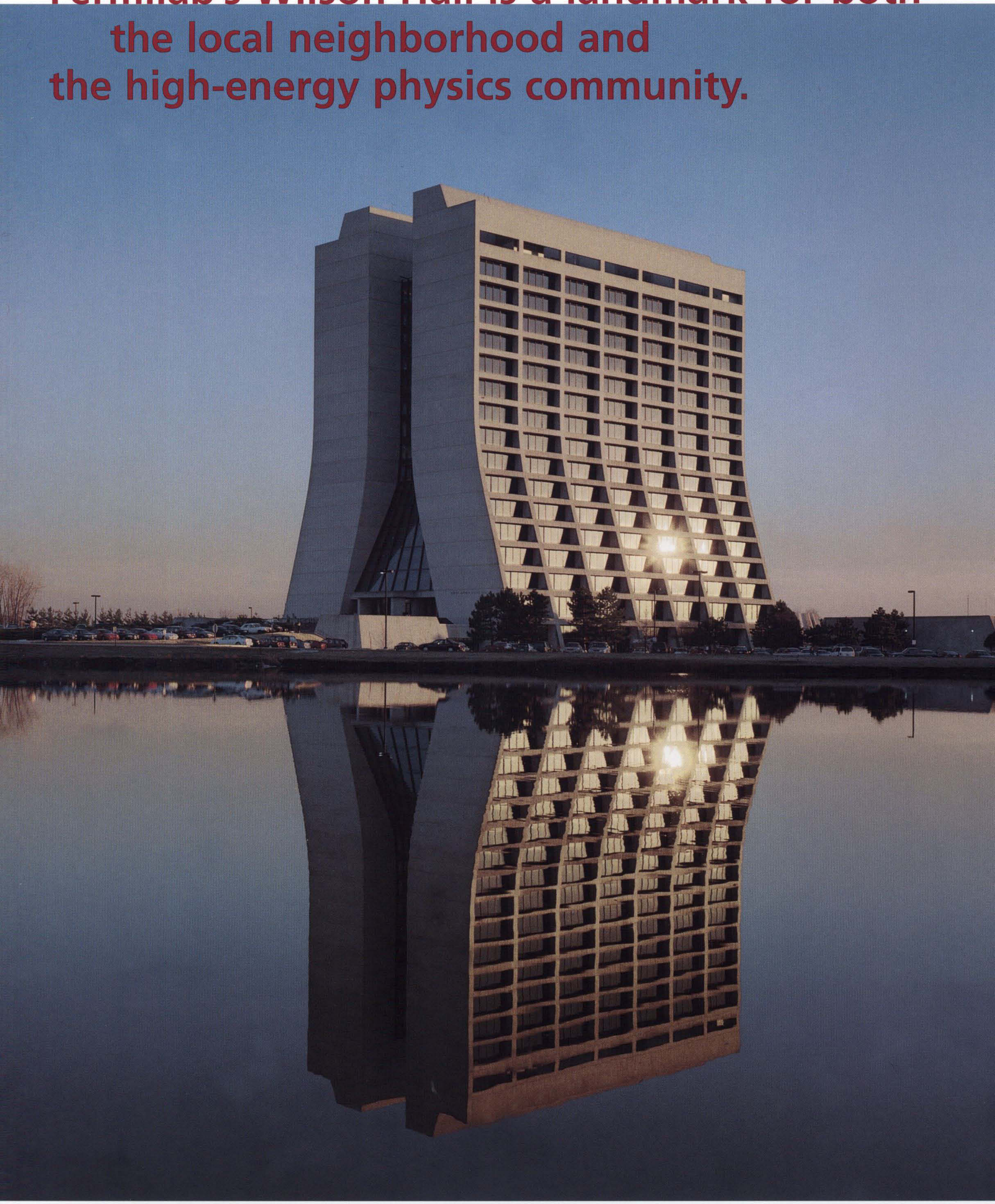
Fermilab currently provides research facilities for about 2,100 particle physicists, from 200 institutions in 34 states and 24 foreign countries. Typically, the U.S. scientists' research is supported by DOE and the National Science Foundation, and in some cases by university funds.

Fermilab began in the early 1970s with a single beam of protons directed at a fixed target and has upgraded its capabilities over the years to take successive steps into the interior of the atomic nucleus. The Laboratory's first major upgrade was the development of the Tevatron, the world's first superconducting synchrotron, with beam energies of approximately one TeV or one trillion electron volts. It operated initially in 1983, and in 1989 the National Medal of Technology was awarded to the leaders of its design and construction team. Another vital upgrade enabled the Tevatron to become a collider, accelerating antiprotons as well as protons to trillion-electron-volt energies, in beams traveling in opposite directions, to produce collisions at selected interaction regions. The first proton-antiproton collisions were achieved in 1985, and now two 5,000-ton detectors, CDF and DZero, track and record the subatomic particles that emerge from proton-antiproton collisions. The collaborations that use these detectors announced in March 1995 the discovery of the top quark, a fundamental particle with an electric charge two-thirds that of the electron, and a mass nearly equal to that of an entire atom of gold. In late 1997, the Laboratory temporarily interrupted taking data at the frontiers of particle physics in order to make major improvements to the Fermilab accelerator complex and the two major collider detectors.

This new accelerator complex got off to a great start in 1999. The last run of the Tevatron fixed-target program was completed, and it was an unqualified success. During this year, experiment collaborations continued to analyze data and uncover new scientific results from preceding collider and fixed target runs, and the Laboratory completed important accelerator-related projects to produce new physics in the next few years. R&D and planning continued on new experiments and on options for future accelerators. In addition, the Laboratory continued its collaboration in three non-accelerator projects at the forefront of research in astrophysics.

In early 2001, when Collider Run II is scheduled to begin at Fermilab, scientists from U.S. universities and others around

Fermilab's Wilson Hall is a landmark for both the local neighborhood and the high-energy physics community.



the world will resume probing the smallest dimensions that humans have ever examined. These scientists will have the world's best opportunity to make important discoveries that could answer some of today's great questions, not only in elementary particle physics, but also in the exploration of the earliest moments of the universe. For example, discovery of the Higgs boson would lead to an understanding of what determines the observed masses of elementary particles. Another example would be definitive observations in support of supersymmetry, the theory which predicts that for every fundamental particle there should exist another related and as yet undiscovered new particle, and which shows how three of the four fundamental forces in nature can be unified.

These scientists will have the world's best opportunity to make important discoveries

In 1968, the laboratory held a design competition for the Central Laboratory Building. Founding Director Robert Wilson inspired a design patterned after the Beauvais Cathedral in France. The building was finished in 1974 and named Wilson Hall.

HIGHLIGHTS OF 1999

In 1999, the various collaborations of experimenters at Fermilab produced a total of 51 new publications based on results from the 1996-97 800 GeV fixed-target run and from further analysis of data from Collider Run I. In addition, 45 Ph.D. candidates completed theses based on research at Fermilab. The CDF and DZero collaborations reported more precise measurements, both in support of leading theories and in the search for new phenomena beyond the current "standard model" of elementary particle physics. Of great interest are new results from CDF and the KTeV collaboration on the very small asymmetry in the behavior of matter in certain particle interactions, namely meson decays that violate what is called charge-parity or time reversal symmetry. This phenomenon is key to understanding how matter came to predominate in our universe, because without it, there would be no stable aggregations of matter in the form of stars, planets, and ultimately life. KTeV observed direct time reversal violation in the behavior of neutral kaons (K-mesons) and firmly established direct charge-parity violation in this system of particles; CDF reported first indications of charge-parity violation in the decay of the heavier and shorter-lived neutral B-mesons.

The Laboratory will run future fixed-target programs with 120 GeV protons from the new Main Injector. A final thirty-two week 800 GeV run with the Tevatron for two of the fixed-target experiments, KTeV and HYPERCP, was completed in January 2000. KTeV is bringing unprecedented precision to the study of matter-antimatter asymmetry in the behavior of kaons. HYPERCP has the goal of observing the direct manifestation of the forces between particles and their antiparticles. The 1999 run enabled both of these experiment collaborations to collect additional data that will tighten the precision of their important measurements. In addition, a collaboration studying the states of "charmonium" (particles composed of a charm and an anticharm quark) resumed taking data in the antiproton accumulator in early 2000. During the 1999 fixed-target run, however, most of the Laboratory's resources were concentrated on completing the Main Injector project and the upgrades of the two collider detectors, CDF and DZero, and on preparing for Run II collider physics.

antiprotons available for colliding beams. All of the accelerator improvements combined will provide a proton-antiproton collision rate ten times that of Run I, the previous collider run at Fermilab.

Secretary of Energy Bill Richardson (left) and Speaker of the U.S. House of Representatives Dennis Hastert (right) turned the keys to the Main Injector to help dedicate Fermilab's newest accelerator on June 1, 1999. Main Injector Project Manager Steve Holmes (center) looks on with approval.

MAIN INJECTOR

The Main Injector is a new 120 GeV accelerator that serves as an injector to the Tevatron and the driver for the production of the antiprotons collected by the Antiproton Source. Due to its increased beam intensity, the Main Injector will allow Fermilab to increase the rate of antiproton production. The Recycler is a storage ring that will allow the recapture of most of the antiprotons that have heretofore been thrown away at the end of each collider store, to increase further the number of

On June 1, 1999, U.S. Secretary of Energy Bill Richardson, joined by Speaker of the U.S. House of Representatives Dennis Hastert, and Illinois Governor George Ryan, presided at the dedication ceremonies at Fermilab for the $260 million Main Injector project, which was completed on time and under budget. The Main Injector then began its commissioning phase in support of the 1999 Tevatron fixed-target run. During 1999, the first phase of Recycler commissioning also moved forward.

Improvements continued in the rest of the accelerator complex, including improved performance of the Tevatron and completion of a major rebuild of the Antiproton Source. Technical modifications are being made to the Tevatron to allow 36 bunches of protons and antiprotons to collide, rather than the six bunches of the last collider run. In addition, construction work was completed for a new experimental hall at CZero. It has been proposed to use the new hall for an experiment dedicated to the physics of the B meson, including an exploration relevant to the matter-antimatter asymmetry in the universe.

CDF AND DZERO UPGRADES

Fermilab's two collider detectors have reinvented themselves for the new, higher event rate environment of Collider Run II. In late 1996, the CDF and DZero collaborations began to tear apart the detectors that observed the top quark. Now the tearing apart is done and the rebuilding nearing completion. Foremost among the challenging schedule issues has been delivery of silicon sensors and readout chips for particle tracking. In early 2001, these more sophisticated, more agile and more powerful detectors will be ready to extract from the barrage of high-energy collisions created by the Tevatron at the rate of a petabyte (10^{15} bytes) of data per year. (It would take a billion floppy disks to hold a petabyte of data.) The Run I data sample of 40 terabytes per detector will be dwarfed by this prodigious new technological challenge.

Gary Teafoe displays a component for a silicon vertex detector produced at the SIDET facility of Fermilab. Both DZero and CDF are making use of this new component.

Fermilab's two collider detectors have reinvented themselves for the new environment of Collider Run II

THE LARGE HADRON COLLIDER

As Fermilab prepares for its next collider run, the Laboratory also has a significant role in building the collider that will eventually overtake the Tevatron at the energy frontier. On December 8, 1997, U.S. Government and CERN officials signed an agreement under which the U.S. will help build a proton-proton collider, the Large Hadron Collider at CERN, the European Particle Physics Laboratory. Through DOE and NSF, the United States

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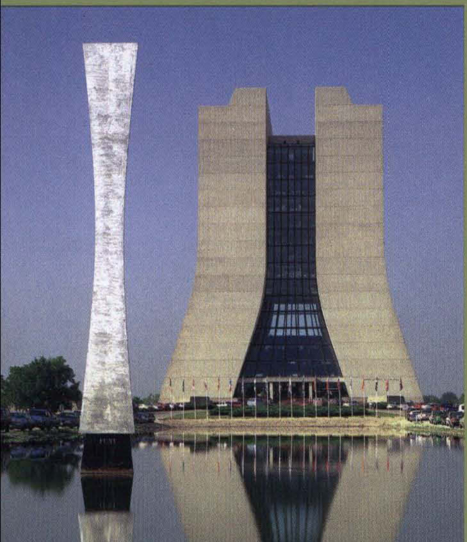
Fermilab experiments will explore the question whether neutrinos are massless, or actually have a small mass.



Robert Wilson designed the 32-foot hyperbolic obelisk in front of Wilson Hall named *Acqua Alle Funi*, or "Water to the Ropes." When an Egyptian obelisk was being erected by pulleys in the square of St. Peter's Cathedral in Rome, it threatened to topple until the order was given to pour water onto the ropes, stiffening the ropes and rescuing the effort.

is investing $531 million over eight years in the LHC and two of its associated detectors. The U.S. is one of several non-CERN-member states, including Canada, Japan, India and Russia, contributing to the LHC.

When the LHC begins operating sometime after 2005, it will reach an energy seven times the energy of Fermilab's Tevatron. The LHC will provide a unique and affordable opportunity for U.S. scientists to continue to work at the energy frontier—and it will allow Fermilab to develop the technologies for building the accelerators that will someday surpass the LHC's capabilities.

U.S. participation in the LHC has important consequences for Fermilab. The Technical Division's Jim Strait is the project manager for the U.S. contribution to the accelerator, leading a collaboration that includes Brookhaven and Lawrence Berkeley National Laboratories and Fermilab. Most of the R&D for the advanced superconducting quadrupole magnets for the LHC's interaction regions has been done at Fermilab, and most of the fabrication of these magnets is also taking place at Fermilab.

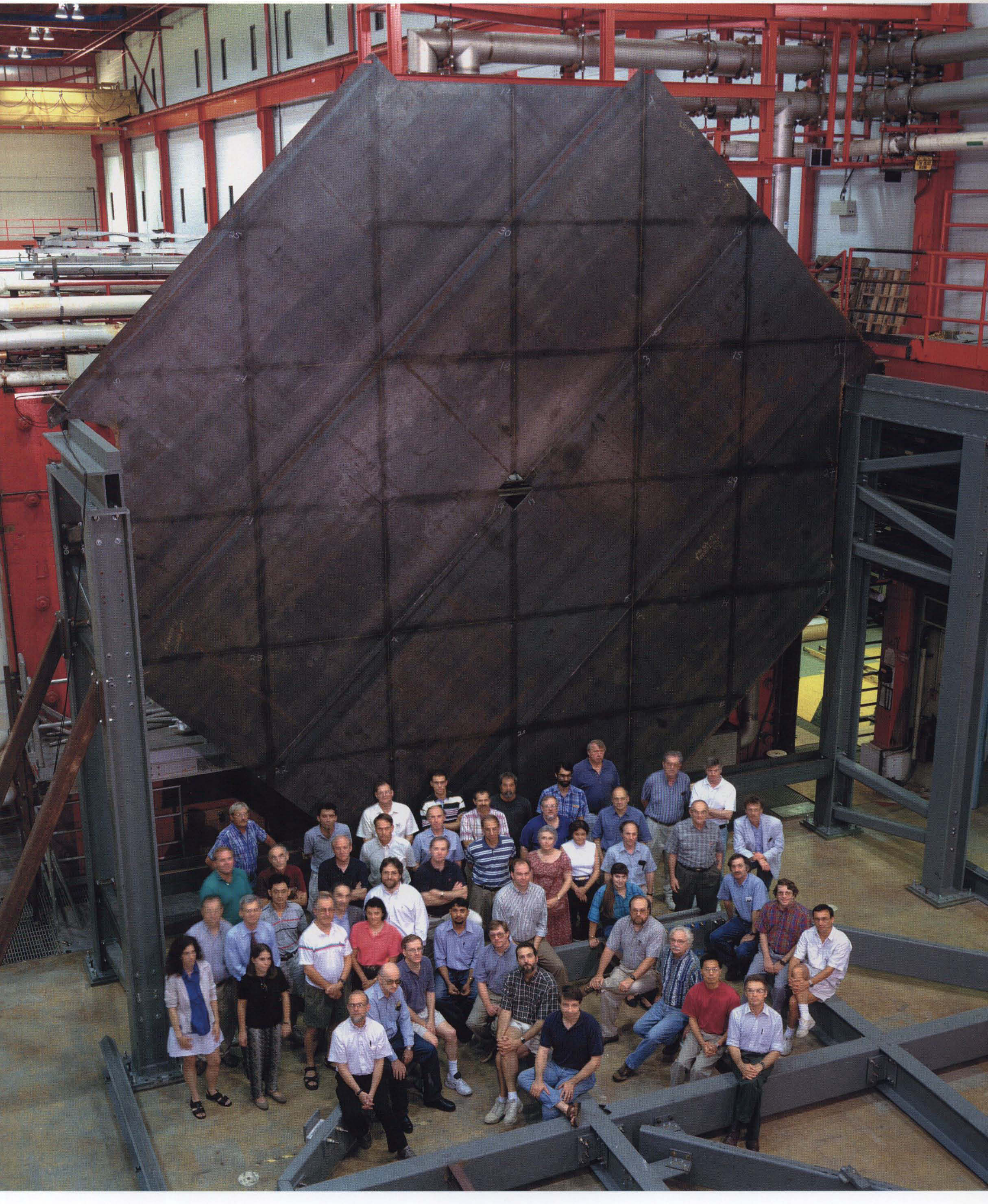
In 1997, DOE and NSF asked Fermilab to oversee project management for the U.S. contribution to the CMS detector, one of the LHC's two major detectors. Several years ago, the U.S. CMS collaboration asked Fermilab to serve both as one of its collaborating institutions and as its host laboratory, and Fermilab and URA agreed. The collaboration made excellent progress in 1999, and the U.S. CMS construction project is currently on-schedule and on-budget. Fermilab has also been chosen to be the major U.S. CMS regional computing center, one of the few such centers around the world.

NUMI AND MINIBOONE

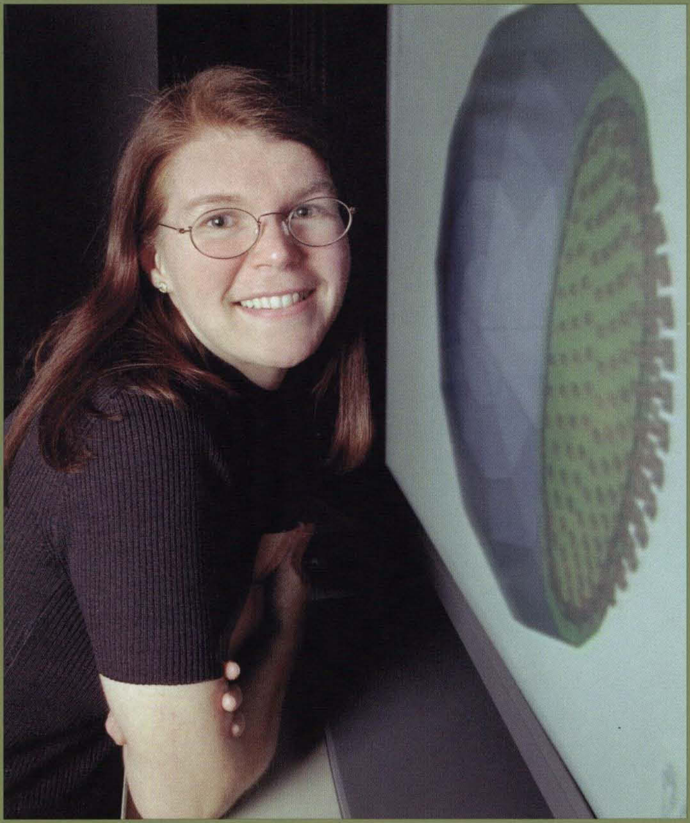
In project NuMI (Neutrinos at the Main Injector), Fermilab will provide a high-intensity neutrino beam for experiments that will explore the question of whether neutrinos are, in fact, massless or actually have a small mass. Fermilab will use the Main Injector to create a beam of muon neutrinos aimed through the earth to the MINOS experiment, a detector deep underground at the Soudan Underground Laboratory, in a former iron mine in northern Minnesota. If MINOS should reveal that some of the muon neutrinos have changed "flavor" to become tau neutrinos during their 730-kilometer journey from Fermilab to Minnesota, that change would confirm that neutrinos do indeed have mass. If they do, the implications of such a result will be profound. Design and engineering work for the beamline began in late 1997. In Fall 1998, DOE reviewed favorably the status of the NuMI project and the MINOS experiment. Civil construction activities began in 1999, both on the Fermilab site and at Soudan. The Laboratory and the MINOS collaboration expect that the experiment will begin operating in early 2003.

During 1998, Fermilab, DOE and NSF approved a separate, complementary neutrino experiment, MiniBooNE, which will use beam from Fermilab's 8 GeV Booster. The MiniBooNE collaboration will search for the flavor change of muon antineutrinos to electron antineutrinos, and will provide a definitive answer to evidence for such neutrino oscillations claimed by an experiment based at Los Alamos National Laboratory. Construction of the

The MINOS collaboration before a prototype slice of the neutrino detecto



MiniBooNE experiment began in November 1999. Civil construction for the new 8 GeV proton beam facility will begin in 2000. The Laboratory is scheduled to deliver proton beam to the experiment by late 2001.



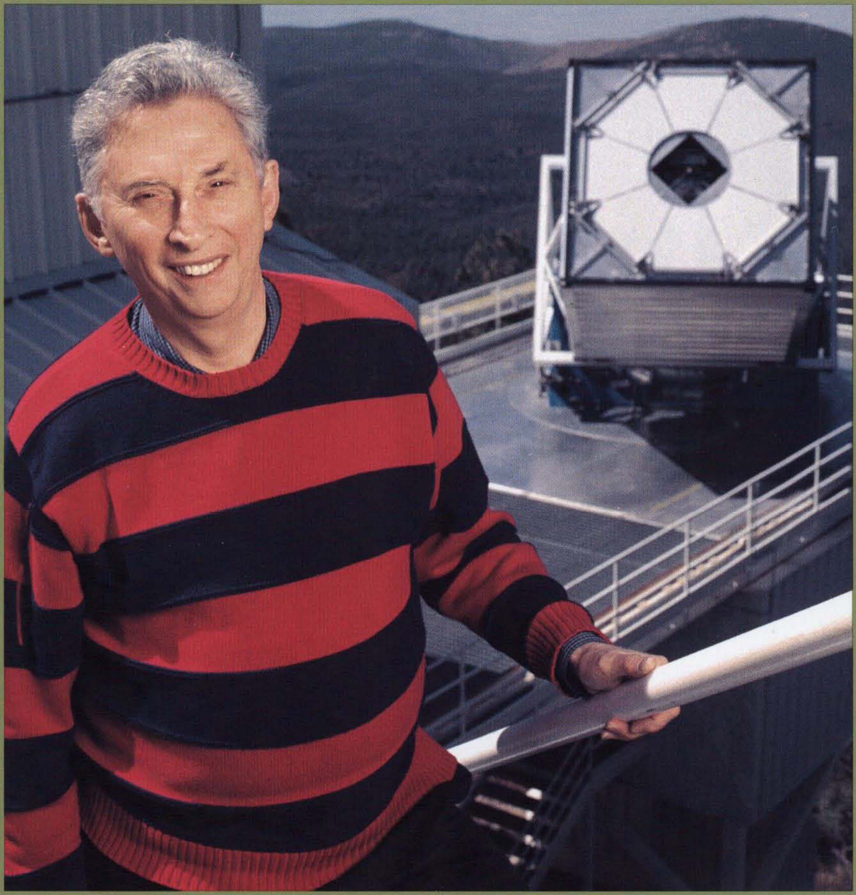
Janet Conrad, of Columbia University, co-spokesperson of the MiniBooNE collaboration, with a display of the detector for the neutrino experiment.

Fermilab is also engaged in a collaboration that aims to find out how matter,

ASTROPHYSICS

The late David Schramm helped to bring astrophysics to Fermilab. He provided the inspiration that led to the creation of the Theoretical Astrophysics group at Fermilab in 1983. Together with astrophysicists Rocky Kolb and Mike Turner, he defined its scientific focus to be the early universe, and then he gave it energy and imagination to make it successful. He urged the creation of an Experimental Astrophysics Group to complement the theoretical work. Such a group emerged at Fermilab in 1986, and is now working in close partnership with the University of Chicago's Astrophysics Department on the Sloan Digital Sky Survey. As a member of the Fermilab Board of Overseers, Dave had urged that the Laboratory's scientific program be expanded to include particle physics in the early universe, the exciting boundary between the traditional realm of particle physics and the field of astrophysics.

All of the proposals for extending the domain of validity of the Standard Model of particle interactions predict new particles. If these particles are stable, then large numbers of them will have survived the moment of creation and will still be present. Should that be the case, they could make up a significant fraction of the mass of the universe. Searches for these massive particles of "cold dark matter" are underway. Fermilab is a member of the collaboration of ten institutions in the Cryogenic Dark Matter Search (CDMS). These collaborators have developed very sensitive detectors that can detect the recoils of germanium or silicon nuclei if they collide with one of these massive particles. The CDMS collaboration has recently made public the most sensitive limits on such dark matter on the basis of the preliminary experiment at a shallow underground site on the Stanford University campus. Final approval for the full CDMS project was received in 1999. Fermilab is managing the project to build a larger and



John Peoples, Fermilab Director Emeritus and Director of the Sloan Digital Sky Survey, with the 2.5 meter telescope at Apache Point, New Mexico.

both dark and luminous, is distributed

more sensitive CDMS experiment in the same Soudan Underground Laboratory that will house the MINOS experiment.

Fermilab is also engaged in a collaboration that aims to find out how matter, both dark and luminous, is distributed. This project, the Sloan Digital Sky Survey (SDSS), will measure the location and red shift of a million galaxies and a hundred thousand quasars in the northern galactic cap. Among Fermilab's many contributions to this project is the construction of the data acquisition system and the software and hardware to process the expected 10 to 20 terabytes of data that will be accumulated during the roughly five-year span of the survey. The SDSS collaboration, comprising nine institutions, has built a 2.5 meter telescope and the associated instruments located at Apache Point, New Mexico. First light in the telescope was recorded with the telescope and imaging camera in May 1998, and additional systems were commissioned during 1999. Important scientific results have already come from the commissioning phase of the survey; seventeen new high red-shift quasars have been discovered, and one of these has the largest redshift ever observed. A new result in early 2000 is the discovery of two "methane dwarfs," objects with masses intermediate between giant planets like Jupiter and the least massive stars. Other new results include the clear detection of gravitational lensing of distant galaxy images by foreground galaxies and the discovery of the most distant quasar.

As a member of an international collaboration of 19 countries, Fermilab is also playing a major role in the Pierre Auger Observatory Project, which will explore the properties and mysterious origins of very-high-energy cosmic rays. *(See Separate Section on Pierre Auger Observatory Project.)*

As the largest U.S. laboratory for particle physics, Fermilab would provide a strong base on which to build new facilities

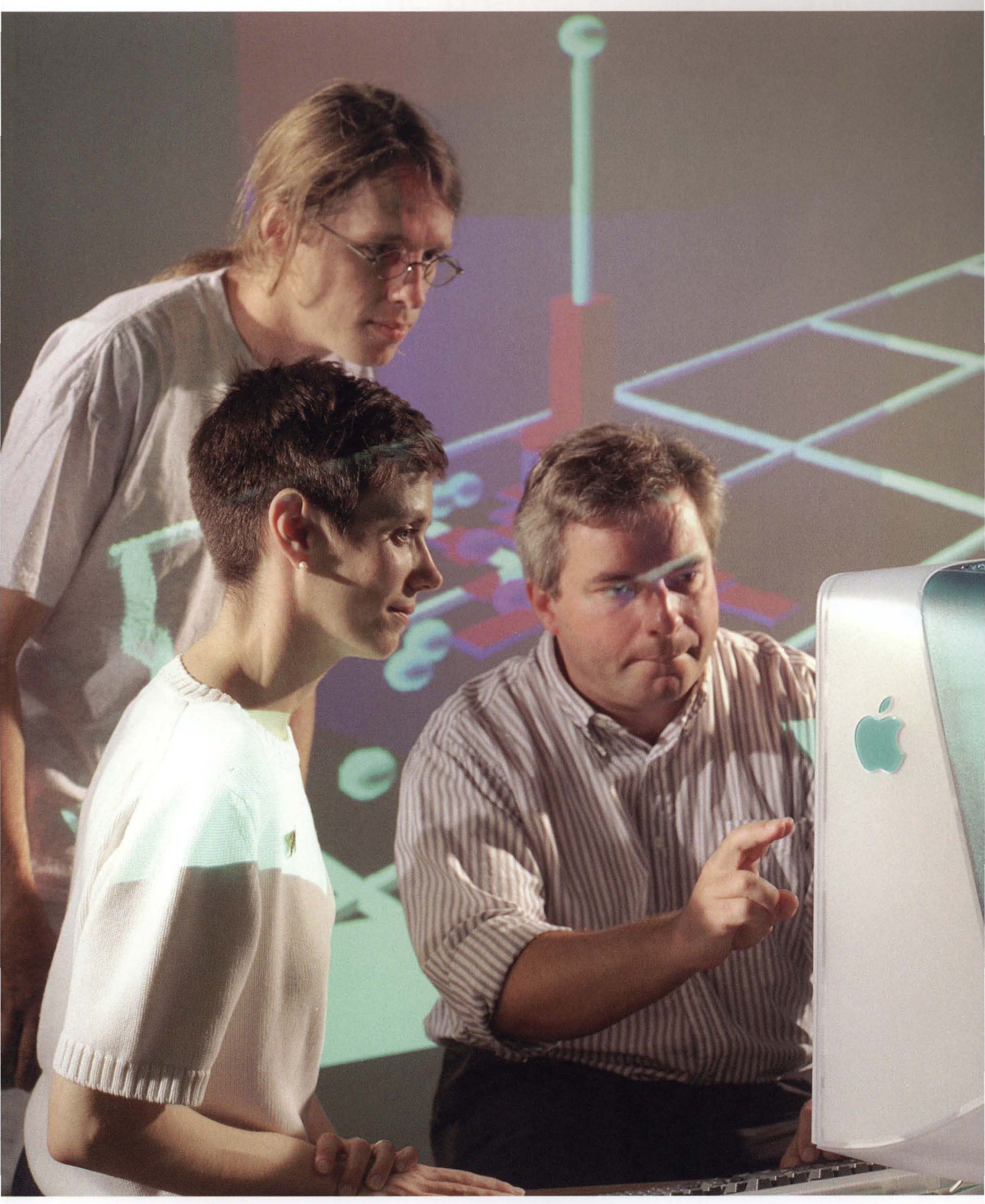
PLANS FOR THE FUTURE

While scientists await new discoveries in the upcoming Collider Run II, they must also plan how to advance the field. The stated goal of the U.S. high-energy physics community is to develop a collider that will be at the energy frontier after the LHC starts operating. Many in the community believe that Fermilab is the natural site for such a collider. As the largest U.S. laboratory for particle physics, Fermilab would provide a strong base of talent and infrastructure on which to build new facilities both on and near the present site. Future accelerator and collider concepts currently under study include a muon storage ring-based "neutrino factory," a 500-1000 GeV electron- positron linear collider, and a 100 TeV very large hadron collider.

High-energy physics has long been a leader in international scientific collaboration. Future progress will require even greater international cooperation to build accelerators and detectors to reach new energy frontiers.

The muon collider option is an interesting concept, but one that needs a long R&D effort to see if it could lead to a new instrument for exploring physics at high energies. The collaboration analyzing this option encompasses a number of laboratories and universities, with Fermilab and the Brookhaven and Lawrence Berkeley National Laboratories as lead laboratories. The collaboration has recently become convinced that a more modest neutrino facility, based on a muon storage ring, is an appropriate first step along the path to a muon collider, and the majority of the effort of the collaboration since the summer of 1999 has been refocused on a possible neutrino factory. The electron-positron linear collider option is receiving the most focused effort around the world. It is seen by its proponents as a natural complement to the LHC in exploring new physics at the Tev mass scale. The ability to build such a collider on or near the Fermilab site and the fact that decisions could be reached relatively soon have convinced the Laboratory to get involved in this effort. Fermilab has now formally joined the U.S. Next Linear Collider (NLC) collaboration. A memorandum of understanding has been signed with the Stanford Linear Accelerator Center (SLAC) outlining Fermilab's participation in the current NLC R&D program. The very large hadron collider (VLHC) option, a proton-proton collider with a center-of-mass energy of 100 TeV, would provide a "mass reach" for exploration ten times greater than that of the LHC. Fermilab's leadership in developing superconducting magnets and the unique advantages of an Illinois site for such a machine make the Laboratory a natural center for R&D toward a VLHC. Fermilab is currently pursuing R&D on two approaches to reducing the cost of a VLHC, one based on high-field (10-12 Tesla) superconducting magnets, and a second based on low-field (2 Tesla) superconducting magnets.

John Womersley makes a point while examining a data display with Amber Boehnlein (seated), of the Computing Division's Physics Analysis Tools group, and Fermilab postdoc Gustaaf Brooijmans. This display they are viewing is projected onto a screen behind them.



Volunteers at the annual Fermilab prairie harvest

SCIENCE EDUCATION

Fermilab's history of achievement in science education and teacher training programs is a tribute to physicists' love of learning and to students' responsiveness to real-world situations. Spearheaded by former Fermilab Director and Nobel laureate Leon Lederman, the education program gives special emphasis throughout to strengthening science education for under-represented groups.

The Leon M. Lederman Science Education Center, dedicated in 1992, drew attendance in 1999 of over 22,000 students and 8,500 teachers in K-12 education programs. The Center offers some 20 programs: teacher enhancement workshops and institutes, opportunities for research participation, development and distribution of instructional materials, a collection of teachers' resources, Laboratory tours, special events, class field trips, and science shows. In 1999, the Center's education webserver received over 2,000,000 hits. Currently, 75 percent of the Center's funding is provided by Fermilab, and 25 percent comes from other federal, state and private sources.

URA also provides financial support for graduate courses at Fermilab. Students must devote so much time to participating in experiments at the Laboratory that they often have difficulty taking needed classes at their home institutions.

Fermilab sponsors fellowships, participates in a Joint University-Fermilab Doctoral Program in Accelerator Physics, and, in collaboration with other laboratories and U.S. universities, helps sponsor the U.S. Particle Accelerator School. The Laboratory also supports faculty members through a guest scientist program and as visitors to the Theory Group.

ENVIRONMENTAL ACTIVITIES

In addition to research in high energy physics, Fermilab has been designated a National Environmental Research Park by DOE. The Laboratory vigilantly oversees restoration and preservation of the site's ecosystems. Over the years, the Laboratory has restored more than a thousand acres of the native tallgrass prairie that once covered the Fermilab site. The prairie is actively managed, including annual prairie burns to help maintain the system's natural cycles. In 1998, Fermilab became a member of Chicago Wilderness, a consortium of nearly one hundred public and private landholders in the Chicago area committed to careful and responsible management of the remaining habitat in the region.

Fermilab has been designated a National Environmental Research Park by the Department of Energy

In 1999, Fermilab renewed and improved its long-range land management plan for the Laboratory site, including more than 1000 acres of restored prairie. Existing tracts were enriched with a diversity of plant species and burned or mowed to discourage the intrusion of brush, trees and exotic plants. Nearly 18 acres of new prairie were created. The U.S. Army Corps of Engineers gave its final approval to the roughly ten acres of constructed wetland created as mitigation for the Main Injector project. Monitoring of this excellent example of a created wetland will continue indefinitely. Substantial achievements continue to be made in the Laboratory's groundwater monitoring program; in 1999, four new monitoring wells were installed.

Wilson Hall in the distance among prairie flowers.

Fermilab received the 1999 DOE Energy Management Award, due in part to the installation of a new efficient cooling system that is expected to cut energy consumption by 60% and eliminate the use of ozone-depleting CFC's. The Laboratory continued to seek out and implement various methods of waste minimization and pollution prevention in 1999, recycling approximately 1150 tons of scrap metal and 150 tons of other waste materials.

TECHNOLOGY TRANSFER

While Fermilab is dedicated to basic physics research, the Laboratory is eager to share its science, technology, and know-how by working cooperatively with U.S. industry to encourage economic development. Fermilab has unique capabilities in designing and operating accelerators, managing very large cryogenic systems, developing and operating fast electronics, creating hardware architectures and software for massively parallel computing systems, and operating industrial-scale applications of superconducting technology. Sometimes advances in these technologies at the Laboratory have applications beyond high-energy physics research, and Fermilab can transfer new technology to industry to foster economic development. Fermilab's Directorate-level Office of Research and Technology Applications (ORTA) facilitates the transfer of technologies developed at the Laboratory.

ACCELERATORS IN MEDICINE

Between 1976 and 1985, the National Cancer Institute funded clinical trials at Fermilab to explore the effectiveness of fast neutrons versus photon therapy in the management of radioresistant tumors. Over 2,500 patients have received treatment at Fermilab's Neutron Therapy Facility. About 25 percent of these patients reside outside Illinois, including individuals from Haiti, Greece, Pakistan, Canada, Mexico and the Philippines. Since 1995 the facility has been operated under contract with Provena Saint Joseph Hospital of Elgin, Illinois.

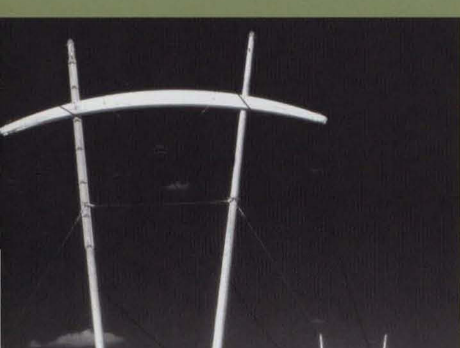
Beyond the borders of Illinois, the NTF has served as a model for more recently built neutron therapy facilities in Michigan, South Africa, and France. Fermilab also built a 250 MeV proton accelerator for the hospital of Loma Linda University Medical Center in California, which began treating patients in October, 1990.

COMMUNITY PROGRAMS

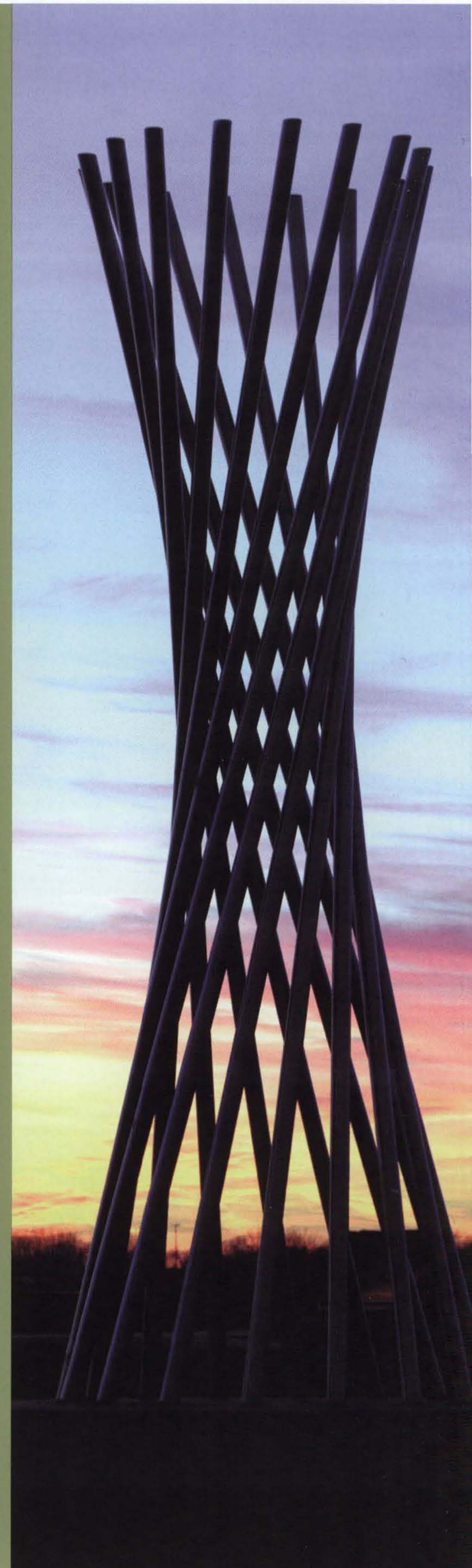
Fermilab's role as a key element of the Illinois High Technology Corridor is complemented by its sponsorship of cultural activities to which the public is invited. Laboratory staff volunteer in supporting an arts series, physics colloquia, films and an art gallery.

LABORATORY DIRECTORS

On March 5, 1999, URA announced the appointment of Michael Witherell as Fermilab's fourth director, effective July 1, 1999. Dr. Witherell succeeded John Peoples Jr., who led the Laboratory from 1989 to 1999. Dr. Peoples continues at Fermilab as a senior scientist and Director of the Sloan Digital Sky Survey. Fermilab's founding director, the late Robert R. Wilson, served from 1968 to 1978, and subsequently served as a member of URA's Fermilab Board of Overseers. Dr. Wilson provided continuing guidance for the aesthetics of buildings and grounds, including sculpture that he created. *(See career profile for Dr. Wilson on page 4.)* Leon M. Lederman, a 1988 Nobel laureate, directed the Laboratory from 1979 to 1989 and is a member of the URA Board of Trustees. His contributions to science education are known worldwide.

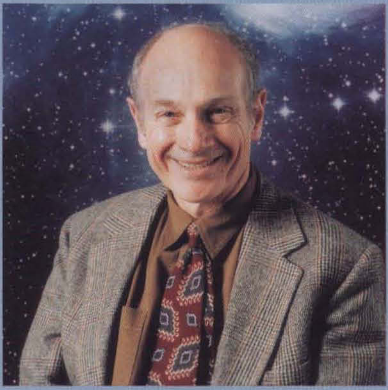


It took a lot of persuading, but Wilson ultimately convinced Commonwealth Edison to construct power poles to his own design specification based on the Greek letter "pi."



Tractricious, 36 feet high, was designed by Wilson with structural design accomplished by Tome Nicol. Each stainless steel outer tube weighs 550 pounds, and the structure can withstand 80-mph winds.

Pierre Auger Observatory Project



James W. Cronin, of the University of Chicago, Nobel laureate and co-leader of the Pierre Auger Observatory Project

Dr. Cronin received the 1999 National Medal of Science for "fundamental contributions to the fields of elementary particle physics and astrophysics and for leading an international effort [Pierre Auger Observatory Project] to determine the unknown origins of very-high-energy cosmic rays." From left to right in this photo, he appears with three of the eleven other 1999 Medal recipients and President Clinton at the White House award ceremony.

COSMIC RAYS ARE FAST-MOVING PARTICLES from space that constantly bombard the earth from all directions. Most of the particles are either electrons or the nuclei of atoms. Of the nuclei, the majority are single protons—the nuclei of hydrogen atoms—but a few are much heavier, ranging up to the nuclei of lead atoms. Cosmic ray particles travel at nearly the speed of light, which means they have very high energy. Some of them, in fact, are the most energetic particles ever observed in nature. To discover the source of cosmic ray particles, scientists measure their energy and their direction as they arrive from space. To measure cosmic ray particles directly requires sending detectors to heights above most of the earth's atmosphere, using high-flying balloons and satellites. However, scientists can also detect cosmic rays indirectly on the surface of the earth by observing the showers of particles they produce in the air, as discovered by French physicist Pierre Auger about 60 years ago.

The Pierre Auger Observatory Project is a broad-based international effort to make a detailed study of the highest energy cosmic rays (about 10^{20} eV, or 100 million times greater than the energy of the protons accelerated by Fermilab's Tevatron). The Project's co-leaders are Dr. James W. Cronin, Professor of Physics, University of Chicago and Dr. Alan A. Watson, Professor of Physics, University of Leeds in the United Kingdom. Thus far, the Pierre Auger collaboration includes over 250 scientists from Argentina, Armenia, Australia, Bolivia, Brazil, China, France, Germany, Greece, Japan, Italy, Mexico, Poland, Russia, Slovenia, United Kingdom, USA and Vietnam. The U.S. collaboration comprises nine universities plus Fermilab, home of the project manager, Dr. Paul Mantsch.

Because the highest-energy cosmic rays are so rare, scientists must cast a huge net to capture even a few. The Pierre Auger Observatory would consist of two giant arrays, each consisting of 1600 particle detector stations spaced 1.5 kilometers apart and covering about 3000 square kilometers, an area about the size of the state of Rhode Island. In order to get a complete view of the heavens as seen from the earth, one array would be located in the northern hemisphere and one in the southern hemisphere. In November 1995, the collaboration selected a site in the Province of Mendoza, Argentina for the southern hemisphere array, and in September 1996 a site in Millard County, Utah for the northern hemisphere array. The total project cost is approximately $100 million.

In a grant to URA on behalf of the U.S. Project participants under Dr. Cronin's leadership, the National Science Foundation and the Department of Energy are providing $7.5 million over four years toward the U.S. share for the construction of the southern hemisphere site. This is planned to be followed by construction of the northern hemisphere site.

URA serves as the sponsoring organization for the U.S. participants, and as such oversees those activities currently funded by the U.S., such as component R&D and production. In the future, URA would have a similar role for the Utah site. In addition, DOE and NSF have designated URA to be the agent representing the U.S. on the Project's international oversight board.

In order to get a complete view of the heavens as seen from the earth, one array would be located in the northern hemisphere and one in the southern hemisphere

In March 1999, an international agreement was signed in Argentina for the organization, management and funding of the Pierre Auger Observatory, and the southern hemisphere site was inaugurated at Malargue in Mendoza Province. During 1999, architectural designs were completed and approved for the buildings at the Central Campus in Malargue and for the first fluorescence detector building. In early 2000, construction was initiated for the "Engineering Array," which will consist of forty surface detector stations and a fluorescence detector telescope unit. Once experience has been gained with the engineering array, construction of the entire southern hemisphere array will begin.

Ten members of the international Pierre Auger collaboration with the first detector station of the Engineering Array, at the southern hemisphere site in Argentina.

Future URA Enterprises

URA has a broad charter for the management of research and educational activities in the natural sciences. The Corporation has been engaged in long-range planning to explore potential new management responsibilities that would be of value to the university research community. As part of this planning, URA has been considering bids on management contracts for selected national research centers and facilities that serve a broad base of national and international users.

mbers of the Fermilab
rre Auger team with a
totype particle detector
ion being tested at Fermilab.

History 1965 - 1999

Fermilab's first three Directors together at the opening ceremony for the Lederman Science Education Center building in 1992 (from right to left) Robert R. Wilson, 1968-1978; Leon M. Lederman, 1979-1989; John Peoples, Jr., 1989-1999.

THE CREATION OF URA MARKED A MILESTONE in government-university cooperation for the management of federal laboratories. Until 1965, individual universities and regional consortia had built and operated facilities under federal sponsorship. It was the unique character of particle physics research—which often involved collaborations among scientists from many institutions—that created the need to establish a truly national management organization. The federal government consulted with the National Academy of Sciences on how to accomplish this goal. The President of the Academy then convened the presidents of the U.S. universities engaged in particle physics, to consider management options for national facilities. Following that meeting, 25 attendees agreed to form a consortium leading to the incorporation of URA.

This concept of fully national, and now increasingly international, cooperative efforts between the federal government and research universities was developed to address the needs of many fields of science. Since 1967 URA has been contractor to the Department of Energy and its predecessor agencies for the design, construction, management, and operation of Fermilab. URA's success in building and operating Fermilab led to its selection as contractor for the nation's next major particle accelerator, the SSC. After the project was canceled in 1993, URA managers and staff assisted with the termination activities, which were essentially concluded by the end of 1996.

Currently, the Fermilab program and its associated scientific and technological enterprises, and U.S. participation in the Pierre Auger Observatory Project represent the core of URA's mission. As appropriate opportunities arise, the corporation will consider submitting proposals to the federal government, or elsewhere, for the management and operation of other facilities and programs in science and engineering.

The creation of URA marked a milestone in government-university cooperation for the management of federal laboratories.

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1999-2000 Fermilab Board of Overseers

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5	Alexander Abashian, Professor Virginia Polytechnic Institute	2001
6	Donald Hartill, Professor Cornell University	2001
7	Jerome Friedman, Professor Massachusetts Institute of Technology	2002

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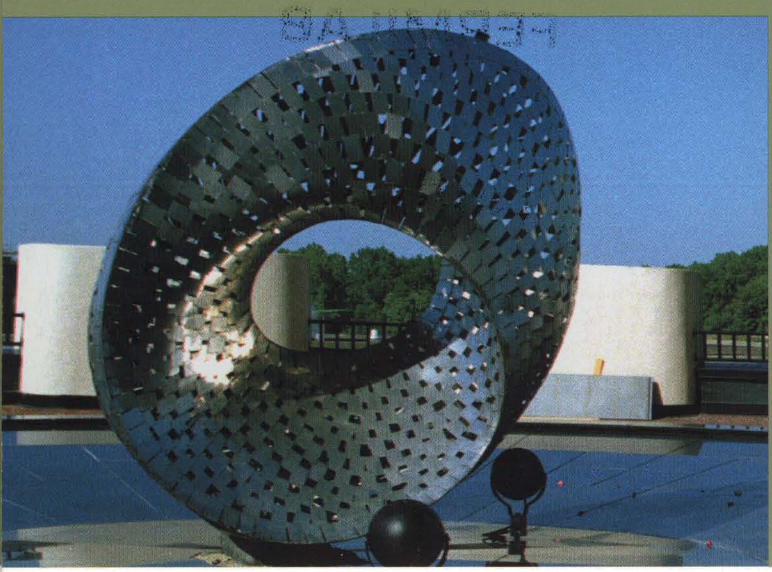

Robert Wilson did the welding himself for *Mobius Strip*, mounted atop Ramsey Auditorium. Wilson welded 3″x 5″ pieces of stainless steel to a tubular form eight feet in diameter.

Finances

UNIVERSITIES RESEARCH ASSOCIATION, INC.
OPERATING STATEMENT
YEAR ENDED SEPTEMBER 30, 1999

Total Revenue	**$ 296,988,832**
EXPENSES:	
Salaries, wages and benefits	$ 137,052,163
Subcontracts and other purchased services	33,742,893
Materials and supplies	29,398,030
Travel, relocation and other employee allowances	7,151,575
Electric power	13,099,067
Inventory usage	4,570,442
Fermi National Accelerator Laboratory support	522,287
Scholarships	125,500
Other	780,334
Total Operating Expenses	**$ 226,442,291**
Cost of property, plant and equipment constructed for DOE	**$ 70,189,281**
Total Expenses	**$ 296,631,572**

The Fermilab logo, designed by Robert Wilson and his colleagues, is symbolic of the combined beam aperture configurations produced by the dipole and quadrupole magnets used in particle accelerators. The logo appears here in an aerial view of the shrubbery in front of Wilson Hall.

Photo Credits:
Fred Ullrich and Reidar Hahn
Fermilab Visual Media Services

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