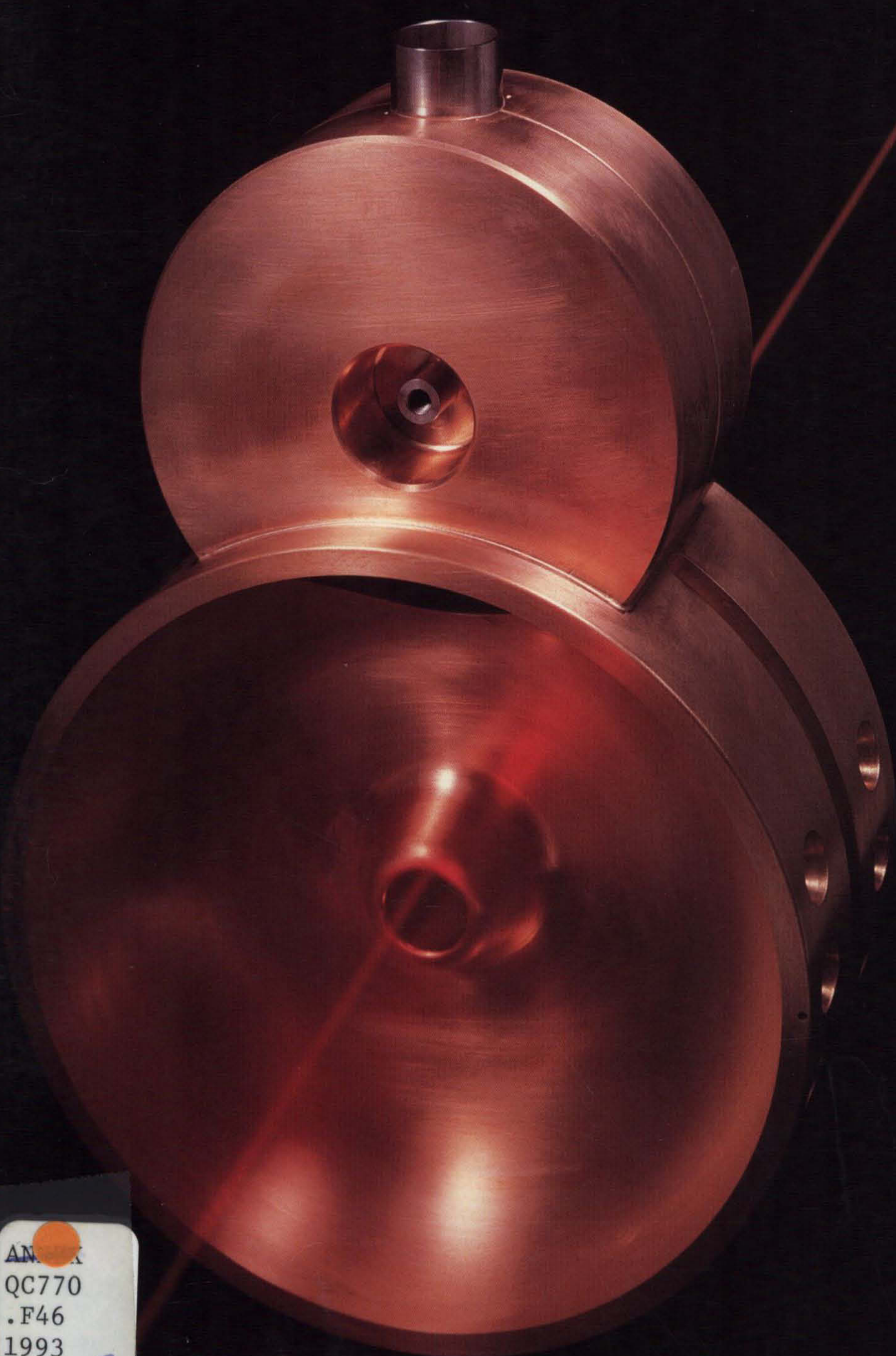
FERMILAB



1993 ANNUAL REPORT

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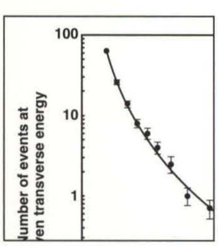
(Front cover)
One of the side-coupled cavities that enabled the doubling of the Linac's energy.

(Back cover)
Drift tubes in the original Fermilab Linac.



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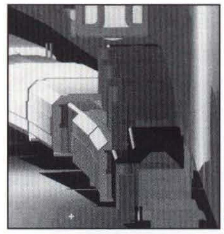
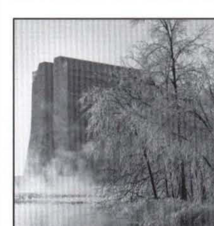




FROM THE DIRECTOR

We seldom recognize the end of an era when we see it. Only later do we look back and say, "Yes, it was then, or then — that was the moment when everything changed." While it is happening, we fail to notice the ground shifting beneath our feet. There are occasional exceptions. On the July morning in 1945 when Los Alamos scientists watched the first atomic explosion in the New Mexican desert, they knew for certain that what they were seeing had changed the world. Likewise this year, when news came from Washington on October 19 that the United States House of Representatives had voted to cut off the funds to build the Superconducting Super Collider, there was no mistaking the moment. For the world of high-energy physics, at least, it was the end of an era.

For us at Fermilab, the effects of the SSC's abrupt end could scarcely be greater. Fermilab had begun to prepare for the day when we would hand over to the SSC our role as the leading U.S. particle physics laboratory, the laboratory at the energy frontier. Like physicists all over the world, we had looked to the SSC as an essential ingredient in the future of our field, the way forward toward the goal of understanding what still eludes us about the nature of matter and energy. Now, suddenly, we must map for ourselves an utterly different future. 1993 was quite a year for high-energy physics.

MUCH TO BE PROUD OF, MUCH TO LOOK FORWARD TO

1993 was quite a year for Fermilab as well, and in most ways a very successful one. As you will read in the pages of this report, Collider Run Ia brought great achievements. The Tevatron met all our performance goals, and more. By the time the run ended on June 1, the Tevatron had delivered to our detectors three times the integrated luminosity of the previous collider run. The Accelerator Division coaxed a peak luminosity of $9.2 \times 10^{30}cm^{-2}sec^{-1}$ from the Tevatron. The accelerator and the detectors functioned beautifully, and Fermilab computing resources met the enormous demands of managing the data the detectors delivered. We did not discover the top quark in 1993, but we gained on it. Both CDF and DØ searched for top and improved the lower limit on its mass. By measuring the lifetime of *B* mesons and observing the B_s into J/ψ plus ϕ decay, CDF also showed the value of an important new tool for top and bottom physics, the silicon vertex detector at the Tevatron collider. DØ showed that it is possible to obtain important physics results with a brand-new detector in its very first run.

We used the summer months of shutdown to improve the Tevatron still more for Run Ib in 1994. As 1993 ended, we were deep in the exciting endeavor of bringing the world's highest-energy collider back up to speed, to do the physics it was born to do — better than ever before. In the upgraded Tevatron we have an extraordinary tool for discovery, and in Fermilab a remarkable laboratory. We have much to be proud of, and much to look forward to.

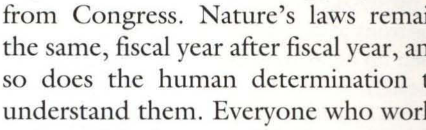
PREDICTING THE FUTURE

When people ask me, as they often do, what the future holds for high-energy physics, I think of the Pogo comic-strip character Fenster Moop, who pointed out 30 years ago that predicting the future is risky because it hasn't happened yet. Instead, he stuck to predicting the past, because "You gotta admit I is safe that way...." To put my own predictive ability in perspective, a year ago I would have told you that in the year 2003 the SSC would be nearing completion in Texas. I would have told you how important the SSC would be to the future of high-energy physics and about the role that the SSC would play in the future of Fermilab. Jeanne Dixon I'm not.

Nevertheless, I do know that Fermilab has a busy decade ahead. We have a Main Injector to build, a quark to find and measure, and much more fixed-target and collider physics to do, in experiments that no other facility can duplicate. We have contributions to make in the converging fields of astrophysics, cosmology and particle physics. We have work to do in accelerator physics, detec tor development and high-performanc computing, to raise the sights and brin down the cost of the physics of th future. And, most important, at least fo the next decade, Fermilab remains th world's outpost on the energy frontier We have great potential over the next 1(years — potential for discovery and fo building the foundations of th strengthened international col laboration that will surely char acterize the great particle accel erators of the future.

THE FUNDAMENTAL THINGS APPLY

At Fermilab, we are what people mear when they talk about Big Science Because of the scale of our researcl tools, we must look to government for the wherewithal to continue our mission. Events this year have reminded us how risky it is to predict the future in these circumstances, and how quickly and profoundly things can change. Intimately bound up as we necessarily are in Washington budget cycles and political decision-making, such concerns sometime threaten to overshadow the science, and the benefits of science for humanity, that are the reason for it all. But, fortunately, nature doesn't depend on an annual appropriation from Congress. Nature's laws remain the same, fiscal year after fiscal year, and so does the human determination to understand them. Everyone who works at Fermilab, in every job, has a part in carrying on the historic effort to explore the fundamental nature of matter. As one era ends and a new one begins, the Fermilab community, employees and users, will continue to contribute most effectively to the understanding of nature's laws and to the Department of Energy's mission of service to the nation by doing what we have done so well together for the past 25 years — particle physics research at the highest possible level. ■



Director John Peoples ascends the stairs to his second-floor office in Wilson Hall.

Throughout the ages, scientists have made tools that allow us to perceive and understand things that are otherwise beyond our reach. With particle accelerators, the world's largest tools, physicists have extended our vision to the world of the very small, studying the basic structure of matter. Using these tools, particle physicists identify the most elementary objects from which all matter is made and determine the rules that govern the way these basic particles combine to form the universe that we know.

FERMILAB: A UNIQUE SCIENTIFIC RESOURCE

Dedicated to revealing the mysterious and beautiful laws of the universe at their most fundamental level, Fermi National Accelerator Laboratory has been an international scientific resource and a source of great national pride for a quarter of a century. Our accelerator complex enables searches for particles that could not be undertaken any where else in the world and draws researchers from over 100 institutions in the United States and 22 foreign countries. Universities Research Association, Inc., a consortium of 80 universities, manages Fermilab for the U.S. Department of Energy.

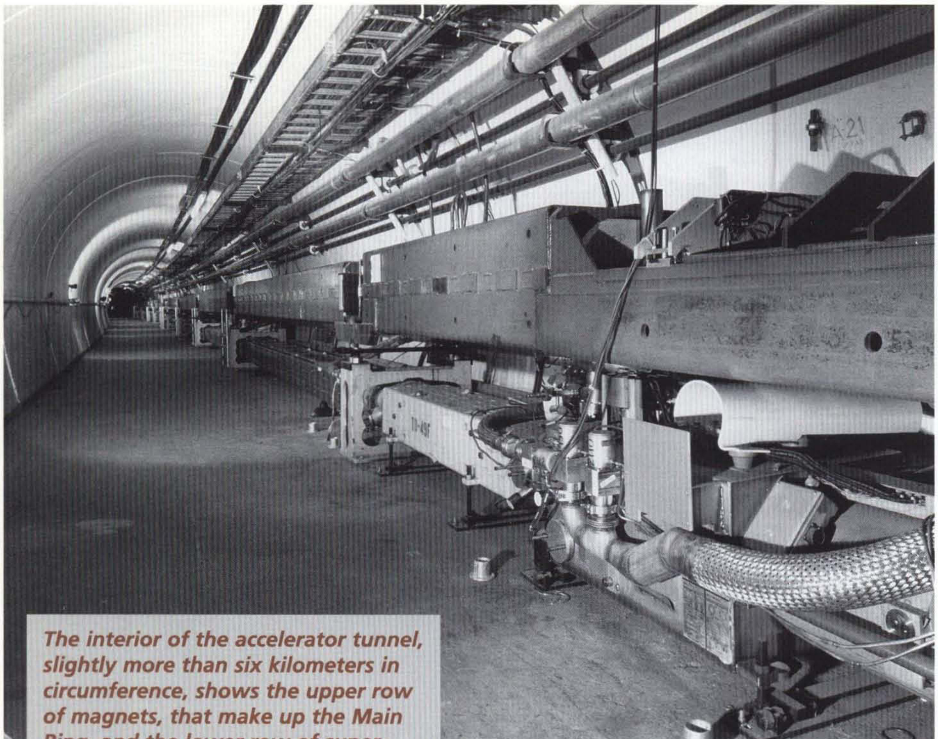
TOOLS TO SEE INSIDE THE ATOM

With magnifying glasses and microscopes we view objects smaller than we can see with the naked eye. Using an optical microscope that magnifies an object about 200 times, we can see red blood cells that are just 0.003 inches across. To see individual strands of DNA, objects that are a few millionths of an inch long, we need a more complex tool — an electron microscope.

With particle accelerators we can proceed to the next level of the microscopic world. All matter is made up of atoms. Each atom, in turn, is made up of a nucleus of protons and neutrons and a surrounding cloud of electrons. An atom is a few billionths of an inch across. A proton is about 100,000 times smaller than that. Particle accelerators let physicists "see" inside atoms, inside the nucleus at the heart of an atom, and inside the protons and neutrons that make up the nucleus.

Generally, the higher the energy of the collisions, the more intimately we can probe the particles and the more interesting and varied are the emerging debris. Furthermore, the highest energy collisions often create totally new particles with properties that are very distinct from those of the original particles. This amazing possibility is stated in Einstein's famous formula, $E = mc^2$, which says that energy can be converted into matter and vice versa.

An aerial view of Fermi National Accelerator Laboratory shows the current accelerator ring and the outline for the Main Injector, now under construction, in the foreground.



The interior of the accelerator tunnel, slightly more than six kilometers in circumference, shows the upper row of magnets, that make up the Main Ring, and the lower row of superconducting Tevatron magnets.

In fact, the very concept of "seeing" changes as we investigate on this minute scale and physicists must figure out size, shape and other characteristics indirectly. Teams of collaborators from many institutions throughout the world have designed and built enormous, complicated detectors to "see" and study the particles emerging from the high-energy collisions. In addition, sophisticated number-crunching computers decipher the enormous quantity of information that is recorded.

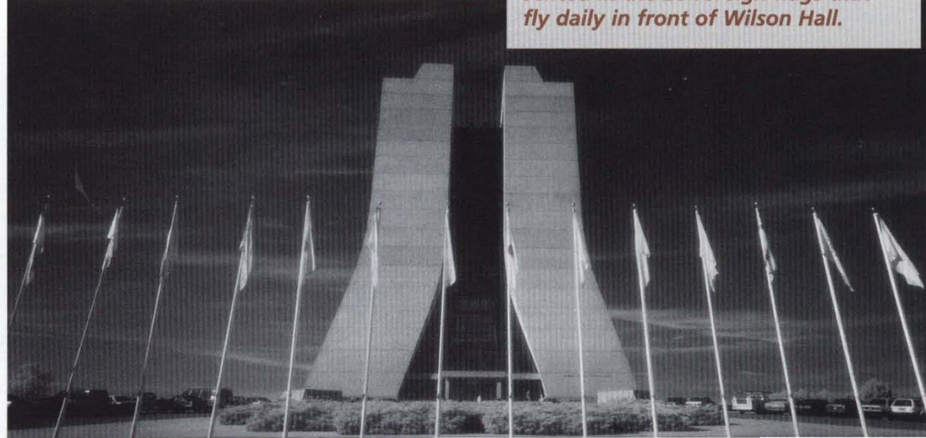
THE FERMILAB ACCELERATOR COMPLEX

Inside a particle accelerator, electrical fields push subatomic particles until they move close to the speed of light. Fermilab accelerates particles in several stages: Source, Linac, Booster, Main Ring and Tevatron. In the higher energy stages, magnetic fields guide the particles in a circular path; they receive an accelerating kick each time they complete a turn. The strength of the guiding magnets dictates the size of the ring. The centerpiece of Fermilab is the Tevatron, a one-kilometer-radius ring in which protons are accelerated to the unprecedented energy of nearly a trillion electron volts. At Fermilab, we can either direct the protons into stationary targets of various materials or bring them into head-on collision with bunches of antiprotons, their antimatter counterparts, which are accelerated in the opposite direction.

BUILDING BLOCKS OF THE UNIVERSE: THE STANDARD MODEL

Decades of painstaking experiments and theoretical insights have led to a surprisingly simple picture of the world of elementary particles and the laws they obey. According to this theory, known as the Standard Model, the most fundamental particles fall into three categories: gauge bosons, leptons and quarks. The gauge bosons give rise to the strong, weak and electromagnetic forces that govern the behavior of quarks and leptons. Leptons comprise the electrically charged electron; two unstable particles that are similar to electrons, but much heavier; and particles known as neutrinos, which have no charge. The Standard Model indicates that a total of six different types of quarks should exist. Ordinary up and down quarks are found in protons and neutrons. The remaining four, whimsically called "strange," "charm," "bottom" and "top," can only be created in high-energy collisions. To date, five of the six types have been found. Only the top quark — quite massive compared to the others — remains to be discovered experimentally.

The accelerator complex, the detectors, and the computers are all tools that help Fermilab to search for the top quark — and other rare phenomena — in order to improve our understanding of the fundamental features of basic matter. ■



Physicists come from all over the United States and the world to conduct their research at Fermilab. Their countries of origin are represented in the 20 foreign flags that fly daily in front of Wilson Hall.

LINAC UPGRADE: A SUCCESS STORY

Fermilab's venerable linear accelerator now operates at twice its original design energy. How did this happen?

The Linac Upgrade Project is a major element in the Fermilab program to improve collider luminosity by increasing beam intensity. By increasing the Booster intensity, more intensity could be injected into the Main Ring. Space charge effects seen by the beam at the time of injection from the Linac limit the Booster beam intensity. An effective way to reduce these effects is to inject with a higher energy beam. The Linac Upgrade has increased the final Linac energy from 200 MeV to 400 MeV. This should result in an approximately 75% improvement in the Booster intensity.

The old 200-MeV Linac was a nine-tank Alvarez drift-tube Linac (DTL) operated at 201.25 MHz. The drift-tube Linac is an efficient accelerator for particle velocities less than 40% the speed of light (100 MeV protons). In the Linac Upgrade the last four downstream tanks were replaced with a more efficient, higher-gradient accelerating structure. This new structure, an 805 MHz side-coupled Linac, accelerates the beam from 116 MeV (at the exit of DTL Tank 5) to 400 MeV within the same physical length as the four DTL tanks that were replaced. The average accelerating gradient in the new Linac structure is about 7.5 megavolts/meter, or three times the gradient in the old DTL.

During 1993 the final installation and beam commissioning of the 400-MeV Linac occurred. Although most of the Linac Upgrade construction was completed in 1992, final installation had to be scheduled according to the Laboratory operating schedule since the Linac is used nearly continuously. The following paragraphs chronicle some of the highlights of the intense and exciting work that took place during the summer of 1993.

Planning and preparations for the installation had begun in October 1992. Final installation began on June 1, 1993. Based on available supervisory and technician staff, a 12-week installation schedule was planned without contingency as stipulated by Laboratory management. The goal was to have the new Linac ready for beam commissioning before September 1. In fact the Linac was ready four days ahead of schedule!

Installation involved approximately 30 technicians and support personnel, 15 engineers and physicists, 16 construction trades personnel: riggers, electricians, pipe fitters and laborers. Machining of various components was done by personnel in the Fermilab machine shops.

The last four DTL tanks, the 200-MeV diagnostic area and most of the old 200-MeV Transfer Line to the Booster, a total of 140 meters of accelerator and beamlines, were disassembled in the first 10 days. The new 805-MHz side-coupled Linac, which had been installed alongside the old Linac in March 1992 and tested at full power, was then moved transversely onto the beamline. The long process of alignment, utility connection, vacuum, waveguide and diagnostic cable installation began immediately and continued through August.

In early July, more effort was shifted to the 400-MeV Transfer Line. Major components consisted of a new electrostatic chopper, Lambertson magnet, a spectrometer magnet in the Diagnostic Area, five dipoles, 17 quadrupoles, an 805-MHz debuncher and the Booster Injection Girder with its septum magnet and four orbit adjusting magnets. By the end of July, all major components of the Transfer Line were installed, and utility and cable connections were well under way.

All rf waveguides, water cooling and vacuum systems had been connected to the new Linac by early August. The Linac enclosure was secured each night, and the rf systems and accelerator modules were powered to begin troubleshooting and fine adjustment of waveguide lengths. The major complication during this period was the shortage of transformers for the 24-MW modulators that power the main rf klystrons. These large, oil-filled transformers were being rebuilt by the vendor in California after it was discovered that they were suffering from an internal electrical discharge. The vendor had fallen behind in the repair schedule, but Accelerator Division personnel orga-

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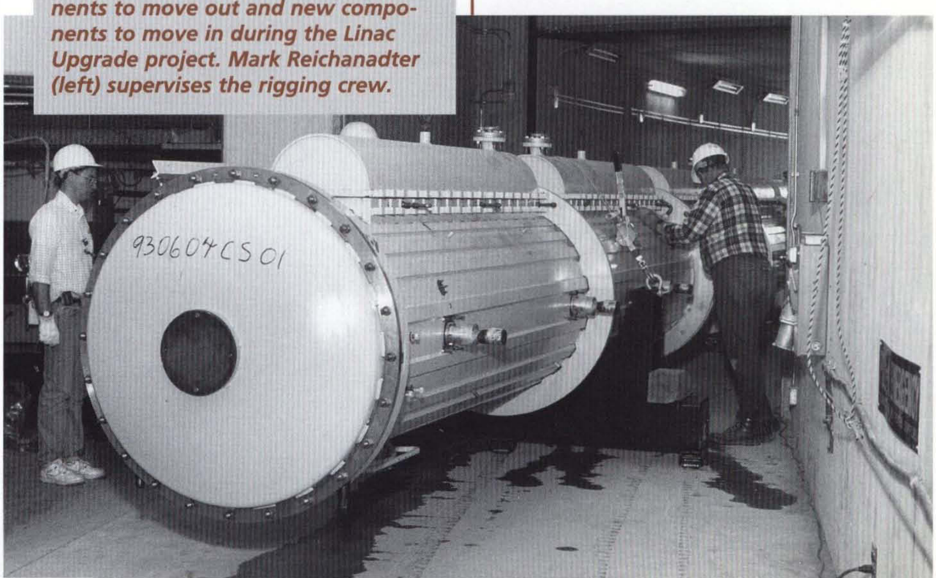
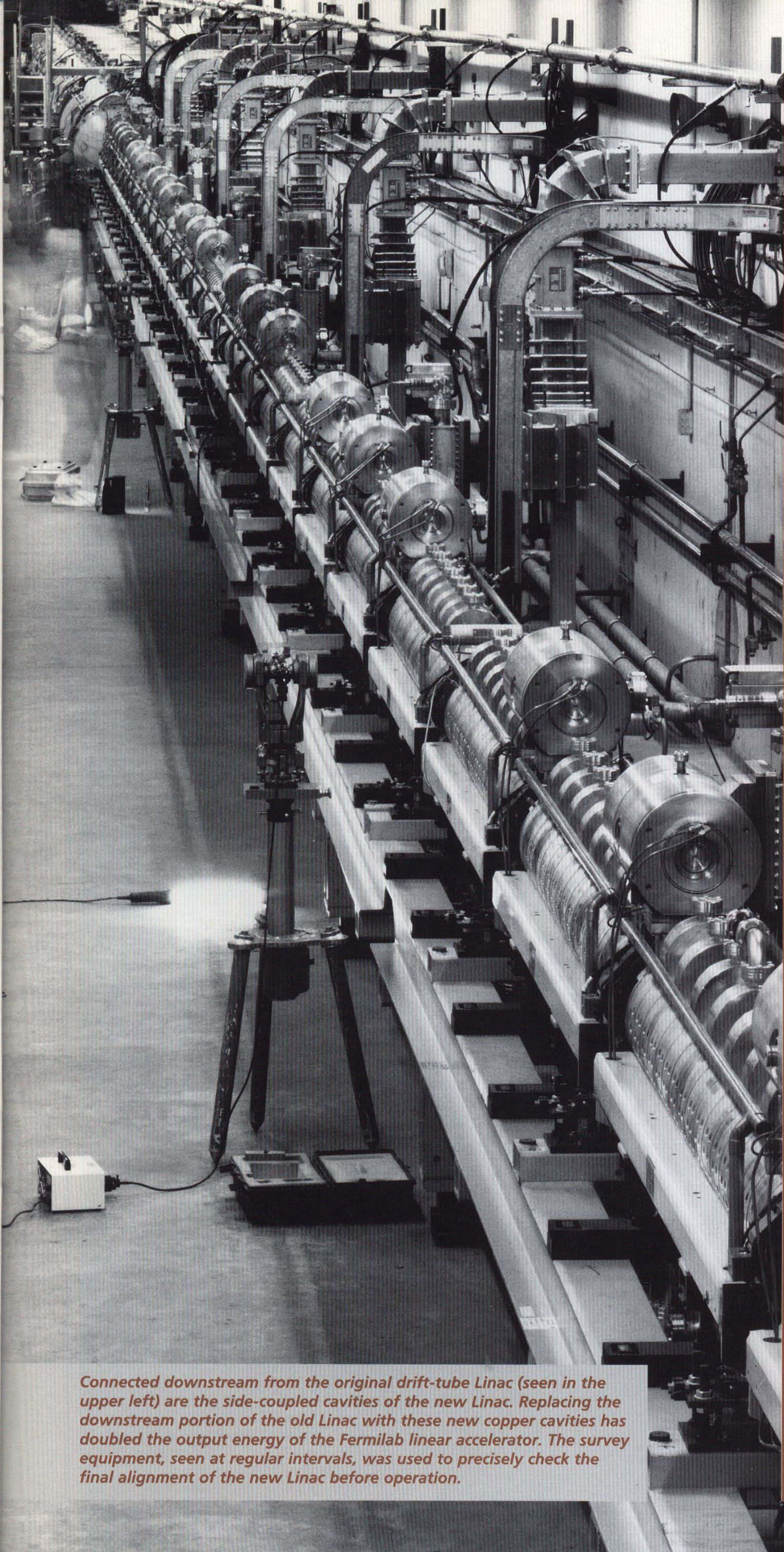


On June 4, drift tube tanks from the old Linac saw their first daylight since the construction days of the original Linac more than 20 years ago. Gliding on special rollers, the tank is escorted out through the Access Pit, constructed in early 1992 to allow old components to move out and new components to move in during the Linac Upgrade project. Mark Reichanadter (left) supervises the rigging crew.



Connected downstream from the original drift-tube Linac (seen in the upper left) are the side-coupled cavities of the new Linac. Replacing the downstream portion of the old Linac with these new copper cavities has doubled the output energy of the Fermilab linear accelerator. The survey equipment, seen at regular intervals, was used to precisely check the final alignment of the new Linac before operation.

LUMINOSITY!

What is it? Why do we need it? How do we get more?

Top is so massive that, of all the particle accelerators now operating on earth, only the Tevatron has enough energy to produce it — maybe. Only one collision in a few billion is likely to produce a top, making the last of the undiscovered quarks very hard to find.

We can improve our chances of finding top by increasing the collision energy, so that top quarks would occur more often, or by making more collisions. The Tevatron is already close to its maximum energy, but we can increase the number of collisions. We do this by increasing a property of Tevatron beams called luminosity.

The more protons and antiprotons we can pack into the hair-thin beams, the higher the luminosity. Imagine a group of people passing through an open gate meeting another group coming through the gate the other way. If the people are few and the gate is wide, not many people will bump into each other. But if the group swells to a crowd and the gate narrows, many more people will collide. The accelerator upgrades of the past few years, new focusing magnets, the newly installed Linac and the coming Main Injector are all designed to increase luminosity by packing more protons and antiprotons into the narrowest possible beams.

We measure the luminosity when protons and antiprotons first collide — the initial luminosity — in units of the number of particles (the size of the crowd) per square centimeter (the size of the gate) per second, called "inverse centimeters squared per second." In Collider Run Ia an initial luminosity of 9.22 x 10^{30} $cm^{-2} sec^{-1}$ was achieved, a world record. In Run Ib, the new Linac will allow us to go even higher. The Main Injector will give the Tevatron a luminosity five times as high.

To improve our chances of discovery what really matters is the number of total collisions in a given time period, called integrated luminosity, expressed in units of inverse picobarns. As beams circulate around and around the ring, repeatedly colliding, the crowd of particles begins to thin, and the luminosity drops. To maximize integrated luminosity, we need to start with a high initial luminosity and keep it high for as long as we can. In Run Ib, our goal is to deliver 75 inverse picobarns of integrated luminosity to the collider detectors. Somewhere in there, will we find a few top quarks?

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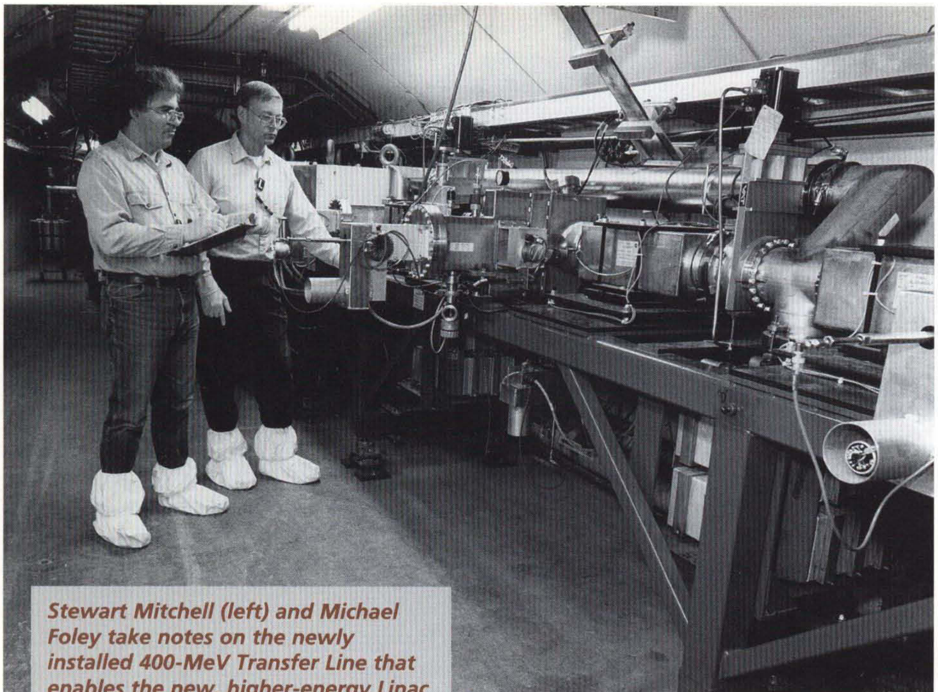
nized an effort to have a Fermilab supervisor work at the vendor's plant daily. Technicians from the Stanford Linear Accelerator Center also worked at the plant to complete critical work. The intense effort was a timely success with adequate transformers on hand to begin beam commissioning.

A final inspection of the Linac and Transfer Line by DOE Chicago Operations Office personnel occurred on August 27. After permission was received, around-the-clock commissioning began the same day. The commissioning plan was developed jointly by the Linac and Booster Departments. The initial goal was to achieve 400-MeV beam at a beam current of about 5 mA as quickly as possible so as to allow 400-MeV Transfer Line commissioning to start. Linac commissioning occurred during three eight-hour shifts, seven days a week. Shift-change meetings occurred between shifts to keep work flowing smoothly. At the noon shift-change meeting, the progress and problems of the previous 24 hours were reviewed and plans for the next three shifts were made. Accelerator Division personnel from nearly every department solved problems and repaired equipment at all hours of the day and night to keep the commissioning effort moving.

On August 28, after a day of parameter setup, 116-MeV beam was established at the end of drift-tube Tank 5 and drifted through the Transition Section and new side-coupled Linac without acceleration. The 805-MHz buncher cavity was used to improve the longitudinal match into the side-coupled structure at 116 MeV.

At 2:00 AM on the morning of August 30, beam was accelerated through Module 1 to 152 MeV. Two days were spent improving the transverse and longitudinal beam match and the beam diagnostic calibrations in the Transition Section and Module 1. With an adequate beam, acceleration through

After emerging from the Linac tunnel, which is about 4 meters below ground, the old drift tube tanks — 16 metric tons and 16 meters in length — are carefully lifted, placed on a trailer bed and hauled away to storage on-site. In early June, four drift-tube tanks were removed within six days.



Stewart Mitchell (left) and Michael Foley take notes on the newly installed 400-MeV Transfer Line that enables the new, higher-energy Linac beam to be efficiently transferred into the circular Booster.

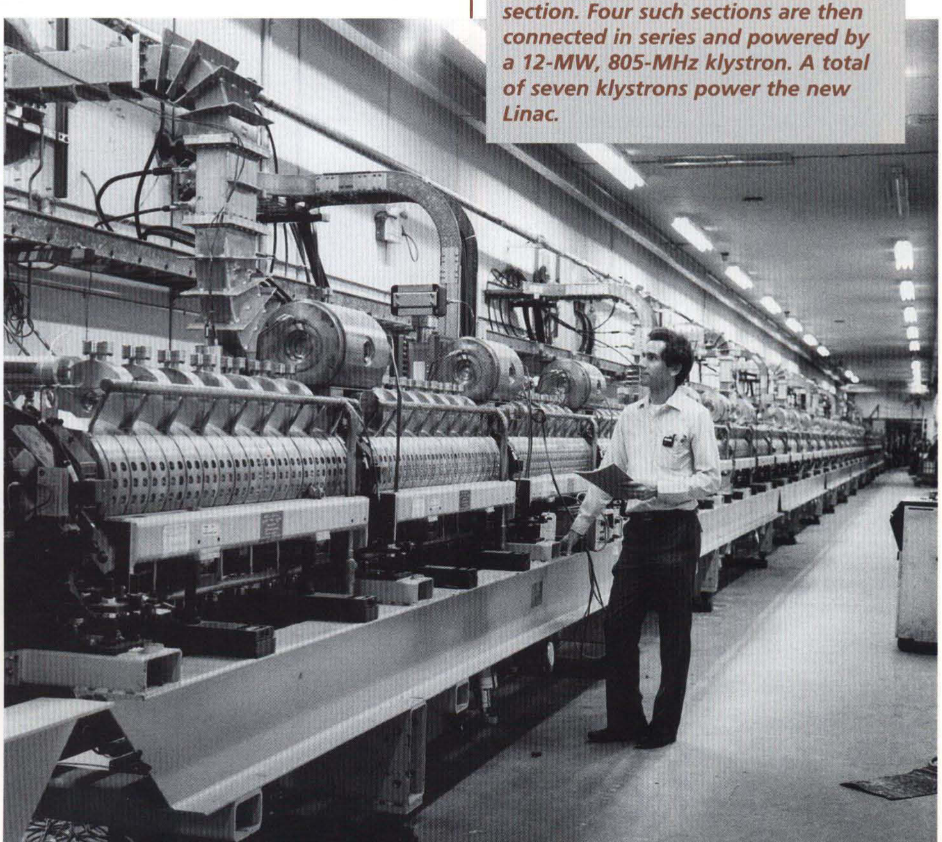
Module 2 to 190 MeV was accomplished on September 2. On September 3 a waveguide modification was made to increase the power flow to the 805-MHz buncher. During this change, the waveguide vacuum seal on the 200-kW Varian klystron was accidentally broken. A spare klystron was installed in only two hours and commissioning resumed.

At 3:00 AM on the morning of September 4, beam was accelerated through Module 3 to 230 MeV. Over the next 12 hours beam was sequentially accelerated through Modules 4, 5, 6 and 7 to 400 MeV. The 400-MeV beam energy was confirmed with the spectrometer magnet at 3:30 PM on September 4. Initial beam transmission was 80% which was good for a first pass through the Linac. The 400-MeV beam was established in less than eight days of commissioning.

Ten days were spent tuning the Linac beam transversely and longitudinally to improve beam transmission. On September 14, a beam transmission of 100% at 12 mA was achieved. By early October, only one month after commissioning began, beam transmission was 100% at the 35 mA design current.

The Booster phase of the Fermilab 400-MeV Upgrade started on September 16. By September 18, beam was successfully transported to the end of the 400-MeV line. Circulating beam at 400 MeV in the Booster was established by September 24 at 12:00 PM. Beam was accelerated to 8 GeV by 7:00 PM on that same day. The intensity achieved was 2.0×10^{11} protons/pulse. Tune-up to higher intensities continued and on October 5, one day after the predicted end date of the commissioning phase, an intensity of 2.0×10^{12} protons/pulse was achieved at 8 GeV in the Booster. As the year ended, tune-up was still continuing at a rate of two eight-hour shifts a day (the other shift occupied with tune-up of the Main Ring) to take full advantage of the smaller emittance growth the Upgrade provided. We have achieved 3.2×10^{12} protons/pulse compared to our highest intensity in Run Ia of 2.4×10^{12}. We are currently running between 2.4 and 2.8×10^{12} protons/pulse until beam dampers in all three planes are installed.

One of the most satisfying experiences for a scientist or engineer is to work as part of a team, around the clock, to solve problems and to bring a new accelerator into operation. The successful completion of the Linac Upgrade and the rapid commissioning of the new equipment is another Fermilab success story.



Robert Noble, Fermilab's project manager for the Linac Upgrade, inspects progress during the final week of Linac installation. The basic fabrication unit for the new Linac is a set of coupled resonant cavities brazed together into a 16-cavity section. Four such sections are then connected in series and powered by a 12-MW, 805-MHz klystron. A total of seven klystrons power the new Linac.

THE 1992-93 COLLIDER RUN

Fermilab's Tevatron Collider established a world record for luminosity in a proton-antiproton machine in 1993, in Collider Run Ia. The new level, 9.2×10^{30} cm^{-2}sec^{-1}, is over four times the luminosity achieved in the previous collider run and represents the culmination of years of preparation and extensive improvements to the machines.

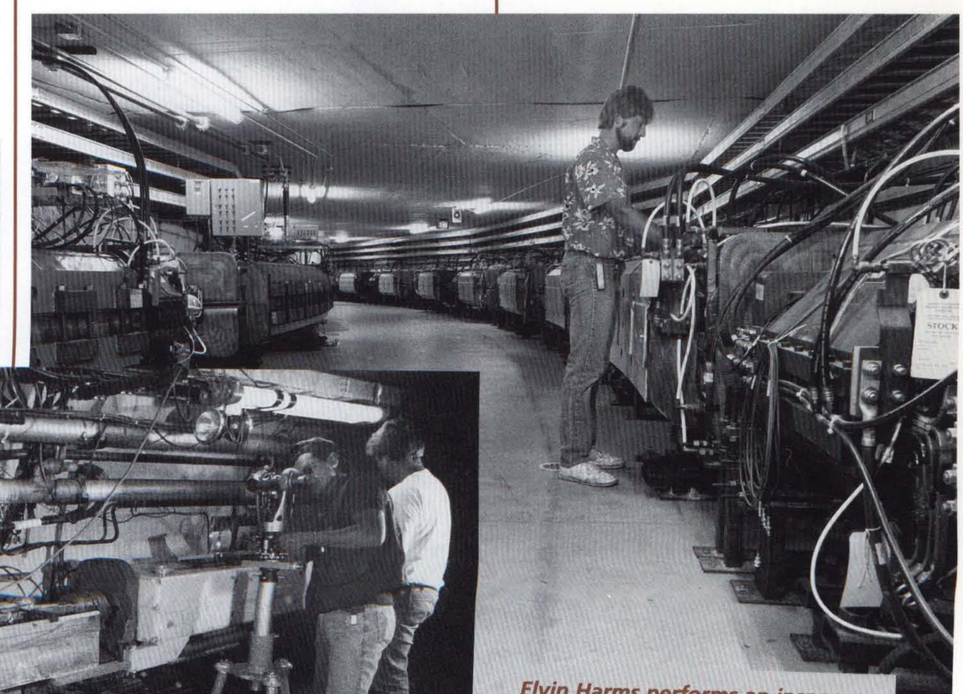
CONQUERING THE BEAM-BEAM FORCE

To appreciate the magnitude of this achievement requires understanding the reasons why we can't simply arbitrarily turn up the accelerator's beam intensity to whatever level we choose. Luminosity itself is proportional to the product of the intensity of the counter-streaming proton and antiproton beams, divided by the areas of the beams' overlapping cross-sections at the point where they meet. Luminosity is the most important measure of the rate at which we can cause high-energy collisions to take place. However, as luminosity increases, a number of other mechanisms come into play to prevent us from further increasing the luminosity. The most important of these is the so called "beam-beam force," the disruptive effect of one beam acting on the other as they rush past each other in close proximity. This force tends to spread out the particle bunches that are being focused into small regions in the center of the detectors where collisions take place. In Collider Run Ia, as in previous runs, the protons were arranged into six bunches that met their six counterpart antiproton bunches twice in each of their revolutions around the ring. In previous runs, the beam-beam forces were relatively large, because they met at as many as 12 collision points around the circumference of the ring, rapidly disrupting the bunches. In Run Ia, we introduced for the first time a number of electrostatic separators. These separators act on the proton and antiproton beams in opposite ways, causing them to follow completely separate helical orbits that collide only at the detectors, minimizing the disruptive influence of the beam-beam forces. It was this improvement, the introduction of electrostatic separators, that directly led to the improvement in luminosity in Run Ia.

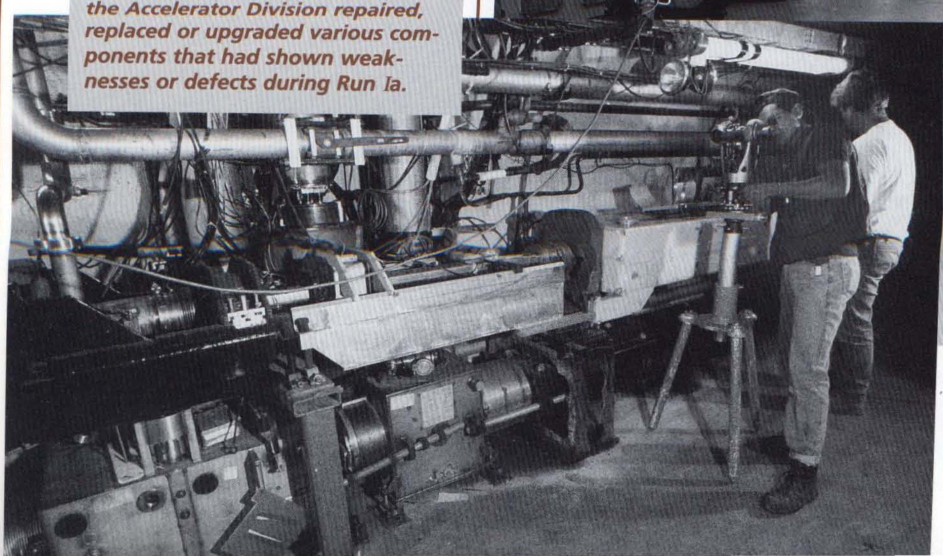
OPERATING IN NEW TERRITORY

We made important improvements to the Antiproton Source — improvements in stacking (the accumulation of antiprotons produced from a target bombarded by proton beams from the Main Ring), cooling (part of the process to increase the density of antiprotons) and efficient extraction of antiprotons from the Antiproton Accumulator to the next stage of acceleration. Because luminosity depends directly on the number of available antiprotons, increasing the antiproton intensity also led to increases in the delivered luminosity as shown in the figure on page 11.

During Run Ia, all the rings that make up the accelerator complex — the Booster, the Main Ring and the Tevatron — operated in new intensity ranges causing new problems to crop up. We made important changes to mitigate the various causes of beam instability. For instance, subtle effects — known as persistent currents — of the superconducting magnets in the Tevatron, could cause catastrophic loss of the protons by the onset of a particularly virulent beam instability. By care-



Elvin Harms performs an inspection in the Antiproton Source prior to start-up. A major project during the summer shutdown was flushing every water-cooled magnet to remove buildup of impurities.



During the summer shutdown, Craig Bradford (right) and Anthony Rodriguez of the Research Division's Alignment Group survey a new Tevatron spool piece in the Main Ring tunnel. In addition to the Linac Upgrade and the low-temperature upgrade, this summer the Accelerator Division repaired, replaced or upgraded various components that had shown weaknesses or defects during Run Ia.

A portable crane lifts an upgraded valve box into place at one of the 24 satellite refrigeration stations that deliver the liquid helium to the Tevatron's superconducting magnets.

fully adding special magnet compensation, we were able to cancel the persistent-current effect and this led to a dramatic improvement in collider performance. Similar problems had to be solved in each of the machines making up the collider.

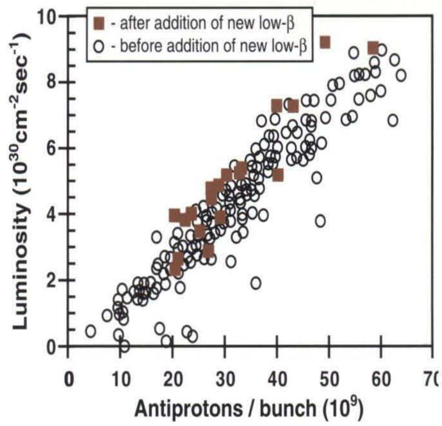
To provide the most data for experiments, the accelerator must do more than achieve high peak luminosities. Effective collider operation also means striving for the highest possible cumulative luminosities, which require the longest possible lifetimes for the stored beams. Run Ia set records for "integrated," or cumulative, luminosities. To accomplish both high luminosity and long luminosity lifetime required careful optimization of the operating conditions in the Tevatron, an effort that took several months.

Perhaps the most profound change in collider operations this past year came from the successful addition of an entirely new detector, DØ. While adding a second detector does not directly increase the luminosity, it increases the physics output of the collider by a factor of two. The inclusion of a second interaction region at DØ meant a complete redesign of the operating point of the collider and led to major changes in the way the particle beams are brought into collision. To manage efficiently the many steps involved in injection, acceleration, orbit separation and the initiation of collisions, we developed a "mastermind" computer-control program to carry out many complex beam manipulations in sequence, automatically. This "Sequencer" program has become the mainstay of operations and deserves much of the credit for the repeatable, reliable performance of the collider during the Run Ia.

ACCELERATOR PHYSICS FERMILAB STYLE

At the end of 1993 we began preparing for Collider Run Ib with high hopes. We hope that the new Linac will bring the Tevatron's luminosity close to a new record of at least $1.5 \times 10^{31}cm^{-2}sec^{-1}$. We hope that, among the data from this unprecedented number of high-energy collisions, our upgraded detectors will find evidence of new phenomena — perhaps the top quark, perhaps something quite unexpected. Besides our high hopes, however, we begin Collider Run Ib with the certain knowledge that this run, like every run in the past, will bring its own unique and challenging problems. As we solve them, one by one, we will learn more about that fascinating science, the art and craft of accelerator physics, just as Fermilab has been doing, with its trademark blend of ingenuity, mastery and zest, for more than a quarter century.

LUMINOSITY VS ANTIPROTON INTENSITY



WORLD RECORDS SET IN COLLIDER RUN Ia

9.22×10^{30} cm^{-2} sec^{-1}	Initial luminosity
2332 nb^{-1}	Integrated luminosity in one week
16.72 nb^{-1} hour^{-1}	Average luminosity for a week of stores
8.05×10^{30} cm^{-2} sec^{-1}	Average initial luminosity in a week
129 hours	Store hours per week
392 nb^{-1} (in 29.7 hours)	Single store integrated luminosity
100%	Stores ended intentionally in one week
4.85×10^{10}	Antiproton stacking for one hour
3.56×10^{10} hour^{-1}	Average stacking rate for one week
150×10^{10}	Peak antiproton stack
404×10^{10}	Antiprotons stacked in a week
411×10^{10}	Antiprotons used in a week

CDF PROFILE

Occupation:
Particle Detector.

Birthday:
October 13, 1985, the day I saw the light of my first particle collision.

Birthplace:
BØ at the Fermilab Tevatron.

Vital Statistics:
5,000-ton detector, 10 meters tall with a 9-meter magnetic waistline and keen vision for electrons, muons and jets.

My collaboration size is:
More than 440 physicists, including 140 graduate students.

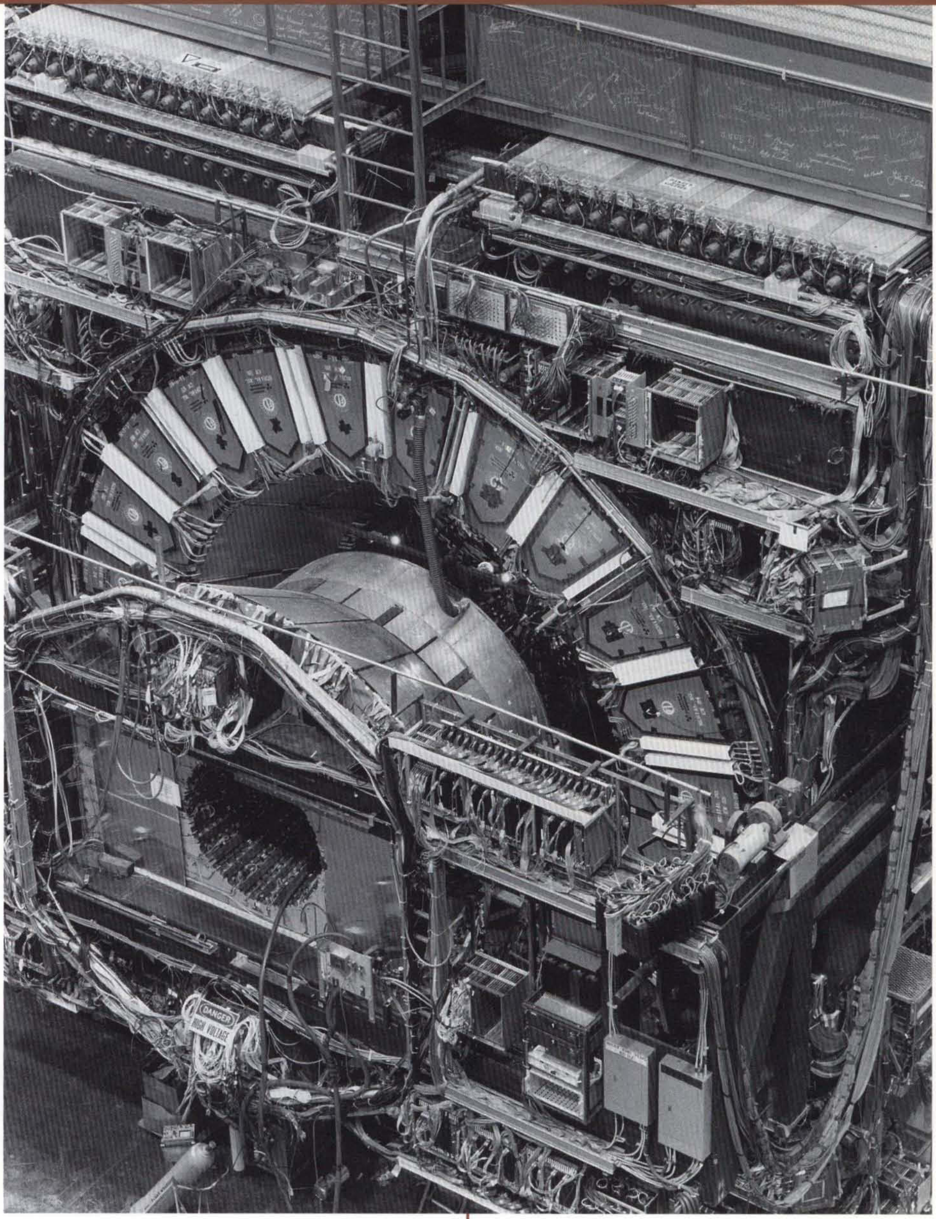
I'm now working on:
Searching for the top quark and understanding how bottom decays.

The achievement I feel proudest of:
When I find the top quark - then we'll talk about proud! Until then I'm proud of carrying on the top search at the energy frontier.

If I could change one thing about myself:
I've already grown much more sophisticated since I was born. Can't wait to try out my new radiation-hard silicon vertex detector in Run Ib! But if I could change one thing, I'd make myself much faster to keep pace with upcoming improvements in the accelerator. I'm working hard to achieve this by upgrading my calorimeters and making other improvements.

If I've learned one thing in life, it's:
Never to underestimate the value of computing. And that the rewards of success are — more collaborators!

My next big challenge is:
Keeping all my hardware, old and new, working efficiently in Run Ib to take data from Tevatron collisions efficiently and clearly, finding the top quark if it's there — and measuring its mass.



My fantasy is:
Detecting a clear, sharp signal for something completely unexpected.

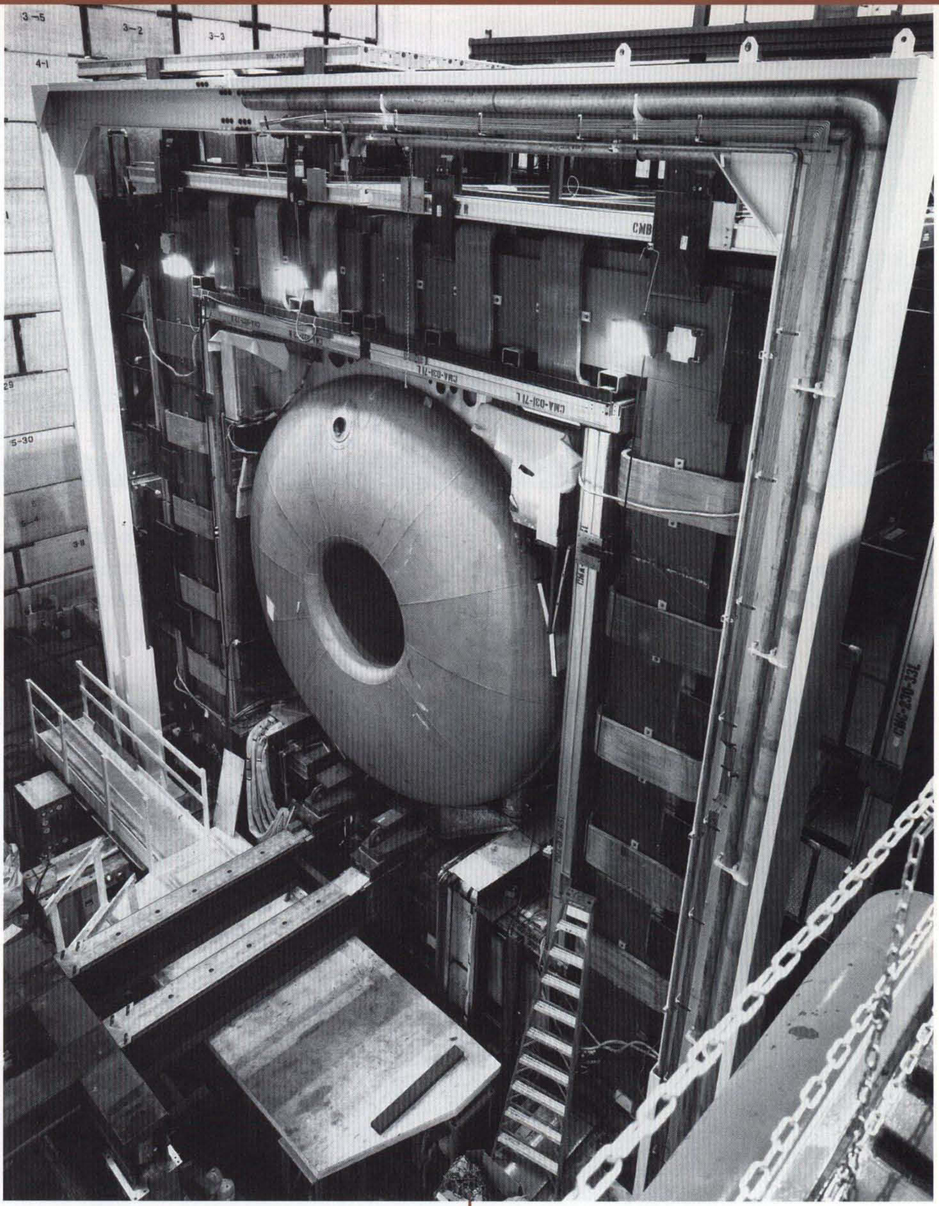
Behind my back people say I'm:
An aging, outdated first-generation detector who has had my day. (Don't bet on it!)

A really great evening to me is:
A double date with a couple of good-looking bosons — and leaving my sister behind.

When people first meet me they say:
"Wow! I didn't realize you were so tall! Do all of those wires really hook up to something?"

Three words that best describe me:
Collider. Detector. (at) Fermilab.

DØ PROFILE



Occupation:
Particle Detector.

Birthday:
February 14, 1992 (eight years after conception).

Birthplace:
DØ at the Fermilab Tevatron.

Vital Statistics:
5,000 tons, 4π μ-lepton coverage, hermetic calorimetry with excellent resolution, and non-magnetic inner tracking.

My collaboration size is:
Over 420 physicists, including 80 to 100 graduate students.

I'm now working on:
A rigorous study of forefront aspects of particle physics: searches for the top quark, the interactions of the electroweak vector bosons W, Z, and γ, measurement of the mass of the W, exploration of the strong force, and the search for new phenomena.

The achievement I feel proudest of:
Learning to crawl, toddle, walk, run and sing — all in the space of about one year.

If I could change one thing about myself:
I would add a magnetic field in my central tracking region, something I am working hard to achieve.

If I've learned one thing in life, it's:
That despite the eight years from my conception, I was far from obsolete at birth. All the physics I had hoped to look for was still waiting to be discovered.

My next big challenge is:
To improve my operating efficiency and my analysis efficiency and to fulfill throughout 1994 the promise my career showed in Run Ia. There is also the challenge of getting over 400 collaborators to sign sophisticated and sometimes controversial analysis papers.

My fantasy is:
Finding a clear, unmistakable signal for a new particle — like top, but not quite top. The world will be completely dazzled by my insight.

Behind my back people say I'm:
Redundant. (They'll find out!)

A really great evening to me is:
Taking lots of data and producing plots for analyses that keep my students and postdocs agonizing until the sun rises.

When I'm feeling sorry for myself I:
Feel unappreciated and that I get blamed for the sins of my older sister.

The one thing I can't stand is:
My housemother telling me which of all the attractive partons (gluons, t quarks and b quarks) I'm allowed to date.

When people first meet me they say:
"My, how compact and well-designed you are! What an attractive detector! "

Three words that best describe me:
Young. Vital. Dedicated. ■

FROM COLLISION TO DECISION: HOW WILL WE KNOW WHEN WE'VE FOUND IT?

A proton, moving as fast as a proton can now be made to move on earth, smashes head-on into an antiproton moving just as fast the other way. Kapow!!! as they say in the comics. Proton and antiproton smash to smithereens, pieces flying in all directions. The pieces are particles — perhaps a dozen different kinds in any one collision. One of them might be the top quark. But how do we know? Is it time to call the reporters with news of a discovery, or is it just another day at the high-energy frontier? The process of deciding is called physics analysis.

A collision is over so fast we could never see it happen, but some of the particles produced in a collision leave behind their "signatures" in a particle detector's guest book, as it were, before they check out. To learn what took place in a collision, physicists use computers to look at these electronic signatures to discover which of several hundred possible particles were present at the scene. Most of the guest list reveals the same old crowd, particles that turn up so often, in fact, that the computers ignore them. Much less often, say one time in a million, an interesting signature turns up and the computer takes note; it might be the mark of one of several intriguing particles. One time in a few billion, it might even be the handwriting of top.

Although we haven't seen the top quark, we think we will recognize its signature. Some particles, including top, exist for such a short time before they decay into other particles that we don't actually find their signatures, but instead those of their decay products. A particle

Physicists discuss the properties of an incoming event displayed on the computer screen in the CDF control room.

we are looking for may have more than one possible decay mode — top has a handful — and thus more than one possible signature. The search gets complicated.

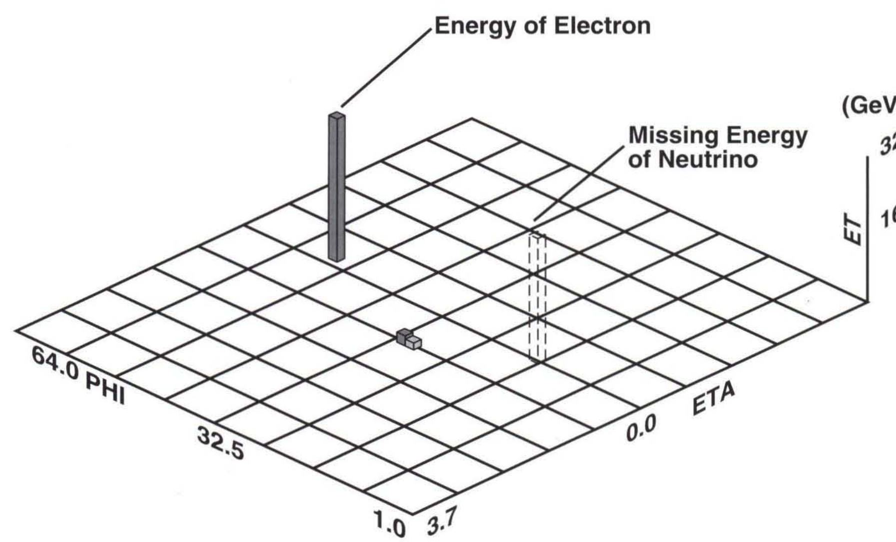
Of the few hundred possible particle signatures, some show up many times; others almost never, depending on an accelerator's energy. We believe that Fermilab's Tevatron has enough energy for top to appear very rarely, once in a few billion collisions. Analysis requires distinguishing a real top signature from those of other processes, called "background," that aren't so rare and that can mimic a top signature. To discover top requires showing conclusively that its signature appears significantly more often than it would in the background alone.

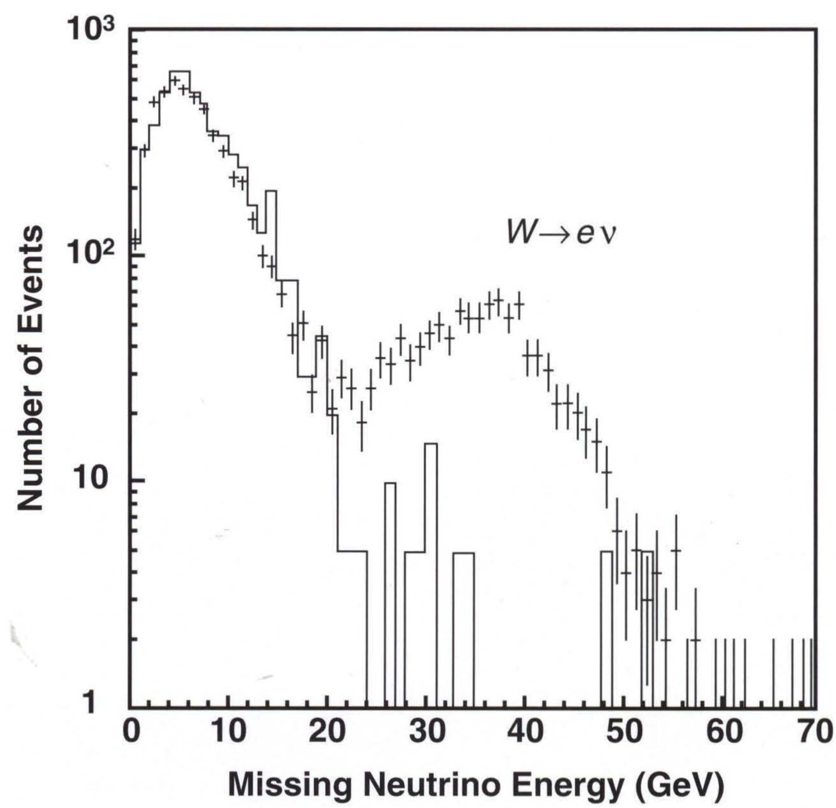
"Some physics discoveries stare you in the face — you almost can't miss them," says CDF collaborator Claudio Campagnari. "You see the signature event and you know you've got it. But top is probably not one of those. Rather than one 'Eureka!' event, top discovery will come by accumulating a lot of different evidence, bit by bit. You could compare discovering top with what happens in a courtroom in a case where there's no smoking gun and you must convince the jury by the accumulated weight of circumstantial evidence."

Like Perry Mason proving his toughest case, physicists from CDF or DØ who find what might be evidence of the top quark must first persuade themselves of what they have found. Next they must convince that most skeptical of juries, their 400-plus collaborators, that the top signatures they have identified are the real thing. When the weight of evidence becomes so overwhelming that even the collaboration formally accepts it, only then can Fermilab make the long-awaited introduction: "World, meet the top quark."

HOW TO READ A SIGNATURE.

A real-life particle signature, like this one from DØ, shows what we would expect to see when a W boson decays into an electron and a neutrino. The "lego plot" below, where the height of the lego tower gives the energy detected in a section of the detector, shows just such an event. The detector has identified and measured the transverse energy of the electron and we can deduce the presence of the neutrino by calculating how much energy is missing from the event if we assume transverse energy is conserved. The combined momenta of electron and neutrino add up to about 80 GeV. But is it really the signature of a W? Without more evidence, the single event by itself is not enough to tell us. If, however, we graph the missing neutrino energy from many such events (graph at bottom), we see a prominent peak for missing energy at about 40 GeV. This bump IS enough to tell us that an object of mass about 80 GeV is decaying into an electron and a neutrino — and enough to tell us that the W exists. The top quark search has produced candidate events whose signatures match what we expect to see in top decays; but to tell us that the signatures really are those of top, we need enough events to produce evidence analogous to the W "bump."





THE MAIN INJECTOR: BUILDING FOR THE FUTURE

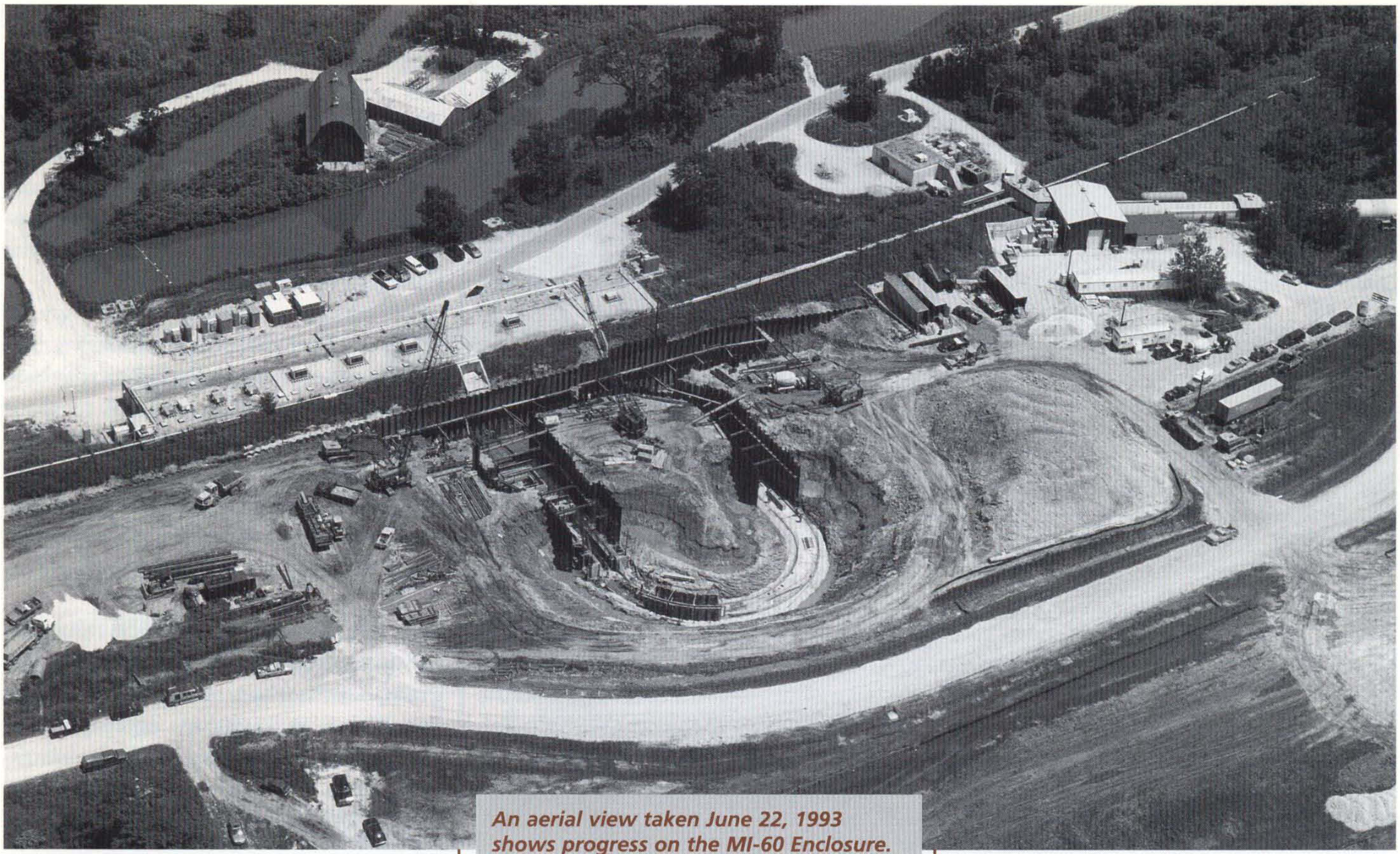
The Fermilab Main Injector Project is the centerpiece of Fermilab's initiative for the 1990s, Fermilab III. The goals of Fermilab III are: to ensure discovery and determination of the properties of the top quark in the present decade, assuming our understanding of nature as described by the Standard Model is correct; to provide a factor of two increase in the mass scale characterizing possible extensions to the Standard Model; to support new initiatives in neutral *K*-meson physics, *b*-quark physics and neutrino oscillations; and to leave Fermilab flexibly positioned for frontier research in the twenty-first century. In order to reach these goals Fermilab plans to attain by the end of the decade a luminosity in excess of $5x10^{31}cm^{-2}sec^{-1}$ in the Tevatron Collider, supported by a new 150-GeV accelerator, the Fermilab Main Injector.

On a wintry March 22, 1993 members of the Illinois congressional delegation joined representatives from DOE and URA for a groundbreaking ceremony for the Main Injector. Shown from the left are Director John Peoples, Representative Dennis Hastert, Senator Carol Moseley-Braun, Senator Paul Simon and Dr. Wilmot Hess, Associate Director of DOE's Office of High Energy and Nuclear Physics. The collaborative efforts of all these officials and the Fermilab staff have made possible the continued progress on this major construction project.

The Main Injector is being constructed tangent to the Tevatron in a separate tunnel on the southwest corner of the Fermilab site. The FMI will be roughly half the size of the existing Main Ring yet will boast greatly improved performance. The Main Injector will produce about four times as many antiprotons per hour ($1.7x10^{11}$/hour) as are currently possible and have a capability for the delivery of three times as many protons to the Tevatron (at least $3x10^{11}$ protons/bunch for collider operations). Additionally the Main Injector will deliver very intense proton beams (more than $3x10^{13}$ protons every 2.9 seconds with a 33% spill duty factor) for use in state-of-the-art studies of CP violation and rare *K*-meson decays, and for experiments designed to search for transmutation between different neutrino generations. Low intensity proton beams emanating from the Main Injector will support test and calibration beams required for the development of new experimental detection devices. In contrast to present capabilities, simultaneous antiproton production and Main Injector slow-spill operation will be possible.

The FMI Project entered its second year of funding in 1993 with a 15 million dollar appropriation. While physical construction was begun in the summer of 1992 with the wetland mitigation project, the first construction of the accelerator facility itself was initiated on February 8, 1993 with issuance of the notice to proceed on the MI-60 Underground Enclosure. Following the official groundbreaking for the project on March 22, 1993, attended by members of the Illinois congressional delegation, contracts were rapidly awarded for other civil and technical component construction activities. Contracts for both the MI-60 Service Building and general site preparation work were awarded in the late spring and summer. Work on these projects is now well advanced. The largest single construction package on the project, the underground accelerator ring enclosure, was released for bid on November 23, 1993. The overall construction strategy for the project is to start at the MI-60 straight section/service building and work counterclockwise around the ring. The MI-60 region is the most complex to construct since at this point only 11 meters separate the Main Injector and the Tevatron. The MI-60 underground enclosure will house the Main Injector rf accelerating cavities, while the above-grade service building will house associated equipment as well as providing the sole major-equipment access hatch to the ring. The remainder of the ring enclosure will house the focusing, bending and correction magnets, vacuum systems, diagnostics, utilities and controls. These devices are supported by small above-grade equipment buildings.

In parallel with the civil construction and design activities, significant progress has been made on contracting for the major dipole magnet subassemblies. The focus of the magnet preproduction R&D program over the past year has been the development of coil and half-core production capability by several industrial vendors. This program follows the successful prototype development phase in which the magnet design was finalized and performance specifications were achieved on two prototype magnets. A contract is now in place to form dipole magnet copper coils. Three coil-insulating vendors currently have R&D contracts and will compete for two partial production contracts. Production of half-cores for



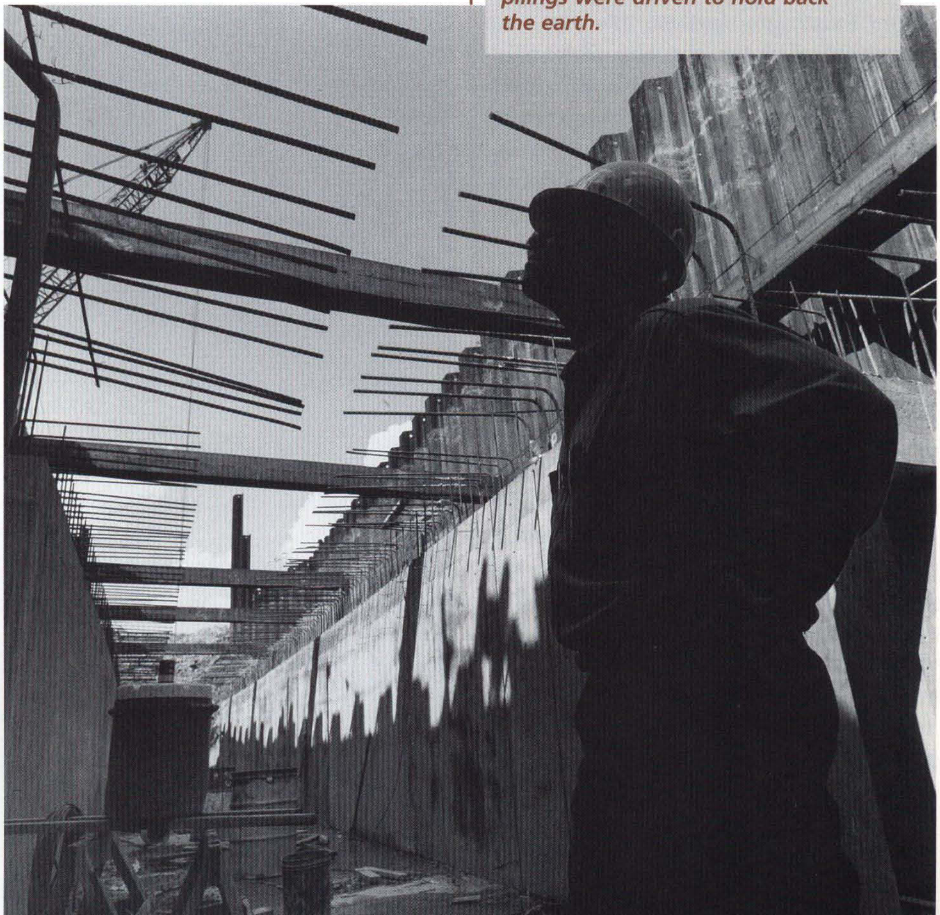
An aerial view taken June 22, 1993 shows progress on the MI-60 Enclosure. Construction of the straight section has begun parallel to the Main Ring. The semicircular excavation provides access to the Main Injector tunnel so that components can be readily installed during construction or removed for needed repair.

the R&D program has been successfully completed by two vendors who will vie for the half-core full-production contract.

R&D on other components has also proceeded rapidly. In September the prototype (10 MVA) dipole power supply delivered current into one of the prototype dipoles, executing the 9,400 ampere ramp that will be required for 150-GeV operations. In addition, the 200-kW prototype rf power amplifier required for beam acceleration at 240 GeV/sec was successfully tested.

Construction activities in FY 1994 will continue to be concentrated on civil construction and the dipole magnets. Funding in FY 1994 and projected funding in FY 1995 are consistent with a funding profile that will allow Fermilab to complete the Main Injector by FY 1998.

At the MI-60 Enclosure, a worker surveys the straight section, the area that will contain the accelerating components. Since the space is about 9 meters below local grade, sheet pilings were driven to hold back the earth.



PIPES, PUMPS, PONDS AND WELLS

Just as it is to life, water is essential to our Laboratory. From the water we drink, to cooling systems for the accelerators, water plays a crucial role in our everyday operations.

The Laboratory uses nearly 250 million gallons of water each year for a variety of applications. Many Fermilab employees are involved in developing and maintaining the vast networks of pipes, pumps, ponds and wells that provide the site with this much needed liquid.

When the Atomic Energy Commission was seeking a site for a national accelerator laboratory, an ample water supply was a primary consideration. Water was needed for drinking, sanitation, industrial applications, irrigation of erosion control plantings, cooling and fire protection.

The surrounding communities, anticipating their own rapid growth, were concerned about the strain a new laboratory's water demands might place upon existing supplies. During our construction phase, the Fermilab management and area municipalities worked cooperatively to ensure that adequate water supplies were maintained to provide service to both Fermilab and its neighbors.

DOMESTIC WATER

Neighboring communities were drawing their water from deep wells drilled to a depth of 1,200 to 1,600 feet into the Cambrian-Ordovician aquifer system — an aquifer that is not rapidly recharged. In order not to compete with the water supplies of our neighbors, Fermilab decided to obtain water from shallow wells. Drilling only 80 to 90 feet, the Laboratory reached the Silurian Dolomite aquifer. This aquifer is recharged locally by percolation of rain water at a rapid rate adequate for the Laboratory's average daily use of 50,000 gallons. Reservoirs were constructed to accommodate peak uses of approximately 150,000 gallons per day.

Today water is supplied to the main site by two wells. One, located near the Central Utility Building, supplies daily site water. The other, located near Site 38, operates as a backup source and has a generator capable of operating the pumps in the event of a power outage. Water is pumped from the wells into underground storage reservoirs where the water is chlorinated and monitored according to Illinois EPA regulations.

Service pumps take the water from the reservoirs into the distribution system. Water travels through this system to the buildings across most of the Fermilab site. Because of their remote locations, DØ has its own well and pumping system and the Village potable water is supplied by the city of Warrenville.

The Laboratory currently has underway two major upgrades to the 25-year-old distribution system, both of which are designed to further improve and protect the quality of water provided to the Fermilab community.

The first initiative involves the sitewide installation of flushing hydrants that are used to scour the distribution pipes and to circulate fresh water to the ends of the system. This process reduces water odors and discoloration by replacing stale water with a fresh supply.

The second project is a backflow prevention program. As part of this program, antisyphon devices are being installed at the system's entry point at key buildings and in areas where domes-

A fountain of water sprays upward in the cooling pond around the Main Ring.

tic water is being used for light industrial applications. Although backflow prevention has always been designed into domestic water systems, our new program adheres to stricter standards now mandated by the State of Illinois and was recently approved by the Illinois Environmental Protection Agency.

Along with these improvement initiatives, Laboratory personnel, in conjunction with an outside consulting firm, conducted a domestic water use survey. Every building was physically surveyed in order to understand how the water coming in is being used and to ensure that all mandated prevention programs are in place.

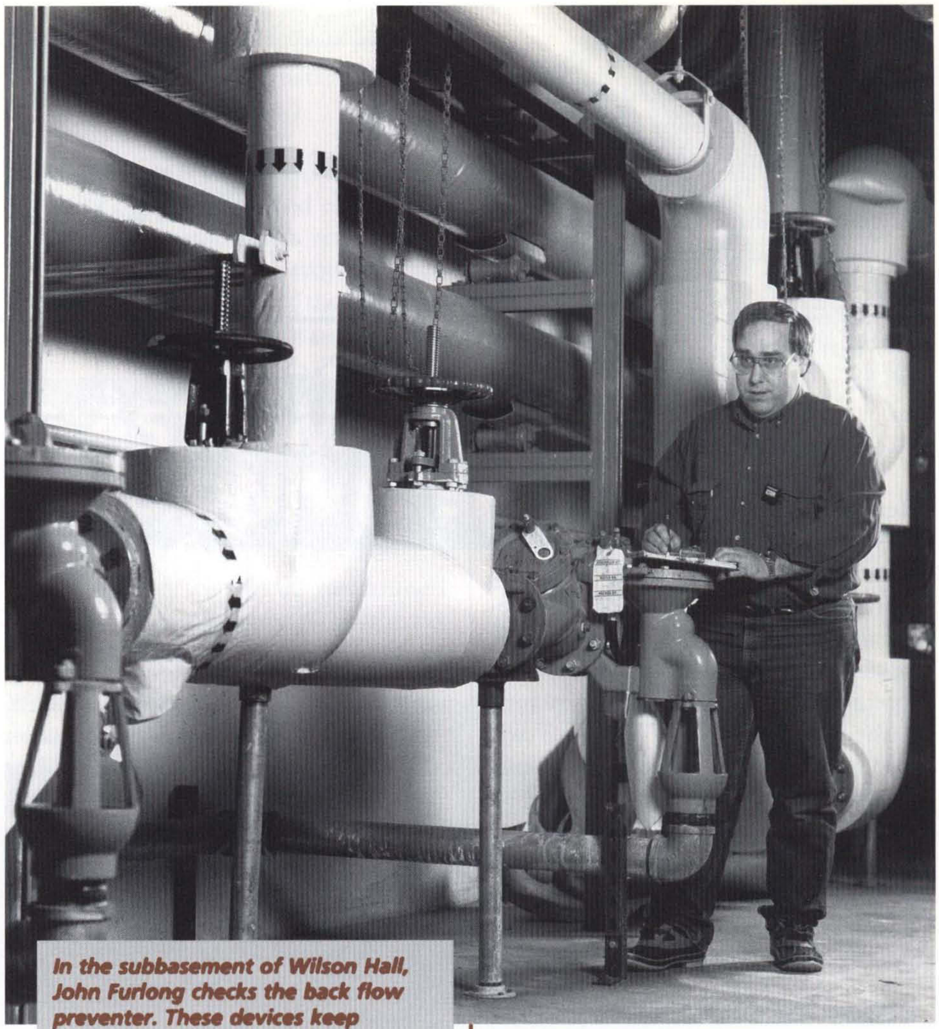
INDUSTRIAL COLD WATER

In addition to domestic water, the Laboratory also needs water for industrial applications. Although our wells supply an ample amount of domestic water, it has always been the Laboratory's philosophy to avoid, when possible, using drinking water resources for industrial applications. When the Laboratory's water systems were being planned, an industrial cold water system was included in the design. This system uses surface water collected in retention ponds to satisfy our cooling and fire protection requirements. The water collected is not potable; people can't drink it; but it can be used in our fire hydrants, sprinklers and cooling systems.

The surface water collected for the ICW system is recirculated, flowing from 2,000 gallons per minute up to 10,000 gallons per minute depending upon the season and the experiments' cooling requirements.

The Laboratory also has a permit to draw water from the Fox River pump station provided the river's flow is not below 275 cubic feet per second. If the river is low, we must go into a water conservation mode until water levels at Casey's Pond are again sufficient.

Major efforts are currently underway to improve the quality of the ICW system. A new flushing program was developed to discourage sedimentation in the distribution system. The entire system was also calibrated and computer hydraulic simulations conducted to identify pressure deficiencies in the underground piping network, which will then be corrected.



In the subbasement of Wilson Hall, John Furlong checks the back flow preventer. These devices keep process water from washing back into the drinking water system when pressure changes occur.

The Laboratory has also expanded its ICW chemical treatment program. In the past, the industrial cold water was chemically treated only in the summer. The water is now treated year round, discouraging bacterial growth in the water supply and distribution system.

To reduce the amount of silt sucked into the system, the pump intake has been raised higher off the bottom of Casey's Pond and a bank stabilization program has been initiated to discourage erosion.

LOW CONDUCTIVITY WATER

Other necessary water networks at the Laboratory are low conductivity water systems. Low conductivity water is deionized water produced from domestic water through a purification process conducted at the Central Utility Building and locally at remote sites. Low conductivity water gets its name because ultrapure water is a poor conductor of electricity. Because of this characteristic, LCW will not short out the current powering the magnets and can be used in the cooling systems for the accelerators and their power supplies.

The Laboratory operates several LCW systems that provide 95°F water for the Booster, Antiproton Source, Main Ring and Tevatron and 55°F water for the Linac. LCW is also needed in cooling systems at CDF, DØ and for fixed-target experiments.

To prevent oxygen from contaminating the water, LCW systems are closed-loop systems. Once water is placed in the system, it does not have to be replaced unless water is drained or there is a leak.

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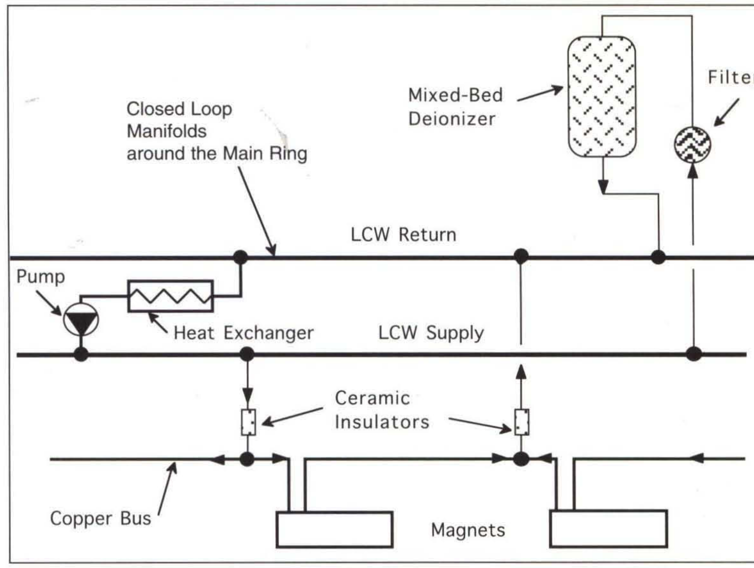
An LCW system includes filters to strain the water and mixed-bed deionizing vessels. The resins in the vessels remove all the minerals from the water. After the water is deionized, it is piped to one of the main systems. The LCW system also includes a make-up tank which doubles as an expansion tank. The make-up tank contains a reserve of LCW that can be used to fill the system if there is a sudden loss of water. The tank is topped with a nitrogen blanket to keep oxygen out of the system.

After the main system is filled, the LCW is constantly cleaned and polished with mixed-bed deionizer systems. Continual polishing removes the minerals that dissolve in the water from the associated piping, magnets and power supplies. If the system isn't constantly polished, a build-up of minerals will begin to form inside the ceramic insulators, which could cause ground faults.

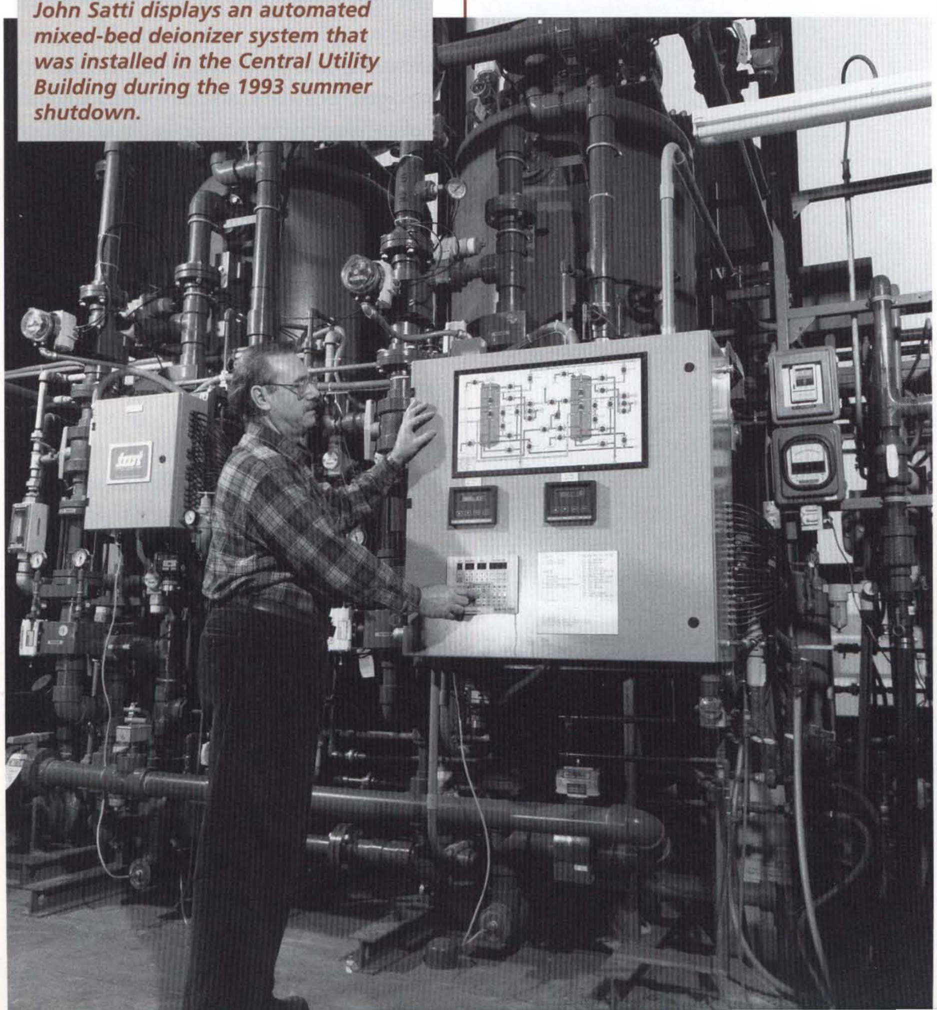
Unfortunately, providing LCW for cooling causes other problems. Deionized water tends to attract solutes and constantly assaults the components in the cooling system. One of the areas where this aggression causes problems is the brazed joints around the ceramic insulators. Weakened joints can cause leaks particularly when stress is placed on the system during startup and shutdown. This year, during our planned shutdown, Laboratory employees tested all the ceramic copper interfaces in the Main Ring using ultrasonic flaw detectors. These detectors can nondestructively test joint strength and thus determine the likelihood of a leak. A total of 1,352 ceramic interfaces were tested in the Main Ring enclosure and those determined to be weak were replaced.

All three of Fermilab's water systems are necessary for efficient operation, but like most resources, are often taken for granted. People rarely think about these systems, unless, of course, something goes wrong. Fermilab employees involved in providing our water systems and their management are working to ensure that they remain "transparent."

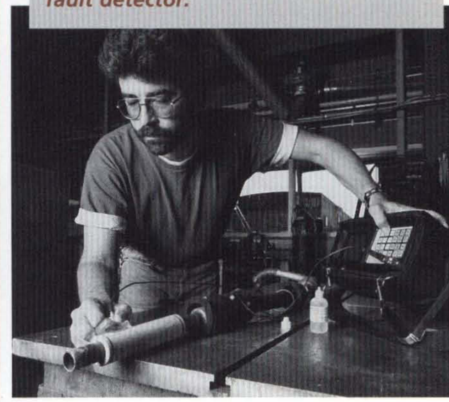
MAIN RING LCW FLOW SCHEMATIC



John Satti displays an automated mixed-bed deionizer system that was installed in the Central Utility Building during the 1993 summer shutdown.



Ronald Kellett tests a repaired ceramic insulator using an ultrasonic fault detector.



MATTER ASYMMETRY OF THE UNIVERSE

Ask anyone working on the Antiproton Source — making antiprotons is tough. A lot of sweat and hard work is necessary to make the mere 10^{14} antiprotons necessary for a single collider run. In comparison, getting the protons for the run is simple — just plug in a bottle of hydrogen. Why is it so difficult to obtain antiprotons when protons are so plentiful?

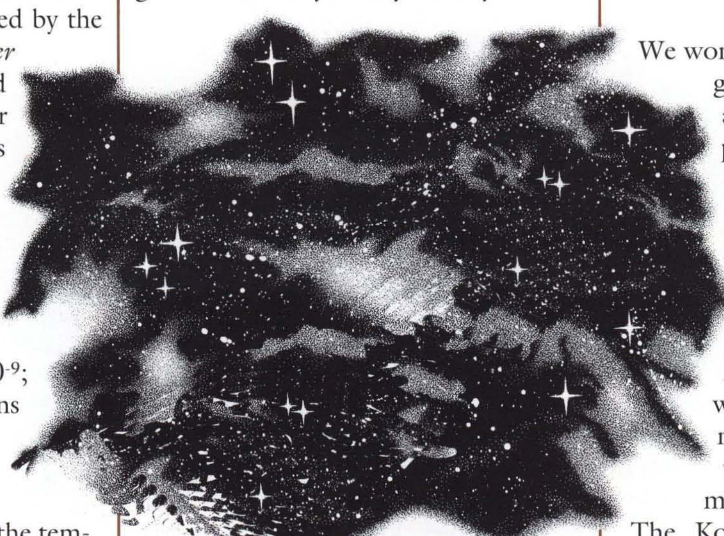
We live in a universe of *matter*. Antimatter does not seem to exist in large quantities anywhere in the universe. This fact can be quantified by the definition of the *baryon number of the universe*, which is defined as the ratio of the number density of baryons minus antibaryons to the number density of photons in the 3-degree microwave background radiation. Today, cosmologists believe that the baryon number of the universe is somewhere in the range 10^{-9}; there are about a billion photons in the universe for every baryon, and no antibaryons.

In the hot early universe when the temperature exceeded the rest mass of the proton, baryons and antibaryons were created from the energy in the background radiation. If baryon number is conserved, then at temperatures above the mass of the proton there should have been *almost* exactly equal numbers of baryons and antibaryons. The baryon number of 10^{-9} implies that for every billion antibaryons, there were a billion and one baryons. As the universe cooled to a temperature below the rest mass of a proton, the antibaryons and baryons annihilated each other, to leave behind the odd extra baryon.

Can the baryon asymmetry of the universe be explained? In 1964 the Russian physicist Andrei Sakharov outlined the ingredients necessary for the universe to develop an asymmetry in the number of baryons compared to the number of antibaryons. One of the requirements is that some reactions must be different for matter than for antimatter (CP violation).

After the proposal of Grand Unified Theories of the strong and electroweak interactions, cosmologists realized that the Sakharov conditions would be present in the GUT era of the universe, about 10^{-35} seconds after the bang.

Unfortunately, we still do not know if GUTs are part of nature. While the origin of the baryon asymmetry in the GUT era remains a possibility, there is little prospect for experimental confirmation of the GUT idea any time soon.

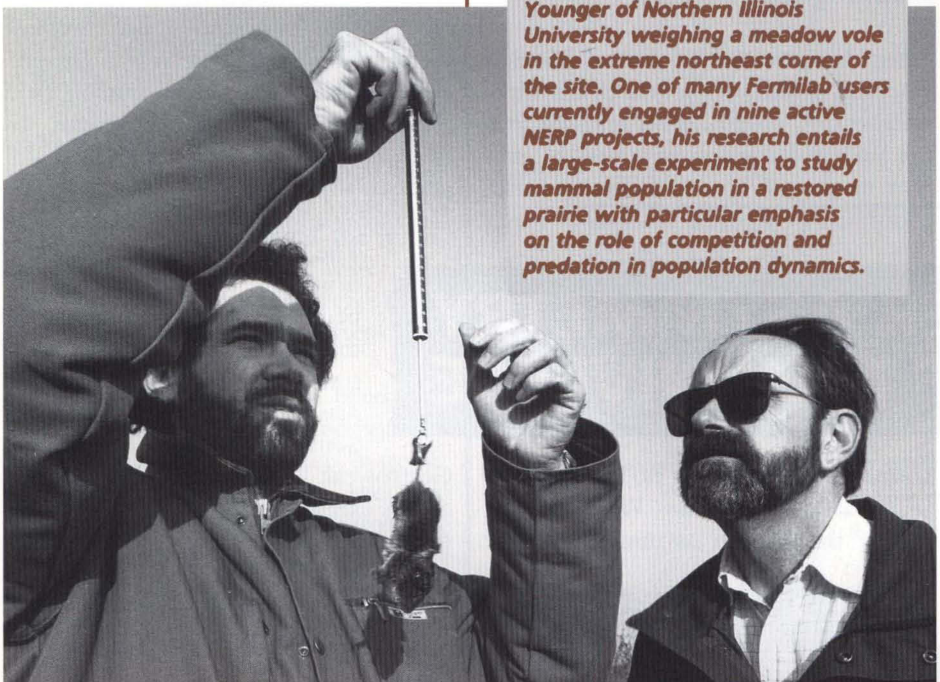


The GUT era may not be the only time the Sakharov conditions were met. In 1985 three Russian physicists, Vadim Kuzmin, Valeri Rubakov and Misha Shaposhnikov proposed that the baryon asymmetry was generated during the breaking of the electroweak symmetry, about 10^{-10} seconds after the bang. They proposed that baryon number can be violated at these temperatures through the action of solitons, known as sphalerons, present in the Standard Model. The necessary CP violation could be provided by the Kobayashi-Maskawa mechanism of the Standard Model.

The electroweak phase transition and electroweak baryogenesis has received a lot of attention from cosmologists and particle physicists. The possibility that the Standard Model of the strong and electroweak interactions can account for the baryon asymmetry has encouraged theorists to pursue difficult field theory and astrophysics problems. In spite of a great deal of effort, it is still unclear whether the Standard Model can account for the baryon asymmetry. The details of the phase transition are difficult to model because the Higgs particle is so massive and the details of the transition depend upon the mass of the elusive top quark. Some cosmologists believe that electroweak baryogenesis is only possible in extensions of the minimal electroweak model.

We won't know if electroweak baryogenesis can explain the baryon asymmetry until all of the parameters of the Standard Model are known. The parameters include the mass of the top quark, the mass of the Higgs boson and the mixing angles in the Kobayashi-Maskawa matrix. All of these parameters are within reach of present or near-future accelerators. The top quark mass will be determined by the Tevatron collider. The Kobayashi-Maskawa parameters will be found by experiments in the *K*-meson program and experiments involving *b* quarks in the Fermilab collider and fixed-target program, in e^+e^- colliders at Cornell and CERN, as well as at dedicated *B* factories.

Perhaps when all the pieces of the Standard Model are known we will finally solve the puzzle of the baryon asymmetry. Perhaps we will discover that the GUT scenario was correct after all. Or perhaps the explanation of the baryon asymmetry will involve some new, unexpected physics. In the meantime, we will have to make antiprotons the old-fashioned way in the Antiproton Source, accelerate them in the collider, and try to learn why there aren't any of them around from information gleaned from their collisions. ■



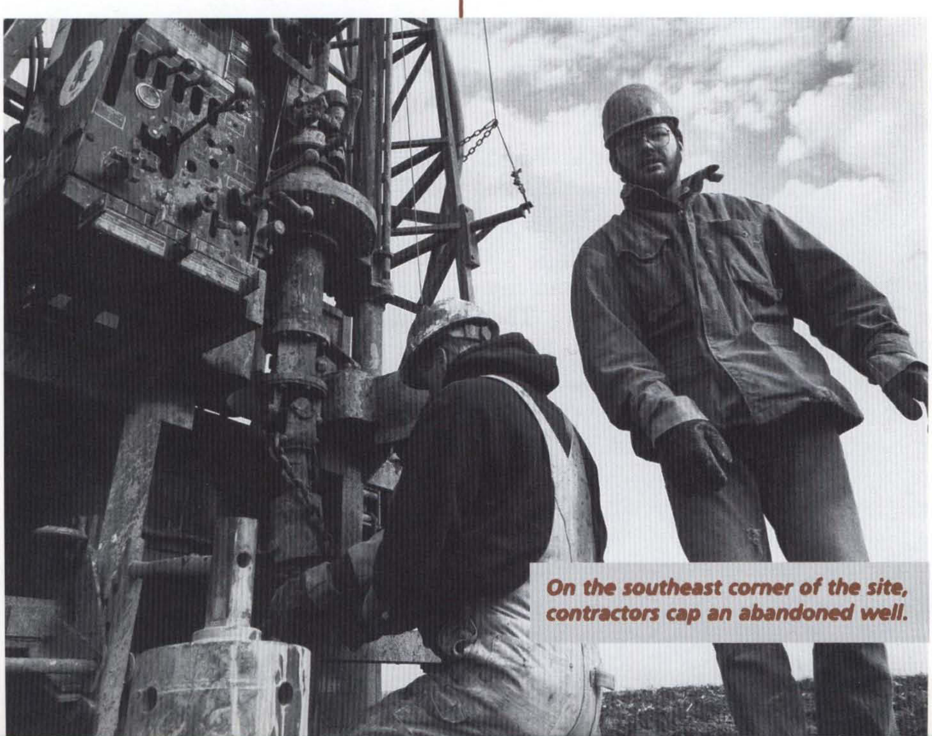
Rod Walton (right), head of Fermilab's National Environmental Research Park, observes John Younger of Northern Illinois University weighing a meadow vole in the extreme northeast corner of the site. One of many Fermilab users currently engaged in nine active NERP projects, his research entails a large-scale experiment to study mammal population in a restored prairie with particular emphasis on the role of competition and predation in population dynamics.

Aimee Vessel cleans a circuit board using an environmentally friendly cleaner that replaces Freon 113, which has an adverse effect on the ozone layer. Fermilab has equipment and certified personnel to remove ozone-depleting substances from air conditioning units. In addition, water-based systems are used to clean parts in order to eliminate air pollutants. The Laboratory's Waste Minimization Committee has instituted Process Waste Assessments whereby employees carefully examine the materials used on the job and then explore ways to reduce the waste generated. In 1993, the Committee started awareness training for Laboratory personnel and made presentations to waste coordinators and building managers.

PROGRESS ON ENVIRONMENT, SAFETY AND HEALTH

The impact and effect of the Environment, Safety and Health Section extends throughout Fermilab — and beyond the site borders. Laboratory policy states that each employee is responsible for the environment, safety and health at the Laboratory. The ES&H Section is supported by professionals in all the Laboratory's organizational units. The 1993 highlights for the ES&H Section included successful wetland mitigation in the Main Injector area, extensive progress in waste minimization and the start of an intensive lab-wide environmental survey known as a Resource Conservation and Recovery Act Facility Investigation.

At Fermilab's Hazardous Waste Storage Facility, Gregory Thompson uses a forklift to place a 55-gallon drum on a truck for removal from the Laboratory. In dealing with its waste, Fermilab follows all Department of Energy and Department of Transportation regulations and has standing contracts with permitted treatment and storage facilities.

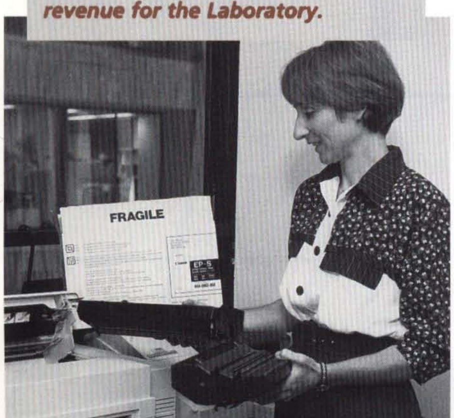


On the southeast corner of the site, contractors cap an abandoned well.

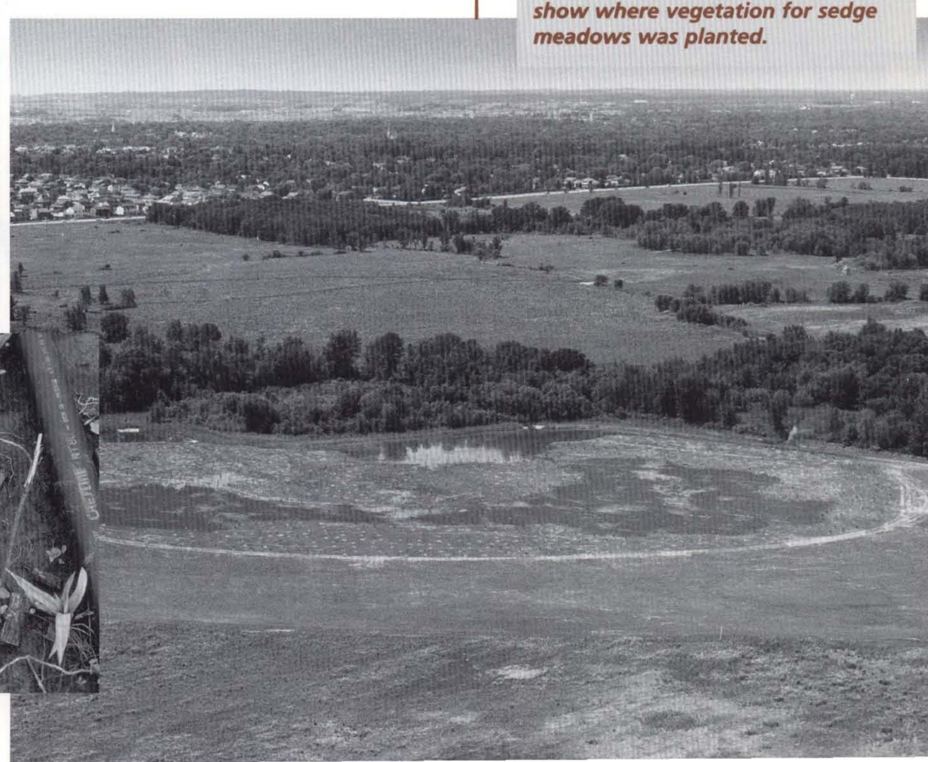
Employees from Technical Support Services Machine Shop (from the left, Carl Penson, Ray Green, Charles Matthews and Chester Shaw) gather at the scrap metal recycling bins. In 1993, the Laboratory sold more than 1.25 million pounds of miscellaneous sheet iron, steel iron, zinc, steel and copper. The Machine Shop has made significant progress in waste minimization by eliminating the need to buy special solvents, by recycling machine coolants and by using a vegetable-based coolant as a cutting oil.

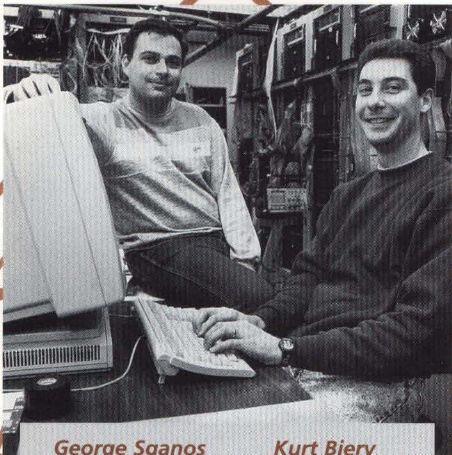
Contractors punch through the ground to recover a soil sample that will be analyzed for possible hazardous contaminants. They are also inserting temporary monitoring wells. Approximately 15 areas of the Laboratory, designated solid waste management units, have been tested this year. This work is part of the Resource Conservation and Recovery Act Facility Investigation that began in late fall.

Patricia LaVallie prepares to recycle the toner cartridge from a laser printer. Cartridges from all over the site are collected at the Property Office and then shipped in bulk off site to be recharged and reused. This particular recycling program keeps cartridges out of landfills and generates some revenue for the Laboratory.



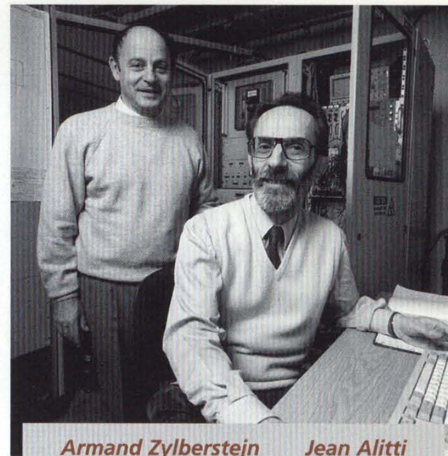
Taken in June 1993, this aerial view looking toward the northwest displays the exemplary wetland mitigation in the area of the Main Injector. Thanks to good management and favorable weather, the project to relocate approximately 10 acres to wetlands in the southwest quadrant of the site has progressed very successfully. About 500 wetland trees were planted. The darker areas in the photograph show where vegetation for sedge meadows was planted.





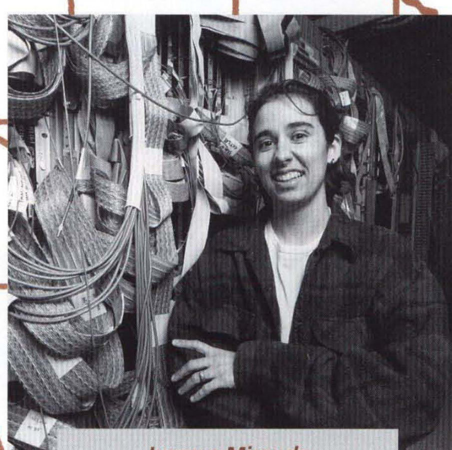
George Sganos
CDF
University of Toronto
Toronto, Canada

Kurt Biery
CDF
McGill University
Montreal, Canada



Armand Zylberstejn *Jean Alitti*
DØ
Centre 'Etudes Nucléaire, Saclay
Cedex, France

RESEARCH AT FERMILAB: AN INTERNATIONAL EFFORT



Jussara Miranda
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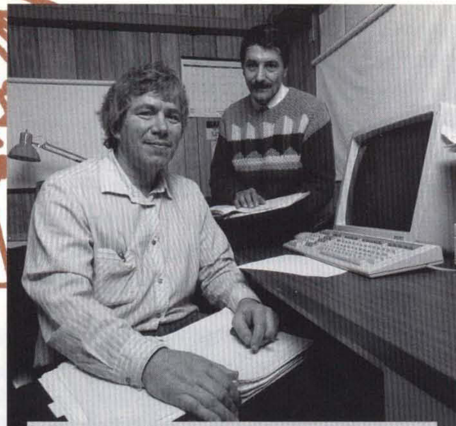
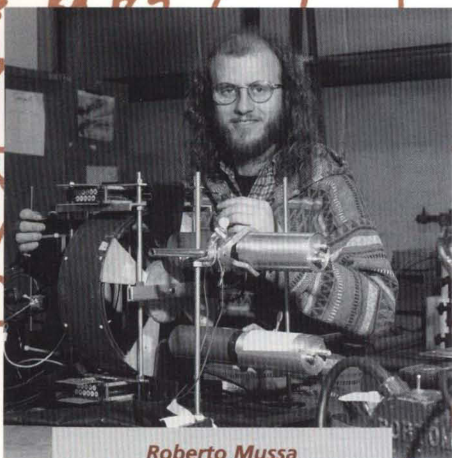
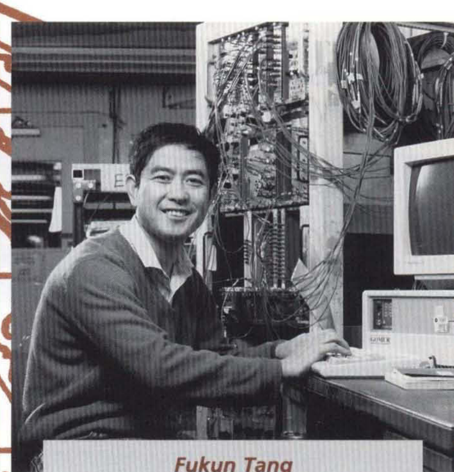
Centro Brasileiro de Pesquisas Fisicas
Rio de Janeiro, Brazil



Victor Bezzoubov   Valeri Evdokimov
DØ
Institute of High Energy Physics
Serpukhov, Russia



Roberto Mussa
E835
University of Turin
Turin, Italy



Fukun Tang
E781
Institute of High Energy Physics
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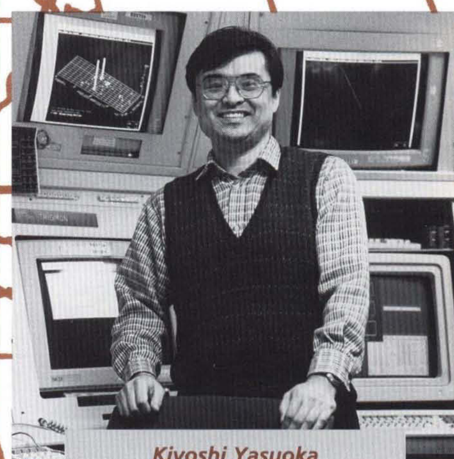


Kiyoshi Yasuoka
CDF
University of Tsukuba
Tsukuba, Japan

High-energy physics is an international activity, with scientists of many nations carrying out their research at the large particle accelerators that are central to this field. Although the exact numbers depend on the changing experimental program, about one-third of Fermilab's approximately 1,800 users are from non-U.S. institutions, from some 15 to 20 countries. The world map illustrates this, with photographs of a few representative visiting scientists superimposed on their home countries. ■

BREAKING BARRIERS: IMPROVING ACCESSIBILITY

The Laboratory has implemented several measures, ranging from administrative procedures to facility modification to state of the art assistive devices, all designed to provide greater accessibility for persons with disabilities.

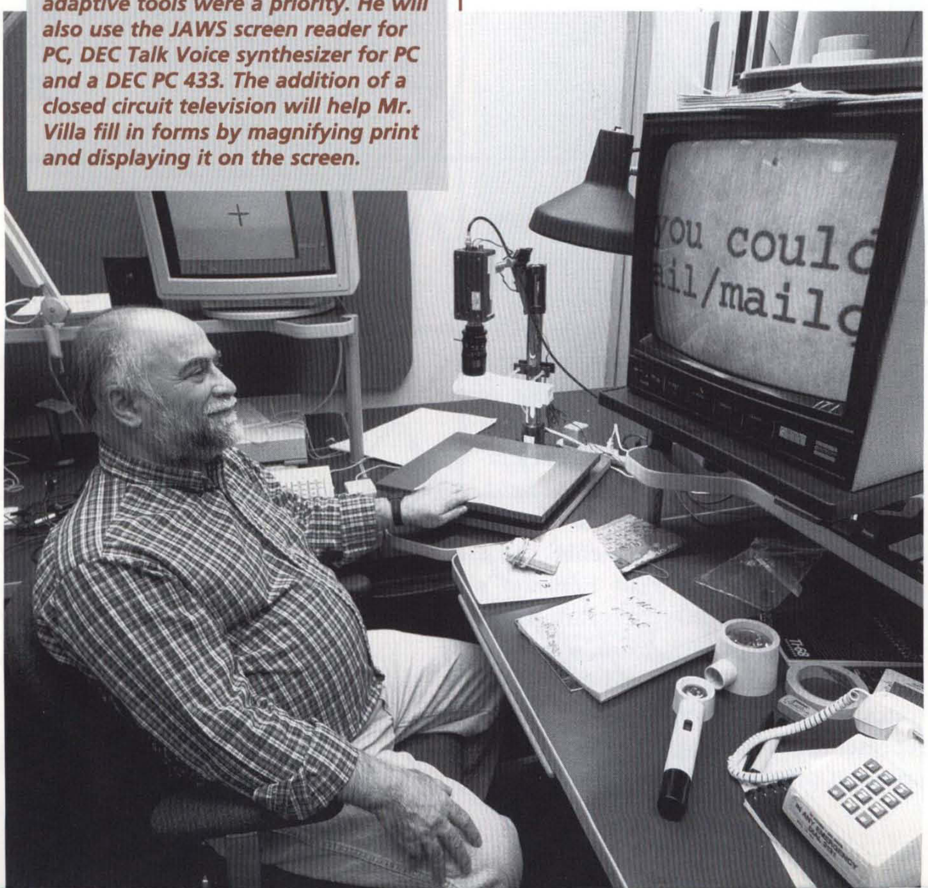
The first of these was the redesign of the employment requisition form that now details the essential functions of each posted position, along with the description of duties and educational and training requisites. Training classes have been provided to divisions and sections by the Equal Opportunity Office to facilitate the mandated functional analysis of each job. Required by the Americans with Disabilities Act of 1990, this process provides the basis for evaluating each candidate for employment based on that person's ability to perform the essential elements of the job and provides greater access to employment for persons with disabilities.

The year 1993 saw the completion of fully accessible rest rooms on the 1st floor, 15th floor and the auditorium level. In the first two locations, to provide greater convenience for visitors and applicants for employment, unisex facilities were designed complete with Braille markers on the doors. On the auditorium level, two new accessible rooms were designed, to provide a greater comfort level for patrons of the art and lecture series, colloquia and workshops. Water fountains in these areas were also redesigned and repositioned.

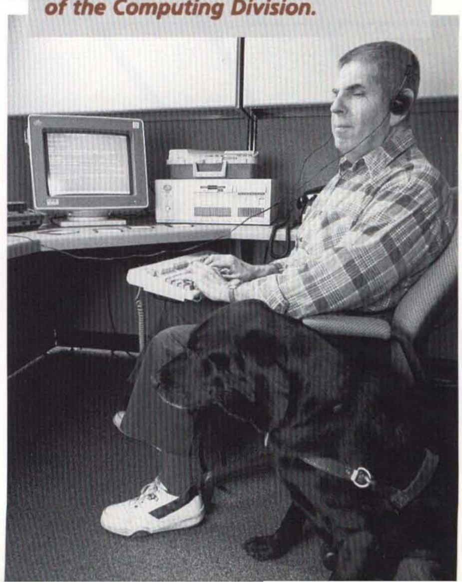
The most exciting development in 1993 has been the acquisition of specialized equipment to assist two visually impaired employees in remaining employed in challenging and value-added tasks. The employees are employed in the Computing Division and Technical Support Section. Both were retrained using the new technology at rehabilitative agencies in Chicago.

Very supportive management teams have helped the Laboratory provide continued challenging employment for two valued and able workers, Roy Jeffries and George Villa. The vendor community was very helpful in suggesting configured systems to transform data from paper to speech. Cooperation, thoughtful planning and the Fermilab can-do spirit are bringing the latest technology in adaptive accommodations to the Laboratory.

Voice synthesis technology and screen readers play important roles in the redesigned assignment for George Villa of Technical Support. A Senior Design Drafter, Mr. Villa was retrained over a period of several months at the Illinois Center for Rehabilitation and Education in Chicago. In his new assignment, he will have responsibility for writing documentation and for a department newsletter that will detail changes in procedures, equipment and software. To assist him with these tasks, he will use the Say It voice recognition and the TruVoice synthesizer for UNIX to recognize words and execute macros. He had used the UNIX platform primarily as a designer, so UNIX-based adaptive tools were a priority. He will also use the JAWS screen reader for PC, DEC Talk Voice synthesizer for PC and a DEC PC 433. The addition of a closed circuit television will help Mr. Villa fill in forms by magnifying print and displaying it on the screen.



Computer Operations Support Technician Roy Jeffries, accompanied by his guide dog Cody, is currently working on documentation of computer procedures for operators. He uses an IBM PC with interfaces for hookups to VAX and UNIX. This puts him on line to "talk" to other systems. To do daily status reports, he uses a voice synthesizer, CW Micro, and a screen reader, Vocal-Eyes. He was retrained at the Chicago Lighthouse for the Blind over a period of five months in word processing in D-base. Formerly, Mr. Jeffries had removed the excess oxide and particles from 9 track tapes. This new assignment reflects the changed technology and allows him to remain gainfully and interestingly employed and to become more of an integral part of the Computing Division.



TESLA: A SUPERCONDUCTING ELECTRON LINAC

In 1993 Fermilab personnel from the Accelerator Division and the Technical Support Section worked on TESLA (TeV Electron Superconducting Linear Accelerator), an international collaboration carrying out R&D on high-energy e^+e^- linear colliders. This collaboration headed by the DESY laboratory in Germany is looking at the feasibility of using superconducting rf cavities to accelerate electron beams to higher energies than ever achieved. With its proven expertise and experience in superconducting materials, cryostat design and large cryogenic systems, Fermilab is making a significant contribution to this international collaboration.

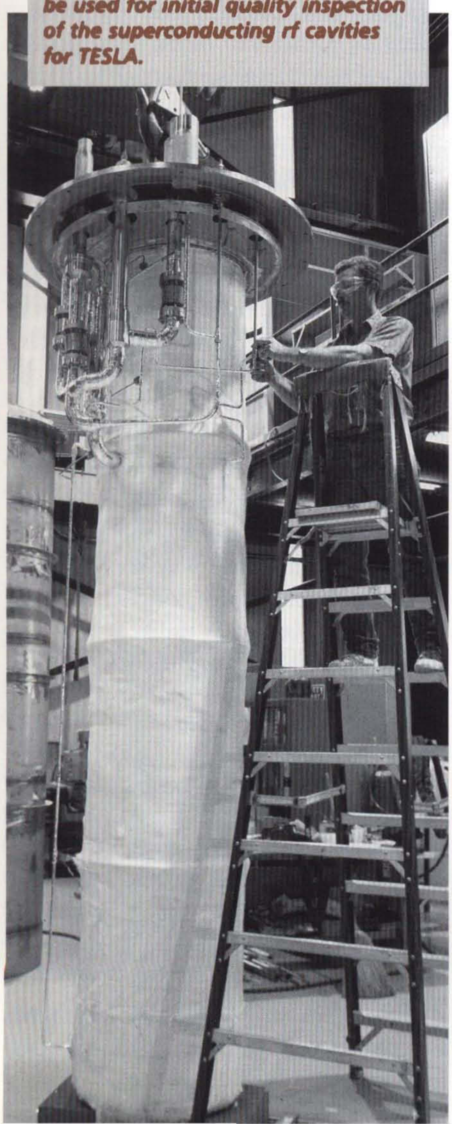
If the accelerating gradient is high enough and the rf systems and cavities can be made cheaply enough, this technique can be used as the basis of designing electron linacs whose beams could collide at center of mass energies of 500 GeV and higher. The superconducting rf has the potential technical advantage that it allows for much more accelerated charge distributed over a longer pulse duration. Because the events and backgrounds are spread over a longer time, the difficulties for an experiment's detectors are diminished.

The major advantage of these systems is the large beam-power-to-wall-plug power efficiencies. This ratio, as much as 25%, either can reduce operating costs or relax the need for very small spot sizes at the collision point.

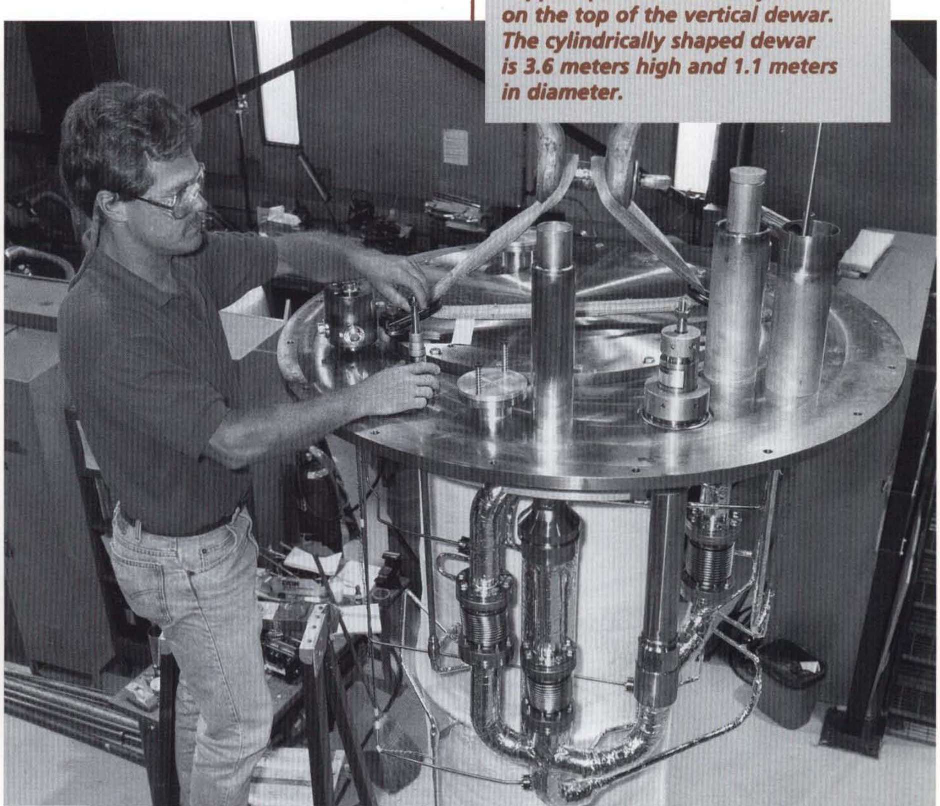
Fermilab is building many components for the TESLA Test Facility (a 500-MeV test linac using superconducting technology) including a vertical dewar and its associated rf insert. This device is used to condition superconducting rf cavities. Fermilab is also building a rf modulator that will be used to power one-half of the test linac. Both the dewar and modulator are almost completed and ready to be shipped to DESY. Other major efforts include building rf couplers, low-level rf systems and controls cards.

On the R&D front, Fermilab is building up capabilities to do rf component testing. In the AØ building there is a high-power normal conducting laboratory setup and in Lab 2 in the Village there is a modest - power superconducting setup. Both setups are used to test rf components that will be needed for the TESLA test facility. Fermilab is also supporting R&D tests at Cornell. Recently a superconducting rf cavity achieved an accelerating gradient of 25 megavolts/meter, the TESLA design goal.

Fermilab physicists are also involved in the physics of linear colliders. Their efforts at present are directed toward the TESLA design efforts and the Final Focus Test Beam at SLAC. It is expected that Fermilab's R&D efforts in future linear collider projects will expand rapidly over the next few years.



Donald Arnold inspects the final assembly of the liquid helium dewar built by the Technical Support Services Section. This dewar will be used for initial quality inspection of the superconducting rf cavities for TESLA.



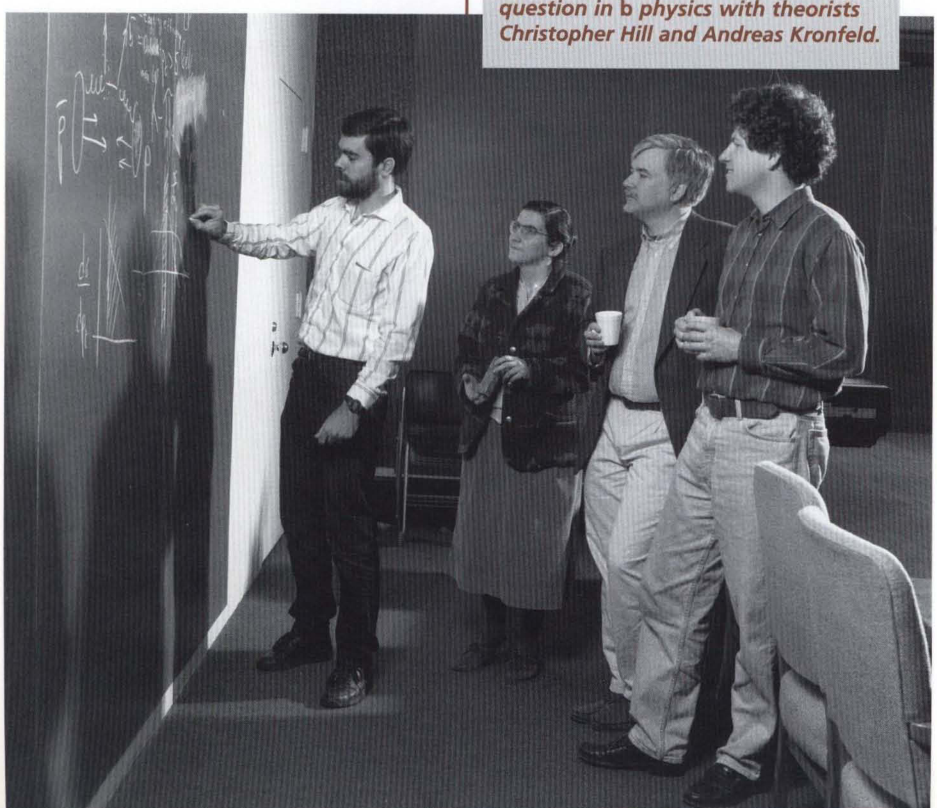
Mark Ruschman of Technical Support performs fine adjustments on the top of the vertical dewar. The cylindrically shaped dewar is 3.6 meters high and 1.1 meters in diameter.

THEORISTS AND EXPERIMENTALISTS: PARTNERS IN THE SEARCH

One difference between physics and other sciences is that physics has a more or less strict division into experimental and theoretical research. The main reason for this is that the laws of physics depend on mathematics in a more basic way than other sciences. Because the talents and training needed to carry out measurements in the lab are different from those needed to carry out mathematical calculations, physicists tend to take one path or the other at the start of their careers. One notable exception to this rule was Enrico Fermi for whom Fermilab is named. Few of us have the consummate experimental and theoretical talent of Fermi in one human frame. But by intense collaboration between experimenters and theorists, we can collectively aspire to have the ability of Fermi.

The theoretical side of this aspiration resides in the Theoretical Physics Department where 20 or so Ph.D. physicists work. The predominant activity of theorists at Fermilab is the elaboration of well-established physical theories. Essentially all phenomena in high-energy physics are remarkably well explained by a theory called the Standard Model. But the connection between the relatively simple equations defining the Standard Model and a derived result predicting an experimental measurement is usually rather involved. It is not uncommon for theorists to spend several months, working alone or in groups, to arrive at a result significant enough for publication.

At Fermilab there is a high level of cooperation between experimentalists and theorists. When an experimenter needs an explanation for a peculiar result, he or she often heads for the third floor of Wilson Hall, which is the home of the Theoretical Physics Department. Together experimentalists and theorists pool their knowledge and insight to understand whether the peculiarity is spurious or whether it can be reconciled with the Standard Model.



From the left, two experimental physicists, Fritz DeJongh and Vaia Papadimitriou, discuss a question in b physics with theorists Christopher Hill and Andreas Kronfeld.

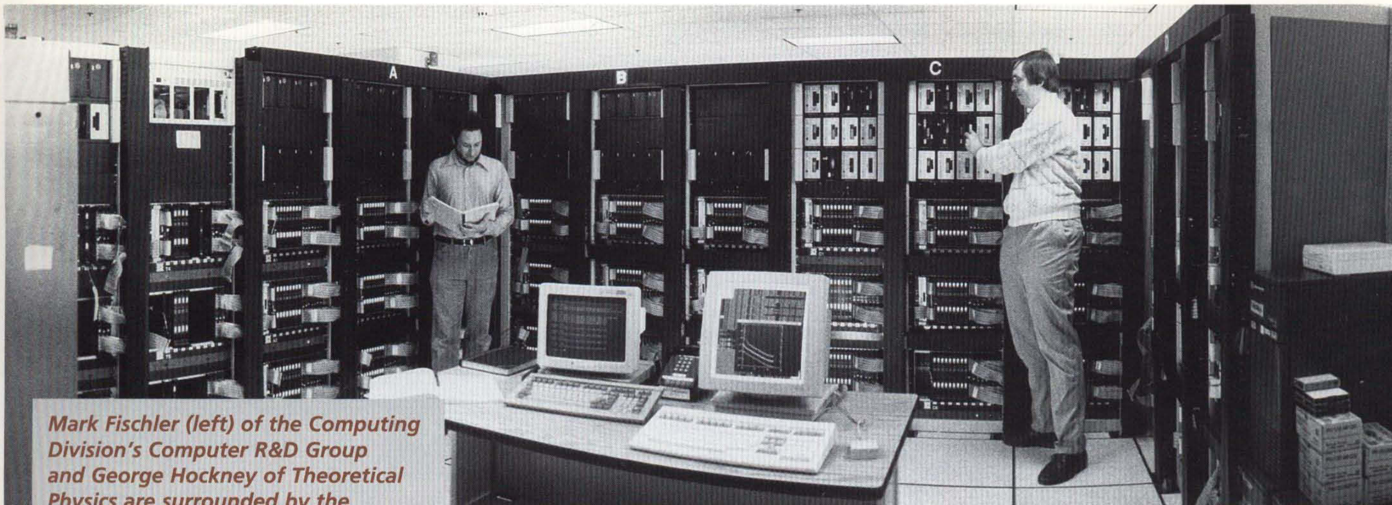
An example of such cooperation is the comparison of the theoretical prediction for W plus jets with measurements performed with the CDF detector.

Another extremely fruitful collaborative effort last year was an informal workshop on the potential of the Fermilab collider to do world-class *b* physics. This workshop brought together experimenters and theoretical physicists. The main advantages of the Tevatron as a site for *b* physics are the copious production of states containing *b* quarks and the wide range of states that are produced. Among the topics discussed at the workshop were B_c mesons, an exotic particle that contains a *b* quark bound with an anti-*c* quark; the possibility of observing CP violation and neutral *B* meson mixing at the Tevatron, especially using self-tagging modes; and the possibility that extremely rare decay modes of the *B* mesons may occur in new and exciting ways.

Another aspect of theoretical physics is the distillation of experimental results into a few central ideas. Theorists draw on their knowledge of the physical theory and weigh it with results from Fermilab and other high-energy physics laboratories. This synthesis not only draws attention to the importance of the individual experiments, but also reveals what measurements should be made in the future.

Once theory and experiment have been confronted in this way, the third duty of theoretical physicists is the invention of new models. One way to verify any physical theory is to concoct alternatives. Moreover, it is unlikely that any theory is complete and theorists would like to know what lies beyond the Standard Model. Sometimes a single new experimental discovery will inspire a new way of thinking. More often patterns emerge that can be discerned after considering the measurements of a variety of experiments. Frequently theorists devise new models using only aesthetics and mathematical elegance as a guide.

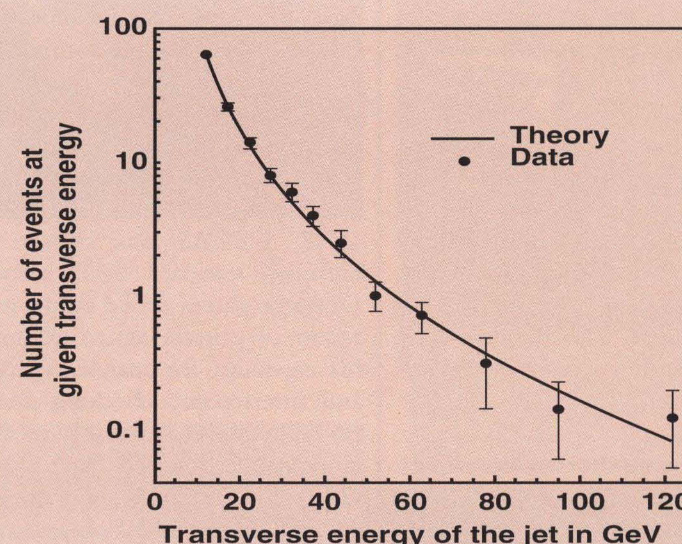
It may seem surprising that aesthetics can play a role in physics, but a good



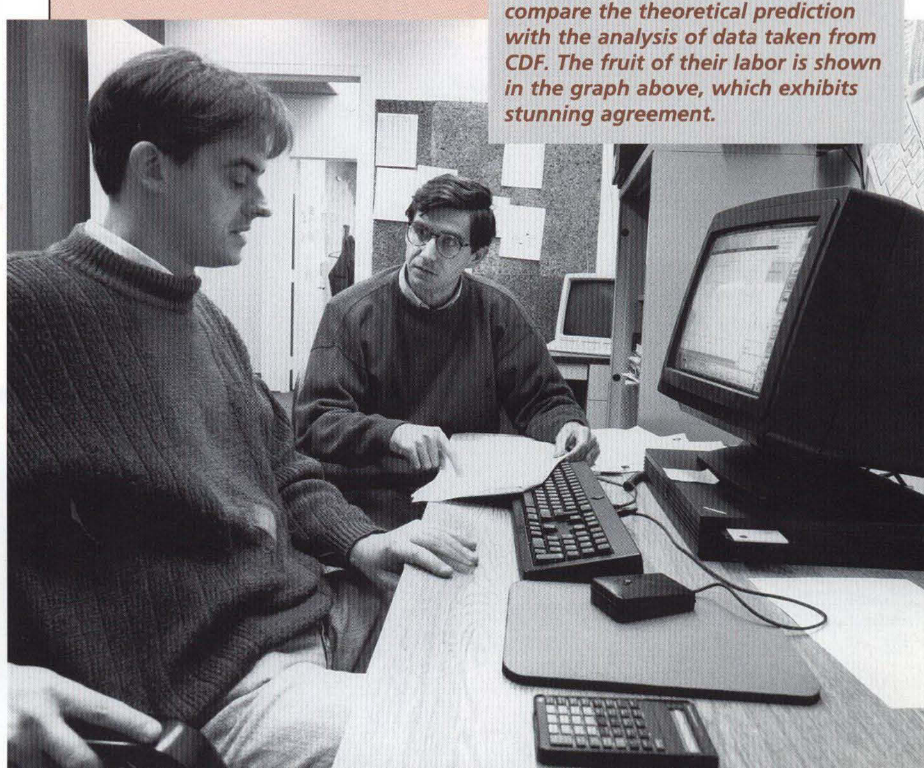
Mark Fischler (left) of the Computing Division's Computer R&D Group and George Hockney of Theoretical Physics are surrounded by the ACPMAPS, one of the most powerful computers in the world. Fermilab theorists use this parallel supercomputer to compute a variety of properties of systems containing heavy quarks. Their results will be essential for linking results from Fermilab experiments to the fundamentals of the Standard Model.

example appears in the Standard Model itself. In 1977, a Fermilab experiment discovered a new particle called the upsilon. It soon became clear that the upsilon is an atom-like structure made out of a (then) new quark and its antiparticle. Extending the Standard Model with just one quark turns out to have very ugly mathematical properties. But the aesthetics can be maintained by introducing quarks two at a time. The new quark in the upsilon was dubbed "bottom" and its partner "top." Since then, experiments performed all over the world have established the validity of this approach, except that the top quark has not yet been seen. Indeed, the circumstantial evidence for the top quark is so strong that discovering top and measuring its properties is one of the major goals of Tevatron experiments.

Nonscientists often ask how theoretical physicists spend their workdays. As in all professions there is a certain amount of drudgery. But many things, such as wrestling with equations, that some people might find tedious, a theorist finds engaging. Methods aside, the motivation and reward for a theorist is the same as for an experimenter: the challenge of obtaining a deeper understanding of nature.



Below, theorist Walter Giele (left) and experimentalist Jose Benlloch compare the theoretical prediction with the analysis of data taken from CDF. The fruit of their labor is shown in the graph above, which exhibits stunning agreement.



EVOLUTION OF CAD/CAM AT FERMILAB

The machine design process is defined as specification of the arrangement, geometry and structure of the elements forming a machine. Two decades ago the process involved the following sequence: (i) the engineer formalized a design concept with a sketch; (ii) the proposed design was analyzed to determine stresses and deformations resulting from the known specific load configurations to which the machine would be subjected; (iii) results of the analysis suggested refinements in the design; (iv) this analysis and refinement process was repeated until a satisfactory prototype design was achieved; (v) a drafter produced drawings, that were sent to a machine shop for fabrication of a prototype; and (vi) the prototype was then tested in a laboratory under expected operating conditions that usually yielded further design refinements. This iterative cycle was repeated until a satisfactory prototype was achieved.

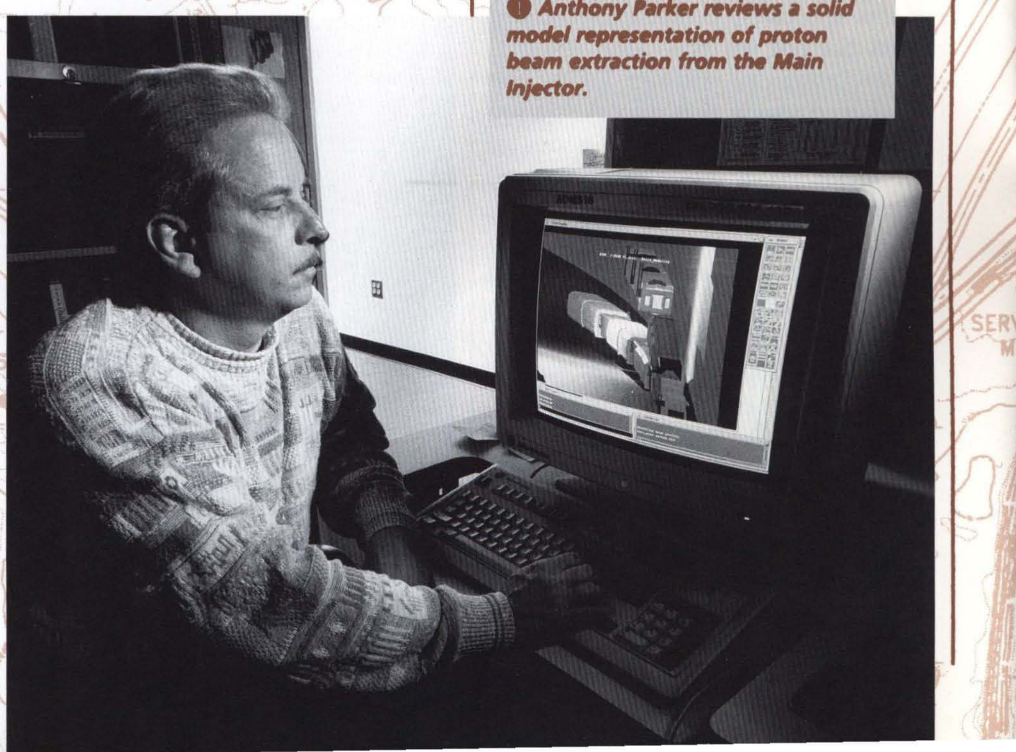
The advent of computer assisted design and manufacturing (CAD/CAM) technology promised an integrated mechanical design process, thus allowing a prototype to be designed, analyzed and machined in one automated sequence. Design changes or improvements could be easily implemented, thus saving time and money and increasing productivity. CAD/CAM pioneers envisioned that a three-dimensional computer model would serve as the master data definition for design, analysis and generation of detailed part drawings and instruction files for numerically controlled machines. The computer model concept introduced the possibility of "numerical experimentation." More "what-ifs" and failure modes could be investigated using a computer model of a critical element than with the prior method of building-and-breaking prototypes in the laboratory, which is expensive and time consuming. This numerical experimentation process was paralleled in other sciences, e.g., creation of new polymers in chemistry, aerospace vehicle design, naval architecture and the design of electromagnetic devices.

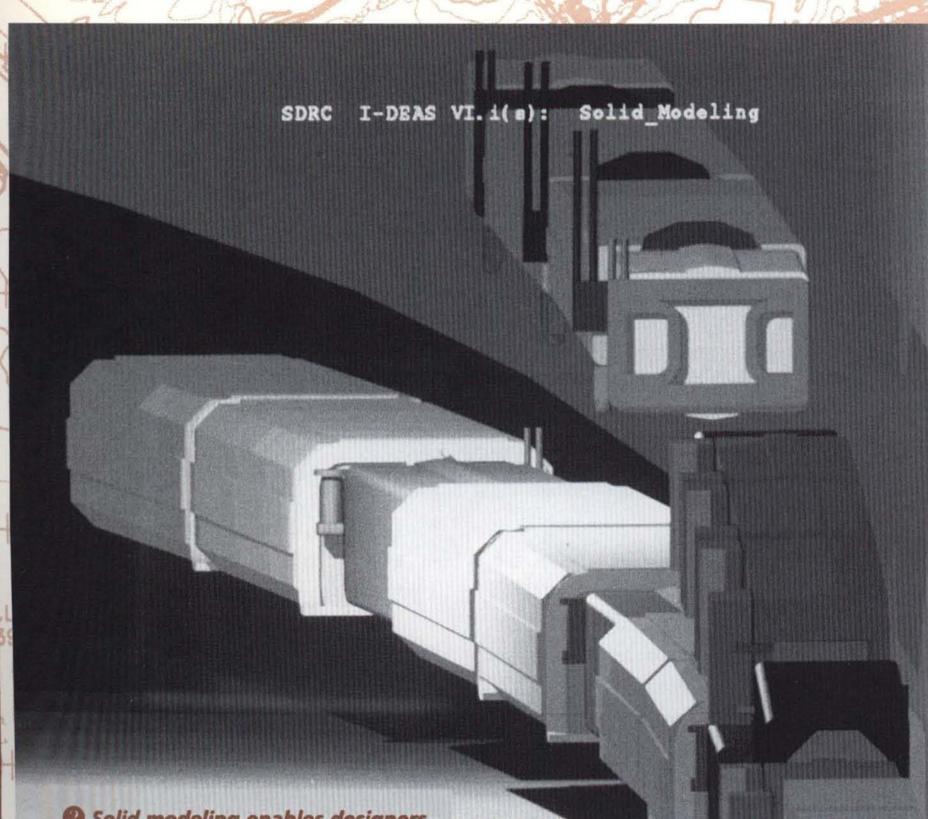
The evolution of CAD/CAM at Fermilab is a reflection of developments in the rest of the CAD/CAM world. Approximately 10 years ago Fermilab began using CAD/CAM software that generated a three-dimensional "wireframe" representation of objects and had surfacing capability for the generation of numerical machining files. Images were time consuming to draw because the software producing and controlling the display resided on a mainframe. As additional terminals were added and usage increased, mainframe response time degraded. In 1988, I-DEAS was chosen as the Fermilab standard CAD software. I-DEAS produces a solid model representation of objects aimed at improving the capability for analysis, visualization and interference checking and has a two-dimensional drafting module for generating detailed part drawings. Other CAD/CAM software such as AUTOCAD and ANVIL has since been acquired to supplement the capabilities of I-DEAS. Over the last several years, I-DEAS has migrated from VAX mini-computers to distributed local networks of UNIX workstations. Individual workstations deliver constant, predictable interactive performance for a given application. The cost per user is much lower than for mainframes or mini-computers. Each workstation has a high-speed graphics processor to relieve its main CPU of graphic display tasks and allow geometric calculations to proceed unimpeded. Local network technology allows efficient sharing of data and information.

At Fermilab most, but not all, of the original promise offered by CAD/CAM technology has been realized over the last 10 years. The time between design iterations has markedly improved, resulting in a streamlined design process. However, the theoretical ideal of a master data definition for design, analysis and numerically controlled machine part files has not been fully implemented. Separate, independent models for the same design are constructed for analysis and numerical machining. Generation of two-dimensional part files from a solid model representation has been inefficient and has fallen short of expectations.

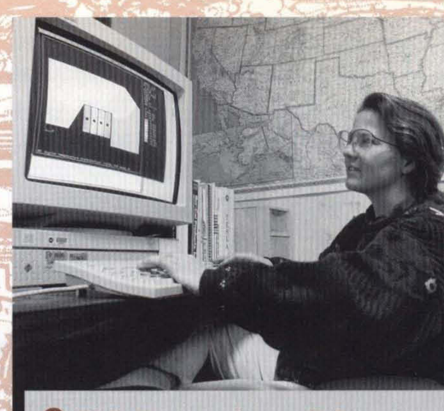
This series of photographs shows the use of CAD/CAM technology in the production of end plates for a Main Injector dipole magnet.

❶ Anthony Parker reviews a solid model representation of proton beam extraction from the Main Injector.





2 ***Solid modeling enables designers to check interferences with existing accelerator hardware.***



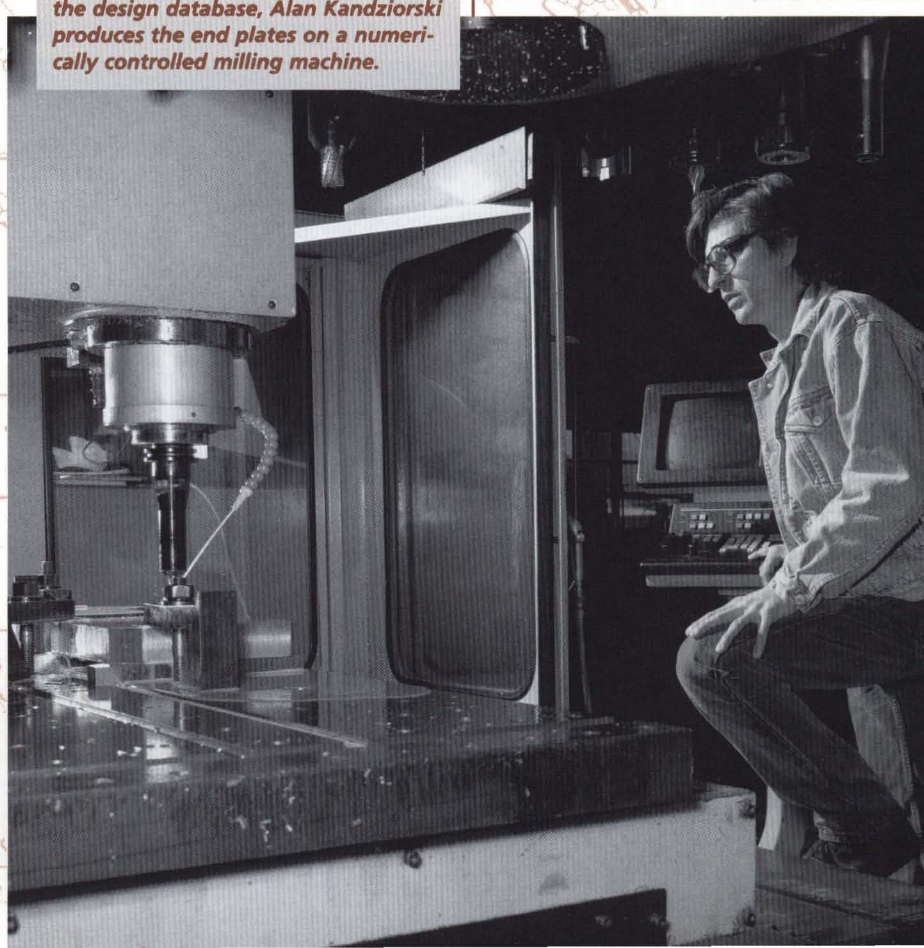
3 ***Tricia Heger reviews a finite element thermal model of a Main Injector magnet cross section. Detailed analysis is the final step in the preliminary design phase prior to creating drafting layouts.***

4 ***After the drafting layout is completed, Alan Kandziorski creates toolpaths for the surfaces of an end plate for a Main Injector dipole magnet.***

In order to survive in the CAD/CAM arena vendors have specialized. The most appropriate CAD software is not necessarily provided by the same vendor who offers the most powerful analysis or CAM software. In fact, many CAD/CAM users even prefer multiple vendors for different solid modeling or drafting applications. This is exemplified at Fermilab by the use of I-DEAS and AUTOCAD for CAD, ANSYS and I-DEAS for analysis, and ANVIL and SMARTCAM for CAM. Integration of these separate elements is a future challenge for Fermilab.

The payoff from an investment in CAD/CAM technology comes from better design visualization, improved accuracy, the capability to implement design changes and a better final product. ■

5 ***Using toolpath data created from the design database, Alan Kandziorski produces the end plates on a numerically controlled milling machine.***



Screened in the background is a superb example of lab-wide collaboration. The preliminary Main Injector CAD drawing by the Facilities Engineering Services Section integrates beamline locations from the Accelerator Division, survey coordinates from the Research Division's Alignment group and aerial data from Aero-Metric Engineering, Inc.

DATA-ACQUISITION SYSTEMS: NEW AND IMPROVED IN 1993

Data-acquisition systems capture collider and fixed-target events at the instant they occur and then carry the data through inspection and reduction until the resulting physics information is saved in computer storage for analysis by physicists. 1993 was a very busy year for DA systems at Fermilab — the fixed-target experimenters participated in the creation of a new system; both collider experiments, CDF and DØ, prepared upgrades to their DA systems between Runs Ia and Ib, in anticipation of increased luminosities of the Tevatron.

COMPUTING DIVISION PLAYS DARTS WITH EXPERIMENTS

DART is the new data-acquisition system being developed through a collaboration between the Computing Division's On-line Support Department and six Fermilab experiments — E781, E811, E815, E831, E832 (KTeV) and E835.

The complexity of the experiments, their data-taking throughput and event filtering requirements range from a few (2-5) to tens (50) of CAMAC/FASTBUS and home-built front-end crates and channels of data and from tenths of Mbytes/sec to 200 Mbytes/sec front end data-collection rates.

Members of the On-line Support Department and each of the collaborating experiments are working together in the design of the system architecture, the development and commissioning of new hardware modules, design and coding of the software components, and integration of the components into working data-acquisition systems.

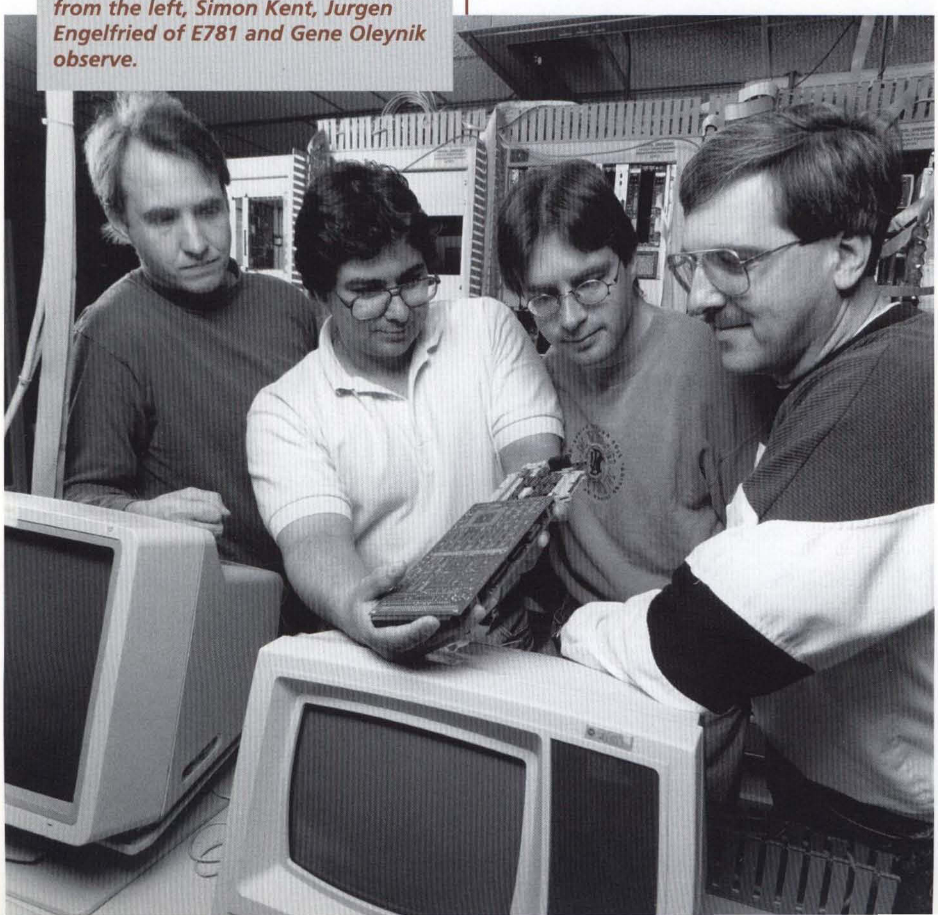
At one extreme, E815 includes a single VME crate and MVME167 20-mip embedded VME processor, which reads out 6 streams of data, records and distributes samples of the data over Ethernet for on-line analysis. (One mip equals one million instructions per second, a measure of computer chip speed.)

At the other extreme, KTeV requires at least 5 VME crates operating "in parallel" into which, during the beam spill, data will be pumped up 8 parallel streams at 200 Mbytes/sec into 4 gigabytes of memory. Workstations of 400-500 mip will read out the memories over VME and process the data in real time to increase the physics sample and record only the best 10% onto tape.

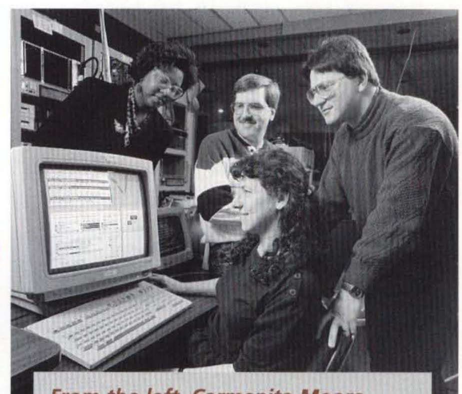
The DART project has been underway for a year. Some parts will get a first exposure in 1994.

DØ DATA TAKING SYSTEM UPGRADES FOR RUN 1b

Two factors motivate the upgrade of the DØ DA system: the expected factor of two increase in collider luminosity for Run Ib and the desire to increase the quality of the data recorded.



Oscar Trevizo holds a prototype of an input/output controller while, from the left, Simon Kent, Jurgen Engelfried of E781 and Gene Oleynik observe.



From the left, Carmenita Moore, Gene Oleynik, George Zioulas of E835 and (seated) Laura Appleton observe the DA message display system developed by DART and CDF.

Anna Majewska of E835 shows members of the On-line Support Group a histogram of simulated events distributed with the DART system. Shown from the left are David Slimmer, Jonathan Streets and Dennis Black.

Richard Kwarciany, Margaret Votava, David Berg and Robert Forster (left to right) investigate the upgraded FASTBUS readout control developed for E781, E831 and KTeV.

The heart of the system is a commercial Ultranet network that delivers data from the front-end electronics to a series of Silicon Graphics computers. These processors make up the Level 3 trigger system; they run analysis programs that make the final trigger decision for each event. The data can be transferred simultaneously from multiple front systems to multiple SGI systems in parallel, increasing the data throughput by up to a factor of five.

A new FASTBUS Readout Controller has been developed to collect the data from FASTBUS front-end modules and deliver it to the VME processors. CDF and the Computing Division developed the hardware and software. Events accepted by the Level 3 trigger are routed via Ultranet to another SGI system dedicated to data logging. From here, a subset of the events are distributed over FDDI (fiber distributed data interface) and Ethernet to various online monitor programs.

While at 100 Hz, the rate of events delivered to the Level 3 processors is now several times that of the previous system, it must be expanded still further for subsequent runs. ■

CDF PREPARES FOR RUN Ib

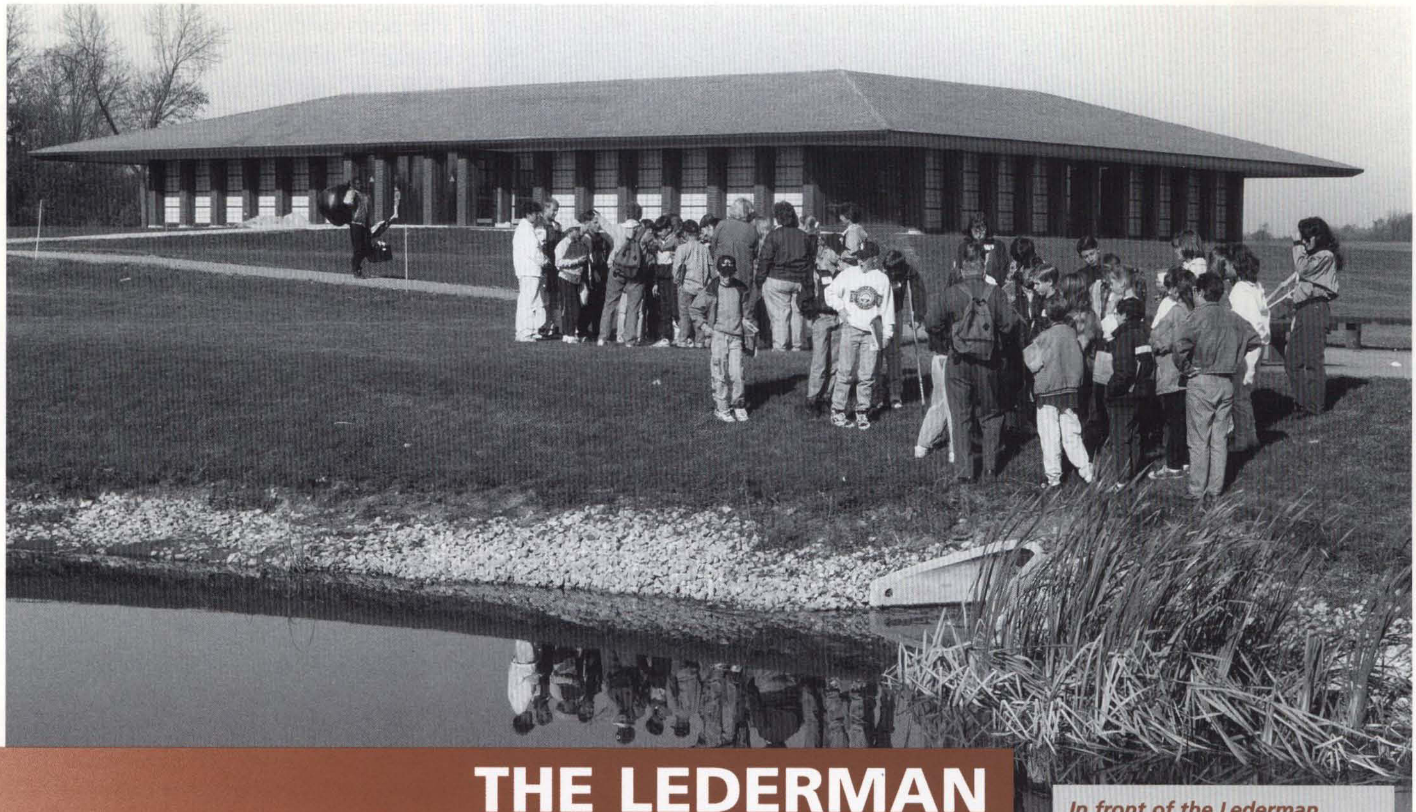
CDF is installing an upgraded data-acquisition system for Collider Run Ib, which began in December 1993, to meet the data rate from the higher beam luminosities.

Improvements have been made to all levels of the triggering and filtering systems that select the few events for recording from among the ~100,000 interactions per second that occur. These improvements include the ability to better identify the properties of jets as seen in the calorimeter at Level 1 and to better identify the properties of jets, electrons and mu leptons at Level 1.5.

During Run Ib more sophisticated algorithms will be applied in the Level 2 filtering system. These include the ability to calculate the location of the interaction vertex and use it to obtain better event parameters and to more accurately identify rare interesting events.

The event-building and recording capabilities of the system have been upgraded by factors of 1.5 and 2 respectively. It is expected that these upgrades will result in increases in both the quality and the quantity of data taken during Run Ib.

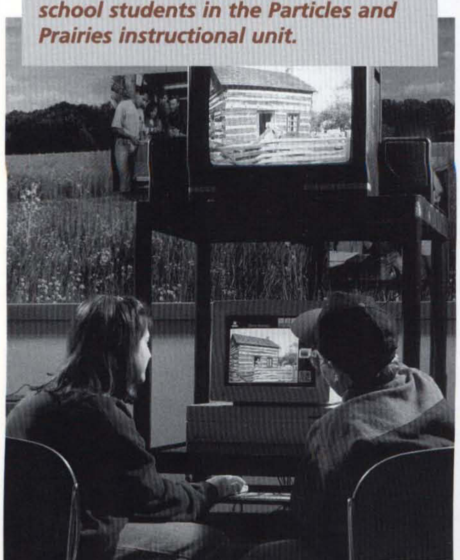
James Meadows, Neal Wilcer, John T. Anderson and Thavichai Sayasane (left to right) check connections on the fiber adapter boards DART is developing for E781.



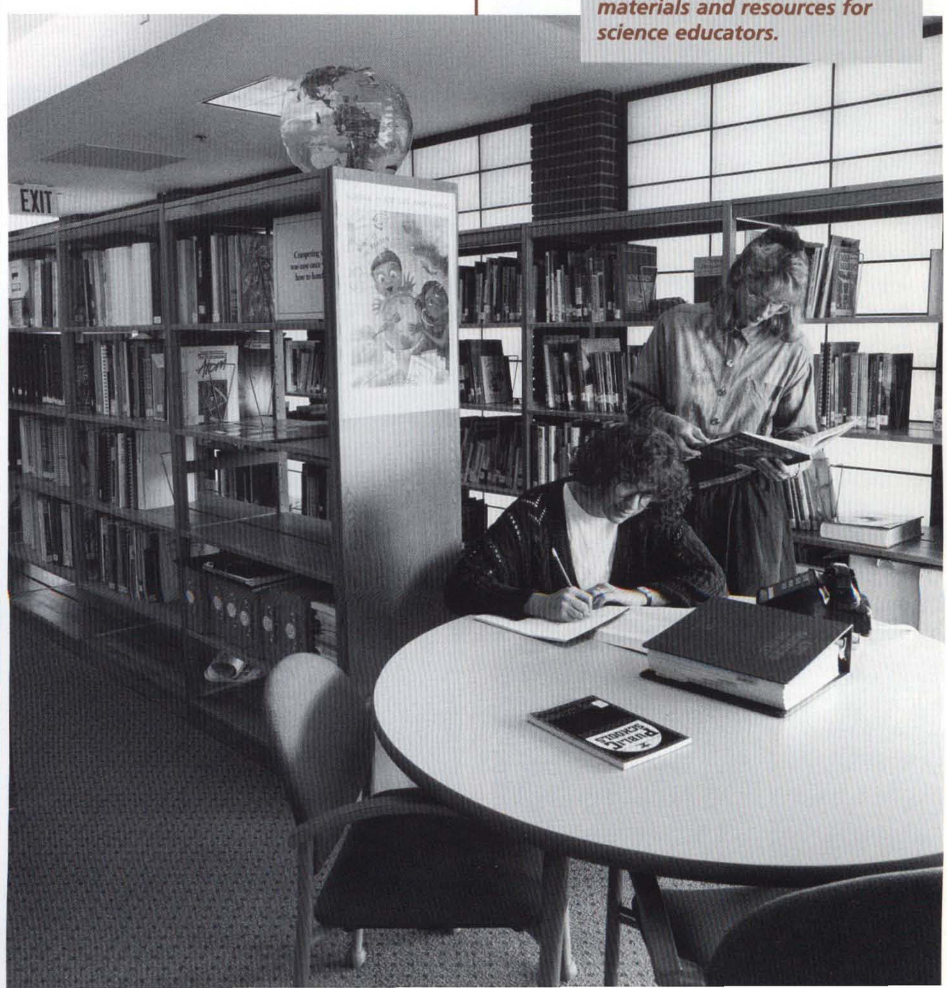
THE LEDERMAN SCIENCE CENTER: A PLACE TO DISCOVER

In front of the Lederman Science Center, students prepare for field study in the Fermilab prairie.

In 1993, the Leon M. Lederman Science Center celebrated its first full year of operation. More than 13,400 students and 1,300 teachers visited the attractive new building to explore scientific topics ranging from acceleration to prairie insects and to discover — or rediscover — the excitement of learning and teaching science.

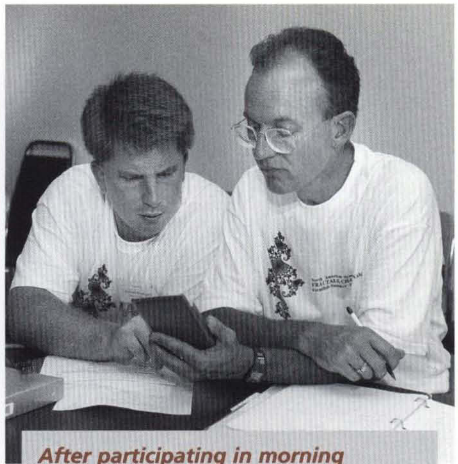


A multi-media station in the Technology Room allows interaction and promotes learning for middle school students in the Particles and Prairies instructional unit.

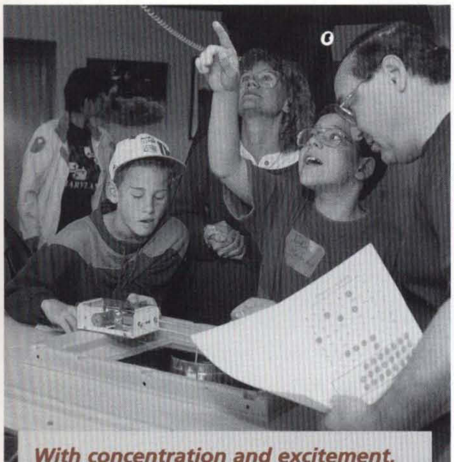


The Teacher Resource Center is a clearinghouse for ideas, materials and resources for science educators.

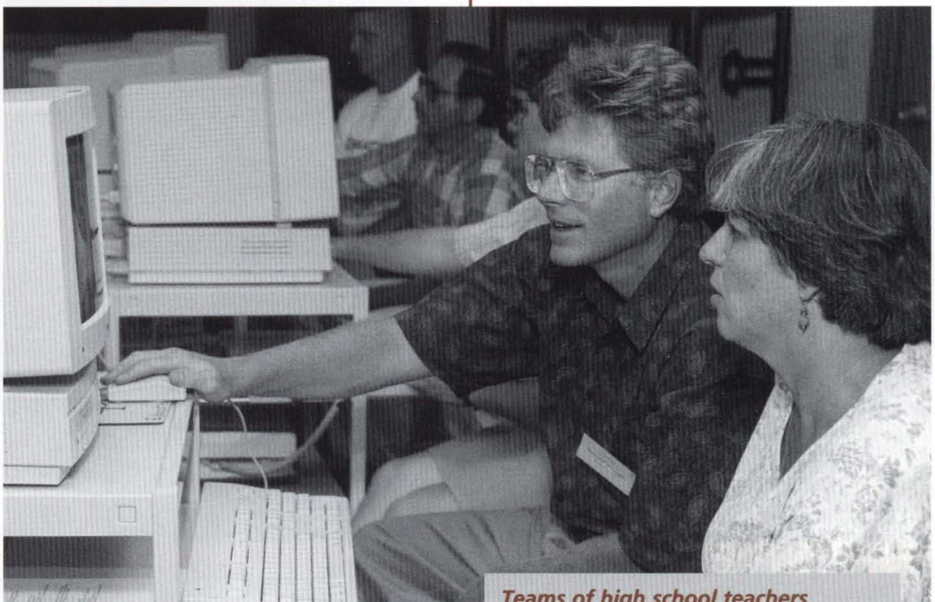
Docent Laura Vazquez (left) assists a student graphing data at "Race for Energy," one of the interactive teaching stations in the Accelerator Room.



After participating in morning lectures given by world-renowned speakers, high school teachers in the Fractals, Chaos and Dynamics Symposium program confer during an afternoon work session.



With concentration and excitement, students explore wave patterns in the Detector Room and record their discoveries in a log book.



Teams of high school teachers gathered at Fermilab as part of the Illinois Leadership Institute. They developed leadership skills and curricular expertise in order to be advocates of change within their local school systems.

On the way to a study site, students listen with rapt attention to Docent Robert Kelly's explanations of the various ecosystems they will encounter. In the rear, Robert Lootens (left) and David Abler observe.

HISTORY AND MISSION OF THE BATAVIA AREA OFFICE

The origins of the Batavia Area Office coincide with the beginning of the National Accelerator Laboratory. In 1966, when Illinois was selected by the U.S. Atomic Energy Commission for the site of what was later to be called Fermi National Accelerator Laboratory, a small cadre of personnel from the Chicago Operations Office was assigned to begin the planning and management of the Laboratory. This group, along with the initial Laboratory management staff, rented office space in Oak Brook. In 1968 after portions of the Laboratory site were acquired, these people moved to temporary offices in Village housing and then to Wilson Hall, a landmark on the prairies of Northern Illinois.

The management style and philosophy of BAO and Fermilab can also be traced back to their first leaders: Kennedy C. (K.C.) Brooks, BAO Area manager, and Bob Wilson, Fermilab's director. These people were committed to getting Fermilab built successfully within the budget approved by Congress. They strongly believed that they needed full commitment and cooperation from both government and the Laboratory. They knew their customers were the Headquarters Program Office and the Laboratory users. Although these early leaders had never heard the phrase "Total Quality Management," they would have felt right at home with what we are now calling TQM. They energetically promoted the concept of satisfying the customer; and obviously this idea worked — their efforts resulted in building a world-class research facility.

BAO has changed in size and nature over its 25 year history; but commitment to the philosophy originally established remains the same today. We still believe the unique working relationship between DOE and Fermilab was a significant factor in the successful construction of the original laboratory and the Tevatron. How does one develop a good working relationship? In the course of building a major project, or even operating an ongoing facility, problems and differences come up. But, if people have the same missions and goals, effective communication is the most important element in developing a strong relationship. Any problem can be resolved if people are forthright with each other. However, effective communication does not happen without honest, sustained effort. BAO has thousands of interactions with Fermilab personnel over the course of a year. Right from the start BAO and Fermilab developed the habit of being open in dealing with each other. This shows in Fermilab's performance as a world-class facility in high-energy-physics research.

K.C. Brooks and Bob Wilson had great respect for the environment. They insisted that science be conducted in harmony with the environment. K.C. and Bob wanted to make Fermilab both unique and beautiful, and they did, at a minimum cost. They even believed that being frugal would enhance productivity. They were committed to doing the best job at low cost, in compliance with applicable government requirements, including environmental, health and safety considerations, and with respect for employee concerns. They were ahead of their time. They developed good relations with the communities surrounding the Laboratory and developed the Open Laboratory Concept. They believed in diversity and strongly promoted equal employment opportunity programs.

Today BAO remains strongly committed to carrying out the vision and philosophy established originally because this philosophy and approach represent the best hope for the future of science. In an era of tight budgets, this style of management is virtually mandatory if science is to progress.

BAO has always viewed its mission as providing a service that helps Fermilab in accomplishing its research program effectively within the framework of the government system and conducting the required oversight for a government Management and Operating contract. Our on site presence and personal familiarity with local conditions enable us to make timely decisions. We recognize that if Fermilab succeeds, we succeed. There are few things in life that give more satisfaction than building something worthwhile and being a part of a successful team.

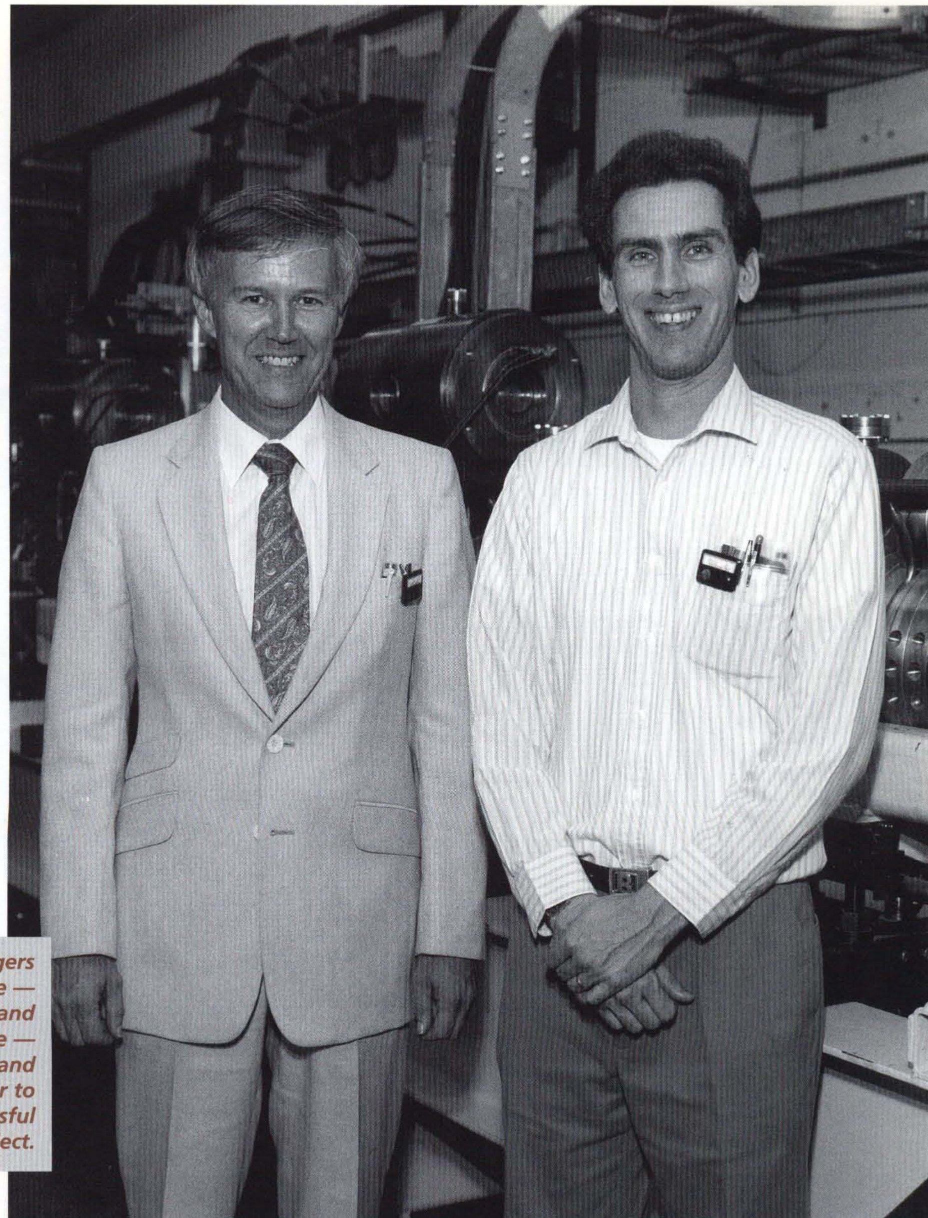
Over the years BAO has responded to various changes within DOE and at Fermilab. Changes currently underway within DOE will surely affect how this office and the Laboratory conduct day-to-day activities. The new mission statement for DOE clearly recognizes the continued need for basic research efforts such as the Fermilab high-energy-physics program. We believe the DOE Core Values and the principles of TQM represent the philosophy that the Batavia Area Office and Fermilab have always endorsed. The BAO pledges to continue to apply these values and principles in our future operations.

DOE and its laboratories face new challenges today. As we have seen in recent Congressional action on the

On August 27, 1993 Andrew Mravca, longtime head of the Department of Energy's Batavia Area Office, signs a memo recommending approval of the Linac commissioning, which allowed the Laboratory to begin injecting beam into the new Linac.

Superconducting Super Collider and other science projects, we can no longer assume that the value of basic research is well understood and supported. We must strive as a team to demonstrate the relevance of our efforts at Fermilab to national needs, including technology transfer, science education and economic development issues. We are challenged, as well, to improve the way we do business. DOE's Quality, Contract Reform and Strategic Planning initiatives, as well as the President's Reinventing Government program, call for us to critically reexamine traditional approaches.

Fermilab's history illustrates how, as a team, DOE and the Laboratory can accomplish great things. We are sure that the DOE/Fermilab team will respond to future challenges in the same successful way. **Andrew Mravca**



The two project managers for the Linac Upgrade — DOE's Norman Hansen (left) and Fermilab's Robert Noble — cooperated closely and continually in order to ensure the successful completion of the project.

DOE CORE VALUES

1. We are customer-oriented.
2. People are our most important resource.
3. Creativity and innovation are valued.
4. We are committed to excellence.
5. DOE works as a team and advocates teamwork.
6. We respect the environment.
7. Leadership, empowerment, and accountability are essential.
8. We pursue the highest standards of ethical behavior.

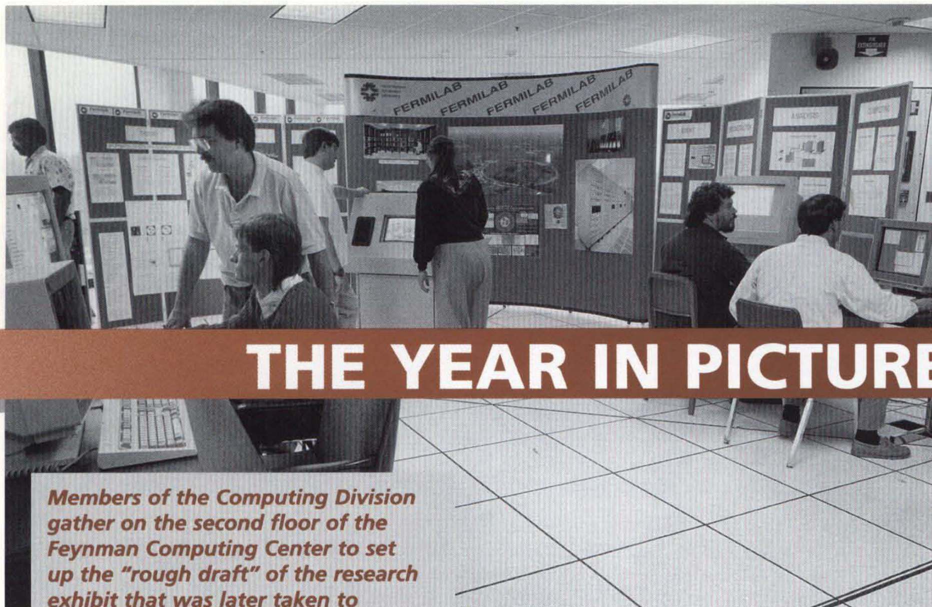
DOE MISSION

The Department of Energy is entrusted to contribute to the welfare of the nation by providing the scientific foundation, technology, policy and institutional leadership necessary to achieve efficiency in energy use, diversity in energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense.

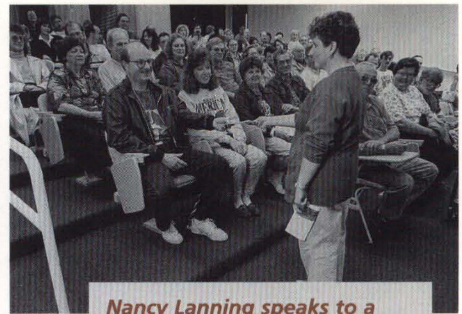
CHICAGO OPERATIONS OFFICE

- Established in 1946 to support Enrico Fermi's pioneering work at the University of Chicago
- Located at Argonne National Laboratory
- Leader in R&D for nuclear technology and nuclear power
- Responsible for $2.4 billion annually in basic research, energy research, development and construction
- Manages contracts for operation of Fermilab, Argonne, Brookhaven, Princeton and Ames Laboratories
- Maintains area offices at each laboratory except Ames

THE YEAR IN PICTURES



Members of the Computing Division gather on the second floor of the Feynman Computing Center to set up the "rough draft" of the research exhibit that was later taken to Portland, Oregon for Supercomputing 93, the premier meeting for the field. The booth demonstrates the kinds of supercomputing that support the four major phases of high-energy-physics research — theory, data acquisition, event reconstruction and physics analysis. Shown clockwise from the front left are Roberto Ullfig, Michael Isely, Karmegam Thayalan, David Potter, Elizabeth Schermerhorn, Marc Mengel and Mark Kaletka.

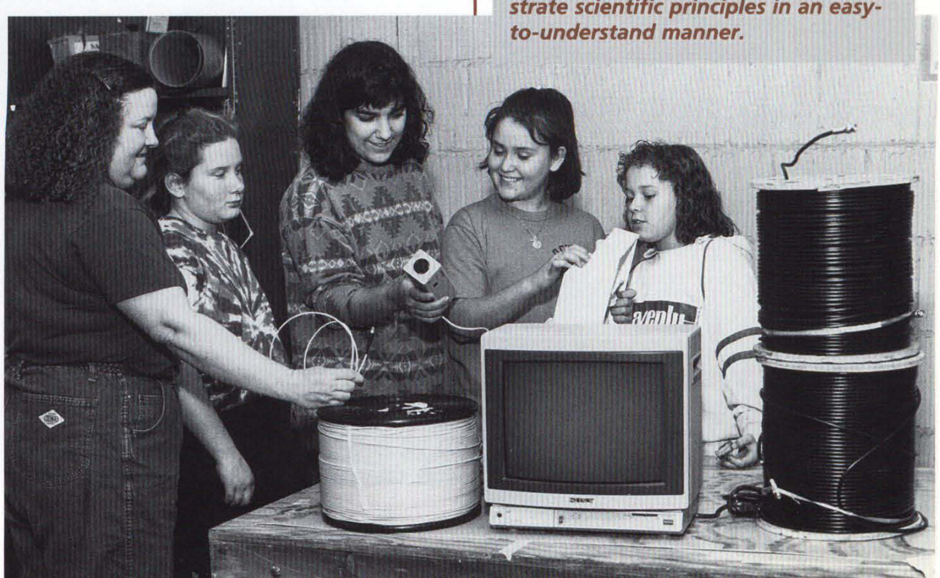


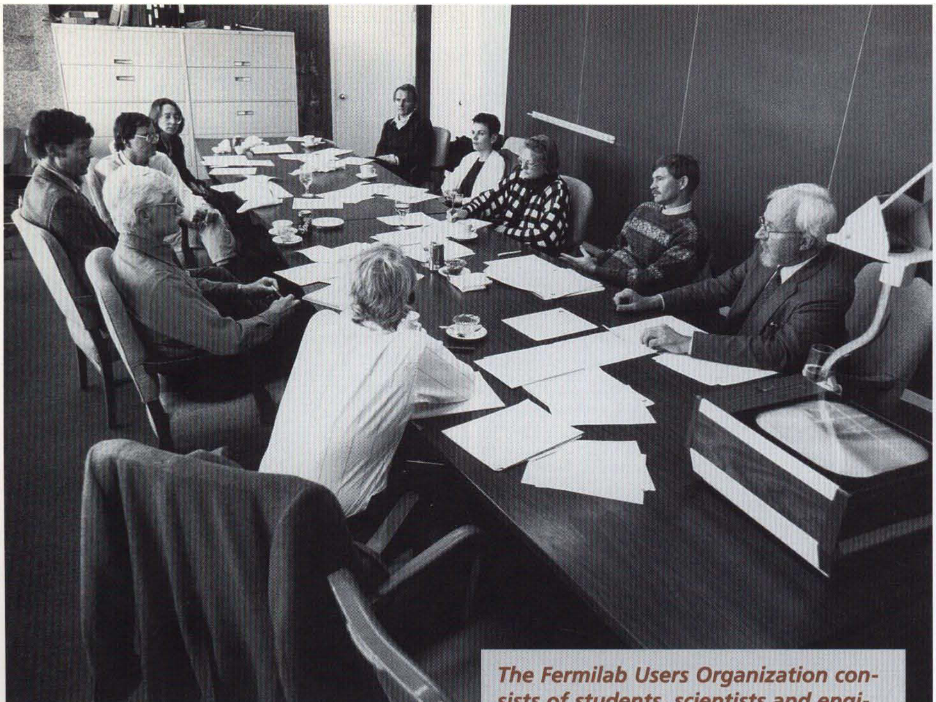
Nancy Lanning speaks to a full house during one of the Summer Sunday Tours offered by the Public Information Office. The tours were particularly popular this year because visitors had the opportunity to see the Antiproton Source.

These Fermilab pioneers celebrated 25 years of continual service to the Laboratory in 1992 and were recognized by Director Peoples on October 1, 1993. Row 1, left to right, Reid Rihel, Jean Lemke, Glenn Lee, Barbara Kristen and Quentin Kerns. Row 2, left to right, John Peoples, Charles Marofske, Lincoln Read, Angela Gonzales and Jan Wildenradt. Not pictured: Carolyn Hines.

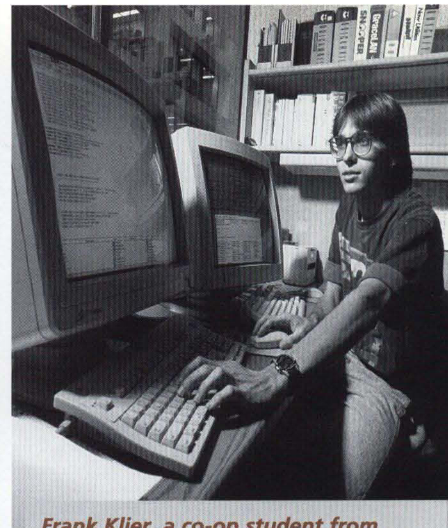
During one of the Business Services Section's monthly management walk-throughs, Steven Bluma of the section's Environment, Health and Safety group examines the tag on a shower/eyewash station at the Shipping and Receiving warehouse. Each month the group conducts an inspection of a different area to ensure that everything is in compliance with safety requirements of the Department of Energy, other federal dictates and the standards set by the Laboratory itself.

At SciTech in Aurora, Miriam Bleadon (center) of Fermilab's Research Division works with members of a Girl Scout troop from Oswego, Illinois on an interactive exhibit "Fiber vs. Coax." Part of the special SciTech Clubs for Girls program, the young people designed, wired, constructed and assembled the entire exhibit. SciTech boasts over 200 exhibits that demonstrate scientific principles in an easy-to-understand manner.

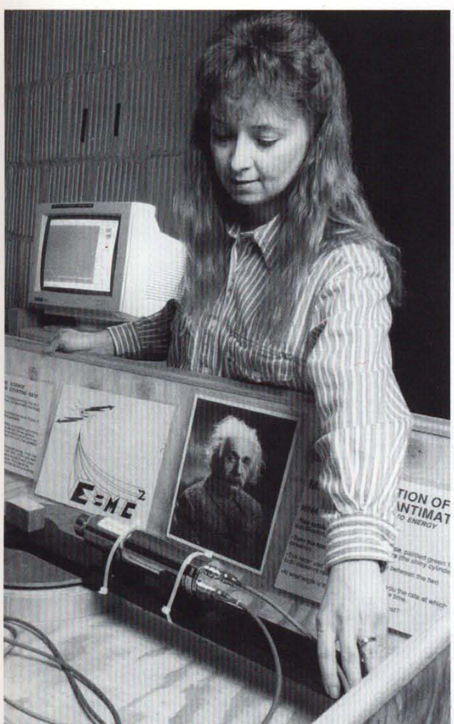




The Fermilab Users Organization consists of students, scientists and engineers from around the world who are involved with the accelerator and the experimental program at Fermilab. Its Executive Committee meets at regular intervals to deal with issues and concerns relevant to the user community. Seated at the table are, clockwise from lower left, Thornton Murphy, Bruce Barnett (UEC Chair), David Cutts, Nicholas Hadley, Sally Seidel, Pekka Sinervo, Amber Boehnlein, Catherine James, John Cumalat and Philip Yager.

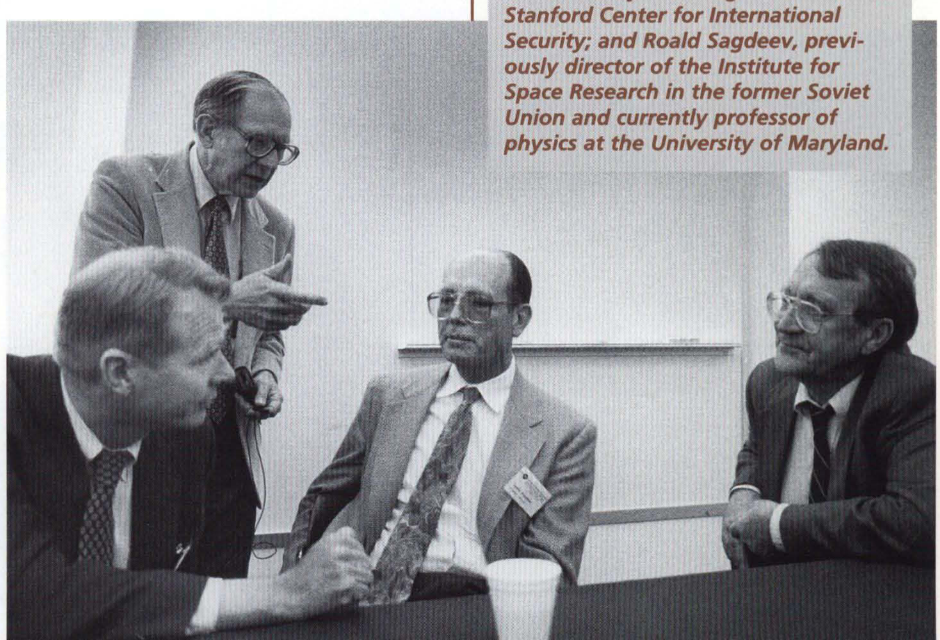


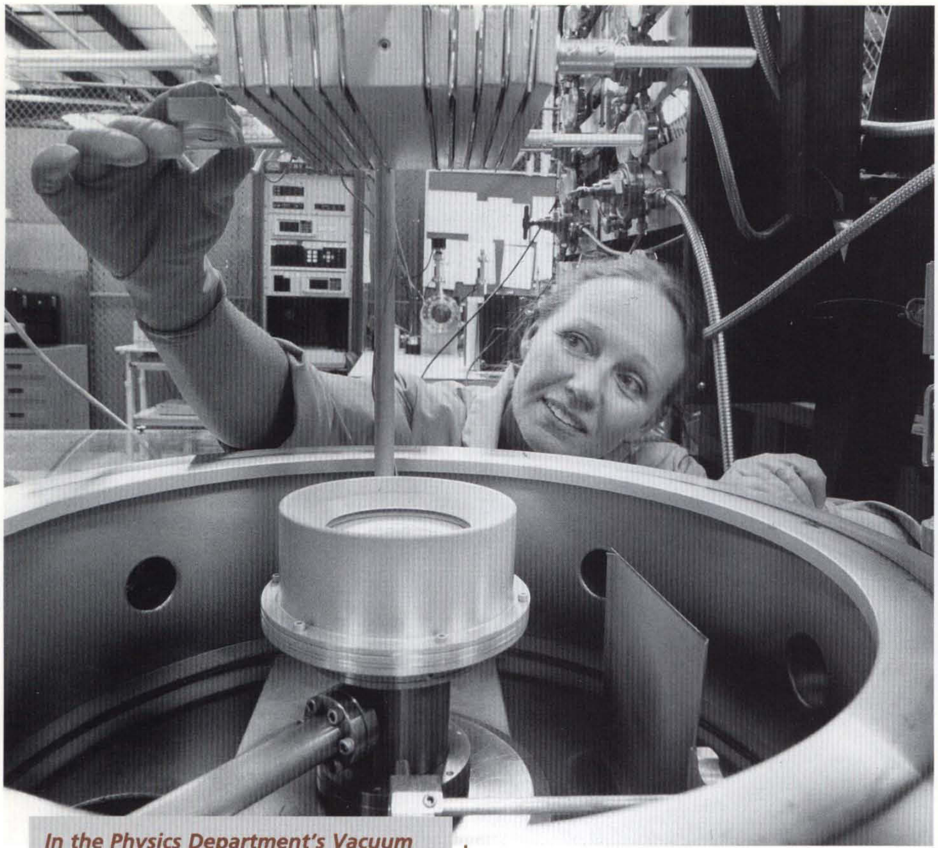
Frank Klier, a co-op student from the University of Illinois at Urbana-Champaign, develops his computer skills as he works with both software and hardware aspects of the Macintosh network for the Environment, Safety and Health Section. The Cooperative Education Program, administered by the Employment Office, provides students an opportunity to gain practical experience related to their major. In 1993, the Laboratory supported 62 co-op students.



Linda Bagby of the Research Division adjusts the photomultiplier tube of the E=mc² exhibition being designed and constructed for SciTech and Ohio's Center Of Science & Industry. Funded by a grant from the Department of Energy, the interactive exhibit seeks to explain the relationship between energy and matter as exemplified by Einstein's famous equation. SciTech located in nearby Aurora, is an exciting hands-on museum for children and adults.

Representatives from local and national business gathered at Fermilab to attend the Thirteenth Annual Industrial Affiliates Meeting and Industry Briefing. Sponsored by Fermilab's Office of Research and Technology Application, the theme of this year's meeting was "Beyond the Cold War: The Changing Arena of Science." Shown, left to right, are Richard Slansky, leader of the Theoretical Division at Los Alamos National Laboratory; Joseph Lach, the meeting chair; Lewis Franklin, formerly of TRW's Space and Defense Sector and currently a visiting scholar at the Stanford Center for International Security; and Roald Sagdeev, previously director of the Institute for Space Research in the former Soviet Union and currently professor of physics at the University of Maryland.



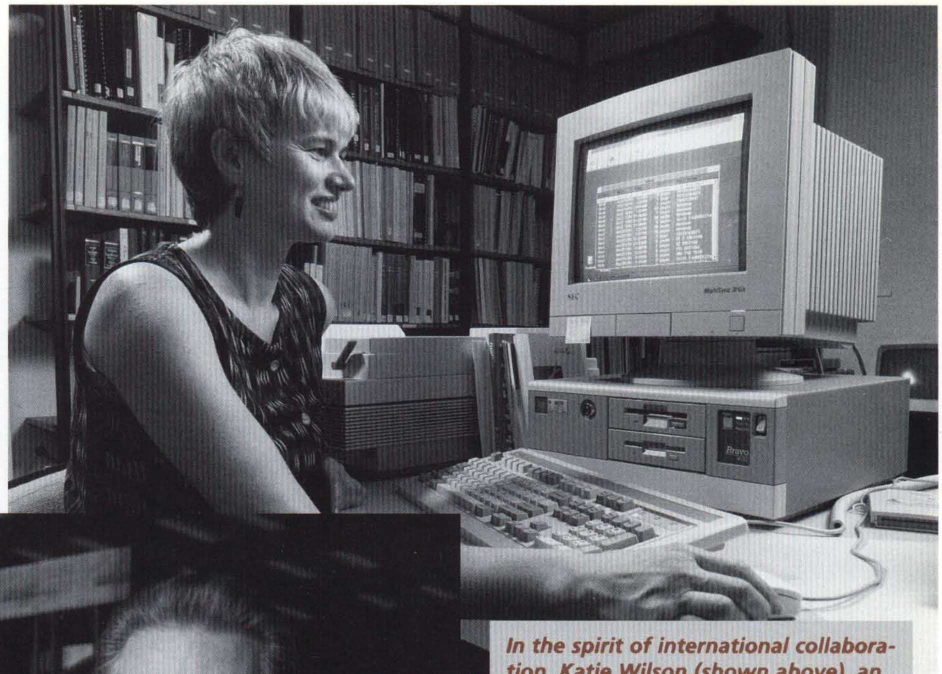


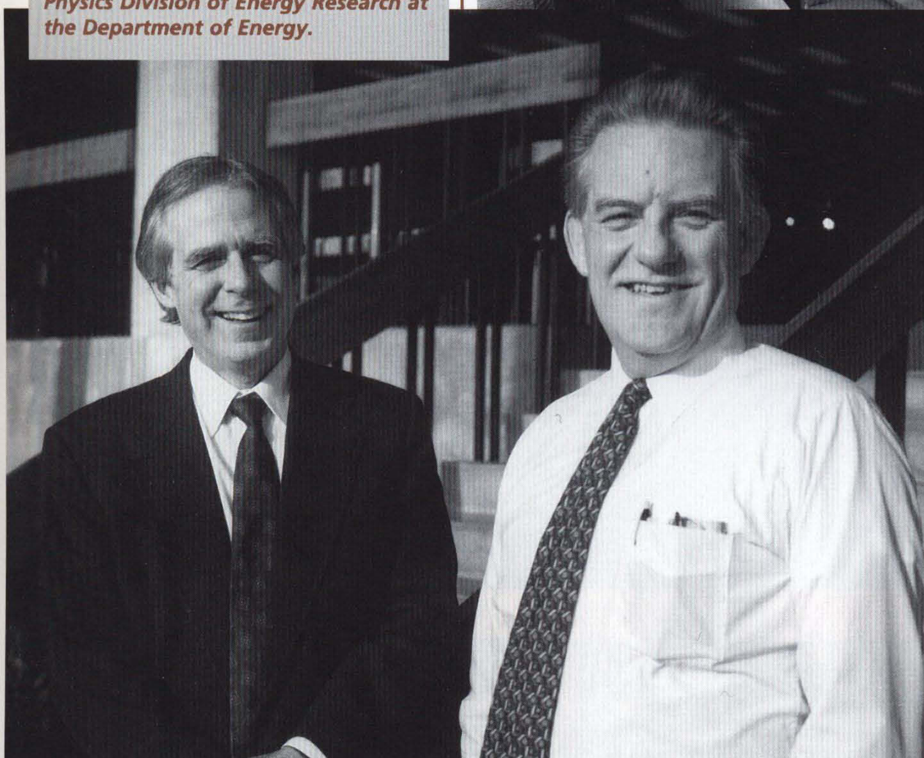
In the Physics Department's Vacuum Deposition Facilty, Eileen Hahn adjusts the quartz-crystal thickness monitor for a sputtering process. She is aluminizing the ends of scintillating fibers to be used in detector tiles for the KTeV experiment. As part of quality control for the process, the monitor ensures that a precise amount of aluminum is deposited on each of the 1,000 fibers. The group supports both production and R&D for a variety of Fermilab projects.

When the new color copier arrived, Lynn Johnson (right) and Cynthia Arnold studied the manual so they could properly instruct employees who will use it for walk-up-service. In 1993, Visual Media Services produced over nine million copies of written material ranging from technical papers to brochures, notices, and manuals.

In order to meet pressing needs for additional space in Wilson Hall, a major renovation project directed by members of the Facilities Engineering Services Section drew close to completion in 1993. A mezzanine between the first floor and the ground floor at the north end of the building was constructed. Members of the Directorate (from the left, Bruce Chrisman, Dennis Theriot and Kenneth Stanfield) study blueprints in the new area.

Continuing a tradition of service beyond the confines of the Laboratory itself, two Fermilab physicists recently spent an extended period of time in our nation's capital. For 17 months, Charles Brown (right) reviewed and recommended funding proposals in high-energy physics as a guest program officer for the National Science Foundation's Physics Division. Richard Carrigan spent most of the 1993 calendar year in the High-Energy Physics Division of Energy Research at the Department of Energy.

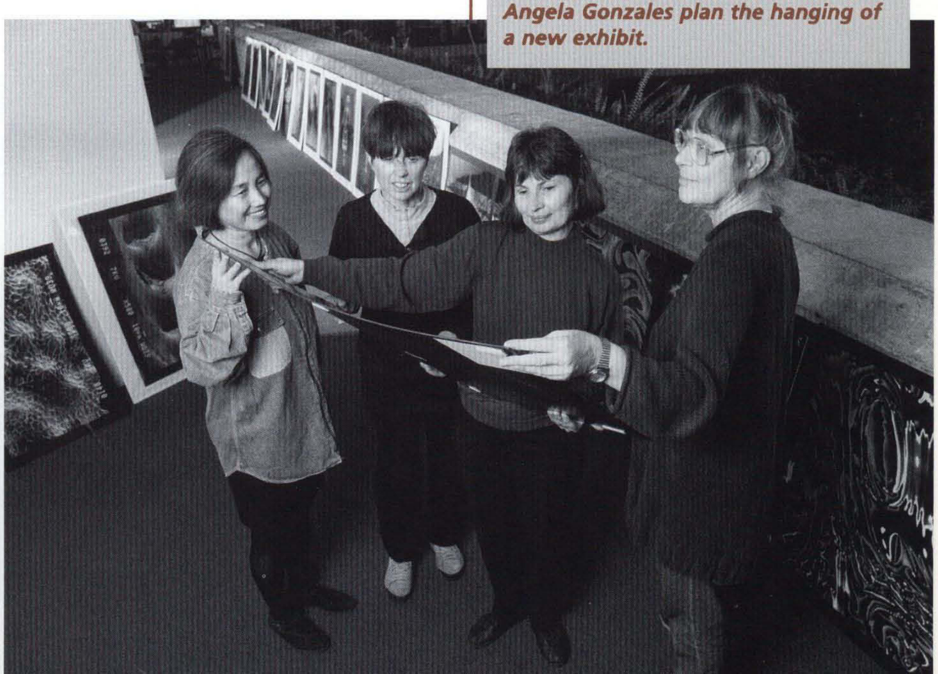


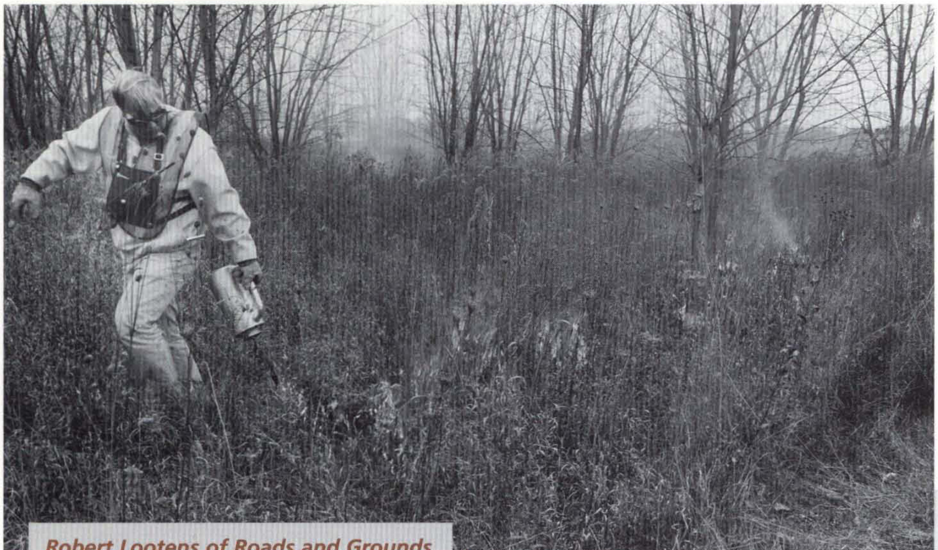


In the spirit of international collaboration, Katie Wilson (shown above), an electronic information specialist from Sydney, Australia, exchanged positions for six months this year with Paula Garrett, Fermilab's head librarian. In 1993, a weekly download of preprint records into the Library's database began. The database now contains records for preprints, technical memos, physics notes, proposals and theses. Searches by authors, collaborations, title words and experiment numbers are all supported.

Since its earliest days, Fermilab has sought to blend the artistic with the scientific. With six different exhibits a year — ranging from folk art to fine art to computer-generated art — the Second Floor Gallery provides space for the display of works of local as well as international artists. From the left, Mizuho Mishina, Nancy Peoples, Saundra Poces (Gallery Manager) and Angela Gonzales plan the hanging of a new exhibit.

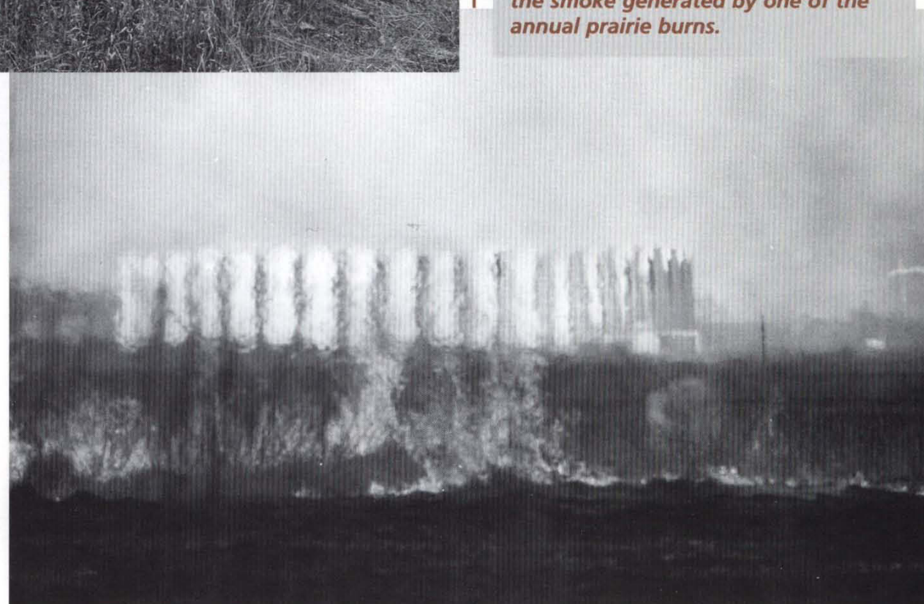
Teolia Jordan (left) and Brett LaVoy of Support Services in the Business Services Section check under the hood in the course of their repair work. In 1993, the Vehicle Maintenance group purchased a new wheel-lift tow truck. The group repairs and maintains the fleet of more than 200 government cars and trucks used for Laboratory business.





Robert Lootens of Roads and Grounds uses a drip torch to start a prairie burn this fall. Controlled fires are set in order to clear plots of weeds and to nourish the soil for the long-rooted species native to the prairie.

The outline of the Feynman Computing Center shimmers through the smoke generated by one of the annual prairie burns.



Continuing the tradition of respecting and enhancing the environment, 400 employees turned out on Arbor Day to assist the Roads and Grounds crew in planting about 130 oak, hickory, walnut and pine trees on the east and west side of the A.E. Sea near the Fermilab Village. Margaret Votava (left) and Eileen Berman pause a moment during their digging efforts.

Thomas Peterson and his sons check out the buffalo pasture. The Facility Engineering Services Section provided informational literature and sponsored two contests.

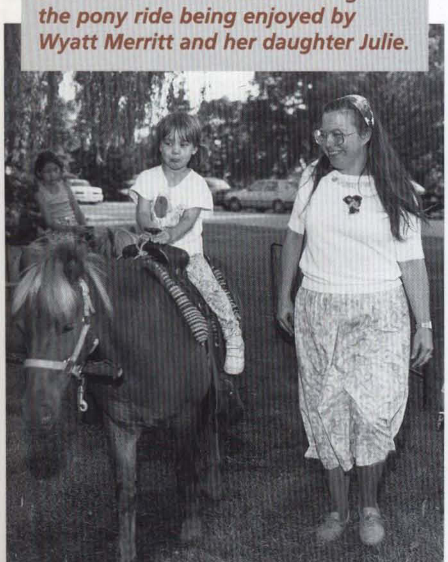
In tents in the Fermilab Village, volunteers from Nalrec, including Edmund Pietras, served a tempting array of picnic food to employees and their families.

Family Day

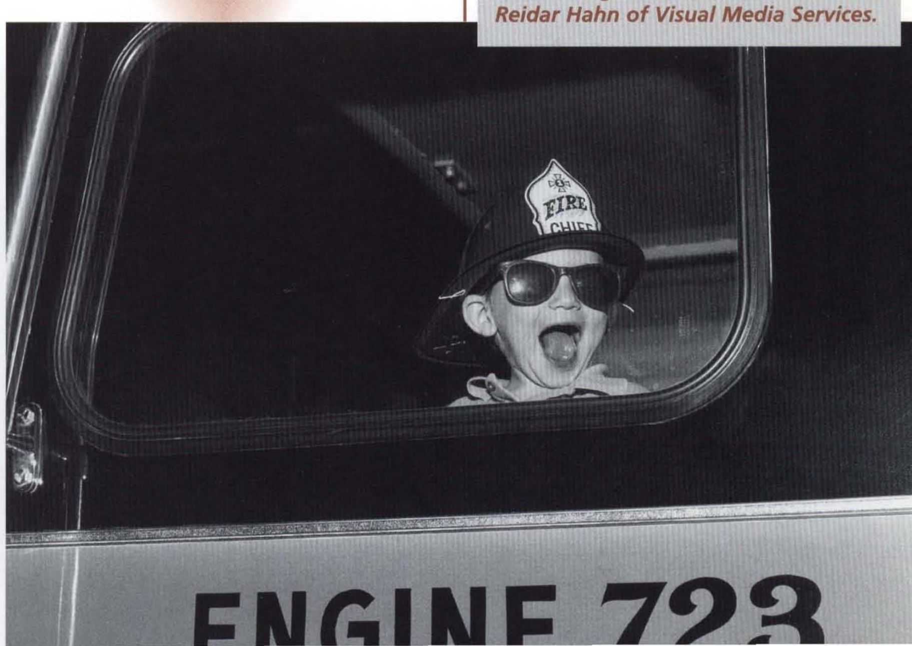
August 6, 1993

Various sections of the laboratory provided special guided tours for employees and their families.

Nalrec, the employee recreational association, organized games, contests and activities including the pony ride being enjoyed by Wyatt Merritt and her daughter Julie.



The Business Services Section opened the doors of the Fire Station — clearly to the delight of Andrei Hahn, son of Reidar Hahn of Visual Media Services.

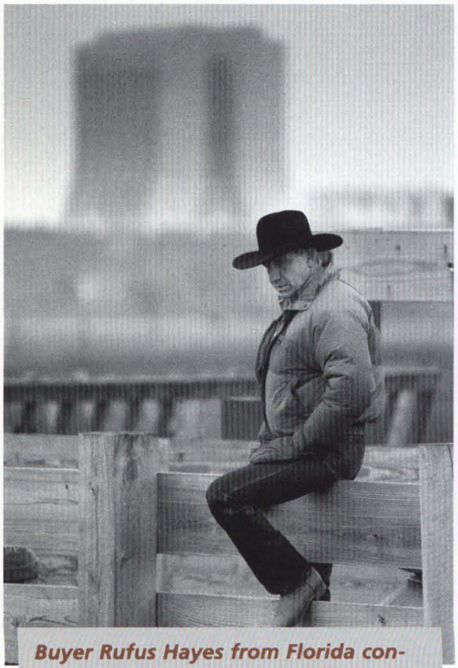


Buffalo Auction

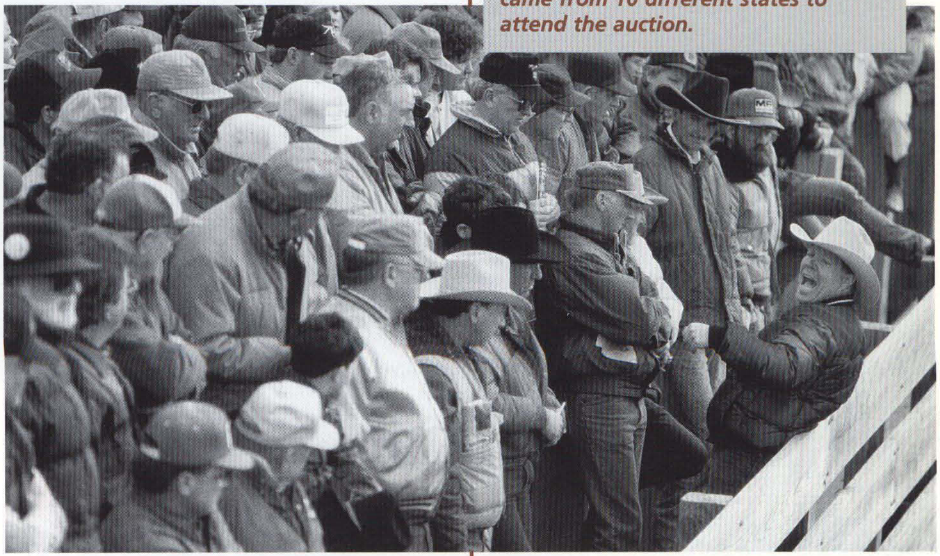
March 26, 1993

Attracted by the healthy, high-quality animals, ranchers and farmers purchased 74 buffalo. The successful spring sale thinned the herd from 132 head to a more manageable 58.

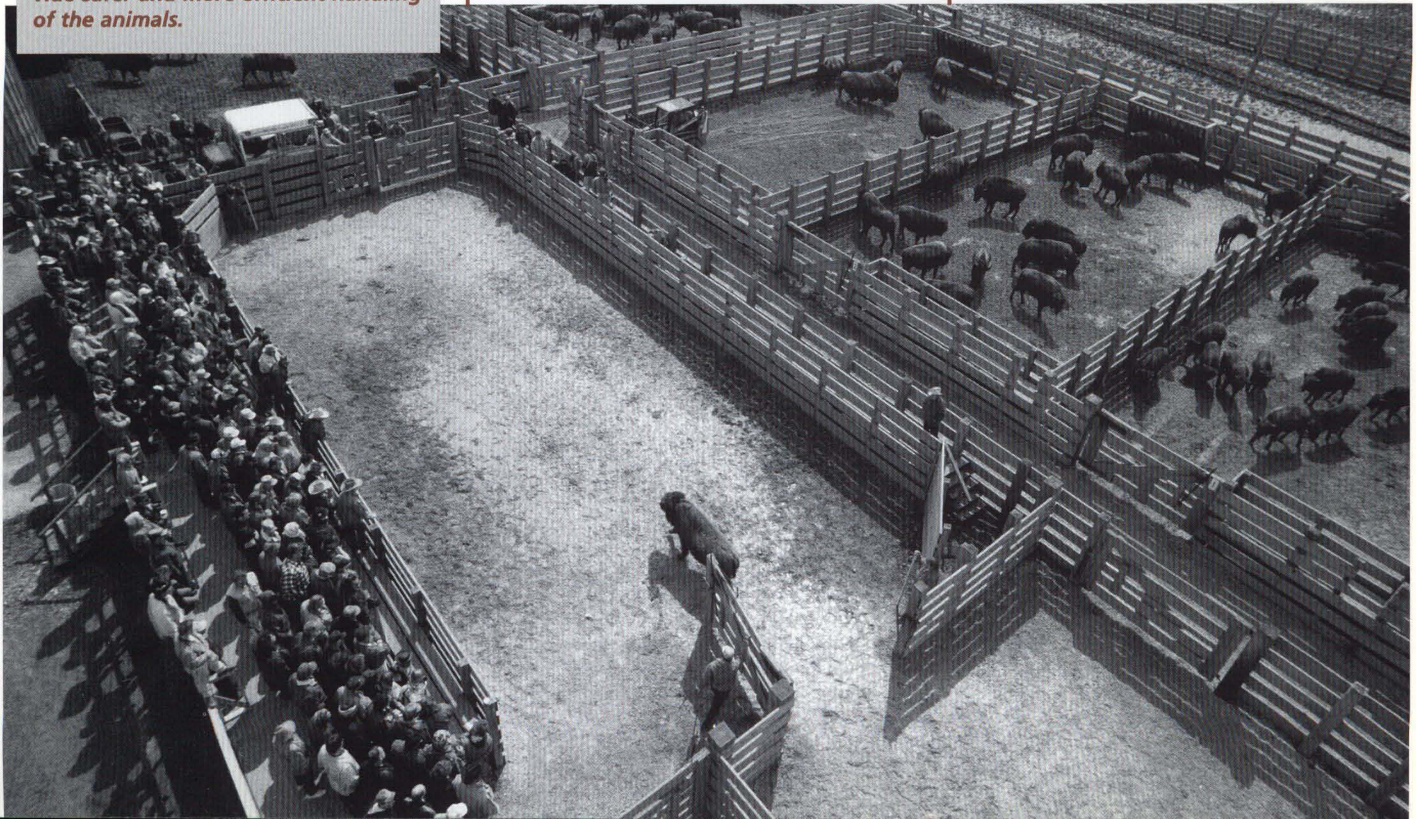
Gatekeepers Lonnie LaSourd (left) and Donald Hansen stand aside as two buffalo rush into the auction pen.



Buyer Rufus Hayes from Florida contemplates the herd prior to the start of bidding.



Seventy-nine registered bidders came from 10 different states to attend the auction.



The Roads and Grounds crew designed and constructed this labyrinth of pens and alleys to provide safer and more efficient handling of the animals.

AWARDS

Alvin Tollestrup (left), receives the California Institute of Technology's Distinguished Alumni Award from its president, Dr. Thomas Everhart. The award, the highest bestowed by the Institute, recognizes superior achievement and conspicuous accomplishment in science, business or public service. Dr. Tollestrup was a major developer of the Tevatron and a co-spokesperson of CDF.

A Federal Laboratory Consortium Award of Merit for Excellence in Technology Transfer was given to seven members of the Technical Support Section for their work on the SSC 50-mm collider dipole magnet project. Posing with Director John Peoples at the April 26, 1993 award ceremony are (left to right) Gale Pewitt, Gregory Kobliska, James Strait, Peter Mazur, Donald Tinsley, Thomas Nicol and John Carson.

On September 27, 1993 the American Society of Mechanical Engineers designated the Tevatron's Cryogenic Cooling System an International Historic Mechanical Engineering Landmark. The cooling system, which brings liquid helium to the superconducting magnets, is a crucial component of the Tevatron. From the left, William Fowler (Fermilab Main Injector Project), John Fernandes (President, ASME), William Warren (ASME), Theresa Lechton (ASME), John Peoples (Director, Fermilab) and Cherri Langenfeld (Manager, DOE Chicago Operations Office) stand with the ceremonial plaque.

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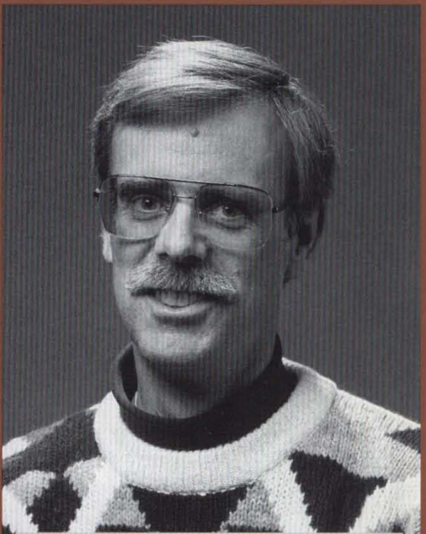
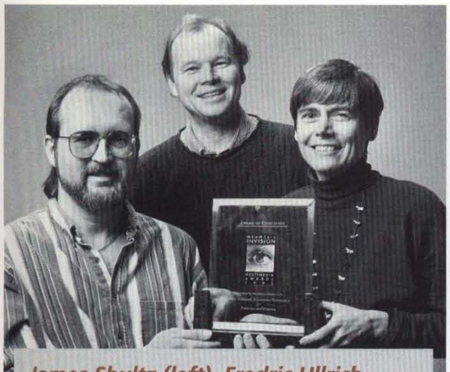
At a White House ceremony on July 29, 1993 President Clinton presented the 1992 Fermi Award to Director Emeritus Leon Lederman. Named in honor of Enrico Fermi, this Department of Energy award is the government's oldest science and technology prize and one of its most prestigious. It honors a lifetime of achievement in the field of nuclear energy. Secretary of Energy Hazel O'Leary (left) and Ellen Lederman enjoy the presentation ceremony.

Each year the American Physical Society honors a few of its members who have contributed to the advancement of physics by independent, original research or who have rendered some other special service to the cause of science. In 1993, five Fermilab employees received this prestigious recognition.

Lillian Hoddeson, elected APS Fellow "for organizing and providing written records of 20th century History of Physics through projects and conferences covering Solid State Physics, Particle Physics, and national laboratories."

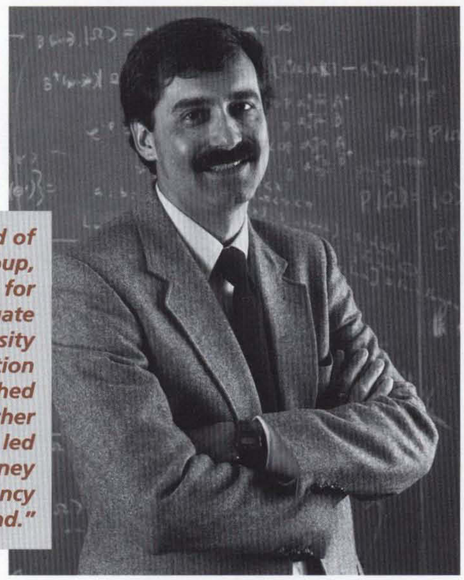


Stephen Holmes, elected APS Fellow "for his leadership in the Antiproton Source, Booster, and Main Injector design at Fermilab."

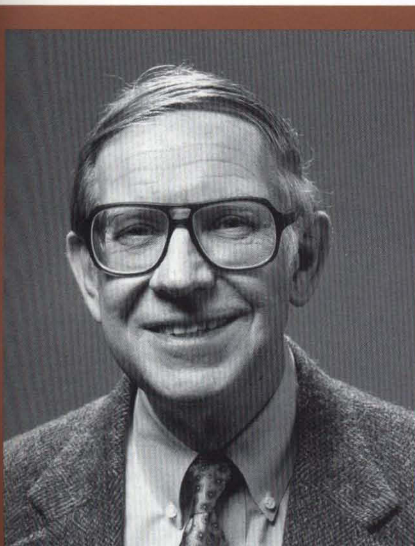


James Shultz (left), Fredric Ullrich and Elizabeth Quigg display the Award of Excellence received from the New Media INVISION 1993 Awards Competition. The award honored the Particles and Prairies Interactive Multimedia Program, which consists of 37 video segments and 10 slide collections and forms an integral part of the middle school science unit developed by the Education Office.

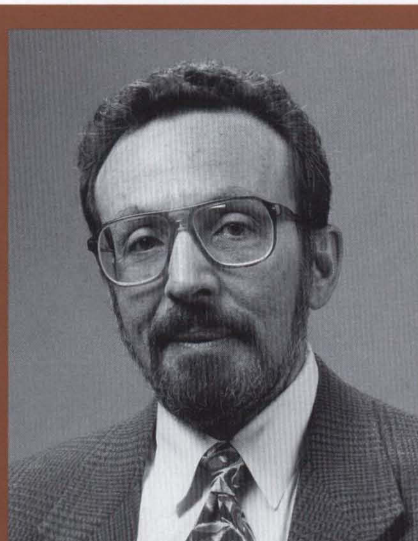
The Fermilab Computing Division was the first group in a national laboratory to receive a Government Computing News Agency Award for Excellence in information resources management. The awards are conferred on Federal agency organizations with a record of excellence in the application of information technology to improve services delivery. The award noted the division's ongoing, pioneering efforts in creating innovative and cost-effective high-performance parallel computing systems in support of the Laboratory's mission in high-energy physics. Pictured are (row 1, from the left) Victoria White, Thomas Nash, Michael Isely, Elizabeth Schermerhorn; (row 2, from the left) Joel Butler, Bruce Chrisman, Kenneth Stanfield, Matthew Wicks and Donald Petravick. Not pictured: Donna Lamore.



Edward Kolb, former head of Fermilab's Astrophysics Group, received Quantrell Awards for Excellence in Undergraduate Teaching from the University of Chicago. The award citation described him as a "distinguished astrophysicist and committed teacher with exuberant style, who has led his students on a wondrous journey through the universe from its infancy to the present and beyond."



Joseph Lach, elected APS Fellow "for work on techniques to produce beams of hadrons and measurements with them to study hadron interactions. For precision measurements of hyperon polarization, their decays, and magnetic moments."



Ernest Malamud, elected APS Fellow "for his leadership in creating an innovative science museum which demonstrates complex concepts of modern science and technology to raise science literacy."

Catherine Newman Holmes, elected APS Fellow "for contributions to the study of the W and Z bosons with the CDF detector, and to the observation of new mesonic states in J/ψ decays."

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ACKNOWLEDGMENTS

Editor: **Ernest Malamud.**

Technical Editor: **Barbara Lach.**

Visual Editor: **Fredric Ullrich.**

Photography by: **Reidar Hahn.**

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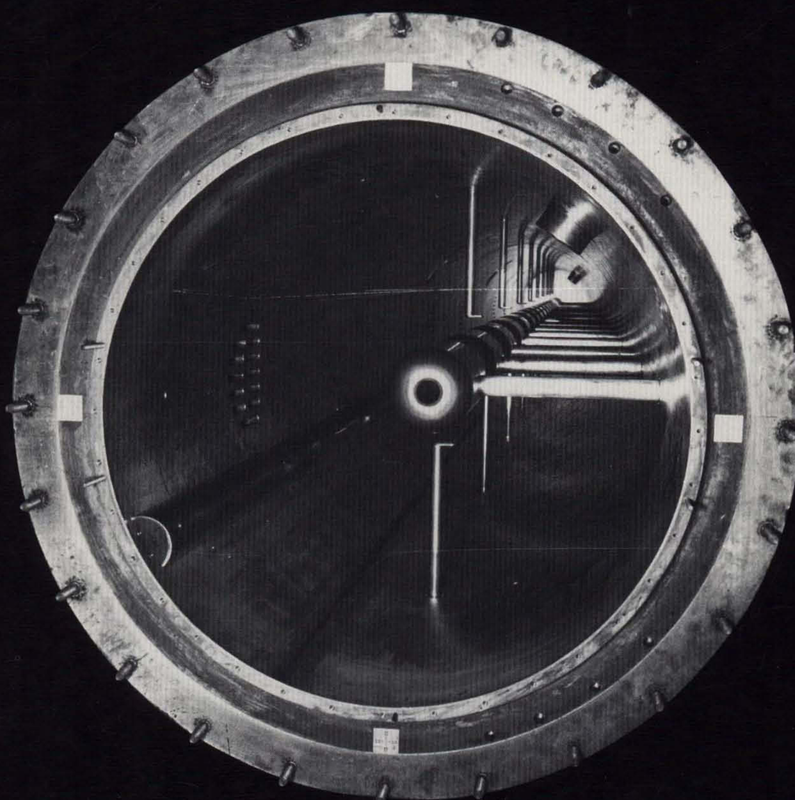
Contributors and Consultants: **Timothy Burke, Sheila Colson, Cynthia Crego, Robert Johnson, Stanka Jovanovic, Jan Olsen, Roy Rubinstein, Rod Walton and members of the CAD Committee: Richard Andrews, Robert Andree, Ronald Currier, Michael Foley, Donald Goloskie, Frank Koenen, Stewart Mitchell, Thomas Nicol and Ralph Siegler.**

Contributing Photographers: **Lynn Johnson, Jon Osing, Robert Paz, Fredric Ullrich, White House Photo.**

Design: **Elaine Weed and Mark Karczewski of Weed Advertising, Naperville, IL.**

This publication was produced with funds from Universities Research Association, Inc.



Fermi National Accelerator Laboratory

Batavia, Illinois

Operated by Universities Research Association, Inc.

Under Contract with the United States Department of Energy