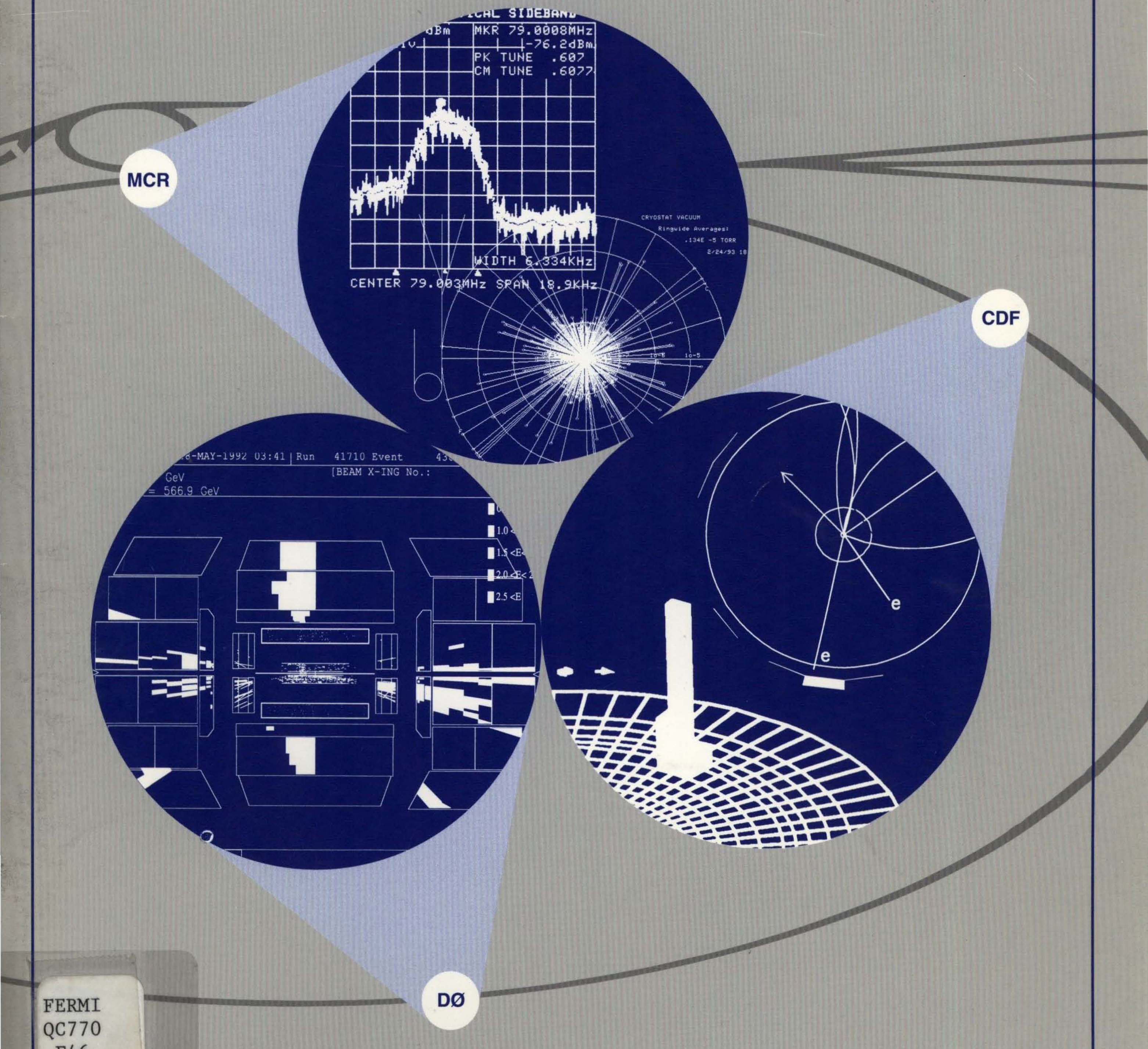
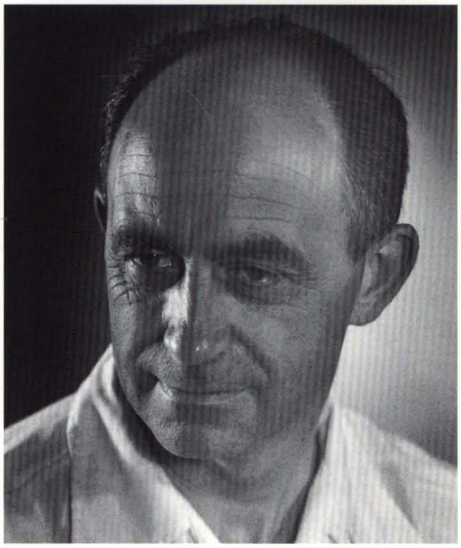
# Fermilab
## 1992





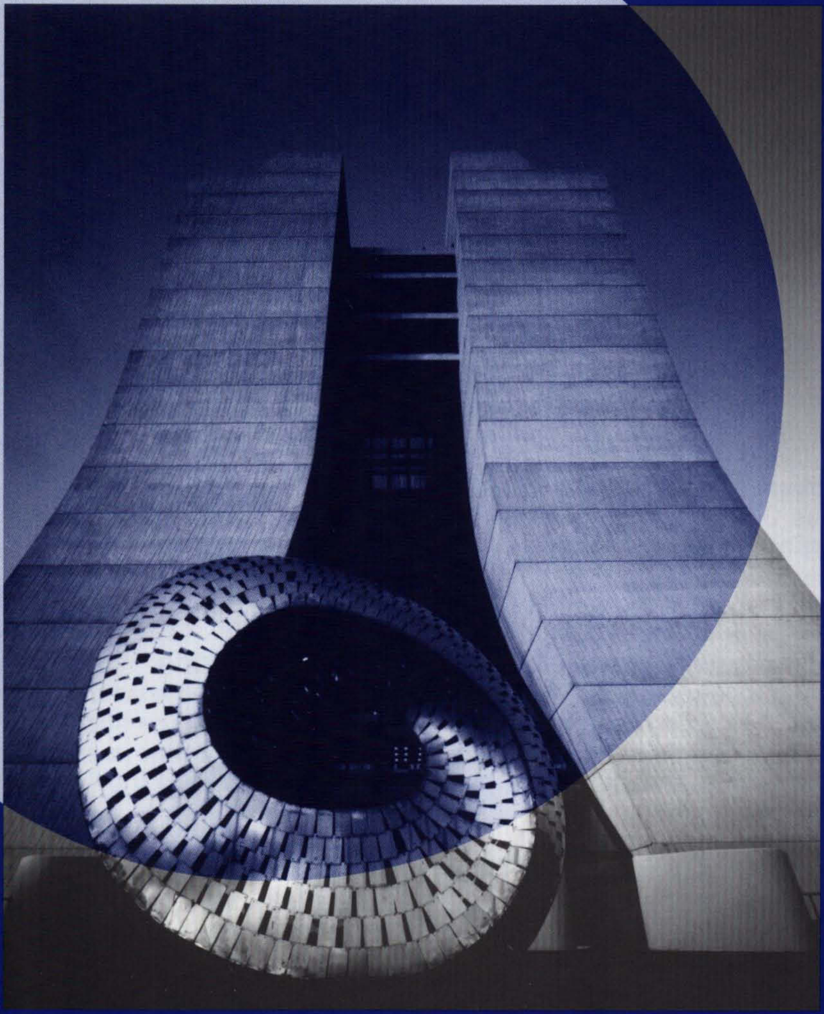
*Enrico Fermi (1901–1954)*
*Pioneering theoretical and experimental physicist.*
*Winner of the 1938 Nobel Prize for his discoveries in nuclear physics.*
*Leader of the team which produced the first self-sustaining chain reaction.*

*"If you go back to the book on methods, you will learn that you have to take experimental data, collect the experimental data, organize the experimental data, begin to make working hypotheses, trying to correlate part of the field until eventually a pattern springs to light."*

— 1951

*"Scientific thinking and invention flourish best where people are allowed to communicate as much as possible unhampered."*

— December 2, 1952



# Annual Report of the Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory
Batavia, Illinois

- Operated by Universities Research Association, Inc.
- Under Contract with the United States Department of Energy

# Table of Contents

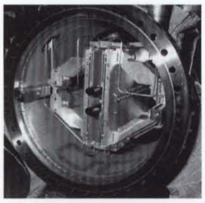
**4**

## From the Director

**6**

## Introduction to Fermilab

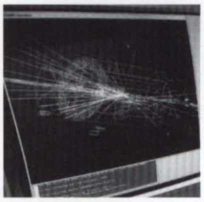
**8**



## Collider Run Sets World Luminosity Records

The record-breaking luminosity achieved this year has made the Tevatron a more powerful scientific instrument than ever. Several ingenious improvements to an astonishingly complex system led to a larger crop of events for the detectors to harvest — and to a better understanding of accelerators.

**12**



## DØ: A Year of Firsts

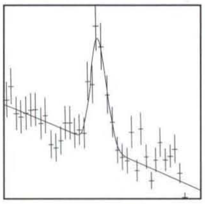
Years of careful planning, building, and testing were rewarded this spring as DØ, the second detector to see colliding beams at Fermilab, took its first data. By fall, the collaboration had several results to report.

**15**

## CDF: *B* Physics from 10 Meters to 10 Microns

Recent improvements to the CDF detector have demonstrated that it is possible to use a hadron collider to study the *b* quark. The successful operation of a new part of the detector, the SVX, made it possible to snare clues to the short-lived particles that decay before they can leave the beam pipe.

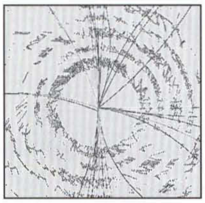
**18**



## Fixed-Target Program: A Cornucopia of Results

Fixed-target experiments and colliding-beams experiments are like different senses: each provides important information; each has purposes to which it is particularly suited. Many significant results were published in 1992.

**22**



## Computing the Nature of Nature

Basic research represents both a path to new knowledge and a route to better technologies. Computing capabilities developed for Fermilab experiments have caught the eyes of IBM and Merck, a leading pharmaceutical company.

**25**

## Impressions: 1967–1992

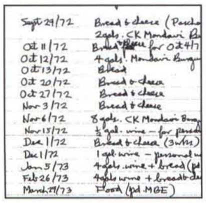
Members of the Fermilab community recall some special moments in the Laboratory's first twenty-five years.

**37**

## Collisions: Transition to a World-Class Collider

One of the most significant decisions in the Laboratory's history was to attempt colliding-beams physics. The quest to realize this idea in the best way possible tested the ingenuity and determination of all who took part.

**40**



| | |
|---|---|
| Sept 29/72 | Bread & cheese (Pasch |
| | 2 gals. CK Mondavi B |
| Oct 11/72 | Bread & cheese for Oct 4/7 |
| Oct 12/72 | 4 gals. Mondavi Burgu |
| Oct 13/72 | Bread |
| Oct 20/72 | Bread & cheese |
| Oct 27/72 | Bread & cheese |
| Nov 3/72 | Bread & cheese |
| Nov 6/72 | 8 gals. CK Mondavi Burg |
| Nov 15/72 | ½ gal. wine – for pers |
| Dec 1/72 | Bread & cheese (3 wks) |
| Dec 1/72 | 1 gal. wine – personal |
| Jan 5/73 | 4 gals. wine + bread (pd |
| Feb 26/73 | 4 gals wine + bread & che |
| March 29/73 | Food (pd. MGE) |

## Early Days of Wine and Cheese

One of the few experiments at Fermilab founded exclusively by theorists, the weekly Wine and Cheese seminar has run for twenty fruitful years. J. D. Jackson, Acting Head of the Theoretical Physics Group, recounts some of the early meetings, in which unmistakable signals of enthusiasm and high spirits were observed.

Director John Peoples examines a log book in the Main Control Room.

# From the Director

John Peoples

Measured by the standard of accomplishments in accelerator and particle-detector technology, 1992 was a marvelous year. Four years ago, when the Laboratory first defined the Fermilab III program, we promised that the Tevatron would deliver a typical peak luminosity of $5 \times 10^{30}$ cm$^{-2}$ sec$^{-1}$ by the time the first phase of Fermilab III was complete. The Tevatron reached this luminosity for the first time in early December, and by month's end had achieved a record luminosity of $7.5 \times 10^{30}$ cm$^{-2}$ sec$^{-1}$. The typical peak luminosity for the month reached our goal. I am delighted that Fermilab kept the promises made for the Tevatron.

This level of performance makes the Tevatron a new collider, because it once more opens new frontiers of particle physics for exploration. Now the pioneers exploring these frontiers are the builders of the CDF and D0 detectors. For the first time, in 1992, the D0 detector took its place on the beamline, and the D0 collaboration made it perform splendidly. The substantially improved CDF detector also performed exceptionally well. Both collaborations have successfully introduced major innovations in technology to meet the challenge of the Tevatron's increasing luminosity and the several hundred particles exploding out of each proton-antiproton collision. Analysis of the ghostly electronic images written onto magnetic tape presented its own formidable challenge to high-performance computing and high-performance file serving. Fermilab is working with industry to expand the performance of highly parallel data processing. While "parallel processing" has become the catch phrase of the day, let me point out that Fermilab started down the parallel-processing trail alone more than a decade ago. We are happy to have company.

This year's accomplishments in accelerator technology remind us of our past — and it is a glorious one. Twenty-five years ago, the National Accelerator Laboratory was founded. Under the direction of Bob Wilson, the Main Ring was brought to life, two years ahead of schedule and six million dollars under budget. On March 1, 1972, protons were accelerated to 200 GeV, the first time scientists had ever accelerated particles beyond 100 GeV. On June 15, 1972, in front of the old Curia, a cheering staff passed around the first bubble-chamber pictures recording the interactions of 200-GeV protons. A year later the Main Ring was regularly delivering 300-GeV protons to experiments, and two years after that 400 GeV became the standard operating energy. Nor did the quest for the highest energy end there. The Tevatron, conceived by Bob Wilson, and built under Leon Lederman's direction, accelerated a proton beam to 512 GeV on July 4, 1983, setting a new record. By January of 1984, the Tevatron was routinely accelerating protons to 800 GeV for fixed-target operation. In 1987, the Laboratory achieved collider operation with 800-GeV proton and antiproton beams, and today beams are regularly accelerated to 900 GeV and then stored at that energy for nearly a day while they collide. The Tevatron remains the highest energy collider and fixed-target synchrotron in the world. However, it is no longer the only superconducting collider. The proton ring of HERA, the electron-proton collider at DESY, the Deutsches Elektronen Synchrotron in Hamburg, came into operation in 1992 and now routinely accelerates protons to 820 GeV. We are proud that our decade and a half of contributions to superconducting magnet technology has borne fruit in another laboratory — and most fittingly at DESY, because DESY staff members working at Fermilab helped make the Tevatron a success.

While we take pleasure in looking back at our achievements, we are fortunate that we can look forward to advancing the frontiers of particle physics by still further increasing the Tevatron's luminosity. During 1993 we will almost certainly reach our luminosity goal of $10^{31}$ $cm^{-2}$ $sec^{-1}$ when we complete the second phase of Fermilab III, the Linac Upgrade. The Linac project completed all of its components at the end of 1992 and placed in operation the most critical system, eight side-coupled cavities and their rf power sources. In the summer of 1993 the upgraded 400 MeV Linac will replace the old 200 MeV Linac, and soon thereafter it will become the source of protons for the Tevatron accelerator complex. Once the 400 MeV Linac begins operating smoothly, it will provide the vehicle for another doubling of luminosity, carrying the Laboratory beyond the records established in 1992.

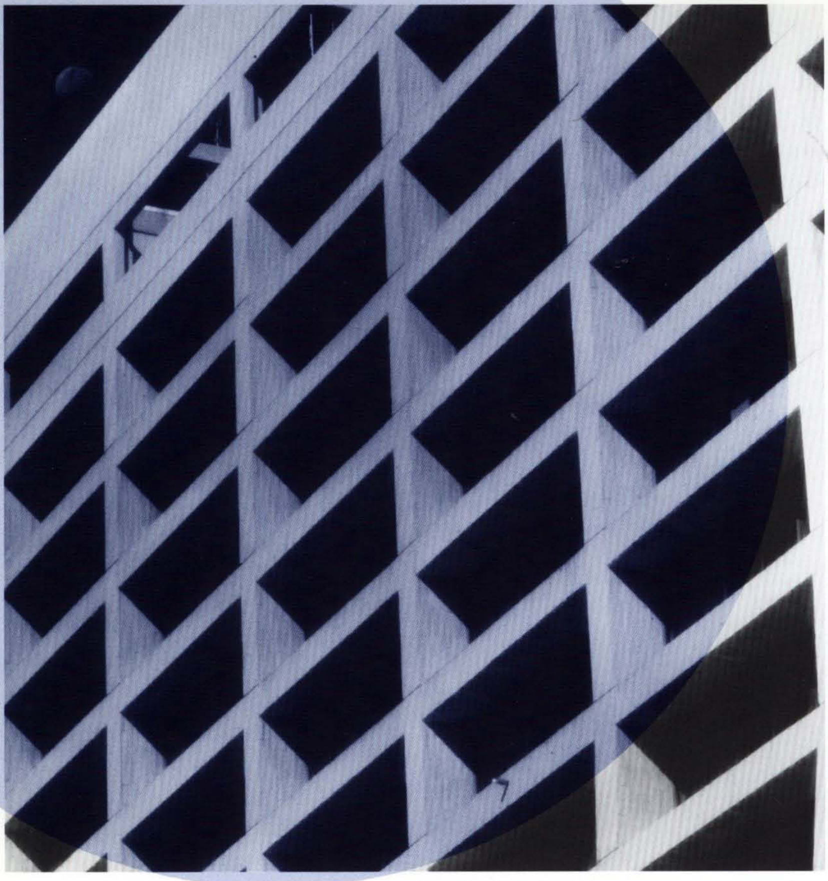
Unfortunately, construction of the Main Injector, the third and crucial phase of Fermilab III, advanced slowly because of limited appropriations in FY1992. Given our nation's great difficulty in coming to terms with its deficit, we must regard the fact that we did get an FY1993 appropriation as a good omen. In spite of our fiscal disappointment, we made solid progress with the funds we had; we cleared the site, completed the Title I design of the conventional construction, and built and thoroughly tested two prototype magnets. When complete, the Main Injector will increase the Tevatron luminosity by at least another factor of five and allow the scientific community working at Fermilab to extend still further the frontiers of particle physics. Building the Main Injector will allow Fermilab to continue to provide a superb laboratory for forefront physics as we begin the twenty-first century.

No reflection on the past year would be complete without recognizing the improvements that the Laboratory staff has made to the conduct of our environment, safety, and health activities. Fermilab has always been a safe laboratory, and the Tiger Team audit verified that. We learned much from the intense four-week Tiger Team visit, and we are using it to improve Fermilab. A year ago we put our revised environment, safety, and health policies in place; for much of the past year we have worked to implement them. I want Fermilab to be a safe place for visiting scientists and for our staff, and I want all of us to have a sensitivity to the environment, while we press on with the search for the fundamental properties of matter.

### *Luminosity and Integrated Luminosity*

*The primary goal of each collider run is to maximize the total number of proton-antiproton collisions observed by the detectors during the course of the run. This number is proportional to the number of protons and antiprotons in each bunch, to the density of the bunches, to the frequency with which bunches collide, and to the length of the run. When physicists speak of an accelerator's luminosity, they are referring to the interaction rate per unit cross section. Luminosity is measured in units of* $cm^{-2}$ $sec^{-1}$.

*Integrated luminosity is luminosity multiplied by time. It is proportional to the total number of interactions delivered to each experiment, and is considered the best measure of accelerator performance, because it reflects the reliability of the machine over the run and the ability of the beams to last in the machine. Integrated luminosity is measured in inverse picobarns* ($pb^{-1}$).



# Introduction to Fermilab

> *"There is a quality of loveliness in the content and in the devices of physics. It is a beautiful creation that has meaning for man's view of himself and his place in the world."*
>
> **— Robert Rathbun Wilson**
> **Founding Director of Fermilab**

For a quarter of a century, Fermi National Accelerator Laboratory has been a national — and international — scientific resource, dedicated to revealing the mysterious and beautiful laws of the universe at its most fundamental. Set amid the rippling grasses of the Illinois prairie, about thirty miles west of Chicago, Fermilab is one of the largest centers for high-energy physics in the world. Named in honor of Nobel laureate Enrico Fermi, who devoted much of his life to understanding the nucleus of the atom, Fermilab draws researchers from 101 institutions in the United States and 22 foreign countries.

What brings them here? Fermilab has the highest energy accelerator in the world, computing innovations that will be tomorrow's state-of-the-art, and a host of experts in theoretical physics, cosmology, engineering, and a wide range of technologies. In 1992, we employed over two thousand people, and 1,064 visiting experimenters worked here. In addition, 533 graduate students conducted research toward their doctoral degrees at Fermilab this year. The free and open exchange of ideas and respect for independent thought that flourish in the best academic institutions have been encouraged by the Universities Research Association, Inc., a consortium of 80 universities, which manages Fermilab for the U.S. Department of Energy (DOE).

## AROUND THE RING

The centerpiece of Fermilab is the Tevatron, a four-mile-long ring in which protons and antiprotons are accelerated to the unprecedented energy of nearly a trillion electron volts. The superconducting magnets that bend the particles' paths were a milestone in accelerator development — and in the domestication of superconductivity from laboratory curiosity to practical tool, useful in magnetic resonance imaging for medical purposes as well as in other accelerators around the world.

Head-on collisions between protons and antiprotons are used to explore matter on the smallest scale now possible. Collaborating investigators from many institutions have designed and built sophisticated instruments several stories high and weighing thousands of tons to acutely observe and record the collisions, in which the particles' energy is transformed into new particles. These transformations provide information essential for understanding the basic order underlying the complexity of our universe. We can also direct high-energy protons into targets of various materials, enabling highly precise measurements that are sensitive to new processes and to slight deviations from predicted values to be made.

## WHAT WE KNOW

Particles that are tiny compared with the nucleus of an atom hold the key to the laws that govern all physical phenomena. Their behavior shapes the answers to a vast range of questions — from why a book will rest on a tabletop but not on a lake, to how a universe with books and lakes and planets and galaxies could emerge from a swirling, almost uniform cloud of subatomic particles.

The paper and ink in this report, the chair you are sitting on, and you yourself are made of molecules, which are made of atoms, which are in turn made up of electrons orbiting a nucleus of protons and neutrons. Each of these particles can exist without changing for a very long time — which is exactly why they are the constituents of the familiar world. But there are many less stable forms of matter: particles that transform themselves into other particles within a tiny fraction of a second.

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 physical theory, known as the Standard Model, the most fundamental particles fall into three categories: the leptons, the quarks, and the gauge bosons. Leptons comprise the electrically charged electrons; two unstable particles that are similar to electrons, but much heavier; and particles known as neutrinos, which are neutral. Two kinds of quarks, called "up" and "down," make up the protons and neutrons, but there are also heavier, less stable quarks. Gauge bosons give rise to the strong, weak, and electromagnetic forces, which govern the behavior of the quarks and leptons.

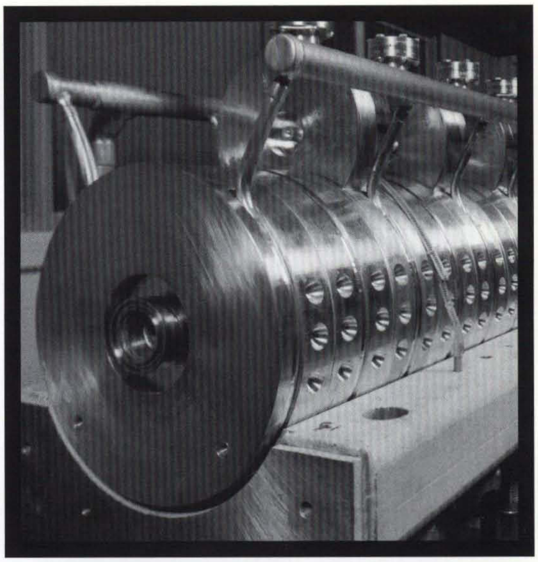
## WHAT WE KNOW WE DON'T KNOW

So far, the agreement between predictions of the Standard Model and experiment has been spectacular. However, there are areas in which the Standard Model has not been well tested. In addition, there are many compelling questions that the Standard Model alone cannot address, and experimental data are required to determine which — if any — of the competing speculations has captured the essence of nature.

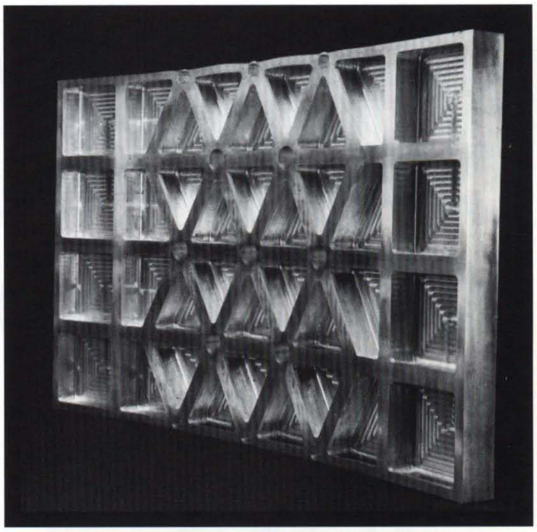
## FERMILAB'S FRONTIERS

Because the mass of the new particles that an accelerator can produce depends on the energy available in a collision, the Tevatron enables searches for particles that could not be undertaken elsewhere. Through its unique fixed target program, utilizing a variety of different particle beams, Fermilab provides access to the high-intensity frontier.

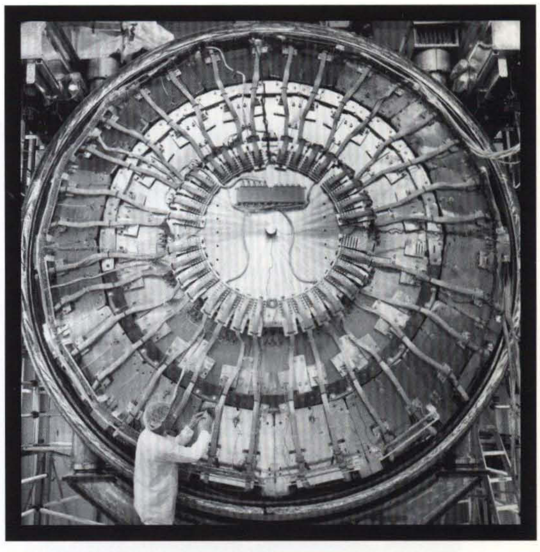
In the past 25 years, Fermilab has helped to shape the content and the devices of high-energy physics. New techniques, new intellectual tools, and new discoveries lie ahead as the Laboratory and its collaborators continue to nurture a deep respect for nature, for people, and for learning.



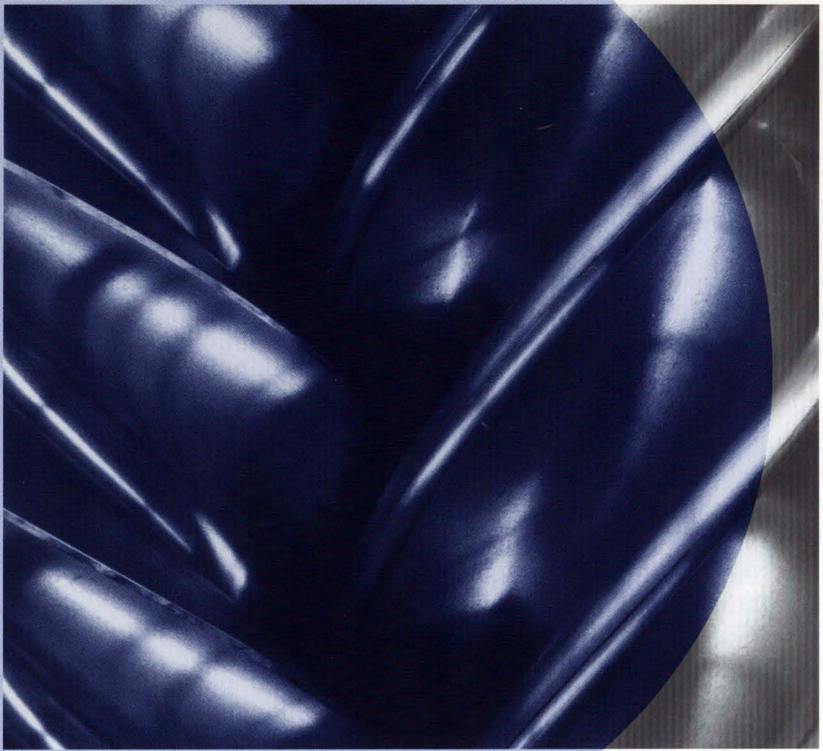
*Prototype cavity for Linac upgrade.*



*Segment of a vacuum vessel for the Solenoid Detector Collaboration.*

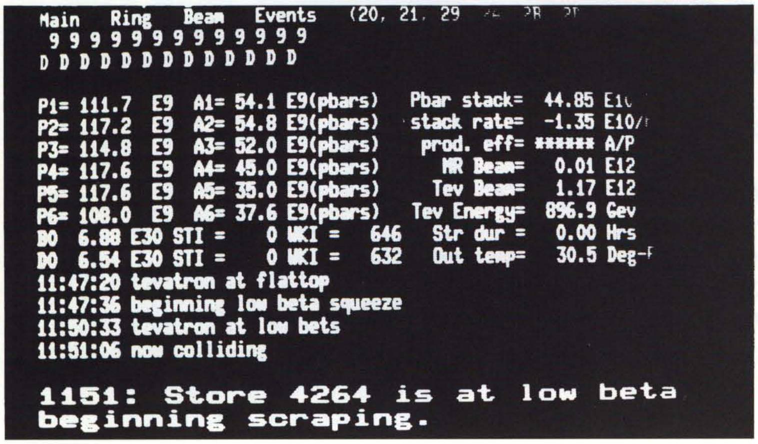


*DØ cryostat.*



*Helium screw compressor.*

# Collider Run Sets World Luminosity Records



```
Main  Ring  Beam  Events  (20, 21, 29
 9 9 9 9 9 9 9 9 9 9 9 9 9
D D D D D D D D D D D D D

P1= 111.7  E9  A1= 54.1 E9(pbars)   Pbar stack=  44.85 E1
P2= 117.2  E9  A2= 54.8 E9(pbars)   stack rate=  -1.35 E10/
P3= 114.8  E9  A3= 52.0 E9(pbars)    prod. eff= ****** A/P
P4= 117.6  E9  A4= 45.0 E9(pbars)       MR Beam=   0.01 E12
P5= 117.6  E9  A5= 35.0 E9(pbars)      Tev Beam=   1.17 E12
P6= 108.0  E9  A6= 37.6 E9(pbars)   Tev Energy=  896.9 Gev
B0  6.88 E30 STI =    0 WKI =   646   Str dur =   0.00 Hrs
D0  6.54 E30 STI =    0 WKI =   632  Out temp=    30.5 Deg-F
11:47:20 tevatron at flattop
11:47:36 beginning low beta squeeze
11:50:33 tevatron at low bets
11:51:06 now colliding

1151: Store 4264 is at low beta
beginning scraping.
```

*Fermilab's town crier, Channel 13, proclaims that collisions of protons and antiprotons into the Tevatron are imminent.*

The cerebral cortex of Fermilab's accelerator complex is the Main Control Room. Whenever the Tevatron needs a new store of particle beams, the Main Control Room is exceptionally alert. As the Tevatron is loaded with beams, six operators and as many as five physicists intently monitor and respond to signals on the computer screens. The transfer lines between the Main Ring and the Booster, the Tevatron, and the Accumulator have already been carefully tuned with sacrificial proton bunches. Six proton bunches, selected by a computer as the fittest of the pack, have just been injected into the Tevatron. It is now time to remove precious antiprotons from the Accumulator and deliver them to the Tevatron. Producing this trillionth of a gram of antimatter, called the stack, has taken days. With the help of sophisticated computer programs, operators have spent an hour setting up and checking the thousands of devices necessary for a successful transfer. As a hush descends, the shot master gives the command to begin transfers.

It is not the simplest order to follow. Painful past experience has taught us that this first pulse of antiprotons can be lost on its way to the Tevatron if any one of 30,000 devices has a problem. Operators are poised over the abort button on the computer, ready to stop the injection procedure at the first sign of trouble. A set of TV screens shows the antiprotons, in the form of 13 little bunches, as they shoot from the Accumulator into the Main Ring, accelerate, and coalesce into a single intense bunch. When the beam current monitor in the Tevatron announces the safe arrival of the antiprotons there is a collective sigh of relief. The procedure is carried out five more times.

When six bunches of antiprotons are zipping around the Tevatron in the opposite direction from the six bunches of protons, the procedure known as a shot is quickly completed. The beams are accelerated from 150 GeV to 900 GeV. Low-beta quadrupole magnets at each of the two detectors, CDF and D0, squeeze the beams down, like a lens focusing light, to make the beams smaller and more intense. This increases the luminosity — the likelihood of a proton running head-on into an antiproton — which is of crucial importance to the experimenters at D0 and CDF. To maintain these intense bunches as the beams circulate through the rest of the ring, the protons and antiprotons are guided along opposing helical orbits, like the strands of a DNA molecule. Only at the two detectors is the helix pinched closed. Around the rest of the ring, the beams never pass through each other. (There is no point in performing without an audience.) Any protons or antiprotons that have strayed from the desired path are scraped away, to reduce the background radiation in the detectors. A store is born, and the adrenaline level in the Main Control Room drops. During the next day or so, as long as every one of another set of thousands of devices all work properly, protons and antiprotons will keep colliding in the detectors. At the same time, new antiprotons are continuously being produced and stacked in the Accumulator for the next store.

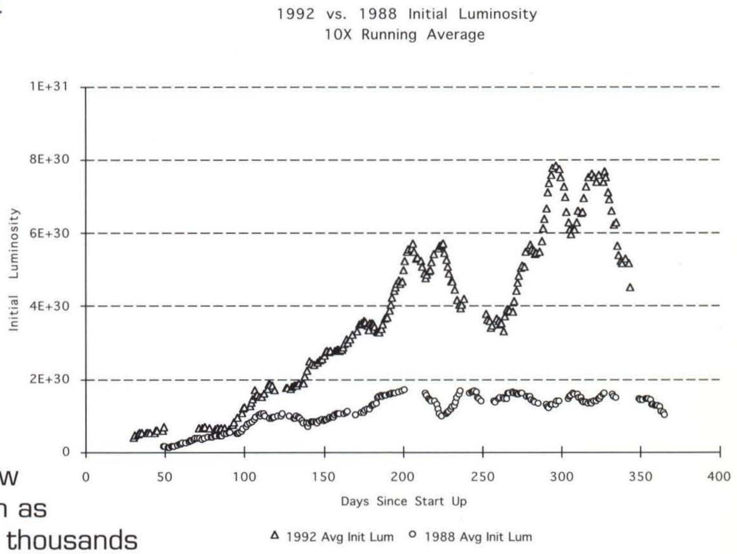
Experimenters have almost insatiable appetites for collisions, because many interesting processes (the production of heavy particles, like the top quark, for example) are exceedingly rare. This run, CDF and D0 were served high-energy collisions at a rate that broke world records for hadron colliders.

| | GOAL | ACHIEVED | UNITS |
|---|---|---|---|
| Luminosity | 5.0 | 7.48 | $10^{30}$ cm$^{-2}$ sec$^{-1}$ |
| Stacking Rate | 4.0 | 4.54 | $10^{10}$/hour |
| Integrated Luminosity | 1.0 | 1.48 | pb$^{-1}$/week |

*Comparison of the peak values of key Collider operational parameters achieved in 1992 with the goals set before the start of the run. Numbers were chosen so that 25 pb$^{-1}$ of integrated luminosity would be delivered to the experiments during the run that began in May 1992.*

What made possible such stellar luminosity? Several accelerator upgrades contributed:

- Electrostatic separators were installed in the Tevatron. By generating separate helical orbits for the antiproton and proton beams, they reduced the number of bunch crossings per turn from 12 to two, minimizing the disruptive effects of the beam-beam interaction that in the last run were the major intensity limitation.
- Improvements to the Antiproton Source stochastic cooling systems, which pack antiprotons into a small volume, dramatically improved both antiproton stacking rates and antiproton bunch density.
- Complicated beam manipulations during shots are now controlled by a sophisticated computer program, known as a sequencer. By automatically setting and checking the thousands of devices involved in a shot, it has increased both speed and consistency of accelerator operations.



During the first three months of the run, the Accelerator Division collided with several accelerator demons: unexpected losses of superconductivity in the Tevatron magnets (called quenches), power glitches, hundreds of random electronics failures, operational errors. Reliability was extremely low. The peak luminosity was only $1.3 \times 10^{30}$ cm$^{-2}$ sec$^{-1}$, and the antiproton stacking rate started off at a miserable $1 \times 10^{10}$ antiprotons per hour. To make matters worse, Fermilab suffered four sitewide power outages. Fortunately, the detectors were also tuning up at the time. When, late in August, D0 and CDF declared themselves ready to take physics data, accelerator reliability increased dramatically, and the number of particles per bunch (beam intensity) started to climb.

People who have been in the high-energy physics accelerator business for a while know better than to go home just because things begin looking good. As luminosities approached record-setting

Continued on next page

*Continued from previous page*

values, a new set of challenges arose. When a beam of charged particles becomes sufficiently intense, it generates an electromagnetic field strong enough to cause a dynamic interaction between the beam and its surroundings. Called beam instability, this phenomenon can, in a matter of milliseconds, cause the beam to grow and leave the machine. The consequences, while interesting to an accelerator physicist, can be devastating to graduate students collecting data for their theses.

During the fall, the bunches were intense enough for the trailing half (tail) of a bunch to feel the electromagnetic wake generated by the leading half (head). This head-tail instability forced the accelerator physicists to use less intense bunches until they discovered how to cure the problem by adjusting certain magnetic fields during acceleration.

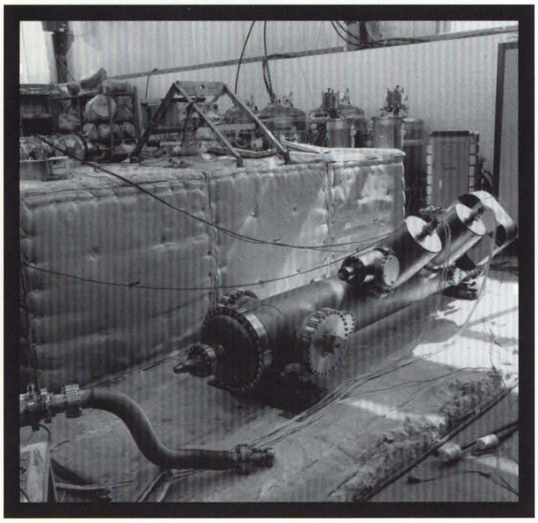
High-intensity proton bunches were made possible in the first place by successfully defeating an instability that arose in the Main Ring at 150 GeV, which caused beam loss during coalescing, the process of forming proton bunches. By shortening the coalescing time from 1 second to 0.12 seconds, the protons were bunched before the instability had a chance to occur. (The process is now known as snap coalescing.)

An instability in the intense core of stacked antiprotons in the Accumulator was found to be caused by positive ions trapped within the beam. Increasing the clearing electrode voltage swept the ions out before they could cause problems. A second instability in the Accumulator caused antiprotons to fall out of their bunches and thus fail to arrive in the Main Ring during extraction. The charge of the bunch was modifying the voltage in an rf cavity. The cavity is now electrically shorted during part of the unstacking process, and the rf unstacking manipulations have been changed.

The cause of poor luminosity lifetime in the Tevatron at 900 GeV was diagnosed as electromagnetic noise from power supplies, which shook the beam. A beam oscillation of as little as 30 angstroms (one hundredth the wavelength of visible light) can slowly increase the size of the beam, reducing luminosity prematurely. (This piece of paper is about a million angstroms thick.) By measuring these oscillations and the beam growth, it was possible to find and quiet the offending magnet power supplies.

A dramatic increase in machine luminosity quickly followed the solution of each problem. Peak luminosities have improved more than fivefold, to $7.5 \times 10^{30} \text{cm}^{-2} \text{sec}^{-1}$, and stacking rates have increased by more than a factor of four, to $4.5 \times 10^{10}$ antiprotons per hour and above. The run goal of 25 inverse picobarns (total integrated luminosity) now seems well within reach.

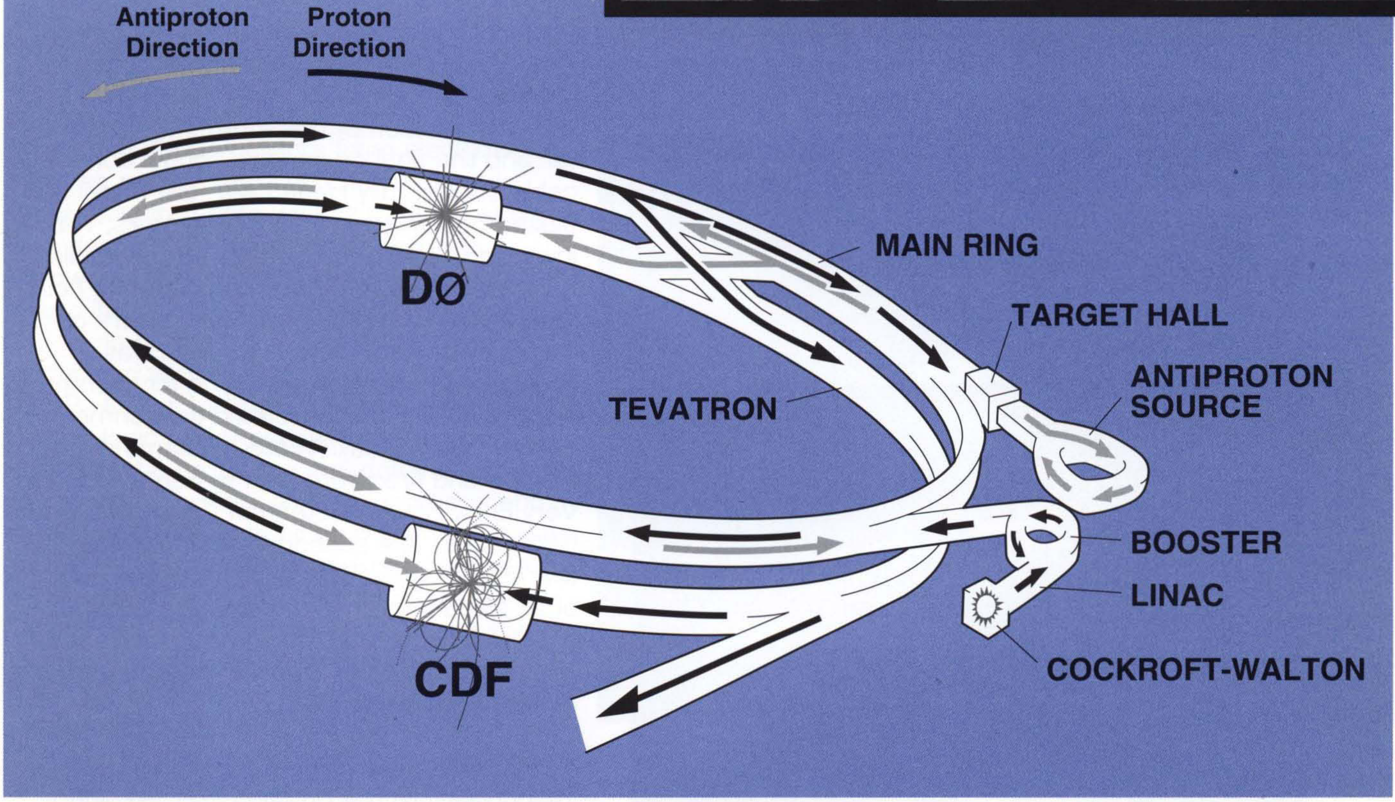
Even as the 500 people in the Accelerator Division look back with pride on what we have accomplished this run, we are also looking to the future. Physics and techniques we are learning now will stand us in good stead for the Linac Upgrade and Main Injector eras. Because of the dramatic increases in beam intensity called for in these upgrades, the innovations and hard work that brought us this far must continue. The adventure has only just begun.



*Shown in the AØ Lab, this electrostatic separator will be baked to release impurities from its interior in order to provide a better vacuum in the beam pipe. Twenty-two of these devices, designed to increase luminosity by maximizing the separation between the protons and antiprotons, were installed in the Tevatron with the last going into place in February 1992.*

*From the left, David McGinnis, Joel Misek and Henry Gusler prepare to install the stochastic cooling pick-up array in the Accumulator Ring of the Antiproton Source. The upgrade improved focusing of the antiproton core as the stack builds up.*

*These four are Fermilab's "run coordinators" who, with delicacy and daring, pilot the Tevatron into its mode of proton-antiproton collisions. From the left, Vinod Bharadwaj, Michael Church and Gerald Jackson. Seated, Alan Hahn.*

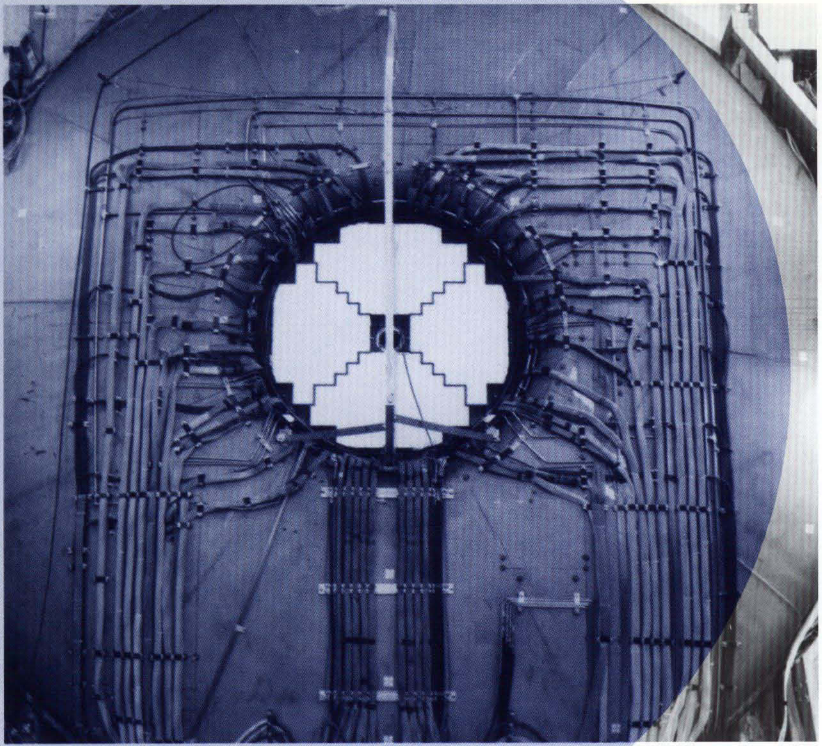


***BIRTH, LIFE, AND DEATH OF A PROTON AND ANTIPROTON AT FERMILAB.***

*Protons from an ordinary bottle of hydrogen gas are accelerated to 0.75 MeV by the Cockroft-Walton generator and then injected into the Linac, where they are accelerated to 200 MeV. In the next 31 milliseconds they whirl around the Booster approximately 20,000 times before being injected into the Main Ring at an energy of 8 GeV. In the Main Ring, they reach 120 GeV in 1.5 seconds.*

*Protons extracted from the Main Ring are slammed into the antiproton production target, a simple nickel disk. For every million protons that strike the target, 20 antiprotons spew out of the downstream end. These antiprotons are sent into the Debuncher Ring and then to the Accumulator Ring, where they are stacked. This entire process is repeated every 2.4 seconds until more than 4 x* $10^{11}$ *antiprotons have been stored.*

*The accelerator is then switched into shot mode. Six bunches of 150-MeV protons from the Main Ring are injected into the Tevatron. Similarly, six antiproton bunches are extracted from the Accumulator, accelerated to 150 GeV in the Main Ring, and injected into the Tevatron, in the opposite direction from the protons. After all 12 bunches have been accelerated to 900 GeV, they are steered into head-on collision in the centers of the CDF and DØ detectors.*



*D0 cryostat.*

# D0: A Year of Firsts

In 1983, at the time of the discovery of the *W* and *Z* bosons at CERN, Fermilab was commissioning the Tevatron, and the Collider Detector at Fermilab and the Antiproton Source were under construction. Director Leon Lederman reasoned that the huge effort required to build the source and Tevatron would be put to better use with an additional, probably small, specialized detector and subsequently called for proposals to build a second, modest, collider experiment at the D0 straight section.

In 1992 the not-so-modest second detector, D0, began to take collider data as part of the Laboratory's concerted effort to find the last predicted but as yet undiscovered quark: the top.

The past year has seen remarkable activity as more than 300 physicists, engineers and technicians from 30 institutions swarmed over the detector like ants getting ready for winter.

Before the roll-in from the Assembly Hall into the Collision Hall could proceed, the north end calorimeter had to be moved about 50 feet over a special I-beam bridge from the clean room to its home on the detector platform. This was followed shortly with the addition of the south end calorimeter and the final cryogenics connections. The cable bridge, fully loaded with the metal and plastic conduits for 100,000 signals, was lowered into position so that signals could be transmitted to the moving counting house where they would be digitized. Rework of muon low voltage power supplies was required before they would run for months without failure in the isolated environment of the Collision Hall. Water systems were flushed and fire protection systems including Very Early Smoke Detection Apparatus were fully tested. The schedule was tight, and there were only a few days for check-out of all electronic channels and the data acquisition system before the detector was completely powered down in anticipation of its 110-foot move.

*John Butler stands in the midst of the D0 Control Room surrounded by the people and the computers that monitor and control the millions of components of the sophisticated and sensitive detector. Counterclockwise from the foreground are: Wlodek Guryn, Michael Tartaglia, Robert Madden, Laura Paterno, Jay Wightman, David Ifversen, Michael Herren, Herman Haggerty, Stuart Fuess, Bruce Gibbard and James Linnemann.*

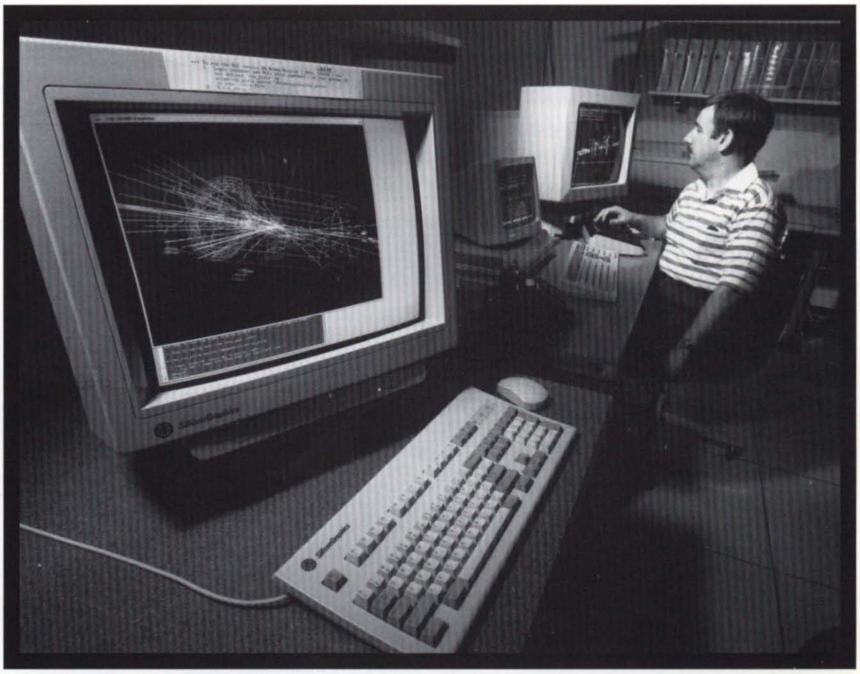
On the afternoon of February 14, 1992, the detector began the final leg of its journey into the Collision Hall. Six and a half hours later the detector was garaged in its nominal operating position without the massacre of a single detector element. It rolled under the lintel with six inches of clearance just as the surveyors predicted.

Once in the Collision Hall the detector checkout ensued. There were small problems to fix such as a low-beta quadrupole that wanted to occupy the same space as the edge of a muon chamber. Operational readiness clearance had to be obtained before detector systems could be powered. The detector platform had to be electrically isolated from the moving counting house. A system that furnished cooled air to the various detector systems had to be installed and tested along with its controls and software. All low-voltage power supplies had to be retested along with their monitoring, alarms and controls software. The beam pipes, both Tevatron and Main Ring, had to be connected, pumped down and monitored. Special scintillation counters around the beam pipes were installed.

In the meantime the Accelerator Division was making its final preparations to turn on the Main Ring and Tevatron, whose beams both pass through the D0 detector. On April 12 the detector saw its first splash of beam particles. They weren't collisions; they were hundreds or thousands of 8 GeV proton-induced Main Ring losses! A month later, on May 12 the first two-jet events from proton-antiproton collisions were observed. They were produced with a tiny luminosity of a few times $10^{-28}\text{cm}^{-2}\text{sec}^{-1}$ yet their observation was truly exciting after eight years of planning, building and testing the detector.

Steadily the luminosity of the collider increased and interesting events began to accumulate. By August, at the time of the XXVI International Conference on High Energy Physics in Dallas, the D0 Experiment presented data on 17 $W \rightarrow e\,\nu$ events and two $Z \rightarrow e\,e$ candidates. In November, at the time of the American Physical Society's Division of Particles and Fields meeting, the numbers of $W$'s and $Z$'s to electron decay modes had increased to 882 and 72 events, respectively. Physics papers presented at DPF covered the top search, inclusive jet cross sections, the single photon cross section, searches for SUSY particles and leptoquarks, and the observation of single and dimuon events from electroweak sources and bottom and charm decays. Newly acquired data were discussed along with descriptions of detector systems hardware and software, and plans for future improvements.

In all respects the detector performed very well up through the end of 1992. As the luminosity increased additional trigger logic and processor nodes were added to the hardware and software trigger systems to increase angular coverage and to allow more events to be recorded on tape. At the end of the year the experiment was taking events at a rate of over 1 Hz. The liquid argon calorimeters worked well and expectations for full coverage with very small missing transverse energy were indeed verified.



*In the D0 scanning room, Stephen Wimpenny of the University of California at Riverside reviews events that might contain a top quark.*

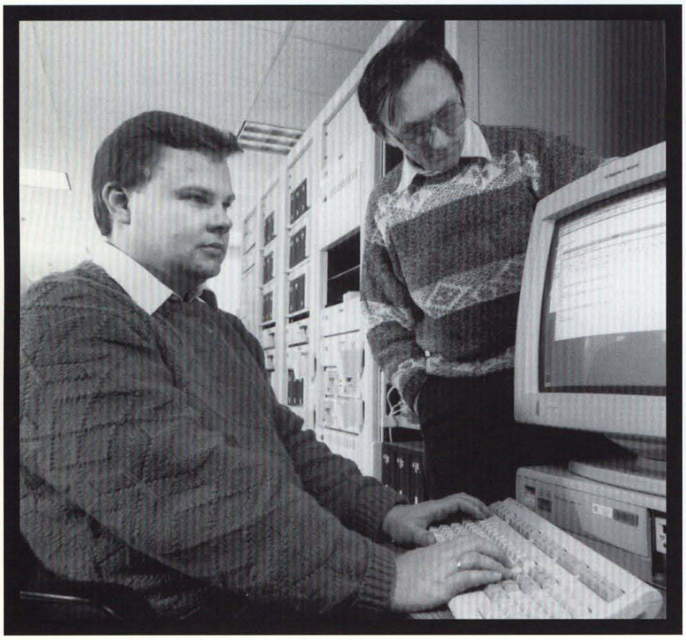
The integrated luminosity delivered to D0 from August to the end of December was nine inverse picobarns with five inverse picobarns logged to tape. About half of the inefficiency was caused by deadtime due to backgrounds associated with the simultaneous operation of the Main Ring in the manufacture of antiprotons. By the end of the year events were being logged to tape at the rate of about one million per month and being reconstructed via a farm of UNIX processors within a few days of being put to tape.

All of this good news augurs well for finding the top quark, measuring its mass, and doing many other experiments that have been conceived over the years. D0 looks forward to a long and productive physics life.

*Continued on next page*

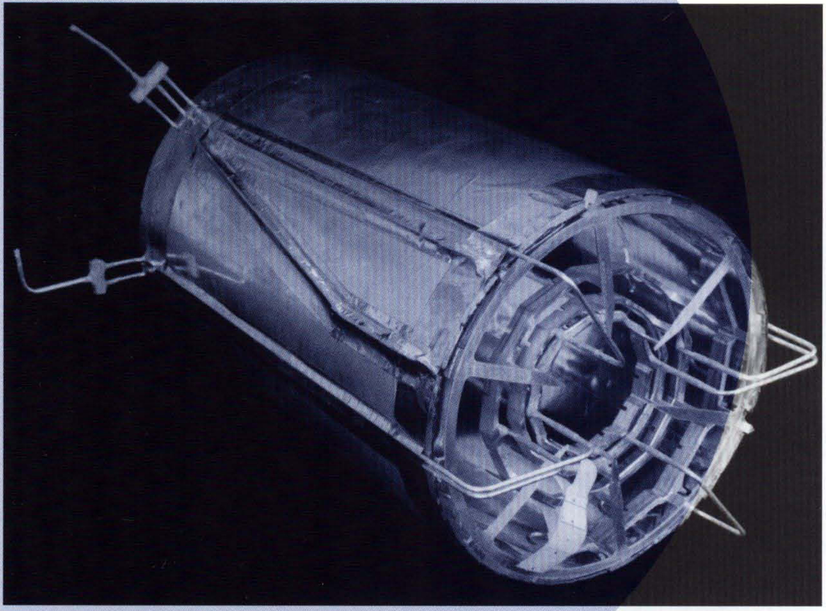
DØ story continued from previous page

Fermilab physicist Boaz Klima addresses his fellow collaborators in the 1 West conference room that was expanded in the fall of 1992. The DØ collaboration meets at regular intervals to discuss the latest data, to share the successes and concerns of the current run, and to plan for the future.



At the Feynman Computing Center, Kirill Denisenko (left) and Adam Para manipulate the off-line data processing nodes. In 1992, DØ recorded five inverse picobarns of data and was able to make a first pass analysis within a few days.

Joan Guida (left) and her twin sister Jan Guida, physicists on the DØ collaboration, discuss a log book entry in the control room. The large screen above their heads is the on-line event display.



*The silicon microstrip vertex detector for CDF.*

# CDF: B Physics from 10 Meters to 10 Microns

In high-energy physics the constituents of matter are studied with particle beams and detectors analogous to studying small objects with a microscope: the accelerator provides the "light" in the form of particle beam radiation with the smallest possible wavelength, and the detectors provide the optics to collect the scattered "light" into a visual image of the object at a human scale. Recent events at the Collider Detector at Fermilab (CDF) illustrate just how apt this microscope analogy has become.

With the 1992 installation of a silicon microstrip vertex detector (SVX), CDF became capable of observing the character of collisions at the scale of 10 microns (about 0.0004 inch). Event details inside the Tevatron vacuum beam pipe can now be studied even though no detector resides inside that beam pipe. This year also saw the original 4,500 ton detector upgraded by the addition of 2,500 new muon wire chambers and 630 tons of steel, all required to make some of these special event observations possible.

The detector is an intelligent microscope, capable of selecting only the events of interest out of the 500,000 collisions occurring each second. Approximately 28 events of the type described below have been seen so far out of a sample of approximately 5 x $10^{11}$ collisions. Compared to the classical microscope, this is like having an instrument that can be programmed to select the one exciting specimen out of a collection of 20 billion slides.

CDF is a complex instrument; it records 115,000 pieces of information about each selected event. The detector requires plenty of care and feeding. Over 400 scientists from five countries collaborate on the detector construction and operation, and on the event analysis. A support staff of another hundred in the Fermilab Research Division keep it running smoothly. Additional support staff in the Computing Division is crucial for the event analysis. And of course without the Tevatron collider "light source" and Accelerator Division personnel, the detector would be blind.

Events containing *b* quarks are the specimens of interest described here. CDF looks for collisions resulting in a *B* meson (containing a *b* quark) plus anything else; the *B* mesons are unstable and decay after living only 1.3 x $10^{-12}$ seconds. Some of the time the *B*'s decay into a *J*-psi ($J/\psi$) particle and a *K*-star particle ($K^*$); subsequently the $J/\psi$

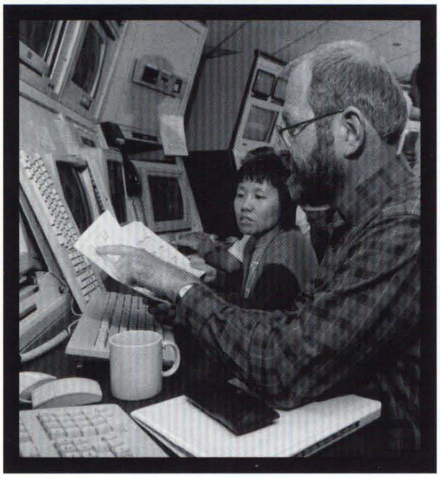
*The curved chamber depicted here is part of the overall upgrade to the central muon detector system that was designed to significantly extend the detector's physics coverage. CDF rolled into the BØ collision hall in March with the first collisions seen in May. Studies continued until August 26, 1992 when CDF declared the detector commissioned and the data of sufficient quality to begin the search for the top quark. Due to increased Tevatron luminosity and increased CDF efficiency, data which took 272 days to accumulate in 1988-89 took only 106 days in 1992.*

Continued on next page

*Continued from previous page*

decays into two muons ($\mu$) of opposite charge and the $K^*$ decays into a $K$ meson ($K$) and a pi meson ($\pi$) of opposite charges. We search for the process $\bar{p}p \to \mu^+ + \mu^- + K^\pm + \pi^\mp + X$.

A picture of CDF **1** is shown at the same scale as the computer generated graphic of an event recorded on magnetic tape. **2** In this view the beams head into and out of the page at the center of the diagram. The shaded areas indicate detector components containing many layers of lead and steel; the darker shading indicates solid steel. Particles that come from the interaction point and penetrate all this material are, typically, charged muons. Such particles deposit energy in the muon wire chambers behind the lead and steel, and that energy is shown in the graphic as X's. CDF also has a region of magnetic field generated by a superconducting solenoid inside the lead and steel components. Charged particles in this region are detected in another wire chamber and the detected particle path is shown in the graphic as a curved line. This particular event was selected by the detector triggering system because it had two muon candidates and two matching curved tracks. The momentum information from these two muons can be combined to measure the mass of the parent $J/\psi$ particle.



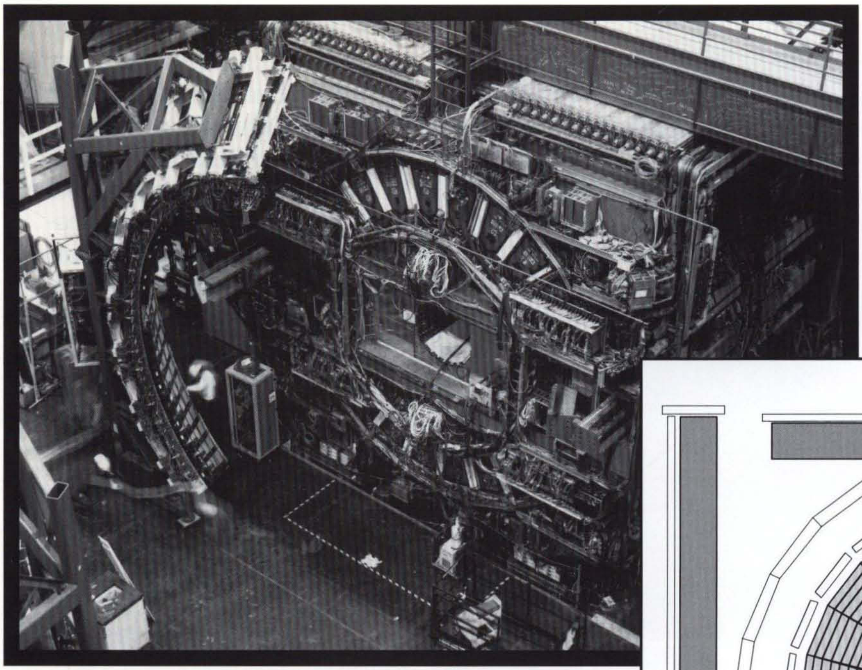
*The CDF control room, staffed around the clock when the experiment is running, is often the scene of intense excitement as well as reasoned discussion. Hans Jensen (right) points out an interesting statistic to Aesook Byon-Wagner.*

Next we zoom in to see what the SVX tells us about the event details right at the interaction point. **3** SVX, a 20-centimeter-diameter device, has 46,000 strips etched in silicon wafers, with separations of 60 microns between the strips. There are four layers of silicon, and these four position measurements can be used to extrapolate the particle paths deep inside the Tevatron vacuum beam pipe. These extrapolated tracks are shown **4** inside a circle with one-centimeter diameter for the same $J/\psi$ event illustrated in **2**. The tiny circle in the center of the picture represents the Tevatron beam, about 140 microns in diameter. Using the tracks from the primary vertex in a given event, the SVX can determine the actual position of the interaction to about 10 microns.

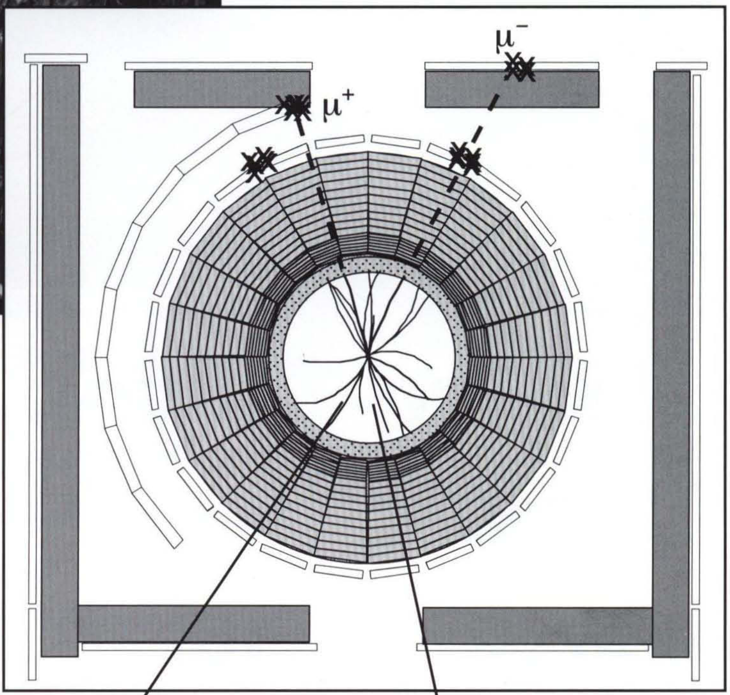
If a *B* moves at nearly the speed of light, then it travels a measurably finite distance before decaying. This distance can be simply calculated by multiplying speed by its short lifetime of $1.3 \times 10^{-12}$ seconds to give 390 microns. This is the average lifetime; some *B*'s live a longer time and some a shorter time. One can see that the muons in this event do not appear to come from the beam spot but instead come from a secondary position several hundred microns away from the beam. This is just what we expect for a *B* meson. Looking closely you will see that two other tracks also come from the secondary vertex. These are the *K* and the $\pi$ meson; the reconstructed mass from these two particles is consistent with the mass of the $K^*$. The information from the $\mu^+$, $\mu^-$, *K* and $\pi$ tracks can be combined to measure the mass of this *B* meson as 5.3 GeV. This is almost exactly the known value of the *B* meson mass and confirms that we are probably looking at a *B* meson.

Finally, notice there is another secondary vertex located below the Tevatron beam. **4** The complete process is $\bar{p}p \to B + \bar{B} + X$ ; we now see evidence of the other *B* meson! The decay of the second *B* is unconstrained — we did not demand that it undergo the decay into $\mu\ \mu\ K\ \pi$ and so now we can begin to study the properties of *B* mesons in general by looking at the second *B* after triggering on the first of the pair. While the combined branching ratio for *B* mesons into $J/\psi$ followed by $J/\psi$ into $\mu^+\mu^-$ is only about one in every 1,500 decays, other decay modes have higher probabilites. For example, the most obvious *B* characteristic is its short lifetime and subsequent decay leading to a potentially visible secondary vertex. Every *B* meson has this property.

Once the collaboration devises a fast trigger to select these events with secondary vertices, CDF will open a new window for the detailed study of one of the six fundamental quarks.

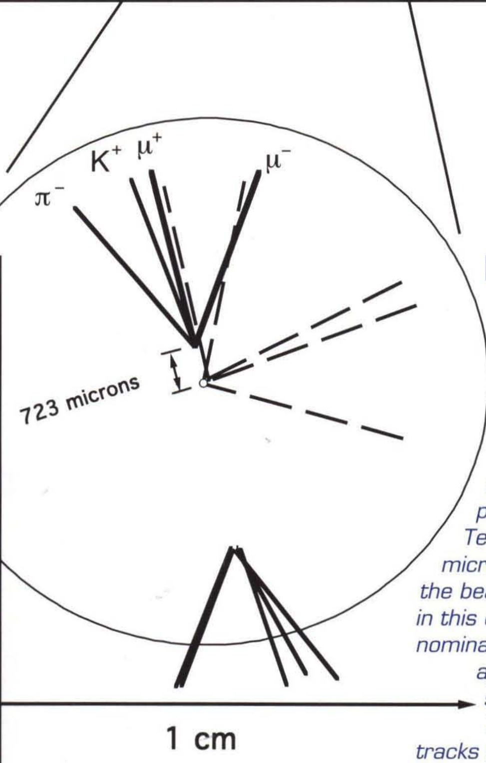


**1**
*The Collider Detector in the CDF Assembly pit just before rolling into the Collision Hall in March 1992. The central part of CDF shown here is a cubic structure about 10 meters on a side. The new muon wire chambers are seen at the top of the detector and in the curved conical stand at the left.*

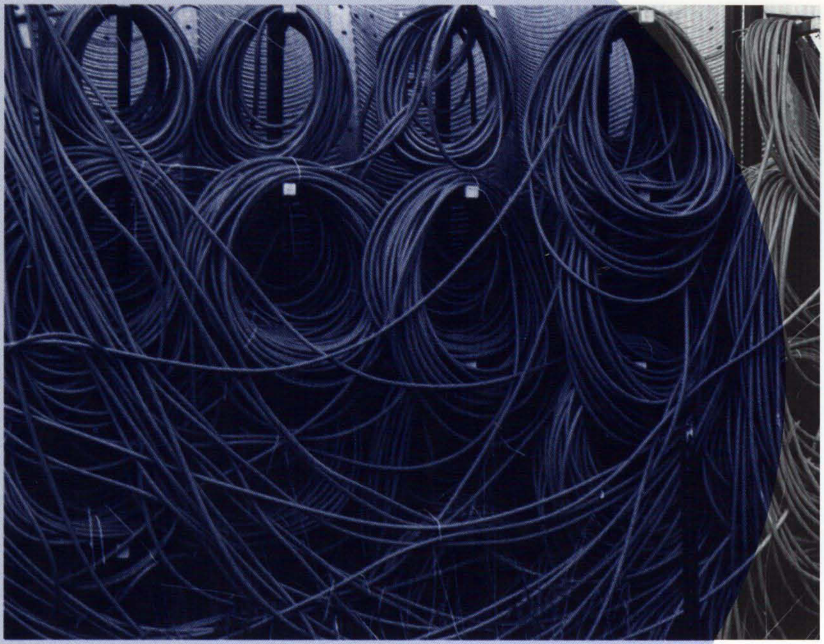


**2**
*Computer graphic representation of the $\bar{p}p\rightarrow\mu^++\mu^-+K^\pm+\pi^\mp+X$ event discussed in the text. The event was selected by the CDF trigger because of the two muon (μ) candidates shown. The $\mu^-$ is detected in the chambers at the top of the dectector. The $\mu^+$ is detected in the conical chambers at one end of the detector. As indicated by the dotted lines, both candidates match to curved tracks measured inside the solenoid magnet.*

**3**
*Humbero Gonzales carefully aligns one of the two barrels of the CDF silicon microstrip vertex detector in its clean room environment just after assembly. The cylinder (actually a 12-sided polygon) is made up of four concentric layers of silicon detectors.*



**4**
*Computer graphic representation of charged tracks extrapolated to the innermost 1.0 centimeter of CDF for the same $\bar{p}p\rightarrow\mu^++\mu^-+K^\pm+\pi^\mp+X$ event shown in* **2** *The tiny circle in the center of the picture indicates the nominal Tevatron beam size (a 70 micron radius contains 90 % of the beam). The $\pi^-$, $K^+$, $\mu^+$, and $\mu^-$ in this event do not come from the nominal beam spot; instead they appear to come from a secondary vertex displaced 723 microns away. Five tracks (dashed lines) do come from the primary interaction point, while five additional tracks at the bottom of the picture come from yet another secondary vertex.*



*Dismantled cables.*

# The Fixed-Target Program: A Cornucopia of Results

> *"In any case, the bottom line on the future of fixed-target physics is one of commitment. Much very good physics is there to be done. The necessary condition is that there be enough people who are willing to do the hard work to get it out."*
>
> — **J.D. Bjorken, Fermilab Annual Report, 1984.**

After nine years, the verdict is in. "Data, data everywhere and lots of it in print" could summarize this report from the fixed-target experiments at the Laboratory. Thanks to the data-runs in 1988 and 1990–1991, there are results on the whole spectrum of particle physics from the measurement of $\alpha$, the parameter that describes how cross sections depend on atomic number, to the observation of the $\Omega_c$, the particle that contains a charm quark and two strange quarks — not to mention measurements of $\alpha_s$, the strength with which quarks bind to the measurement of the magnetic moment of the $\Omega^-$ particle. Enough Greek!

The so-called Standard Model acts at present as the conceptual framework or picture for experiments in particle physics. While the colliding-beam experiments search for the top quark at the highest energies, fixed-target experiments study the details of the Standard Model. They search for the unexpected, they test the theory in as many aspects as possible, using different beams and targets, measuring a host of different processes with incisive precision to resolve old problems and reveal new issues and to challenge our understanding of the elementary particle world. The list of experiments that took data in the 1990–1991 run is in the Table. Following is a sample of the results from the fixed-target program presented this year.

A highlight of the year was the report of the discovery of the $^1P_1$ state of charmonium by E760 using a hydrogen gas-jet target, which intercepts the antiproton beam circulating in the Antiproton Accumulator to generate the reaction $\bar{p}p \to \bar{c}c$. ❶ The experiment measures the masses and widths of the $\bar{c}c$ states directly from the antiproton beam energy and has used the excellent energy calibration of the Antiproton Accumulator to report new precision measurements of the masses and widths of several charmonium states. ❷ The observation of the $^1P_1$ state has long been the goal of charmonium experiments, since its mass gives crucial information about the nature of the strong interactions between quarks.

Two other major highlights were the reports by E687 of the observation of the $\Omega_c$, (ssc) baryon and two $L=1\,D^{**}$ mesons from their data using a high-energy photon beam on a beryllium target. ❸ E687 has also obtained the most precise values in the world for charm particle lifetimes. See ❹ for two plots of the $D_s$ signal for different decay lengths. The other peak in the plot is the $D^+$.

Just by comparing the relative sizes of the two peaks, one sees that the $D_s$ lifetime is shorter than the $D^+$. **5** E769 published data on hadroproduction of charm — including the A-dependence from their multi-element target and the x dependence. E791, the successor to E769, used a 500-GeV pion beam and accumulated data from 20 BILLION interactions. **6** This data set is expected to yield over 100,000 identified charm decays.

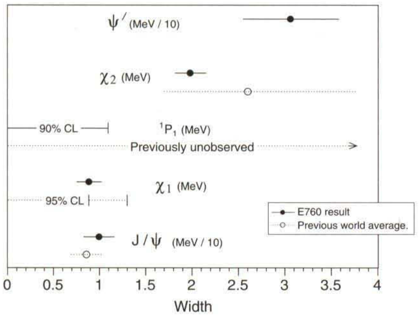
On the theme of particle properties, E800 measured the magnetic moments of both the $\Xi^-$ and the $\Omega^-$. **7** Various techniques are used to generate polarized hyperons as needed to measure magnetic moments. Superb precession data for the $\Xi^-$ is obtained. **8** The results on the polarization of hyperon production confound the present models — counter-revolutionary was the phrase used by the Russian raporteur at the DPF conference. **9** E761 was a study of hyperon radiative decays and settled the issue of the asymmetry parameter in the $\Sigma^+$ radiative decay

*Continued on next page*

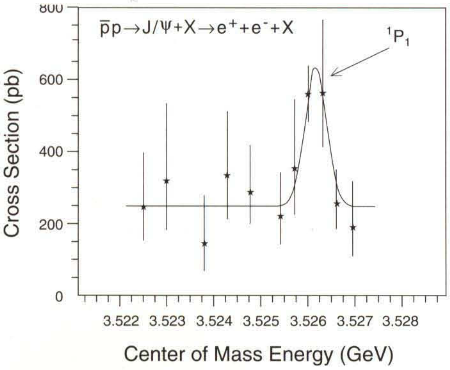
Experiments that took data in 1990-91

| EXPERIMENT | | INSTITUTIONS | PHYSICISTS | STUDENTS | OTHER | TOTAL |
|---|---|---|---|---|---|---|
| E665 | Muon scattering | 17 | 62 | 30 | 10 | 102 |
| E672 | Hadron jets | 6 | 26 | 3 | 2 | 31 |
| E683 | Photoproduction of jets | 10 | 25 | 10 | 2 | 37 |
| E687 | Photoproduction of charm | 12 | 64 | 28 | 32 | 124 |
| E690 | Particle search | 5 | 20 | 8 | 7 | 35 |
| E704 | Polarized beam | 16 | 56 | 9 | 19 | 84 |
| E706 | Direct photon | 9 | 40 | 18 | 5 | 63 |
| E760 | Charmonium | 7 | 48 | 17 | 23 | 88 |
| E771 | *B* production | 21 | 90 | 22 | 16 | 128 |
| E773 | $\eta^{+-},\eta^{00}$ | 5 | 20 | 9 | 2 | 31 |
| E774 | Electron beam dump | 4 | 9 | 0 | 0 | 9 |
| E782 | Muon in 1 m BC | 10 | 27 | 8 | 5 | 40 |
| E789 | *B* production | 8 | 29 | 6 | 5 | 40 |
| E791 | Hadroproduction of charm | 13 | 52 | 25 | 4 | 81 |
| E800 | Magnetic moment | 5 | 8 | 7 | 2 | 17 |
| | | | 576 | 200 | | |

**1 *E760***

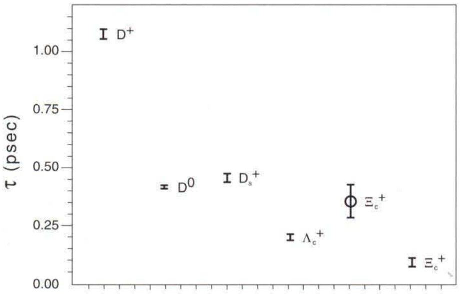


**2 *E760***

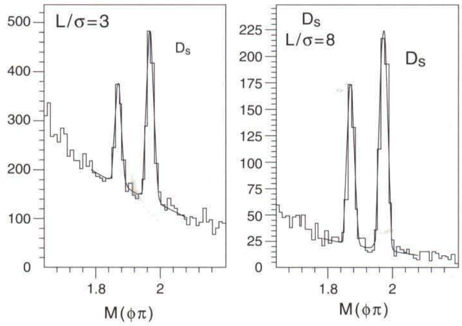


**3 *E687***

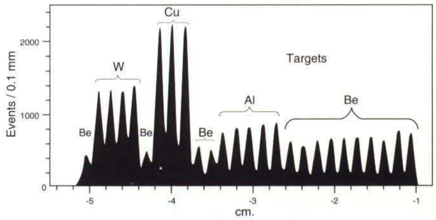
Results on Charm Lifetimes



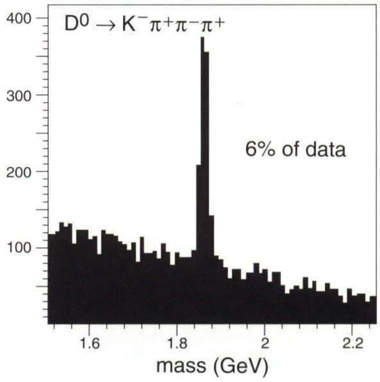
**4 *E687***



**5 *E769***

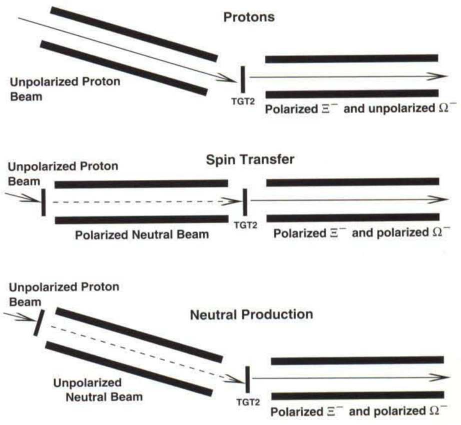


**6 *E791***

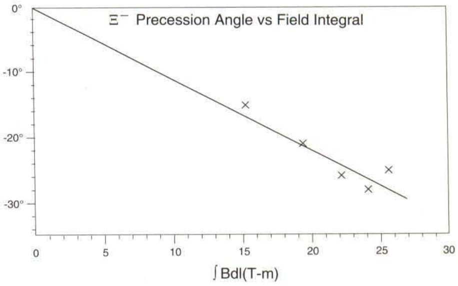


**7 *E800***

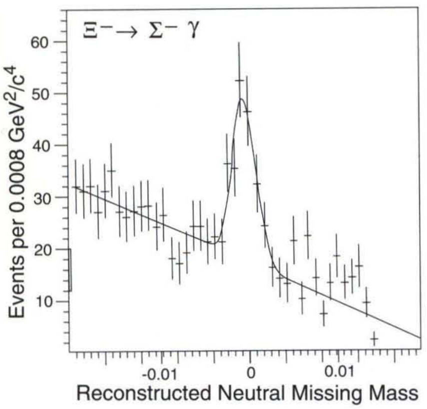
*Methods for making polarized hyperons*



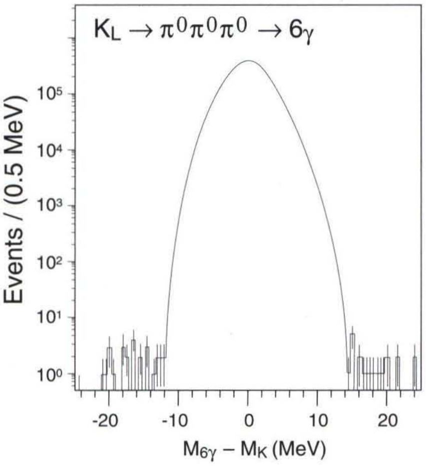
**8 *E800***



**9 E761**



**10 E731**



*Continued from previous page*

and accumulated the first large sample of $\Xi^-$ radiative decays. This experiment also produced the first demonstration of magnetic moment precession using a bent crystal.

The decay of the neutral *K* meson is the only process known to science that violates the combined Charge and Parity (CP) symmetry. The precision study of neutral *K* meson decays, E731, has presented several results based on its full data sample including measurements of $\Delta\phi(=\phi^{+-} - \phi^{00})$, $\tau_S$ the lifetime of the $K_S$, and $\Delta m$, the mass difference between the $K_L$ and the $K_S$. The major aim of the experiment is the measurement of the CP violation parameter $\varepsilon'/\varepsilon$. As an example of the quality of this experiment's data, witness the $K_L \rightarrow 3\pi^\circ$ peak. **10** The signal to background ratio is about a million to one.

**11** Fixed-target experiments study several processes to learn how quarks and gluons distribute themselves "inside" particles, the quark and gluon distribution functions q(x) and G(x). Neutrino beams, muon beams, proton and pion beams have all been used and each contributes to test the theory and to complete the picture. Measuring the gluon distribution in particles other than the proton has been a particular challenge. **12** E705 has published its data on $\psi$ and $\chi$ production by pions and protons. While the ratio of $\pi^+$ to $\pi^-$ production is about 1, the ratio of pion to proton production increases as a function of the momentum of the produced $\psi$ suggesting that the gluon distribution is relatively harder in the pion than in the proton. **13** Another approach to measuring the gluon distribution was taken by E706, which measures direct photon production.

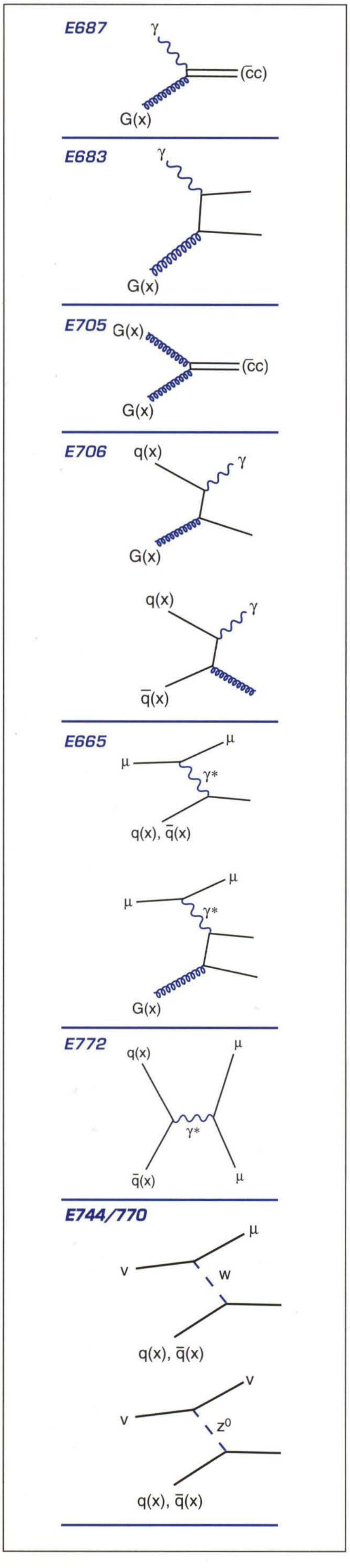
The muon-scattering experiment, E665, has exploited the 450-GeV muon beam from the Tevatron to good effect. Muon scattering offers the ability both to probe the nucleon and to test the theory of the strong interactions. E665 measures the incident muon, the scattered muon and the fragments of the struck nucleon. **14** In a novel analysis, the rates of "two jet" and "three jet" events are used to test the theory of the strong interactions. The experiment may also settle the long-standing issue of "shadowing" or just when a virtual photon begins to see nuclei like a real photon. The extra energy of the Tevatron's muon beam allows E665 to see details of the onset of shadowing for the first time.

Data from the E744/770 neutrino-scattering experiments provide some beautiful measurements of the quark distributions. This set of experiments studies neutrino interactions both to determine the form of the weak interaction and to probe of the structure of the nucleon. The theory of the interactions between quarks predicts that the measured structure of the nucleon changes slightly as neutrinos scatter with more or less violence. **15** This measured change can be compared with the theoretical prediction; this plot summarizes a large body of work in experiment and theory and the agreement is quite impressive.

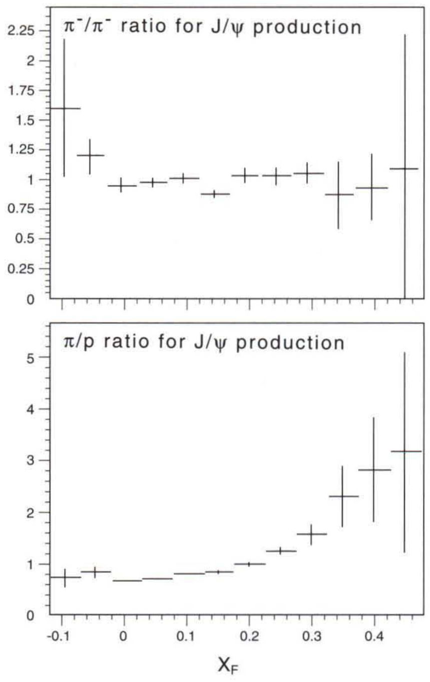
A nice example of the way the same issue can be addressed with different techniques is in testing if the $\bar{u}$ quark distribution in the proton is the same as the $\bar{d}$ quark distribution. Both muon-scattering experiments and experiment E772 which studies production of muon-pairs in proton-nucleus collisions can study this. **16** The E772 data is compared to predictions based on muon-scattering data. With the quark distributions well measured, experiments are beginning to measure the anti-quark distributions, too.

It is clear from this sampling that the fixed-target program is reveling in a wealth of data. It is producing precision results on a whole spectrum of particle physics, clarifying long-standing issues, and challenging our understanding of nature at its most elementary with new observations.

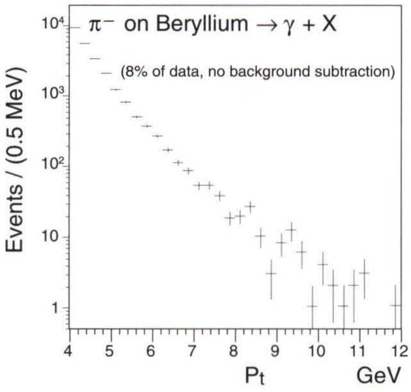
### 11



### 12 *E705*

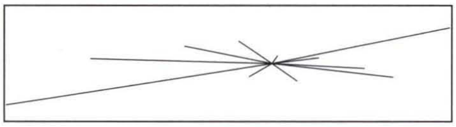


### 13 *E706*

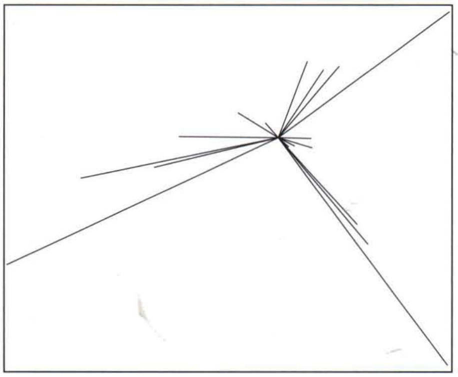


### 14 *E665*

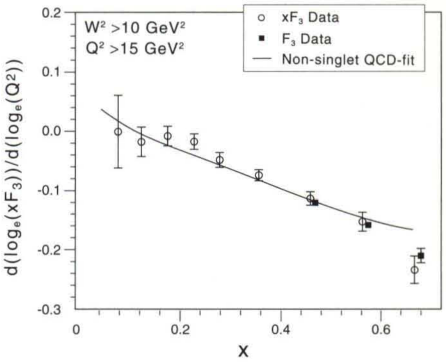
***Two-Jet Event***



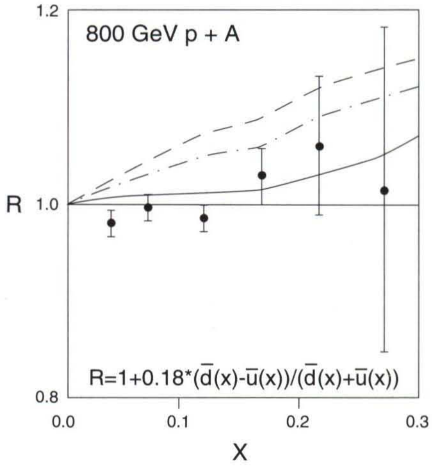
***Three-Jet Event***

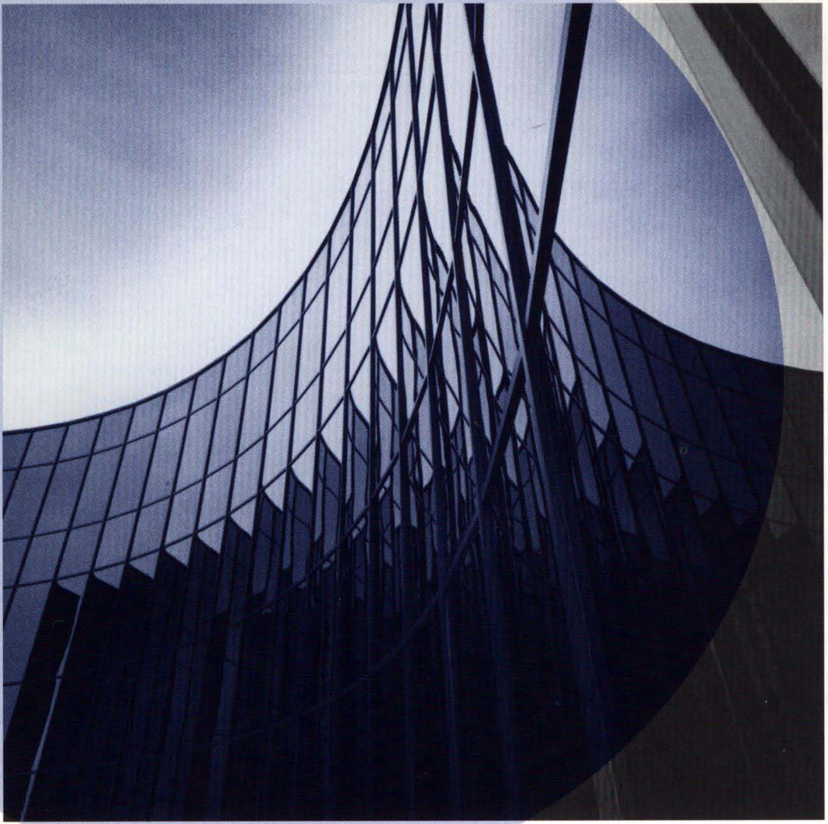


### 15 *E744/770*



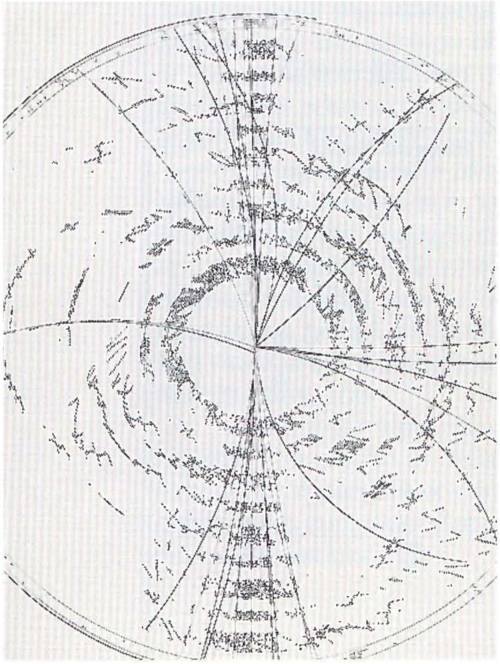
### 16 *E772*





*Facade of Feynman Computing Center.*

# Computing the Nature of Nature



*Of the billions of collisions in an accelerator, only a tiny number gives useful scientific results; to reconstruct and identify them, as in this reconstruction, takes some of the world's most powerful computers. In meeting the challenge of managing experimental data, Fermilab has emerged as a key contributor to the design of the next generation of the nation's computers.*

What are the ultimate particles of matter? The ultimate forces of nature? In the search to understand the inner workings of the universe, physicists at Fermilab use high-energy particle accelerators in experiments that push the extreme limits of computing.

The Computing Division operates a diverse collection of computing hardware and software systems in a successful program designed to satisfy the Fermilab high-energy physics community's voracious appetite for computing.

One of these systems — called "farms" — is a collection of relatively inexpensive workstations that are centrally managed as distributed parallel computers. Fermilab is the recognized pioneer in workstation cluster computing with some of the largest production farms in existence. There are two farms currently in production at Fermilab, each with over 100 workstations that provide 7,000 VAX 11/780 equivalents. These farms use a Fermilab-developed system of software, Cooperative Processes Software, to do system management and parallel computing. This new approach to high-performance, parallel computing far exceeds the power of a traditional mainframe.

As one of the leading developers of cluster technology, many other sites with large computing demands are seeking assistance from Fermilab in establishing their own farms. To facilitate the transfer of this technology into the commercial domain, Fermilab is collaborating with IBM and Merck & Company, Inc., a leading US pharmaceutical company. Fermilab and IBM are refining the cluster approach for solving large computational problems with cost-effective technology. At the end of 1992, Fermilab was developing a Cooperative Research and Development Agreement with Merck and IBM. Fermilab is assisting Merck in installing a farm computing environment at their Rahway, New Jersey site. The collaboration will investigate the applicability of Fermilab hardware and software approaches to the industrial domain of computer-assisted discovery.

The lattice-gauge supercomputer, ACPMAPS, was another 1992 success story. This distributed-memory, highly parallel computer was built as a collaboration between the Computing Division's Computing R&D Department and the Theory Department of Fermilab's Research Division. The first generation ACPMAPS, which achieved 5 GigaFLOPS (peak), was used for calculations that resulted in findings that increased our understanding of the strong nuclear interaction. These findings were reported at several international conferences. During the year, the computer was upgraded to next generation processors, increasing its peak performance to 50 GigaFLOPS and assuring its status as one of the most powerful computers in the world.

Recognition of the Computing Division's achievements as a leader in the development and use of high-performance computing has resulted in invitations to speak at conferences, including SuperComputing '92 held in Minneapolis.

A DOE-appointed review panel, led by Dr. Bill Buzbee of the National Center of Atmospheric Research, reviewed and endorsed the division's activities and plans in computing. The panel included experts from outside the high-energy physics community. Their report unanimously concluded that "Fermilab is one of the world's leading laboratories in cluster technology and parallel computing." This exposure has provided opportunities for the division to establish collaborations with computer vendors, aimed at advanced architectures for both data-intensive and compute-intensive problems. Other areas in which the division offers expertise include the previously mentioned farm computing, management of large distributed systems, and performance monitoring in high-performance, parallel computers.

Throughout the year, the Computing Division continued to carry out its mission of providing robust computing services to the Fermilab community, while taking big strides forward in new projects.

A significant initiative was the creation of file-server systems for the CDF and DØ detector facilities. Both of these experiments collect huge amounts of data that must be stored and then retrieved for subsequent analysis. The Computing Division met this challenge in cooperation with the detector collaborations by building separate file-server systems, based on widely available, low-cost disk storage accompanied by tape cartridge and robotic cassette. They were available at the start of the 1992 Collider Run and have been in continuous heavy use.

The use of the UNIX-operating system has continued to grow throughout both the division and the Laboratory. A growing number of desktop UNIX and VMS systems require support. Two new large UNIX-based projects are underway to develop general purpose batch and interactive services for the Laboratory.

Support for computing requires more than technology. The division has instituted organizations to support specific programmatic groups that use its resources. The DØ Computing and Analysis Group, staffed by both physicists and computing specialists, pursues computing projects in the interest of the experimental group, and communicates the special needs and requirements of the group to the Computing Division. Similar groups have formed for CDF and SDC. Another group has formed in Fermilab's Experimental Astrophysics Group that is collaborating in the Sloan Digital Sky Survey, a program to map more than a million galaxies.

### *A Short Glossary*

*Ethernet - A very common network protocol and physical medium that allows many computers to be interconnected. The most common networks at Fermilab are Ethernet and FDDI, a higher performance successor to Ethernet.*

*File and Tape Servers - Computers that handle data traffic. They either store and retrieve files of data from local or remote holding areas or they serve to read and write to and from tapes. Common tapes used at Fermilab are 8-mm tapes similar to video cassette tapes.*

*FLOPS - Floating Point Operations Per Second. A measurement of calculation speed for those computations that are typically done in scientific and engineering applications. GigaFLOPS - A billion FLOPS. Any machine delivering over a GigaFLOP is certainly a supercomputer.*

*UNIX - An operating system which has become a very popular system because of its widespread use in the "open system" computing environments.*

*Fermilab's farm-clusters include over 300 workstations, interconnected with Ethernet and configured with file and tape servers. Fermilab's Cooperative Processes Software tools let users divide jobs into logical processes, then distribute and manage them across a farm. A batch system — a required feature for large multiuser, multiplatform environments — manages the job execution, resource allocation and system administration. This array of computers dwarfs Mark Haibeck of the Computing Division.*

# IMPRESSIONS

## 1967–1992

*Three directors have wisely, creatively and courageously led Fermilab through the past 25 years. From the left, they are John Peoples (1989–present), Leon Lederman (1979–1989) and Robert Wilson (1967–1978).*

In the 25 years that Fermilab has existed, its character has been shaped by countless people. Even before it was brought forth, its godparents debated what qualities in this center for research would help the physics community flourish. Since March 7, 1967, some 10 thousand employees have dedicated themselves to building and caring for the Laboratory. It has been a home to thousands of visiting investigators, who have come from across the country and from many parts of the world, seeking enlightenment and bringing fresh points of view. Everyone from the administrative assistant who has been here longer than Wilson Hall to the graduate student who drove past the bison for the first time last week contributes to the aspirations and achievements and spirit of this place.

A complete understanding of every aspect of the Laboratory will always remain elusive. This collection of thoughts and reminiscences by and about some of the people who have helped to make Fermilab is not meant to chronicle its scientific or technological or political history. The portraits are highly individual, but they do have one thing in common: each writer has experienced the happiness of seeing what the human mind and heart, at their best, can create.

I started my Fermilab career at the twin office buildings in Oak Brook in April of 1968. It was a tremendous culture shock to come from a well-organized, business-like operation to what appeared at first observation to be utter chaos. I learned very fast that what seemed to be mass confusion was in reality excitement and enthusiasm for the project.

We moved to the village shortly thereafter and our office was in a bedroom in one of the small Village houses. Most of the other houses were still occupied by families who had not yet moved. The Purchasing Department received a lot of visitors, and our receptionist never got tired of directing salespeople to "the second bedroom on the right." There we were, purchasing sophisticated high-tech hardware, while outside our window kids were playing and homemakers had wash hung out to dry.

Schedules were extremely tight, and we felt a lot of pressure to obtain early deliveries and at the same time keep costs to a minimum. We succeeded beyond anyone's expectations; the accelerator was built ahead of schedule and below budget.

One of my memories is attempting to rent a very large tent for the groundbreaking ceremonies and being turned down by everyone. This was December, and no one would risk a liability suit caused by snow collapsing the tent. Finally, I found someone willing to do so, with a disclaimer of liability. As bad luck would have it, it did snow that day, and our maintenance people had to keep brushing off the buildup. It was a nervous afternoon for me.

We had great cooperation from the Atomic Energy Commission. Although we had to submit every procurement over 10 thousand dollars to them for approval, K.C. Brooks, Fred Mattmueller, and Andy Mravca were fair and prompt in their reviews.

We had a very strong program of reviewing suppliers' affirmative action programs. The Laboratory was founded in an atmosphere of concern for human rights, and we were very aggressive in carrying out the program with Laboratory suppliers.

**Dick Auskalnis**
**Procurement Manager, 1968–present**

I don't know what the real world is like; the only place I've worked is at Fermilab. I started in 1971 in the summer between my junior and senior years in high school and came back the next summer after graduation for full-time employment, since I hadn't yet decided what to do with my life. For about my first five years here, I was known as "Carolyn Gifford's daughter," of which I was proud. My mother worked in the Purchasing Department from 1968 until her retirement in 1981, and everyone who knew her liked and respected her. My sister, Marge Harvey, has been in the Accelerator Theory Department for almost 20 years. And last, but not least, I met my husband in 1975 at the Users' Center; he was a graduate student from the University of Illinois working on an experiment here. He joined Fermilab in December 1981. My family alone has invested about 65 years in Fermilab. Whew!

It's hard to decide what to write about. Should I tell you about the time Rudy Dorner brought the buffalo head through the office and Shirley Burton fainted? Or should I tell you about the time I was dressed up like "Mary Hartman, Mary Hartman" with braids and Shirley's jumper, and Dr. Wilson walked up? Or should I tell you about the time Carol Weissert (Peaches), Marilyn Paul, and I tricked Tom Groves into thinking he was on the phone with his daughter in Papua, New Guinea? Or the time Tom Regan and I were in the dunk tanks at the picnic dressed as bride and groom (we fought back with squirt bottles!)? Or the time that Taiji Yamanouchi dressed up as E.T.? Or the time Leon hypnotized the chicken?

It sounds like it has been a lot of fun and games over the years, but believe me, a lot of hard work justified these short departures. I have learned a lot, and even some physics through my job in Program Planning with Taiji and the Physics

Advisory Committee. Taiji and I have worked together so long we are able to finish each other's sentences. Working with Roy Rubinstein, I have met countless foreign visitors, made arrangements for them, and helped to solve their problems. Roy and I have also suffered through the production of about a dozen Research Program Workbooks together.

I've been pretty busy my first 20 years at Fermilab and I look forward to the next 20 to help me decide what to do with my life!

**Jackie Coleman**
**Administrative Assistant, Directorate, 1971–present**

---

In 1968, the once extensive native Illinois prairie was mostly a memory. What little remained, existed as hidden remnants known only to a few scientists and amateur preservationists. Bison roamed only in scattered small pens.

All this was destined to change when the National Accelerator Laboratory came to the far western edge of the Chicago suburbs and Dr. Robert R. Wilson was chosen as its first director. Dr. Wilson, born in Wyoming, had a deep appreciation of nature and instinctively recognized the ecological potential of this 6,800-acre site. He believed that good science could not exist without a pleasing and friendly environment. Art and nature were his solutions for creating that environment.

One of his ideas was to restore bison to the fields of Fermilab. Four cows and a bull were purchased in 1969. At about the same time, Dr. Wilson hired me as the first site manager. I came to the Lab after six years with the State of Illinois Department of Conservation. But those years had not prepared me to deal with our new residents. That educational process was at times frustrating, but mostly it was fun and exciting. The lessons were many and always came at the most inconvenient of times.

The very first one began as soon as we tried to unload the first bison from the delivery truck. That job fell to Jack Riffle. He loved to tell the story over and over again. Snorting bulls and bucking cows. Cattle prods that didn't have much effect on the bison and bent in half in his hands. Jack climbed on top of and in and over the truck and the loading chute. He coaxed and prodded and hollered and swore (just a little). Finally, Oh Boy and his new family hit the ground running and took over their new home — and our hearts.

My second opportunity to learn came with the first bitter cold snow storm. As I drove past the buffalo corral, just after dawn, I was shocked to see the entire herd lying on the ground covered with snow. I was sure they were all dead. And if they were domestic cattle I would have been correct. As I got out of my car to inspect the bodies, they began to get up, one by one. The snow had drifted over the sleeping animals, and they were so well insulated the small amount of escaping body heat wasn't sufficient to melt the snow. We learned they didn't like to use the barn for shelter even in the worst weather.

One of my favorite stories involves the first "blessed event" for our herd. Ask any new father — it is not an easy time. As usual Mom knew exactly what to do and she did it well. Dad, on the other hand, blew it. Once the calf was on the ground, Oh Boy thought he had to help it up. He used his horns to lift the calf and, in the process, flipped it over his head and rolled it around the corral. The cows were not impressed. They milled around and bellowed. They grunted and stomped. But Oh Boy was going to help, even if it killed the kid. To quote a famous movie question: Who do you call???

John Lill was the Fire Captain that day, and his shift responded to our cries for help. With sirens wailing and lights flashing they showed up, and we began the birthday rodeo.

The bison went nuts and we almost went with 'em. Fire hoses were laid out and we sprayed water on Oh Boy and the cows and the calf and ourselves and on darn near everything in sight. It got muddy and slick and messy, but finally we convinced Oh Boy to back off. Or perhaps we all just got tired. I do know that Mom and her calf simply walked away.

Bison and protons. Bison and antiprotons. Bison and quarks. I will have many memories of Fermilab, most of which will start out with Bison and........!

**Rudy Dorner**
**Emergency Services Coordinator, 1969–present**

Bob Wilson has always been deeply concerned, not only about science and accelerator design, but also about human rights and aesthetics. An early outrageous decision of his did a lot to set the tone that still guides the architecture and general appearance of the Laboratory.

Way back when construction of the central laboratory building was just starting, Bob became concerned about the looks of the surface of that vast area of concrete. He wanted it to look as if it had been poured into a random structure of boards and plywood that would serve as forms. After a series of meetings with Parke Rohrer, the construction manager, in which Parke indicated that the contractor had a scheme that he believed would meet Bob's standards, Bob gave his approval to cast the first large mass — tens of tons of concrete — which would support one segment of the building and would have a large area exposed to view. The contractor proceeded to build the forms, using plastic sheets, and cast the structure. When it was finally unveiled, at about five o'clock one evening, Parke, with some misgivings, invited Bob and me to the building site to inspect the contractor's handiwork. Lo and behold, the desired graininess of the pseudo-plywood was absent. Bob expressed his dissatisfaction in his usual strong terms. Parke agreed that the surface did not meet expectations, and indicated that they would do better on the next one.

"No," said Bob. "I want this one demolished and a new one poured in its place!"

After that, there was no doubt in Parke's mind but that the details of aesthetics were going to be important in this project. He was one of the staunchest advocates and implementers of that philosophy.

……

In June 1967, as soon as the Laboratory was born, we started to work on a policy statement about human rights. Such statements are required now, but they had not been heard of then. (It must be remembered that in 1967 there was as yet no government policy on affirmative action. It had not been invented.) Having such a statement in place from the beginning gave us an important head start: it brought to the Laboratory a highly selected group of key people. Interviewees who had any serious reservations about the desirability of affirmative action were highly unlikely to join the Laboratory. Chuck Marofske, an early recruit in a key position, has been a strong activist for affirmative action ever since. But our biggest early windfall was the recruitment of Kennard Williams as the head of our Affirmative Action Program. He undertook to go into the inner city and interview gang members. He had an almost infallible intuition about which ones were ready to give up gangs, give up drugs, and make it in the world of work. We hired them, paid for six months' technical training in Oak Ridge, Tennessee, and then brought them to the Laboratory. That was an incredible success story.

During that period I was assigned the task of meeting, one-on-one, with the heads of all the various minority factions in and around Chicago. Our project was in trouble because Illinois had failed to pass an open housing law, and Martin Luther King and others had committed themselves to stopping the construction of the Laboratory.

Gradually we were able to win over most of the powerful factions as they began to believe that we at the Laboratory were serious about affirmative action and minority employment. In one pair of interesting encounters the head of the most vehement opposition visited us and threatened all kinds of violence against us, personally as well as institutionally. He was quickly followed by one of the friendly contingents with an offer to do anything, and I mean anything we might want, to get that other group out of the way.

When Bob and I left the Laboratory in 1978, 20 percent of our employees were minority members.

……

At the very beginning of the Fermilab project, it was clear that to hold to the rapid schedule that we had projected in order to cut construction costs, we would have to get the first building started during the fall and winter of 1967–1968. It also was clear that Congress was not going to provide the kind of funding that would be required. The URA trustees approved a proposal that they would pay for the construction of the building, if the federal government would agree to reimburse them by buying the building if the authorization and appropriation went through.

Bob and I decided to go to Washington and present the idea to the Atomic Energy Commission chairman, Glenn Seaborg. At a day's notice we made an appointment to meet with him, and he listened sympathetically to our story. He thought the idea was a good one, but informed us that its implementation would require the agreement of the other AEC commissioners. He called them together on the spot, and they agreed that the idea was a good one. Seaborg instructed Bob Hollingsworth, the general manager of the AEC (its chief executive officer) to call together the appropriate business, political, and legal people to describe the decision to them. The same afternoon we found ourselves in a room with about 50 of the key staff members of the AEC.

Hollingsworth presented the idea and asked if there were any questions. The chief legal counsel got up and stated that the proposal was illegal. The chief political consultant and the chief business officer stated that it simply could not be done.

Bob Hollingsworth then got up and, with considerable affect, told the assembled multitude that it appeared that they misunderstood the nature of their jobs. The commissioners, he reminded them, were the decision makers, and the staff was there to implement the decisions made by the Commission. The Commission had enunciated its policy. Now he was instructing the staff to go back to their offices and by the next morning to have generated a plan by which that policy could be implemented.

And so it was done.

**Ned Goldwasser**
**Deputy Director, 1967–1978**
**University of Illinois at Urbana–Champaign:**
**Professor of Physics, Emeritus**
**Vice–Chancellor, Emeritus**

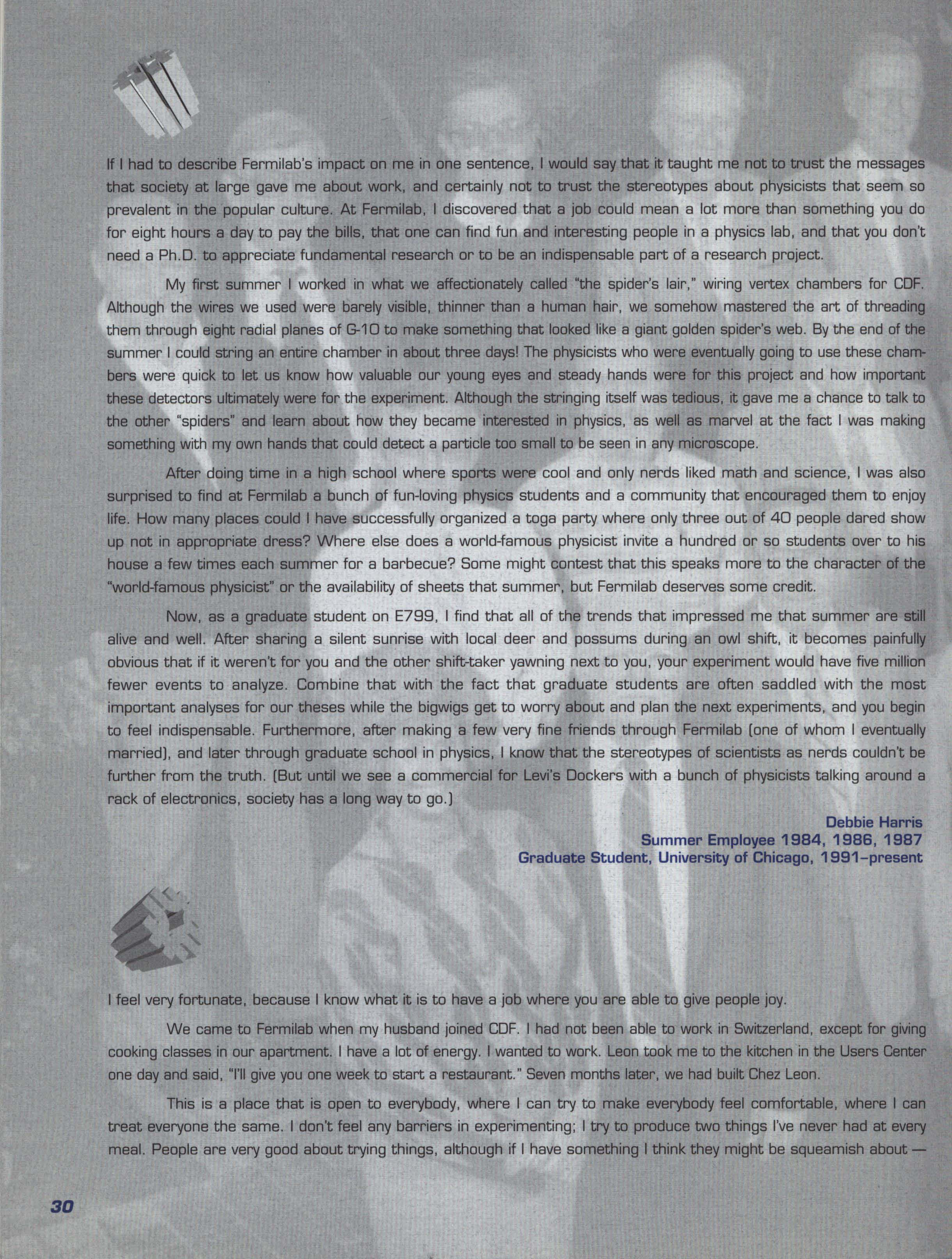
* * *

I have been at Fermilab since July 2, 1968. My ID number is 66. Part of my job has been to act as a driver for the directors and their guests from time to time. I have had the opportunity to meet people that I am sure I would not have met had I not been working here. I had the experience of picking up Mrs. Enrico Fermi; she was coming to the dedication of Fermilab. She said to me, "I guess you were expecting an older woman, weren't you?" I said, "Yes, Ma'am, I was." She said, "I used to live with a bunch of old ladies, but I moved away. They did not have a whole lot to talk about." We were coming down the Stevenson Expressway when she asked me how fast I was going. I told her I was doing about 50 miles an hour, expecting her to ask me to slow down, but she just said, "I am used to going much faster than that!"

One particular time I had to take Dr. Wilson to the airport because he was going to receive an award from President Nixon. He was running very late, so I was driving very fast to get him there on time, when Dr. Wilson said, "Mack, I thought I put on a suit, but this coat and pants don't match. Can we go back so that I can get dressed?" Well, we did go back — and he still made his plane!

I think the annual run with the director might have started with a trip I made to the airport with Dr. Lederman. We arrived at the airport as his flight was being announced for departure; we were about six city blocks from his gate. We both grabbed his bags and began to run. I took the escalator and Leon took the steps. I reached the gate and began to look for Leon, but he was so much faster that there he was, coming down from the plane to look for me.

**Mack Hankerson**
**Expeditor, 1968–present**



If I had to describe Fermilab's impact on me in one sentence, I would say that it taught me not to trust the messages that society at large gave me about work, and certainly not to trust the stereotypes about physicists that seem so prevalent in the popular culture. At Fermilab, I discovered that a job could mean a lot more than something you do for eight hours a day to pay the bills, that one can find fun and interesting people in a physics lab, and that you don't need a Ph.D. to appreciate fundamental research or to be an indispensable part of a research project.

My first summer I worked in what we affectionately called "the spider's lair," wiring vertex chambers for CDF. Although the wires we used were barely visible, thinner than a human hair, we somehow mastered the art of threading them through eight radial planes of G-10 to make something that looked like a giant golden spider's web. By the end of the summer I could string an entire chamber in about three days! The physicists who were eventually going to use these chambers were quick to let us know how valuable our young eyes and steady hands were for this project and how important these detectors ultimately were for the experiment. Although the stringing itself was tedious, it gave me a chance to talk to the other "spiders" and learn about how they became interested in physics, as well as marvel at the fact I was making something with my own hands that could detect a particle too small to be seen in any microscope.

After doing time in a high school where sports were cool and only nerds liked math and science, I was also surprised to find at Fermilab a bunch of fun-loving physics students and a community that encouraged them to enjoy life. How many places could I have successfully organized a toga party where only three out of 40 people dared show up not in appropriate dress? Where else does a world-famous physicist invite a hundred or so students over to his house a few times each summer for a barbecue? Some might contest that this speaks more to the character of the "world-famous physicist" or the availability of sheets that summer, but Fermilab deserves some credit.

Now, as a graduate student on E799, I find that all of the trends that impressed me that summer are still alive and well. After sharing a silent sunrise with local deer and possums during an owl shift, it becomes painfully obvious that if it weren't for you and the other shift-taker yawning next to you, your experiment would have five million fewer events to analyze. Combine that with the fact that graduate students are often saddled with the most important analyses for our theses while the bigwigs get to worry about and plan the next experiments, and you begin to feel indispensable. Furthermore, after making a few very fine friends through Fermilab (one of whom I eventually married), and later through graduate school in physics, I know that the stereotypes of scientists as nerds couldn't be further from the truth. (But until we see a commercial for Levi's Dockers with a bunch of physicists talking around a rack of electronics, society has a long way to go.)

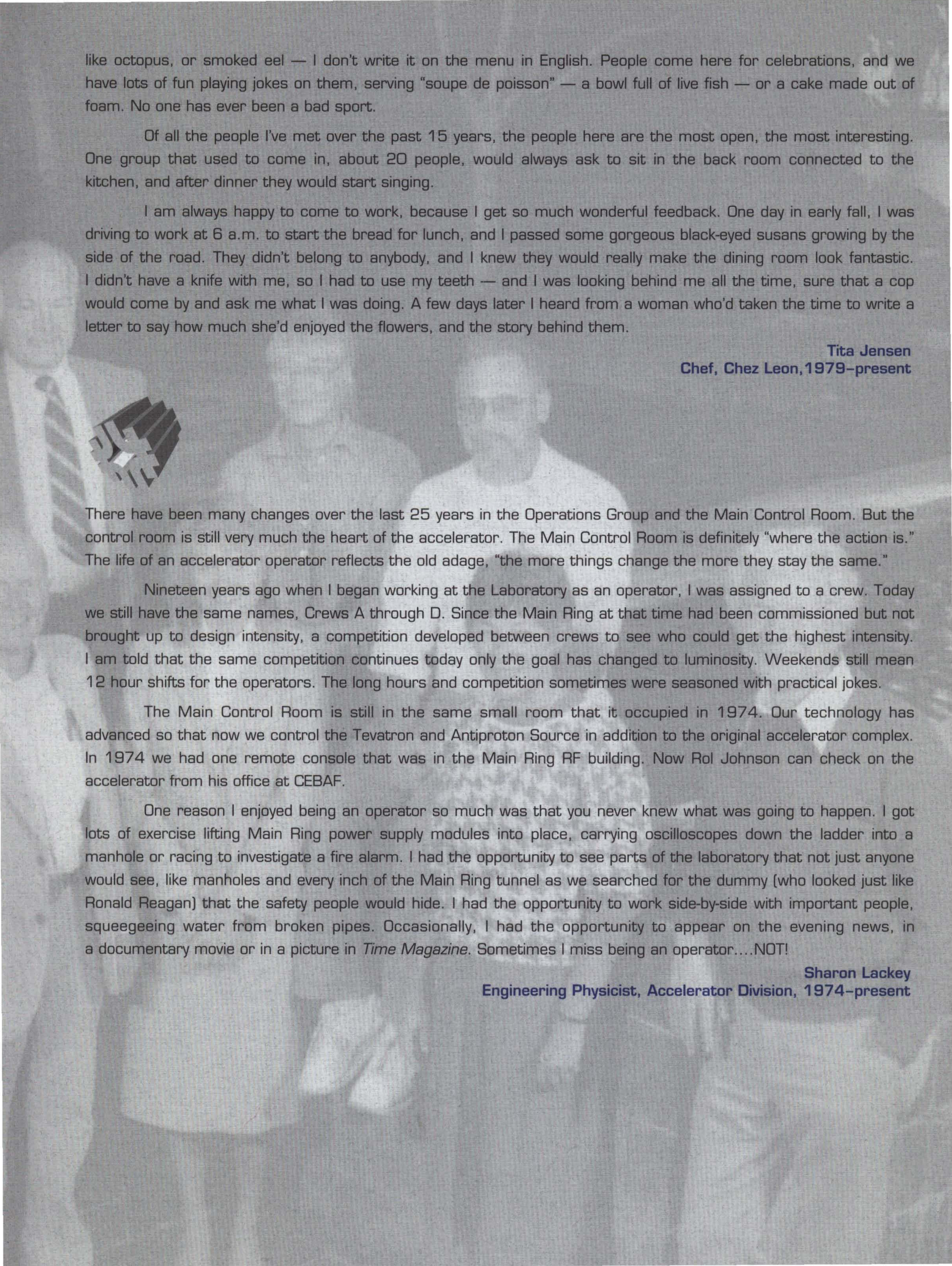
**Debbie Harris**
**Summer Employee 1984, 1986, 1987**
**Graduate Student, University of Chicago, 1991–present**

---

I feel very fortunate, because I know what it is to have a job where you are able to give people joy.

We came to Fermilab when my husband joined CDF. I had not been able to work in Switzerland, except for giving cooking classes in our apartment. I have a lot of energy. I wanted to work. Leon took me to the kitchen in the Users Center one day and said, "I'll give you one week to start a restaurant." Seven months later, we had built Chez Leon.

This is a place that is open to everybody, where I can try to make everybody feel comfortable, where I can treat everyone the same. I don't feel any barriers in experimenting; I try to produce two things I've never had at every meal. People are very good about trying things, although if I have something I think they might be squeamish about —



like octopus, or smoked eel — I don't write it on the menu in English. People come here for celebrations, and we have lots of fun playing jokes on them, serving "soupe de poisson" — a bowl full of live fish — or a cake made out of foam. No one has ever been a bad sport.

Of all the people I've met over the past 15 years, the people here are the most open, the most interesting. One group that used to come in, about 20 people, would always ask to sit in the back room connected to the kitchen, and after dinner they would start singing.

I am always happy to come to work, because I get so much wonderful feedback. One day in early fall, I was driving to work at 6 a.m. to start the bread for lunch, and I passed some gorgeous black-eyed susans growing by the side of the road. They didn't belong to anybody, and I knew they would really make the dining room look fantastic. I didn't have a knife with me, so I had to use my teeth — and I was looking behind me all the time, sure that a cop would come by and ask me what I was doing. A few days later I heard from a woman who'd taken the time to write a letter to say how much she'd enjoyed the flowers, and the story behind them.

**Tita Jensen**
**Chef, Chez Leon, 1979–present**

There have been many changes over the last 25 years in the Operations Group and the Main Control Room. But the control room is still very much the heart of the accelerator. The Main Control Room is definitely "where the action is." The life of an accelerator operator reflects the old adage, "the more things change the more they stay the same."

Nineteen years ago when I began working at the Laboratory as an operator, I was assigned to a crew. Today we still have the same names, Crews A through D. Since the Main Ring at that time had been commissioned but not brought up to design intensity, a competition developed between crews to see who could get the highest intensity. I am told that the same competition continues today only the goal has changed to luminosity. Weekends still mean 12 hour shifts for the operators. The long hours and competition sometimes were seasoned with practical jokes.

The Main Control Room is still in the same small room that it occupied in 1974. Our technology has advanced so that now we control the Tevatron and Antiproton Source in addition to the original accelerator complex. In 1974 we had one remote console that was in the Main Ring RF building. Now Rol Johnson can check on the accelerator from his office at CEBAF.

One reason I enjoyed being an operator so much was that you never knew what was going to happen. I got lots of exercise lifting Main Ring power supply modules into place, carrying oscilloscopes down the ladder into a manhole or racing to investigate a fire alarm. I had the opportunity to see parts of the laboratory that not just anyone would see, like manholes and every inch of the Main Ring tunnel as we searched for the dummy (who looked just like Ronald Reagan) that the safety people would hide. I had the opportunity to work side-by-side with important people, squeegeeing water from broken pipes. Occasionally, I had the opportunity to appear on the evening news, in a documentary movie or in a picture in *Time Magazine*. Sometimes I miss being an operator....NOT!

**Sharon Lackey**
**Engineering Physicist, Accelerator Division, 1974–present**

One Saturday afternoon, while looking out the window of my office next to the control room of the accelerator, I was intrigued by a very novel architectural and engineering feat that was in progress. It was the beginning of construction of the Ramsey Auditorium. The building was designed by Bob Wilson, personally, after he had rejected a much more expensive design proposed by professional architects. The building is circular in shape. Its outer walls consist of very heavy prefabricated concrete U-channels, which stand on end and lean inward at the top against the roof structure to form a squat truncated cone. These sidewall members are each about 10 feet wide, 30 feet high, 10 inches thick, and weigh perhaps 20 tons. The first of these channels was about to be erected.

A steel spider web, which would serve as the structural support system of the roof, was already in place at the center of the ring. This web was supported at roof height by a temporary support in the middle of the structure. Two cranes were located at opposite ends of one of the diametric roof beams. Each crane raised a channel into an erect position. Then, simultaneously, they tilted their channels inward, inch by inch, to lean against the opposite ends of the girder. In this way, the horizontal thrust of the weight of each channel against the roof structure was balanced by the thrust of the channel at the opposite end of the roof beam. This was done so precisely that the large horizontal forces were balanced, and the roof structure was not disturbed. When the channels were bolted to the roof structure and the lifting cables detached, the whole system was stable. I watched the whole process repeated many times during the afternoon. By the end of the day the U-channels were all in place, leaning against the central roof structure like a bunch of stacked straws.

When the building was completed, I was pleased to find the architectural impact of the design to be very exciting. The building is beautiful, both inside and out, and has excellent acoustics. It is a harmonious element in the overall beautiful architectural composition of Fermilab.

**Boyce D. McDaniel**
**Fermilab Guest Scientist, 1972, 1974, 1980**
**Professor of Physics, Cornell University**

* * *

One of my strongest impressions of Fermilab is the tightwad culture instilled by its three directors — three directors who have known how to build accelerators cheap. As smart as these guys are, they never even learned to spell billion. When accelerators have been proposed at Fermilab, it has been common to hear critics say the cost estimate is too low, the schedule too optimistic, and the technical goals unattainable. Yet somehow these three directors have succeeded brilliantly in developing a world-class laboratory — and in a parsimonious manner.

Let me tell you a bit about these directors. Robert Wilson led the Fermilab team to build the original accelerator for $250 million. In the face of critics who said it couldn't be done, the Wilson team built the accelerator on schedule and for $6.5 million below the estimate, and not only met the technical goals but achieved double the energy level that Wilson had committed to. These achievements, I believe, resulted from his management style and were accomplished with sensitivity to aesthetics and respect for the environment. Wilson had the gift to blend aesthetics and the environment into the base design. He stressed simple design features and was committed to competitively bid fixed-price construction contracts.

With Leon Lederman at the helm, the building of the first large-scale superconducting accelerator was successfully accomplished. Like Wilson, Lederman also had a parsimonious management style. In fact, the 21-foot-long superconducting dipole magnets for the Tevatron were built for $41,000 each — yes, I really mean $41,000 each — and he still complained it was too much. Let me tell you, Lederman was so tight that on a business trip to Washington, D.C., he refused to rent a car because it cost too much. He would rather bum a ride and save the money for physics. In spite of his obsession with cost cutting, however, he established an educational program with Fermilab physicists donating their time as teachers. He never stopped striving to do more for less.

John Peoples's parsimonious management style was perhaps influenced by a childhood experience. John wanted to earn some money by helping with some excavation work his father was having done. When the job was finished, John asked why his pay amounted to only five cents an hour when he knew the workmen were getting five times that. His father informed John that, compared with the workmen, he had performed even less than a nickel's worth of work an hour. Learning from this a lesson regarding the value of money and performance, John led his team to complete the Antiproton Source within the cost estimate while meeting all the technical goals. The accelerator luminosity achieved in 1988 was more than double the goal. In December 1992, following some accelerator improvements, the Laboratory set a new world record of $7.45 \times 10^{30}$ $\text{cm}^{-2}$ $\text{sec}^{-1}$.

In retrospect, this tightwad culture has stood the test of time. These three directors were able to lead the Laboratory to reach seemingly unattainable goals in a cost-conscious and highly creative manner. I believe the management philosophy that has produced low-cost accelerators at Fermilab since its beginning represents the wave of the future. In an era of ballooning federal deficits, the way for science and technology to progress is to follow the Fermilab philosophy.

**Andrew E. Mravca**
**Atomic Energy Commission, Assistant Manager for Technical Operation, 1968–1972**
**Atomic Energy Commission, Deputy Area Manager, 1972–1973**
**U.S. Department of Energy, Manager, Batavia Area Office, 1980–present**

My introduction to the Lab was during grad school, when I visited an old college pal who was working here. I was impressed that first day with the atrium in Wilson Hall and with all that acreage.

The Lab provides a very special environment for an engineer. Most companies that produce products for the market place have very limited engineering opportunities. Electrical engineering projects here range in frequency from DC to light and in power from picowatts to megawatts — the EE equivalent of soup to nuts! Engineering here also requires a system approach early in one's career. An engineer can be involved from the conceptual stage of a design, through construction, all the way to commissioning the final hardware. This type of opportunity is obtainable in industry only after many years of experience.

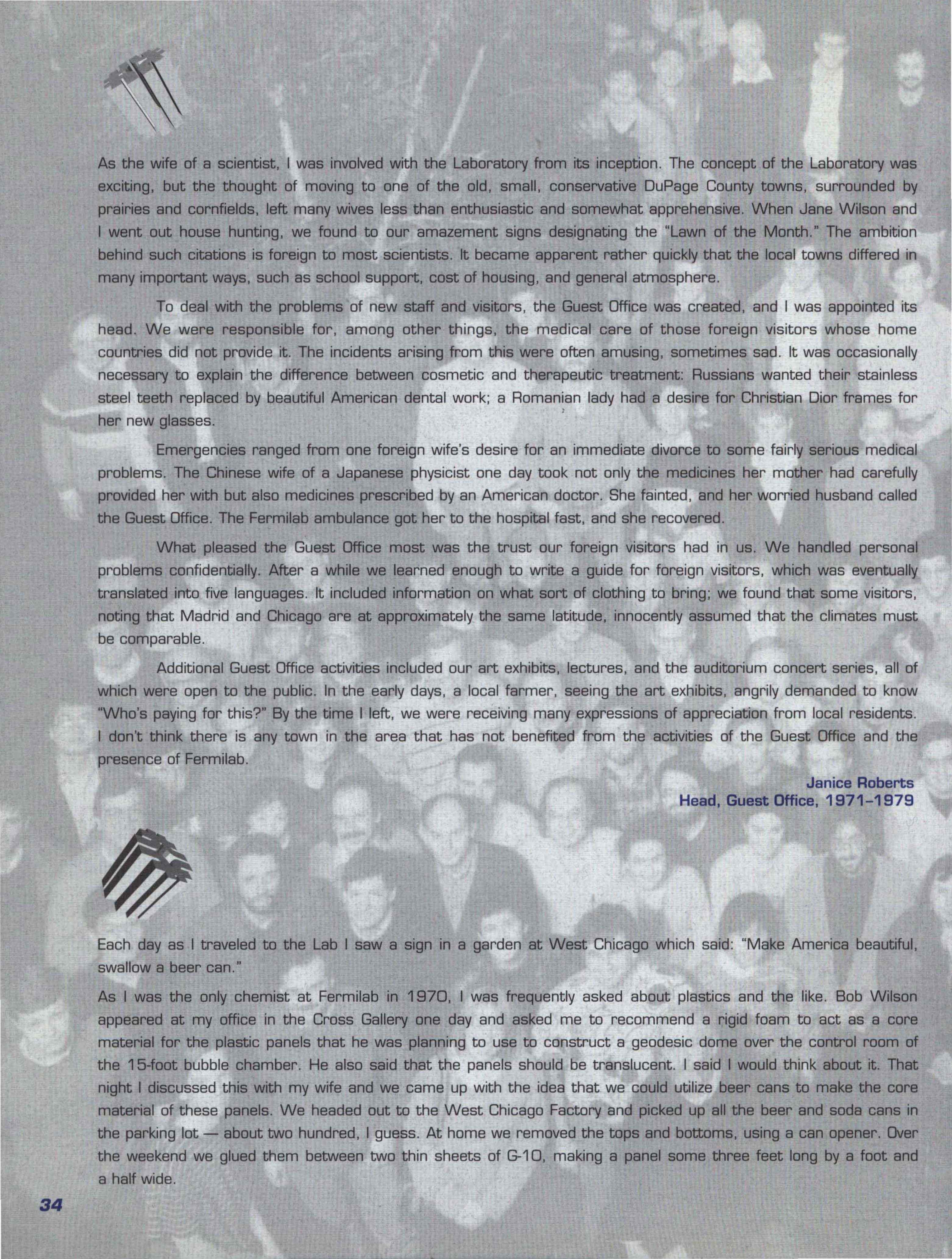
Whether or not my engineering proves to be successful is not measured by people but by the particle beams that circulate in our accelerators. In the early days of the Antiproton Source, for example, nothing we did with the machine would allow stacking of antiprotons to more than 50 billion particles. This was pretty sad for a machine that was designed for eight times that number. As it turned out, our electronics were not perfect and the beam knew this fact. We had to redesign part of the system. Today we can stack more than a thousand billion antiprotons, more than twice the design level. I've always said that the beam is the Karnak of the Laboratory — it knows all the laws of physics by heart. You really can't fool mother nature.

People at Fermilab — ranging from pioneers who founded the Lab to new hires — are some of the most talented I have met. An accelerator requires the contributions of many different disciplines to work symbiotically. I have worked with cryogenic engineers on our superconducting filters and feedback systems, with civil engineers on where to pour concrete for our tunnel, with mechanical engineers on new instrumentation gadgets, and with physicists on the fundamentals of particle accelerators.

There is nothing stale about working here. The atmosphere is very similar to a college environment in that we are learning fundamentals. Light bulbs still go on in my head when I discover something new or finally understand something that I was supposed to have learned back at the University of Illinois.

It's been almost 15 years now since my first visit to the Lab. The atrium and site are still impressive, even though most of us take them for granted. But now I am more impressed by the efforts of thousands of people working together to make one of the most complicated machines ever built work every day.

**Ralph J. Pasquinelli**
**Engineer, Accelerator Division, 1978–present**



As the wife of a scientist, I was involved with the Laboratory from its inception. The concept of the Laboratory was exciting, but the thought of moving to one of the old, small, conservative DuPage County towns, surrounded by prairies and cornfields, left many wives less than enthusiastic and somewhat apprehensive. When Jane Wilson and I went out house hunting, we found to our amazement signs designating the "Lawn of the Month." The ambition behind such citations is foreign to most scientists. It became apparent rather quickly that the local towns differed in many important ways, such as school support, cost of housing, and general atmosphere.

To deal with the problems of new staff and visitors, the Guest Office was created, and I was appointed its head. We were responsible for, among other things, the medical care of those foreign visitors whose home countries did not provide it. The incidents arising from this were often amusing, sometimes sad. It was occasionally necessary to explain the difference between cosmetic and therapeutic treatment: Russians wanted their stainless steel teeth replaced by beautiful American dental work; a Romanian lady had a desire for Christian Dior frames for her new glasses.

Emergencies ranged from one foreign wife's desire for an immediate divorce to some fairly serious medical problems. The Chinese wife of a Japanese physicist one day took not only the medicines her mother had carefully provided her with but also medicines prescribed by an American doctor. She fainted, and her worried husband called the Guest Office. The Fermilab ambulance got her to the hospital fast, and she recovered.

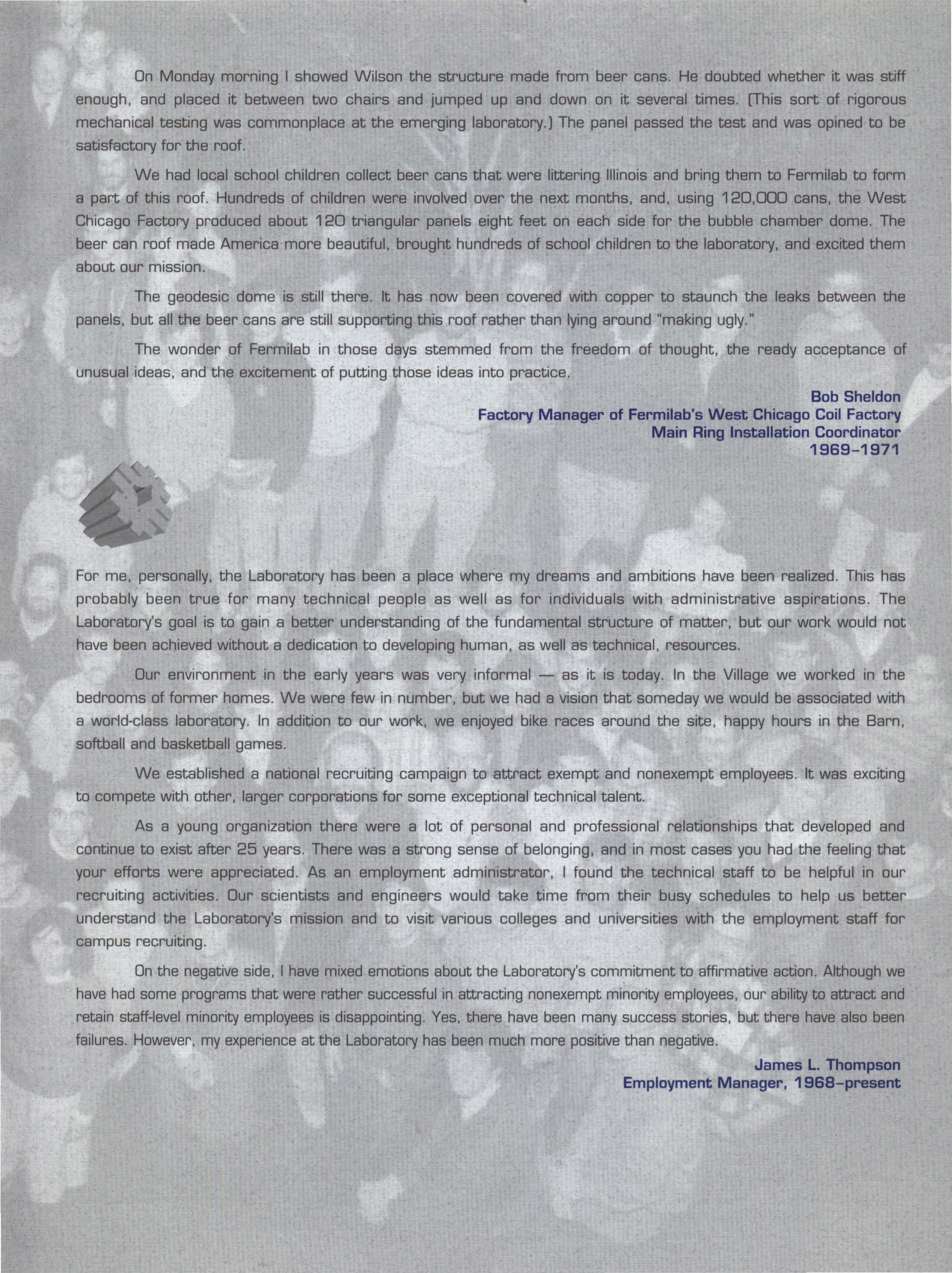
What pleased the Guest Office most was the trust our foreign visitors had in us. We handled personal problems confidentially. After a while we learned enough to write a guide for foreign visitors, which was eventually translated into five languages. It included information on what sort of clothing to bring; we found that some visitors, noting that Madrid and Chicago are at approximately the same latitude, innocently assumed that the climates must be comparable.

Additional Guest Office activities included our art exhibits, lectures, and the auditorium concert series, all of which were open to the public. In the early days, a local farmer, seeing the art exhibits, angrily demanded to know "Who's paying for this?" By the time I left, we were receiving many expressions of appreciation from local residents. I don't think there is any town in the area that has not benefited from the activities of the Guest Office and the presence of Fermilab.

**Janice Roberts**
**Head, Guest Office, 1971–1979**

Each day as I traveled to the Lab I saw a sign in a garden at West Chicago which said: "Make America beautiful, swallow a beer can."

As I was the only chemist at Fermilab in 1970, I was frequently asked about plastics and the like. Bob Wilson appeared at my office in the Cross Gallery one day and asked me to recommend a rigid foam to act as a core material for the plastic panels that he was planning to use to construct a geodesic dome over the control room of the 15-foot bubble chamber. He also said that the panels should be translucent. I said I would think about it. That night I discussed this with my wife and we came up with the idea that we could utilize beer cans to make the core material of these panels. We headed out to the West Chicago Factory and picked up all the beer and soda cans in the parking lot — about two hundred, I guess. At home we removed the tops and bottoms, using a can opener. Over the weekend we glued them between two thin sheets of G-10, making a panel some three feet long by a foot and a half wide.



On Monday morning I showed Wilson the structure made from beer cans. He doubted whether it was stiff enough, and placed it between two chairs and jumped up and down on it several times. (This sort of rigorous mechanical testing was commonplace at the emerging laboratory.) The panel passed the test and was opined to be satisfactory for the roof.

We had local school children collect beer cans that were littering Illinois and bring them to Fermilab to form a part of this roof. Hundreds of children were involved over the next months, and, using 120,000 cans, the West Chicago Factory produced about 120 triangular panels eight feet on each side for the bubble chamber dome. The beer can roof made America more beautiful, brought hundreds of school children to the laboratory, and excited them about our mission.

The geodesic dome is still there. It has now been covered with copper to staunch the leaks between the panels, but all the beer cans are still supporting this roof rather than lying around "making ugly."

The wonder of Fermilab in those days stemmed from the freedom of thought, the ready acceptance of unusual ideas, and the excitement of putting those ideas into practice.

**Bob Sheldon**
**Factory Manager of Fermilab's West Chicago Coil Factory**
**Main Ring Installation Coordinator**
**1969–1971**

---

For me, personally, the Laboratory has been a place where my dreams and ambitions have been realized. This has probably been true for many technical people as well as for individuals with administrative aspirations. The Laboratory's goal is to gain a better understanding of the fundamental structure of matter, but our work would not have been achieved without a dedication to developing human, as well as technical, resources.

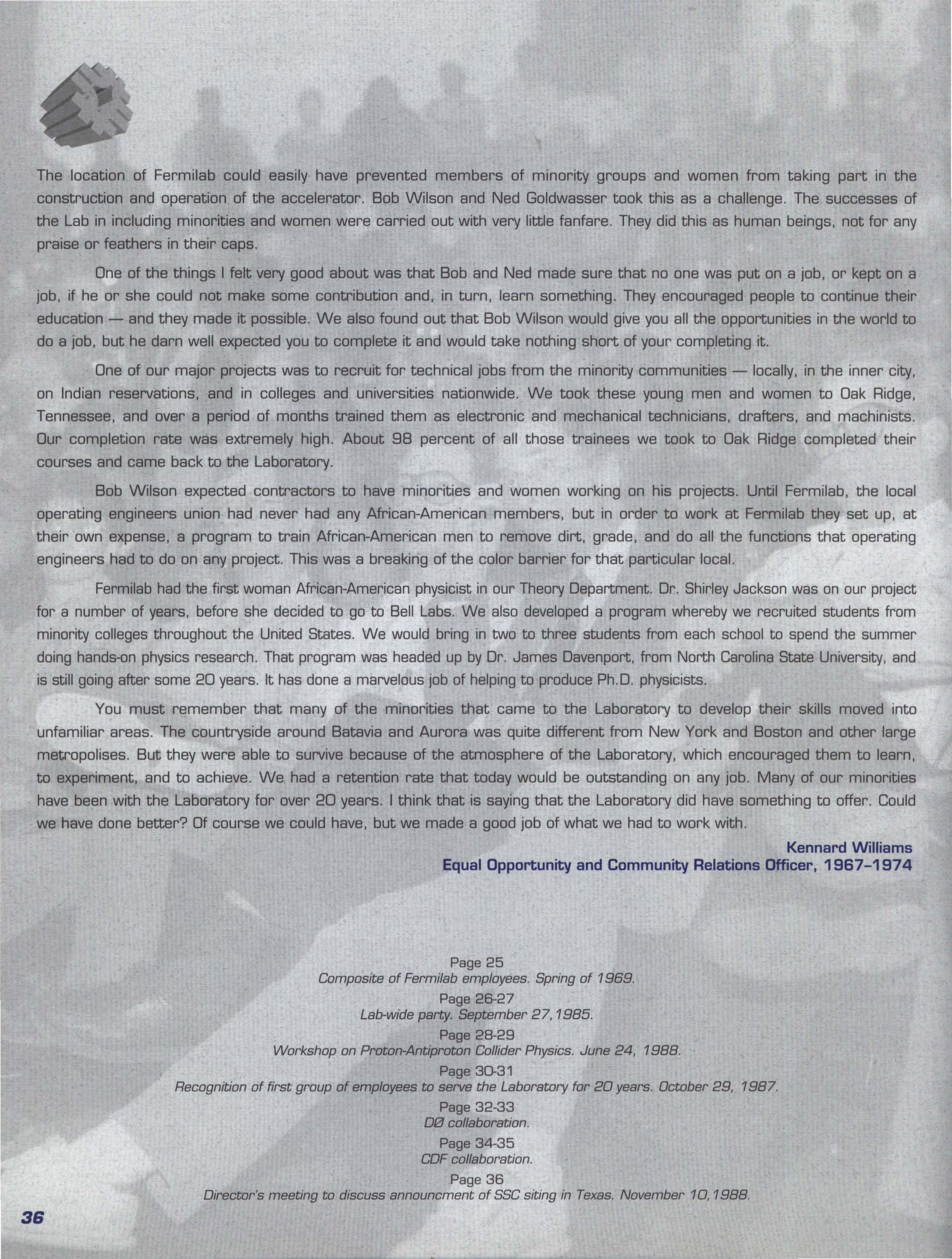
Our environment in the early years was very informal — as it is today. In the Village we worked in the bedrooms of former homes. We were few in number, but we had a vision that someday we would be associated with a world-class laboratory. In addition to our work, we enjoyed bike races around the site, happy hours in the Barn, softball and basketball games.

We established a national recruiting campaign to attract exempt and nonexempt employees. It was exciting to compete with other, larger corporations for some exceptional technical talent.

As a young organization there were a lot of personal and professional relationships that developed and continue to exist after 25 years. There was a strong sense of belonging, and in most cases you had the feeling that your efforts were appreciated. As an employment administrator, I found the technical staff to be helpful in our recruiting activities. Our scientists and engineers would take time from their busy schedules to help us better understand the Laboratory's mission and to visit various colleges and universities with the employment staff for campus recruiting.

On the negative side, I have mixed emotions about the Laboratory's commitment to affirmative action. Although we have had some programs that were rather successful in attracting nonexempt minority employees, our ability to attract and retain staff-level minority employees is disappointing. Yes, there have been many success stories, but there have also been failures. However, my experience at the Laboratory has been much more positive than negative.

**James L. Thompson**
**Employment Manager, 1968–present**



The location of Fermilab could easily have prevented members of minority groups and women from taking part in the construction and operation of the accelerator. Bob Wilson and Ned Goldwasser took this as a challenge. The successes of the Lab in including minorities and women were carried out with very little fanfare. They did this as human beings, not for any praise or feathers in their caps.

One of the things I felt very good about was that Bob and Ned made sure that no one was put on a job, or kept on a job, if he or she could not make some contribution and, in turn, learn something. They encouraged people to continue their education — and they made it possible. We also found out that Bob Wilson would give you all the opportunities in the world to do a job, but he darn well expected you to complete it and would take nothing short of your completing it.

One of our major projects was to recruit for technical jobs from the minority communities — locally, in the inner city, on Indian reservations, and in colleges and universities nationwide. We took these young men and women to Oak Ridge, Tennessee, and over a period of months trained them as electronic and mechanical technicians, drafters, and machinists. Our completion rate was extremely high. About 98 percent of all those trainees we took to Oak Ridge completed their courses and came back to the Laboratory.

Bob Wilson expected contractors to have minorities and women working on his projects. Until Fermilab, the local operating engineers union had never had any African-American members, but in order to work at Fermilab they set up, at their own expense, a program to train African-American men to remove dirt, grade, and do all the functions that operating engineers had to do on any project. This was a breaking of the color barrier for that particular local.

Fermilab had the first woman African-American physicist in our Theory Department. Dr. Shirley Jackson was on our project for a number of years, before she decided to go to Bell Labs. We also developed a program whereby we recruited students from minority colleges throughout the United States. We would bring in two to three students from each school to spend the summer doing hands-on physics research. That program was headed up by Dr. James Davenport, from North Carolina State University, and is still going after some 20 years. It has done a marvelous job of helping to produce Ph.D. physicists.

You must remember that many of the minorities that came to the Laboratory to develop their skills moved into unfamiliar areas. The countryside around Batavia and Aurora was quite different from New York and Boston and other large metropolises. But they were able to survive because of the atmosphere of the Laboratory, which encouraged them to learn, to experiment, and to achieve. We had a retention rate that today would be outstanding on any job. Many of our minorities have been with the Laboratory for over 20 years. I think that is saying that the Laboratory did have something to offer. Could we have done better? Of course we could have, but we made a good job of what we had to work with.

**Kennard Williams**
**Equal Opportunity and Community Relations Officer, 1967–1974**

Page 25
*Composite of Fermilab employees. Spring of 1969.*

Page 26-27
*Lab-wide party. September 27, 1985.*

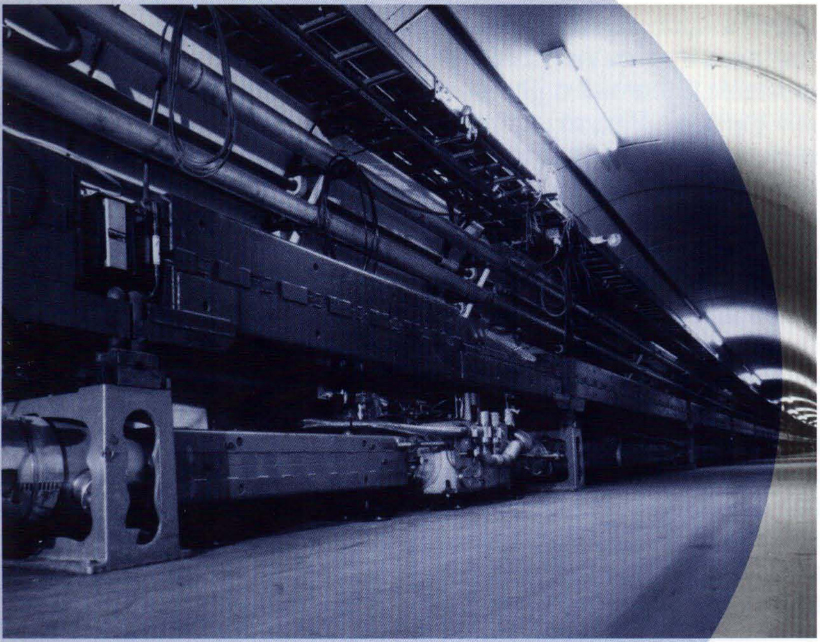
Page 28-29
*Workshop on Proton-Antiproton Collider Physics. June 24, 1988.*

Page 30-31
*Recognition of first group of employees to serve the Laboratory for 20 years. October 29, 1987.*

Page 32-33
*D0 collaboration.*

Page 34-35
*CDF collaboration.*

Page 36
*Director's meeting to discuss announcment of SSC siting in Texas. November 10, 1988.*



*Interior of Main Ring tunnel.*

# Collisions: Transition to a World-Class Collider

*Jubilant crew in Main Control Room applauds the first 512-GeV proton beams in the Tevatron. This record-setting energy was achieved at 3:27 a.m. on July 3, 1983. Celebrating are (left to right, standing) Linda Klamp, Robert Shafer, Roland Johnson, David Beechy, Robert Flora, Frank Nagy, and Daniel Patterson. Seated are Ferdinand Willeke, Frank Turkot, and Hans Jostlein.*

"The winter of 1983 was a cold one. Very cold. There were a couple of twenty-below-zero days," John Peoples remembers. Peoples has good reason to remember that winter. He was then in charge of building the Antiproton Source, which meant spending weeks on end in one of the least cozy places imaginable: an unheated tunnel. Money and schedules were too tight to wait for the three to four inches of ice that had built up on the tunnel walls to melt, and the flock of heaters that had been rounded up from every corner of the Laboratory were having about as much effect as a hairdryer aimed at a glacier. "We had to get the cable trays in then, so we could install the magnets on time. We just pressed ahead, chipping the ice away to put the cable trays in place."

Ice in the tunnel was just one of the hurdles cleared by Fermilab in the course of making possible what now happens routinely thousands of times a second: collisions between the two highest energy particle beams in the world.

Motivation for colliding beams had been around for decades. Whenever two particles come together, the higher the energy in the center-of-mass frame, the higher the mass of the new states that can be produced, and the smaller the structure that can be investigated. If only one particle is initially moving, nature slaps a progressive tax on higher energies. Multiply the energy of the accelerator in a fixed-target experiment a hundredfold, and the effective gain in the center-of-mass energy increases by only a factor of 10. However, when two particles accelerated in opposite directions collide head-on, much more energy is available for making new particles.

In 1975, the incentive for reaching higher energies became even more alluring. The discovery of neutral currents, at CERN, had whetted appetites for further experimental examination of a model that claimed to unify the weak and electromagnetic forces. The Weinberg-Salam model predicted that the carriers of the weak force, the $W$ and $Z$ bosons, would weigh in at an impressive 80 to 90 GeV, almost a hundred times the mass of a proton. No accelerator then on Earth could summon up enough energy to create such massive particles in a fixed-target experiment, but anyone sufficiently visionary and ambitious could see two places where colliding hadron beams could reach sufficient center-of-mass energies: CERN and Fermilab. Carlo Rubbia, then at Harvard, first made the suggestion to both laboratories.

*Continued on next page*

Continued from previous page

The notion was so appealing that, in the summer of 1976, the Fermilab Physics Advisory Committee found itself with a handful of proposals to consider. The first was to build a small synchrotron next to the Main Ring to accelerate protons to about 25 GeV and bring them into collision with 400-GeV beams from the Main Ring. The second had a title worthy of Batman — "Clashing Gigantic Synchrotrons" — and called for colliding 150-GeV beams from the Main Ring with 1000-GeV beams from the Energy Doubler (as the Tevatron was then called). The third idea was to make and collide antiprotons with protons in either the Main Ring or the Doubler.

"It was finally decided," wrote Ned Goldwasser, reporting on the PAC meeting, "to reject all of them." The advice was to "focus on the rather difficult job of constructing the Doubler, of doing so on a rapid time scale, and of exploiting all of the opportunities associated with the Doubler, including the production of colliding beams." The Laboratory was also encouraged to investigate the challenges of producing sufficient antiprotons to collide with protons in the Doubler. With characteristic clarity, Goldwasser then announced the response of the Laboratory, as determined by director Bob Wilson: "We intend to do so."

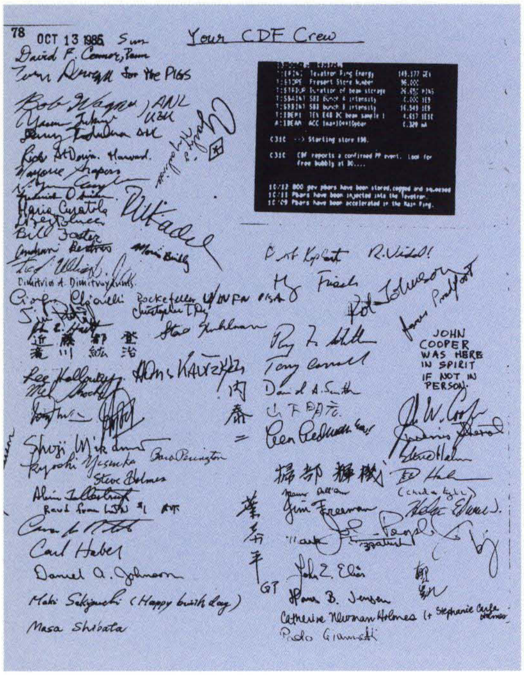
The PAC had zeroed in on the option with the greatest promise. The 2-TeV center-of-mass energy that could be obtained by colliding protons and antiprotons in the Doubler not only dwarfed that contemplated by the other proposals; it dwarfed anything envisioned anywhere else.

It was also the option that posed the greatest technical challenges. "Back in 1976, very few people understood how hadron colliders worked," says John Peoples. "It wasn't clear that this was going to be a success." Only one hadron collider had then been built: CERN's Intersecting Storage Ring.

Colliding antiprotons and protons instead of protons and protons meant that a single set of magnets would suffice to control both beams. (Because their masses are identical and their electric charges are exactly opposite, protons and antiprotons of equal energy moving in opposite directions respond identically to electromagnetic manipulations.) For this purpose, the Doubler had important advantages over the Main Ring: higher energy and better vacuum (so beams could circulate for longer periods without being depleted by collisions with stray gas molecules), among others. On the other hand, the Main Ring had one distinct advantage over the Doubler. It was already built.

Different people weighed the choice differently: the chance to make a long-term investment in a machine that had the potential to be the world's pre-eminent accelerator sometime in the future, if everything worked well enough, against the chance to do something relatively quick and dirty that just might bag the first *W* boson. In December of 1976 Wilson announced the creation of the Colliding-Beam Experiments Department to plan "for the exploitation of colliding beams in the present Main Ring tunnel," but it took a couple of years for all the different trails that were being blazed at the Lab to converge. In the meantime, the problem of inadequate funding for the Tevatron consumed Wilson's attention and eventually led him to resign.

Wilson's resignation took effect in February 1978. Eight months later, Leon Lederman was appointed Director. On November 11, 1978, Lederman held a review of collider options that came to be known as the Armistice Day Shoot-Out. To clarify the Lab's approach to achieving proton-antiproton collisions in the Tevatron and to examine whether trying to achieve lower energy colliding beams made sense for the nearer future, Lederman asked advocates of different strategies to make their cases. He also convened a panel of judges — from outside as well as inside Fermilab — and requested them to "embarrass the advocates as much as possible with penetrating, incisive questions."



78 OCT 13 1985 Sun

Your CDF Crew

```
T:EFINJ  Tevatron Ring Energy       149.377 GeV
T:STORE  Present Store Number        96.000
T:STRDUR Duration of beam storage    26.052 MINS
T:SBAINT SBD Bunch A intensity        0.000 1E9
T:SBBINT SBD bunch B intensity       16.549 1E9
T:IDEPI  TEV E48 DC beam sample 1     4.617 1E10
A:IBEAM  ACC Ibeam+10e+10pbar         0.329 mA

0310  --> Starting store 096.

0310   CDF reports a confirmed PP event.  Look for
       free bubbly at B0....

10/12 800 gev pbars have been stored,cogged and squeezed
10/11 Pbars have been injected into the Tevatron.
10/09 Pbars have been accelerated in the Main Ring.
```

David F. Connor, Penn

for the PIGS

Bob Wagner ANL

UCLA

ANL

Rick St Denis. Harvard.

Marjorie Shapiro

Maria Curatolo

Bill Foster

Dimitrios A. Dimitroyannis

Giorgio Chiarelli

Rockefeller

INFN PISA

Christopher T. Day

近 藤 都 登

滝 川 紘 治

JOHN COOPER WAS HERE IN SPIRIT IF NOT IN PERSON.

Tony Carroll

内

藤

=

David A. Smith

山下明宏

J. W. Cooper

Steve Holmes

Shoji Mikamo

Kiyoshi Yasuoka

Barry Barish?

Alvin Tollestrup

Carl Haber

Daniel A. Johnson

Maki Sekiguchi (Happy birthday)

Masa Shibata

Jim Freeman

John Z. Elias

Hans B. Jensen

Catherine Newman Holmes (+ Stephanie Carlie Holmes)

Paolo Giannetti

R. Vidal!

At 3:10 a.m. on October 13, 1985, CDF recorded its first proton-antiproton collision. The group assembled in the control room that early morning signed the log book to commemorate and celebrate this momentous occasion.

Dignitaries walk through the tunnel of the Antiproton Source during the formal ceremony to dedicate the Tevatron. From the left, Alvin Trivelpiece, Secretary of Energy John Herrington, Alvin Tollestrup, John Peoples, Leon Lederman, Ernest Malamud and a DOE staffer.

Two conclusions emerged from the review. The original decision to aim for proton-antiproton collisions at 2 TeV was strongly reinforced, and a decision was made against diverting effort and funds in pursuit of lower energy collisions. In effect, Fermilab chose to cede the first *W*'s to CERN, which was already making serious preparations for the hunt.

"It played out as a long-term strategy," says accelerator physicist Chuck Ankenbrandt. "People always want to do the best physics that's not impossible. Eventually, Fermilab would have three times CERN's energy and would beat them to whatever lay beyond the *W* and *Z*."

Whatever lay beyond the *W* and *Z* was then about as mysterious as the lands where sixteenth-century cartographers drew "elephants for want of towns." "Everything was misty in those days," remembers phenomenologist Chris Quigg. "But a Main Ring Experiment where the best you could possibly hope for was to find a few *W*'s seemed extremely limited. Why bring the Lab to a dead end for something that someplace else could soon easily do physics with, instead of pursuing the possibility of finding something new?"

"We didn't have the financial resources CERN did," says Peoples. "Back then, there was about a factor of two difference; today it's more like a factor of four. For most things in life, 10 percent makes a huge difference: after 10 months, somebody's one month ahead." Nevertheless, "At every point we felt we had to take some technical risks. It was simply not going to make sense to build exactly what CERN had built."

For the project to succeed a source of more than 10 billion well-behaved antiprotons had to be designed and built. Extensive modifications had to be made to the Main Ring and the Tevatron to accommodate the Antiproton Source and collision halls for the experiments. Control systems for both beams had to be devised. Detectors capable of making sense of the collisions had to be designed and built. And beam had to be supplied to users with approved fixed-target experiments. Murphy, as in Murphy's Law, frequently seemed to be writing the script: people involved in each aspect of the project faced the equivalent — or worse — of ice in the tunnel.

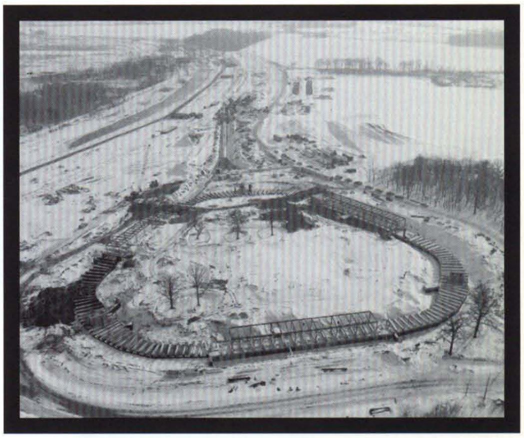
By Friday, October 11, 1985, when the Tevatron was formally dedicated, colliding beams had not yet been seen by CDF. By midnight on Saturday, beams finally made it all the way to the Tevatron, but still no collisions were observed. Peoples, exhausted, went home, promising to be back at six the next morning. "I was just beginning to learn," he says, "that I wasn't indestructible." He slept too deeply to be woken by repeated phone calls from Helen Edwards. When he returned to the Lab, he found that everyone else had just gone home — in triumph, after celebrating (with champagne and sake) 20 minutes' worth of collisions.

Those first collisions between protons and antiprotons had been preceded by collisions of many other kinds. Administrators had collided with budgets. Accelerator builders had collided with experimenters' schedules. True-blue believers in one way of doing things had collided with others just as strongly convinced that something else was better. Just about everybody had collided with nature. The machine that emerged from those collisions is a reminder of what human beings, in their more determined moments, can accomplish. In recognition of the extraordinary technological challenges that were surmounted in building the Tevatron, President Bush awarded Helen Edwards, Dick Lundy, Rich Orr, and Alvin Tollestrup the National Medal of Technology in 1989.

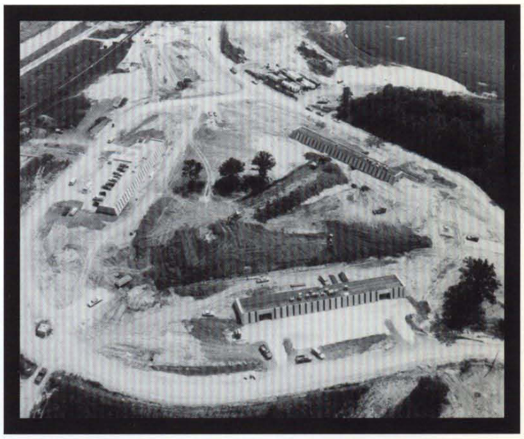
"The advantage of having a very good collider and a very good Antiproton Source has given us a special place in the physics world," says John Peoples, "and I think the people in the Laboratory recognize that they've done something very special together."

*A series of aerial photographs records construction progress on the Antiproton Source.*

*October 7, 1983*

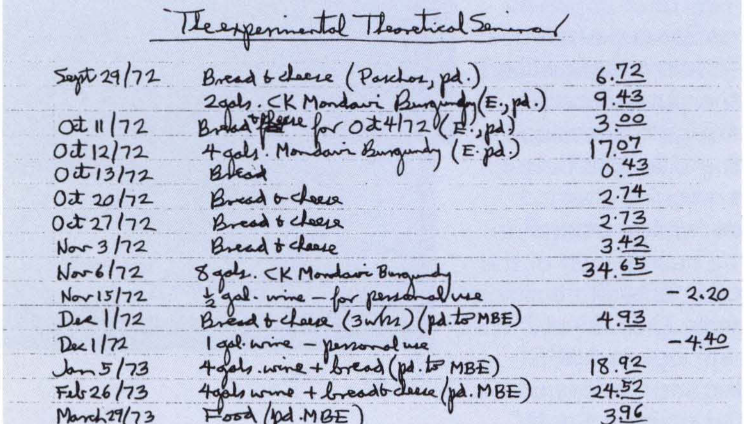


*February 1, 1984*



*July 20, 1984*

# Early Days of Wine and Cheese



Expenses

The experimental Theoretical Seminar

| | | | |
|---|---|---|---|
| Sept 29/72 | Bread & cheese (Paschos, pd.) | 6.72 | |
| | 2 gals. CK Mondavi Burgundy (E., pd.) | 9.43 | |
| Oct 11/72 | Bread + cheese for Oct 4/72 (E., pd.) | 3.00 | |
| Oct 12/72 | 4 gals. Mondavi Burgundy (E. pd.) | 17.07 | |
| Oct 13/72 | Bread | 0.43 | |
| Oct 20/72 | Bread & cheese | 2.74 | |
| Oct 27/72 | Bread & cheese | 2.73 | |
| Nov 3/72 | Bread & cheese | 3.42 | |
| Nov 6/72 | 8 gals. CK Mondavi Burgundy | 34.65 | |
| Nov 15/72 | ½ gal. wine – for personal use | | – 2.20 |
| Dec 1/72 | Bread & cheese (3 wks) (pd. to MBE) | 4.93 | |
| Dec 1/72 | 1 gal. wine – personal use | | – 4.40 |
| Jan 5/73 | 4 gals. wine + bread (pd. to MBE) | 18.92 | |
| Feb 26/73 | 4 gals wine + bread & cheese (pd. MBE) | 24.52 | |
| March 29/73 | Food (pd. MBE) | 3.96 | |

*The first page of J. D. Jackson's expense ledger illustrates the success of the seminar as well as meticulous record keeping.*

Twenty years ago, on September 29, 1972, CK Mondavi Burgundy flowed for the first time at NAL, thanks to the initiative of the Theory Group, in particular, Marty Einhorn. These were early days at the National Accelerator Laboratory. The 1972 Rochester Conference, held in Chicago and Batavia, had passed more or less successfully into history two weeks earlier. The buffalo roast and the bunting that camouflaged the raw concrete in the half-finished auditorium had done their work. The accelerator was running, sort of; results from the 30-inch bubble chamber and the internal target at C0 had been reported at the conference. The High-Rise and the Meson and Proton areas were nearing completion and particle beams were being coaxed away from the Main Ring. The Village was still headquarters.

That year the Theory Group, comprising Henry Abarbanel, Marty Einhorn, Steve Ellis, David Gordon, Mannie Paschos, and Tony Sanda, was "led" by its second outside acting head. This core was augmented by numerous visitors, some for brief stays and others for longer periods (for example, Myron Bander, Bill Frazer, and Chris Quigg for three months that fall, John and Mary Bell and Miguel Virasoro for a month). Housed in the right "wing" of the Director's Complex in the Village, these theorists led a simple but satisfying life, collaborating on the burning issues of hadron and neutrino physics at 200–400 GeV. Visits and seminars by Bjorken, Feynman, and Low, among others, helped to provide the stimulating atmosphere of an established lab.

Bob Wilson and his troops in the field were straining to complete the experimental areas and to raise the energy and intensity of the machine. The early experiments struggled to be ready for whatever the machine would produce. Typically, work on the accelerator proceeded during the week; late on Friday beam to the experiments was begun for the weekend. With luck, there would be some hours of running.

The contrast of the theorists "doing their thing" while the machine builders and experimenters heroically did the necessary spurred Einhorn to propose a weekly seminar to help provide some sense of common purpose and intellectual food for the whole community. To avoid conflict with urgent meetings of one sort or another, 4 p.m. on Friday afternoon was chosen. Obviously there had to be a "come-on" to draw people back to the West Conference Room of the Director's Complex at the end of each stressful week. Wine and cheese were the answer. The acting group leader and Marty cut a deal. Marty would do the shopping; the acting group leader would pay. All we needed was a name. We struck on "The experimental Theoretical Seminar," with a small *e* on experimental because it was just that.

The West Conference Room was a modest-sized room that held 30–40 people, undoubtedly the whole ground floor of somebody's former residence. Veterans remember large wooden tables surrounded by government-surplus chairs, a portable screen for use with the overhead and slide projectors, and green chalk boards on the walls. I recall that the wine (in paper cups), Wisconsin cheddar, and bread lasted about 15 minutes at the beginning. Then the bar was closed and the talk began.

My 1972–73 Pocket Diary for Physicists shows that Jim Sanford gave the first talk, on September 29, 1972, to about 40 people. My informal expense ledger for that date shows \$6.72 for bread and cheese (M. Paschos pd.) and \$9.43 for 2 gals. CK Mondavi Burgundy (MBE pd.) A diary entry for October 12 reads, "MBE owes me 93 cents (change on the wine) √" The item reflects my punctiliousness and Scottish blood; the tick mark demonstrates my successful tenacity!

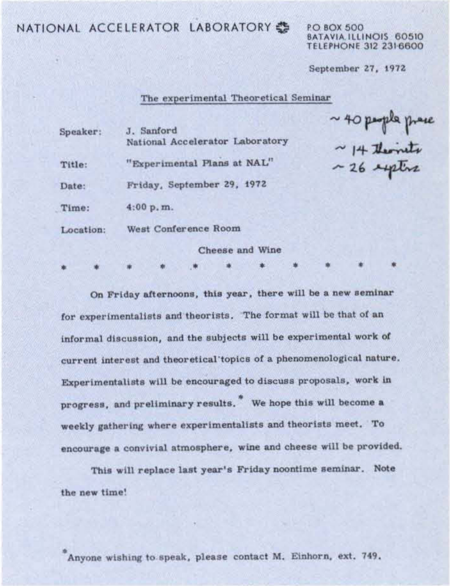
In the first nine months there were 31 talks, over half on experiments, with theory and accelerator topics for the rest. (Paul Reardon gave "A Description of the Energy-Doubler Project" on February 2, 1973.) Clearly, we had gotten off to a vigorous start. Einhorn recalls an occasion when Bob Wilson came in a bit late. The wine and cheese were gone and there was not an empty chair. Bob turned over a trash can and sat down. Typical of Bob, and typical of the seminar, too. People did come. The room was normally packed to overflowing. One of my notations on the attendance had the addition, "2/3 ELG, 5/6 Jimmy W," indicating that even the bureaucrats came when they could. The wine gently loosened the tongues of otherwise inhibited questioners, and even of speakers. A story from Chris Quigg, perhaps enlarged by repeated tellings, is of Jimmy Walker coming in, helping himself to some wine, and departing, just as Henry Frisch was about to begin his talk. Henry remarked that Jimmy had been his senior thesis advisor at Harvard and he had met him there only once, for a similar period of 15 seconds. (As they say in the *Congressional Record* [laughter ensued].) More seriously, Einhorn comments, "It was an important civilizing physics event in the days before the High-Rise. It also provided a focus for communication at a time when people were all spread out and busy with their own affairs; I recall hearing Don Edwards inform us all on beam dynamics in the accelerator."

A momentous pocket diary entry reads, "December 14 - 2:45 a.m., 400 GeV/*c*, $10^{11}$ ppp!" Nothing to do with "Wine & Cheese," but indicative of the exciting times in late 1972.

While I recall vaguely the wine and the talks that year, my most vivid memory is of my encounter with Priscilla Duffield over the wine. Priscilla, a tall, imposing, no-nonsense woman, was Bob Wilson's administrative "muscle." I don't know what her official title was but she was the major-domo, the "enforcer," the person who ran the Director's Office for Bob Wilson and Ned Goldwasser, protecting them from trouble and annoyance. If you had a problem about facilities or administration, you talked to Priscilla. One day, a month or so after the seminar's debut, word about the Friday afternoon goings-on reached Priscilla. She stormed into my office, looking for my scalp. "What do you think you're doing, serving wine at that seminar? Don't you know it's illegal to spend government money on such things?" I said that I wasn't spending government money on the wine. She said, "Well, who *is* paying for it?" I said, "I am." And she said, "Oh." It was the one time I saw Priscilla just a little bit penitent.

"The experimental Theoretical Seminar" began as an experiment to fill a need. Right from the beginning it flourished. By June 1973 it was held regularly in the Village Curia and its name was changed to "The Joint Experimental-Theoretical Seminar." Its chief creator, Marty Einhorn, told me recently, "I also recall continually having to increase our allotment of cheese and wine to the point where the expense broke your budget and the Lab [actually URA] took the seminar over."

Now, 20 years on, the Friday Wine and Cheese seminar still lives, with that new, now old, title not far from the original. A heretical thought: Is it now time to start a new tradition? — **J.D. Jackson**



NATIONAL ACCELERATOR LABORATORY

P.O. BOX 500
BATAVIA, ILLINOIS 60510
TELEPHONE 312 231-6600

September 27, 1972

The experimental Theoretical Seminar

Speaker: J. Sanford
National Accelerator Laboratory

Title: "Experimental Plans at NAL"

Date: Friday, September 29, 1972

Time: 4:00 p.m.

Location: West Conference Room

~40 people prese
~14 theorists
~26 exptrs

Cheese and Wine

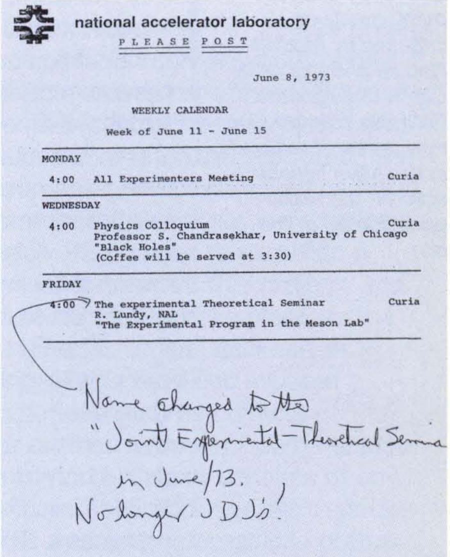
* * * * * * * * * * *

On Friday afternoons, this year, there will be a new seminar for experimentalists and theorists. The format will be that of an informal discussion, and the subjects will be experimental work of current interest and theoretical topics of a phenomenological nature. Experimentalists will be encouraged to discuss proposals, work in progress, and preliminary results.* We hope this will become a weekly gathering where experimentalists and theorists meet. To encourage a convivial atmosphere, wine and cheese will be provided.

This will replace last year's Friday noontime seminar. Note the new time!

*Anyone wishing to speak, please contact M. Einhorn, ext. 749.

*Announcement of the first seminar, held September 27, 1972, with notations of attendance.*



national accelerator laboratory

PLEASE POST

June 8, 1973

WEEKLY CALENDAR

Week of June 11 - June 15

MONDAY

4:00 All Experimenters Meeting Curia

WEDNESDAY

4:00 Physics Colloquium Curia
Professor S. Chandrasekhar, University of Chicago
"Black Holes"
(Coffee will be served at 3:30)

FRIDAY

4:00 The experimental Theoretical Seminar Curia
R. Lundy, NAL
"The Experimental Program in the Meson Lab"

Name changed to the
"Joint Experimental-Theoretical Semina
in June/73.
No longer JDJ's!

*The All Experimenters Meeting and the Physics Colloquium continue to be important entries on the Laboratory's weekly calendar.*

# Main Injector Construction Begins

*Working swiftly to meet deadlines imposed by Mother Nature and the Army Corps of Engineers, Fermilab created nine new acres of wetlands in the Main Injector area on the southwest corner of the site.*

Fermilab's newest accelerator, the Main Injector, will significantly enhance the scientific reach of the Tevatron proton-antiproton collider by supporting luminosities in excess of $5 \times 10^{31}\text{cm}^{-2}\text{sec}^{-1}$. Permitting the simultaneous operation of fixed-target and colliding-beam modes, the Main Injector opens for exploration a rich array of crucial questions such as CP violation, the transmutation between different neutrino generations, and detailed studies of quark properties.

The Fermilab Main Injector (FMI) Project passed its most significant milestone to date when, on September 22, 1992, DOE authorized the application of appropriated construction funds towards development of the Title II (detailed) design and the initiation of civil construction. This authorization followed the submission to and acceptance by DOE of the Main Injector Title I (final conceptual) Design Report in August, and the initiation of the wetland mitigation project in July. In the wake of this action a $3.6 million contract was entered into with the Herlihy Mid-Continent Construction Company for the MI-60 underground enclosure, the first conventional construction directly associated with the project.

Earth moving on the Main Injector actually began with initiation of the wetland mitigation project on July 24, 1992. This work, which was triggered by acceptance by DOE of the FMI Environmental Assessment and subsequent issuance of a "Finding of No Significant Impact," has involved substantial earth moving required for the creation of nine acres of new wetlands. Creation of these wetlands is required by the permit issued to DOE by the U.S. Army Corps of Engineers under the aegis of the U.S. Clean Water Act. The newly created wetlands reside in the Main Injector infield and are created in compensation for the six acres of wetlands that will be filled by the completed project. Initiation of this work in advance of acceptance of the Title I design was specifically authorized by DOE in order to meet the June 1993 expiration date of the Corps' permit. Earth moving on this project was completed in early fall, leaving only spring plantings and five years of monitoring in order to satisfy the Corps' permit conditions.

Following DOE acceptance of the FMI Title I Design and issuance of authorization to initiate Title II, Fluor-Daniel, the architectural/engineering firm engaged by Fermilab on the FMI project, proceeded rapidly to develop bid packages for all civil construction work associated with the project. The overall construction strategy has been established as starting at the MI-60 straight section/service building and working counter clockwise around the ring. The MI-60 straight section represents the point of closest approach between the Main Injector and the Tevatron — at a separation of about 11 meters. 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 has providing the sole equipment access hatch to the ring. The MI-60 Underground Enclosure was released for bid in mid-November with the bid opening conducted on December 22. The bidding was extraordinary both for the number of bidders (30) and the competitiveness of the bidding. A significant number of the bids received were below the budgeted price for this activity.

In parallel with the civil design activities, significant progress was made on identifying vendors for the major dipole magnet subassemblies. On December 23, a contract was signed with Everson Electric Company to form copper coils for the dipole magnets. Contracts for the other major sub-assemblies are expected to be signed in early 1993. Construction activities in FY1993 are to be concentrated on civil construction and the dipole magnets. It is expected that sufficient funding will become available in FY1994 to initiate procurements related to other technical components while continuing to press forward with the civil construction. ◆

# Surveying the Environment

*Using a 200 item check list, Steven Banovetz carefully records either the presence or absence of a plant within a one meter square sampling plot. During 1992, the ES&H staff conducted a systematic monitoring of prairie plants in most of the reconstructed prairie acreage.*

Although the mission of Fermilab is high-energy physics, the location and character of the Laboratory site offer ample opportunities to investigate environmental and ecological questions. Recognizing this, DOE designated Fermilab as a National Environmental Research Park in 1989. DOE maintains seven such parks in the system; others are located at Savannah River Ecology Laboratory, Oak Ridge National Laboratory, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, and Pacific Northwest Laboratory. The goal of DOE's nationwide network of research parks is to provide for long-term environmental research over a large geographical area to explore the impact of energy development and use on the environment.

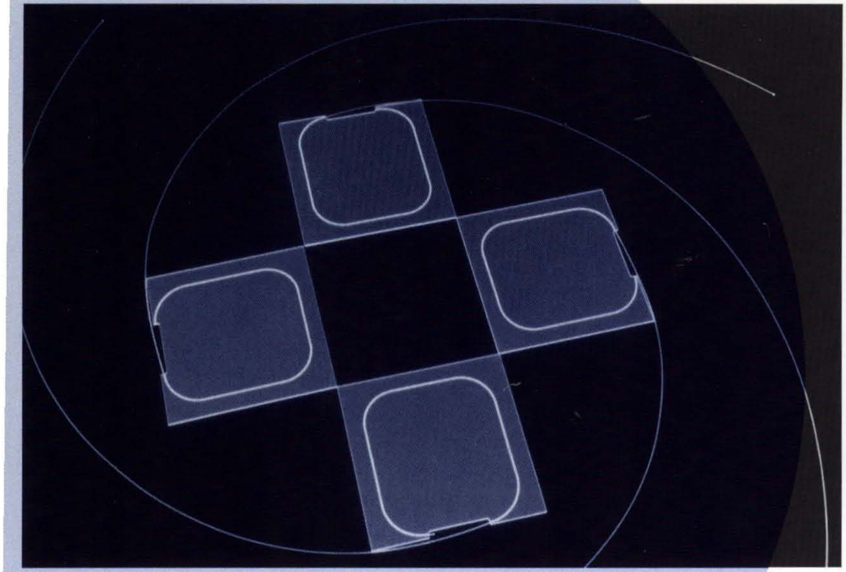
Because Fermilab's research budget is dedicated to physics, environmental research is conducted by outside researchers who enter into a contractual agreement with the Laboratory in much the same way as visiting physicists. Researchers propose a project and, for the most part, provide their own funding. Proposals are reviewed by the staff of the Research Park in the ES&H section, then by an Environmental Advisory Committee before approval. The committee is composed of six distinguished ecologists from across the country. There are six projects currently underway, and two more are under review. Projects include studies on population dynamics of Eastern Bluebirds, soil structure in restored grassland, and the evolution of plant defenses against herbivory. Ecologists at Fermilab and Argonne National Laboratory are currently initiating a 300-acre experimental manipulation area at Fermilab that is designed to provide a rigorously controlled outdoor laboratory for the study of long-term grassland community dynamics.

In addition to the Research Park activities, Fermilab has been the home of one of the most ambitious prairie reconstruction efforts in the midwest since 1975. This project has been accomplished completely through the efforts of a volunteer committee. Beginning in 1992, the nearly 1,000 acre project came under scientific scrutiny for the first time. The reconstructed areas were extensively sampled, and plant community structures were characterized for each. The goal is to establish a comprehensive database on this project, and to document changes that take place as the project undergoes ecological succession.

Also in 1992, Fermilab initiated a major study to investigate the effects of whitetail deer on the many plant communities at the Laboratory. This study consists of an exhaustive effort to characterize plant species composition at a variety of forest and prairie sites. Deer will be excluded from one-half the sites for several years. Changes will then be noted in the annual make-up of the plant community in protected areas relative to the unprotected controls.

Fermilab's role in furthering our knowledge in ecology and environmental science is significant, and is bound to grow as these programs gain momentum. Results from this work will help to fulfill an important goal of DOE: learning more about our interaction with the environment. ✤

*As a component of prairie management, controlled fires are used to destroy undesirable plants and to encourage the growth of native grasses. David Shemanske of Roads and Grounds drips kerosene to ignite a spring burn in the area surrounding the Margaret Pearson Interpretive Trail.*



*Scintillating tiles.*

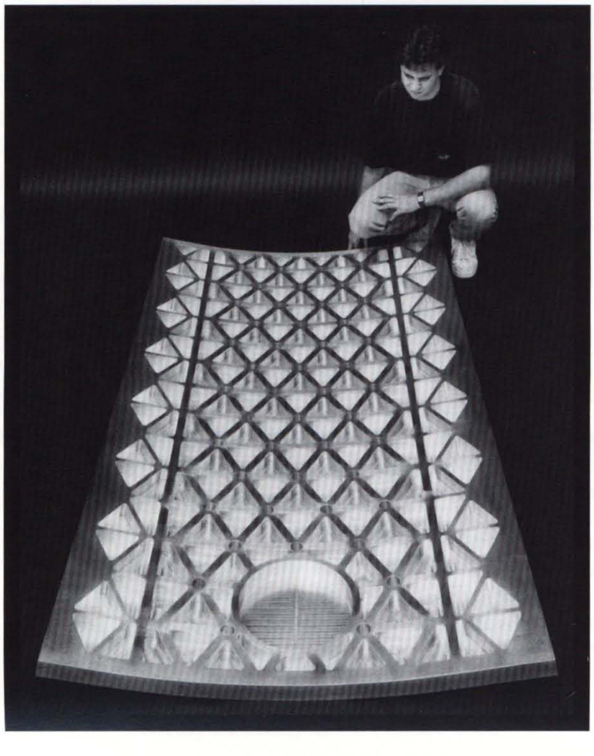
# SDC: A State-of-the-Art Detector for the SSC

The CDF and DØ detectors at Fermilab, gigantic and complex as they are, will be dwarfed in size and complexity by future detectors now being designed for the Superconducting Super Collider (SSC). Detectors extend the range of human perception to the world of the very small. As energies climb, the scale of structure that humans can resolve becomes smaller, but the collisions that must be recorded and interpreted in order to accomplish this become increasingly complex.

The Solenoid Detector Collaboration (SDC) is an international group of over 1,000 physicists and engineers who are collaborating on one of the two major experiments at the SSC. Since SDC is the logical extrapolation of CDF and DØ, the only hadronic collider detectors in the United States, it is natural that Fermilab physicists play a major role in the SDC. Physicists here have amassed immense experience in operating, triggering, and analyzing data from these types of detectors and it is expected that over the next decade many physicists currently working on CDF, DØ and elsewhere will join the SDC effort.

SDC is being designed to detect the large number of particles emitted in each beam-beam collision, to select interactions of interest, and to record the vast of amount of data. SDC will consist of several different subsystems: charged particle tracking, calorimeters to measure energy deposition by individual particles or "jets" of particles, and muon detection and measurement. In turn, each of these subsystems consists of a large number of individual detectors connected to electronic circuits for readout and calibration. Because of the high event rate planned for the SSC, the demands on the trigger system, which selects events of interest, are particularly difficult.

SDC development work dovetails with much of the ongoing Fermilab programs. In the case of CDF, the scintillation tile/fiber calorimetry used in the "plug upgrade" has been adopted by SDC for the central calorimeters. There is a looser connection to the Fermilab program of high-rate triggering and data acquisition. In particular, the KTeV project (the search for direct CP violation in the $2\pi$ decays of the neutral kaon) and SDC share a common calorimeter front-end pipelined electronics system where the data is digitally stored while trigger decisions are made.



*William Poore kneels to inspect one segment of the prototype vacuum vessel for SDC's solenoid magnet. The shell utilizes a fabrication technique known as isogrid to provide a very high strength-to-weight ratio in the aluminum panels.*

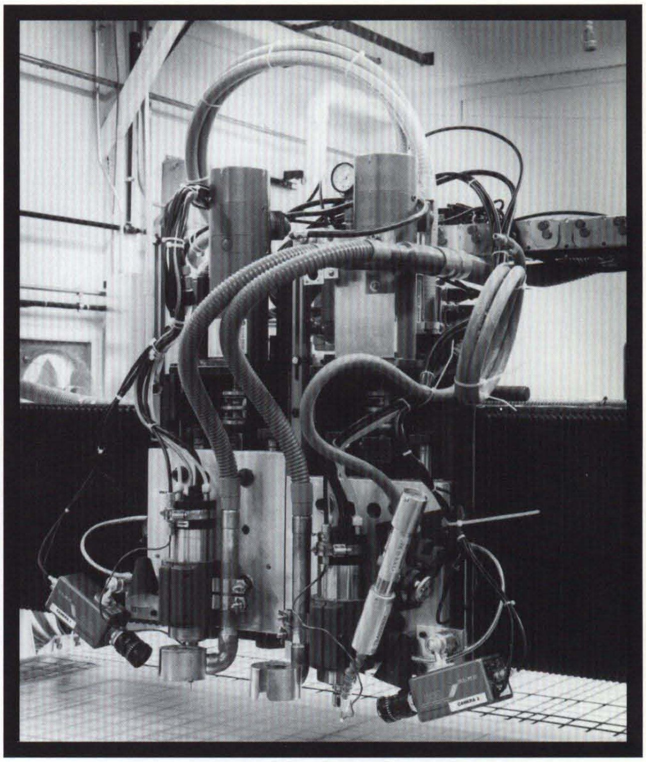
The SDC Department has moved into office space on the seventh and eighth floor of the west side of Wilson Hall. That group is responsible for the design of the SDC hadronic calorimeter steel absorber structure. Construction of these structures will be the responsibility of the Chinese (IHEP/Beijing) and Russian (JINR/Dubna) SDC collaborators. The SDC Department serves as a nexus for liaison with these groups and with others — France (Saclay), Japan (Tsukuba), and Italy (Pisa) — who are also responsible for portions of the calorimetry.

The SDC Department also supports R&D on front-end readout electronics (electronics closest to actual detector element) in collaboration with Research Division support departments. There is a very active effort on solenoid magnet design carried out largely by the Research Division's Mechanical Department. R&D on scintillator is done jointly with the CDF Department and the Physics Department. Electronics work on Application Specific Integrated Circuits for front ends, pipelines, triggers and data acquisition is proceeding. The SDC electronics efforts are a natural fit to the existing Fermilab program as seen in the fruitful joint effort with the KTeV project.

The design, prototyping, engineering and construction of this massive detector incorporate many state of the art technologies. Thus, test beam time has became a critical issue. All the SDC systems need test beam time to perform system level tests of full scale prototypes. A proposal was submitted to Fermilab requesting the full-time use of a beamline for SDC after the current collider run. The SDC created a fully engineered Technical Design Report in April 1992. Subsequent reviews by the SSC Program Advisory Committee and DOE were favorable. A complete cost and schedule were also reviewed. During 1992, SDC was approved for construction. As a result of the conversion of SDC from an R&D phase to a construction phase, the structure of the effort at Fermilab changed. Project management of subsystems of the SDC detector was taken on as the responsibility of Fermilab physicists. Paul Mantsch of the Technical Support Section (TSS) is the calorimeter subsystem Project Manager and a project management group was created in TSS to handle this responsi-bility. The calorimeter prototype and production modules will also be assembled and tested by groups in TSS.

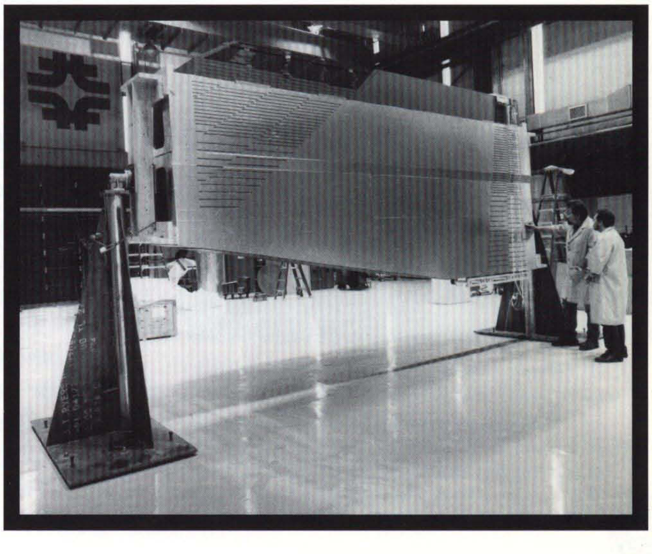
Bill Foster is task manager for calorimeter front end electronics. This effort remains in the Research Division as a joint project between the SDC Department and the Electrical/Electronic Department. The Computing Division (CD) provides two project managers for the SDC effort: Joel Butler for the trigger system and Irwin Gaines for data acquisition and off-line computing. Another branch of SDC has, therefore, opened in CD to help fulfill the responsibilities of Fermilab in these two areas.

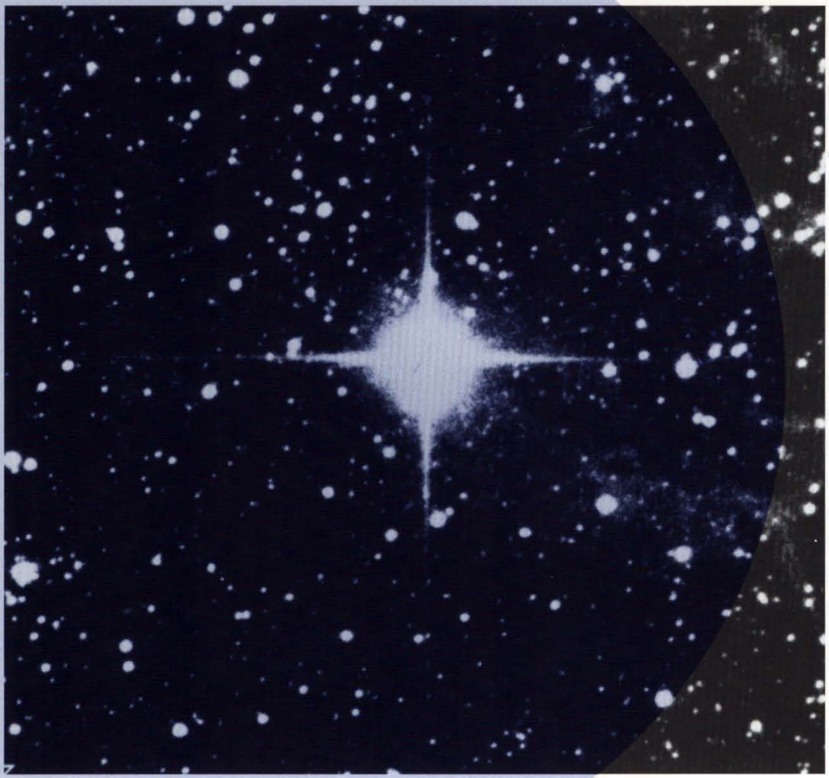
Clearly, the SDC effort is expanding. There is a "core group" in the SDC Department in the Research Division, with branches in TSS and CD. These three groups, with aid from many other support groups at the Laboratory, are now starting to build elements of a powerful new detector that will begin to run at the SSC, collect large amounts of new data, make important discoveries, and yield new insights into the nature of our physical world.



*Located in the Physics Department's Detector Construction facility at Lab 8, the Thermwood machine is a 3-axis router which is programmable to four decimal places. For the SDC detector, the machine takes a sheet of 4-mm thick scintillating plastic, cuts it into 50-cm square pieces, and carves out the tiny grooves which will hold the scintillating fibers.*

*Standing beside the wooden mock-up of an SDC calorimeter wedge, John Chyllo (left) and Charles Keyser of Argonne National Laboratory discuss the placement of the optical readout fibers on the module. In 1992, construction began on two prototype wedges made of steel and lead. In the completed detector, there will be a total of 64 wedges.*





# Surveying the Structure of the Universe

*"The fields of particle physics and cosmology will remain closely linked for some years to come, as physicists and astronomers continue their efforts to understand the fabric of space, the structure of matter, and the origin of it all."*

— **Alan Guth,**
**Professor of Physics,**
**Massachusetts Institute of Technology**

The Experimental Astrophysics Group pursues astronomical research that complements the work of the Theoretical Astrophysics Group and in 1992 worked on two major projects. The Drift Scan Camera will be used on the 3.5-meter telescope at Apache Point, New Mexico to image strips of the sky. The Sloan Digital Sky Survey (SDSS) is a project to map $\pi$ steradians of the northern sky, using a new 2.5-meter telescope at the same site. The SDSS collaboration includes the University of Chicago, Princeton University, Fermilab, the Institute for Advanced Study, the Johns Hopkins University, and the Japan Promotion Group. Individual group members also continue to pursue their own research.

## THE DRIFT SCAN CAMERA

The Drift Scan Camera will begin operation in 1993. The major components are being integrated at Fermilab: the dewar, shutter, charged-coupled device (CCD), readout electronics, control electronics, and data acquisition system. The CCD contains four million pixels, each 24 microns square. The control and readout electronics were designed and constructed in the Research Division/Electrical /Electronics department. The On-line Support Department developed a data acquisition system with a UNIX workstation as host, controlling VME-embedded processing and i/o to handle the high data rate. We will test the complete camera at Fermilab and deploy it at Apache Point when the telescope is complete.

The Drift Scan Camera will address the following questions about the universe:

- **Test the Cosmological Principle.** Cosmological theories often rely on the fact that the universe is isotropic and homogeneous. We will test this by counting the number of galaxies in several long strips in the sky. Current tests are limited by the statistics of small samples and systematic effects in calibrating the counts between north and south.
- **Measure Galaxy Evolution.** Galaxies are the link between the big bang and observed large scale structures in the universe. How a gas cloud coalesces into a galaxy and continues to develop plays a big role in both the formation of structure and the appearance of galaxies. Depending on the overall history of star formation, galaxies in the past may have been redder or bluer, brighter or fainter, than they now appear. By measuring the surface density of faint galaxies (i.e. galaxies presumably at significantly earlier cosmic epochs) as a function of apparent brightness, and in different spectral bands defined by filters, we can place useful constraints on the nature of this evolution.

- **Measure Structure Evolution.** The clustering of galaxies on large and small scales is our handle on the evolution of the universe from a fluid of constant density to what we see today. We will probe the clustering of galaxies down to angles of one arcsecond, using faint galaxies whose distance (redshift) we estimate from their color. Thus, we will see how the galaxy clustering changes with time.
- **Study Quasars and Active Galactic Nuclei.** Quasars are known by their redshifts to be the most distant discrete objects, and are inferred to have enormous intrinsic brightness. The fact that they can vary on short time scales means that their energy source must be small in size, for example a massive black hole. Continued observations of variable quasars and active galactic nuclei will constrain theoretical models of these mysterious high energy density objects.
- **Measure the Hubble Constant ($H_0$) and Deceleration Parameter ($q_0$).** These parameters describe the general expansion of the universe. $H_0$ measures the rate of expansion of the universe and $q_0$ is its time derivative. A key to measuring them is to develop reliable distance scales for objects with known redshifts. Astronomers use type Ia supernovae as standard candles, allowing their apparent magnitude to provide a measure of their distance that is independent of redshift. Once a supernova has been detected, we will be able to measure how its brightness changes during the following months. These measurements, along with redshift determinations, yield $H_0$ and, once enough supernovae have been measured, $q_0$, which is directly related to the overall mass density of the universe. This density determines whether we live in a closed universe, which will eventually collapse back on itself in the "big crunch," or an open universe, in which the expansion continues indefinitely.

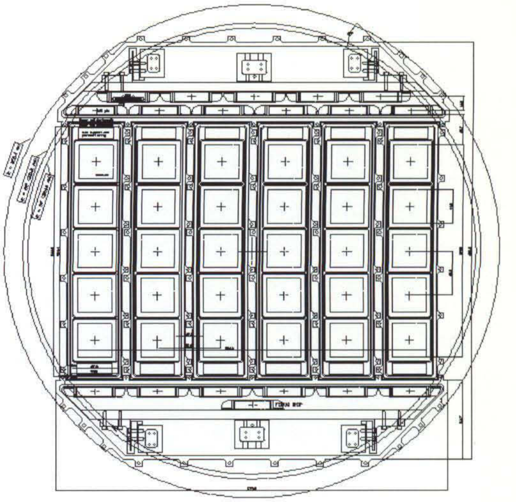
## THE SLOAN DIGITAL SKY SURVEY

The SDSS will operate in two modes. First, it will image the sky using a camera containing 48 imaging CCDs. Hundreds of millions of galaxies, quasars, and stars will be identified in this imaging data. Second, the spectra for one million selected objects will be measured during the five year survey, mapping out the three-dimensional structure of the universe. As data streams from the Apache Point site (200 Gbyte of imaging data on a clear night!), a data processing system at Fermilab will calibrate and archive the results. This survey is uniquely capable of uniformly covering a large area of the sky, enabling powerful statistical tests of competing models of cosmology, structure formation, and galactic evolution. A crucial factor is the ability to select targets consistently throughout the survey, in different patches of the survey area, throughout the five years of operation.

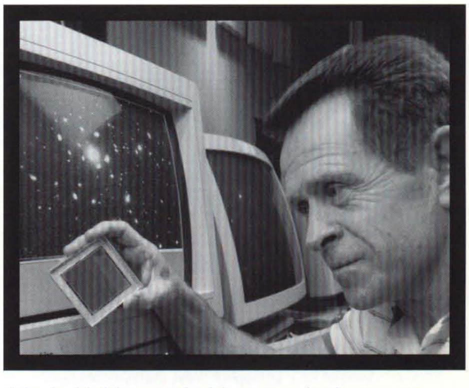
Fermilab provides support for specification and delivery of the major data systems for the SDSS. During 1992, several technical and oversight committees, composed of members of the SDSS as well as outside reviewers, approved the specification documents for the major data systems: Survey Strategy, Survey Operation, and Data Processing. The Experimental Astrophysics Group collaborated with the On-line Support Department to define these requirements.

A data processing system that will allow us to uniformly calibrate the survey requires two distinct kinds of development: system development and science algorithm development. In 1992 a team of SDSS scientists developed a software prototype of the final data processing system, which allows us to continue developing and testing modules integrated into this standard framework. Completed data systems will be delivered by the beginning of the test year of operation for the SDSS, November 1994, when we will use actual observing conditions and data to fine tune the software and parameters to conduct the survey.

Particle physics and cosmology share many scientific goals, and also, as the collaboration of the Experimental Astrophysics Group with others at Fermilab demonstrates, many technical tools that can be developed and used collectively to help us "understand it all."



*The mechanical design for the main imaging camera shows the central array of 30 large CCD chips. Smaller CCDs are used to ensure precise alignment. In order to minimize electronic noise, the chips will be operated inside liquid nitrogen dewars.*



*Merle Haldeman holds a two-inch square CCD chip for the Drift Scan Camera. Utilizing the largest CCD commercially available enables full sky coverage with reasonable resolution. The computer monitor displays an image of a field of galaxies typical of the data to be produced by the survey.*

*Richard Kron, survey director, describes a galaxy image to Ruth Pordes, head of the Computing Division's On-line Support Department which has collaborated closely with the SDSS scientists in the specification and initial development of the major data systems for the survey.*

*The new Leon M. Lederman Science Education Center.*

# Science Education: Hands On

*For people like Katherine Harkay, a Fermilab Accelerator Physics Graduate Research Appointment provides a crucial part of graduate training. The APGRA program addresses the dearth of opportunities for experimental research in accelerator physics. Harkay, working toward her Ph.D. at Purdue University, uses the Fermilab Booster to conduct her thesis research on longitudinal beam instabilities. To complete her degree requirements, her thesis must be approved by her Fermilab advisor, Patrick Colestock, as well as by her university advisor. All students in the program give a seminar once a year at the Lab, an invaluable opportunity to have their work reviewed by other accelerator physicists. Graduate students at any institution may apply to the Accelerator Division.*

According to people who have actually gotten their hands dirty trying to make an accelerator work, theoretical models of how an accelerator behaves are fine to zeroth order, but first- and second-order understanding is not yet very well developed. Or, as Mike Syphers puts it, when a problem arises, "You can come up with a nice theoretical solution that will never work in practice."

In 1988 Syphers became the first person to earn a Ph.D. in accelerator physics through Fermilab's Accelerator Physics Graduate Research Appointment program. The University of Illinois at Chicago granted his degree, but he learned most of what works in practice at Fermilab, where his thesis project involved improving the transfer line that shifts protons from the Booster to the Main Ring. "It was great experience," says Syphers. He credits the opportunity to work on hardware design, installation and commissioning with giving him insights not available through purely theoretical study.

Like every student in the APGRA program, which has 17 other current or previous participants, Syphers had two advisors: one member of the faculty at his university, and one member of the Accelerator Division — in his case, Don Edwards. The eight who have received their degrees have taken their expertise to laboratories or to industry. Mike Syphers is now a group leader at the SSC in, as it happens, the Accelerator Theory group.

……

"Any opportunity to influence kids to think that science isn't ugly, sticky, hard, nasty, and for strange people is very important," says Dr. John Rhodes. Rhodes is the principal of the Gary School, an elementary school in West Chicago.

Members of the Fermilab community have been working to introduce precollege students and their teachers to what physicist Richard Feynman called "the pleasure of finding things out" for over a decade. In 1979, when the high school students came to the Lab for the first series of Saturday Morning Physics lectures, the idea that a national laboratory should take an active role in precollege science education was a novelty. Because Laboratory funds could not be used for such purposes, a not-for-profit corporation, Friends of Fermilab, was established in 1983.

A long-cherished dream of the Friends was realized this fall, when the Leon M. Lederman Science Education Center opened. Stanka Jovanovic, manager of Fermilab's Education Office, anticipates that several thousand teachers and 20 thousand students will visit the Center annually, either in school groups or for programs like Science Adventures, day or half-day informal classes designed for classroom teachers or for students and parents. The clean lines of the red-brick building designed by founding director Bob Wilson evoke the "prairie houses" of Frank Lloyd Wright. The airy interior has a resource center where teachers can discover together how to become better science teachers, a science lab and a computer and technology classroom where structured programs can be conducted, and a host of informal interactive learning stations aimed at middle-school students, including interactive videos based on Fermilab accelerators and detectors. There is no hint of anything ugly, sticky, or nasty. "The place is very special," says Rhodes. "Kids feel that they are special to be going there, and so science becomes special."

The guiding philosophy of the Education Office, according to program manager Marge Bardeen, is to put teachers in leadership positions. This approach may not sound especially avant-garde. But ask John Rhodes what the most important aspect of Fermilab's Education Office programs is, and he is likely to respond, "They listen to us."

……

A former post office in Aurora, complete with carved eagles over the doors, is headquarters for the interactive science center known as SciTech. Behind the door still labelled "Postmaster" is the office of the executive director, Ernest Malamud. Malamud, a physicist who has been at Fermilab since 1968, decided when he was 12 to pursue a technological career after learning to build electric motors in a summer course. After spending a six-month leave working at the Exploratorium in San Francisco, he decided to found a hands-on science center.

Fermilab's director and Board of Overseers have helped Malamud to realize his goal by approving salary support for him and for another couple of Fermilab employees who work part time helping to develop exhibits. Argonne provides similar support, and both national laboratories, AT&T Bell Labs, the NALCO Chemical Company, the Amoco Research Center, and the Environmental Monitoring Laboratory are leading sources of the people Malamud calls "our grass-roots, high-tech volunteer consultants."

The SciTech approach to interesting students in math and science is to involve them in as many ways as possible. School field trips bring about a thousand students a week to explore and experiment with exhibits on physics, mathematics, and chemistry. Twenty of the exhibits have been built by girls 10 to 14 years old, led by women in technical fields like Linda Bagby and Mimi Bleadon of Fermilab's Research Division. On school holidays, paid high school and college student explainers help visitors interpret exhibits. And, for students and parents who can't come to SciTech, SciTech comes to them. Ten exhibits from the museum are set up in a school for a week. After the students explore the exhibits, a SciTech explainer helps them investigate further and draw conclusions. A West Aurora teacher describes this approach as "an excellent, highly educational program that students and teachers alike learn from."

*Students explore the realms of sound, heat, light, magnets, electricity, chemistry and mathematics at SciTech. "We're about stimulating curiosity," says operations manager Naida Omholt. "We try to show people that science and math help explain things that are around us all the time." In the last four years, exhibits from the museum floor have also been loaned to more than two hundred schools.*

# The Year of the Tiger

*Deputy Director Kenneth Stanfield (left) and Harry Season, leader of the Tiger Team, discuss the next day's schedule with Jean Lemke of the Response Team Office which served as a crucial communication center during the Tiger's one month stay at Fermilab.*

1992 was the year of the Tiger at Fermilab. It was the year that our Laboratory's environment, safety and health policies, procedures and programs came under the tough scrutiny of DOE. During the year we all worked together for a common cause and created an energy and excitement reminiscent of our early "pioneering" days.

The impetus of the Fermilab environment, safety and health (ES&H) activities of 1992 was a 10-point initiative outlined three years earlier by Secretary of Energy James D. Watkins. The initiative was designed to strengthen environment, safety and health programs and "set a new course toward full accountability for the department and its contractors." Under the new program, Admiral Watkins pronounced that ES&H objectives would take precedence over production or research objectives and he established independent "tiger teams" to conduct environmental compliance assessments of all DOE operating facilities. These actions aimed at establishing what came to be known as "the new culture." Over the next several months Fermilab worked with DOE and the other national laboratories to create a new era of heightened awareness, commitment and responsibility toward ES&H concerns.

DOE began its Tiger Team Assessments in 1989. Facilities with demanding environmental issues were appraised first. Less critical facilities were examined last. Fermilab was 34th in the succession of reviews, making us one of the last DOE-funded laboratories to undergo a Tiger Team Assessment.

Fermilab used the time preceding the assessment to conduct a very critical internal assessment of our ES&H and management programs. This self-examination gave us the opportunity to look closely at how we do business at Fermilab and to evaluate our strengths and weaknesses. We also performed, with the assistance of outside consultants, an extensive, site-wide Occupational Health and Safety Administration Compliance inspection; formed an Environment, Safety and Health Policy Advisory Committee to organize and evaluate the Laboratory's response to ES&H issues; developed an ES&H self-assessment plan and opened an Office of Self-Assessment to provide the overall coordination of our self-assessment program.

As the assessment drew closer, Director John Peoples appointed employees and users to serve on a Tiger Team Task Force. The duties of the Task Force, under the direction of Deputy Director Kenneth Stanfield, included preparing for the Tigers' arrival, accommodating the Tigers during their stay, facilitating interviews and preparing the corrective action plan after the Tiger's departure.

These final days were also a time for Fermilab employees and users to review ES&H policies and procedures, take necessary corrective action and discuss questions and concerns with their supervisors. As a community, we came to realize that safety was not something to be done by the safety department but something in which we all had ownership and responsibility.

The Tigers arrived at Fermilab on May 11, 1992, with a team of 55 technicians from DOE and private firms chosen for their expertise in specific functional areas. Their stay lasted almost a month. Over that time, they rigorously reviewed every facet of the operation and management of our Laboratory. Included in the assessment were questions on how we handled hazardous materials, disposed of waste and monitored air, soil, water and effluent discharges. They combed the site and conducted their assessment by talking with managers, employees and users in order to get an accurate picture of the status of our ES&H programs. They also reviewed countless pieces of documentation pulled together and centralized in a Tiger Team Library. Throughout the examination, Fermilab employees made themselves available to assist, working many long hours to ensure that the Tigers were getting the information that they needed to accurately assess our Laboratory.

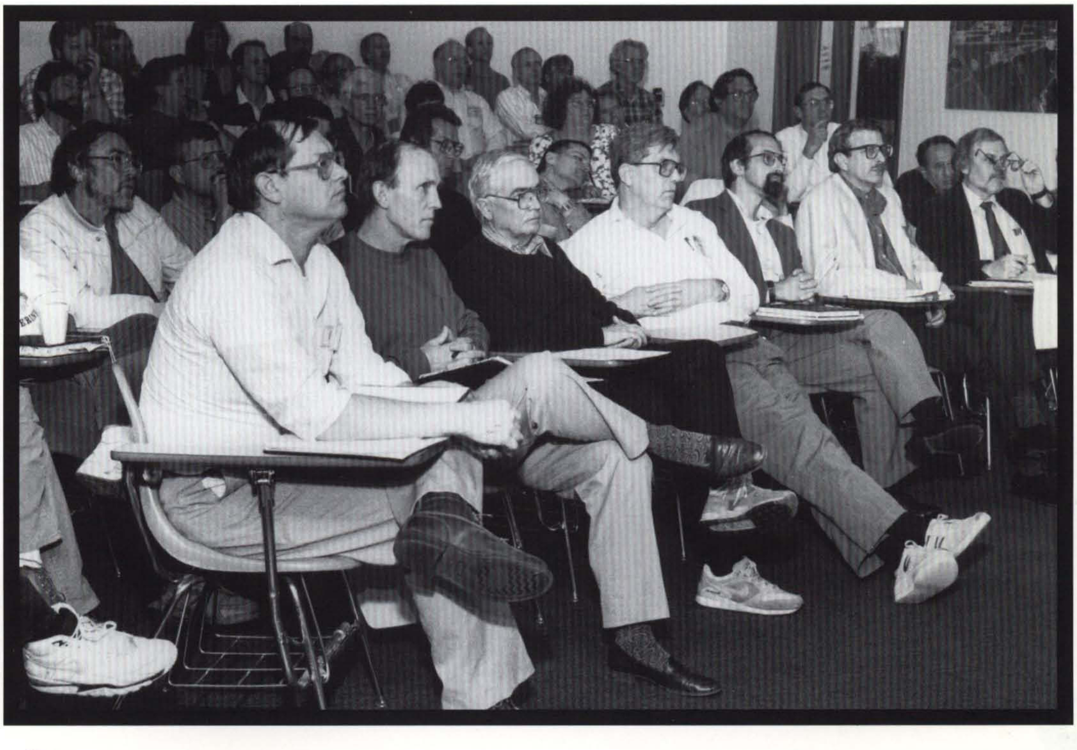
The Tigers left the Laboratory on June 8, after a public close-out meeting. The result of the visit was a formal report that was transmitted to the Secretary of Energy outlining our strengths and weaknesses.

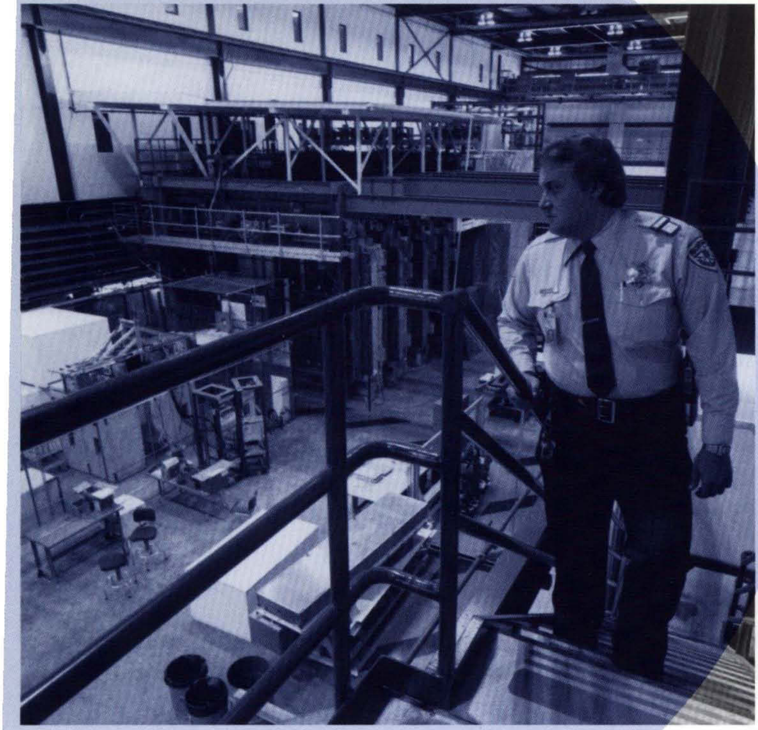
The Tiger Team found that our Laboratory had already identified most of their findings in our own self-assessment. None of the Tiger Team's findings warranted the cessation or curtailment of operations, or presented a significant risk to either public health or the environment. The Tiger Team's report commended Director John Peoples and the Fermilab community for "consistently displaying ownership and responsibility for the safe, healthful, and environmentally responsible operation of the Laboratory."

The results of the report were not perfect and we learned that we have much work ahead, but the Tiger Team found that we have the right attitude and level of commitment to meet the challenge. "For the most part, the Tiger Team findings and concerns are related to those additional steps that Fermilab must take to ensure that it operates in full compliance with applicable laws and regulations," said Harry Seasons, Tiger Team leader.

Operating our Laboratory in a safe and responsible way has always been part of the Fermilab fabric. The Tiger Team members found that we have "many islands of excellence." Over the coming years, we will work to expand these islands and plan our research so that it never compromises health, safety or the environment.

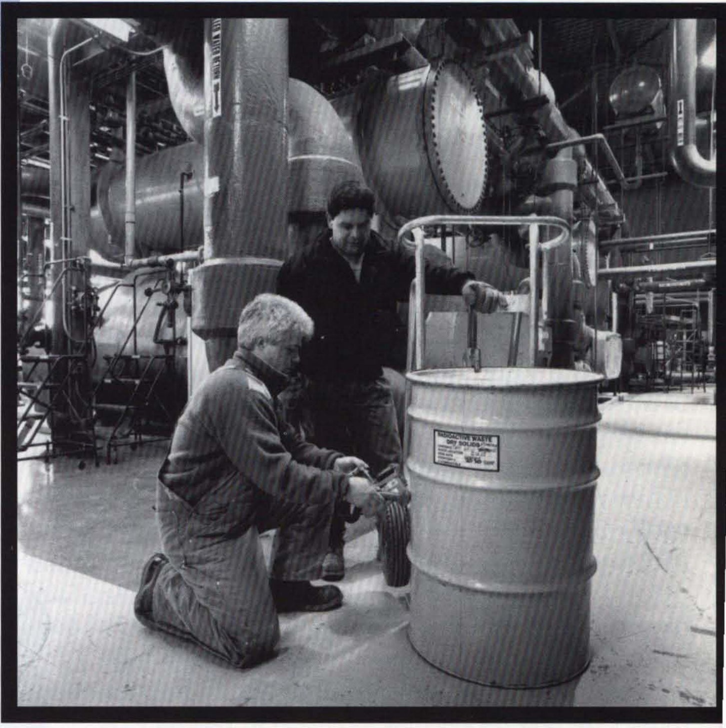
*Fermilab employees and Tiger Team members listen intently during the daily close-out sessions which offered a forum for reporting activities.*



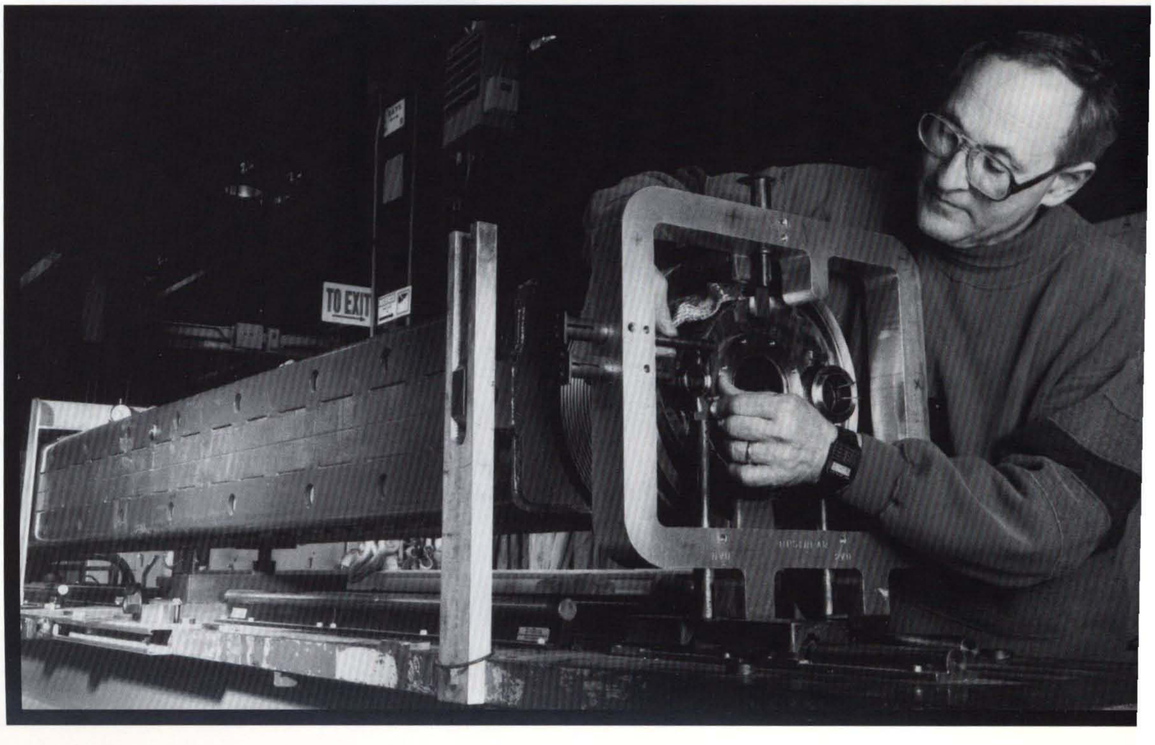


During his regular patrol, Security Officer David Lorenz inspects the large open area of the New Muon Lab. Security staff is on-site 24 hours a day, seven days a week to ensure a safe and secure environment. Officers check specified areas at least twice each shift; they look for fire, smoke, electrical appliances which are turned on and unattended, unsecured doors, and slip-trip-fall hazards. The security staff also conducts theft, accident and injury investigations, handles parking and traffic control on the site, and responds to emergencies.

# The Year in Pictures



In the Central Utility Building, radiation technician Steve Carrigan kneels to survey a 55-gallon steel drum to determine its dose rate. After the documentation is checked, Driver Tony Villa will take the container to one of the on site processing facilities. There, members of the Radiological Control group sort and screen the waste, and repackage it for shipment to the Hanford Disposal Facility in Richland, Washington. In the course of a year, Fermilab generates about 4,000 cubic feet of radioactive waste, equivalent to the waste generated by a midsize hospital.



Armand Bianchi adjusts measuring devices on a Main Injector magnet at the Magnet Test Facility. Detailed studies of field shapes at the end of these magnets allowed design refinements of the iron shapes to minimize field errors.

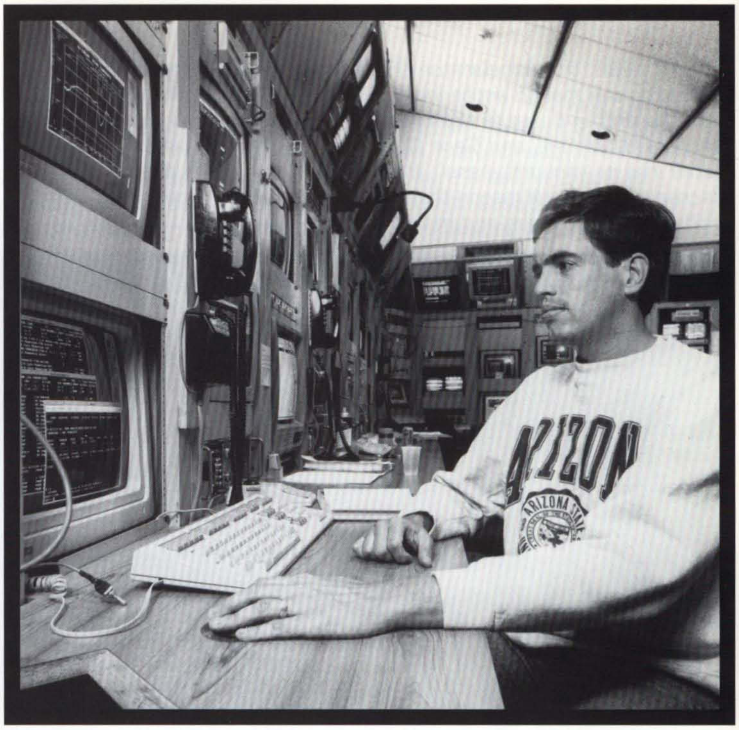
*During 1992, the Accelerator Division Mechanical Support Group was rebuilding the meson septa in the Switchyard. The septa are used to split the proton beam to the different fixed-target experimental areas. Michael Hines (left) and Gene Opperman insert the frame of a splitter septa into its vacuum vessel. The rebuilding project is designed to decrease the spark rate in the septa, thus opening opportunities for higher beam energies and more reliable operation.*

*Scott Hawke (left) and Tom Anderson adjust the height of the detector carriage in the Source Projector Room at the Radiation Physics Calibration Facility. Different radioactive sources are placed behind the concrete wall and the carriage is moved remotely along the railroad tracks.*

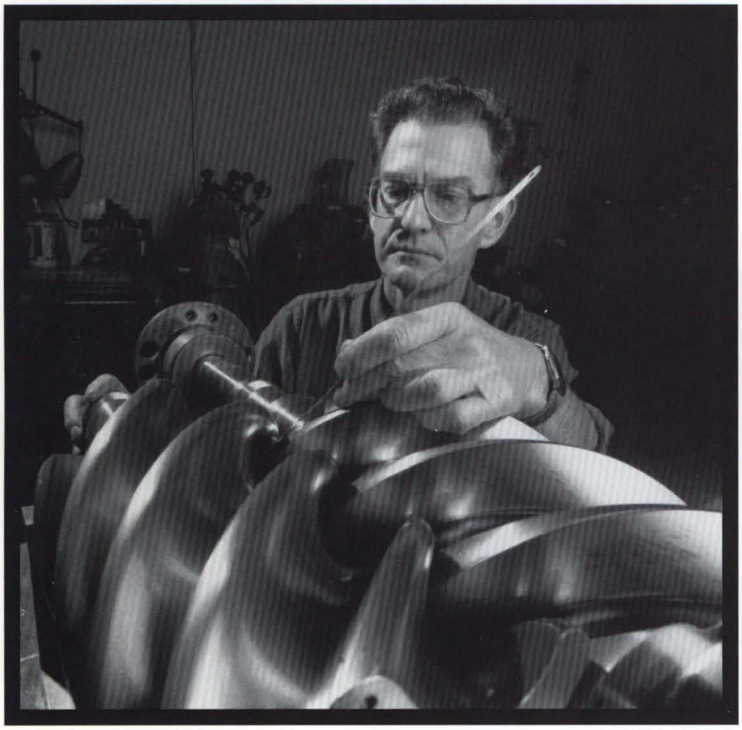
*There are four of these 15-foot survey monuments, designed by the Facilities Engineering Services Section to the specifications of the Research Division's Alignment Group, located around the site of the Main Injector. In addition, there are 10 lower survey monuments which will permit the accurate surveying necessary for this major construction project. Harold Stephen (left) of FESS greets John Shales of the Seagren/Shales construction company after inspecting one of the structures.*

*The Fermilab Physics Department has long been involved in the design and fabrication of various components for the Laboratory's experiments. Working in Lab 7, Lauren Jones (foreground) and Eileen Hahn position scintillating fibers in a guide before sputtering one end of the fibers with reflective aluminum. Scintillator material is used to track charged particles, and coating the end with aluminum makes the fiber act like a mirror.*

*Neural networks, data processing architectures modeled on the current understanding of pattern recognition in animal nervous systems, are finding increasing application in high-energy physics both as an algorithm for data analysis and as hardware for triggering systems. Bruce Denby (right) and Clark Lindsey fit a special chip into the neural network board of their drift chamber.*

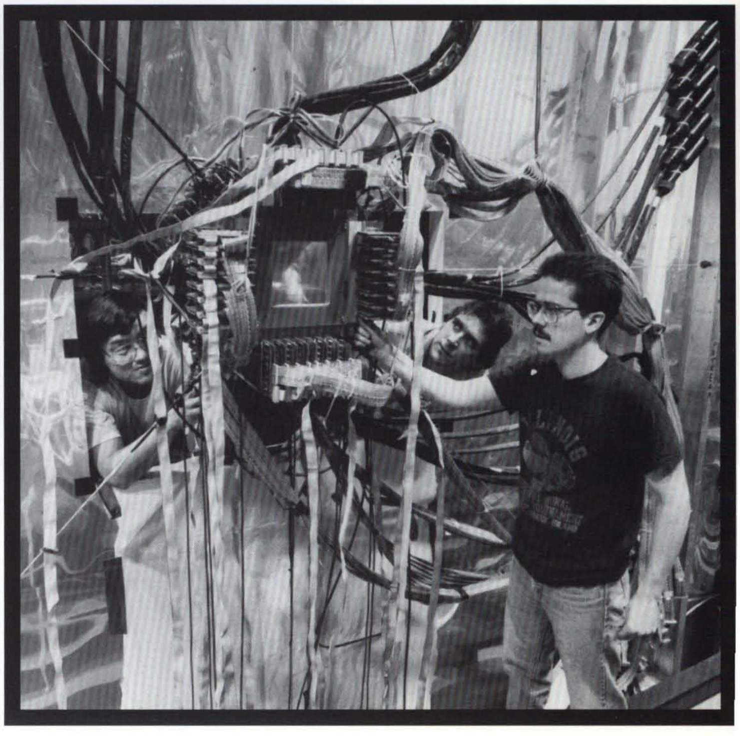


*James Morgan calmly studies his monitors in the Main Control Room. The last half of 1992 produced a series of record-setting performances for the Tevatron. On September 14, 1992 the Tevatron shattered its own record initial luminosity of 2.07 x $10^{30}$ $cm^{-2}sec^{-1}$ set in the previous collider run. Operation steadily and continually improved, and at noon on December 19, 1992 the accelerator achieved a world-record luminosity of 7.45 x $10^{30}$ $cm^{-2}sec^{-1}$.*



*To ensure a continual, reliable flow of liquid helium to the Tevatron's superconducting magnets, there are 34 screw compressors that compress the gaseous helium. Bill Martin inspects tolerances and clearances on a prototype high-efficiency 3,600 rpm rotor. The Cryogenic System Compressor Group performs all the industrial work and maintenance on this system that is crucial to Tevatron operation.*

*From the left, Rumgsheng Guo, Mark Adams, and Timothy Carroll examine E665's small angle wire chamber which is behind the square reflecting window. Utilizing the world's highest energy muon beam, this detector explores the internal structure of protons, neutrons and nuclei. Sheets of aluminized mylar form an "environmental hut" which helps to control the temperature and humidity around sensitive apparatus.*

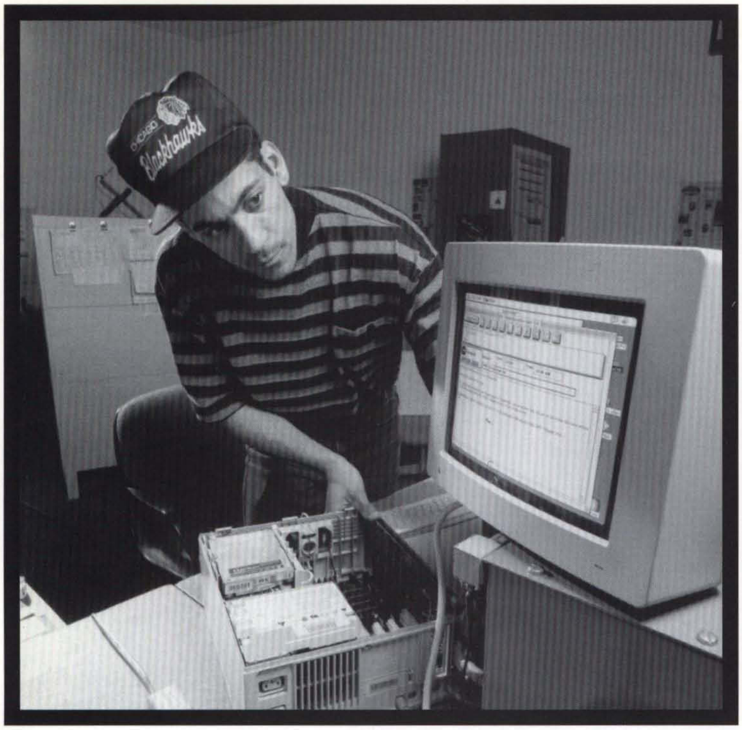


*As a member of the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Fermilab brings students to the Laboratory for summer employment. Participating in this program in 1992, D'Anthony Woods worked in the Material Development Laboratory preparing samples of scintillating plastics that are more radiation resistant than those used in the current generation of detectors.*

*Stephen Anderson worked as an intern in the Accelerator Division's Control Group while studying engineering at the University of Illinois at Chicago. He helped to test new circuit boards designed for the cryogenic refrigeration upgrade. The Control Group is responsible for the hardware and software that sense and monitor all the various parameters which must be controlled for the smooth and efficient operation of the Tevatron.*

*Bob Johnson and Bonnie Connor of Purchasing are pleased with their day's work. In the 1992 fiscal year, the Business Services Section placed 57% of its goods and services dollars with small businesses and 3.4% with minority-owned businesses. This achievement is particularly noteworthy considering that many of the high-tech commodities and services required by the Laboratory are available only from large corporations.*

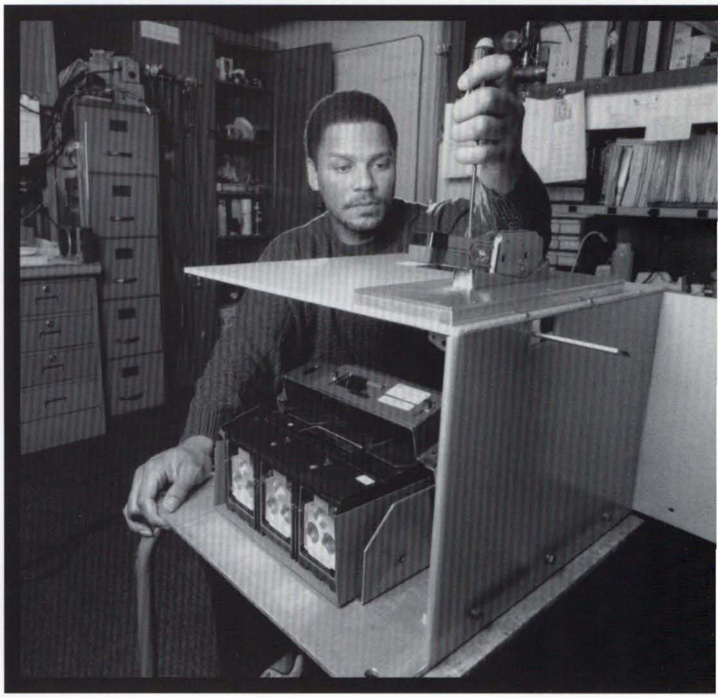
*Helmut Braun, a visiting experimenter from Germany's Wuppertal University, sits in front of a Cerenkov counter for E665. This detector, composed of 144 separate mirrors, is used to study the properties of hadrons emerging from deep inelastic collisions with protons, neutrons and heavy nuclei.*



The Equipment Support Group provides in-house repair for the 57,000 electronic instruments and systems crucial to the functioning of all aspects of the Laboratory. In 1992, the 17-member group repaired more than 10,000 pieces of equipment ranging from oscilloscopes to personal computers to accelerator control systems to equipment for individual experiments. Technician Eric Balthazar performs diagnostic repair on a Macintosh in the group's work area in the Feynman Computing Center.

Anna Pla-Dalmau of the Research Division's Particle Detector Group examines a scintillator test sample. The small cylindrical samples, consisting of a polystyrene base doped with different fluorescent compounds, will be analyzed for various spectroscopic properties as scientists seek to find the most effective materials for the next generation of detectors.

Mitchell Adamus checks the calibrations of the rf probes to determine the accelerating field inside the cavities of the new Linac. During the Tevatron shutdown in the summer of 1993, four tanks of the old Linac (to the left) will be removed and replaced by seven new accelerating modules operating at higher accelerating fields and higher frequency. The upgraded Linac will increase the output energy from 200 MeV to 400 MeV and reduce the transverse size of the beam in the Booster,



A member of the Accelerator Division's Electrical and Electronics Support Group, Leroy Middlebrooks adjusts the control mechanism on a safety switch assembly for a power supply. This switch provides technicians a safe means to disconnect and to lock off the incoming 480-volt, three phase power. The group designs, builds and tests the specialized electrical equipment required by the division, and in 1992 was heavily involved in the low-beta project and the Linac upgrade.

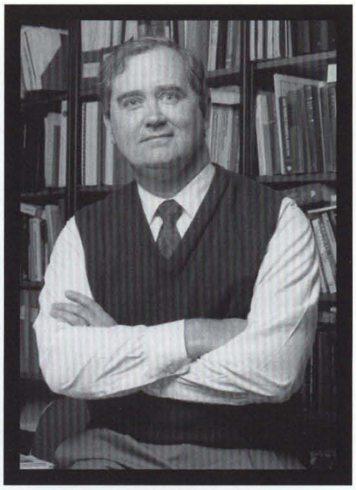
*Winter scene on the Fermilab site.*

# Awards

*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. Election to Fellowship is limited to no more than one-half of 1 percent of the membership of the Division of Particles and Fields.*

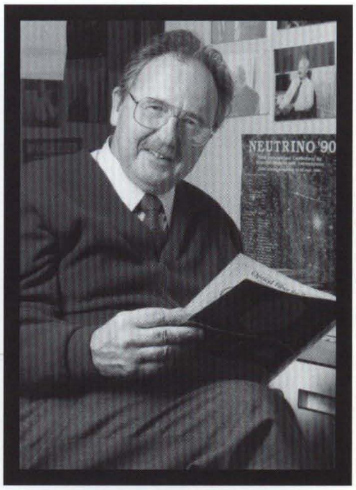
*Robert Kephart of the Research Division, elected APS fellow "for his leading role in building, operation and physics of the CDF Detector."*

*Deputy Director Kenneth Stanfield, elected APS Fellow "for contributions to the success of the U.S. High-Energy Physics program as an experimental physicist and as a leader and manager of the Fermilab research program for 15 years."*

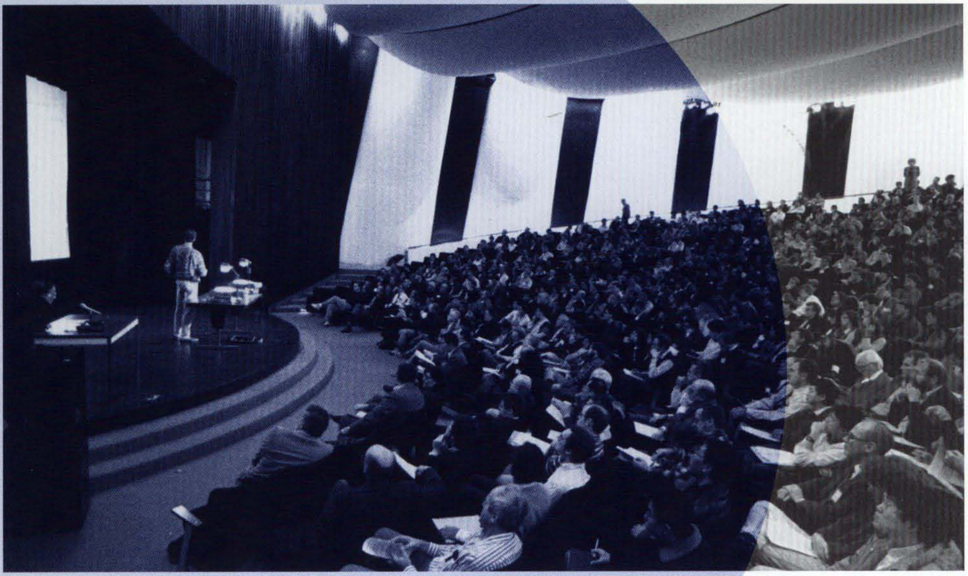


*The American Association for the Advancement of Science elected Chris Quigg of the Theoretical Physics Department to the rank of Fellow "for distinguished research in high-energy physics and theory of the fundamental interaction of the elementary particles."*

*Arlene Lennox, Head of Neutron Therapy, was elected as a representative of the American Association of Physics Teachers to the Executive Committee of the American Physical Society's Forum on Education.*



*Drasko Jovanovic of the Physics Department was elected chairperson of the American Physical Society's Forum on Education, a new component of APS designed to foster physics education on a variety of levels. One of its prime goals is to encourage research physicists to collaborate with local high school teache*



*A packed house in Ramsey Auditorium listens intently during a plenary session of the seventh American Physical Society's Division of Particles and Fields (DPF) meeting. A record-breaking number of physicists attended the conference, held at Fermilab November 10–14, to hear the latest reports from laboratories around the world. In addition to two days of plenary sessions, 475 talks were given during the three days of parallel sessions. Fermilab's Rajendran Raja and John Yoh served as cochairpersons of the successful event.*

# Events

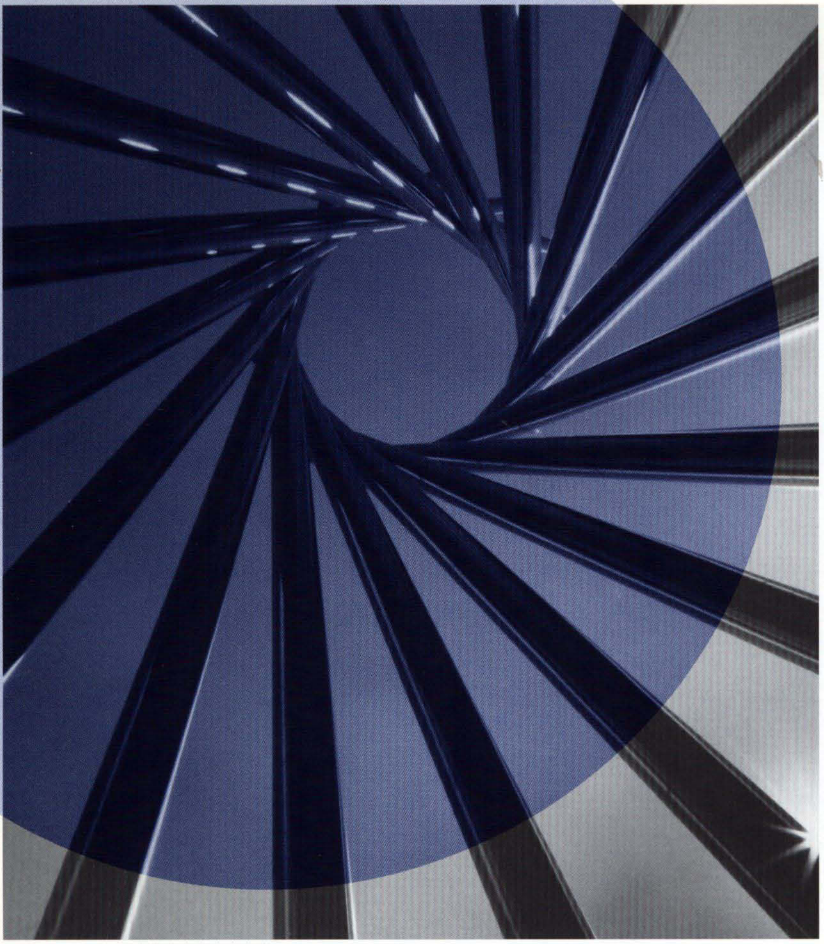
*The Leon M. Lederman Science Education Center was officially dedicated on September 25, 1992. The participants in the traditional ribbon-cutting ceremony included (from the left), Robert Wilson, Nancy Peoples, Stanka Jovanovic, Bruce Mason, John Peoples, Leon Lederman, Ellen Lederman, Secretary of Energy James Watkins, and Marjorie Bardeen.*

*On June 15, 1992 Fermilab employees gathered in the atrium for a cake and coffee celebration of the 25th anniversary of the Laboratory's founding. Director John Peoples cuts the first slice from the towering cake as John Barry (near right in plaid shirt), whose staff arranged the festivities, observes. Dr. Peoples gave special recognition to 10 employees who have served 25 years at Fermilab. They are Angela Gonzales, Carolyn Hines, Quentin Kerns, Barbara Kristen, Glenn Lee, Jean Lemke, Charles Marofske, Lincoln Read, Reid Rihel, and Jan Wildenradt.*

*In conjunction with the American Association for the Advancement of Science's Public Science Day, Fermilab brought the entire student body from the Gary Elementary School in West Chicago to the Laboratory for science demonstrations and discussions. Using curved mirrors to demonstrate the formation of a real image, Gaston Gutierrez captivates students during their lunch break.*

*In celebration of Leon Lederman's seventieth birthday, on September 24, 1992 his colleagues gathered for an international symposium to honor the Nobel laureate and Fermilab's second director. Edward Kolb served as Master of Ceremonies for the festive dinner that followed.*

*Cynthia Sazama (left) and Marilyn Rice quickly confer during the registration of the more than 1,000 physicists who attended the Division of Particles and Fields meeting. The Conference Secretariat compiled countless lists, juggled complicated logistics, generated mountains of paper and solved last-minute crises in their successful organization of this major meeting.*



*Spokes of the sculpture Tractricious frame a cloudless summer sky. The 12-m high structure, composed of 16 stainless steel outer tubes made from scrap cryostat tubes from the Tevatron's dipole magnets, stands in front of the Industrial Center Building. The Fermilab site is sprinkled with several other large sculptures as well as colorful and functional rectangular-shaped buildings, old white farmhouses, sturdy concrete structures, and the 16-story Wilson Hall, which soars over the Illinois prairie.*

# Acknowledgments

Editor: **Ernest Malamud**
Technical Editor: **Barbara Lach**
Visual Editor: **Fred Ullrich**

Science Writer: **Kate Metropolis**

Authors: **Mike Church, John Cooper, Cindy Crego, Gene Fisk, Dan Green, Steve Holmes, J. D. Jackson, Gerry Jackson, John Peoples, Stephen Pordes, Chris Stoughton, Rod Walton**

Authors of Impressions: 1967–1992
**Dick Auskalnis, Jackie Coleman, Rudy Dorner, Ned Goldwasser, Mack Hankerson, Debbie Harris, Tita Jensen, Sharon Lackey, Boyce D. McDaniel, Andrew E. Mravca, Ralph J. Pasquinelli, Janice Roberts, Bob Sheldon, James L. Thompson, Kennard Williams**

Contributors and consultants:
**Chuck Ankenbrandt, Marge Bardeen, James Chimbidis, Sheila Colson, Cindy Crego, Judy Jackson, Stanka Jovanovic, Adrienne Kolb, Paul Mantsch, Chuck Marofske, Tom Nash, Jan Olsen, Naida Omholt, John Peoples, Betsy Schermerhorn, Alvin Tollestrup**

Photography: **Reidar Hahn**

Design: **Elaine Weed** and **Mark Karczewski** of Weed Advertising in Naperville

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

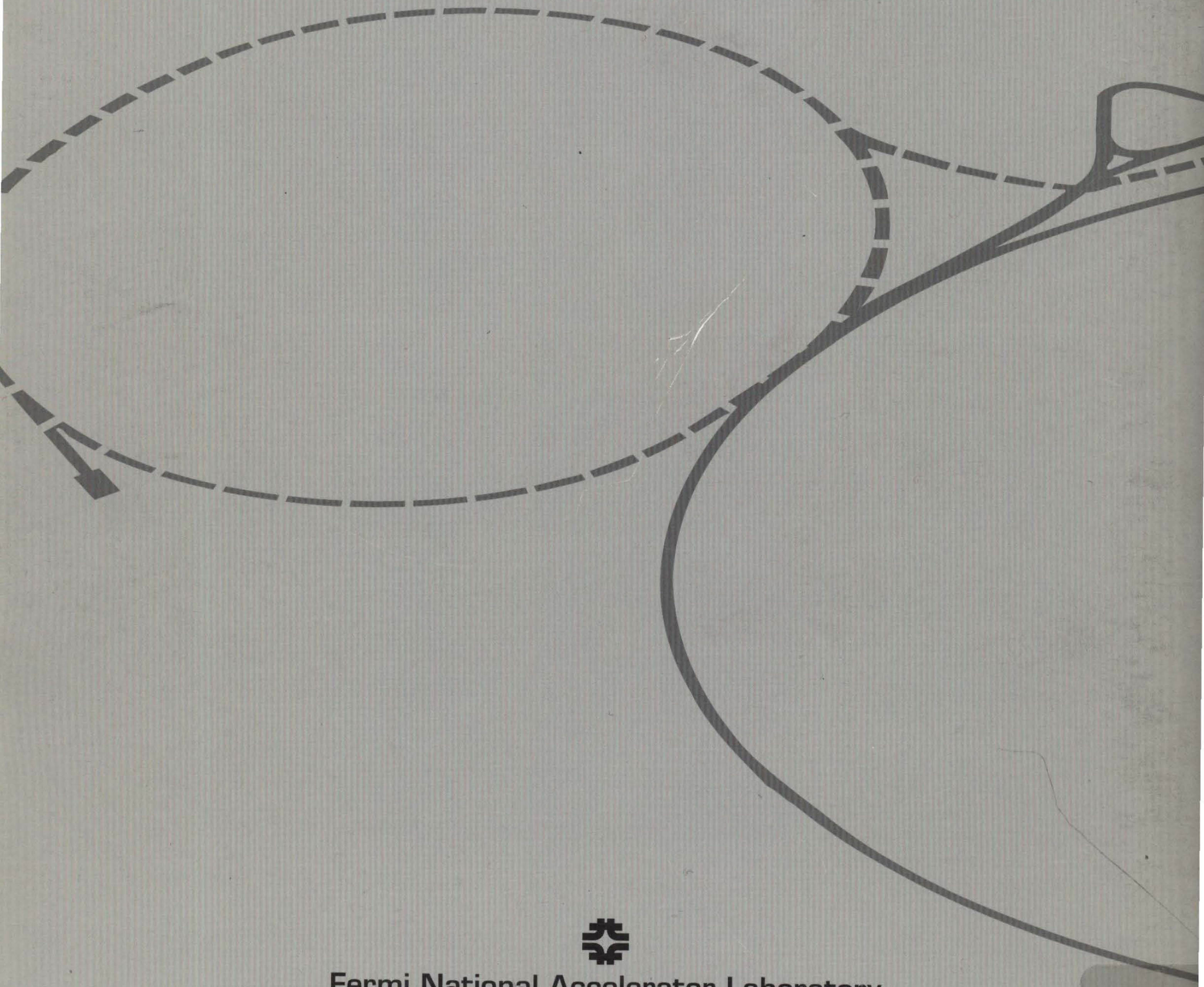
Photo credit:
Frontispiece: **Los Alamos National Laboratory**
**p.49: Darris Harris of Martin/Grime & Company**

# URA Member Universities

(Universities Research Association, Inc.)

- Alabama
  - University of Alabama, Tuscaloosa
- Arizona
  - University of Arizona
  - Arizona State University
- California
  - University of California, Berkeley
  - University of California, Irvine
  - University of California, Los Angeles
  - University of California, Riverside
  - University of California, San Diego
  - California Institute of Technology
  - San Francisco State University*
  - Stanford University
- Colorado
  - University of Colorado at Boulder
- Connecticut
  - Yale University
- Florida
  - Florida State University
- Hawaii
  - University of Hawaii at Manoa
- Illinois
  - University of Illinois at Urbana-Champaign
  - University of Chicago
  - Northern Illinois University*
  - Northwestern University
- Indiana
  - Indiana University
  - University of Notre Dame
  - Purdue University
- Iowa
  - University of Iowa
  - Iowa State University
- Louisiana
  - Louisiana State University
  - Tulane University
- Maryland
  - University of Maryland
  - Johns Hopkins University
- Massachusetts
  - University of Massachusetts at Amherst
  - Boston University
  - Harvard University
  - Massachusetts Institute of Technology
  - Northeastern University
  - Tufts University
- Michigan
  - University of Michigan
  - Michigan State University
- Minnesota
  - University of Minnesota
- Missouri
  - Washington University
- New Jersey
  - Princeton University
  - Rutgers, The State University of New Jersey
- New York
  - Columbia University
  - Cornell University
  - University of Rochester
  - Rockefeller University
  - State University of New York at Buffalo
  - State University of New York at Stony Brook
  - Syracuse University
- North Carolina
  - University of North Carolina
  - Duke University
- Ohio
  - Case Western Reserve University
  - Ohio State University
- Oklahoma
  - University of Oklahoma
- Oregon
  - University of Oregon
- Pennsylvania
  - University of Pennsylvania
  - Carnegie-Mellon University
  - Pennsylvania State University
  - University of Pittsburgh
- Rhode Island
  - Brown University
- South Carolina
  - University of South Carolina
- Tennessee
  - University of Tennessee at Knoxville
  - Vanderbilt University
- Texas
  - University of Texas at Arlington
  - University of Texas at Austin
  - University of Texas at Dallas
  - University of Houston
  - University of North Texas
  - Prairie View A&M University*
  - Rice University
  - Southern Methodist University*
  - Texas A&M University
  - Texas Tech University
- Utah
  - University of Utah
- Virginia
  - University of Virginia
  - College of William and Mary
  - Virginia Polytechnic Institute and State University
- Washington
  - University of Washington
- Wisconsin
  - University of Wisconsin at Madison
- Canada
  - University of Toronto
  - McGill University
- Japan
  - Waseda University

* Denotes an associate member institution



**Fermi National Accelerator Laboratory**
Batavia, Illinois

*Operated by Universities Research Association, Inc.*
*Under Contract with the United States Department of Energy*