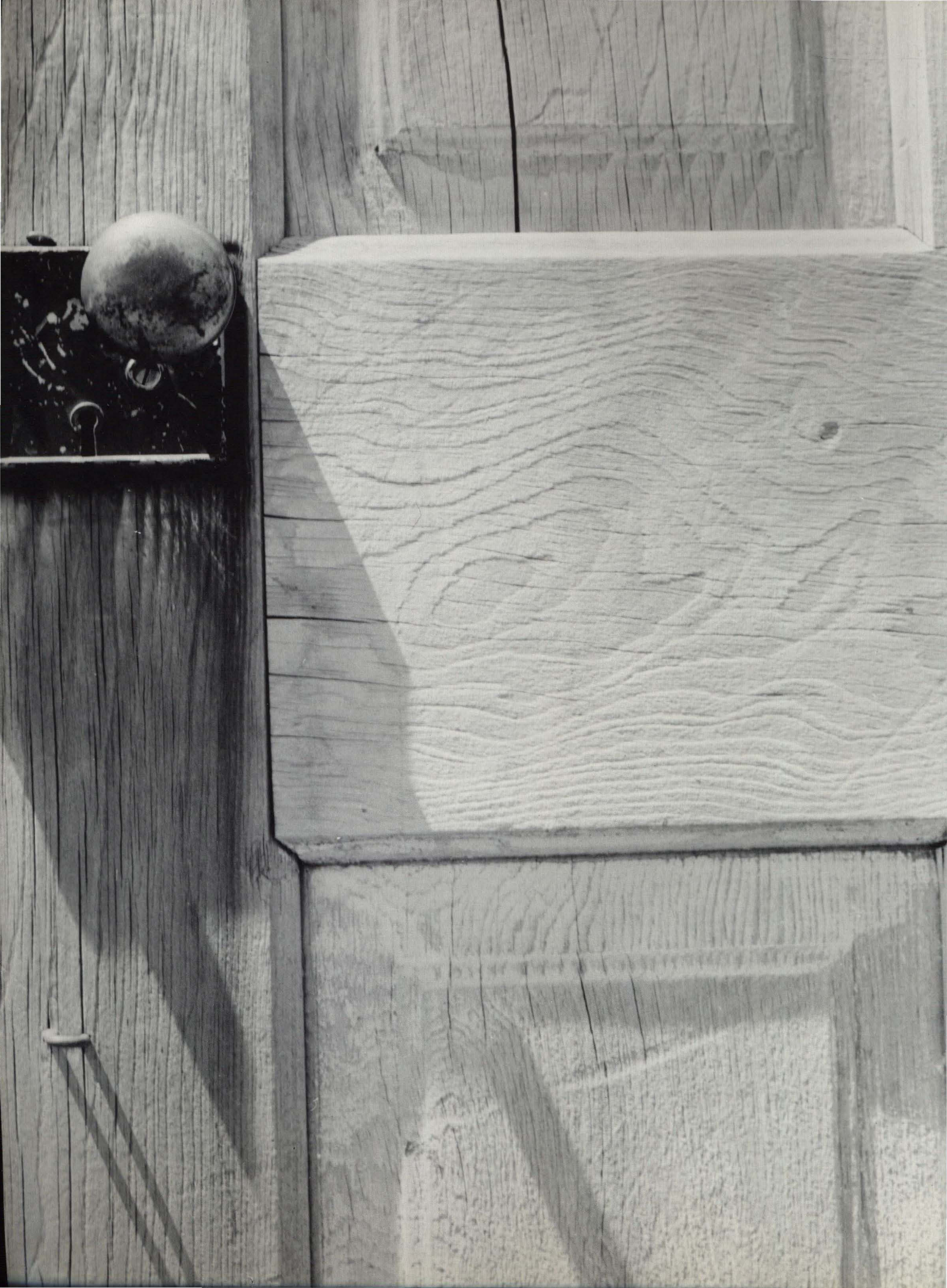

FERMILAB 1988



Fermilab 1988

Last Annual Run with This Director

Thursday, June 1, 1989, 7:00 a.m.

Meeting at A0
Opposite Wilson Hall

Anyone who finishes is invited
to a free breakfast in the Cafeteria

Fermilab 1988

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

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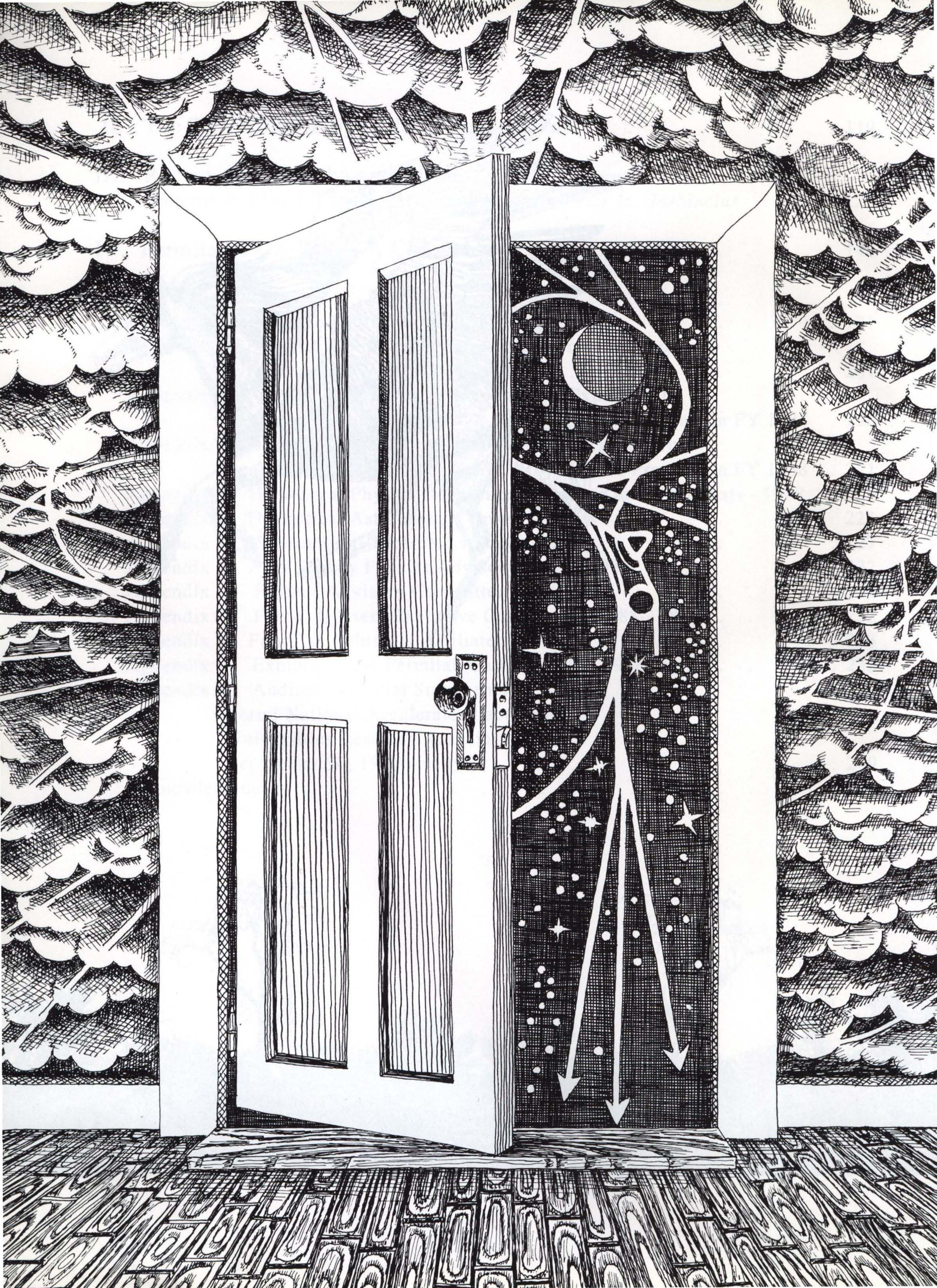


I. The State of the Laboratory

Old maps are wondrous things. How often do we peasant appreciators pause at a store window to see these distorted, yet recognizable perceptions of the world, so artfully drawn by cartographers of long ago. And to many of us, the most compelling sections of these maps are labeled "*terra incognita.*" As it was given to the explorers of the planet then, so it is now given to the physicists at Fermilab to step ashore on unknown territories - here, the territory of 1.8 TeV, provided by the TEVATRON Collider.

There is a tendency, especially among "middle-aged" physicists, to remain calm and imperturbable in the Collider Detector at Fermilab (CDF) control room where the collisions of 900-GeV protons and 900-GeV antiprotons are recorded and displayed. It is left for the very young and for the very. . . mature to grow terribly excited, to wonder and point, even to shout and dance as event after event is painted on the display screen. After all, this is *one-point-eight T-E-V*!!, three times higher than anything that went before. . . Yeeoww! Collisions so energetic that equivalent cosmic-ray events fall upon the Earth at the rate of one event per square meter per year. These collisions, we love to tell our lay audiences or our in-laws, existed in this Universe only at a time 10^{-13} sec after creation in the big bang.

What can we expect, as CDF keeps increasing the number of events on tape? The top quark, of course! It is only a question of time (and money and hard work and ingenuity). If we are very skillful and if our luck holds out, CDF should amass an amount of data five times the target goal of 1 pb^{-1} set a year ago. The mass-energy domain probed at the level of ~5 pb^{-1}, or a few times 10^{11} inelastic collisions, takes us well above the W and Z. CDF notes that the dijet mass spectrum contains about 100 events per pb^{-1} at a mass above 300 GeV. Thus, we can expect about 500 to 1000 events which are equivalent to constituent collisions above 300 GeV. If you have a favorite theory containing favorite particles, Estia Eichten and his friends in the Fermilab Theory group will tell you how many events will contain these particles at 5 pb^{-1}.

All of this is to introduce this annual report with an exultation about how well the Laboratory and its machines are performing. One year ago we planned to allocate 11 months to the second Collider run in order to insure that CDF would collect 1 pb^{-1}. In late January, we delivered 1 pb^{-1} in two (highly selected) of our best weeks! Somewhere else in this report, the details of these successes are given. This is, after all, an overview.

What! Another annual report? How could the year have passed so quickly? There we were in January of 1988, overjoyed with a very successful fixed-target run and debating whether we should yield to the various agonizing pleas for extension. The run at 800 GeV was servicing the

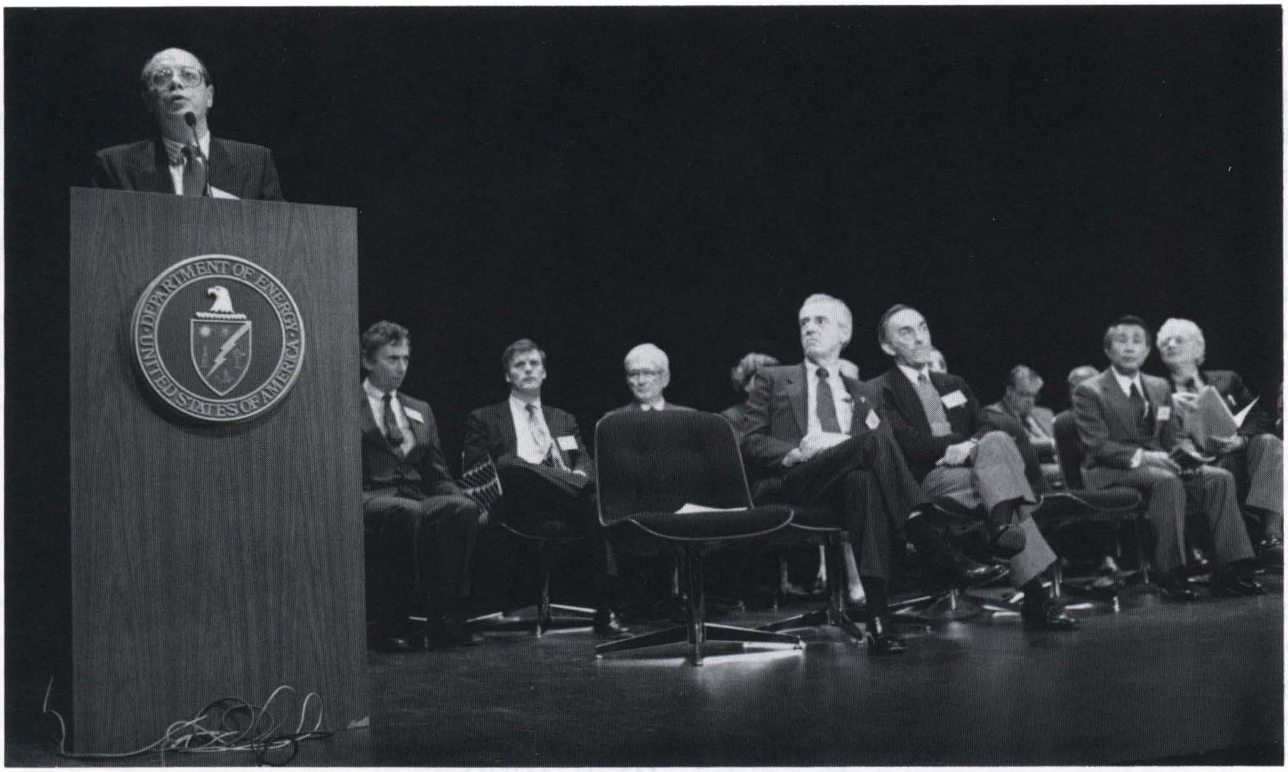
← Change *is the handmaiden Nature requires to do her miracles with. The land that has four well-defined seasons cannot lack beauty, or pall with monotony. Each season brings a world of enjoyment and interest in the watching of its unfolding, its gradual, harmonious development, its culminating graces. - Mark Twain,* Roughing It, *Chapter XV.*

John Elias (CDF) at one of the CDF Control Room consoles, where events are displayed with kaleidoscopic grandeur on the monitors as they occur at the heart of the detector.

largest number (15) of experiments yet, test beams were in full swing, a fire in E-687 was still an active memory when the experiment went back on the air, taking good data. Ultimately we terminated the longest-yet fixed-target TEVATRON run in mid-February and someone took the now-famous photograph of some fraction of the 35,000 magnetic tapes piled high on the floor of the Computing Center. The Lab then went into a studies mode which included accelerator experiments aimed at assisting the design of the Superconducting Super Collider (SSC) (and a better understanding of the TEVATRON), and inspection of TEVATRON magnets in order to understand the problem of failures of superconducting SAVER magnets under fixed-target ramping stress. In June of 1988, we began bringing up the second Collider run with a schedule of a very long 11 months.

In 1988, the machines were on for nine months of the calendar year. This was divided into 1.5 months of fixed-target physics, 6.5 months of Collider physics, and 1.0 month of studies and SSC research. The three months of off-time were devoted to maintenance, repairs, saving power money, and diagnosis of superconducting-magnet problems, and to changeover from fixed-target to Collider operation.

Data analysis of past experiments takes time - the platitude of the decade. Nevertheless, a surprising amount of data was presented at meetings over the past year and some of these have even managed to creep into that infinite source of oobleck [see Dr. Seuss, *Bartholomew and the Oobleck*, 1949, Random House] called *Physical Review* (or *Physical Review Letters*). These are re-



Robert O. Hunter, Jr., Director of the U.S. DOE's Office of Energy Research, speaking at the formal ceremony marking Fermilab's twentieth anniversary (December 2, 1988).

viewed by Alvin Tollestrup (our Wilson Prize Fellow) and by Peter Garbincius.

We had a fair year of honors. Having mentioned the Wilson Prize (American Physical Society), we also collected a MacArthur Fellowship Award and an election to the National Academy of Engineering for Helen Edwards, and one of those Nobel things, a sort of SSC consolation prize, people snickered, for Lederman.

Last year we celebrated the twentieth year of the Laboratory. We had then set December 2, 1988, as the date to commemorate the move to the Lab from Oak Brook on December 3, 1968. This would be a traditional Fermilab celebration: dignitaries, speeches (of course!), an opportunity to bring in famous and interesting people, to make new friends and to show off this splendid place with its awesome accomplishments. Then, when the dignitaries had departed in their limos and helicopters, the real Lab-wide party would begin. It all took place - almost as planned. Almost, it was canceled, almost. This is because on November 6, the U.S. Department of Energy (DOE) announced that it had chosen Texas as the best possible place to build the SSC. Reading this from the AP wire was a shock which, at this writing, has still not worn off, much as we know we must accept the decision and get on with the science for which this Laboratory exists. Perhaps the deepest angst in accepting this decision is the realization that not everyone (and clearly not the bureaucrats who made the decision), not everyone really understands the uniqueness of Fermilab as an institution of unmatched technical success, of rare architectural splendor, a Laboratory that succeeds in its mission of providing the "best possible facilities for the doing of particle physics" in an intellectual environment that shares science with art, architecture, music, ecology, and education of the young. There was no model for Fermilab. We hope that we have provided a new model for what a university-managed national laboratory can be.

Since this is the last overview from this administration, it isn't a bad idea (and who is to stop it?) to review the achievements of the past decade. I have nine bullets and a very brief paragraph on each one. To introduce this paean of self-praise (how like the recently departed President Reagan with whom I now identify completely!), I note that I arrived at the Lab in September of 1978 as Director Designate. I found good and bad news. The group that Bob Wilson had assembled was really magnificent! We did have the most crucial asset: human resources. The vision of a superconducting accelerator (Energy Saver, Energy Doubler) was very clear. The tradition of architecture and ecology were firmly established, as was the style which somehow strove to preserve individuality within the need for impressive collaborations. The bad news was that in the transition, the focus had been lost, the Lab was impoverished, and the physics program was hostage to an under-funded SAVER project; a project whose physics goals were ill-defined.

The achievements, scientific and otherwise, are now described:

Fermilab 1978-1989

I. Major Construction Projects

A. Energy Saver

The world's first superconducting accelerator emerged from a long period of R&D starting at Fermilab in 1973. By 1978, understanding of magnets was mature but not yet to the point where mass production would begin. The concept of an "R&D machine" was evolving and late in 1978, it became the basis for the future of the Laboratory via the TEVATRON program. The funding history had put an increasingly significant burden on the operating budget through the years 1979-1982. The SAVER project began officially in July of 1979 and accelerated its first beam in July of 1983. The total cost of the SAVER, including its extensive R&D, was $120 million. Project leaders were Rich Orr and Helen Edwards, with enormous leadership assists from Richard Lundy and Alvin Tollestrup.

B. TeV I

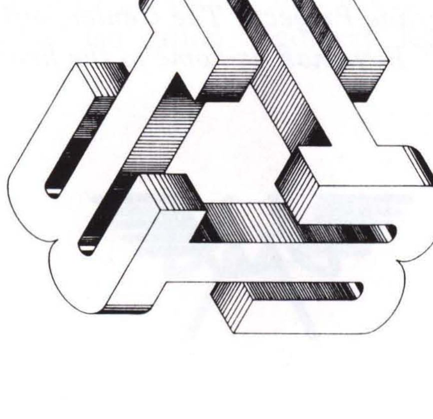
This would convert the SAVER into a storage ring for protons and antiprotons which would be arranged to collide head-on in two places at a total energy of up to 2 TeV with a design luminosity of 10^{30} cm^{-2} sec^{-1}. It involved construction of an Antiproton Source system, based upon several years of R&D, and a dramatic change from pre-1982 ideas. Construction started in 1982 and the first engineering test was September 1985. The total cost of TeV I with its R&D was $130 million. The second full-scale run in 1988 exceeded the design luminosity and reached 2.07 x 10^{30} cm^{-2} sec^{-1} at 1.8 TeV. Project managers were John Peoples and Don Young, assisted by Gerry Dugan and a demon crew of younger recruits to the accelerator business.

C. TeV II

This was a package of improvements which were designed to supercharge all the beamlines that carried beam to experimental areas. These were upgraded to 1000 GeV and in four cases, completely new beams were constructed. The time frame was 1982-1985. Cost: $70 million. The TEVATRON Fixed-Target Program has run in 1984, 1985, and 1987 with increasing numbers of beamlines and experiments. In 1987, fixed-target data filled 35,000 high-density magnetic tapes. The project leader was Tom Kirk, embedded in a supportive Research Division under a series of Heads: John Peoples, Peter Koehler, and Ken Stanfield.

D. The TEVATRON Fixed-Target Program

Starting in 1980, new approvals were largely confined to "TEVATRON-era" experiments based upon 800-GeV protons. Seven major spectrometers were constructed and many other experiments upgraded. Over the period 1980-1987, about $80 million went into this program. See Section E. The leaders here were Koehler and Stanfield assisted by Ray Stefanski, Peter Garbincius, Roger Dixon, and a cast of not-enough physicists.



Aerial view of the new 74,000-sq-ft Feynman Computing Center, end result of the 4-year Fermilab Central Computing Upgrade Project. The Center, officially dedicated on December 2, 1988, in honor of Richard P. Feynman, is home to the heart of the Lab's computing.

E. Collider Detector at Fermilab

In 1981, an earlier decision to have Fermilab manage the major detector to observe $\bar{p}p$ collisions was formalized and construction began. A CDF Department was created and Co-Spokespersons appointed, one from Fermilab and one from the university collaboration. This $70-million detector, a collaboration of 10 U.S. universities and three national labs, and institutions in Japan and Italy, was completed in time for its first scientific run in December of 1986. The 1987 run will result in some 20 Ph.D. theses. In July of 1988, CDF began a new run which was designed to deliver about 50 times the amount of data collected in 1987. The "discovery run" is scheduled to be completed on May 31, 1989. The directors here were Alvin Tollestrup and Roy Schwitters, with a strong assist from Dennis Theriot and Bob Kephart. Here again, the support of the Research Division heads, most prominently Ken Stanfield, was essential.

F. DØ

This detector was designed to occupy a region of the Accelerator normally devoted to extracting the beam for fixed-target physics. Proposals for the DØ detector initially called for small, superclever experiments which could change after each run. Proposals were all deemed unsatisfactory and the unusual step was taken to appoint a spokesperson who was charged with assembling a group to design and construct a detector along a set of criteria selected by the Fermilab Physics Advisory Committee. Construction began in 1984 with an extensive collaboration similar to CDF. The design profited from actual CERN collider experience. DØwill be ready for physics in late 1990. The responsibles are Paul Grannis, Gene Fisk, and Roger Dixon.

G. Computing

In 1983, the Ballam Committee was empaneled to advise the Laboratory on its computing needs. The vastly enhanced demands of the TEVATRON program implied a dramatic increase in computing power. This was designed in three stages: a powerful VAX Cluster "front-end," a mainframe "number-cruncher," and a farm of parallel microprocessors. The program also called for a new Computing Center, which became operative in September 1988, and has been dedicated as the Feynman Computing Center in memory of Richard P. Feynman. The net effect is that we have been catapulted from a backwater computing entity into one of the best there is, but we are still short of the needs! Heroes here are Hugh Montgomery, Jeff Appel, and Jack Pfister.

H. The Advanced Computer Program

A small group of physicists, now known collectively as the Advanced Computer Program (ACP), was funded to create a system of multiprocessors which would concentrate on event reconstruction. The parallel microprocessor design began in 1983 and toward the end of 1985, a cluster of 100 nodes of ACP was applied to analyze data from a fixed-target experiment. The parallel handling of event reconstruction enabled users to apply the computing equivalent of almost one VAX 780 per node. This system is now used by 20 institutions; a second-generation system 20 times faster is in process. ACP is the basis of an unusual collaboration with Fermilab theorists who want to calculate HEP parameters numerically "on-the-lattice." ACPMAPS (the ACP Multi-Array Processor System), as the joint effort is known, has had a successful test run with 16 nodes and awaits money. Credit goes to Tom Nash.

I. The Upgrade

Various options for advancing the TEVATRON facility had been considered as early as 1980. Experience with the Collider, the status of physics, the onset of SSC, and the evolution of the Fixed-Target Program are all ingredients in decision making. In 1988, extensive interactions with users and the wider community led to a specific formulation of a set of phased upgrades which, if funded and implemented, will insure that the TEVATRON facilities will be world class through the end of the 1990s and beyond the SSC. The Accelerator Division is credited here. Helen and Don Edwards, Mike Harrison, Steve Holmes, and many others led the way.

II. Intellectual Environment

A. Astrophysics Group

Particle physics in the past decade has increasingly found common ground with early-Universe cosmology. The science connections provide a two-way flow of information. Fermilab innovated the creation of an Astrogroup in the environment of experimental HEP. This connection was assisted by a three-year NASA innovative program grant. The group of two senior physicists, three five-year-term appointments, and several post-doctoral appointments, has achieved an international reputation for excellence. Credit two shy astronomers: Rocky Kolb and Michael Turner, with an assist from David Schramm.

B. Bj

A vital task is to bring the best talent to the Laboratory. By far the most spectacular feat along these lines has been the recruiting of James D. Bjorken (Bj) from a westerly coast. Bj arrived at Fermilab in 1979 as one of the U.S.'s most productive theorists. His leadership and advice to the experimental program has been outstanding. Credit Bj.

C. Director's Reviews

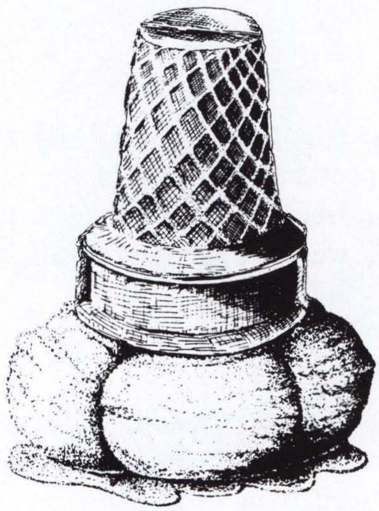
A technique was established to conduct in-depth reviews of the progress in constructing experiments. This was needed in the TEVATRON era since the time between approval and completion averaged three years. The reviews were designed to compare original objectives with a changing physics scene, detect places where additional Laboratory resources may be needed, and to compel the group to a thorough re-examination of its own progress. The Director, Program Planning, and selected experts are invited to listen to the exhaustive presentations, which have often exceeded six hours. Taiji Yamanouchi did all the organizing and found ways to fix many of the problems.

D. Director's Coffee Hour

A means for bringing to one place the physicists and students of the Laboratory (who are too spread-out) in a brief daily respite where coffee and cookies are served, relaxed conversation takes place, ideas and plans are exchanged. A changing population of about 30 to 40 people arrive before, during, and after the cookies vanish.

E. Distinguished Lecture Series

Special efforts are made from time to time to bring to Fermilab the most provocative and distinguished personages in the field of science and its contiguous activities. Names like Rabi, Hawkings, Glashow, Weinberg, Drell, and Fitch were among the lecturers. As a part of this, we held a two-year "Arms Control and International Security Seminar" series with prominent speakers from all points of view: here names like Ackerman, Adams, Bethe, Garwin, Inman, Keyworth, Mark, Panofsky, Perry, Rathjens, Simon, Steinbruner, Teller, von Hippel, Woodruff, and Yonas, were among the speakers. All of this is designed to raise the temperature of the Lab's intellectual atmosphere in the expectation that a stimulated mind is better at solving its problems.



Heavy Flavors - 88

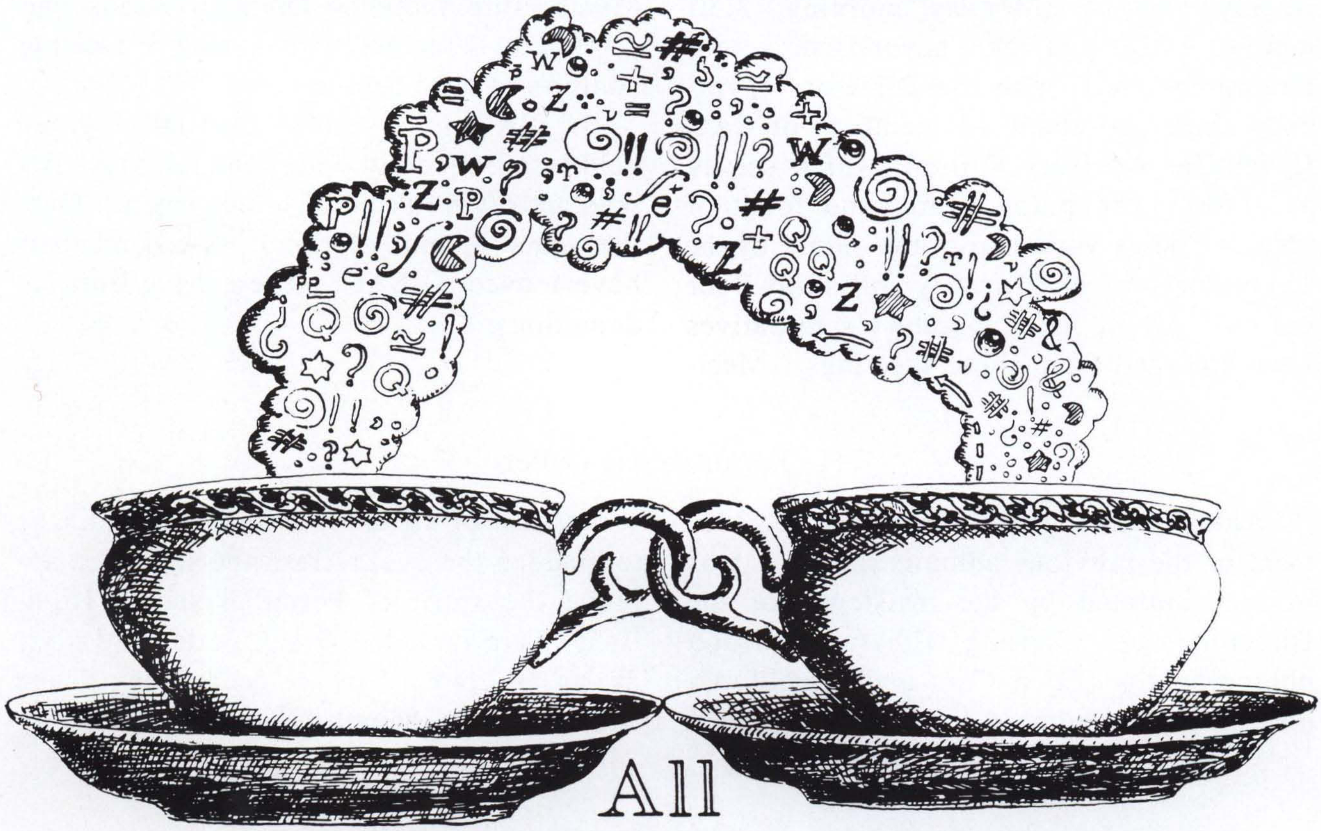
F. History of Particle Physics Symposia

In 1980, Fermilab's resident historian organized the first conference: "The Birth of Particle Physics (1930-1950)." Papers by Dirac, Lamb, Rossi, Anderson, and others recorded the emergence of the modern phase of particle physics out of cosmic rays and quantum electrodynamics. The resultant book was published by Cambridge University Press, received widespread praise, and was reissued in paperback in 1986.

The second conference was held in 1985 ("From Pions to Quarks") and covered the intensive development of the field in the 1950-1965 period. This will yield another book scheduled for early 1989. A third symposium (they get more difficult as they approach the present time) is thought to be appropriate for 1990. It should cover the period from quarks to the Standard Model, i.e., 1965-1984. The trilogy will supply a record of the intellectual and sociological underpinnings of this activity we call High-Energy Physics.

The retrospective sessions are a marvelous contrast to the day-to-day activities of the Laboratory and serve as a reminder of our heritage. Lillian Hoddeson, working with Adrienne Kolb, also looks after the History of Accelerators reading room, data collection, and archives.

DIRECTOR'S COFFEE BREAK



All
Grad Students,
Users and Staff
are Invited to Gather
in the Second Floor Lounge
for a Period of Conversation,
Coffee, Tea and Cookies.
at 3:30 p.m Monday - Thursday
First Day: Monday, March 5

G. SAG and "Jr. SAG"

A communication and management device begun in September of 1978, this is a weekly meeting (Monday morning, 8:30 a.m. to 10:00 a.m. and beyond) of senior Laboratory staff, with the Director. Typically there are about 12 members of SAG (Scientific Advisory Group), which serves as a forum, sounding board, and fount of ideas. Topics varied from the future of the Laboratory to the quality of third-floor coffee. All of the Laboratory's initiatives have emerged from these meetings. Meetings were sometimes stormy and momentous, occasionally just stormy, rarely dull. Membership includes Division Heads and Associate Directors with a slowly rotating addition of wise people.

Jr. SAG is a similar discussion group held less frequently with younger physicists who are often in middle management. Over the years several of the Jr. SAG members have moved to SAG. There have been no demotions.

H. Fermilab Art Gallery

Although this was technically an achievement of the previous administration, it was in fact initiated by the insistence of the Director-to-be. Starting with two Chicago photographers (Ellen Carr and Harold Allen), it has brought a long and delightful succession of art exhibits [see Appendix L] to gladden the eye, refresh the soul, and improve the spirit of Fermilab staff. Highlights have included Greek pottery, Martyl, Wynn Bullock, "Art in Technology," and William Clift. Saundra Poces is art curator.

Greek Vases of the Fifth Century B.C.

Fermilab March and April, 1980

Fermilab's initiatives at Pan American education cooperation (reaching to the shores of Rio de Janiero and beyond) are described in VI.

FermiCenter

III. Education

A. Saturday Morning Physics

In 1979, the Lab wrote to the principals and Science Department heads of about 70 high schools in a 20-mile radius out from the Laboratory, asking them to nominate some 3-5 students, juniors and seniors, to attend a 10-week, 3-hour session at the Lab on Saturday mornings. This session is repeated three times a year, and each session has about 100 students. The lectures are followed by subdividing into four groups, each with an instructor who answers questions and conducts a tour of a Lab activity. The last lecture is "graduation," complete with parents and a ceremonial diploma. By now some 2500 alumni exist. This program and its success stimulated the formation of Friends of Fermilab and a host of educational activities. Drasko Jovanovic is the headmaster here.

B. Friends of Fermilab

Organized and incorporated in 1982 as a not-for-profit fund-raising organization, Friends of Fermilab (FFLA) organized itself with a President, Program Manager, and Board of Trustees. Its mission is science education, making use of the unique human resources of the Laboratory. Its star program is the "Summer Institute For Science Teachers," initiated in 1983. Programs include "Beauty and Charm for Junior High Schools"; "Topics in the Teaching of Modern Physics" for updating standard introductory courses; distribution of *Resources for the Science Classroom* and Saturday Morning Physics videotapes; "Target: Science and Engineering" for gifted minority students; and the teacher-support networks Physics West and Chemistry West, etc. FFLA looks forward to the creation of FermiCenter, a new visitors' and education building into which they can bring their many activities [see H. below]. We must mention Stanka Jovanovic and Marge Bardeen, a team formed in heaven.

C. Illinois Mathematics and Science Academy

In December 1983, the Director, with the help of Friends, initiated a curriculum workshop designed to establish a structure for a public school for gifted children. What emerged was a three-year residence school which would offer to the very best of Illinois students, entering from their freshman year in high school, accelerated and enriched programs in science and mathematics, but also in social studies, language, and the humanities. The Academy opened in 1986 and, in 1988, scored highest among Illinois recipients of National Merit Scholarship awards. Fermilab scientists are continually involved as mentors, lecturers, advisors, and genial uncles and aunts.

D. Ph.D. Program in Accelerator Science

In 1985, the Laboratory wrote to many of its participating university physics departments, noting the severe shortage of people trained in Accelerator Science. The proposal was that each department would endeavor to send one student every three or four years to the Lab, after a successful qualifying examination. The Lab would find a sponsor and Ph.D. problem in experimental or theoretical (or both) accelerator physics. Reports would be sent to a campus contact, noting the progress of the student. The degree would be granted by the sending university after defense of the thesis. This would establish a unique source of trained Ph.D.'s in accelerator science.

At the time of this writing (early 1989), nine students have participated in the program, representing eight universities. Two students have received Ph.D.'s and one student has received a master's degree. Roy Rubinstein is the Registrar of this enterprise.

E. Wilson Fellowships

In an effort to compete with universities for physicists on the assistant-professor level, the Laboratory advertised, in 1980, for applicants to a three-year fellowship named for R. R. Wilson. Two brands were defined: Experimental Particle Physics and Accelerator Physics. Recipients, usually two to four years beyond the Ph.D., received a special salary and the freedom to select whatever scientific activity they wanted with no obligations. By 1988, some 18 Wilson Fellows had profited from this award. First Tom Nash, and lately Rolland Johnson, head this program.

F. Video News of the Week

To improve communications within the Laboratory documenting Lab activities, a video group was created. A video news of the week containing three to five items of general interest to Laboratory staff is shown in the Atrium. Visiting lecturers are interviewed, exciting milestones recorded, safety and educational tapes shown. A growing archival library of Laboratory events is frequently called upon by media interested in Fermilab or in high-energy physics. Fred Ullrich's initiatives have been crucial here.

G. URA Minority Fellowships

At the urging of the Laboratory, Universities Research Association (URA) established graduate fellowships for outstanding minority candidates. The source of students is the Lab's summer program for minority students that was started in the early Seventies and which now has about 400 alumni. Frank Cole was a moving force.

H. Visitors' and Education Center (FermiCenter)

It has been a long-standing ambition to concentrate the Lab's educational activities into a dedicated area. The possibility of combining this with a visitors' center and hands-on museum has made this a very attractive proposition. The U.S. DOE (education desk) has pledged $300,000 to initiate the first phase of a three-phase Center that would provide about 15,000 square feet of classroom, exhibit, office, and lecture-hall space. It is expected that construction will start in the fall of 1989.

IV. Fermilab Industrial Affiliates

The Fermilab Industrial Affiliates was formed in 1980 as a mechanism for what is now called "technology transfer." Some 40 corporations, ranging from AT&T, Westinghouse, and GE to small start-up companies, pay a $1000-per-year membership fee. The more specific goals are to improve communications between the academic research at Fermilab and industrial research. The annual meetings in May are well attended and documented with a monograph which features the themes of the meetings, e.g., "Industrial Participation in Large Science Projects," "Supercomputer Developments in the Universities," or "Applications of Particle Physics: Out on the Limb of Speculation." Dick Carrigan and Richard Lundy are the keys here.

V. Annual Reports

Starting with the 1979 year, the Laboratory began to issue an annual report which documented the work of Fermilab via a series of informed reports, Director's overview, etc., and replete with photographs and art work. The accumulation of such reports is another record of the history of the Laboratory. First Rene Donaldson, then Richard Fenner did this, as well as many of Fermilab's publications. Angela Gonzales is the key to the elegance of this annual report and the rest of Fermilab's spectacular publications.

VI. Pan American Activities

Many of our near neighbors in Latin America have scientific traditions that go back as far as those of this nation. Political instability, among other factors, has inhibited the evolution of this scientific talent even though the same European scientific traditions have sparked both North, Central, and South America. Starting in 1981, and following visits to Colombia and Mexico, the Director began to study an exchange program and the possibility of establishing at Fermilab a Pan American center somewhat like the Trieste Center for Theorists from developing countries, but here concentrating on experimental science. The Director became a co-chairman of the Board for the International Center for Physics in Bogota, Colombia, and organized the first Pan American Symposium on Collaboration in Physics in Cocoyoc, near Mexico City. This was sponsored by Fermilab, the National Science Foundation (NSF), and the

Mexican Physical Society. The third such conference was held in Brazil in 1987 and the fourth is scheduled for Argentina towards the end of 1989.

Some 40 Latin American physicists, engineers, and students are in residence at Fermilab. Several experimental users groups, basing their research at the Lab, have been created. Through a joint grant from the NSF and DOE, made via the American Physical Society, some $400,000 has been expended in small grants to physicists in five of the most developed of Latin American nations. Over 150 boxes of books and journals have also been collected and mailed to small institutions. Roy Rubinstein has held the Pan American desk at Fermilab.

VII. Users Center, Chez Leon, and the Gym

These were created starting in 1978 as social centers for physicists, students, and Village dwellers. The Users Center opens after 5:00 p.m., boasts a bar, meeting rooms, music room, TV room. All kinds of social events occur, including evening physics soirees (''Physics in the Pre-Proposal State''). Chez Leon is a gourmet restaurant open only two days a week, but it has obtained much fame and is used heavily in Laboratory entertaining. The Gym was created by a URA grant of $200,000 and provides exercise rooms, indoor tennis, volley ball, basketball. The flavor of the complex can be gleaned from a visit to the crowded bar on a Friday after the seminar. These activities are self-supporting. Chuck Marofske, John Barry, above all Tita Jensen and those pesky users, were all involved.

VIII. Day Care Center

To our knowledge, this is the first one ever established at a national laboratory. The original proposal was flatly rejected by DOE, but now it has become standard as a way of making life bearable for working mothers and visiting scientists at the Laboratory. The Center serves about 80 children, ages 6 weeks to 6 years, and 13 teachers. It is self supporting; Linda Braddy is Headmistress.

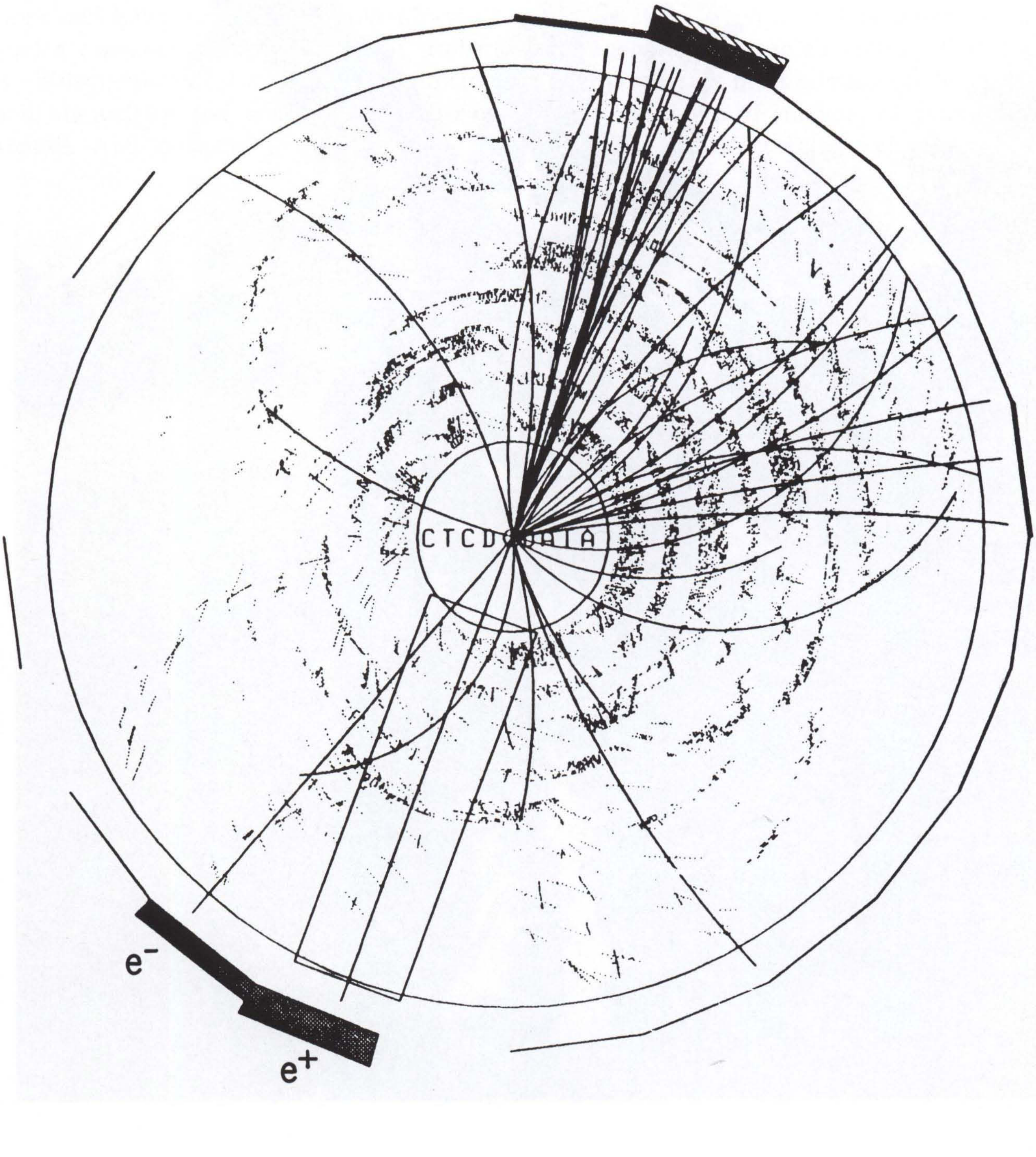
IX. Cancer Treatment and the Loma Linda Proton Therapy Accelerator

The Fermilab Neutron Therapy Facility (NTF) has been operating since 1975. In 1985, the National Cancer Institute, NTF's funding agency, withdrew its support. The Laboratory supported the reorganization into MINT (Midwestern Institute for Neutron Therapy) and began to operate the facility as a self-supporting organization. At that time, the collaborating doctors asked the Lab to investigate supplying protons for a new facility. The cost seemed very high and so the Lab began a series of workshops at which the relevant medical and accelerator experts could communicate. Out of this came the proposal that Fermilab build a proton accelerator (250 MeV) designed to be installed in a hospital (Loma Linda University Medical Center in California).

This variable-energy synchrocyclotron (70-250 MeV) is scheduled to be shipped to

Loma Linda from Fermilab in the summer of 1989 following fairly extensive testing at Fermilab. At the hospital, it will supply five treatment rooms with precisely delivered proton beams designed to handle 1000 patients a year. Deep-seated tumors, brain malformations, and eye diseases are some of the special areas where proton irradiation is thought to be beneficial.

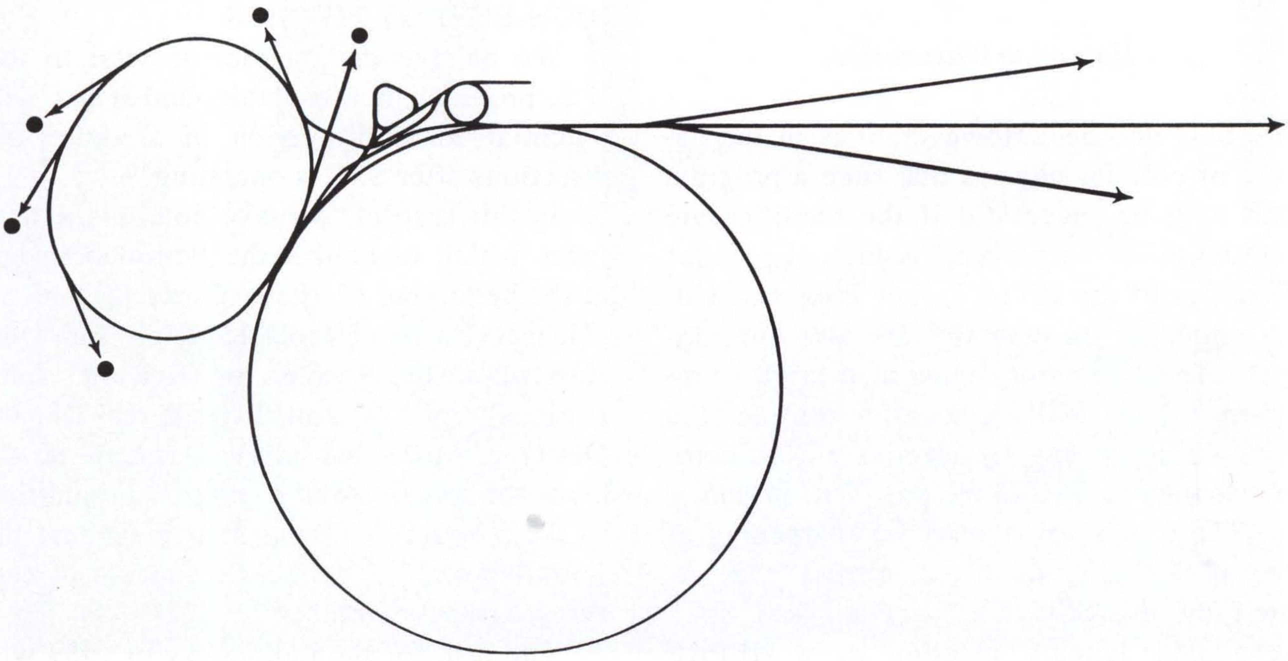
Wilson started it all, but the Loma Linda machine was organized and interfaced to Loma Linda by Phil Livdahl, and commissioning is being overseen by Rich Orr and Jack McCarthy. Our NTF is managed by Arlene Lennox.



Comments

These were years of the evolution of an institution, its facility, and its people. So many were important and not yet mentioned: Bruce Chrisman, assisted by Jim Finks, who kept the administrative wheels turning, Andrew Mravca of the Batavia Area Office of the DOE. The DOE! It is difficult to imagine how any of the above list could have happened without Mravca's guidance and constructive harassment. Robert R. Wilson looked after all the architecture and his artistry and wisdom were also essential. And so on and so on.

Now as to the future, the Laboratory has been refining an upgrade program for many years, one which would be required even if SSC had come to Fermilab. Here, we have the highest energy in the world, achieved at a considerable investment of effort and treasure. It seems natural to exploit this advantage at least until the SSC begins to do physics. Such a goal is congruent with the generally accepted notion that high-energy physics must continue to be exciting and productive of science, of young investigators, and of detector technology in the



← *". . .your war is finished and your conquest achieved. . .wherefore we beseech you to return homeward. . .for your journey is finished with honour. . ."*

Hats off to Waxahachie.

pre-SSC decade. However, it is in the nature of collider physics that such a program can only be successful if the facilities are continuously improved, ergo: Upgrade! Benefits to the Fixed-Target Program with *its* emphasis on diversity are also substantial. The Laboratory must also craft a program which will gradually replace the high-energy focus by physics riches complementary to SSC in the post-SSC period.

The year also witnessed a sharpening of Fermilab's upgrade plans, greatly accelerated by the SSC site decision and by a scheduled January meeting of a HEPAP Subpanel on the "next ten years." This is described by Michael Harrison in what follows. We believe it to be a responsible plan for insuring vigorous exploitation of the world's highest energy accelerator with a reasonable balance between fixed-target programmatic research and the push on the higher energies. We told two CDF stories in the preamble to the upgrade. (1) With 1 pb^{-1} already quickly scanned, it is fairly plausible that any discovery-level new physics that CDF may achieve will be at the level of one or ten or a few tens of events, at most. Thus, it is already clear that luminosity in excess of $\sim 100\ pb^{-1}$ is essential to address the physics of the discovery. (2) As mentioned above, ~100 events with dijet mass greater than 300 GeV implies tens of thousands of events beyond LEP II and HERA. The point is that at present luminosities, $\leq 2 \times 10^{30}$, CDF is working, events are clean, and the upgrade will do really HIGH-ENERGY PHYSICS.

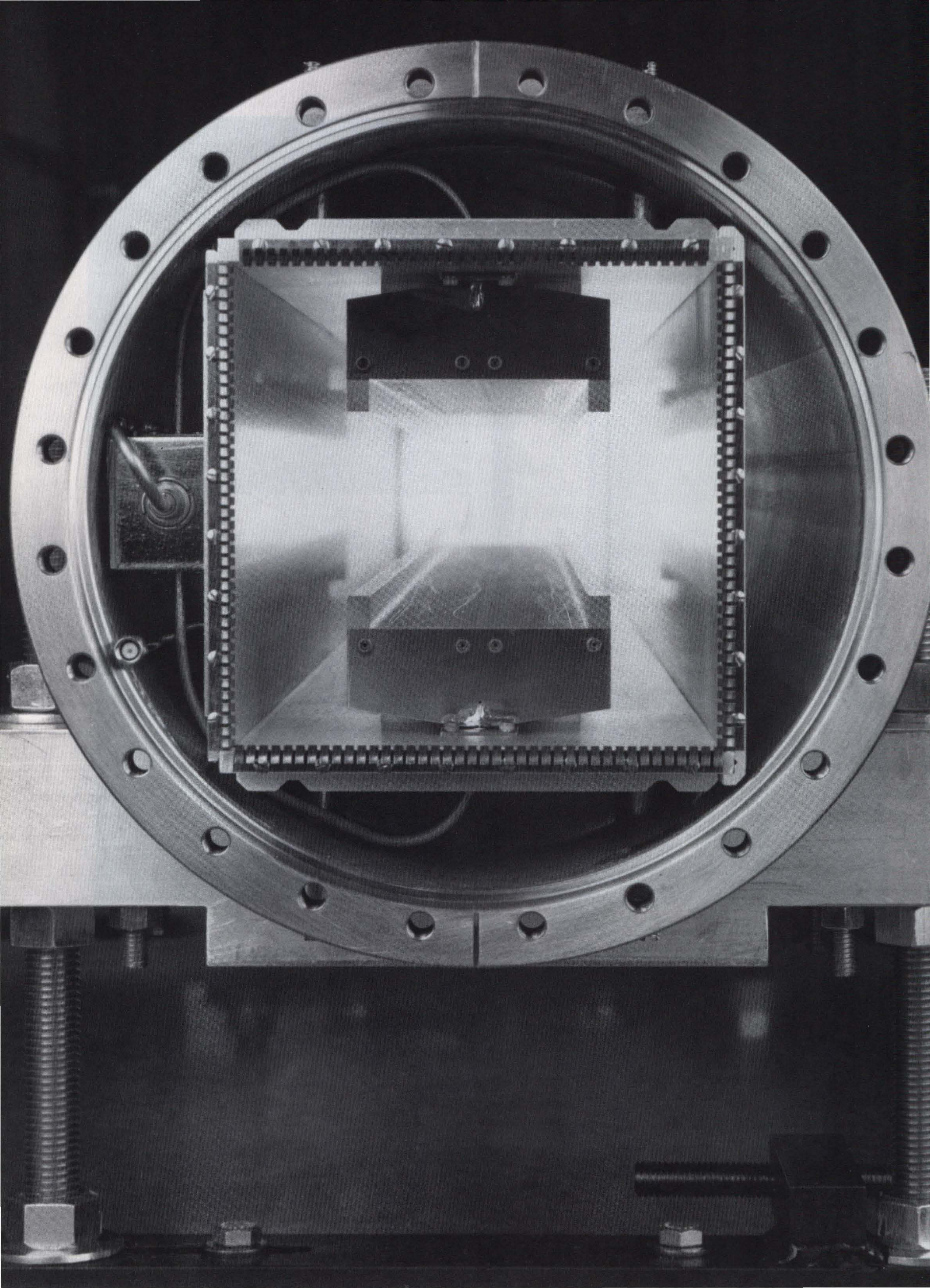
We believe the upgrade is vital to the U.S. program, is affordable, and it has rich potential for continuation in a variety of directions after SSC is operating.

In this respect, we take note of the new faces which embellish the Fermilab image at the beginning of 1989. Gerry Dugan and Michael Harrison replace Helen and Don Edwards in the Accelerator Division. John Peoples replaces Phil Livdahl as Deputy Director. More and more Fermilab physicists are actually doing physics in addition to their normal chores. It is clear that the Fermilab staff is eminently capable of carrying out the upgrade.

The task for the Laboratory in 1989 will be to do its physics, to collaborate with and support the SSC, to forgive and try to love the DOE, and to campaign vigorously for its obligation to exploit the TEVATRON via the upgrade.

Leon Lederman


BEWARE!



The Accelerator Division

John L. Crawford and David Finley

The year began with the Accelerator in the final phase of a fixed-target run which had commenced on June 15, 1987; before the run ended on February 15, the seventh and last TEVATRON dipole failure occurred on February 4. Despite the unfortunate spate of magnet failures, the run exceeded all expectations, with some 2.2 x 10^{18} protons delivered in nearly 2900 hours of operation. The peak extracted intensity for the run was 1.80 x 10^{13} ppp, not quite up to the 2.0 x 10^{13} we had hoped for, but the TEVATRON ran for extended periods at greater than 1.6 x 10^{13} ppp with excellent stability and reliability. Figures 1 and 2 summarize the 35-week fixed-target run.

Near the end of the fixed-target run, the Switchyard Beam Position Monitor system and associated application software was used as a position servo to maintain beam position through the Meson beamline. Once this system is made fully operational, it promises much-improved position stability throughout the Switchyard.

On the Pbar Source front, an E-760 installation and study period was scheduled during which the gas jet target and detector were installed in the A50 pit; the jet was made operational and the detector saw p-p collisions. Protons were decelerated in the Accumulator from 8900 MeV/c to 3500 MeV/c (through transition) via a γt jump.

Following a two-week period of SSC-related studies, the Accelerator was shut down for three months of maintenance and development work. The Division's primary mission during this period was to inspect and repair as many TEVATRON dipoles as

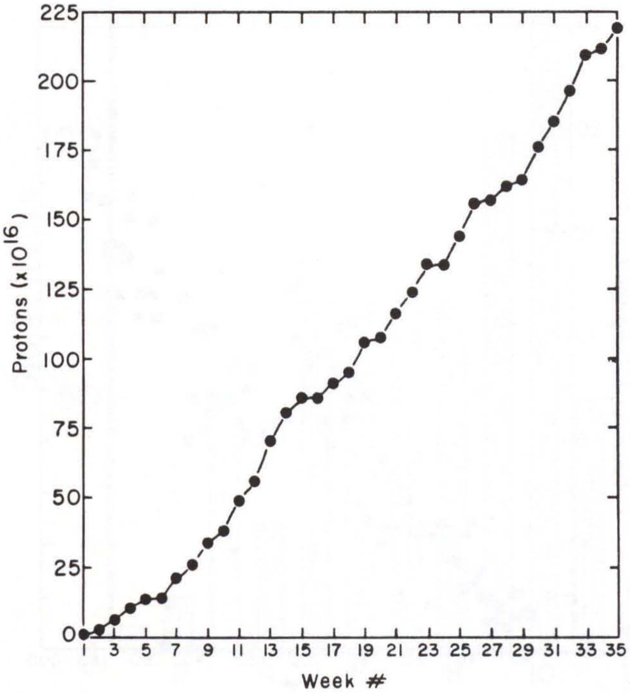


Fig. 1. TEVATRON fixed-target operation, integrated HEP hours at 800 GeV.

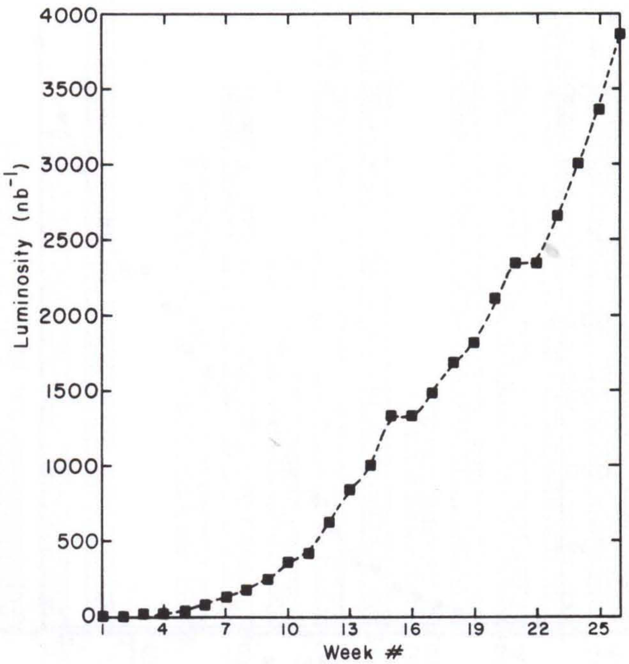


Fig. 2. TEVATRON fixed-target operation, integrated intensity at 800 GeV.

possible; inspection consisted of visually examining the magnet lead areas using a borescope and utilizing two industrial gamma-ray sources to take x-ray pictures of the magnet ends. The magnets were examined to see if the leads were properly tied down (to prevent flexing and strand breakage), if the G10 lead-clamping blocks were intact and were sufficiently far away from the end of the single-phase can, and whether the beam-tube insulation was tied down. All magnets in six houses (A1, A2, A3, A4, B1, and E1), out of 24 houses in the ring, were examined, with 138 out of 200 magnets undergoing some degree of repair. Seven magnets were found to have broken lead strands and so were replaced.

A second major undertaking during these three months was the installation of a redesigned Main Ring overpass in the D0 interaction region. The original D0 overpass was installed in 1984 and was intended to be more of a "proof-of-concept" test bed than a permanent operational feature. A known shortcoming of the original design was an undesirable increase in the vertical dispersion function around the Main Ring and a dispersion mismatch between the Main Ring and the TEVATRON (leading to emittance growth in the TEVATRON). The new design lengthened the overpass by some 700 feet (although the height remained the same) and incorporated a near clone of the B0 "double dogleg" vertical bending system.

A 900-GeV ramp was established on May 26, 150-GeV circulating beam on May 27, and by May 29 the orbit was smoothed all the way to 900 GeV. Antiprotons were injected into the TEVATRON on June 6, and by June 12 we had our first 1.8-TeV 6 x 6 store with an initial luminosity of 4 x 10^{28} cm^{-2} sec^{-1}. (6 x 6 is shorthand for 6 proton bunches colliding with 6 antiproton bunches; all of the 1987 Collider run was 3 x 3.)

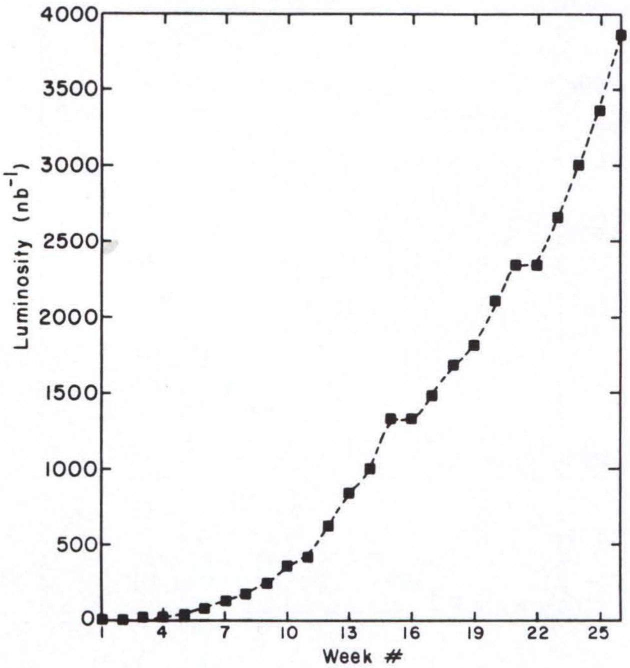


Fig. 3. TEVATRON Collider operation, integrated luminosity at 900 GeV.

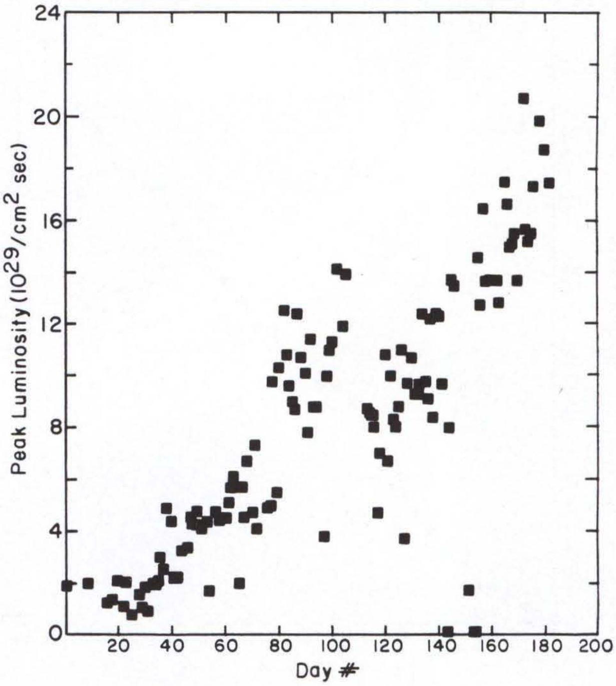


Fig. 4. TEVATRON Collider operation, peak luminosity/day.

Collider operation was sporadic for the first four weeks, but by week six it had surpassed the integrated luminosity of the entire 1987 run. Since then the performance of the TEVATRON Collider has been nothing short of phenomenal - we reached 3 x 10^{29} cm^{-2} sec^{-1} (our "operational goal") on July 28, the design peak luminosity of 1.0 x 10^{30} cm^{-2} sec^{-1} was reached on September 7, an integrated luminosity of 1000 nb^{-1} (1 inverse picobarn) was delivered by September 24, 2000 nb^{-1} by November 5, and 3000 nb^{-1} by December 4. As this report goes to press, the integrated luminosity is nearing 4.0 pb^{-1}, the peak luminosity has exceeded 2.0 x10^{30}, and store duration is averaging 13.8 hours. Figure 3 shows the integrated luminosity through December 18, while Fig. 4 shows the progression of the peak initial luminosity. Figures 5 and 6 detail the weekly performance of the Collider.

Meanwhile, the Pbar Source has not been resting on its laurels; its performance has also astounded accelerator aficionados. The peak stack achieved exceeds 81 x 10^{10} pbars, the number of pbars stacked in one week has reached 175.5 x10^{10}, the stacking rate per hour has been as high as 1.898 x 10^{10}, and as of this writing the Source has operated for 39 days without interruption. (As an aside, on November 9 a glitch on the commercial power grid caused the 81-milliamp pbar stack to be lost - some have suggested that this was the largest number of antiprotons annihilated in one fell swoop since the big bang.)

Why is the Collider performing so well? The present run is delivering integrated

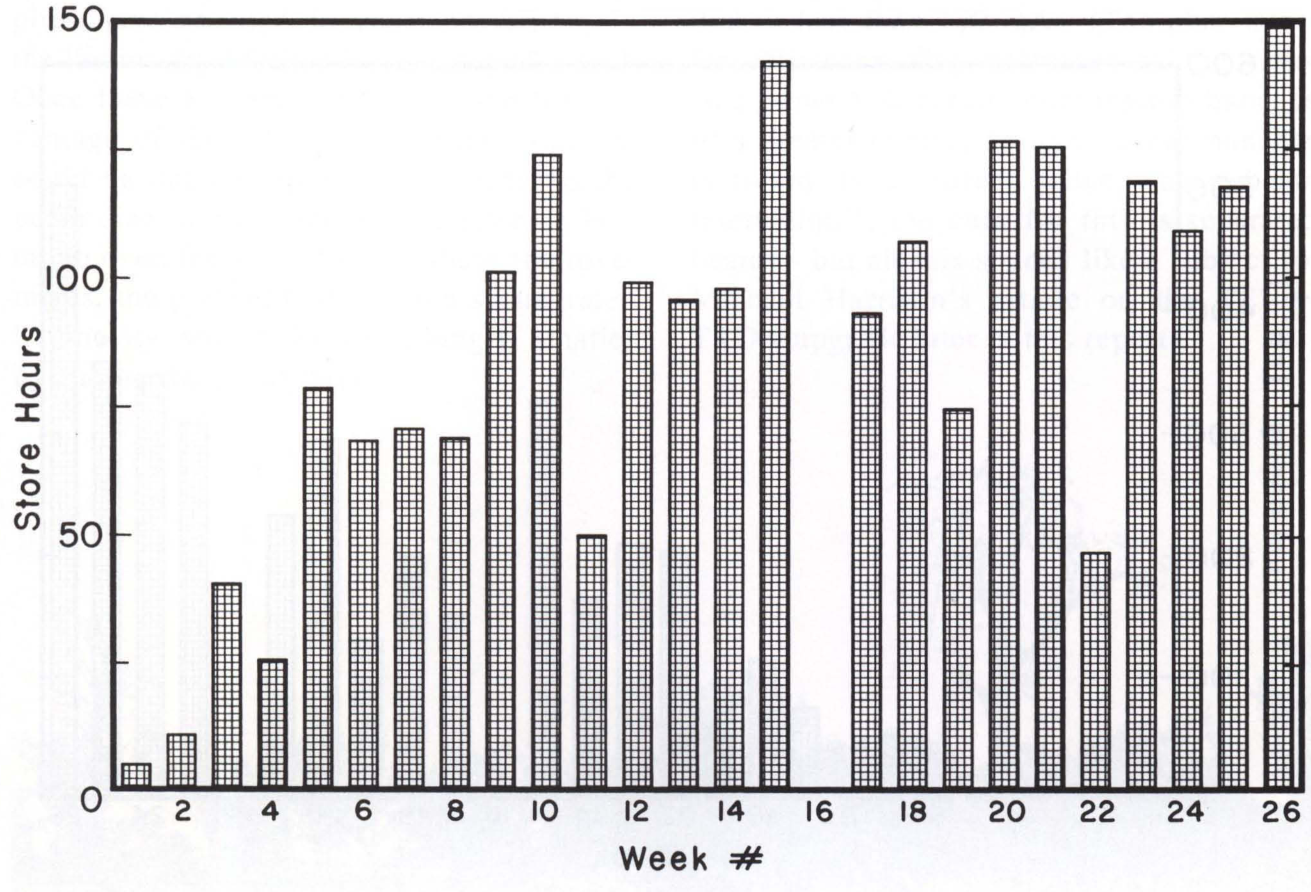


Fig. 5. TEVATRON Collider operation, integrated store hours/week.

luminosity at a rate which is about 20 times greater than that delivered during the first Collider run. This spectacular difference is not (entirely) the result of luck. Indeed, by the time the first run ended in May 1987, the intermeshing of improvements which were needed among all the accelerators had been clearly identified. During the intervening fixed-target run, the process of improvements for the second Collider run had already begun.

There are more antiprotons available this run. Main Ring and Accumulator improvements have resulted in a very much improved stacking rate. For instance, Main Ring intensity has averaged about 1.7 x 10^{12} ppp on stacking cycles, compared to 1.2 x 10^{12} last run; in the Pbar Source, the Accumulator aperture was increased to the design value and the horizontal dispersion in the low-dispersion straights was corrected, core cooling was improved due to the introduction of microwave mode dampers, and Debuncher betatron cooling times were reduced by the addition of optical notch filters. These improvements, coupled with improved TEVATRON reliability, have resulted in larger stacks. The larger stacks have made it profitable to extract bunches six times instead of only three times from the Accumulator. Once the bunches have been extracted, the improved Main Ring transmission and coalescing have resulted in higher intensity single bunches at 150 GeV. These improvements have resulted in an overall gain factor of about seven.

Getting the particles into a single high-intensity bunch in the Main Ring at 150

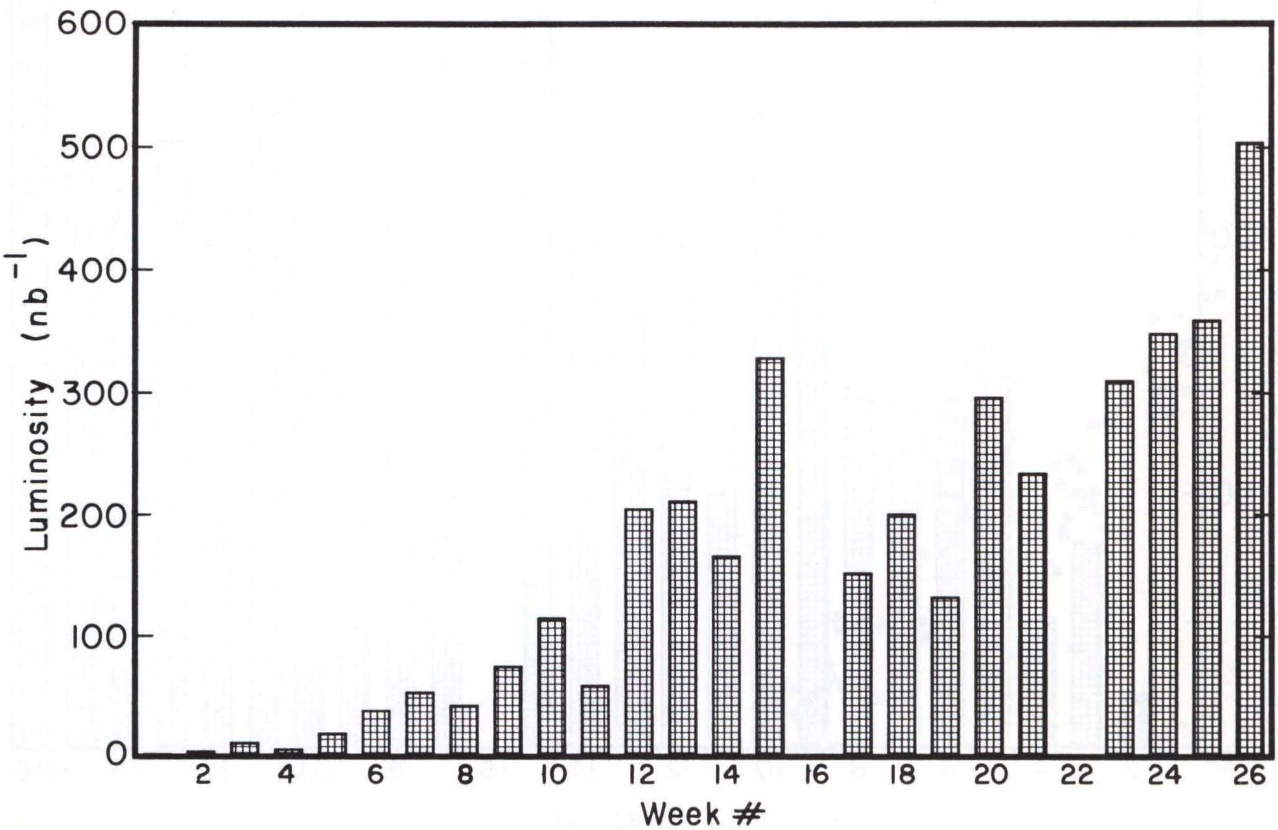
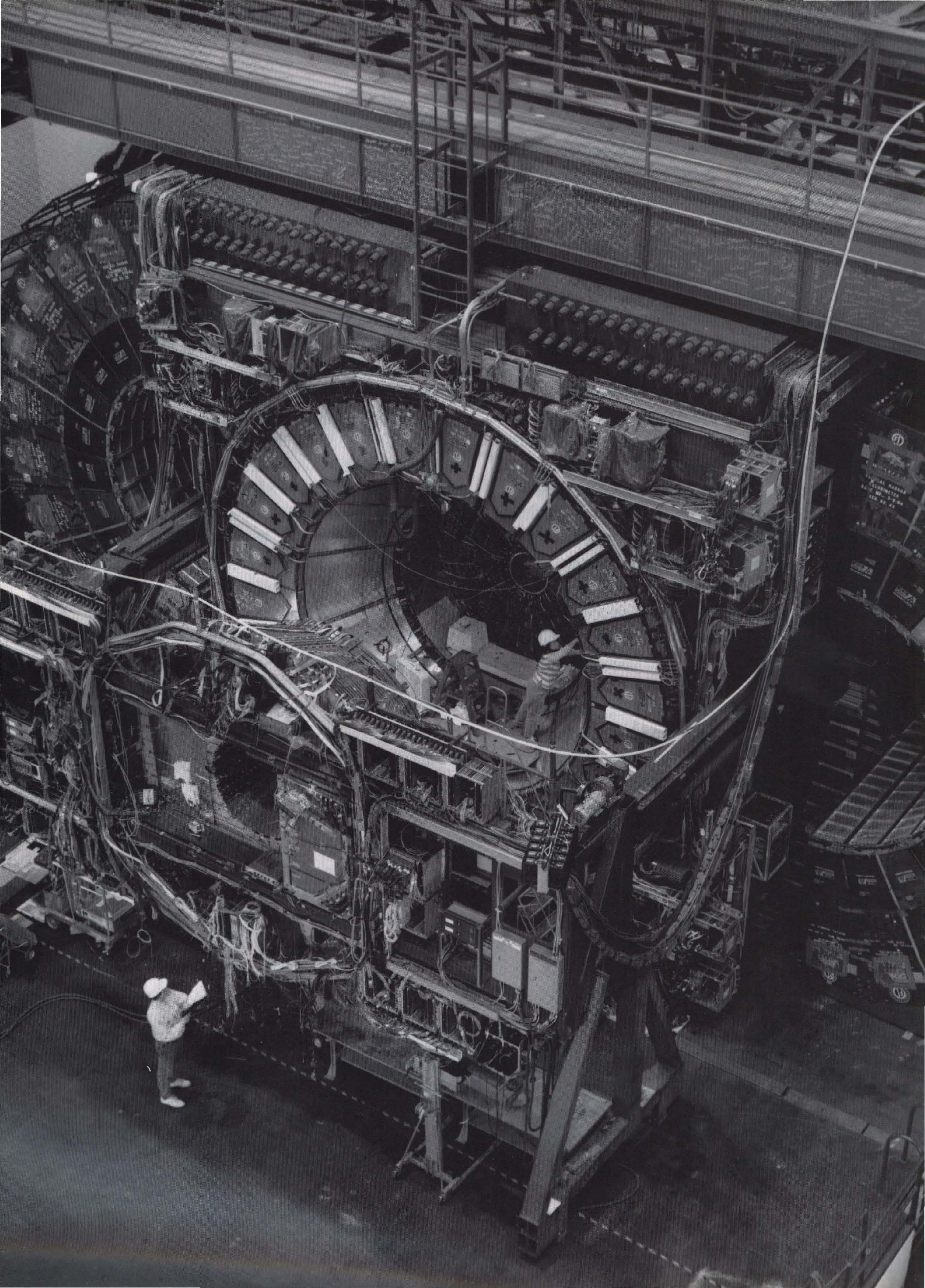


Fig. 6. TEVATRON Collider operation, integrated luminosity/week.

GeV is only part of what is required for large integrated luminosity. In the first run, one of the major problems was not being able to obtain sufficiently small beam sizes in the TEVATRON and, even if they had been small enough, not being able to keep them small during a store. The transverse emittances of the beams in the TEVATRON during the present run are half as large as in the last run. This is because the vertical dispersion match between the Main Ring and the TEVATRON was improved by the reconfiguration of the D0 overpass, and because the compensation of the time-dependent higher order multipole fields in the TEVATRON magnets has been greatly improved. The abort kicker power supplies were identified as the primary source of the anomalous transverse emittance growth during the last run; modifications to these supplies have resulted in an improvement in the luminosity lifetime by a factor of 2 to 3. Once these kickers were fixed, the full advantage of the "100% mini-beta" squeeze could be implemented and this reduced the beam size at the Collider Detector at Fermilab even further. Without these improvements, the present Collider run's integrated luminosity would be disturbingly smaller by another factor of three.

There have also been operational improvements which are necessarily invisible if they are successful. These invisible improvements are nonetheless very important to the integrated luminosity. One of these items is the policy of relentless pursuit of things which kill stores. The improved diagnostics, controls, and applications software needed to accomplish this for each killed store involves the continuing efforts of many individuals. Without question, it is their constant effort which keeps the Collider functioning as well as it does.

Can a similar improvement factor be expected for the next Collider run? The answer is a resounding "no" - not without an upgrade program. Even now, the stacking rate drops steadily as the stack size grows, so that without improvements in the Pbar Source, peak stacks will probably be limited to less than 100 mA. (The pbar transfer efficiency also decreases as the stack size grows.) Creating more intense bunches or a greater number of less intense bunches is foiled by an effect called "beam-beam interaction"; the cure for this is separated beams - but all this sounds like a subject for Michael Harrison's article on the TEVATRON upgrade later in this report.



The Collider Detector at Fermilab

Alvin V. Tollestrup

1988 has been the first year with CDF in full operation. The time has been spent in reducing the data from our first run, preparing the detector for the second run, and finally operating the detector from May through the end of the year during which time more than 1-1/2 inverse picobarns of integrated luminosity was obtained. During the year we have also celebrated our first papers published on the physics runs of 1987, and in addition have watched with pride as more than 20 theses have been started and several finished during the year.

The year started with the installation of 24 inches of additional iron shielding around the Main Ring beam pipe across the top of the CDF collision hall. The ceiling of the hall was not strong enough to support the load of the dirt on the outside plus the additional steel shielding on the inside. However, some clever engineering from Wayne Nestander's Construction Engineering Services Department resulted in an expeditious solution. The dirt on the outside, whose weight was about equal to the weight of the additional iron shielding, was first removed. While the iron shielding was being installed, additional concrete support beams were put in place across the ceiling but outside the hall. The dirt was then replaced, and the whole project was completed in a record time of eight weeks.

The detector was not yet complete at the start of the year. The forward hadron calorimeter modules had only half the chambers in them, and this work was finished. The Roman Pots were installed in order to cover small-angle collisions much better than we had previously planned, and all of the calorimeters were recalibrated in the test beam.

All this work was finished in May, ready for the Collider to come into operation again, and the major work of bringing the new and more sophisticated triggering system into operation was begun. We were very pleasantly surprised by having a luminosity of more than 10 times that achieved during our 1987 run. But this required the trigger system to work with unprecedented rejection power. To see the difficulty, consider that at a luminosity of 10^{30}, there are over 40,000 collisions per second at the interaction point. However, the new and exciting physics is contained in very rare collisions. For instance, $p\bar{p} \rightarrow W \rightarrow e\nu$ production occurs only at the rate of about 1 every 44 million collisions. Since events can only be written to magnetic tape at the rate of about one per second, the job of the trigger system is to sift through this large number of collisions and write the interesting events to tape while making sure that none are lost. And, of course, it is important to keep in mind that the really exciting new physics such as supersymmetric particles or signals of physics beyond the Standard Model, might occur at the rate of only one-in-a-billion collisions.

To help record the rare events, two new trigger systems were brought on line during

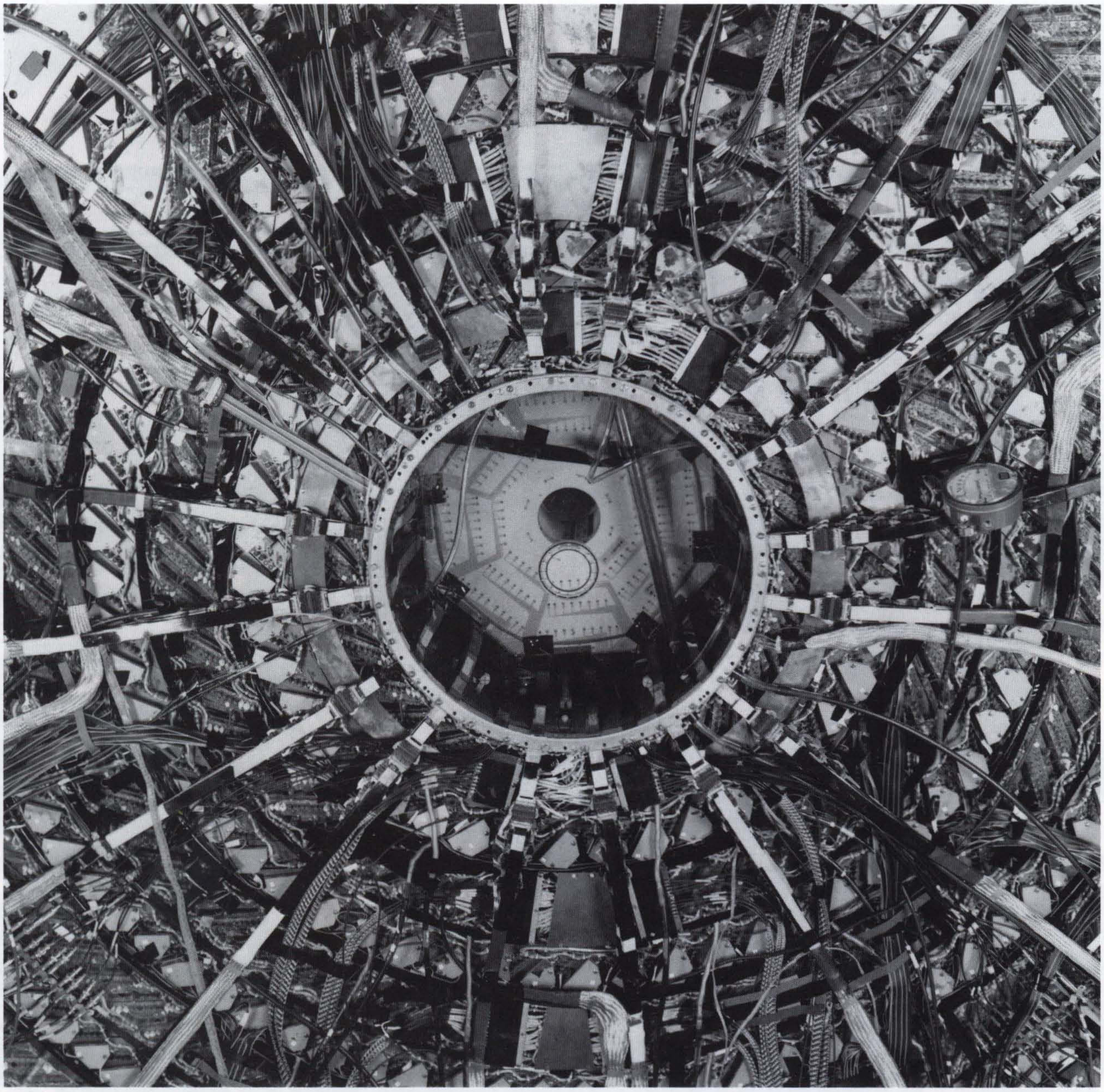
← *The Collider Detector at Fermilab, fully appointed, undergoes a final check.*

the early part of the run. The first was a Level-2 system that was designed and built at the University of Chicago. This is a combination of analog and digital techniques that allow a large number of different triggers to be implemented. Each trigger can be pointed at some interesting type of physics; for instance, high-p_t jets, isolated electrons from W's or Z's, single photons, and so forth. This system was working very well by the beginning of September. At this point a friendly contest between CDF and the Accelerator Division started to take place. The luminosity had been projected to be 3 x 10^{29} during the run, and the Accelerator was already achieving a spectacular luminosity of 10^{30}, which slowly climbed to 2 x 10^{30} by the end of the year. At this rate, even the sophisticated Level-2 trigger system was not able to purify the events enough to keep the rate to tape down to one per second. Fortunately, plans had been made for this eventuality, and the equipment was in place. The technique was to use an Advanced Computer Program system of about 50 parallel processors to completely reconstruct each event as it came out of Level 2. Physics cuts could then be placed on the event stream to even further refine and select the types of events that were written to tape. This was particularly necessary in the case of the top signal where the electron or muon from the top decay might be a relatively low-momentum particle (if the top is light) which could easily be lost in all of the quantum chromodynamics (QCD) processes that take place. Some heroic work by the CDF Level-3 Group had this system working by the end of the year. This is the first time that events including tracking have been completely reconstructed online in a detector of this size. One can stand in front of the online monitor and watch ''quark-quark'' scattering events displayed completely reconstructed with tracks in the tracking chambers and jet-like energy flow ''Lego Plots'' from the calorimeters!

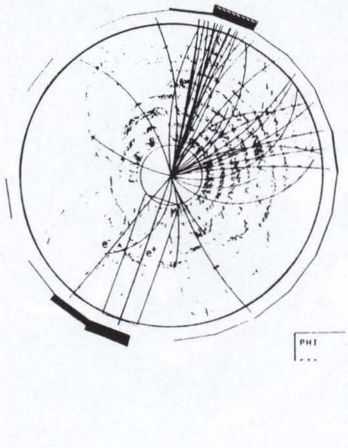
At the end of the year, we had over 1-1/2 inverse picobarns of data on tape. In these events, there are about 1500 W's and 200 Z's observed via their leptonic decay mode, and the top signal is being hotly pursued in competition with CERN to see who can find this elusive particle first.

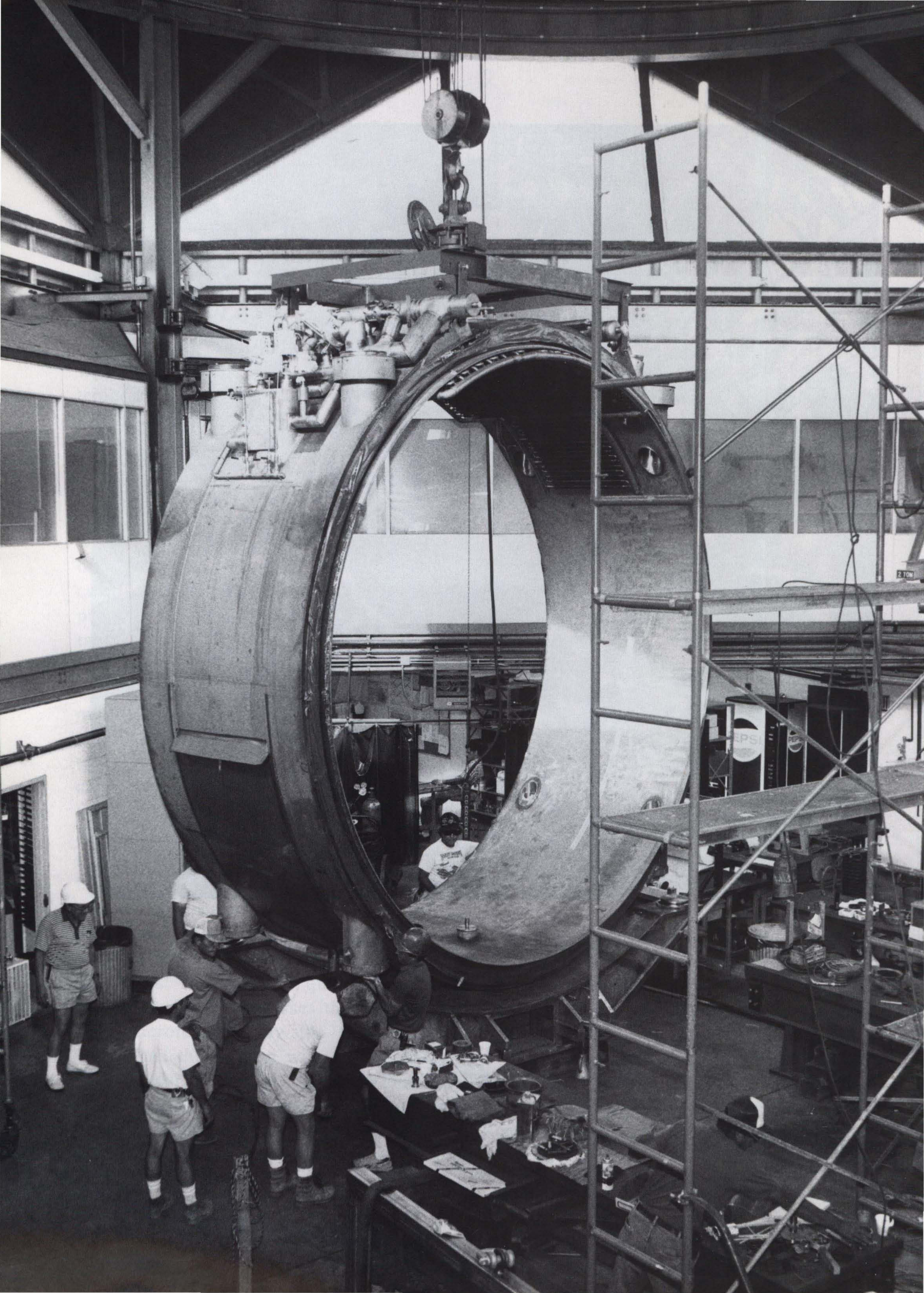
Needless to say, this large amount of data has placed a heavy burden on the Computing Center, and the new facilities that are coming online are welcomed indeed. Again, the ACP will help reduce this enormous amount of data to DST form where it can be analyzed at the universities and other laboratories of the CDF collaboration.

The year has seen the publication of our first paper on Log s physics. In addition, three more papers are ready for submission: one on the inclusive spectrum of high-p_t jets that has set new limits on the compositeness of the quark, one on the production cross section for W's, and one on the limits for production of supersymmetric particles. At the American Physical Society Meeting in Baltimore in April 1988, CDF completely dominated two sessions on collider physics with over 20 presentations. The high energy available at the TEVATRON Collider made it possible to extend our knowledge of high-energy collision processes in a number of directions, even though we only had about 30 inverse nanobarns of data. The fact that we have more than 50 times as much data at present and will have several hundred times as much data by the end of the run has created a real aura of excitement for the coming year.



End view of the CDF tracking chamber.




2 TON

The D0 Experiment

Paul Grannis

As Fermilab passed its two-decade watershed in 1988, the D0 collaboration passed its first half decade. Notable progress was made toward installing D0 as the premier feature in the Laboratory landscape during its third ten years.

The D0 year began with its fifth week-long workshop, held this time in a place even colder than Fermilab in January. We recall it being by a lake in Rip Van Winkle country - and like the venerable gentleman, no one now can quite remember how we got there or back again. One day, during a -15° warm snap, a tractor made a state transformation from the ice surface to the lake floor 60 feet below. The collaboration spent the next morning discussing cryogenic accident prevention while watching the levitation of the tractor. The prevailing spirit of cabin fever greatly helped our discussions of high-luminosity trigger designs, offline event reconstruction algorithms, and installation plans. The failure of telephone links to the outside world even aided the progress of the beam studies concurrently under way at Fermilab. This severed the remote computer login interference by the workshop kibitzers on the progress of the crew at work in the NWA test beam.

As the year progressed, there were many signs of progress throughout the collaboration. Two new groups (University of Michigan and University of Arizona) joined the effort of preparing the detector. The Saclay group finished the construction of the Transition Radiation Detector and took it to a CERN beamline for final tests (it exceeded the design goals for electron/pion discrimination). Calorimeter modules from Brookhaven National Laboratory arrived regularly at Fermilab for tests at the NWA test-beam facility, or for final tests prior to installation. The first of the stainless steel calorimeter module sections arrived from Serpukhov, ready to be mated with the uranium sections under construction at Fermilab. Meanwhile, the large electromagnetic calorimeter disks were started at Lawrence Berkeley Lab. Steady operations in labs 5, 6, and 8 in the Fermilab Village churned out muon chambers at a steady rate; by the fall, two-thirds of the 150 needed chambers were complete and piling up in any part of the Lab left unguarded and unoccupied.

A large part of the collaboration focused upon tests performed in the NWA beam, both before and after the termination of the fixed-target-run cycle. Data collected with beam demonstrated that various calorimeter modules performed very well and that portions of the vertex and forward drift chambers could achieve their design specifications. These beam tests also brought to light some operational difficulties which were subsequently studied and fixes imposed (change of high-voltage polarity for calorimeters and change of gas for the vertex chamber). Of equal value to the specific detector tests was the opportunity to gain experience with various parts of the electronics and software system intended for the final system. We managed to run the

← The cryostat for the D0 experiment's central calorimeter.

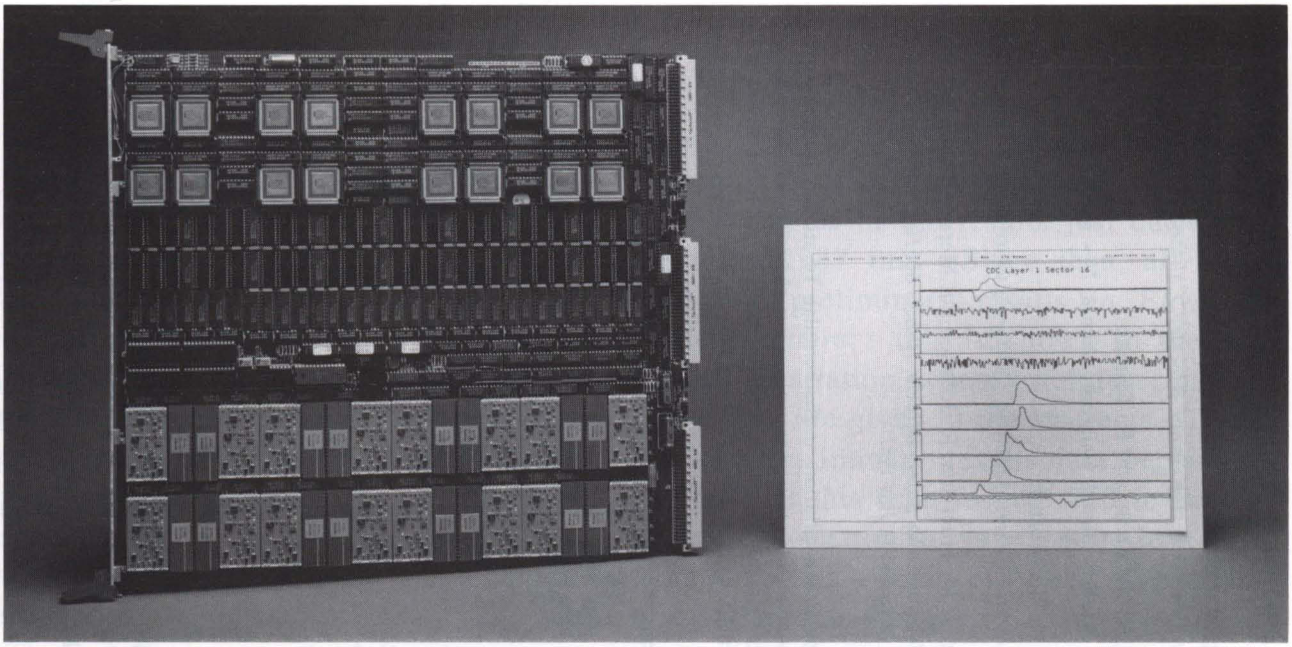
test using DØ electronics and trigger, monitoring systems, multiprocessor data acquisition and filtering system, and we also used the first version of the DØ online software. Most of this worked very well - and learning to use all the pieces together gave us valuable insights for evolutionary improvement as well as operating experience which should aid the commissioning of DØ itself.

Work at the DØ hall has expanded dramatically throughout the year. The large magnetized iron toroids, delayed by difficulties in welding the surplus steel, are expected to be completed and powered before the year's end. Installation of the muon chambers has begun; chamber resolutions measured with cosmic rays *in situ* were better than expected. Cable installation between detector and moving counting house is under way. A large clean-room for calorimeter installation was built; the central calorimeter cryostat has been lowered into this room and is being readied for module insertion at year's end. Electronics crates are being loaded into the moving counting house and connected to the final trigger and data acquisition hardware in the fixed counting areas. The VAX 8810 host computer was installed in its final location.

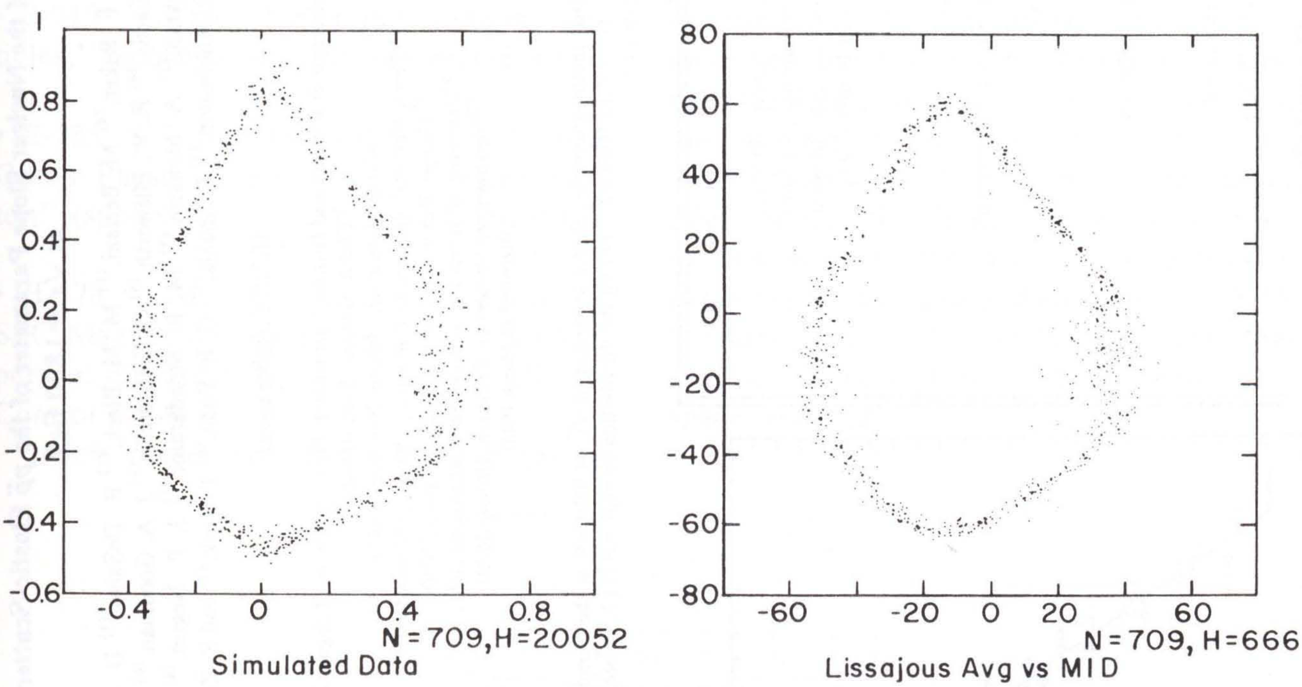
Various test activities have started at DØ; several muon chambers were installed near the collision point to monitor Main Ring backgrounds and to test their performance under high-rate conditions. More recently, several sectors of the central drift chamber were put in their eventual location at the intersection point; the first proton-antiproton collisions at DØ have now been recorded! Both of these tests use final versions of digitization, trigger, and acquisition electronics through to the DØ host computer.

Not content with all of this activity in home labs, test beams, and collision hall, DØ has continued its experimentation in administrative arrangements. Because of the realities of the Accelerator schedule and the current superb operation of the Collider, the Laboratory and DØ have undertaken a high-priority push to complete DØ in time for the next Collider run in late 1990. In order to capitalize on Lab resources, the Fermilab support of DØ was moved (back) from Accelerator Division (AD) to Research Division - though retaining much vital support from AD. Since this schedule acceleration requires the transfer of some FY90 funding to FY89, DØ has received considerable scrutiny from DOE review committees and has set a new record for the most "bottoms up" cost estimates in a year. As a result, we can confidently report that the DØ Detector is a better bargain than Grade A sirloin at less than $5 per pound.

After five years of designing, testing, building, and cajoling, DØ is taking visible reality with its promise for new discoveries as bright as ever. Physics at the Far Side is on the way!



A flash analog-to-digital converter board (left) for central-detector tracking, with results from a particle passing through part of the detector (right). The bottom six traces show the passage of a single particle.



Data (calculated and Lissajous) from 5-meter-long muon drift chambers located on the underside of the central iron toroid. The position of muons in the direction of the wires is determined by measuring the charge induced on cathode pads parallel to the wires.

Experimental Investigation of Nonlinear Dynamics in the Fermilab Tevatron

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(Received 11 July 198)

The nonlinear dynamics of transverse particle oscillations in the Fermilab Tevatron is studied experimentally and compared with prediction. Accurate measurements of various phase-space features are obtained. A theoretically expected metastable state of the accelerator, with particles captured on nonlinear resonance islands, is demonstrated experimentally, and stability of the state is investigated.

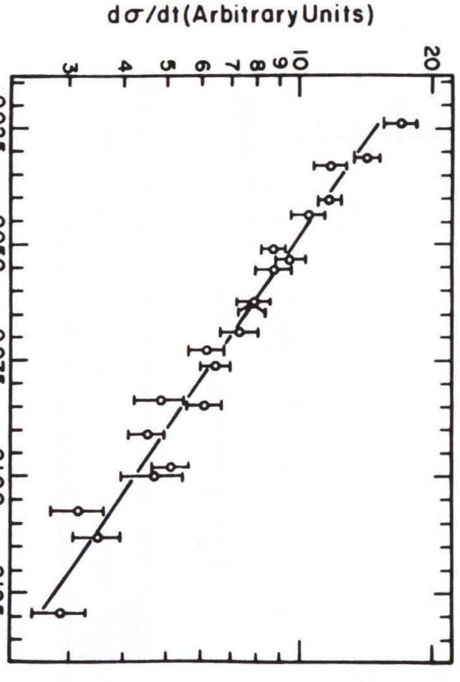

FIG. 3. Elastic-scattering distribution obtained for one run;

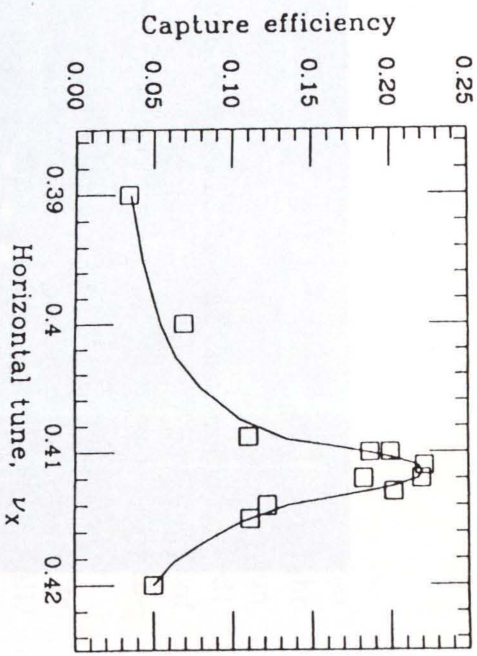

FIG. 6. Capture fraction measured as the island amplitude is moved through the deflection amplitude, by varying the base tune. The curve only guides the eye.

Measurement of the Nuclear Slope Parameter of the $p\bar{p}$ Elastic-Scattering Distribution at $\sqrt{s} = 1800$ GeV

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(Received 18 March 1988)

We have studied proton-antiproton elastic scattering at $\sqrt{s} = 1800$ GeV at the Fermilab Collider, in the range $0.02 < |t| < 0.13$ (GeV/c)^2. Fitting the distribution by $\exp(-B|t|)$, we obtain a value of B of 17.2 ± 1.3 (GeV/c)$^{-2}$.

Small Collider Experiments

Roy Rubinstein

It is a tradition in this section of the *Fermilab Annual Report* to remind the reader that, yes, there really are other Collider experiments in addition to the high-profile CDF and its upcoming colleague, DØ. These other (low-profile) experiments have the characteristic of studying a physics "niche" - some particular physics question which the large, general-purpose detectors are not ideally suited to study. There are three of these experiments; in addition we include here an experiment studying the Collider itself.

The experiments are the following:

- E-710 "Measurements of Elastic Scattering and Total Cross Sections," (spokespersons: Orear, Rubinstein). Located at E0.

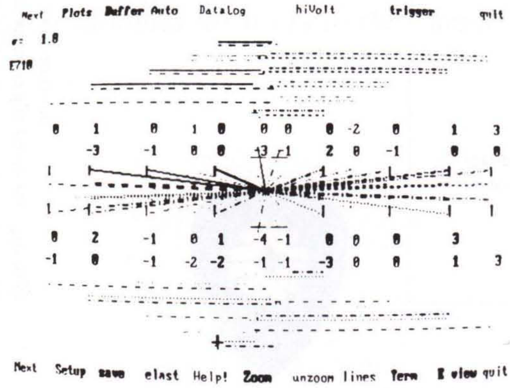
- E-713 "Search for Highly Ionizing Particles," (spokesperson: Price). Located at D0.

- E-735 "Search for a Deconfined Quark Gluon Phase of Strongly Interacting Matter," (spokesperson: Gutay). Located at C0.

- E-778 "An Experimental Study of the SSC Magnet Aperture Criterion," (spokesperson: Edwards). Located at the Accelerator Control Room.

Alert readers of this section might remember that in the 1987 report, there were descriptions of these experiments, together with examples of the results just emerging from the 1987 run. Since then, all have published preliminary results in *Physical Review Letters*; this is shown in the adjoining illustration, where brief descriptions of the data are given in the abstracts. There are also preliminary results just becoming available at this time from E-710 in the $\bar{p}p$ total cross section at $\sqrt{s} = 1800$ GeV, and from E-735 on a study of Λ^0 and $\overline{\Lambda}^0$ production at the same energy.

Following the 1987 run, all experiments made equipment improvements based on their experiences in that run. In addition, many improvements subsequently made to the Accelerator have greatly helped the experiments; these improvements include increased luminosity, the ability to scrape the circulating beams to remove halo, and the movement of injection components away from the beams following beam injection into the TEVATRON. At the time of this writing, the three particle-physics experiments are taking data in the 1988/89 Collider run. All indications are that excellent data is being taken - watch this space next year!



Multiplicity Dependence of the Transverse-Momentum Spectrum for Centrally Produced Hadrons in Antiproton-Proton Collisions at $\sqrt{s} = 1.8$ TeV

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The transverse momentum of charged particles produced within the pseudorapidity range $\eta = -0.36$ to $+1.0$ has been measured in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV. The charged-particle multiplicity of each event was measured with a 240-element cylindrical hodoscope system covering the range $-3.25 < \eta < 3.25$. The average transverse momentum as a function of the average charged-particle density per unit of pseudorapidity is presented. Events are observed with average charged-particle density as high as 32 per unit of pseudorapidity.

PACS numbers: 13.85.Hd

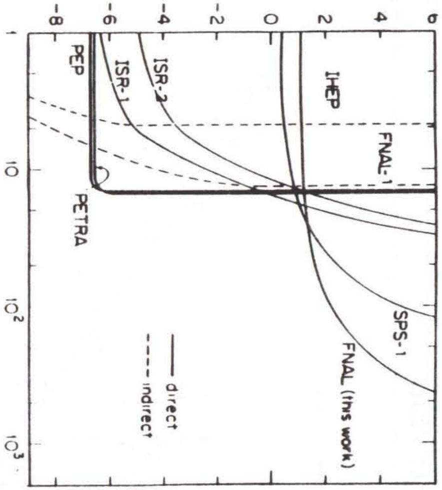

FIG. 3. Upper limits on normalized production cross sections (see text).

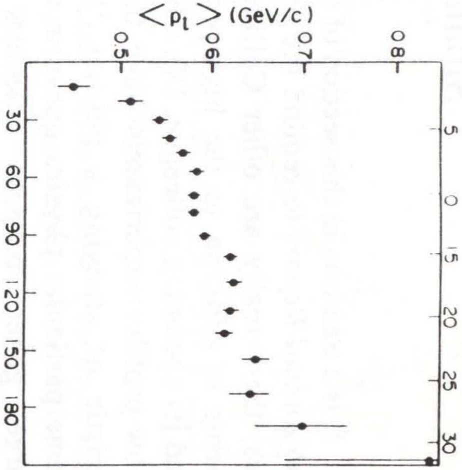

FIG. 5. $\langle p_t \rangle$ as a function of N_c and $\langle dN_c/d\eta \rangle$ for all charged particles with $N_c \geq 2$, averaged over the interval 0.15 GeV/c $< p_t <$ 3.0 GeV/c.

Search for Highly Ionizing Particles at the Fermilab Proton-Antiproton Collider

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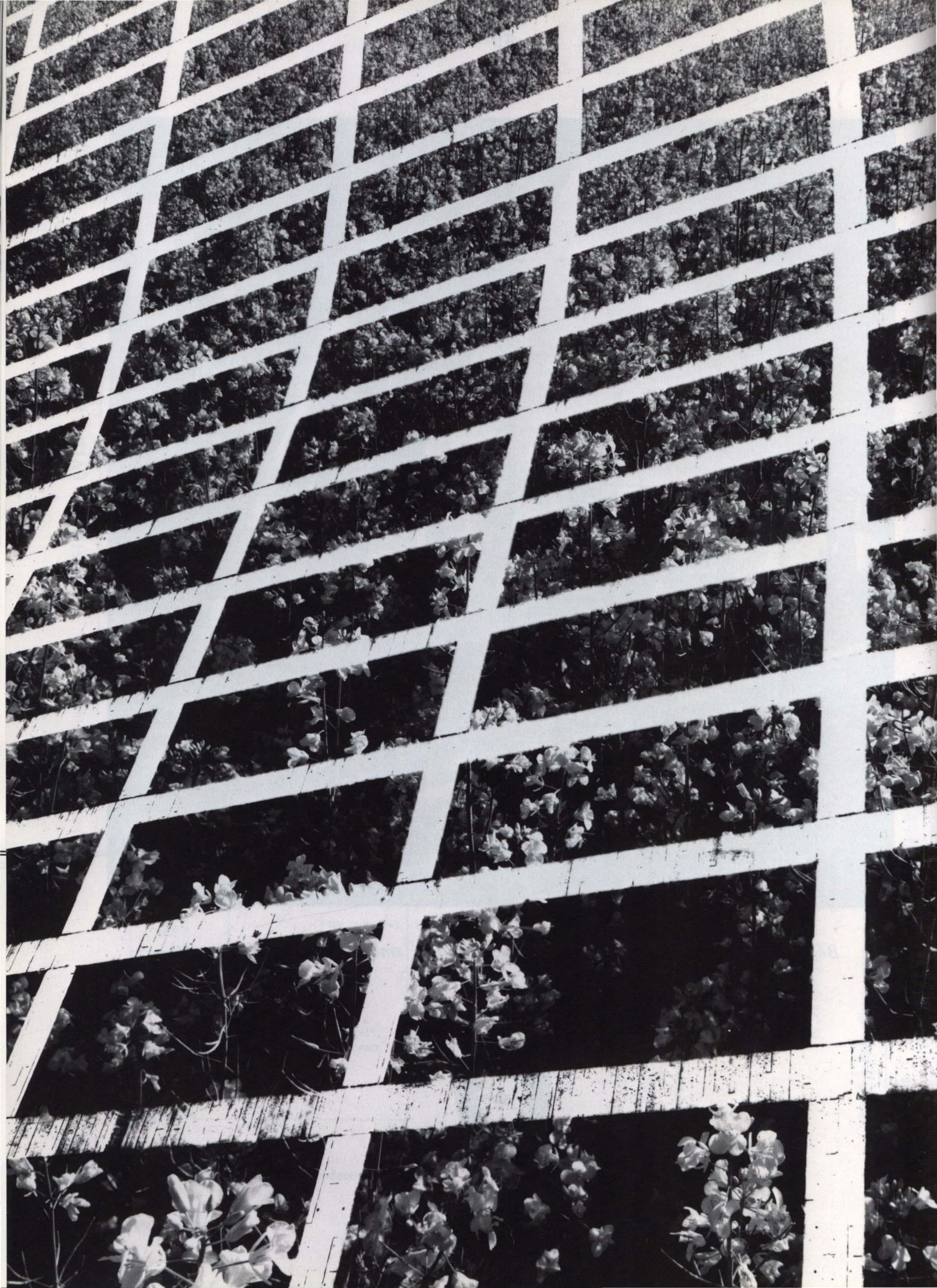
(Received 17 August 1987)

In a search for highly ionizing particles produced in $\bar{p}p$ collisions at $\sqrt{s} = 1800$ GeV, polycarbonate and CR-39 plastic track detectors were exposed to an integrated luminosity of $\sim 5 \times 10^{32}$ cm^{-2}, and UG-5 glass detectors were exposed inside the vacuum system to look for short-range particles. No highly ionizing particles other than hadronically produced spallation recoils were detected.

PACS numbers: 13.85.Rm, 14.80.Hv

Be it ever so humble: portahomes for users at the "small" collider experiments.



The Theoretical Physics Department

William A. Bardeen

Members of the Theoretical Physics Department have contributed to a broad spectrum of the current issues of elementary physics research during the past year. The Department continues to play its essential role in the intellectual life of the Laboratory. The group now consists of nine permanent members (two are presently on leave), four Associate Scientists with five-year appointments, and eight postdoctoral Research Associates. Fermilab provides a focus for the research of several faculty members from surrounding universities as well as a number of long-term visitors from universities and research institutes around the world. In addition, Fermilab has its traditional Theory Visitors Program, which provides hospitality and support for a large number of physicists from the local, national, and international physics communities. This year has seen a dramatic increase in visits of our colleagues from the Soviet Union. The Theory Visitors Program makes Fermilab a central crossroads for the exchange of the newest theoretical ideas. It also provides an opportunity for useful interaction between the theoretical community and the many experimental physicists who find Fermilab the focus of their research.

The Theoretical Physics Department organizes the weekly Theoretical Physics and Joint Experimental-Theoretical Physics Seminars. The group also organizes an annual workshop for the study of new theoretical developments of mutual interest. Members of the Department contribute to the Fermilab Academic Lecture Series, which is addressed to the broader physics community at Fermilab. In September, the Theoretical Physics Department hosted the annual symposium on lattice field theory, "Lattice 88," which attracted over 200 participants from around the world to discuss the latest developments in lattice gauge theory.

Research highlights in 1988 range from fundamental problems in field theory and superstrings to supercollider phenomenology. A particularly active area of research involves the application of quantum chromodynamics, the theory of strong interactions, to relevant physical problems using techniques of perturbative field theory. Ellis has focused on the hadroproduction and photoproduction of heavy flavors where complete calculations of the first non-leading corrections to the cross section have been achieved. These calculations have led to a precise bound on the mass of the top quark from UA1 data and will be essential to the analysis of the new data from the current run of the CDF detector. Arnold and Reno have completed a complex perturbative analysis of the second-order corrections to the production cross sections of W and Z bosons with high transverse momenta. Parke and Mangano have exploited the structure of string theory amplitudes to develop approximate estimates of cross sections for multiparton processes in hadron colliders. Their results will have direct implications for understanding the backgrounds for discovery physics in the CDF Collider. The interplay between string models and field theory is being extended to the higher loop order by Kosower. Other perturbative calculations include the study of soft gluon contributions to the inclusive Drell-Yan cross sections (K-factors) by Mackenzie, the study of Higgs boson production by

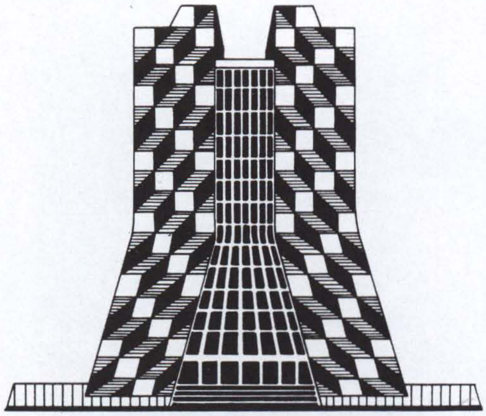
Golden, and the analysis of B meson decay processes by Grinstein. Using the large N_c approximation, Bardeen has continued a study of the effects of strong interaction dynamics on the weak decay matrix elements for K meson decay amplitudes. Lindner and Albright have made a systematic study of the renormalization effects on the phenomenological structure of fermion mass matrices in the Standard Model of electroweak interactions and the implications for the recent observations of weak mixing in the B meson system. Higher order bounds on the Standard Model parameters have been extended by Lindner with implications for the available range of top quark and Higgs masses.

The lattice formulation of quantum chromodynamics provides a unique method for the systematic analysis of strong dynamics in the non-perturbative domain. The Theoretical Physics Department and the Advanced Computer Program have collaborated on the development of a computing engine for serious lattice gauge theory calculations. During the past year, the software for this machine has been written and the hardware designed and built. Currently the collaboration is finishing debugging on a small-scale, 16-node (320 megaflop peak speed) parallel computer and is looking forward to the construction of a 256-node system in the next year. Hockney has led the development of the software system, called CANOPY, which will provide a flexible operating environment for lattice gauge calculations. Mackenzie has focused his efforts on developing physics software and algorithms for the project. A full program of physics applications for the complete system is being developed by a group including Eichten, Mackenzie, Hockney, Thacker, and Kronfeld of the Theoretical Physics Department. Analytic studies by Eichten and B. Hill will permit extensions of realistic numerical calculations to heavy quark systems.

Progress has also been achieved in more formal areas of particle-physics research. Itoyama and Thacker have completed an analysis of the Virasoro algebra structure which they discovered in certain two-dimensional, integrable systems and which may have important implications for strings and conformal field theories. Maillet has developed extensions to the algebraic structures used in the formulation of multi-dimensional integrable systems. Griffin has extended parafermion methods for solving nontrivial conformal field theories which may be used to study superstring compactification problems. Taylor has focused on the large quantum corrections to the long-distance behavior of superstring models which cause the running of coupling constants and other interesting physical phenomena. Pisarski has continued the analysis of Polyakov string models and other consistent alternatives to the standard theories of fundamental strings.

The interface between astrophysics, cosmology, and particle physics has been a productive area of research, particularly at Fermilab with the proximity of the Theoretical Astrophysics Group. C. Hill has continued his study of cosmic strings and field theories defined in curved background spaces. He has joined Grinstein in a study of the phenomenological implications of "wormhole" physics based on Coleman's treatment of the wavefunction of the Universe. K. Lee has also studied the physical implications of wormholes but in the context of axion models with emphasis on the proper interpretation of vacuum wavefunctionals. Problems associated with baryon number production in the evolution of the Universe were studied by McLerran and Arnold.

The future research of the Theoretical Physics Department will continue to involve a broad spectrum of physics issues from the questions of direct phenomenological interest to the more formal aspects of quantum field theory and superstrings. The anticipated completion of the 256-node lattice gauge engine will make Fermilab the central focus of realistic calculations in non-perturbative quantum chromodynamics and its application to the solution of many important physics issues.



The Theoretical Astrophysics Group

Edward W. Kolb

We are pleased to report that 1988 was a year of continued expansion of both the Universe and the Fermilab Theoretical Astrophysics Group. The year saw the continuation of research directions that have proved successful in the past, as well as the exploration of new avenues of research in the particle/astrophysics area.

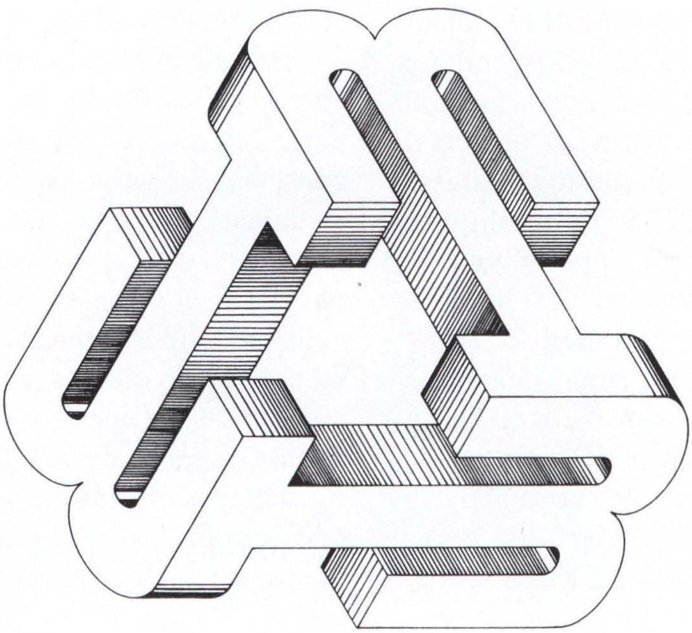
The success of any research group is determined by the people in the trenches doing the physics. Senior appointments in the cosmological trenches at Fermilab are Edward Kolb and Michael Turner. In addition to Kolb and Turner, David Schramm of the University of Chicago spent the month of September in residence at Fermilab. The year started with Andy Albrecht and Neil Turok as Associate Scientists. In September, Neil left Fermilab for a faculty position at a small, liberal arts finishing school in Princeton, New Jersey, and Joshua Frieman left SLAC to join our Group as an Associate Scientist. In 1988, three research fellows on foreign fellowships left the Group and we welcomed another. Phillipe Jetzer said good-bye to the prairie of Fermiland for the hills of Switzerland as a research fellow at the world's second most powerful accelerator laboratory. Frederique Grassi finished her French CNRS fellowship at Fermilab and accepted an appointment at the University of Illinois in Champaign-Urbana. Sirley Marques returned to Brasil to continue research in the area of general relativity. Armando Perez of the University of Valencia was awarded a Fullbright Fellowship to study abroad. We are happy to welcome him to Fermilab. Our elite corps of postdocs now consist of Edmund Copeland, Angela Olinto, Ruth Gregory, Dongsu Ryu, and David Haws. Kim Griest, a postdoc in the Astronomy and Astrophysics Department of the University of Chicago, has continued to play an active role collaborating with members of the Group on a number of projects. We will miss our departing postdocs: Jamie Stein-Schabbes, David Bennett, Marcelo Gleiser, and Albert Stebbins. We wish them the best in their scientific careers.

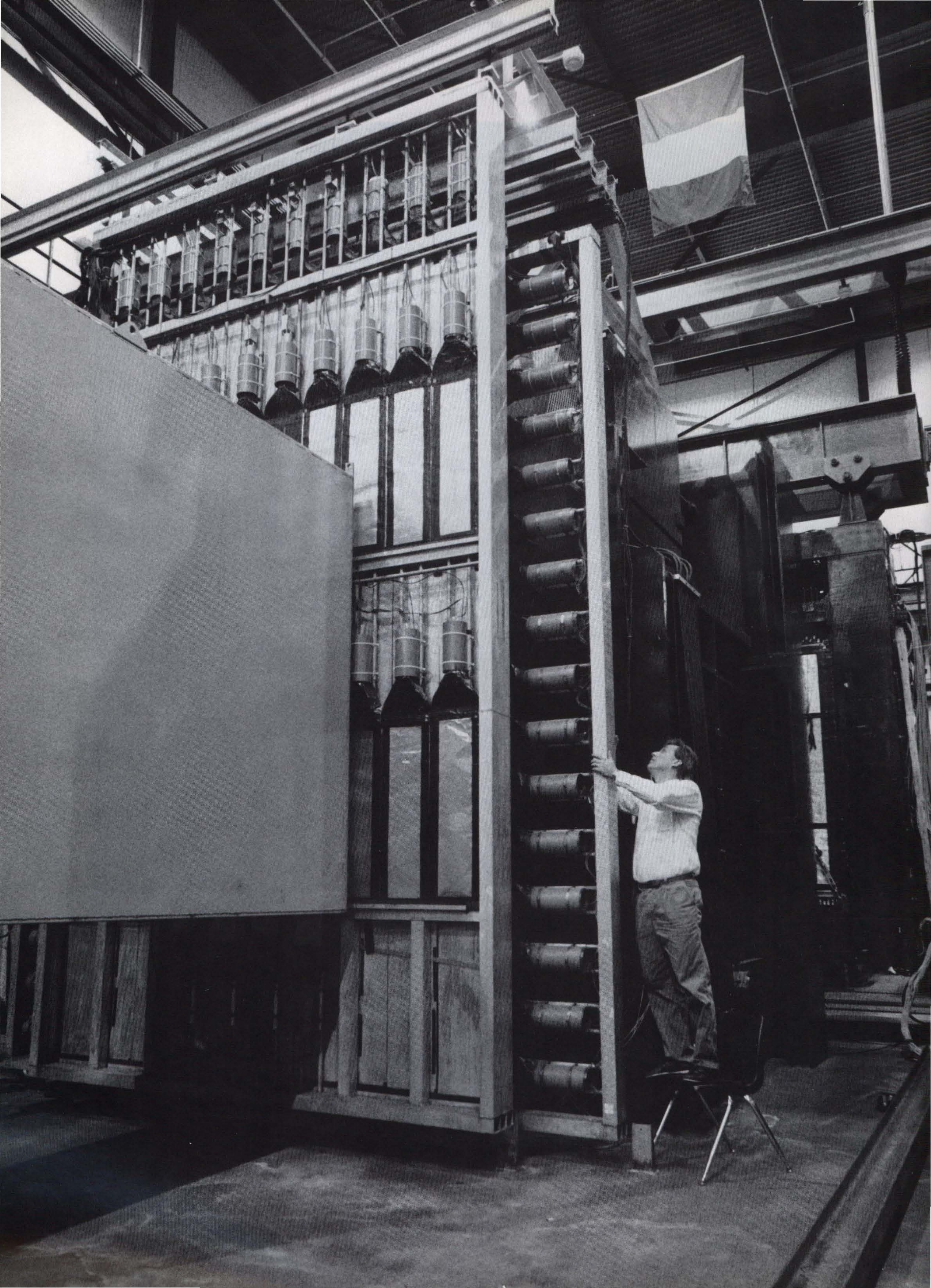
The Astrophysics Group continued the tradition of May workshops in particle astrophysics. Our workshop this spring was on a subject of interest to both particle physicists and astrophysicists: "QCD in Astrophysics." We are already hard at work planning the 1989 May workshop: "Wormhole Physics." We expect the wormhole workshop to be the most successful one we have ever had. Several members of the Astrophysics Group and Theory Department are already actively working on wormhole physics. Do not be surprised to find a number of people on the third floor of Wilson Hall caught up in wormhole mania by May.

The 43 publications by members of the Astrophysics Group in 1988 reflect the diverse interests of the Group. Angela Olinto continues to work on strange-quark matter, a subject that might have observational consequences for astronomy and high-energy physics. Dongsu Ryu is hard at work developing the numerical tools necessary to model the evolution of structure in a universe with elementary particle dark matter. Ruth Gregory is modeling the interactions of matter with cosmic strings. The subject of cosmological phase transitions continues to be an area of active research in the Group. David Haws, Ed Copeland, Rocky

Kolb, and Josh Frieman all worked on the phenomenology of cosmological phase transitions. Andy Albrecht and Neil Turok have just completed a massive computer effort simulating the cosmological evolution of a network of cosmic strings. The run has just completed and they are in the process of analyzing the data. We all expect new and interesting results from the effort. We would also like to acknowledge the cooperation of the Fermilab Computing Department in the project. Mike Turner and Dave Schramm (with occasional contributions from Chris Hill of the Theory Department) continue to lead the effort in large-scale structure. Supernova 1987A is fading in brightness but not in interest. Kolb, Schramm, and Turner continue to exploit this remarkable event to limit the properties of elementary particles.

Over 40 visitors to the Astrophysics Group in 1988 have given seminars and colloquia, collaborated with members of the Astro and Theory groups, and in general, contributed to the intellectual atmosphere of the Laboratory. Group members continue to be active in Saturday Morning Physics, Academic Lectures, and other programs of the Laboratory.





Reseach Division Support Departments and Highlights of the Fixed-Target Program

Peter H. Garbincius and Kenneth C. Stanfield

The Fermilab Research Division assists in the planning of the Laboratory's physics program and provides strong, direct support to all aspects of this program. This includes direct support of the fixed-target experiments and beamlines, direct support of the Collider experiments, computing for all aspects of the physics program, and theoretical physics and astrophysics. One of the highlights of this past year was the return of the D0 project management to the Research Division from the Accelerator Division. This was done in order to provide an increased level of support through redirection of Research Division effort.

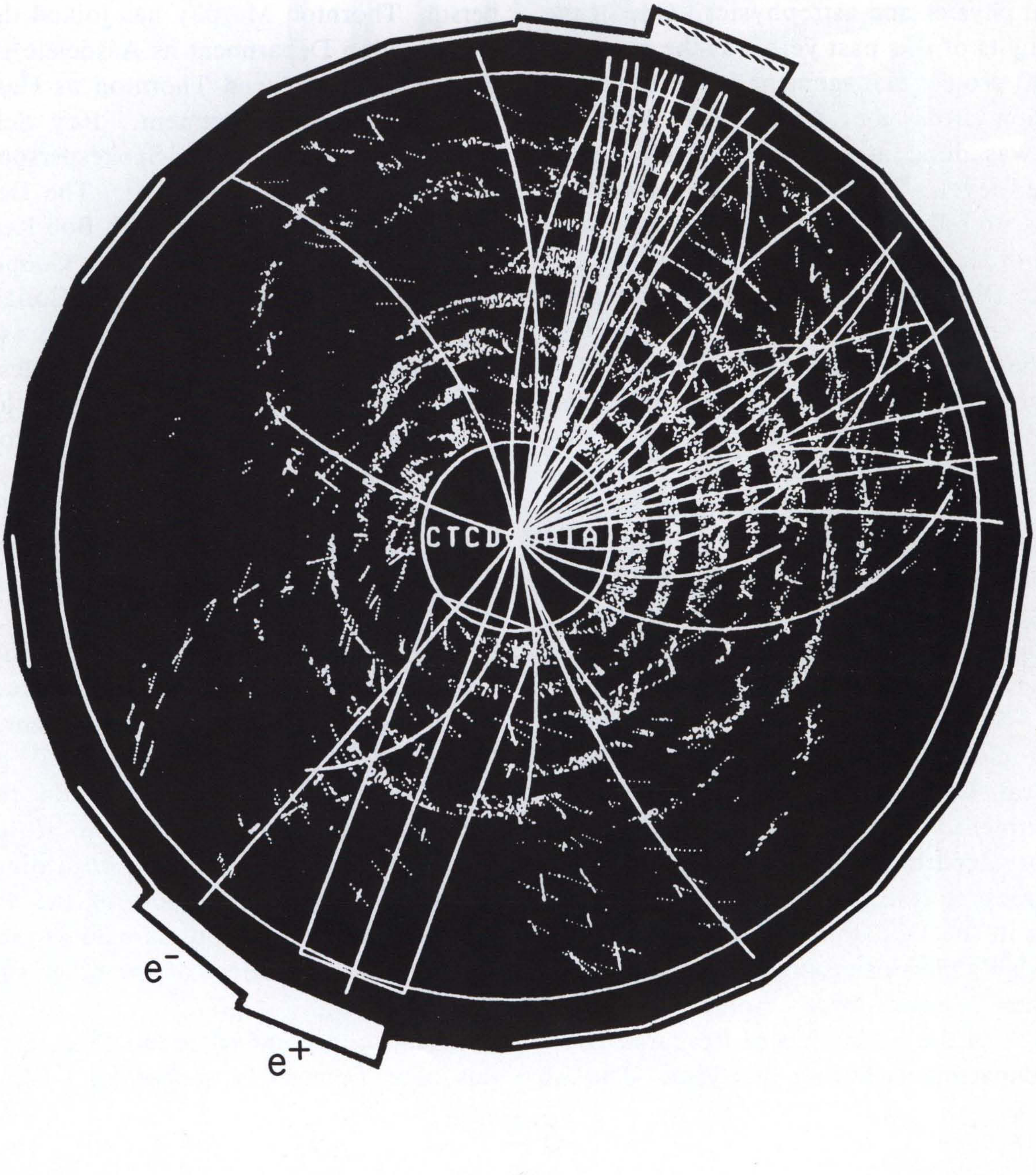
In order to carry out its mission, the Research Division is organized into departments with specific programmatic responsibilities plus support departments. The former category contains the Collider Detector Department, the D0 Construction Department, the Theoretical Physics Department, and the Research Facilities Department (primarily responsible for planning and coordinating the Fixed-Target Physics Program). The support departments are the Computing Department, the Administrative Support Group, the Cryogenics Department, the Advanced Computer Program, the Electronics/Electrical Department, the Mechanical Department, the Site-Operations Department, and the Safety Group. The support departments provide expertise and resources to the users and other departments in the Division in overall support of Fermilab's physics program.

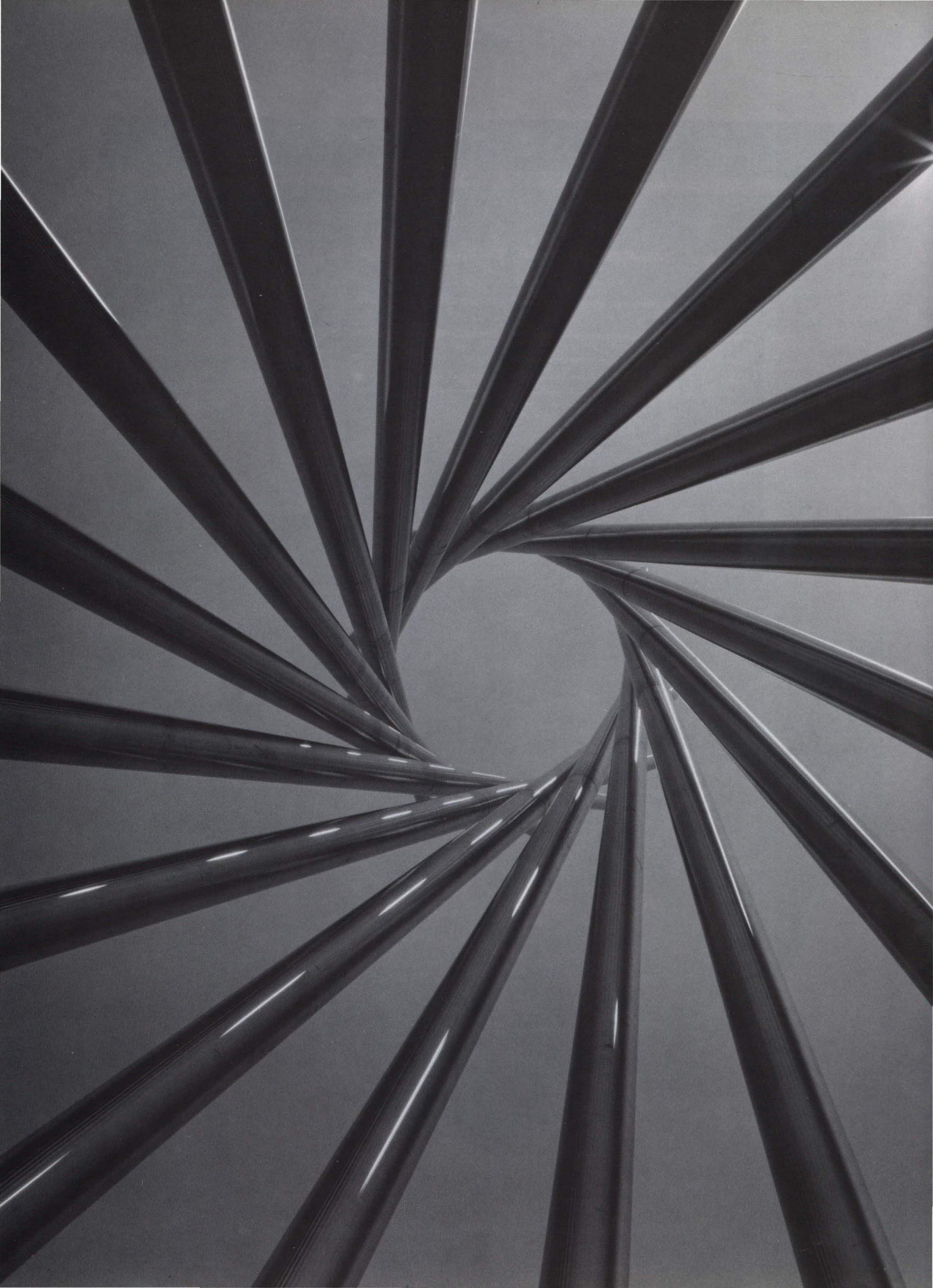
There have been some important changes in the leadership of Research Division departments during this year. The D0 project was reorganized when it joined the Research Division. Paul Grannis and Roger Dixon are now Co-Project Managers. Roger Dixon became Head of the D0 Construction Department with Gene Fisk serving as Deputy Department Head. In addition, Gene became a Deputy Spokesperson for the D0 collaboration. Paul Grannis continues as Spokesperson. Thornton Murphy has joined the D0 Construction Department as Associate Head. Rich Stanek replaced Thornton as Head of the Cryogenics Department. Roy Schwitters stepped down as Co-Spokesperson and Co-Department Head at CDF. The Department has been reorganized with Bob Kephart as Department Head and John Cooper as Deputy Department Head. The Collaboration elected Mel Shochet to serve as Co-Spokesperson along with Alvin Tollestrup. Peter Cooper and Joel Butler have joined the Computing Department as Associate Department Heads and Vicky White has been promoted to Associate Head. Ed Barsotti has been named Deputy Head of the Electronics/Electrical Department under Bob Trendler.

Reports from the leaders of the Collider Detector Department, the D0 Construction Department, the Theory Department, the Computing Department, and ACP group will be found elsewhere in this report. Here, we will get the perspective of the Research Facilities Department regarding the on-going efforts in support of the Fixed-Target Physics Program, as well as the perspective of the leaders of the other support departments.

From our point of view, this past year has been immensely successful. We have seen the completion of a most successful fixed-target run which was the first to utilize the full complement of TEVATRON II beams and experiments. As the Director noted earlier in this report, this run accumulated over 35,000 data tapes. The long and successful career of the 15-ft Bubble Chamber came to a conclusion with 3,000,000 pictures during its lifetime and 200,000 holograms during this last run. In addition, the remainder of the approved Neutrino program was completed. An accelerated schedule for D0 was adopted which will enable the first physics run to begin in late 1990. In collaboration with the Accelerator Division, CDF is exceeding all goals set for this run.

Let us now hear from some of the dedicated leaders of the Research Division who helped make 1988 one of Fermilab's best years ever.





The Research Facilities Department

David F. Anderson, Stephen Pordes, and Raymond J. Stefanski

The Research Facilities Department is organized into three groups: the Beams Group, the Facilities Support Group, and the Particle Detector Group. The Beams Group serves as liaison with fixed-target experiments, designs and commissions beamlines for operation, and carries out functions for long-term planning. The Facilities Support Group provides technical assistance to experiments and facilities. The Particle Detector Group carries out the design and development of new techniques for high-energy physics research.

In the past year the activities of the Beams Group have been directed toward the future. The Group has been developing beam designs for the 1989 run, evaluating experiments for future runs, and participating in the development of new experiments for the Laboratory. New beam design involves modifications to existing beams required by changes in the experimental program. In particular, a new design for a transport system for PWest has been completed to transmit 900-GeV protons to the High Intensity Lab for E-771. The PEast beam will have its energy increased to 500 GeV based on the design work carried out this year. This beam will be used by E-791 at the Tagged Photon Lab. The Wide Band beam will deliver nearly twice the number of photons for E-687 and E-683, due to a novel design that will allow both positrons and electrons to be delivered to the lead converter. A new muon beam has been designed and will be ready for the 1989 run for E-782 using the Tohoku Bubble Chamber. This beam will deliver around seven muon pings per spill for the bubble chamber. The MWest beam has been re-designed to transmit a greater yield of particles at 530 GeV, the operating energy of E-706 and E-672. Considerable effort has also gone into reconciling the differences in beam tune as delivered from the Switchyard to the three experimental areas. Understanding this primary transport system is important for the delivery of beams to the experimental areas with minimal losses.

The Group has also been involved in developing a better understanding of our test-beam needs for the future. Because the Lab provides test-beam facilities for CDF, DØ, a detector for HERA, and for SSC R&D, the test-beam program has become much more active than in the past. This will require that the MBottom beam be revived for the '89 run, and design work is in progress to achieve this end. An effort is also in progress to find ways to fit in additional users in the MTest beam along with CDF and T-755.

New experiments that were approved in the last year represent additional liaison work for the Beams Group. The approvals for E-771 and E-791 required that the spectrometer magnets in the High Intensity Lab and in the Tagged Photon Lab have their coils rebuilt because of aging effects. The Beams Group provides coordination with the Magnet Facility for this effort. The approvals for E-771 and E-781 require the development of new VLSI electronics for the detectors. The Beams Group helps with coordination for the development and testing of these new devices. The installation of new experiments such as E-774, E-789, E-773, E-761, E-781, and E-791 require liaison work provided by members of the Beams Group.

The Beams Group is also involved in the development of new research programs for Fermilab. In particular, in the last year, the Group was involved in developing a proposal to carry out R&D for a new collider detector dedicated to do "bottom" physics. The Group was involved in the spectrometer magnet design, computer event simulations, developing an interface with the TEVATRON, and developing details for a particle identification system. In addition, the Group helped to enumerate the fixed-target opportunities for a new 150-GeV main injector. These involve the possibility of bringing up the fixed-target experiments and operating test beams during a Collider run, and providing opportunities for a kaon factory, high-rate neutrino experiments, or new polarized proton experiments. The Group's involvement in these activities evolves naturally from its design work on beams and experiments.

The Group also maintains and improves the beamline design software packages called TRANSPORT, TURTLE, and HALO. These routines are used for external beam design, including primary, secondary, and tertiary beams. This year, an effort was begun to interface these routines with a generalized input package to help streamline the process of preparing engineering drawings for the beamlines. Members of the Beams Group have also been instrumental in the development of software systems for the cryogenic control system, the applications programs for the beamline control systems, and for support software for the Alignment Group.

The Facilities Support Group is responsible for the operation of experimental facilities and for providing technical assistance to experiments within the Research Division. The Group provides the Ziptrack magnetic-field-measurement apparatus and support for the operation of the Tagged Photon Lab Spectrometer (E-791), and the MWest spectrometer (E-706/E-672). With the help of the Mechanical and Site-Operations Departments, a new Ziptrack was built in the last year to provide for a more reliable mechanical structure and a more modern computer interface. The Tagged Photon Lab spectrometer is being refurbished and improved for E-791. This Group is also involved in the construction of the calorimeter and other detectors for E-760. The Group is involved in setup of the new scintillation fiber facility and in production of the scintillating fiber for the E-687 calorimeter. In addition, this Group is leading the design and development of a beam-spill structure monitor. This will give operators an online reading of any anomalous structure that exists within the spill due to power supply ripple or other causes.

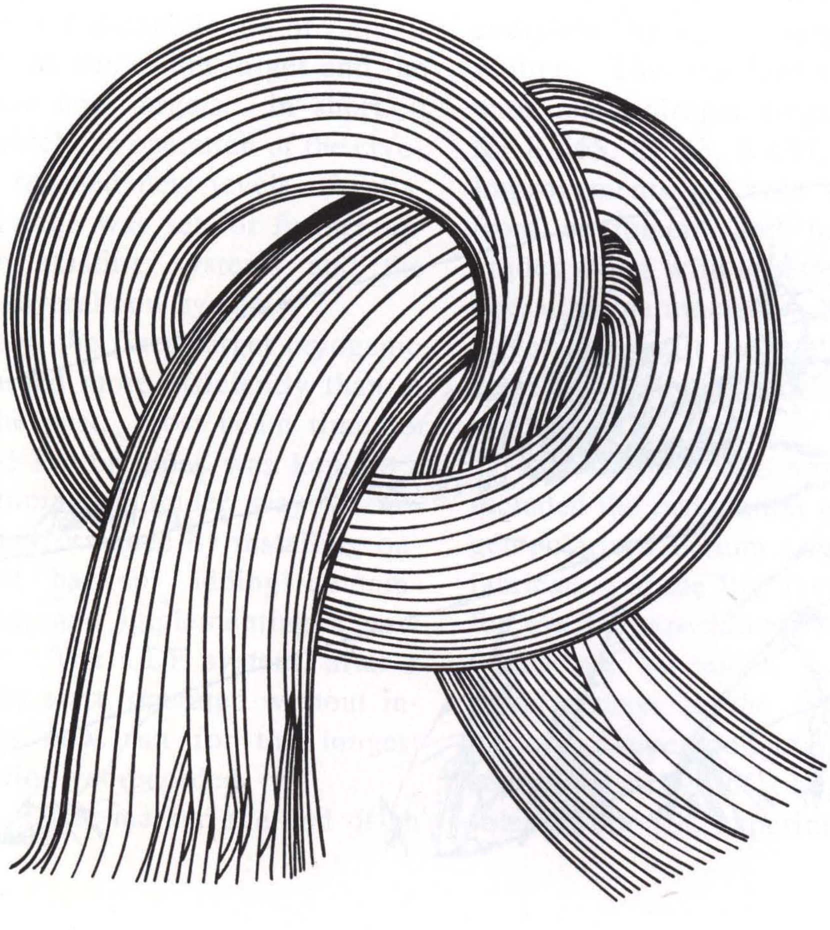
Within the Facilities Support Group, the Electronics Group provides special-purpose electronic modules to experiments. Examples are the high-voltage controller for E-760, the rf clock countdown module for E-687, and the LED pulser system for E-665. It is developing a standard status display and alarm system to allow experiments to have a central monitor of their critical systems (e.g., gas, high and low voltages). The Group has made a small contribution to the Application Specific Integrated Circuits project and is heavily involved with the new fast encoding and read-out ADC's designed in the Physics Section.

Also within the Facilities Support Group, the Mechanical Group services experimental facilities, and runs Lab 6, which provides mechanical support to experiments, including E-740 (DØ). The Group also collaborates on the design of experiment gas systems and is generally responsible for building and installing them.

The primary role of the Particle Detector Group is to develop new detector techniques, many of which will be used in future high-energy physics experiments. This Group has also taken on a major role in the construction of a tungsten-scintillation fiber electromagnetic calorimeter for E-774, and the construction of a much larger calorimeter for E-687. These devices will be made ready for the '89 run.

In the last year, a substantial part of the Particle Detector Group's effort has been in plastic scintillator R&D. This includes work on the development of dopants that will increase the amount of scintillation light produced, the attenuation length of fibers, and improvements in the resistance of the scintillator to large amounts of radiation. The Group also makes clad fiber preforms that can be used to draw scintillating fibers.

The Particle Detector Group has also applied for a patent for a new crystalline scintillator, whose main application is in Positron Emission Tomography (a field of nuclear medicine) and possibly in high-rate experiments in physics. Work is also ongoing in the development of a new crystalline material, which may be used as a very fast and compact electromagnetic calorimeter.



The Cryogenics Department

Richard P. Stanek

The Cryogenics Department is responsible for the design, fabrication, and operation of cryogenic systems in the Research Division. These systems include superconducting magnets, liquid hydrogen targets, and liquid argon calorimeters. To accomplish this mission, the Department is organized into two groups: the Operations Group, and the Projects and Support Group.

This past year was characterized as one of accomplishment and change for the Department. It marked the end of a very successful fixed-target run and a changeover to operations of the CDF superconducting magnet. It heralded the end of an era for the 15-ft. Bubble Chamber and the start of new assignments for many of the chamber's personnel. It saw the completion of Experiment 772 with its deuterium target and the planning of five new targets. In short, it was a year in which the operation of the cryogenic systems reached new levels of reliability and the stage was set for further upgrades to the existing systems and the installation of several new systems.

Operationally, the fixed-target cryogenic systems performed more efficiently than at any time in the past. Lost beam time for the Meson and Proton lines was kept to a minimum. Planning is under way to improve system performance by installing online equipment backup, adding contamination filtering, and implementing a new control system. The CDF system, after a somewhat shaky start, operated without incident and has now run for the longest trouble-free period yet recorded.

February 1, 1988, marked the end of an era when the 15-ft. Bubble Chamber, the last large cryogenic chamber, completed its seventeenth and final experiment, E-632. A last, old-fashioned Bubble Chamber party, the "15 Foot Fest," was held to celebrate the decommissioning. Several long-time experimenters and early chamber builders spoke and recounted tales of the good old days. The soon-to-be-published proceedings should be a fitting tribute to the remarkable technology which served the physics community so well for so long.

The hydrogen target effort was aided by the compilation of the "Guidelines for the Design, Fabrication, Testing, Installation and Operation of LH_2 Targets" document. This represents the most formalized and complete hydrogen target standard ever written. This standard comes just in time, with new hydrogen targets "on the board" for E-665, E-683, E-687, E-690, and E-704. Improvements in these systems will come from equipment and instrumentation upgrades along with a better understanding of operating parameters. A 1-liter hydrogen target was built and delivered to the University of Illinois for operation at their accelerator.

Planning for the next fixed-target run included the installation of the E-704 hydrogen/polarized helium target system and the fabrication of the Big Test Beam Calorimeter for the DØ experiment. Additional projects which are scheduled to continue include modifications to the test stands for SSC prototype superconducting magnets and the conceptual design of a large superconducting solenoid for SSC experiments.

Banks of scintillation counters for E-705, placed in perspective by Merrill Jenkins (Fermilab).

The Electronics/Electrical Department

Robert C. Trendler

The Electronics/Electrical (E/E) Department is responsible for much of the design, development, implementation, and maintenance of the electronic and electrical devices that are used in the experimental areas. Examples of these devices are radiation and electrical interlocks, beamline controls, power supplies, beam instrumentation and safety electronics. 1988 began with a fixed-target run in full swing. Most of the E/E Department people were deeply involved with helping to make this run Fermilab's most successful. Besides the effort needed to keep the systems operational, considerable direct support was given to the experimental groups. An example of this is the installation, at E-687, of the Department-designed, IR-100 Award-winning Video Data Acquisition System, which allowed, for the first time at Fermilab, observations of scintillating fiber target tracks. Other examples include: the implementation of a Fermilab standard event identification system for use by all experiments; the reliability upgrade of the E-705 Cluster Finder; the completion of the design and prototype testing of the CDF Event Builder, which should eventually provide significant event-rate enhancement; and the production and commercialization of several CAMAC modules for use by many experiments.

With the end of the fixed-target run in mid-February, the E/E Department shifted gears. Maintenance and upgrade work started immediately and new project development began in earnest. During the rest of 1988, several hundred power supplies were upgraded, computer monitoring of all beamline enclosures and safety devices was completed, and countless other devices (motor controllers, instrumentation, etc.) were upgraded. Even with all this, another very important milestone was achieved; the beamline control system upgrade, EPICURE, is in full operation. The experimental areas now have a control system that integrates all controls: power supplies, cryogenic systems, etc. The control system is part of a broad network that allows experimenters and operators unprecedented access to and control of beamline devices. Control-system workstations will permit operators to monitor and control the beamline parameters with significantly improved efficiency. These control-system developments required important advances in software and hardware implementation. New microprocessors, such as the 80386, were used in a number of hardware implementations. New power supply and vacuum controllers, among others, have been designed and built for enhanced beamline operation. Even though there is much still to be done, this is an important milestone and we look forward to improved operation in future runs.

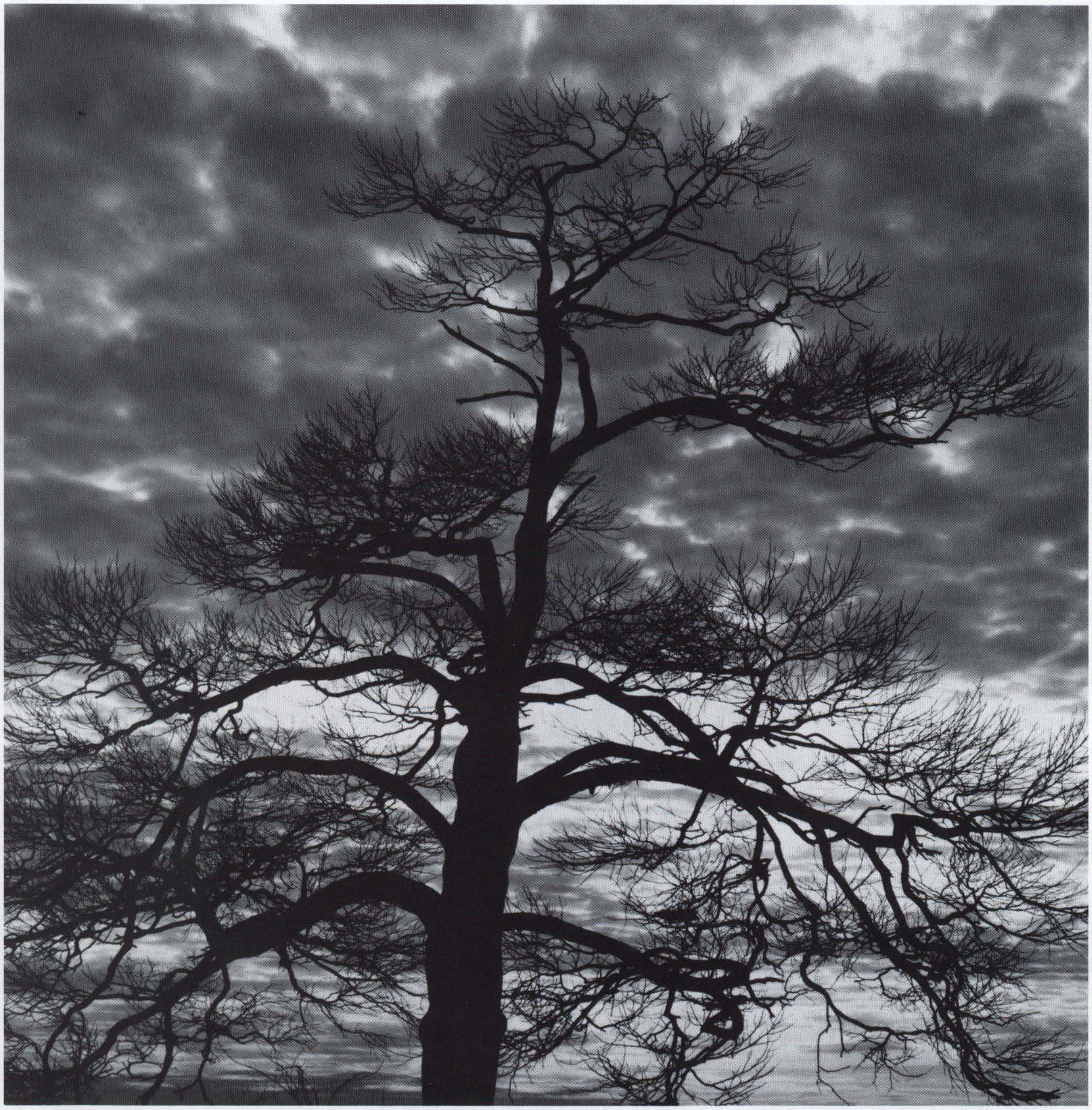
The broad responsibilities of the E/E Department continue to require active support for many of the other departments in the Research Division and elsewhere at Fermilab. These include controls, electromechanical design, FASTBUS design, power-system design, and general electronics design support. A large commitment to the DØ experiment is ongoing. Among the tasks being done for DØ are: 28,000 hybrid circuits and 400 motherboards for the muon chambers, electrical power system design, the DØ master clock system, and drafting and technician support. In the experimental areas, major changes are planned in the Proton and Neutrino areas requiring, in some cases, civil construction work. The electrical design necessary for the implementation of these upgrades has been completed. Except for installation, controls, radiation interlocks, etc., requirements are complete.

In other areas, electrical design and installation effort for the Loma Linda medical accelerator is ongoing and the E/E Department Printed Circuit Facility continues to supply large numbers of prototype quality printed-circuit boards and films for all of Fermilab. Additionally, they construct specialized beam detectors (SWICS, ion chambers, beam foils, etc.) for Fermilab groups and experiments.

It is the four major groups in the E/E Department that fulfill these responsibilities: the Power Systems and Interlocks Group, the Electronics and Instrumentation Development Group, the Data Systems Group, and the Controls Group. Each of these groups have design and maintenance responsibility, and each also has access to several commercially procured, computer-aided design/computer-aided engineering (CAD/CAE) systems to assist them with their design work. CAD/CAE systems are an integral part of modern electrical engineering practice, and consistent upgrade of these systems is imperative. Advanced software tools are also essential for continued development success. The groups also have responsibility for a number of new research and development tasks. Examples include Application Specific Integrated Circuits (ASIC) and data acquisition system proposals for the proposed Bottom Collider Detector and SSC projects, significant new software implementations, new developments in electromechanical control, innovative beam detection devices (spill structure monitors, ''glowing screen'' detectors, etc.), high-speed fiber-optic data transmission research in collaboration with the Japanese, and research studies of new data acquisition architectures.

A major initiative, begun last year, is the enhancement of the Department's microelectronics capability. Additional personnel and computer-assisted design tools have been added to the effort. Even though staffing and design-tool limitations restrict our ability to respond, and requests from experimenters for chip development exceed present capability, the Department has made impressive progress. For example, Fermilab-designed ASIC's developed for E-771 will have wide application throughout high-energy physics. The development of ASIC's using high-speed bipolar transistor arrays is becoming commonplace. Significant progress with CMOS ASIC design has also been made. Other important parts of the microelectronics effort include: performing in-depth studies of radiation damage to various custom integrated circuits used primarily in vertex detectors; developing techniques for using existing chips in new configurations; developing and evaluating new chip architectures for data acquisition systems; and evaluation of a broad range of commercially available integrated circuit processes.

The E/E Department is looking forward to 1989. We are developing equipment and systems for Fermilab and its experiments that will require the best from us. We eagerly anticipate the opportunity to work on leading-edge hardware and software projects.



The Mechanical Department

John F. Lindberg

The Mechanical Department assumes responsibility for essentially all the mechanical workings of the experimental areas, including all the beamlines and experimental facilities. New physics projects are generally initiated in the Department, including concept design, design engineering, fabrication, and assembly. In addition, the Department supports other groups by carrying out maintenance operations. To a great extent, the target areas for all beamlines are designed, built, and maintained by the Mechanical Department. Radioactive handling is a Department responsibility and is carried out in a facility called the Target Service Building. Currently, this is the only dedicated radioactive handling facility at the Laboratory.

Though the major portion of 1988 has been a shutdown year for the Fixed-Target Program, a great deal of activity has taken place. Two intense efforts in process are support of the DØ test area in the Neutrino Area and the installation of E-760 Phase I and II in the Antiproton Source at AP-50. Experiment 760 Phase I was only a test; we are continuing with not only modifications to the Phase I detector, but ongoing design of the Pb glass calorimeter detector, Phase II. Phase I and Phase II detectors will be "married" for the late 1989 run.

Many modifications were and are being made in the Meson Area. The Meson Target Train was pulled and refurbished. Modifications to the MTest, MWest, MPolarized, and MEast beamlines were started and are continuing in these areas. Experiment upgrades are also in process. A new experiment (E-789) is being installed in the MEast line.

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The Neutrino target area has been reconfigured to support the new family of experiments in Neutrino. These include experiments in the NWest test beam (E-740), NK beam (E-782) and NEast (E-690). Tests of Zeus calorimeter modules are also scheduled to be carried out in Lab E. These modules will be used in HERA at DESY. NMuon-line modifications are complete and the beamline is ready to run.

A number of beamlines in the Proton Area (PWest, PEast, and PCenter) are undergoing major changes. Aside from beamline changes in PWest and PEast, the analysis magnets for these areas are also being completely reworked. The wideband beam, PBroadband, is undergoing some major construction changes which are scheduled to be completed in FY89. A new experiment on this beamline, E-683, is also being installed.

Special projects associated with the experimental areas are also a Department responsibility. The mechanical design and fabrication of a precise magnetic field measuring device, Ziptrack II, was completed this year. Tooling for the manufacture of scintillating fibers was designed and built in-house. An Advanced Computer Program tape drive and loading system is currently in design/fabrication with prototype testing scheduled for mid-FY89.

1988 ushered in a new engineering and design era for the Mechanical Department, with considerable effort being devoted to learning and applying ICEM computer-aided drafting to our work. The Laboratory as a whole will be switching from ICEM to IDEAS software sometime during 1989, so the Mechanical Department will continue to upgrade its skills in CAD and CAE.

The Site-Operations Department

Gregory Bock

The various groups of the Site-Operations Department (SOD) are responsible for much of the installation and support of the fixed-target experiments and the operation of the beamlines. While one SOD group (Alignment) has always had a much wider sphere of responsibility - being responsible for alignment and survey throughout the Laboratory - this past year saw the responsibility of the other groups in the Department also moving outward: helping electrical power and controls at the new Feynman Computer Center, assisting with the installation of the Loma Linda medical accelerator, and increasing our involvement in the support of the Collider experiments.

During the nine-month fixed-target run, the Operations Group ran the 15 beamlines to the 16 experiments, including test beams and areas for the CDF and D0experiments. The SOD support groups were doing their part to keep things running throughout while busily installing E-760 in the Pbar Source.

After the shutdown, many of the Operations support groups began working on projects directly related to the new EPICURE control system being developed by the E/E Department for the fixed-target beamlines. Operators helped construct, and began to operate, the new Ziptrack developed by the Research Facilities Department. Late in the year, this Group took on the responsibility for the on-shift monitoring and operation of the CDF HV system during the Collider run.

Other groups began similarly diverse activities, including readying plans for major new construction projects in the PBroadband beam and for a new beamline, NK, in the Neutrino Area. A major effort has been in the construction of the D0 muon chambers, requiring assistance from most of our groups - alignment fiducials, transportation and storage, assembly, and leak checking. Alignment control system work, including new automated field procedures and data base development, are already in early use for installations of major new beamline upgrades in the four Proton Area beamlines.

The site has had a face lift of painting, landscaping, and blacktopping. We completed our new office area at the Proton Assembly Building and moved in, consolidating three of our six locations around the Laboratory into one. We've made good progress in controlling water leaks in enclosures and roofs (yes, we know there are still some out there), and began to tackle the noise pollution problem in counting rooms. Ongoing safety inspections continued - we've nearly finished a systematic inspection and documentation of all the power panels in the experimental areas, and catalogued, tested, and documented all lifting fixtures.

At the beginning of 1989 we will be returning most of our efforts to the experimental areas. The new low-conductivity water cooling system for PBroadband and PEast will be finished soon. Major new experimental installations requiring large efforts include E-761 in the PCenter beamline, E-690 in the modified NEast beamline, E-782 in the new NK line, E-771 in the new PWest beamline, and E-683 in PBroadband. Upgrades to continuing experiments E-706/E-672, E-665, E-687, and E-704, as well as the test-beam areas, are expected. We are anxious to help make the next fixed-target run even more successful than the last.

The Research Division Safety Group

J. Donald Cossairt

The Safety Group is responsible for assuring that all activities in the Research Division comply with Laboratory safety policies in the most efficient manner possible. The emphasis in this Group is to support the safe performance of the experimental program. This work involves considerable interaction with all departments of the Division and with the Safety Section. An important element of the effort is to maintain a deep understanding of the experimental program and its goals through involvement with all facets, from conceptual design to completed project. Many safety problems are posed by modern high-energy physics experiments in the areas of fire protection, industrial hygiene, environmental protection, general industrial safety, and radiation safety. Often these hazards are present simultaneously and the solutions have to be carefully thought out in order to resolve conflicts.

During this past year a major effort has been undertaken to upgrade the fire protection systems in all experimental areas. The motivation for this is to protect the costly high-energy physics instrumentation from damage as well as to protect personnel. A new type of smoke-detection system called VESDA (very early smoke detection apparatus) is being installed in most of the experimental halls. This system passes air drawn from the building into the beam of an intense xenon lamp. Particulates such as combustion products are then detected by the reduced transparency of the air in the light beam. One such device can provide a reasonable degree of sensitivity for a large portion of a major experimental hall. Additional portions of this project include the installation of conventional smoke detectors and the introduction of automatic sprinklers in buildings which do not already have them. The Safety Group also participated in the development of improved flammable gas systems for experiments.

Efforts in the area of industrial hygiene and environmental protection continued in earnest this year. A number of problems associated with the R&D efforts of the Particle Detector Group of the Research Facilities Department were solved. Increased national interest in the area of environmental protection has had a corresponding effect upon our concerns and efforts dealing with hazardous- and special-waste disposal. Continuing efforts in oxygen-deficiency-hazard control this year involved the Group's participation in the upgrades to the fixed oxygen monitor system.

Industrial safety efforts continued in the form of numerous inspections, including many done with great success by the various department heads. Our efforts to control the fabrication of pressure vessels and cryogenic systems through the application of Laboratory engineering standards continued. Lifting fixtures and crane-load tests are monitored throughout the year.

In radiation safety, continuing efforts are made to keep abreast of program modifications in order to assure proper design of shielding and provision for appropriate radiation-safety interlocks. This involves much close work with the Research Facilities Department and the Electronics/Electrical Department. During the most recent fixed-target run, a large number of measurements of the muon radiation fields were made in collaboration with the Safety Section. The results were compared to calculations using the updated program of Van Ginneken, CASIM, with satisfactory results. Extensive measurements were carried out of the airborne radioactivity produced by the targeting of beams both in the fixed-target areas and, in collaboration with the Safety Section and the Accelerator Division, at the Pbar Source. These results, too, have been successfully compared with calculations and will further our understanding of such problems in future operations of the program.

Improvements in the radiation detector monitoring system are continuing. A major new project is that of supervising work with uranium in support of the DØ effort. Many procedures have been developed by the Accelerator Division to deal with the problems presented by this material. The transfer of this activity to the Research Division allows us to use the work done in the past as a basis for dealing with the ongoing safety concerns of the present with respect to the uranium work.

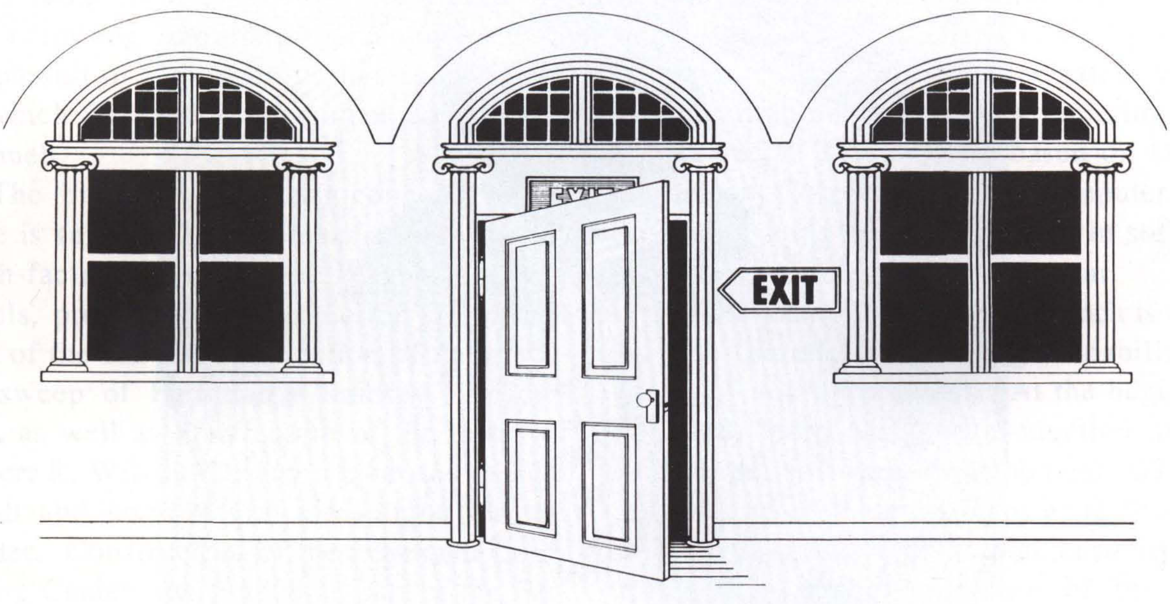
An important component of our safety program continues to be training. We train many individuals and groups in specific safety topics. Special instruction is provided to new employees as they join the Division. A good deal of informal training is done while conducting the many safety inspections and through the distribution of written materials.

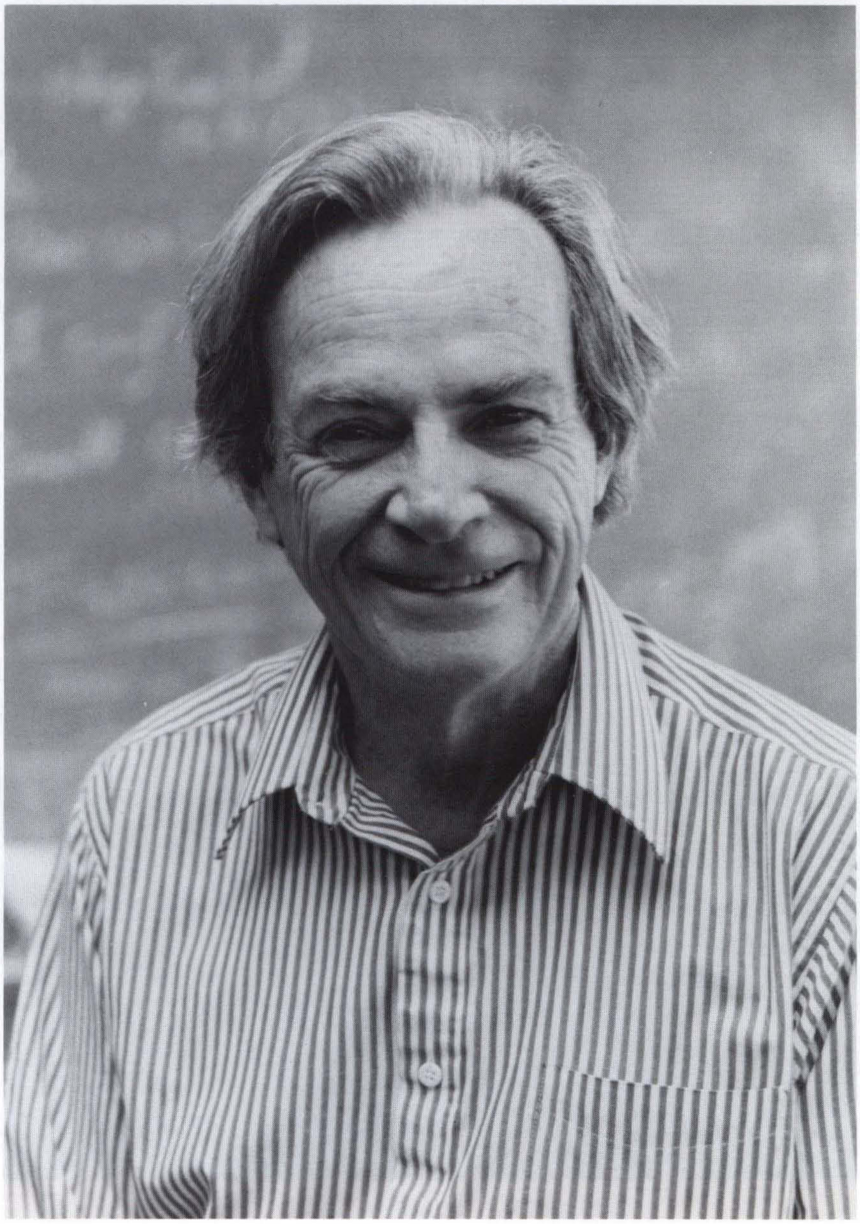
The Administrative Support Group

Barbara K. Edmonson

The Administrative Support Group (ASG) is comprised of the 22 secretaries and administrative assistants who serve the departments in the Research Division. In addition to their regular assignments members of the Group provided support for three major conferences during 1988: the 1988 Symposium on Lattice Field Theory: Lattice 88 at Fermilab in September; the IEEE Conference in Orlando, Florida, in November; and the Workshop on Scintillating Fiber Detectors for the SSC, held in the Chicago area in November. Members also serve as: Training Project Coordinator for oxygen-deficiency-hazard training, secretary to the Mass-11 Users' Group, member of the Lab Furniture Committee, and Emergency Floor Wardens.

As the ASG enters its third year as an organizational entity, the combined ability of its members to provide coordinated, standardized support to all departments in the Research Division continues to increase the efficiency of the Division.





Dedication of the Feynman Computing Center

Fermi National Accelerator Laboratory

December 2, 1988

The Computing Department

Jeffrey A. Appel

For the Computing Department, 1988 was a year of expansion: expansion of staff, expansion of physical space, and expansion of responsibility.

While people are the most significant part of the Department, the most visible expansion is the new Feynman Computing Center. The Center was dedicated on December 2, 1988. In attendance were members of the family of Richard P. Feynman, Nobel Laureate, inspiring teacher, and one of the most outstanding physicists of our age. The building is an elegant, three-story structure of approximately 74,000 square feet. It provides room for the growth necessitated by the increasing importance of computing to the pursuit of high-energy physics, the field to which Richard P. Feynman contributed so much.

The building's pre-cast concrete backbone is supported on a steel frame, as is the north-facing glass facade. The pre-cast panels provide both protection from the heat of the sun and a reflection of the graceful sweep of Fermilab's Ramsey Auditorium, as well as a reflection of the tastes of Robert R. Wilson, Director Emeritus of Fermilab and architectural consultant for the Center. Construction of the Feynman Computing Center was funded as part of the Fermilab Central Computing Upgrade Project, a Congressional Line Item in the federal budget.

The expansion of responsibilities of the Computing Department continues a trend of many years' duration. Nevertheless, the trend has significantly picked up steam in 1988. As early as the report by the Ballam Committee in 1983, it was recognized that Fermilab computing would need a significant infusion of manpower and other resources. At the same time, the amount and types of computing activity in the high-energy physics community generally increased beyond what was anticipated at the time of the Ballam Committee report. These factors underlie the Department's growth.

The central computing capacity was expanded by a factor of three in processing power. Possibly even more significant than this very large increase, is the fact that it was implemented within the framework of a new Fermilab computing environment. This environment provides a three-pronged approach to the computing problems of high-energy physics research. The first prong is a user interface and computer gateway connecting high-energy physics experimenters world wide. This system, based on Digital Equipment Corporation VAX computers, the VMS operating system, and rich in software tools, was doubled in size this year.

The second prong of this approach is based on the parallel processing capability of farms of microprocessors. At the beginning of 1988, there was one production system and three software development stations. By the end of the year there were four production systems with a total capacity five times that at the beginning of the year. These systems are dedicated to the reconstruction of raw data from the physics experiments at the Laboratory and require the existence of stable computer programs to be effective. The farms of microprocessors are based on the hardware and software developed by the ACP at Fermilab. The systems installed this year were all built with commercial components supplied by (mostly) local industry.

Providing flexibility between the front-end system and the microprocessor farms is the third prong, a large general-purpose scientific computer system. This year marked the introduction of a new architecture, selected as the result of a competitive acquisition for this system. We have installed Amdahl 5890 hardware and IBM VM operating system software. One of the most significant features of this large scientific computer system is the Interlink software and hardware which provides connectivity to the front-end computers in a truly transparent way. This provides a platform for users to set up flexible solutions to their computing needs, using both front-end friendliness and general processor power for later stages of analysis.

A great deal of effort has gone into bringing the system into useful productivity. These efforts had achieved significant results by the end of the year. One example is the first production use of ACP systems for offline analysis by the CDF collaboration. This followed intensive work to improve software development tools and speed, new capabilities to handle the much larger and complex CDF code, and introduction of more-powerful host processors for the microprocessor farms. Experiment 731, on CP violation in neutral kaon decay, has already submitted physics results for publication. These results are based on ACP analysis of the data taken in the 1987 fixed-target run.

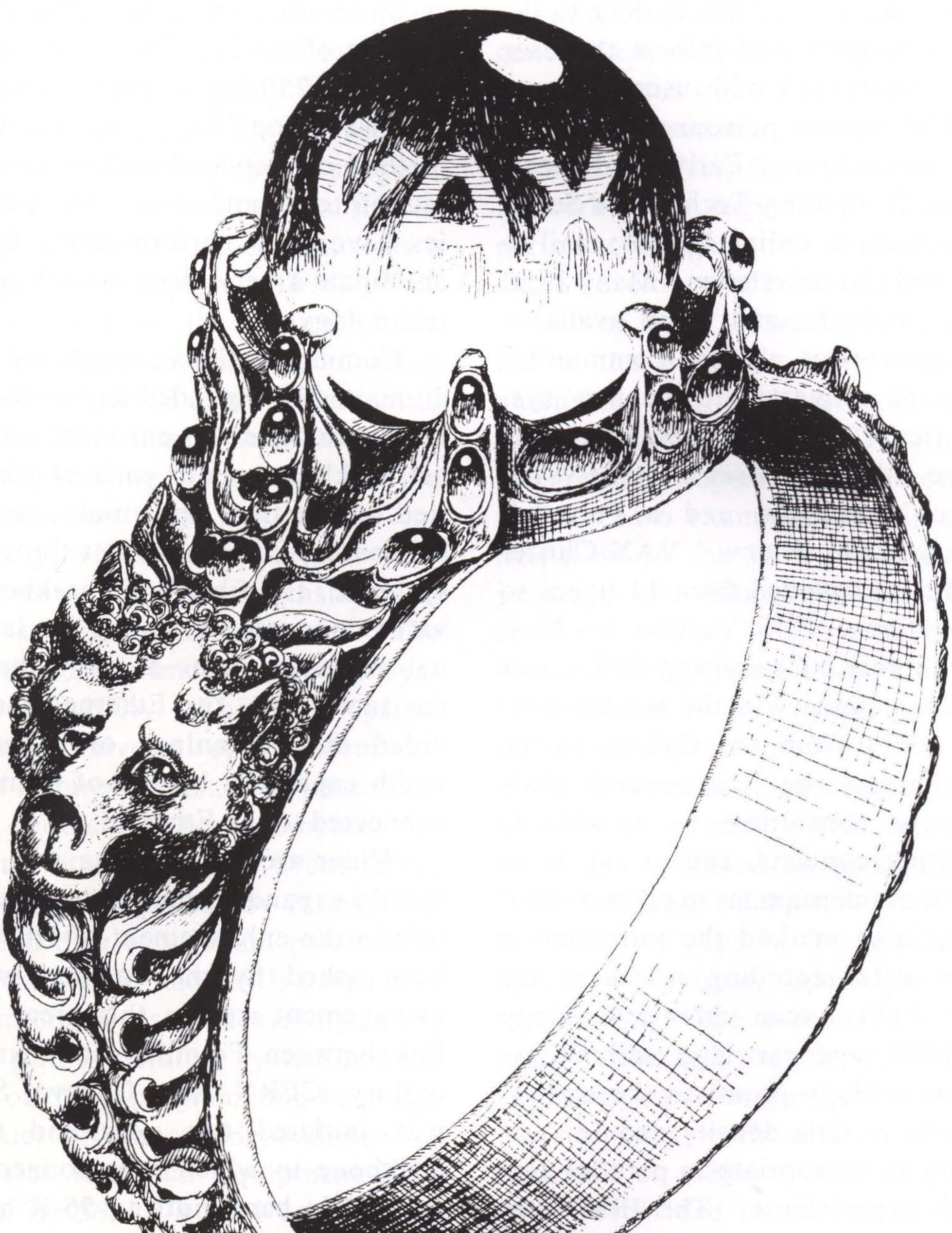
Most of the expanded capabilities described above were funded as a part of the Central Computing Upgrade Project, which also paid for the new Feynman Computing Center building. Additional funding for computing came from the equipment budget in the Department, but significant expansion of local computing was also funded by individual departments at the Laboratory. These individual department-level funds have been dedicated to the installation of local clusters of workstations. These clusters are then networked to other Laboratory systems. Computing Department support for these systems, however, goes far beyond communications systems. The Department has also accepted a role in system management and software support.

The Field Maintenance Group has installed 80 VAXstation 2000's and 40 VAXstation 3200's in the past year. Maintenance of these, as well as the VAX 11/780's on site, are new services provided by the Field and In-House Repair groups from their new quarters on the third floor of the Feynman Computing Center. Altogether, this new distributed computing is one of the biggest growth areas of Computing Department responsibility.

This year's personnel growth has been motivated in particular by the growing complexity of the distributed computing environment. The addition of the new large scientific computer, with its new operating system responsibilities, has had a more modest effect on growth. Most of the additional manpower required in this area was obtained by realignment of responsibilities in the operating systems groups. The older Cyber environment has been frozen and will be maintained for about two years to allow for the smooth migration of users to appropriate parts of the three-pronged approach to computing problems in the new Fermilab environment.

The arrival of the Amdahl system and its integration into the new Fermilab environment, however, was a big effort in the Department this year. The Department worked very closely with the user community, at first with a group of "Early Birds," to provide the environment neces-

VAX Cluster Users Guide



Fermilab Central Computing Facility

sary to convert and run physics analysis programs under the new VM operating system and to use the new Interlink connectivity effectively. Many sources of information were used to tune the system to the Fermilab environment and inform the user community: interviews with users; discussions with VM support personnel at CERN, SLAC, and Brookhaven; Early Bird meetings; classes; Computing Techniques Seminars; documentation; online NEWS; mail to AMDAHL; and the newsletter. Many local utilities and products, and some available from the high-energy physics community, were written or converted to the new system. Significant new documentation was provided: the "Amdahl User's Guide," the local utilities document, and a Fermilab VM Summary card. A new "VAX Cluster User's Guide" (expanded from 11 pages to about 250) reflects VMS Version 5. Near the end of the year a Consulting Office was opened. The impetus was the needed conversion of codes from the Cybers to the Amdahl computers, but the general goals are to improve consulting, to be able to track consulting contacts, and to cut down on the number of interruptions to other work.

This year also marked the introduction of two new data recording media at the Laboratory: helical scan video technology and IBM 3480 tape cartridge technology. The video technology promises the earliest major upgrade in data density and less expensive systems appropriate to parallel data recording in experiments. The IBM technology is targeted for use in the Computing Center where it also promises reduction in space required for offline data storage.

A video technology copy facility is part of the beginning of the new data recording media era at the Laboratory. Following significant test efforts, the 8-mm technology was selected for support. Many of the helical scan drives have been ordered at the Laboratory and by many university groups. The video media, small cartridges the same as those used in home video cameras, are capable of storing a dozen standard 10-1/2-in.-reel, 6250-bpi magnetic tapes' worth of data. The copy facility is intended first as a method of distributing data summary information to remote sites. The first such copies have been performed for CDF and we anticipate a very large growth in use of this technology.

Communications capability was also dramatically expanded during the year. The Laboratory site was enhanced with an Ethernet backbone, major parts of which are carried on the fiber optic links, connecting local coaxial Ethernet cables through bridging systems. The fiber optic backbone also provided connectivity among the largest terminal switch systems at the Laboratory. At the same time, the Ethernet backbone provided the beginnings of expanded bandwidth capability by use of terminal servers connected to the Ethernet.

Wider area networking was also significantly expanded. Fermilab played a leading role in the enhancement of HEPnet and has been asked by the community to take a management role in this area. A satellite link between Fermilab and our sister laboratory, CERN, near Geneva, Switzerland, was initiated this year and the HEPnet backbone to which it is connected was increased in bandwidth to 56-K baud. In addition, the Laboratory was connected to NSFnet, which is beginning to provide greater connectivity to the many National Science Foundation-funded research collaborations which have not already developed their own direct connections to the Laboratory.

The end of the fixed-target run, and startup of the Collider run, earlier in the year required a great deal of support work from the Department. The end of the Neutrino experiments meant a greater-than-usual load of electronic equipment turned in for checkout and redistribution. While the end of the fixed-target run also reduced the load on data acquisition computer support, the number of systems remaining active in the field beyond the end of the run was a new development this year. These VAX systems, connected to the central VAX Cluster, are providing additional computing during the interim period as a supplement to the very overloaded central VAX Cluster.

Far from providing a breather for the data acquisition software groups, the interim period provides an opportunity for software system upgrades and installation of new data acquisition architectures. The new Computing Department-supported system is called PANDA. This new system provides a more universal open-systems architecture. It features workstations networked to the data acquisition host computer for experiment monitoring, online event filtering in flexible microprocessor farms, and more front-end data acquisition parallelism using both FASTBUS- and VME-based systems. The microprocessor flexibility is the result of the pSOS operating system and the introduction of the C programming language for greater microprocessor independence.

The Physics Research Equipment Pool (PREP) grew by 5% to a total value in excess of $26 million. FASTBUS hardware is now 13% of the pool by value. Of the 6000 items which cycled through the Instrument Repair Group this year, 2800 were new items. PREP and the Instrument Repair Group also operate from the third floor of the Feynman Computing Center.

The use of these more complex electronic modules provides a maintenance challenge. New techniques and systems will be required. In anticipation of this, the Department has begun an Artificial Intelligence Expert System project to develop a test stand for one of the more complicated FASTBUS modules. In an even more futuristic project, the applicability of neural network technology for problems from experiment triggers to reconstruction algorithm development is being pursued.

All of these technology challenges have led to the need for better communication among the staff and user communities, and the attempt to leverage Department effort by greater cooperation with other laboratories. Two examples of this are the participation in the HEPVM community and joint software efforts with CERN. The first such joint effort is the production at Fermilab of an interactive version of MINUIT for inclusion in the Physics Analysis Workstation project.

Given the above expansion of activity, it is perhaps surprising that the Department has only increased its personnel by about 20% this year. Growth was dominantly in the areas of support for physics software, operating systems, operations, and communications. Because of this and anticipated continued growth, the Department's structure was reorganized from two into four domains, each with an associate head responsible. Several of the support groups were subdivided to allow for greater flexibility and better platforms for further growth. Such growth will be required to address the continued expansion of the role of computing in future high-energy physics research.

Members of the Advanced Computer Program in 1988 huddle amidst the equipment. Front to back: Carla Barros (a visitor from Brazil), Chip Kaliher, Mark Fischler, Arnaldo Valderrama, Joe Biel, Lisa Rauch, Mike Isely, Thomas Nash, Paul Lebrun, Thinh Pham, Hari Areti, Matt Fausey, Rick Hance, Mark Edel, Bob Atac, Ted Zmuda, Don Husby, and Art Cook.

The Advanced Computer Program

Irwin Gaines

1988 saw progress being made on three broad fronts in the ACP group. First, the original multiple microprocessor systems are assuming an ever-increasing role in the Fermilab computing environment. Next, a 16-processor prototype (with the computing power of a Cray XMP) of our lattice gauge machine was brought into operation. Finally, pieces of the second-generation ACP multiprocessor systems (MIPS development systems and Exabyte tape cartridges) began to be seen as we prepared to introduce the full-scale system in 1989.

By the end of 1988, there was more available computing power at Fermilab in the form of ACP systems than in any other form, as the size of the installed ACP systems had surpassed the Cyber, Amdahl, and VAX Cluster. This processing power was distributed over five production systems actively engaged in experiment-data reconstruction (with a sixth system scheduled to be added in early 1989); five development systems for code compiling, testing and debugging; and several online systems, including CDF's Level-3 trigger. Planned expansions will bring the total ACP processors at Fermilab to over 500 in early 1989. Ten fixed-target experiments have used these systems, and CDF production was also running (although not without some difficulties in getting started).

The Computing Department had taken over virtually all support for the first-generation ACP systems by the end of 1988, including system installation, hardware maintenance, system and application software development, and user support. The ACP group continued to help out where our expertise was needed, most recently in helping to train Computing Department techs in ACP-system assembly and maintenance, and in writing a new traceback and post-mortem dump facility for easier code development.

In spite of its successes, the initial ACP multiprocessor system is recognized to have some inherent limitations. First, it is based on five-year-old technology, in particular the Motorola 68020 microprocessor. Newly available commercial processors make it now possible to assemble even cheaper and more powerful systems. In addition, the relatively primitive system software available for the 68020 systems has proved to be a burden when porting extremely complex programs, such as those of CDF, to the ACP environment. Fortunately, the newer processors are accompanied by much more robust operating system environments, insuring that the newer ACP systems will not be subject to the limitations of the first-generation systems.

1988 saw the start of two new ACP systems: the lattice gauge supercomputer and the MIPS-based second-generation multiprocessor system. The lattice gauge supercomputer is a collaboration between the ACP and the Fermilab Theoretical Physics Department. Described more fully in last year's annual report, it is based on both a new processor board and on a new interconnect scheme. The processor board is based on Weitek's XL chip set, a three-chip processor which executes C and FORTRAN programs and can achieve peak floating point performance of 20 MFLOPS (20 million floating point operations per second). The interconnect scheme uses the newly designed Bus Switch Backplane, a 16 x16 crossbar switch allowing aggregate data bandwidths of 160 MByte/sec. Both the processor board and the backplane were successfully prototyped during 1988, and by year's end a 2-crate, 16-processor system with the computing power of a Cray X/MP was running lattice gauge applications.

Another crucial piece of the lattice gauge project is the CANOPY system software, which allows users to prepare application programs to run on the machine without needing to know any of the hardware details. CANOPY allows the user to express the problem using the natural concepts of grid, sites, field variables at each site, and tasks that are performed for all of a set of sites. Synchronization and intersite communication tools are also provided. This system also became fully operational during 1988, and is now in use preparing and running applications on the 16-processor system.

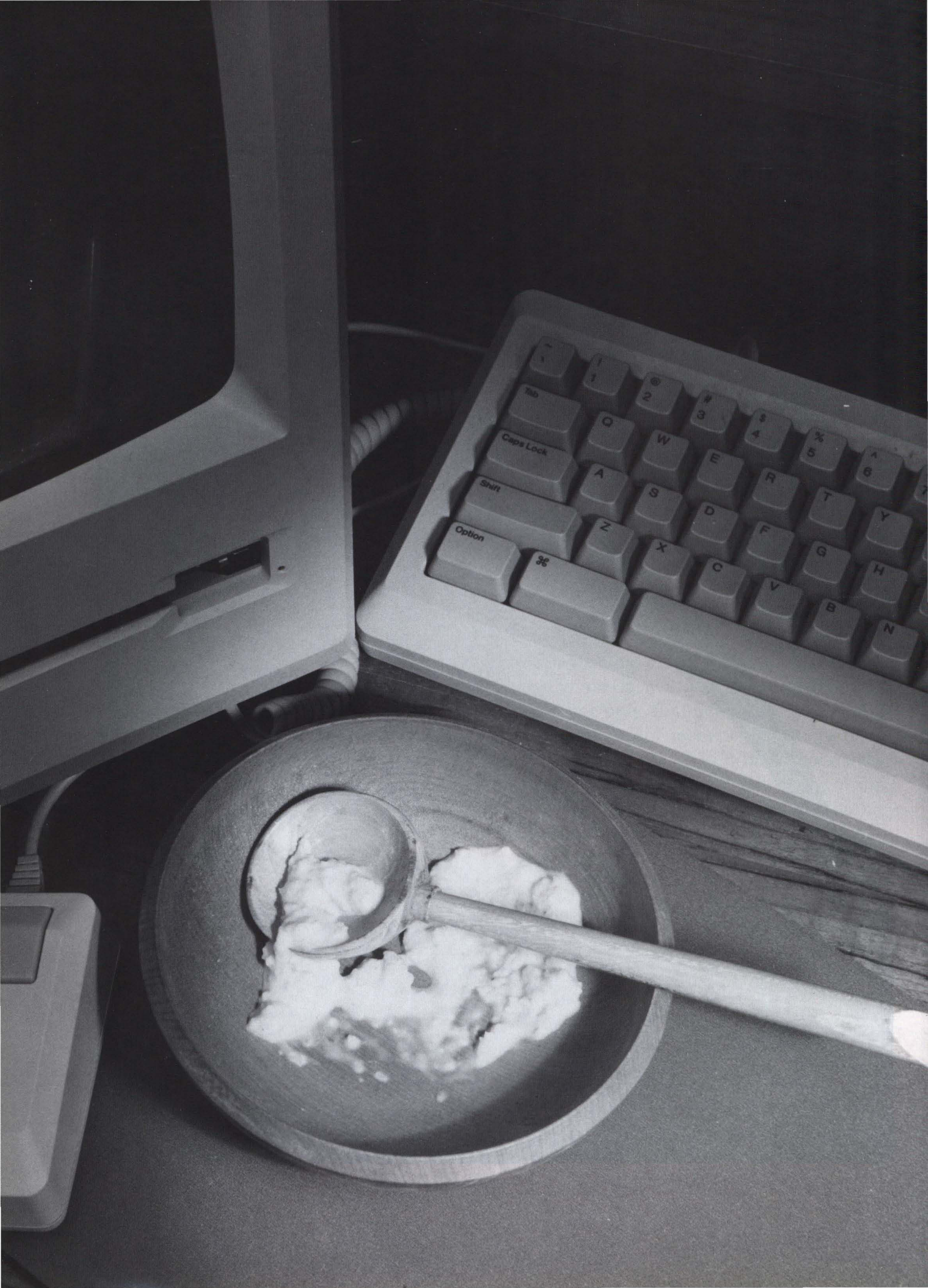
The goal of the lattice project, of course, is not the small prototype system, but rather a full-scale, 256-processor, 5-GigaFLOP system. Encouraged by the success of the small-scale system, we are going ahead with the construction of the full system. Subject to the availability of funds, it should be completed this year and will immediately make Fermilab a world leader in lattice gauge calculational capability.

The second-generation multiprocessor project also involves a new CPU board, but in addition includes a powerful new software package that will make the new system much easier to use than the first-generation system, especially in the area of program development and debugging. The CPU board uses the R3000 processor from MIPS. This chip set (which has also been chosen by Digital Equipment Corporation for use in their new high-performance workstation) has been benchmarked as a factor of 20 times more powerful than the first-generation CPU's. The board will include a floating-point co-processor, instruction and data caches, 8 MBytes of memory, a full VME master and slave interface, and a memory expansion bus allowing expansion up to 32 MBytes of memory.

Design of the board was almost complete by the end of 1988, with prototypes expected in early 1989 and crates of these powerful new processors being available for use by summer. Several MIPS development systems are already in place at Fermilab, allowing users to begin porting their application code to the MIPS processor.

These CPU boards will run the UNIX operating system, which provides a robust environment for program development as well as the framework for the second-generation software. This software gives the user a set of tools (message passing, remote subroutine calls, and data block transfers) for use in multiprocessor systems, allowing not only first-generation-like applications but also more complex parallel programs. The use of TCP/IP network standards will allow any workstation or processor running either UNIX or VMS to be incorporated for use in the multiprocessor system. Moreover, the availability of UNIX in the processing nodes allows any node in the system to do input/output and other functions which were reserved for the host CPU in first-generation systems. The software package is nearing completion, with users starting to test multiprocessor applications in early 1989.

Other pieces of the second-generation ACP systems are also beginning to be widely used at the Lab. Notable are the Exabyte 8-mm video tape devices, which were originally investigated as a way to achieve cheap parallel input/output to match the high computing capabilities in second-generation systems. These tapes have now been adopted as a standard by the Computing Department [see previous article], and will also see use in data acquisition systems in the next fixed-target run.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The Physics Section

Daniel R. Green

"A monk told Joshu, 'I have just entered the Monastery, please enlighten me.'

Joshu asked, 'Have you eaten your rice porridge?'

The monk replied, 'I have eaten.'

Joshu said, 'Then you had better wash your bowl.' "

Zen Flesh, Zen Bones, P. Reps
Anchor Books, New York

The year just passed has been momentous. We had a very fruitful fixed-target run, and are in the midst of a spectacular Collider run (integrated luminosity of better than 1 pb^{-1}). The task for the next year is to clean up our bowl and prepare for enlightenment. Indeed, these two data runs will serve to begin the realization of the physics potential of the TEVATRON Collider, and will make Fermilab the nexus for high--energy physics. The experimenters have been well served, and we eagerly await the harvest of publications.

The fixed-target run supplied beam to about 15 experiments. The Physics Department had major construction and installation responsibilities for nearly all of them. That run lasted nine months until its completion in mid-February of 1988. After a pause for TEVATRON magnet repairs, the Lab shifted gears and went into a colliding-beams run which continues at the time of writing. The hope is to shift the frontier of $\bar{p}p$ collider physics across the Atlantic and win the race to find the top quark. The Accelerator has performed marvelously, delivering luminosity far in excess of what was expected. The Physics Department's job in Collider mode is to provide support for two of the small Collider experiments, E-710 and E-735, as well as partial detector construction responsibility for DØ (E-740) which, it is hoped, will take data during the next (1990) Collider run.

The Physics Department continued throughout the year in its normal mode of supporting Fermilab staff physicists in their research efforts. In general, this is the task of the Department. In particular, the engines of that support are the postdocs. Unfortunately, the number of postdocs and Wilson Fellows has levelled off at about 25. However, the implication of continuous data taking, coupled with analysis times which exceed the duration of data collection, is that we need more postdocs to staff the next round of experiments. Given this realization, we intensified the recruitment of the best new Ph.D. physicists with the aim of increasing our steady-state number from 25 to 35. To date, we have not succeeded in attaining this goal. Besides their major role in doing physics, the postdocs often naturally move up into Fermilab staff jobs after an average of about four years. This infusion is crucial to the health of the Laboratory and is perhaps the top priority of the Physics Department.

The other 70 people in the Physics Department - engineers, technicians, drafters, and scanners - are more permanent. They have as their mission the direct support of physics research at Fermilab. To that end, the Department is organized into support groups. The Electronic and Mechanical Support groups supply the engineering, design, and construction of experimental apparatus. During the last year, the Mechanical Group has adopted the Lab-wide standard CAD program, IDEAS. The Electronic Support Group's professional staff has expanded to three engineers this year. The FEWG project (Front End Working Group) is a joint venture with the Research Division to provide fast and cheap analog-to-digital converters (ADC) and time-to-digital converters (TDC). It is similar in spirit to the previous joint venture which resulted in the Fermilab Smart Crate Controller. The design responsibility for the ADC and TDC resides in the Physics Department. The engineering staff is now conversant with CAMAC, VME, and FASTBUS. Finally, the electronics production staff is now entirely converted to personal-computer electronic design tool, PCAD.

After the engineering and procurement has been done, detector construction proceeds at the production facilities staffed by the Physics Department. These "Task Groups" reside in Lab 6 (chambers), Lab 8 (calorimeters), and the Wilson Hall basement (Scintillator Shop and Vacuum-Deposition Facility). Last year we hired a senior person to run the Wilson Hall shop, and expanded the staffing, thus turning it into a full-fledged facility. A Task Group is also supplied to the major new experiments. Last year, we set up Lab 3 (E-760), and purchased a spectrophotometer in order to test their lead glass. The D0 Task Group continued their efforts this year, capped by the successful rigging-in of the first muon detector. The Lab 6 Group is also doing some R&D work on scintillating fibers (L3) and a time-projection chamber (E-665). This Group also recently inaugurated an automated PC-based source tester for chambers (with E-683).

The completed detectors leave the factories to be installed in experiments. To that end, each experiment has assigned to it a Lead Technician whose job it is to expedite the installation, running, and repair of that experiment. These people are our front line - right in the trenches. With the recent contraction of the Neutrino program, the Department can now assign each experiment a unique Lead Technician without double counting. These technicians are there to ensure Departmental support of the data-taking phase of an experiment.

This year there was a shift in emphasis from merely getting experiments ready to analyzing the flood of new data from the last fixed-target run. This aspect of an experiment gets support from the Data Analysis Group. First, that Group staffs the Film Analysis Facility. This facility consists of four scanning/measuring tables controlled through CAMAC by a VAX780. This last year, the obsolescent and unreliable electronics associated with these tables was entirely redesigned and rebuilt. We are busily analyzing data from the film-based experiments E-632, E-665, E-733, and E-745.

Another, more recently organized aspect of the Data Analysis Group is support for experiments which are not film based. The first line of support comes in supplying Data Aides for E-665, E-687, E-705, E-706, and E-769. The role of these Aides is to submit analysis jobs, organize and label tapes, and keep statistics. The paradigm is the success of the E-691 data analysis efforts.

The second line of support came this year when PLAC (Physics Local Area Cluster) was conceived and built. The Film Analysis VAX 780 was used to talk to the main Fermilab cluster. The 9th and 10th floors of Wilson Hall were wired up in Ethernet. Finally, a number of workstation packages was purchased. Each workstation package consists of a μVAX3200 workstation plus an EXABYTE 8-mm tape drive, with a large WREN disk drive. At present we have six workstation packages, and many software products are installed. The concept is that each major Fermilab experiment will ultimately have its own PLAC workstation. What comprises a workstation will clearly evolve as new equipment is purchased in the future. Additional benefits come from putting the Mechanical Group's CAD stations on a PLAC workstation with IDEAS resident there, thus greatly improving the response time.

In an attempt to create a synergistic "critical mass," office space for experimenters and Guest Scientists is provided on the 9th and 10th floors of Wilson Hall. Other tools which are supplied are terminals, stand-alone PC's, software, and laser printers. The Department has a small cluster of MAC's and MAC II's connected by APPLETALK to printers. The staff contributes secretarial services, word processing, and figure drafting for aid in publication of papers. This year the departmental office became involved in conferences by helping the Users Office with the Polarization Conference, and organizing the Particle Identification Symposium. Travel funds for conferences, workshops, and group meetings are also provided. This year we enlarged and completely renovated the Departmental 10th Floor Conference Room, and constructed an electronic-mail list of all Fermilab Physicists. This list has many uses. For example, the Department sends out E-Nalcal, the daily list of colloquia, seminars, meetings, and workshops, to all those on the list who wish it. This service is handy for those living in areas not serviced rapidly by normal mail.

The Department maintains subscriptions to several journals and periodicals, which are displayed in a "Reading Room" to encourage experimentalists to keep up with the literature. The Physics Department also sponsors the Fermilab Wednesday Colloquium. As in the past, Academic Lectures are organized by the Physics Department. Their purpose is to provide university-style lectures to the graduate students and postdocs who are resident at the Laboratory but working for collaborating universities. In a more informal atmosphere, the Physics Department organizes a monthly "Food for Thought" dinner whose purpose is to bring together postdocs in experiment, particle theory, accelerator, and astrophysics. These same experimental high-energy physics postdocs aid in the highly successful Saturday Morning Physics Program for high school students.

The year 1988 saw a shift toward the analysis of data. As Fermilab becomes a steady-state producer of TEVATRON-era physics, an equilibrium in the support functions of the Department will be reached. For example, we have several new experiments: E-683, E-704, E-760, E-761, E-771, E-773, E-774, E-781, E-789, and E-791. Simultaneously, the older experiments need operational support and we need to help experimenters put the data taken in 1987 and 1988 into publishable form. Clearly, as long as Fermilab is doing physics, the Physics Department has a well-defined job to do.

Superconducting Super Collider dipoles under test at Technical Support Section's Magnet Test Facility.

The Technical Support Section

Paul M. Mantsch

Magnets for accelerators, and superconducting magnets in particular, play an essential role in high-energy physics research. The Technical Support Section (TSS) was originally organized to build the more than 1000 superconducting magnets required for the TEVATRON. Later a similar number of conventional magnets were built for the Pbar Source for the TEVATRON Collider (TEVATRON I) and for the high-energy beamline upgrade for the fixed-target experimental areas (TEVATRON II). Once these projects were completed, staff was sharply reduced and activity was confined largely to repairs and spares, shop services, and small-scale fabrication. More recently, participation in the SSC program included the design of the dipole cryostat, and assembly and testing of magnets delivered from BNL. The development of superconducting magnets was pursued on a very low level.

A comprehensive program to upgrade the TEVATRON together with a decision in 1987 to build complete SSC dipoles at Fermilab, however, has had a dramatic impact on Technical Support. Nine physicists and engineers have been added to the staff to strengthen superconducting-magnet R&D, fabrication, and testing. In support of this new level of activity, designers and technicians have also been added. The total staff (including term hires) increased from 316 in January 1988 to 352 at present. Instruments for R&D and magnet testing have also been upgraded. Improved analytical tools, both hardware and software, for magnet structural design have been procured, a more powerful CAD system has been installed, and new machines and techniques for automated machining and inspection have been acquired.

Greatly strengthened both in talent and in resources, the Technical Support Section is taking on the tasks of helping to insure the best possible physics program for Fermilab and a successful magnet for the SSC.

The TEVATRON Upgrade

The proposed program of upgrades to the TEVATRON begins with luminosity enhancements for the Collider and ends with an energy increase of a factor of 1.8 or more. This upgrade will rely on Technical Support for both conventional and superconducting magnets.

The first step in this program, high-gradient quadrupoles for low beta at the B0 and D0 collider detectors, is under way. The next step is a new Linac. Following the new Linac, a new 120- to 150-GeV Main Injector will replace the old Main Ring and will occupy a new tunnel. Although many components of the old Main Ring will be used, magnets of a new design will be built. Finally, a new TEVATRON ring will be installed in the main tunnel. The magnets for this ring will be designed to ramp to 6.6 tesla (1.5 TeV) for fixed-target running and up to 8.8 T (2 TeV) at reduced temperatures for Collider operation.

Low-Beta Quadrupoles

The program to produce high-gradient quadrupoles for the B0 and D0 interaction regions was started a little over two years ago. The objective is to have the quadrupole lenses and associated optics in place for the first run of the DØ collider detector in late 1990.

The program required the development of two new magnets. The first was a high-gradient quadrupole (1.4 T/cm) and the second a low-current "corrector" (0.7 T/cm). For comparison, the gradient of a standard TEVATRON quadrupole at 1 TeV is 0.7 T/cm.

The high-gradient quadrupole design is characterized by cold iron, high current density, precision conductor placement, and fully supported constant perimeter ends. Three test models of the coil for this design have been built and tested. The cryostats for these quadrupoles use the design concepts developed at Fermilab for the SSC. Cryostat models are also being built.

The quadrupole corrector features a one-shell coil and "cable" made up of five separately insulated, rectangular monolithic conductors. Subsequent to winding the coil in the normal way, the conductors of each cable are connected in series to achieve a quadrupole with an operating current of a little over 1000 amps, i.e., five times less than a magnet using the standard Rutherford-style cable. The first model of this magnet is being assembled.

Production winding of the first of the low-beta quadrupoles is now under way. The goal is to have all of the magnetic elements completed in early 1990.

The New TEVATRON

Preliminary planning for a new superconducting ring took place at the 1988 Snowmass Summer Study. A dipole of 3-in. aperture operating at about 4.2 kelvin can achieve a field of 6.6 T with a reasonable operating margin. At 6.6 T the stresses seen by the new coil are already 25% higher than those seen by the TEVATRON at operating field. Magnets of this aperture and performance for the HERA ring at DESY have been successfully demonstrated.

For higher fields it is necessary to reduce the temperature to about 1.8 K. If the magnet is structurally sound, it can reach 8.8 T with some margin. Here the coil stresses are about 17 Kpsi, or 2.4 times those of the TEVATRON. To insure that the necessary coil loading can accommodate the magnetic forces, the coils must be cured and collared at stresses substantially in excess of 17 Kpsi. The strength requirements of the insulation, the cable, and the collar structure necessary to support these stresses are very demanding. It has also been determined that removal of heat from ramping losses in fixed-target operation is not practical at 1.8 K. Field levels of 8.8 T would therefore only be possible for Collider operation.

Design work on these magnets is under way. This effort will take maximum advantage of the lessons of the TEVATRON as well as the wealth of data taken on the performance of the SSC-model magnets.

The Superconducting Super Collider

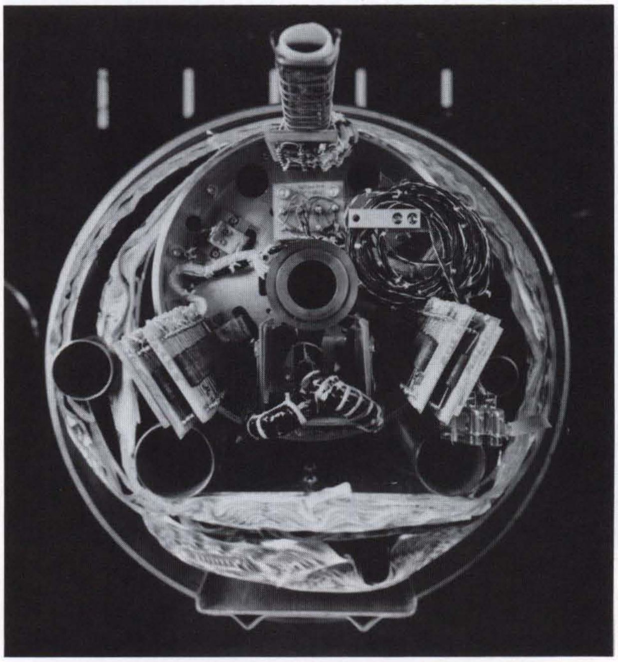
When the SSC research and development program began in earnest in 1985, Fermilab was assigned the task of developing a suitable cryostat for the coil/cold-mass assembly to be built at Brookhaven. Fermilab was to assemble the cryostat around the cold mass and test the completed magnet on specially built test stands at the Magnet Test Facility (MTF).

Fermilab successfully completed the first-generation cryostat in time for the first cold mass to arrive from BNL in the summer of 1986. The very-low-heat-leak cryostat design features a folded post support using glass and carbon fiber composites, an effective radiant heat shield system, and a simple and continuous magnet-to-magnet interconnection. In 1988, a second-generation cryostat of simpler construction and improved performance was successfully tested. The cryostats have performed well on every magnet built to date.

Also in 1986, modifications were undertaken to MTF to accommodate full-length SSC dipoles. One TEVATRON stand was converted in 1986 and a second was commissioned in early 1988. The second stand has an improved design and will allow the magnet to be operated at superfluid helium temperatures (1.8 K).

Since June of 1986 a series of eight coil assemblies have been delivered to Fermilab. The first several magnets exhibited poor performance. The first four suffered from erratic quench performance. The fourth, D000Z, failed from a coil short during tests. To date only the first magnet in the series has had magnetic measurements.

Poor quench performance of these early magnets resulted in the addition of increasing numbers of diagnostic instruments to subsequent magnets. These sensors included strain gauges, voltage taps, temperature sensors, and deflection gauges. All of this led to costly and time consuming modifications to the Magnet Test Facility. What had been intended to be a facility for cooling magnets for magnetic measurements evolved into an elaborate program to analyze and understand the poor quench behavior of the magnets.



SSC cold mass end.

In light of the difficulties with the long magnets, Fermilab proposed to develop a second set of full-length tooling based on the proven design used for the TEVATRON. The tooling consists of full-length curing and collaring presses and a full-length press for applying the yoke and helium containment skin. This tooling will provide high-precision coil sizing and uni-

SSC cryogenic support post.

formity for better magnet performance and reliability. The tooling design also incorporated features for improved production efficiency. This effort was just getting under way when it became necessary to divert funds to MTF to accommodate the massive instrumentation installed on the latest SSC magnets. As a result, the dipole tooling effort was suspended for six months. In August of 1988, tooling work resumed.

The original intention of the Fermilab magnet fabrication effort was to use the existing design directly and improve its performance by using more precise tooling, better molding and collaring techniques, and quality-control methods developed for the TEVATRON. As time went on it became clear that significant weaknesses remained in the basic magnet designs both at Lawrence Berkeley Laboratory (LBL) and Brookhaven. Particular problem areas include: end geometry and support, coil preload, creep sensitivity, coil mechanical support, and vertical field plane stability. All of these problems had been successfully addressed in the TEVATRON or in refinements applied to the Fermilab low-beta quadrupoles.

It was necessary to decide on the configuration that would ensure a successful magnet could be built at Fermilab. At operating field the SSC dipole coils are subjected to stresses similar to those of the TEVATRON. The difference in fabrication difficulty must then come from the smaller coil radius of the SSC. The SSC radius is a little over half that of the TEVATRON. The radius has little effect on the difficulty of obtaining a precise and well-supported geometry in the body of the coil. The end, however, is more difficult because of tighter bend radii and the potential for higher cable stress. The first change proposed by Fermilab to the existing coil design, therefore, was an improved end design that fully supported the coil, reduced the number of parts, and minimized the internal cable stress as well as the possibility of turn-to-turn shorts. These constant perimeter/minimum stress ends require that an analytical description

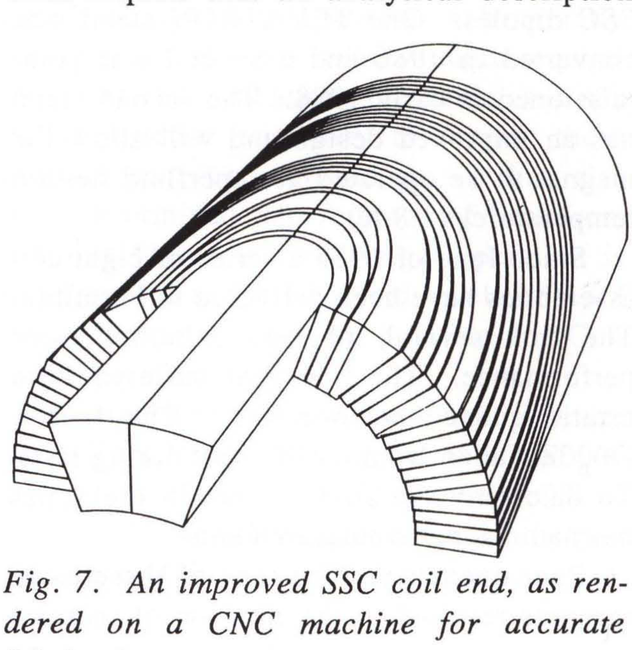


Fig. 7. An improved SSC coil end, as rendered on a CNC machine for accurate fabrication.

of the coil geometry obtained by the constant perimeter requirement be transferred to the CAD system to construct the complex end-support pieces and spacers. The CAD-specified parts are converted to computer numerically-controlled (CNC) tool paths which are used to machine the necessary parts (Fig. 7). The first of the ends using this technique have been successfully fabricated on an LBL-style coil.

Besides the end modifications, various schemes for supporting the collared coil with the yoke are being examined. Once the appropriate yoke configuration has been selected, the yoke/collared coil will be preloaded by pressing and welding the two halves of the helium containment skin over the coil/yoke assembly. Once these and other modifications have been thoroughly proven on short (1.8 m) models, the final design will be transferred to the long tooling for full-length magnet fabrication.

The shakedown of the long tooling is expected to be complete around mid-1988. Tests of design modifications on short models and the final specification for the magnet is expected about the same time. Completion of the first cold mass is expected before the end of 1989.

A highly reliable magnet design is crucial to the success of the SSC. It is hoped that in bringing Fermilab's experience, and the TEVATRON experience in particular, to bear on the SSC dipole design and fabrication, a successful and reliable magnet can be made.

Conventional Magnets for Accelerators around the Country

The unique capabilities in Technical Support for the fabrication of magnets for accelerators attract requests for assistance from around the country. During 1988 about 80 conventional magnets were built for various projects.

Magnets for Oak Ridge and LBL

A 25,000-lb prototype magnet for a heavy-ion storage ring at Oak Ridge has been completed and shipped. Prototype cores were built for magnets for a synchrotron light source at LBL.

The Loma Linda Medical Accelerator

The Technical Support Section is fabricating magnets for this new proton-therapy synchrotron as part of a cooperative effort between Fermilab and the Loma Linda Medical Center [see J. Richie Orr's article elsewhere in this report]. The ring and beam extraction magnets have been completed.

The Cutting Edge

The TEVATRON upgrade, SSC, and other challenges demand design, fabrication, and testing tools that complement these tasks.

Engineering and design capability has been recently enhanced by the installation of a more powerful CAE/CAD/CAM package called IDEAS. The TSS/Material Development Group provides Laboratory-wide training for these tools.

The Machine Shop upgrade passed another milestone with the addition of a third CNC milling machine. This will bring the total number of CNC machines to five. Each month the power of these machines is used to solve new problems. Recently, for example, a model accelerating cavity for the Linac upgrade was machined by the Mazak CNC lathe to the required precision in the first pass. The shop was able to verify this precision with their recently acquired coordinate measuring machine.

The quality control/inspection lab of the TSS/Material Control Group has recently acquired a new larger coordinate measuring machine with direct computer control. The demand for such precision measuring machines is constantly escalating. All the magnet projects use laminations in tooling, support collars, and in yokes. Measurement of laminations is necessary for the verification of stamping dies. Timely measurement of incoming parts both from local shops and from shops off site is also critical to the fabrication programs.

Reflections

The TEVATRON Collider is a remarkably successful instrument for high-energy physics. Troubles with the SSC magnets have, indeed, demonstrated how truly remarkable this first large superconducting accelerator really is. The skills that made the TEVATRON possible, and the experience gained in its construction, are still firmly in place at Fermilab. Bright young people who have recently come to Technical Support will help reawaken the spirit of the TEVATRON to ensure success in the projects before us.

The Safety Section

Larry Coulson

Regulatory Experience

The past year was marked by a flood of new Department of Energy orders and draft orders, primarily in the areas of environmental protection, hazardous waste, and ES&H (environment, safety, and health) budgeting. Therefore, much of the Safety Section's (SS) staff time has been taken up with reviewing and commenting on draft orders, preparing plans, implementing new orders, and preparing the many forms of ES&H budgets requested. DOE appraisals in the areas of health physics, industrial hygiene, occupational medicine, and safe packaging operational review all rated Fermilab as "excellent." We were rated as "good" in the areas of industrial safety, fire protection, and emergency preparedness.

Fire Protection

One way to minimize potential fire loss is to control avenues of spread. In high-energy physics labs such as Fermilab, cable runs have been a major concern in this area (highlighted by the major fire which occurred last year in the Wideband Lab). It was already known that vertical cable runs present an important means of fire spread, but little was known about horizontal runs. In order to assess the fire-spread hazard from horizontal cable runs, Fermilab undertook a series of test burns which mimicked cable-tray configurations and cable mixes typical of those existing in underground tunnel enclosures and support buildings at the Laboratory. The tests were designed very conservatively, with a heat source more intense and prolonged (up to 60 minutes) than any real source which could be identified. In general, fire would not propagate in horizontal cable trays. Power, PVC, and planar "twist 'n' flat" cables could not be ignited, or else rapidly self-extinguished when the burner was turned off. Only polyethylene insulated "Hardline" coaxial cables and flat-ribbon cables supported propagation, but at an extremely slow rate (less than two inches per minute). In addition, gas pressure built up in the hardline cables and caused periodic rupturing of its aluminum casing resulting in a loud popping, fireballs, and heavy smoke. Temperatures measured within and outside the cable bundles indicated that automatic sprinkling systems would not be actuated reliably. Intumescent paint applied directly to the cables was found to effectively stop both horizontal and vertical propagation.

NIOSH Radiofrequency Survey

Fermilab uses radiofrequency power to accelerate particles in the Linac, Booster, and Main Ring accelerators. Although electromagnetic fields are well-constrained to the interiors of these devices by operating parameters, there was concern that a small fraction of this power may be radiating into adjacent occupied locations at intensities exceeding exposure guidelines. Monitoring conducted by Lab personnel suggested that exposures were probably within acceptable limits. However, these results were questionable due to limitations in the instrumentation and inexplicable behavior in the intensity as a function of location.

In order to clarify this potential problem, Fermilab requested a health-hazard evaluation from NIOSH (the National Institute for Occupational Safety and Health). This organization was also interested in evaluating radiofrequency fields at a particle accelerator and they agreed to conduct the evaluation. None of their measurements exceeded accepted guidelines. The highest field strength values were 3000 V^2/m^2 and 0.024 A^2/m^2. Both of these occurred in highly localized areas of the Linac and represent 40% and 45% of the appropriate 200-MHz standard, respectively. They found no detectable radiation in the majority of their surveys (less than 40 V^2/m^2 and 0.001 A^2/m^2).

Occupational Injuries

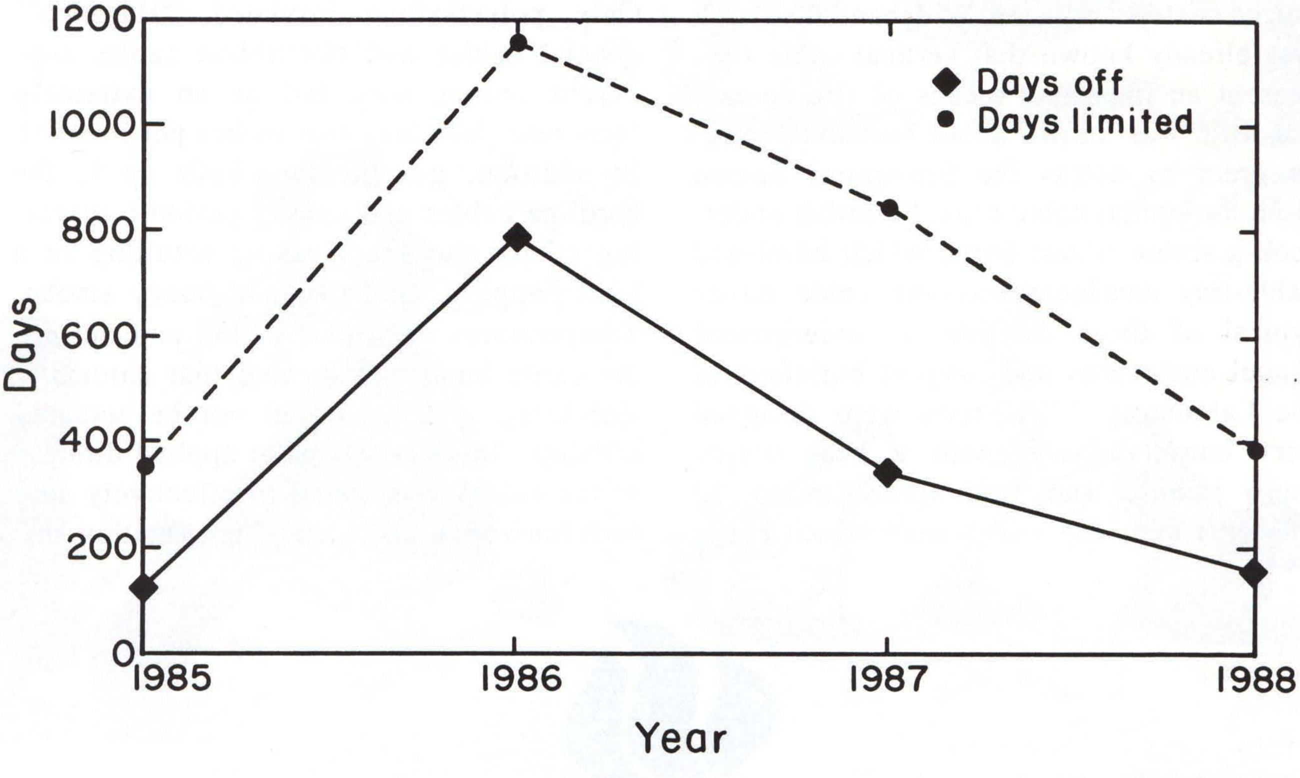


Fig. 8. Number of days off and days of limited duty from occupational injuries for Fermilab employees, 1985 - 1988 (values through 1988 extrapolated).

Figure 8 shows the number of days off and days of limited duty from occupational injuries experienced by Fermilab employees over the past several years. Values for 1988 have been extrapolated beyond the time this report was drafted to the end of the year. Fermilab's record continues to improve and the lost work-day rate (days off plus days limited per 100 person-years) for 1988 is down to 25. Although this rate is significantly worse than the average for all DOE research contractors (15), it is also better than that for all U.S. workers (66).

Figure 9 shows the 1988 injury costs as a function of the part of the body affected. The kinds of accidents which occur at Fermilab are typical of those that would be encountered in any light-industrial facility and not from unusual, high-tech hazards. Back injuries, predominantly from overexertion, continued to account for more of the cost than any other type (31%). Finger injuries came in second with 27%. Most of this loss resulted from two "serious" finger injuries, although there were also many routine "suture" cases as well.

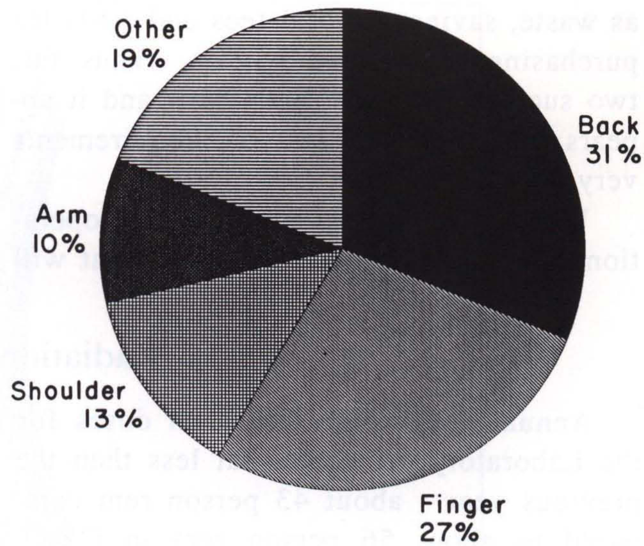


Fig. 9. 1988 injury costs as a function of the body part affected.

Emphasis on back-injury prevention continued with predisposition screening of all employees obtaining medical exams, as well as back-care training of exposed employees. Costs from back injuries dropped significantly over the past year and it may be that this program is beginning to bear fruit.

Radioactive Waste

As mentioned in last year's annual report, Fermilab has been actively engaged in a sorting and screening program since January 1987, resulting in a significant reduction of radioactive waste sent to the burial site. In addition to this, a program to utilize the low-level activated metal material in the production of usable shielding was initiated. The results of this program have been equally gratifying. In the past 2-1/2 years, we have built six shielded storage facilities with a combined volume of 20,000 cubic feet and we are currently in construction of a processing facility which will have a usable area of 3000 square feet. These buildings have been constructed using low-level activated material, encapsulated in concrete, at essentially no cost to the Laboratory due to the savings realized by recycling this material and not incurring the disposal fees.

A new pilot program has been started to evaluate the concept of building portable shield blocks. Since the Laboratory uses many of these each year at a significant cost, the utilization of low-level radioactive material to increase the density of these blocks will result in less material shipped as waste, saving disposal fees and costs for purchasing new shield blocks. Thus far, two such blocks have been built and it appears that they will suit our requirements very well.

When this program goes into full operation, the only radioactive material that will be waste (and thus shipped for disposal) will be compactible material and other items unsuitable for encapsulation into shielding. It now appears that Fermilab will be shipping about one truckload of radioactive waste per year instead of 15 or 20, with a significant cost savings.

Radiation Exposures

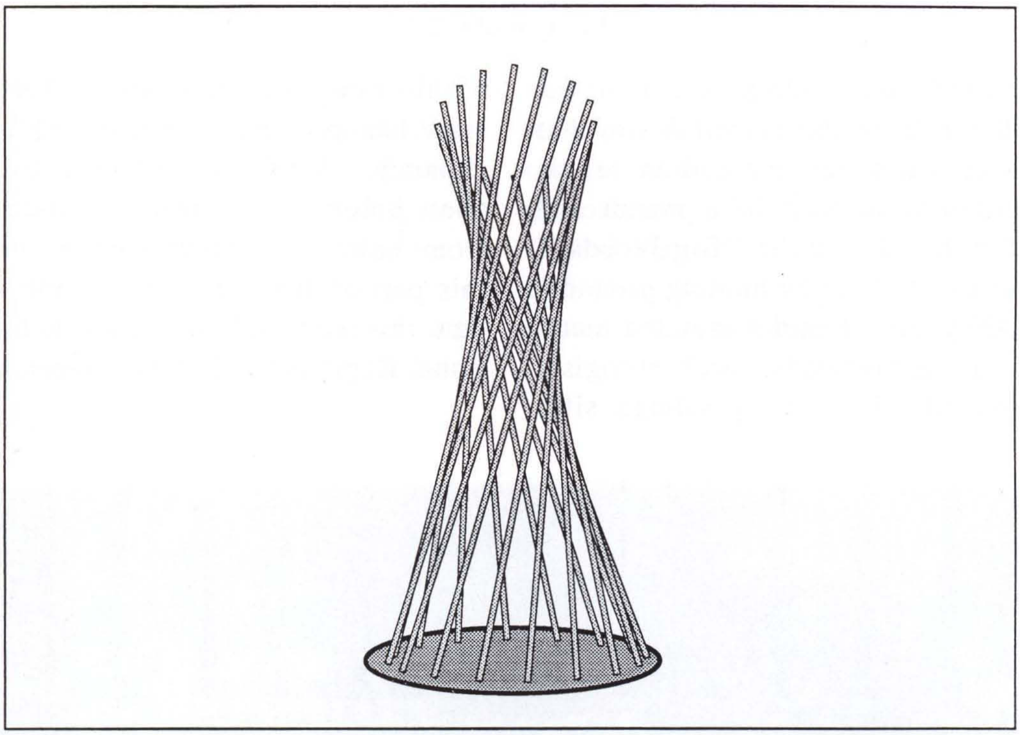
Annual whole-body radiation doses for the Laboratory are somewhat less than the previous year - about 43 person rem compared to about 56 person rem in CY87. This is primarily due to the relatively short part of the year in which the Fixed-Target Program was in operation. Collider operations generally result in lower total doses to personnel due to a reduction in the number of people potentially exposed and the reduced activation of accelerator components compared to fixed-target running. The extensive Collider operation during 1988 has the added benefit of a substantial decrease in the off-site radiation dose due to muons, which arise primarily from the fixed-target experiments.

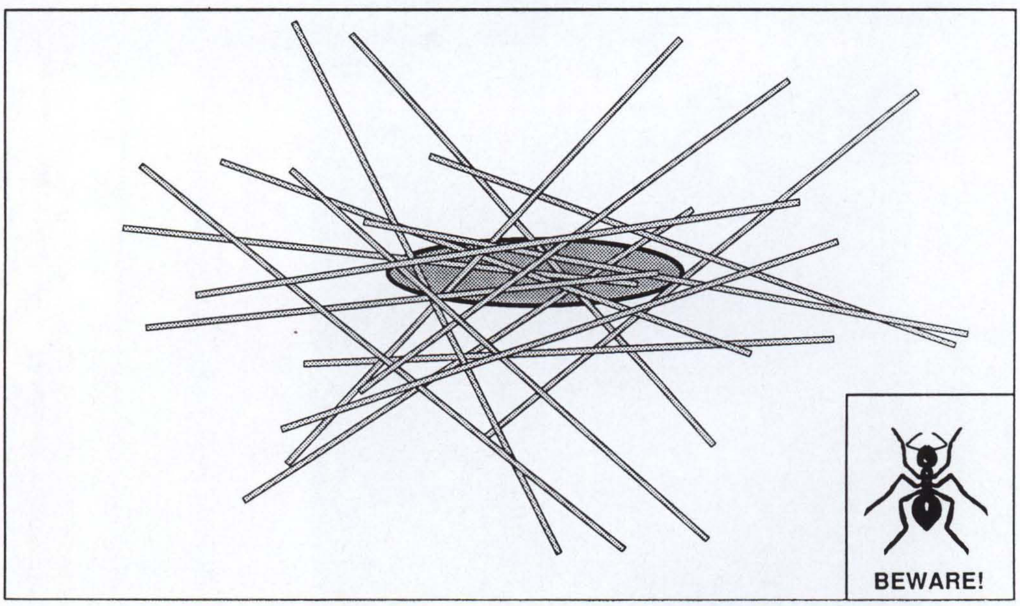
On the down side, we continue to experience an increase in beta dose and extremity exposures due primarily to the construction of the uranium-liquid argon calorimeter for E-740. In addition, for the first time we have begun to see evidence for some internal uptake of depleted uranium in a few workers involved in the calorimeter work. This has resulted in tighter controls and modifications in procedures for calorimeter assembly.

A separate and unrelated incident involving an internal uptake of 241Am due to a broken radioactive source resulted in a substantial Laboratory effort to prevent the possibility of a recurrence. While the incident in question did not result in any individual receiving a dose in excess of the legal limits, it did serve as a reminder that such incidents should be treated with care and that institutional recovery from them can prove difficult and time-consuming.

On the regulatory side, the reporting requirements for annual radiation exposures at the Laboratory became much more involved due to major revisions in the relevant DOE order. We must now provide to DOE annual doses for each monitored Laboratory employee, user, and subcontractor, as well as any visitor with a positive exposure. We must also provide information about each person's occupation and employment status. A by-product of this change has been improvements in our computerized database for personnel dosimetry record-keeping. This is but one example of the rapidly evolving regulatory environment in the safety area.

Another area of change concerns the start of our participation in the DOE Laboratory Accreditation Program (DOELAP) for personnel dosimetry. This program was begun by DOE in an attempt to ensure some amount of reliability and consistency among the dosimetry programs at each of its laboratories. It involves a series of "blind" radiation exposures followed by our evaluation of the delivered dose, as well as an on-site evaluation of our program.





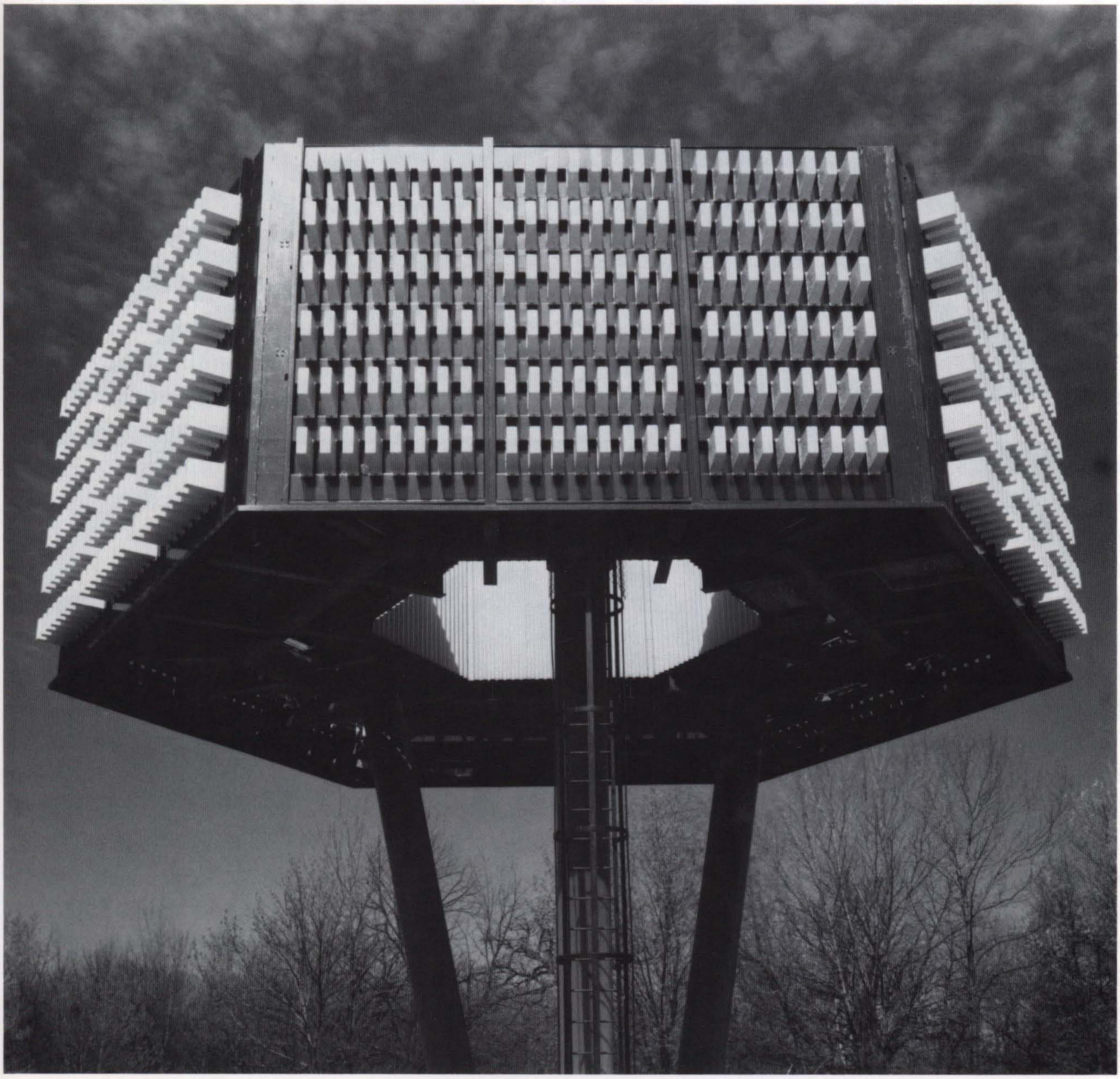
On the technical side, several improvements were made in our program to study neutron radiation fields at various locations around the site. We took delivery of a complete set of eight 6LiI scintillators, photomultiplier tubes, bases, and associated electronics for use with our multisphere system. In addition, we received a new computer system for use in data acquisition with these detectors.

Archaeology

During 1988, archaeologists completed surveying the 15% of the Fermilab site that had yet to be examined for Indian relics. Since Fermilab is located in a marsh and prairie area at the edge of the "Big Woods," this land has been a "happy hunting ground" for over 8000 years. Besides isolated materials such as arrowheads, archaeologists have discovered 25 camp or village sites within Fermilab boundaries. One of these sites has provided evidence of a long occupancy. Artifacts have been found 18 inches below the surface. Such evidence from below the plow zone is unusual for this part of Illinois. As a result, it is likely that this site will be eligible for the National Register of Historic Places.

DOE Environmental Survey

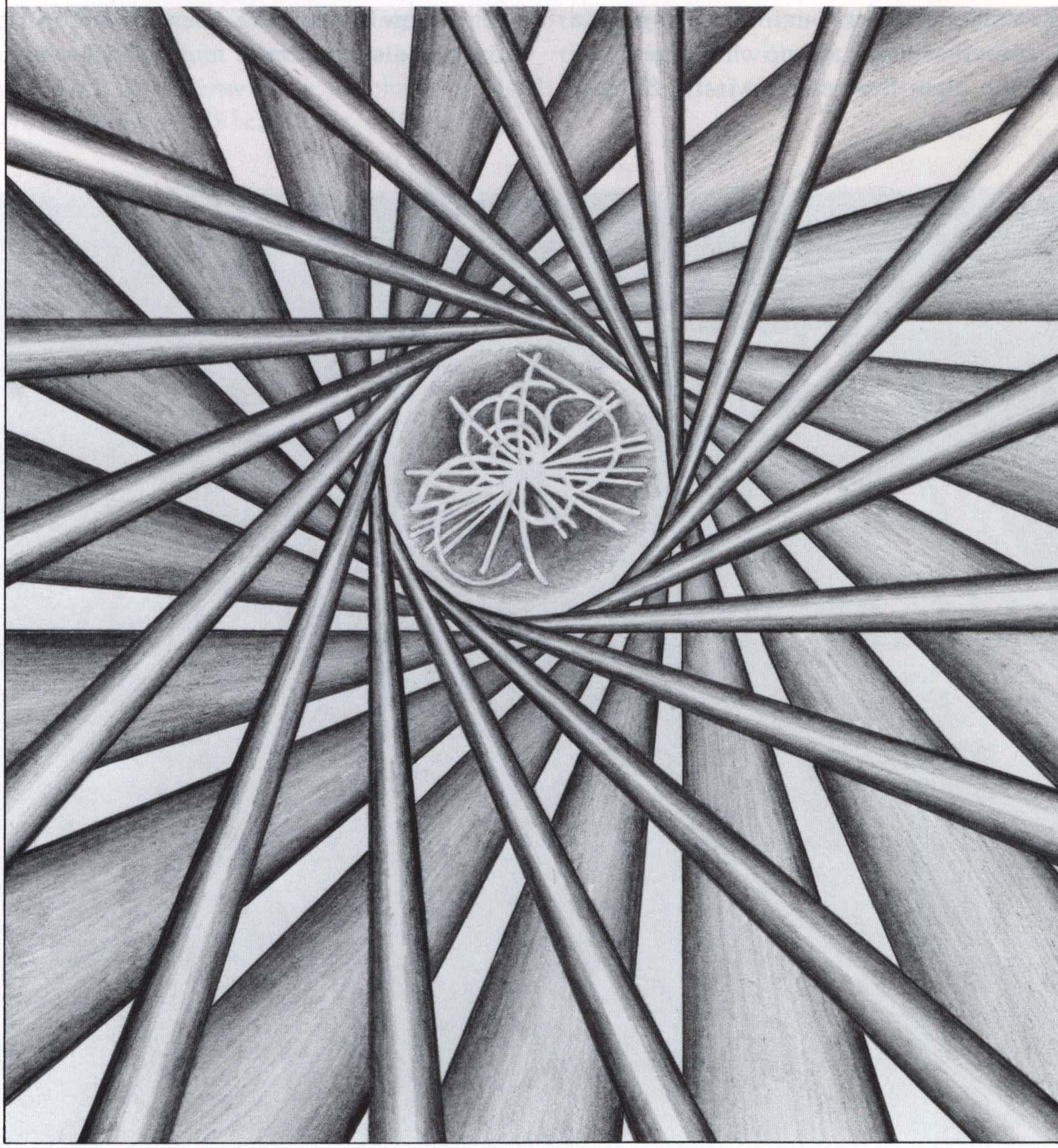
The DOE Environmental Survey held in September 1987 found five potential long-term environmental concerns. In 1988, all five potential problems were investigated and no environmental problems revealed. For example, tests in our Main Ring pipe field show that there are no chromates outside of the pipe; tests at the Master Substation reveal only traces of transformer oil; tests in nine boring holes in the experimental areas showed no significant levels of radioactivity; PCB's from the Master Substation Capacitor Tree have been removed; and 19 new wells have been drilled to improve the distribution of monitoring wells.



Fermilab Industrial Affiliates Roundtable on

The Science-Technology Spiral and the Pace of Progress

Fermilab **May, 1988**



The Office of Research and Technology Application

Richard A. Carrigan, Jr.

Fermilab is partly responsible for the biggest single technology transfer from a DOE laboratory since nuclear reactors were developed. This outrageous statement may even be true. The industrial-scale superconducting technology base developed for the TEVATRON Collider is one of the principal cornerstones for the half-billion-dollar-a-year medical resonance imaging (MRI) market. Up to now the TEVATRON is by far the largest superconducting project built. Indeed, prior to the recent surge in medical imaging technology, Fermilab was the only source in the world for practical experience with industrial-scale superconductivity.

Fermilab developed that technology in such a way that industry could learn from the technology development at every step. Sensitive and innovative contract management produced an environment where a viable, competitive, industrial-scale wire industry came into existence. This type of technology transfer, "the good old-fashioned kind," is among the most effective.

This important technology transfer took place during the 1970s. It was done without new legislation, without Small Business Innovation Research grants, without any of the new technology transfer tools so popular in the 1980s. Amazingly, there was not even an ORTA, an Office of Research and Technology Application, at the Laboratory. (It is hard for the present incumbent to imagine this. Who responded to the inquiries and filled out the countless forms that appear nowadays?)

Most surprising of all, the TEVATRON builders didn't even know they were transferring technology. They set out to build the TEVATRON for fundamental scientific research. They had no idea that a million or so additional patients would have the benefit of MRI diagnosis because the TEVATRON advanced commercialization of MRI technology by at least a year.

There are several points here. Good science and good fundamental technology can produce very significant commercial and socially-useful products. Those results can come from an entirely unexpected direction. In the words of Phil Anderson, a famous Nobel Prize winner who frequently criticizes particle physics, "The golden eggs are very seldom produced by the golden geese." Few people claimed the TEVATRON would be a golden technology goose when it started. Yet, it helped to hatch a marvelous technology egg: industrial-scale superconducting technology.

With the passage of years and legislation, Fermilab now operates a full-service Office of Research and Technology Application. The breakthrough occurred in 1987 when a Licensing Officer was added to the staff. The office handles the Fermilab Industrial Affiliates program, patenting, licensing, a related State of Illinois technology-transfer program, as well as a myriad of other coordination and reporting activities. In this whirlwind of paper it's easy to lose sight of the real mission: transfer technology.

Fermilab's pursuit of elementary particle physics has, as a by-product, produced technology of interest and use to other fields. During 1988, we filed our 500th Federal Application Assessment. It was on FIRUS-88, a significant update to the extensive alarm system in use around the site for many years. The new technology was developed by Charles Briegel, Kevin Cahill, Allen Franck, and Richard Mahler of the Accelerator Division Controls Group.

Interestingly, this number of technology ideas is roughly comparable to the number of experimental proposals the Lab has received. Now, with more awareness of the importance of national-laboratory inventions, there are five inventions received for every new physics proposal. Of course, new technology ideas spring out of Technical Support and the Accelerator Division as well as from the experimental program.

With new federal legislation and a rising concern about competitiveness, there is now increased emphasis on licensing Laboratory technology. During 1988, the Universities Research Association, the consortium of universities that manages Fermilab for the Department of Energy, negotiated its first license on a computer-controlled high-voltage power supply developed by Tom Droege of CDF. Other licensing possibilities are under investigation.

Much of the Laboratory technology is not licensable. Still, like the TEVATRON, it can have a significant impact. The Loma Linda proton accelerator for medicine, along with an associated infrastructure like Proton Therapy Cooperative Group, an interest group representing universities, laboratories, hospitals, and companies around the world, may lead to substantial use of this technology. Other concepts for accelerator application pop up regularly within the Accelerator Division. The Advanced Computer Program also continues to flourish. Discussions are already under way about licensing parts of the ACP second-generation systems. Elements of the system are now being marketed outside of physics by an Illinois company.

These big projects are not the only interesting technologies that develop at the Laboratory. There is a wealth of controls technology here that uses such standards as FASTBUS and VME. This year a triad consisting of Fermilab, the University of Illinois at Chicago, and Kinetic Systems Corporation, has been seeking ways to broaden the use of FASTBUS. The effort is funded with State of Illinois money received from the Illinois Department of Commerce and Community Affairs (DCCA).

New cryogenic technology is constantly appearing. The drive to produce large-scale, super-fluid helium cooling for 2° K operation of magnets has produced new technology. Peter Mazur, Moyses Kuchnir, Tom Peterson, and others have developed valves, compressors, and refrigeration concepts addressed to this new challenge.

This year, for the first time, Fermilab had four industry-Laboratory exchanges. These were carried out with funding from DOE, DCCA, and the companies themselves. Participants included Omnibyte, General Dynamics, Babcock and Wilcox, and Martin-Marietta. Typically, an engineer visits Fermilab for six months to work on a problem that is mutually interesting to Fermilab and the engineer's parent company. We are on the lookout for more opportunities and other industrial organizations.

The Fermilab Industrial Affiliates organization also continues as a fruitful link with companies interested in Fermilab technology. The eighth annual meeting of the Affiliates was held May 26 and May 27. The meeting had an outstanding program with speakers such as Donald Frey, former CEO of Bell and Howell; Hirsh Cohen, consultant to the Director of Research, IBM; and Richard Nicholson, then Assistant Director of Mathematics and Physical Sciences, National Science Foundation. We had our largest attendance ever, over 160 people.

Now that Fermilab has passed its twentieth birthday and come of age, where will the future Loma Lindas and ACP's come from within the Laboratory? My own view is we should encourage one or so of our new technology projects here to reach for the skies every year. The most important motivation must always be to press into regions where no one has gone before in pursuit of our own fundamental program. Still, we should look over our shoulder and see how we can integrate U.S. industry, as well as the needs of other applications for the technology, into the quest.

Here are some of the hotter candidates. The Particle Detector Group headed by David Anderson has developed remarkable new scintillators with direct relevance to positron emission tomography imaging. This is a medical technology that monitors body chemistry as it takes place. The potential market is comparable to MRI. Could we develop a hospital-, university-, or industry-based collaboration that would speed this into application and also strengthen the particle detector effort? Another opportunity will continue to be 2° K technology. Here it is harder to identify users outside of particle physics. Still, the subject has the same feel the TEVATRON did a decade ago.

My favorite pick for a Fermilab technology of the '90s is the artificial-intelligence/expert-system area. Clearly, Fermilab and the SSC will both guzzle down software like an over-imbibed sailor. Spurred on by the all-consuming need for computing time for particle physics experiments, Fermilab programmers are already involved in topics like rule-based software and neural networks. At the same time, DOE has favored URA with the opportunity to license software. We can jump into the next decade of software development with nary a thought of the outside world. The other option is to give a little thought to our unique contributions and how they might find use outside the field of particle physics. With a little luck the general impact of particle-physics software requirements in the '90s could make the TEVATRON's impact on MRI pale by comparison.

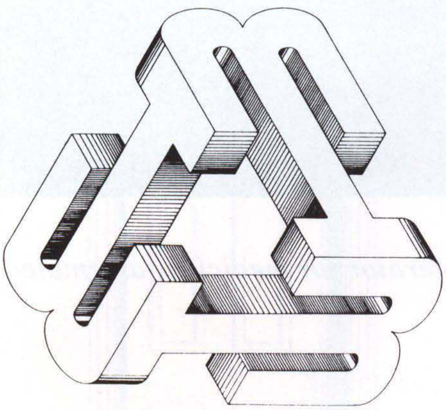
The Neutron Therapy Facility

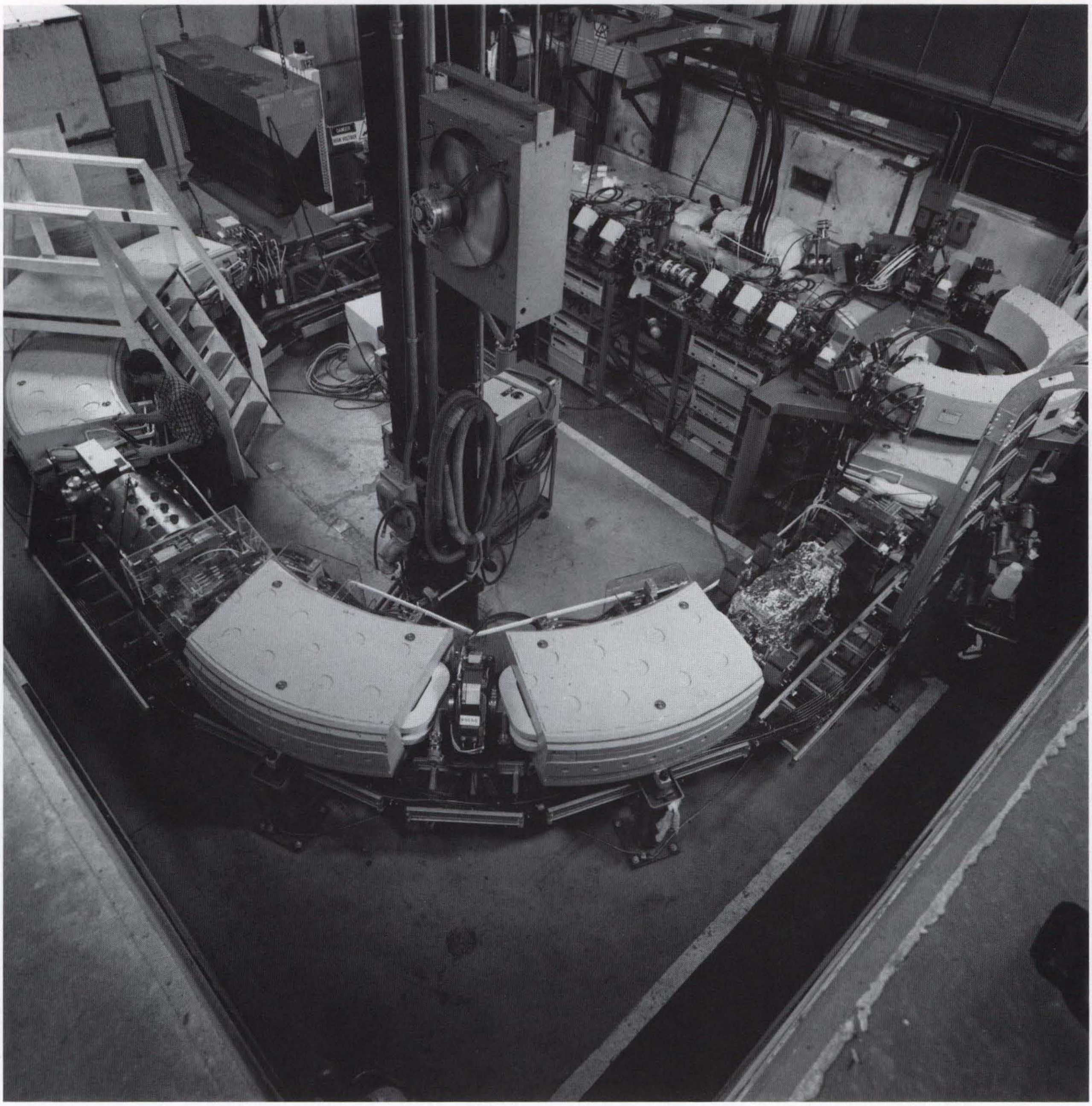
Arlene J. Lennox

After 12 years of clinical trials, including careful long-term follow-up studies, it has become clear that for some tumors, neutron therapy is superior to conventional photon therapy. At the time of this writing, neutron therapy is available at only three places in the United States. In the spirit of technology transfer, and eager to make this type of treatment available to more patients, we have begun preliminary work on designing a medical proton linac suitable for hospital-based fast neutron therapy as well as a lower energy linac to produce epithermal neutrons for treating brain tumors using Boron Neutron Capture Theory. We are also consulting with physicists from China and Israel who are planning to use existing physics-research accelerators for neutron therapy in a manner similar to our parasitic use of the Fermilab Linac beam. It was rewarding to hear that the South African group we assisted a few years ago treated their first patient in September.

This year we completed the upgrade of the Neutron Therapy Facility controls system by replacing the 12-year-old medical microprocessor with an IBM PC/AT which communicates with the VME bus/68000 beamline microprocessor by means of a dedicated Token Ring. A major effort went into transferring our Cyber-based patient planning software to the newly installed Amdahl scientific computer and we are developing software to take advantage of the three-dimensional display capabilities of a Silicon Graphics work station.

In summary, the Neutron Therapy Facility has spent this year improving the efficiency of its own operation as well as reaching out to assist others in making neutron therapy more widely available.





The Loma Linda proton accelerator for medicine, assembled for commissioning in Fermilab's Industrial Complex.

The Loma Linda Medical Accelerator

J. Richie Orr

A very small proton synchrotron, only 20 feet in diameter, is being created by Fermilab under a work-for-others agreement with the Loma Linda Medical Center at Loma Linda University in California.

This accelerator is intended for treatment of cancer using a beam of protons whose energy, location, and intensity can be carefully controlled.

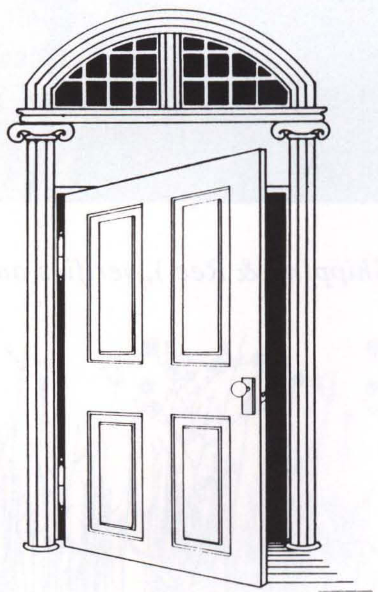
Although proton therapy has been in the cancer-treatment repertoire for many years (in fact, it was proposed by R. R. Wilson more than 40 years ago [see *Fermilab 1987 Annual Report*, pg. 115]), this new machine is the most precise and flexible treatment instrument ever attempted.

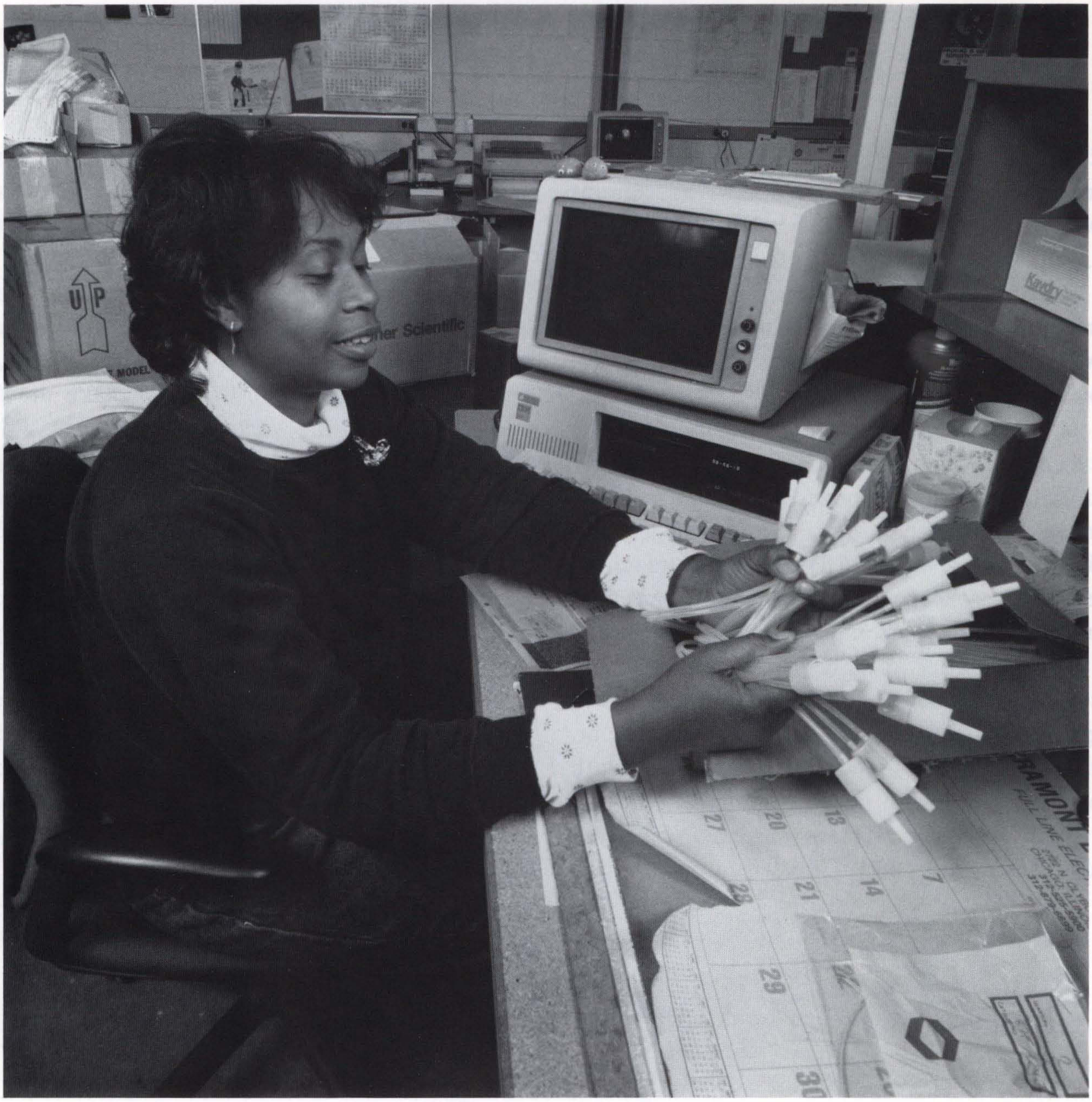
Construction of this little medical accelerator is now complete. The project was given a push when a troop of experts arrived from the Accelerator Division with banners flying and bugles blowing.

The injection system has been operated and has delivered 2-MeV protons to the Main Ringlet. Although the injection system worked well from the beginning, it has been decided to add beam-profile monitors to this beamline to facilitate reaching higher intensities.

Acceleration and extraction studies are under way at this time. Protons have been accelerated to the required peak energy range of 250 MeV. In order to make much more progress, the vacuum in the ring will have to be improved by at least a factor of ten. In addition, a beam-transport system must be installed before experiments with extracted beam can begin. The work at Fermilab with this accelerator is expected to occupy the balance of the winter and spring of 1989.

The machine is coming to life quite smoothly. This is a tribute to the experienced accelerator physicists, engineers, and technicians who have labored for two years to design and construct this flexible little synchrotron.





Marilyn Collins (Bus. Serv./Shipping & Rec.), verifies an order against the PARS entry.

The Business Services Section

James E. Finks, Jr.

To quote Frank Sinatra, "it was a very good year" for the Business Services Section. The quality and amount of support provided to the Laboratory in 1988 was outstanding. In addition, numerous initiatives were undertaken to improve and expand that support even further in future years, and to seek out new avenues where the Laboratory may secure additional cost reductions.

The Facilities Management Department completed an installation of two 345-kV transformers at the Master Substation that included transformer rigging, bus ducts, and relaying. An equipment building was constructed for the Roads and Grounds operations. The Wilson Hall entry deck was re-covered and a new snow-melting system installed. Site custodial quality was improved and costs reduced by subcontracting the service. The Ramsey Auditorium's manual stage-rigging system was replaced with a modern power-assisted system. In addition, 11 miles of roads were resurfaced, 18 parking lots were paved, 3200 feet of sidewalks were replaced, 23 curbings were converted to handicapped accessible, 13,000 feet of fencing were installed around the bison pasture, 13 miles of roads were striped, 152 trees were planted, the bison pasture retention pond was refurbished, 100 acres of land were tilled and planted in prairie grass, and 6700 pounds of prairie seed was harvested.

The Material Department completed the bidding and award of a new $8.6-million computer system. Competitive bidding also resulted in an annual $2.3 million reduction in the Laboratory's liquid nitrogen and helium costs.

The Accounting Department devoted many hours in its efforts to customize, and prepare to install in FY89, its new computerized Payroll/Personnel System and Accounts Payable System.

The Information Systems Department installed a new digital-image identification card system and established a payroll disaster recovery plan. The Department invested major amounts of staff support to new preventive maintenance and a new Payroll/Personnel System which will become operational next year. Further, a System Design Methodology was developed and placed in production which standardizes the approach to design and installation of Information Systems applications.

James Davenport (far left), of Virginia State University, Coordinator of Fermilab's Summer Internship in Science and Technology program, with his 1988 interns.

The Laboratory Services Section

Charles F. Marofske

Automated services provided by the Fermilab Library continue to expand. More than 8000 preprint records in SLAC's High Energy Physics database now contain Fermilab Library numbers which have been added or tagged by Fermilab Library staff. NEWBOOKS, a product now available on the FNAL VAX Cluster, lists new books ordered for the Library. Plans and specifications for the purchase of an automation system, which will provide online access to the Library's catalog, are being evaluated. 750 books and 18 new journals were added to the Library collection. The Library is now coordinating Laboratory subscriptions to journals, magazines, and other periodicals through a subscription agent.

In 1988, the Publications Office moved to new quarters in Wilson Hall. This move allowed further streamlining of Publications Office technical report-production operations by, among other things, consolidating files and establishing a laser-printer queue address which permits Fermilab authors to transmit their technical reports electronically, as opposed to hand or mail delivery of hard copies. The Office prepared and disseminated 55 technical memos, 33 physics notes, and 78 preprints (exclusive of theoretical physics and theoretical astrophysics preprints) in 1988. As in the past, the Office continued to produce in their entirety *FermiNews*, *Fermilab Report*, *FermiTec*, the Industrial Affiliates Roundtable, and this annual report, in addition to various special publishing projects.

The Visual Media Services group has expanded capabilities over the last year. A new studio and video editing area have been built to accommodate the demand for video training tapes and still photography. Over the past year, Visual Media Services shot just over 1260 jobs that document the varied activities and projects of the Laboratory. Twenty videotape projects were completed over the year, mainly focusing on training at Fermilab. Visual Media Services continues to utilize all of its duplicating equipment to the maximum and has made over 6,000,000 copies for the various activity groups.

During this past fiscal year, the size of the Laboratory staff increased by 35 persons. In the 12-month period, over 225 new employees were put on payroll. The Employment Office maintained a busy schedule of recruiting visits to campuses and career fairs. More than 500 applications are received in a typical month by the Employment Office.

The Medical Office completed over 1000 physicals in the year. In addition, oxygen-deficiency-hazard physicals continue for employees, contractors, and experimenters. As a new service, the Medical Office implemented the inclusion of the coronary-profile risk factor (detection of high-risk coronary candidates) into all routine physicals.

Under the leadership of the Equal Opportunity Office, the Laboratory has continued its participation in Imprint (Illinois Minority Pre-College Internship Program) and the National Consortium for Graduate Degrees for Minorities in Engineering, Inc., and also sponsored the 18th Annual Summer Internship in Science and Technology. The 19 participants were selected nationwide from undergraduate candidates majoring in physics, computer science, or engineering. In cooperation with the Friends of Fermilab, the Laboratory provided enrichment experiences for 25 talented area high school sophomores and juniors through the "Target: Science and Engineering Program." Roberto Vega, a Fermilab Graduate Fellowship Student, became the first graduate of this program in May 1988. He was awarded his Ph.D. in Physics from the University of Texas at Austin.

The Public Information Office continues to provide a number of services to the general public. This translates into more than 10,000 persons visiting the Laboratory via guided tours. In FY88, the Public Information Office offered a total of 277 guided tours, two-thirds of them being for school groups from six different midwestern states. Uncounted additional visitors avail themselves of the Laboratory's open-door policy by taking our self-guided tours and by utilizing the hiking, biking, and skiing trails.

Fueled by the nation-wide interest in the SSC, Public Information has seen a continual flow of reporters, writers, and photographers this past year. In-depth articles on Fermilab have appeared in the *Chicago Tribune*, the *Chicago Sun-Times*, *The Christian Science Monitor*, *The Scientist*, and *Audubon*, and there has been additional coverage by local and national radio and TV.

Public Information also continually responds to a wide variety of written and phone inquiries ranging from the high school student in Carol Stream, Illinois, who is curious about superconducting technology, to the hobbyist in Pennsylvania who is building a scale model of Fermilab.

In 1988, the Activities Office focused attention on the newly renovated Users Center with increased use of rooms as a meeting place for experiment groups, clubs, and leagues. Some remodeling in the Gym has improved the aesthetics, while the addition of new equipment has kept it competitive with outside health clubs. Occupancy averaged 86% for the Lab's on-site housing facilities, which number 157 units. The Day Care program continues to provide a nearby solution to family concerns for parents working at the Lab. Day Care enrollment is now 68 students ranging from infants to kindergarten age.

The Fermilab kitchen presented over 21,000 meals this past year and provided catering for conferences and meetings.

Physics at Fermilab in the 1990's

August 15-24, 1989 — Breckenridge, Colorado

Announcing a workshop sponsored by the Fermilab Users Organization to explore future fixed-target and colliding-beam physics options at Fermilab.

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Working groups are being organized which address the following issues:

Theoretical Issues for the 1990's

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Accelerator and Beam-Line Options

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Collider Physics

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Fixed-Target Physics

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p̄ Accumulator Physics

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New Physics Opportunities

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Instrumentation, Test Beams, and SSC R&D

•

Organizing Committee

J. Bjorken – Fermilab
S. Errede – U. of Illinois
T. Ferbel – U. of Rochester/SSC
M. K. Gaillard – UC Berkeley
F. Gilman – SLAC
D. Green – Fermilab (Co-Chair)
K. Heller – U. of Minnesota
L. Lederman – Fermilab
H. J. Lubatti – U. of Washington (Co-Chair)
J. Peoples – Fermilab
M. Strovink – UC Berkeley/Fermilab

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For information please contact:

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II. The TEVATRON Upgrade

During 1988, plans were solidified for the exploitation of the Fermilab facilities during the next decade in the pre-SSC era. The successes of the Collider and Fixed-Target programs, based on the excellent performance of the TEVATRON, provide a solid base on which to build for the future. The upgrade program is designed to enhance both of the physics programs with increases in the beam intensities and energy, well beyond those achieved today, within the framework of an antiproton-proton collider. Various other options for upgrade schemes were also examined in some depth. A complex of 20-GeV rings acting as a post-booster to increase the Main Ring injection energy and provide increased antiproton storage were considered, as was the construction of a second TEVATRON to allow proton-proton collisions at 1 TeV. Neither of these schemes provided the overall benefits and flexibility of the proposed program that we outline here, which also maintains compatability with the collider detectors.

Collider physics demands a continual increase in luminosity with each run in order to maintain the discovery potential for new physics. The TEVATRON I project set 10^{30} cm^{-2} sec^{-1} as the design luminosity, and that has been achieved. The new program aims to increase the luminosity from run to run until a peak of $\sim 2.5 \times 10^{31}$ cm^{-2} sec^{-1} is reached. Finally, a doubling of the energy to 1.8 TeV will further extend the physics reach. Attaining luminosities of this level requires enhancements to the present rate of antiproton production and storage together with the production of denser, brighter bunches of particles. The fixed-target program also benefits from the increased energy and intensity, as well as the availability of lower energy (150 GeV) beams on a year-round basis.

The upgrade program proceeds through three phases. The first is centered around changes to the TEVATRON optics to accommodate two high-luminosity interaction regions and high-intensity particle bunches, together with increasing the Linac energy from 200 to 400 MeV. The second stage consists of replacing the Main Ring with a new Main Injector in a separate tunnel enclosure. The final step would then be to install a new superconducting ring in the space currently occupied, with the Main Ring capable of approximately twice the peak field of the TEVATRON. Let us examine each step in more detail.

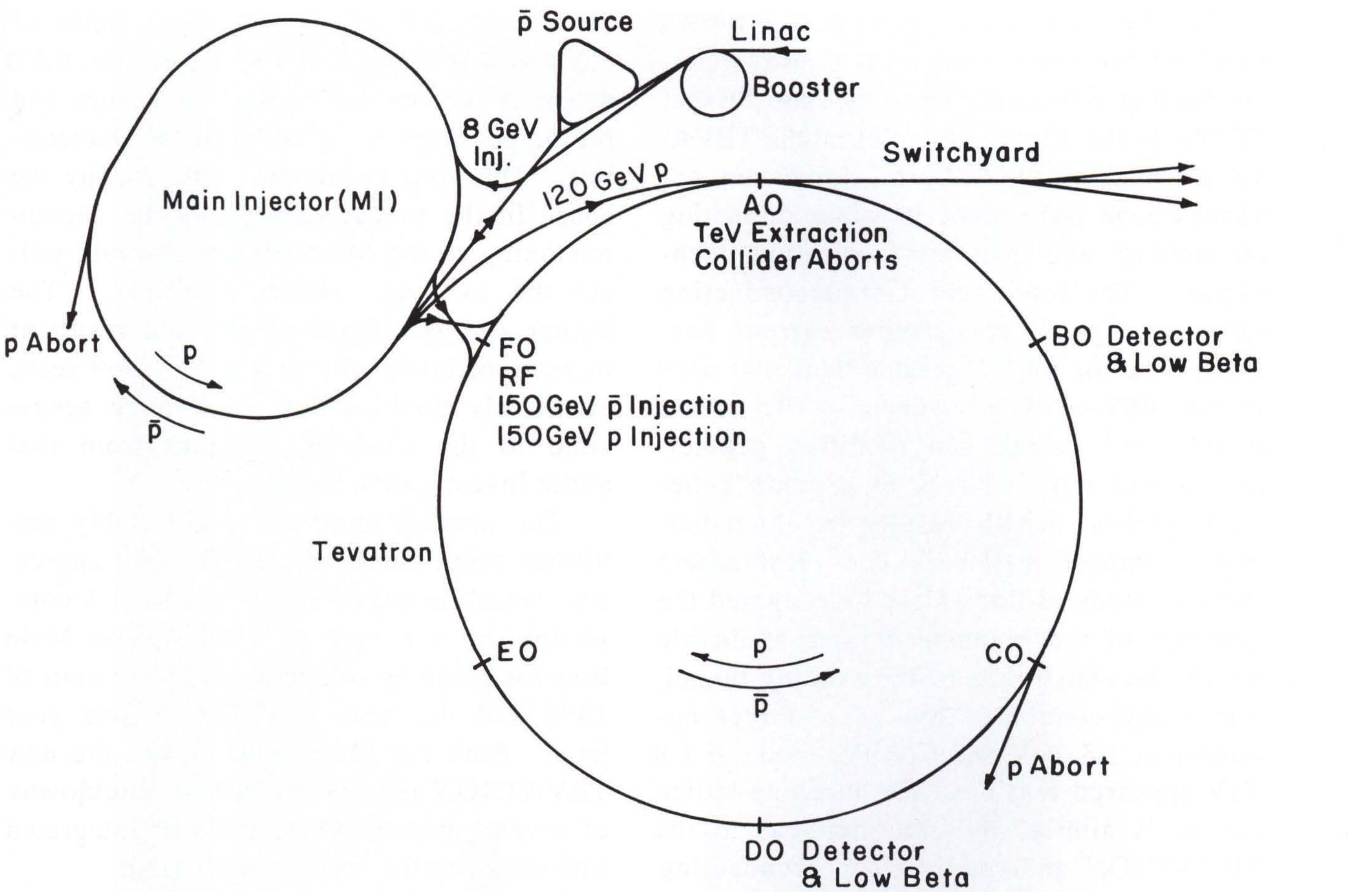
The initial stage in the program addresses the limitations on luminosity in the present operation. The TEVATRON, using six bunches of protons and antiprotons, is limited in the peak luminosity by the availability of antiprotons and the so-called beam-beam tune shift. This latter phenomenon is due to the effect of the counter-rotating bunches of particles as they pass through each other at the collision points and results in particles being lost from the beams, which limits the useful lifetime of the stores. The strength of this effect is proportional to the density of the bunches and the number of bunch collisions taking place per revolution. Limiting the bunch intensity to achieve adequate beam lifetimes results in a limited luminosity. However, with six-bunch operation, the beams collide at 12 places in the accelerator, even though only two of these collision points will be used in the upcoming runs. A scheme to remove the unwanted collision points by separating the circulating beams inside the accelerator with a system of electrostatic deflectors has been developed. These deflecting plates are incorporated into the design of new collision regions which will be installed in the D0 area for the new detector and retrofitted in the existing B0 region. Reducing the number of collision points from 12 to 2 will allow the luminosity to be increased by up to a factor of six from the current value, provided sufficient antiprotons are available to achieve this. In order to increase the antiproton production rate to attain these large stack sizes, modifications to the Pbar Source aperture, stochastic cooling, and proton targeting system will be made to increase both the number of protons hitting the production target and the yield of antiprotons collected by the Source. The increase in stacking rate is estimated to be a factor of three.

The final and crucial step in the phase 1 upgrade is the doubling of the Linac energy. In the present operation of the accelerator chain, the limiting factor on the available proton intensity is the space charge interaction at low energy in the booster. This effect, the coulomb interaction between the individual particles in a bunch, results in an increase in the beam size emerging from the Booster as the proton intensity is increased. At a bunch intensity of $\sim 2 \times 10^{10}$ ppb, the beam size becomes too large to be accepted by the Main Ring. Doubling the output energy of the Linac reduces the effective strength of this space charge interaction resulting in smaller, denser beams from the Booster. We estimate an increase of proton intensities of 1.7 through the Main Ring and into the TEVATRON. Higher proton intensities benefit both Collider and fixed-target operation. In the Collider mode, the antiproton production rate will increase as well as the intensity of the proton bunches undergoing collisions. We estimate that the peak luminosity at the end of phase 1 to be as great as $\sim 10^{31}$ cm^{-2} sec^{-1}, a factor of five higher than today. Fixed-target operations of $>3 \times 10^{13}$ protons per cycle would greatly expand the scope and flexibility of the experimental program.

Also included in phase 1 is a system of cryogenic compressors (to be installed in the satellite refrigeration stations) which would lower the operating temperature of the TEVATRON by 0.5 K, resulting in an increase in operating energy of 100 GeV.

The second phase of the upgrade involves replacing the Main Ring with a new accelerator, in its own enclosure, called the Main Injector. The existing Main Ring was designed to provide fixed-target proton beams with an energy of 400 GeV. As such, it is not at all optimized to the present requirements of the Collider Program. Introduction of overpass regions around the collider-detector areas and beam-transfer points have resulted in machine optics which restrict the useful aperture and limit the proton intensity.

The proposed Main Injector addresses these problems and more. A schematic layout of the accelerator complex including the Main Injector is shown in Fig. 1. Bi-directional beam transfers to the TEVATRON take place across the F0 straight section. Connections to the Pbar Source and the Booster for 8-GeV and 120-GeV beam transfers take place largely in common beamlines following existing installations. A 150-GeV beamline joins the Main Injector directly to the Switchyard providing access to the experimental areas. The circumference is roughly half that of the Main Ring and two cycles of the Main Injector are needed to load up the TEVATRON for fixed-target operation. The peak energy of 150 GeV requires 300 dipoles running at 17 kG. The focusing strength in



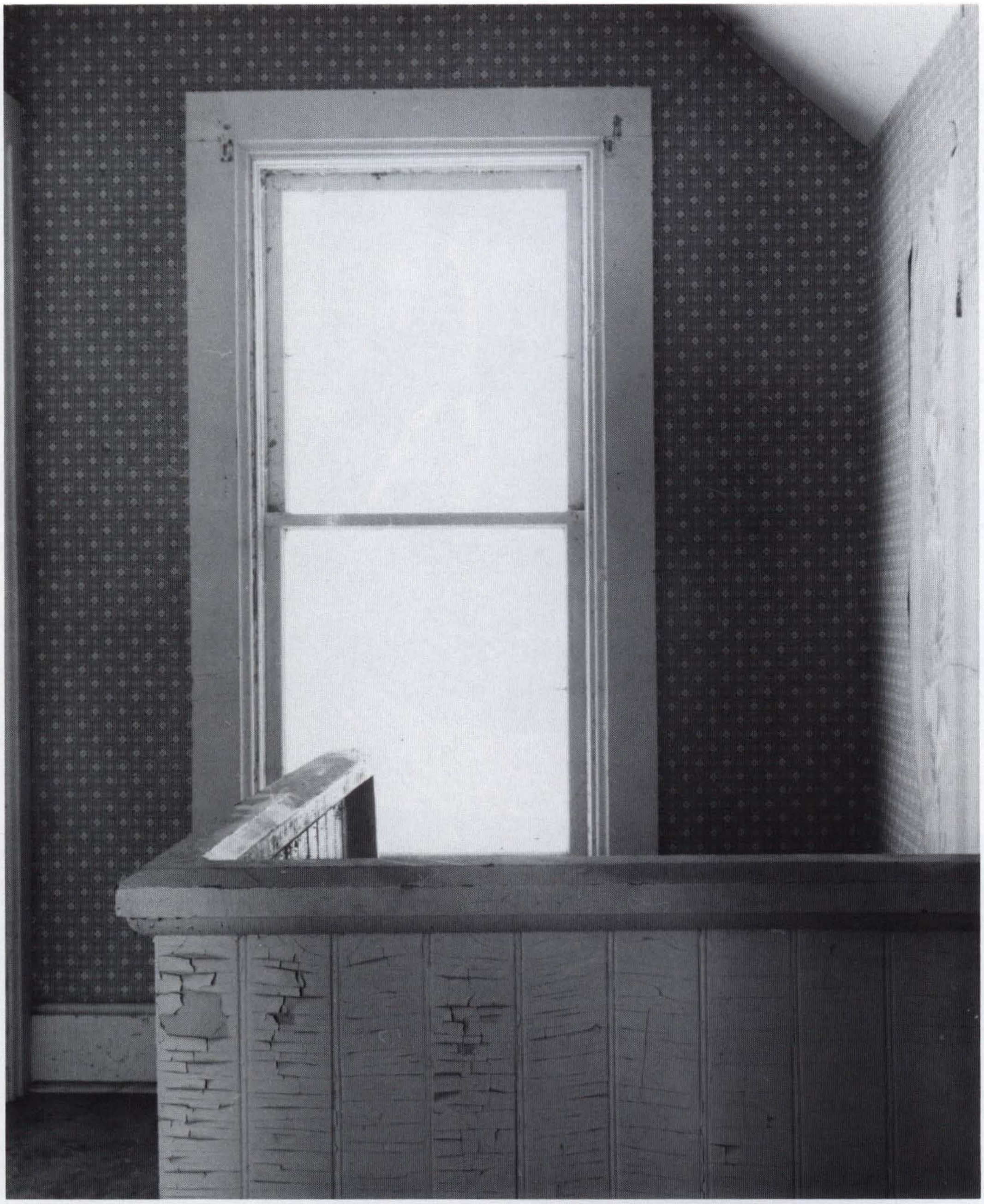
Schematic layout of the proposed Main Injector.

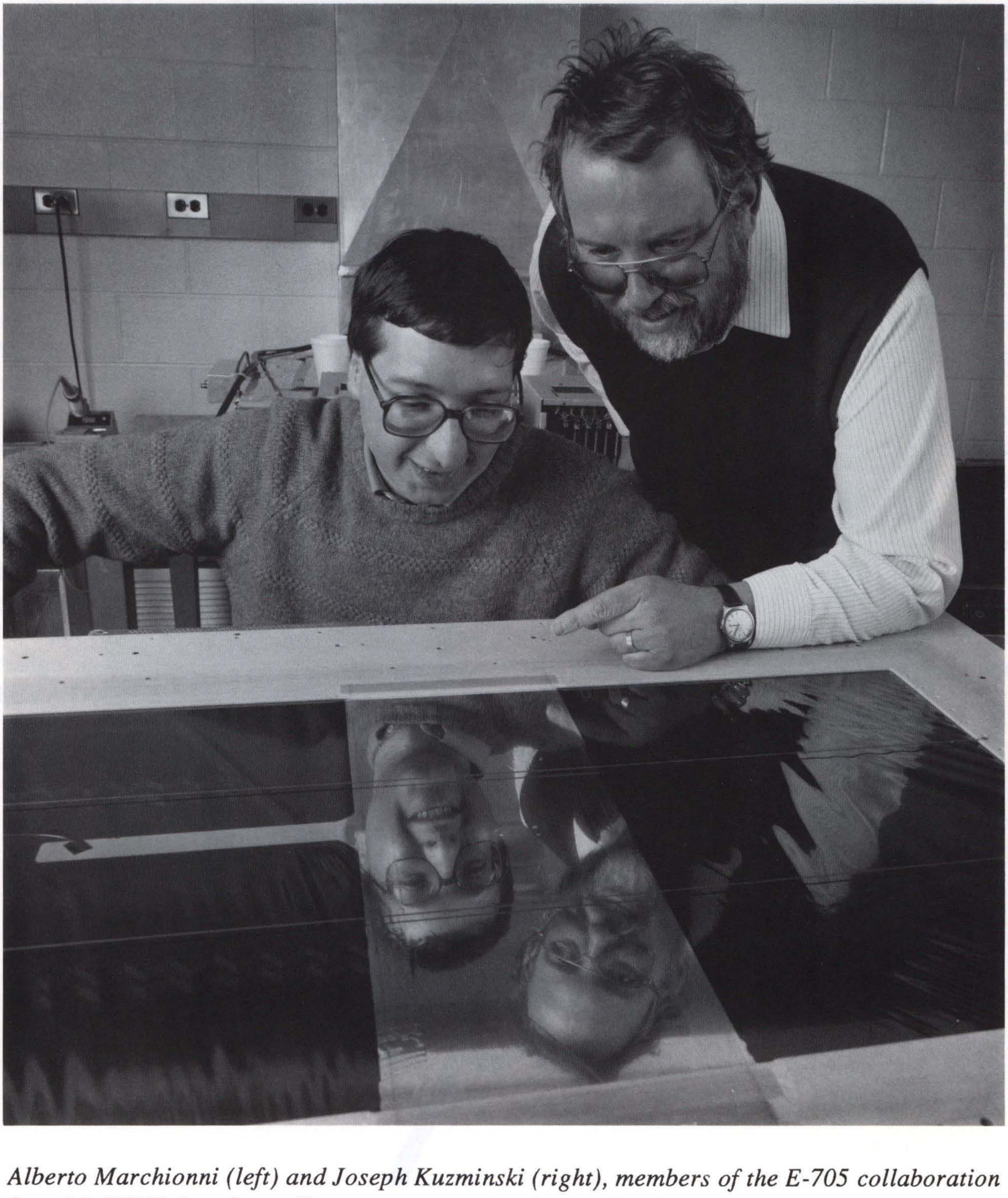
the machine lattice is twice that of the Main Ring, resulting in an estimated dynamic aperture of three times that available now. This accelerator will be capable of using the full intensity generated by the Booster with higher injection energy, producing 3 x 10^{13} protons per cycle, a factor of three increase over current operation. It is designed to be a rapid-cycling machine and can accelerate and deliver on target 120-GeV beam for antiproton production at a 1.5 s cycle rate, 120-GeV slow spill with a 1 s spill length runs on a 3 s cycle.

There are many benefits to the physics program from this scheme. The increased yield of antiprotons into the Source, higher transfer efficiencies, and denser proton bunches are estimated to result in a peak luminosity of 2.5 x 10^{31} cm^{-2} sec^{-1}. The TEVATRON fixed-target intensities would rise to 6 x 10^{13} per cycle. Test beams through the Switchyard to the fixed-target areas during Collider operation would allow experiments to debug and fine tune their spectrometers well in advance of data taking. Experimental backgrounds in the collider detectors caused by Main Ring operation will be removed. The high beam intensities and rapid cycling nature of the Main Injector provide a powerful tool for physics research on its own. Intense beams of neutral kaons and neutrinos would provide a unique facility for CP violation and neutrino oscillation experiments where the intermediate energy regime is favorable to this kind of physics.

The final phase of the upgrade program involves the construction of a new superconducting accelerator to replace the TEVATRON. In the 10 years or so since the TEVATRON magnets were built, significant advances have been made in superconducting technology and magnet fabrication techniques. The more recent superconducting cable is capable of carrying current densities a factor of 1.6 greater than that used in the TEVATRON magnets. The cosine θ-style coil design can modified geometrically and with wedges to provide better field quality, which results in a smaller, more compact magnet. The most recent summer study at Snowmass investigated the question of the highest energies attainable within the constraints of the existing tunnel. The study concluded that fixed-target operation at 1.5 TeV and Collider mode at 1.8 TeV appeared feasible. The machine lattice design is similar but not identical to the TEVATRON and requires superconducting dipoles capable of reaching peak fields of 6.6 T at 4.2 K, and 8.0 T at 2.0 K. An R&D program is now under way to design and prototype magnets with these characteristics. This new accelerator will occupy the space in the tunnel vacated by the decommisioning of the Main Ring and would utilize the existing collider detectors. The higher energy, together with the resultant increase of luminosity to 4 x 10^{31} cm^{-2} sec^{-1}, effectively doubles the mass range accessible to the Collider Program from that under investigation today.

The upgrade program is a suitably ambitious proposal for the 1990s. An aggressive schedule would result in phase 1 completion by the end of 1991. The Main Injector could be in operation by the start of 1994 and the new TEVATRON one year later. Both the Main Injector and the new TEVATRON require accelerator shutdowns of several months which must be integrated into the overall operational program.





Alberto Marchionni (left) and Joseph Kuzminski (right), members of the E-705 collaboration from McGill University, reflect on a proportional wire chamber.

III. Recent Accomplishments of the Fermilab Fixed-Target Physics Program

In addition to the quest to understand the fundamental workings of the Universe, one of the most alluring attributes of experimental elementary particle physics is its constantly changing, but ever cyclic aspect. As we delve deeper into the secrets of nature, new observations and new theories continuously arise. This leads to new questions to ask and new propositions to test. Often the technology does not even exist to continue our search. We invent. We develop. We take our first tentative steps. It is all terribly exciting, learning to walk in a totally new environment. Sometimes our first grasps find gold. More often, a long process of learning, maturing, and understanding is necessary. This long growing process leads to a tremendous capability and potentiality. A large fraction of the progress in our field springs out of this dedicated program to scan new horizons, to search deeper and with more acute eyesight, and to find those tiny jewels hidden inside the mountain. These new jewels of insight, knowledge, or understanding again lead to another series of questions and the cycle begins again.

The Fermilab TEVATRON Fixed-Target Physics Program is a major step in this evolutionary process. Although it is built upon the experience of decades of experimentation at lower energy particle accelerators, the combination of a higher energy and higher duty-factor accelerator, the correspondingly increased secondary beam energies and intensities, and the invention, application, and maturing of new technologies for particle physics have produced a great capability for doing outstanding physics. Although we are still in an era where there is great potential, the Fermilab Fixed-Target Physics Program has already produced some gems, either in new observations or in clarifying less-well understood aspects of the Standard Model.

What are some of these new technologies that have had an impact on the way we do physics? There are new high-resolution technologies such as silicon microstrip detectors, laser holography, high-resolution optics, hybrid emulsion spectrometers, and scintillating fibers. Particle identification has been extended through the use of ring imaging Cerenkov counters and transition radiation detectors. And last, but definitely not least, are the data acquisition applications of trigger processors, buffer memories, and parallel processor analysis machines. All of these technologies have been applied and matured at Fermilab since the TEVATRON began operation.

What are the questions that the TEVATRON Fixed-Target Physics Program poses to the Standard Model? Is quantum chromodynamics the correct theory of the strong interaction? Is SU(2) x U(1) the correct electroweak theory? What is the difference between the three families of quarks and leptons? Do the heavier quarks have other, different properties? What about the mysterious CP violation? Is it part of the Standard Model, or is it something beyond? Each of these questions is often addressed using many different probes and techniques, each with its own trick or subtle nuance.

The most recent fixed-target physics run ended in February 1988, accumulating some 35,000 raw data tapes. Most of these data are still to be analyzed. Preliminary physics results are starting to emerge from this most recent (1987-88) fixed-target run. In addition, significant final results from previous runs continue to be published. This review will try to show our progress over the last year in the areas of heavy-quark production and properties, CP violation, weak decays, magnetic moments, electroweak phenomena, and hard-collisions processes. It will also look ahead to preparations and goals for the next run.

Of the Fermilab fixed-target physics experiments that completed data taking in the last few years, E-691, a study of the photoproduction of charmed particles, continues to be the most productive experiments in terms of publications and, in the author's judgment, one of the most beautiful. The quantity and quality of charmed particle data produced is unsurpassed even by electron-positron colliders. An example of such is Fig. 1, the mass plot of $D^+ \Rightarrow K^- + \pi^+ + \pi^+$ for the complete E-691 data sample. This mass peak contains over 4100 observed D decays into this single channel. The charmed particle lifetimes measured by E-691 for the D^0, D^+, D_S^+, and the Λ_c are the world's most precise. During 1988, this group has also published limits on D^0 - $\overline{D}^0$ mixing, results on the decays of charmed particles into non-strange states, decays into two kaon states, and the measurements of semi-leptonic decays of the D^0 (Fig. 2).

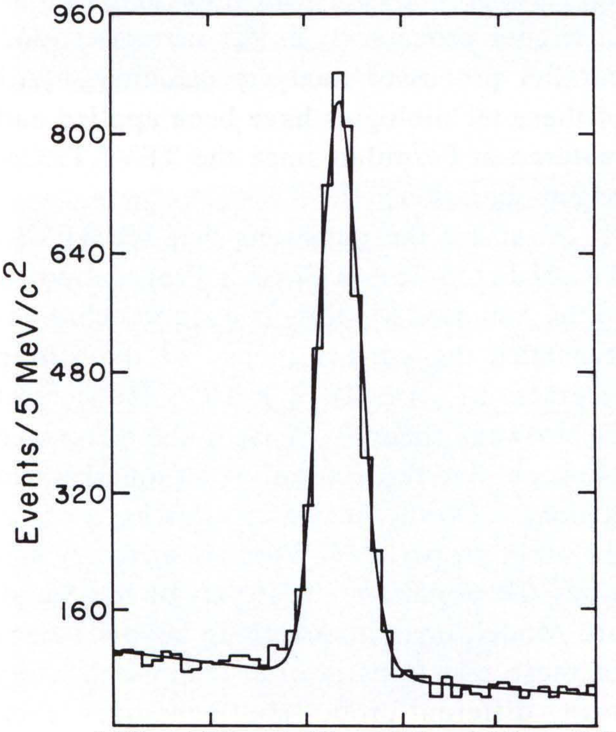


Fig. 1. The entire data sample of $D^+ \Rightarrow K^- + \pi^+ + \pi^+$ for E-691. The peak contains approximately 4100 of these decays.

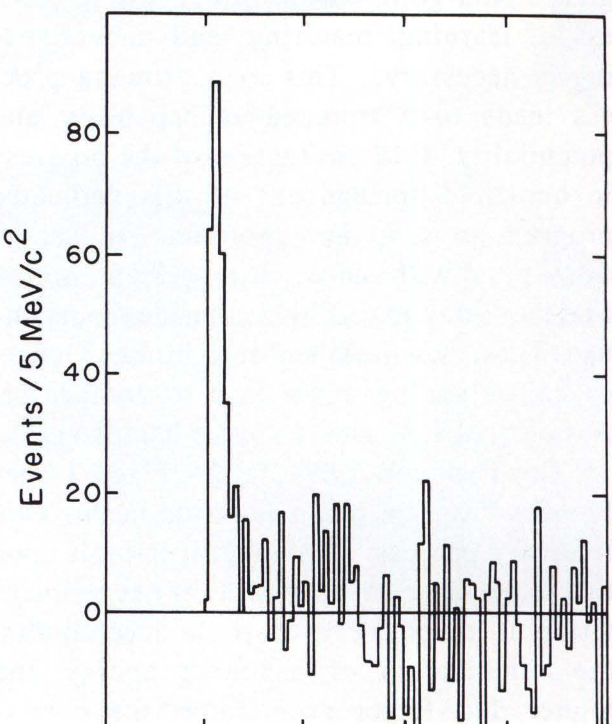


Fig. 2. The E-691 observation of the decay chain $D^{*+} \Rightarrow D^0 + \pi^+$ followed by $D^0 \Rightarrow K^- + e^+ + \nu_e$. Note that the peak is at the invariant mass of the D^{*+}.

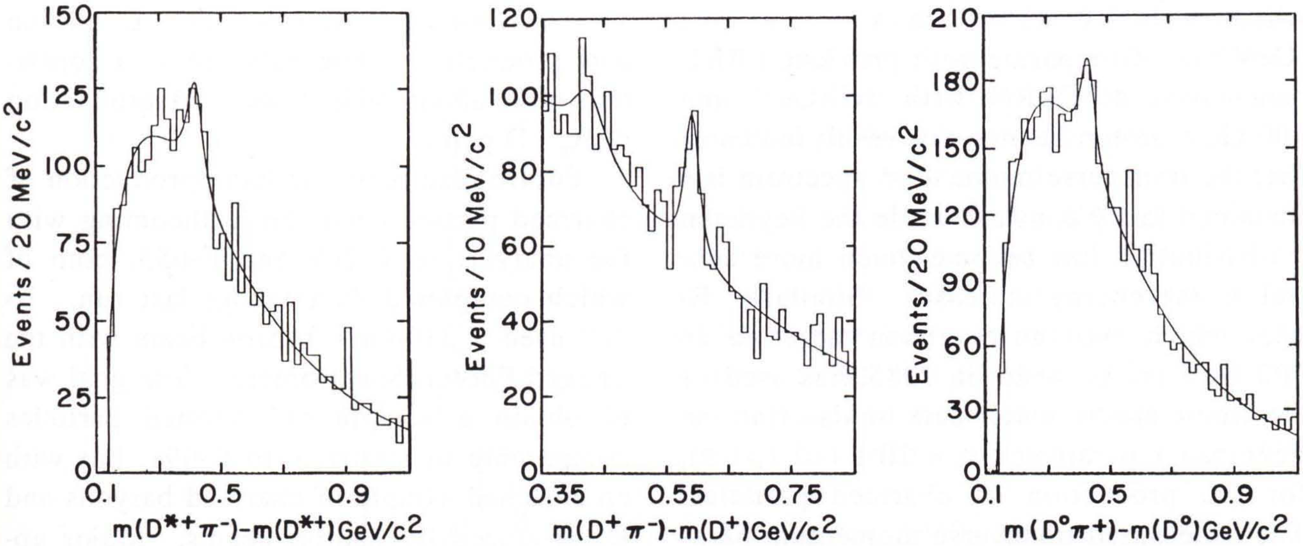


Fig. 3. The E-691 observation of the doubly excited charm states a) D^{**0} (2420), b) D^{**} (2453), and c) D^{**+} (2443).

This group has recently reported three additional excited charmed meson L = 1 states (Fig. 3). These states are the D^{**0} (2420) => D^{*+} + π^- which has been observed by ARGUS and CLEO, D^{**+} (2443) => D^{*0} + π^+, and D^{**0} (2453) => D^+ + π^-.

E-691 also studied the dynamics of charm photoproduction determining the Feynman x and transverse momentum dependence for the single D mesons (Fig.4)

$$\frac{d\sigma}{d x_f \, d p_t^2} = A\,(1 + a\,x_f)\,(1 - x_f)^n \exp(-b\,p_t^2 - c\,p_t^4)$$

where a = 14 ±10
n = 2.95 ±0.22
b = 1.07 ±0.05 $(\text{GeV}/c)^{-2}$
c = -0.04 ±0.01 $(\text{GeV}/c)^{-4}$

These production dynamics results await interpretation in light of the photon gluon fusion model for heavy quark production.

Three other Fermilab groups have recently published results on the dynamics of hadroproduction of charm using proton beams. E-743 used LEBC, the CERN LExan Bubble Chamber, in a Fermilab 800-GeV proton beam in 1985. The total production rate of charged plus neutral D mesons was measured to be 48 (+10, -8) microbarns. The Feynman x and transverse momentum distributions were measured to be

$$\frac{d\sigma}{d x_f \, d p_t^2} = A\,(1 - /x_f/)^n \exp(-a\,p_t^2)$$

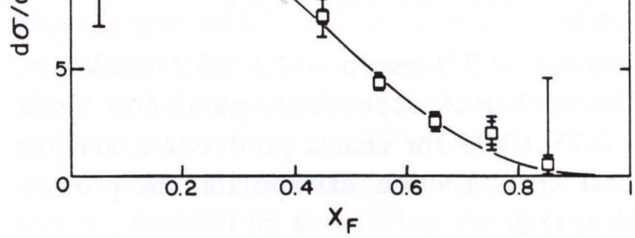


Fig. 4. The Feynman x distribution for photoproduced D mesons from E-691.

where n = 8.6 ±2.0, and a = 0.8 ±0.2 $(GeV/c)^{-2}$. Comparing with previous LEBC data taken at CERN with 360-GeV and 400-GeV proton beams, this result indicates that the transverse momentum spectrum has remained fairly constant while the Feynman x distribution has become much more central as the energy increases. Similarly, E-653, which used an emulsion target in an 800-GeV proton beam in 1985, has used its electronic spectrometer data to also find the Feynman x parameter, n = 10.1 (+2.1,-1.9), for the production of charmed particles. Their measured transverse momentum parameter a = 1.29 (+0.25,-0.23) $(GeV/c)^{**-2}$.

E-613, an experiment that completed data taking in the 400-GeV pre-TEVATRON era, recently published the final results on the direct production of neutrinos using a proton beam. The conventional model of the source of these prompt neutrinos is the production and subsequent decay of charmed particles. E-613 then detected the interactions and energy spectrum of these prompt neutrinos and was able to unfold the parameters of the initial charm production. The rates of ν_μ and ν_e production were observed to be equal, consistent with the decay of charmed particles as the primary source of the neutrinos. They found the invariant cross section for charm hadroproduction (note the leading factor of E) to behave as

$$E \frac{d\sigma}{d^3p} = A\,(1 - x_f)^n \exp(-a\,p_t)$$

where n = 3.2 and a = 1.5 ±0.2 $(GeV/c)^{-1}$. The nuclear A-dependence parameter alpha = 0.75 ±0.05 for charm production, and the total cross section extrapolated to protons (A = 1) is

$$\sigma_{D+\overline{D}} = 57.2 \pm 2.9 \pm 8.5 \text{ microbarns/nucleon at 400 GeV}$$

This assumes predominant D - $\overline{D}$ meson pair production. The data are also consistent with about 40% associated production of Λ_c - $\overline{D}$ pairs.

Future results on the hadroproduction of charmed particles will be forthcoming with the analysis of E-769 and E-653, both of which completed data taking last run. E-769 used a 250-GeV hadron beam with the Tagged Photon Spectrometer. The goal was to obtain a sample of charmed particles comparable in statistics to E-691, but with an enriched sample of charmed baryons and D_s^+ produced by hadron beams. Major upgrades included the use of both the CERN DISC (Differential Isochronous Self-focusing Cerenkov counter) and a TRD (transition radiation detector) to simultaneously tag pions, kaons, and protons in the 250-GeV beam (Fig. 5). An innovative data acquisition system based on the Fermilab-developed Advanced Computer Program (ACP) processors, smart crate controllers, and VME buffer memories was able to log a record 450,000,000 events on tape. Major data analysis is necessary before physics results will be available. Extensive new experimental upgrades are being prepared by E-791 to continue to substantially increase the data sample for charm hadroproduction, again using the Tagged Photon Spectrometer for the next running period. E-653 used both 800-GeV protons (1985 run) and 600-GeV pions (1987 run) with emulsion targets. The E-653 proton emulsion data is presently being analyzed in Japan. E-653 anticipates about 1000 charm - anti-charm pair events and a handful of beauty - anti-beauty pair events to be found in this sample.

It has been 25 years since the discovery of CP violation, the mysterious property observed only in the decays of K^0 mesons in which there is a non-symmetry under the

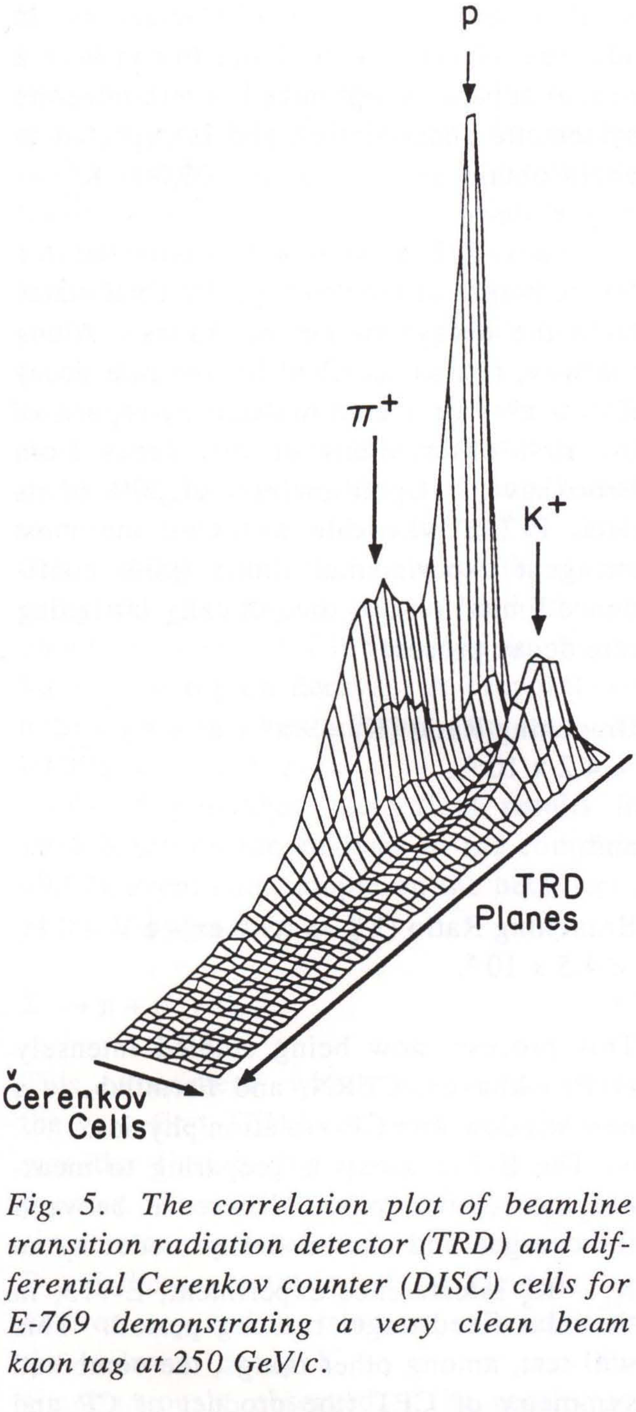


Fig. 5. The correlation plot of beamline transition radiation detector (TRD) and differential Cerenkov counter (DISC) cells for E-769 demonstrating a very clean beam kaon tag at 250 GeV/c.

combined operation of Charge Conjugation (replacing particles by their anti-particles) and Parity Inversion (spatial reflection as in a mirror). Conservation laws are one of the basic foundations of physics. However, parity non-conservation in nuclear beta decay was observed in the late 1950s. This turned out to be a crucial observation in understanding the V-A (vector minus axial vector) left-handed form of the weak interaction. In 1964, CP violation was observed at Brookhaven National Laboratory by Cronin and Fitch, et al., and the physics world is still trying to understand its origin. There are extensive experimental programs at CERN, Fermilab, Brookhaven, and Los Alamos to attempt to observe CP violating effects, along with many theoretical attempts to understand and interpret CP violation.

During the 1960s and early 1970s, the Universe seemed to include only three quarks. An obscure model by Bjorken and Glashow predicted another heavier quark, the charmed quark, which would allow the four quarks to be grouped into two families of two quarks and two leptons each. This model then provided for almost all known particle transitions, specified by one parameter, the Cabibbo mixing angle. The only exceptions appeared to be the CP violating K decays. This model was verified by the discovery of the charmed quark. The discovery of the bottom quark (by Leon Lederman et al. at Fermilab) and the tau-lepton (by Martin Perl et al. at SLAC) indicated the existence of the third family of quarks and leptons. The particle mixing rules for a universe with three families were formalized in the Kobayashi-Maskawa matrix. This included three independent mixing angles, and an overall quantum mechanical phase angle which would lead to a physically observable phenomenon. This special phase is believed to be the extra degree of freedom responsible for CP violation.

An especially sensitive test of CP violation is provided by comparing the decays of neutral kaons into two pions. Small differences in the relative rates of K^0_L and K^0_S into

$\pi^+ + \pi^-$ and $\pi^0 + \pi^0$ are sensitive to the origin of the CP violation. The observations may be quantified in a single term, the Real part of $(\varepsilon'/\varepsilon)$. CP violation may come about in two different ways. There can be the spontaneous transformation of quarks into anti-quarks in the parent K-meson, corresponding to the ε term, or there can be direct CP violation in the decays of the pure CP components of the parent K-meson, corresponding to the ε' term. Such a CP-violating decay would be evidenced by a difference in the charged and neutral decay rates. The Standard Model would anticipate a value of 0.001 - 0.007 for this ratio $Re(\varepsilon'/\varepsilon)$, where the uncertainty in the prediction is due mainly to the assumed mass of the top quark, which has not yet been observed. Another model, the superweak theory, assumes that all CP violation occurs in the initial state mixing, not in the decay, thereby predicting $Re(\varepsilon'/\varepsilon) = 0$.

During 1988, NA31, an experiment at CERN, published a non-zero result for the $Re(\varepsilon'/\varepsilon) = 0.0033 \pm 0.0011$ (combined statistical and systematic uncertainty). This was based on a sample of 109,000 $K^0_L \Rightarrow \pi^0 + \pi^0$ decays, the most technically challenging of the four decays to be measured.

A similar measurement was recently published by Fermilab E-731 of $Re(\varepsilon'/\varepsilon) = 0.0032 \pm 0.0028$ (statistics) ± 0.0012 (systematics) based on a sample of 6700 $K^0_L \Rightarrow \pi^0 + \pi^0$ decays obtained in the 1985 run. The 1987-88 run produced 300,000 of these neutral K-long decays and is expected to produce a definitive result within a year. The experimenters believe that this sample will reduce the statistical uncertainty to the ± 0.0006 level and the systematic uncertainty to the ± 0.0008 level. This overall uncertainty level of ± 0.0010 in the $Re(\varepsilon'/\varepsilon)$ would be sufficient to confirm whether the non-zero result of the CERN NA31 experiment is not just a statistical fluctuation. In addition, NA31 is continuing to run with a rebuilt apparatus, optimized to minimize the systematic uncertainties, and is expected to again obtain approximately 100,000 $K^0_L \Rightarrow \pi^0 + \pi^0$ decays.

The E-731 apparatus is optimized for the detection of electromagnetic final states from the decays of neutral kaons. Along the way, it also searched for the rare decay $K^0 \Rightarrow \pi^0 + e^+ + e^-$ stimulated by reports of the first observations of this decay from Brookhaven. Upon analysis of 20% of its data, E-731 was able to quote the most stringent experimental limits (90% confidence limits) on this theoretically intriguing rare decay process

Branching Ratio $(K^0_L \Rightarrow \pi^0 + e^+ + e^-)$
$< 4.2 \times 10^{-8}$

and

Branching Ratio $(K^0_S \Rightarrow \pi^0 + e^+ + e^-)$
$< 4.5 \times 10^{-5}$.

This process, now being studied intensely at Brookhaven, CERN, and Fermilab, is a new window into CP-violation physics.

The E-731 group is preparing to measure the relative phase difference between the charged and neutral decay modes by an K^0_L - K^0_S interference experiment, E-773, in the next fixed-target running period. This will test, among other things, the combined symmetry of CPT (the product of CP and Time Reversal Invariance).

E-621 is an experiment searching for the CP-violating three-pion decay of the short-lived neutral kaon

$K^0_S \Rightarrow \pi^+ + \pi^- + \pi^0$.

This experiment attempted to observe interference effects between the CP allowed K-long and CP-violating K-short decays into three pions. The relevant parameter is η_{+-0}, which is the ratio of the amplitudes for the K-short to K-long decays. A preliminary result has been reported by E-621 based on an analysis of about 10% of the data that it took during the 1985 running period. This result was $/\eta_{+-0}/ = 0.035 \pm 0.016$ with a phase $\phi_{+-0} = -221^{\circ} \pm 28^{\circ}$. Previous experiments have constrained $/\eta_{+-0}/$ to be less than 0.35. The complete data sample of 3,000,000 three-pion decays is anticipated to produce an uncertainty in η_{+-0} of about 0.003, roughly the level at which theory expects this process to occur, and also at about the level of CP violation in the K-long => two-pion decays. A proposal has been submitted to extend this data set to the 90,000,000-event level.

E-715 published their final results in 1988 based on the analysis of the complete 49,671-event data sample on the beta decay of the Σ^- hyperon.

$\Sigma^- \rightarrow n + e^- + \bar{\nu}_e$

This experiment, which took data during the very first TEVATRON run in 1983-84, was the first high-statistics study of this process. It used a polarized Σ^- beam and simultaneously measured the Σ^- polarization P and the asymmetries of the electron, α_e, neutron, α_n, and neutrino, $\alpha_{\bar{\nu}_e}$. In addition, the hadronic decay $\Sigma^- \rightarrow n + \pi^-$ was also simultaneously observed. The results are listed in Table 1. The observation that the g_1 and f_1, the axial vector and vector form factors respectively, were of opposite sign resolved a long-standing discrepancy with the Cabibbo model of hyperon decays. This experiment was the first to measure the weak magnetism form factor f_2 and was the first to begin to reach the sensitivity to the form factor g_2 due to an induced pseudotensor, or weak electricity. In conclusion, this experiment helped to verify the Cabibbo model and added further constraints on the theory of broken SU(3). An upgraded version of this experiment, E-761, will study the radiative decays of the Σ^+ and Ξ^- hyperons during the next run.

Table 1

$\Sigma^- \rightarrow n + e^- + \bar{\nu}_e$ Parameters from E-715

$P = +0.236 \pm 0.043$

$\alpha_e = -0.519 \pm 0.104$

$\alpha_n = +0.509 \pm 0.102$

$\alpha_{\bar{\nu}_e} = -0.230 \pm 0.061$

$g_1/f_1 = -0.327 \pm 0.007 \pm .019$
from neutron spectrum, assuming $g_2 = 0$

$g_1/f_1\ (q^2 = 0) = -0.328 \pm 0.019$
general fit of all asymmetry data

$f_2/f_1\ (q^2 = 0) = -0.96 \pm 0.15$

Last year's annual report described the attempts by E-756 to produce a polarized Ω^- beam. The polarization produced directly in primary proton interactions was observed to be too small to be useful for determining the Ω^- magnetic moment. A new targeting scheme was developed to produce a polarized neutral hyperon beam at ±2 milliradians production angle. This beam was re-targeted, producing a zero degree Ω^- beam. The polarized Λ^0 and Ξ^0 hyperons in this beam then transferred their polarization to the produced Ω^-. The Ω^- polarization at 320 GeV (400 GeV) was about 7 % (15%), sufficient to measure the magnetic moment. The world's first result based on the sample of

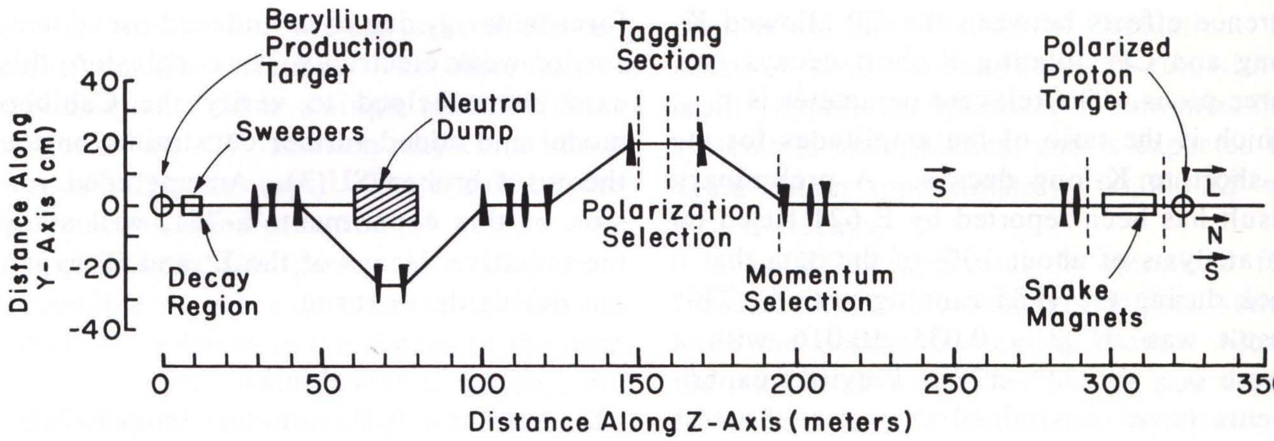


Fig. 6. Layout of the new Polarized Proton Beam.

22,000 polarized Ω^- was a magnetic moment of -2.0 ±0.2 nuclear magnetons. Along the way, the world's most precise measurement of the magnetic moment of the Ξ^- was determined to be -0.64 ±0.02 nuclear magnetons, based on analysis of 500,000 Ξ^- decays out of a total of 40,000,000 on tape. Although the measurement of the Ω^- magnetic moment is impressive, it is not yet of sufficient precision to stringently test the broken SU(6) theory. An approved future run expects to obtain about 100,000 polarized Ω^-, with the goal of reducing the uncertainty in the magnetic moment to the order of 0.03-0.06 nuclear magnetons.

The Polarized Proton Beam is a new, unique, record-setting beamline (see Fig. 6). The world's highest energy (185 GeV/c) polarized protons, and antiprotons, too, are produced in the parity-violating decay of neutral Λ hyperons. The individual proton momentum, position, angle, and polarization are measured along the beam transport. A series of 12 ''Siberian Snake'' dipole magnets are available to rotate the proton polarization between longitudinal, horizontal, or vertical directions. Two polarimeters are used to measure the absolute polarization of the beam. One uses the Primakoff effect in the Coulomb field of a heavy nucleus to photoproduce single pions. The second method uses Coulomb-Nuclear interference in the pp elastic scattering. The resulting asymmetries can be used to measure the beam polarization. The first results using this new polarized proton beam were obtained from a five-day test run in 1987. The ''analyzing power'' for the production of π^0's is related to the pro-

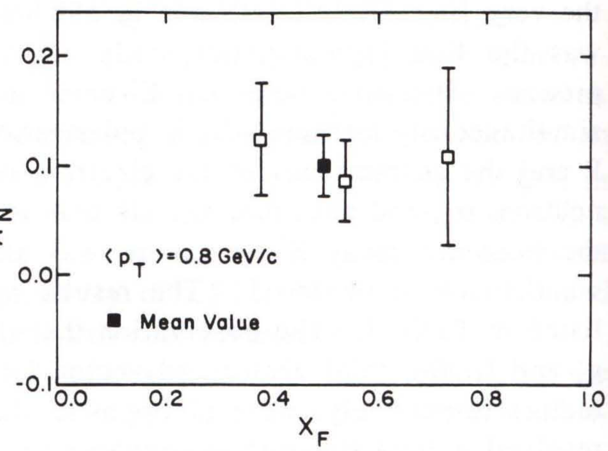


Fig. 7. The analyzing power A_N for π^0 production by 185 GeV/c polarized protons as measured by E-704.

duction asymmetries using a polarized beam (Fig. 7). The average analyzing power is measured to be $A_N = 0.10 \pm 0.03$ at $x_f = 0.52$ and $p_t = 0.8$ GeV/c for π^0 production by polarized protons. This first result is in qualitative agreement with quark model predictions of 0.19 ± 0.02 for π^0 production at high Feynman x. E-704's goals for the next run include measuring the difference in total cross sections and production of mesons and hyperons for configurations where the longitudinal polarizations of both the beam and target are parallel and antiparallel, and observing production of mesons and hyperons using a transverse polarized beam.

The massive Lab E high-luminosity neutrino detector obtained data using the wideband quad triplet neutrino beam during both the 1985 (E-744) and the 1987-88 (E-770) running periods. In addition, the high-resolution Lab C neutrino detector (E-733), the holographic 15-ft Bubble Chamber (E-632), and the holographic Tohoku Bubble Chamber (E-745) took data during these running periods. The 800-GeV TEVATRON has opened a new energy range for such experiments above 300-GeV neutrino energy (Fig. 8).

A major priority of the Lab E group was in the study of neutrino production of events with two muons with the same charge. One of the neutrinos is assumed to be the recoil muon from a common charged current weak interaction. The second neutrino is a decay product of some state produced at the hadronic vertex. Prior lower energy results published by groups at both CERN and Fermilab had indicated that there might be production of same-sign dimuons in excess of that anticipated by the current Standard Model. Such an excess appeared to be increasing as the neutrino energy increases.

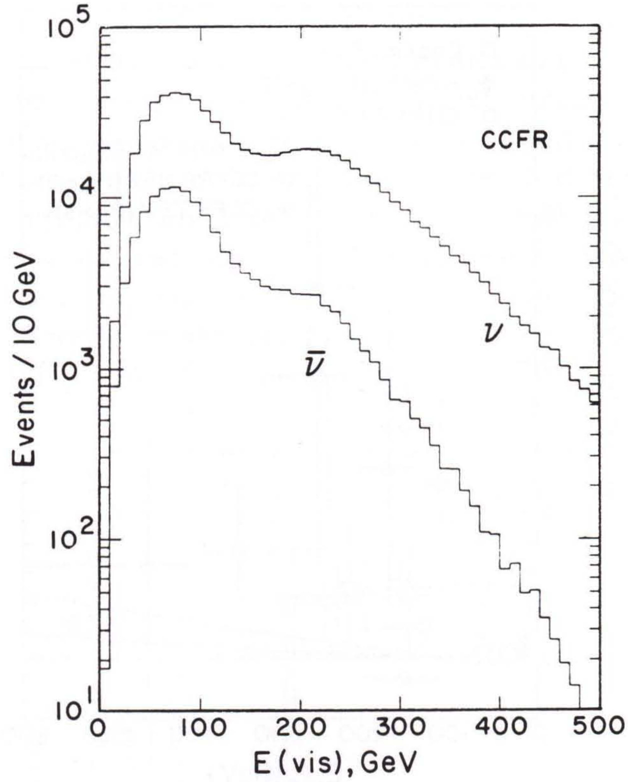


Fig. 8. The TEVATRON neutrino event energy spectrum produced by the Quad Triplet neutrino train and measured in the Lab E detector.

E-744 observed 101 ±10 (15 ±4) same-sign dimuon events produced by a neutrino (anti-neutrino) beam. The total expected background rate from randomly overlapping events, the decays of pions and kaons produced either at the hadronic vertex or within the hadronic calorimeters, and misidentified three-muon events, was 82.5 ±12.4 (8.6 ±1.3) events. This corresponds to a rate for the production of same-sign dimuon events by neutrinos of $0.24 \pm 0.43 \times 10^{-4}$ (90% C. L. = 0.92×10^{-4}) for 30 - 300 GeV and $3.40 \pm 1.96 \times 10^{-4}$ (90% C.L. = 6.38×10^{-4}) for 300 - 600 GeV. These rates are consistent with the Standard Model QCD expectations

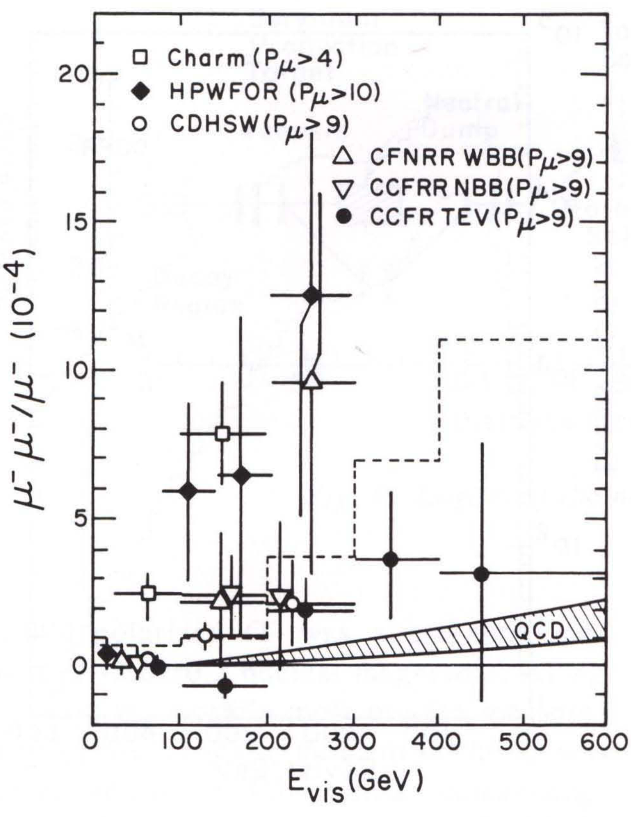


Fig. 9. Rates for same sign dimuon production relative to single-muon charged-current neutrino events for E-744, denoted CCFR, and earlier experiments.

(Fig. 9), and show that the lower statistics, lower energy data showing an excess of same-sign dimuons do not extrapolate to higher energies and improved statistical accuracies. The Lab E study of opposite-sign dimuons shows agreement with the Standard Model for the production and decay of charmed particles. This study also indicated that the amount of the strange-quark sea in the nucleon is only about one-half of the average of the up-quark sea and down-quark sea. The final results from Lab E are expected to include studies of the nucleon structure functions along with increased statistics from the 1987-88 run on same-sign and opposite-sign dimuons and the inverse muon decay process.

The other neutrino experiments continue to analyze the large amount of data taken during the 1985 and 1987-88 runs. The Tohoku Bubble Chamber (E-745) is studying production of charmed particles along with a study of the EMC effect for neutrino interactions from heavy targets. The 15-ft Bubble Chamber (E-632) is also studying charmed particle production along with pions produced by the coherent scattering of the longitudinal component of the axial-vector weak field. The Lab C group, E-733, is studying the nucleon structure functions, the Weinberg angle, and searching for weakly interacting massive particles (WIMP's) which may be generated in the neutrino production target and subsequently decay in the Lab C detector.

E-706 is another new experiment, receiving beam for the first time in the 1987-88 running period. The dominant component is the large Liquid Argon Calorimeter for the study of direct production of single photons using pion, kaon, and proton beams. A magnetic spectrometer analyzes the components of the hadronic jet recoiling against the trigger single photon. Theoretically, the production of single direct photons at high transverse momentum is expected to be dominated by the quark-quark annihilation and quark-gluon Compton scattering processes. By measuring the transverse momentum and rapidity distributions for the single photon, the gluon structure functions of the incident beam particles may be determined. A first look at about 10% of the E-706 negative beam data reveals the transverse momentum distribution for single direct photons out to p_t = 8 GeV/c (Fig. 10). The data range is anticipated to be extended out to p_t = 12 GeV/c during the next run.

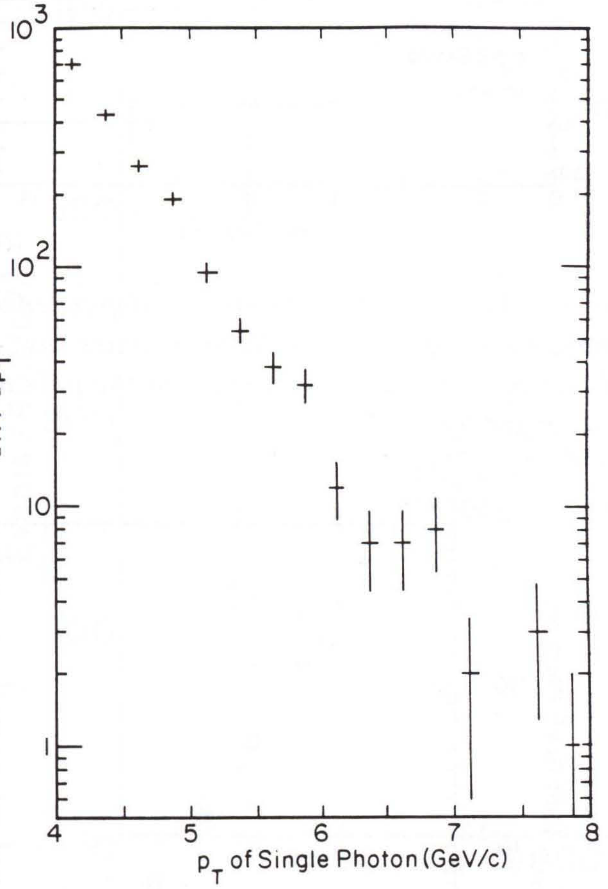


Fig. 10. Preliminary p_t spectrum of single gamma rays corresponding to approximately 10% of the negative beam sample accumulated by E-706 during the 1988-89 run.

E-672, a study of jets, direct photons, and hadron states produced in association with the hadro-production of J/Ψ, runs simultaneously with E-706. This experiment uses a magnetized iron toroid spectrometer to trigger on high-mass dimuon pairs and then reads out the Liquid Argon Calorimeter and magnetic spectrometer. The 1987-88 run provided about 5000 J/Ψ events using a 530-GeV π^- beam with various nuclear targets. The typical J/Ψ dimuon mass distribution and the A-dependence of the J/Ψ are shown in Figs. 11 and 12.

During the 1987-88 run, E-711 completed its study of the systematics of high-mass di-hadrons. A calorimeter-triggered two-arm spectrometer was used to sort out the leading, or highest momentum, hadrons in proton-produced jet events. The charges, positive and negative, of these leading hadrons are expected to be correlated with the charges of the constituents in the underlying hard scattering process. The invariant

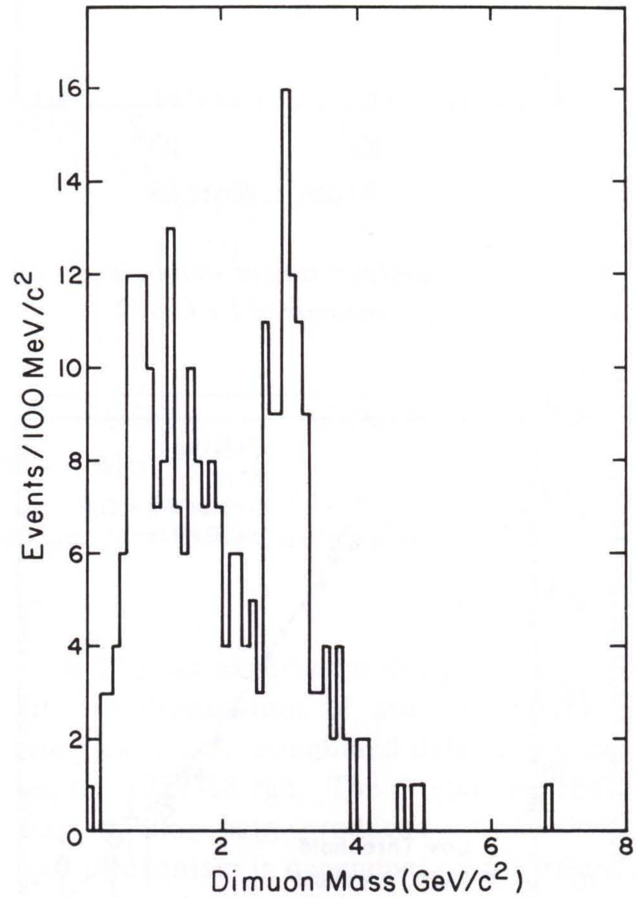


Fig. 11. A sample of the dimuon mass spectrum accumulated by E-672 during the 1987-88 run. This sample represents those dimuons identified in the E-672 iron toroid spectrometer, track-linked to, and measured by, the E-706 magnetic spectrometer and silicon microstrip vertex detector.

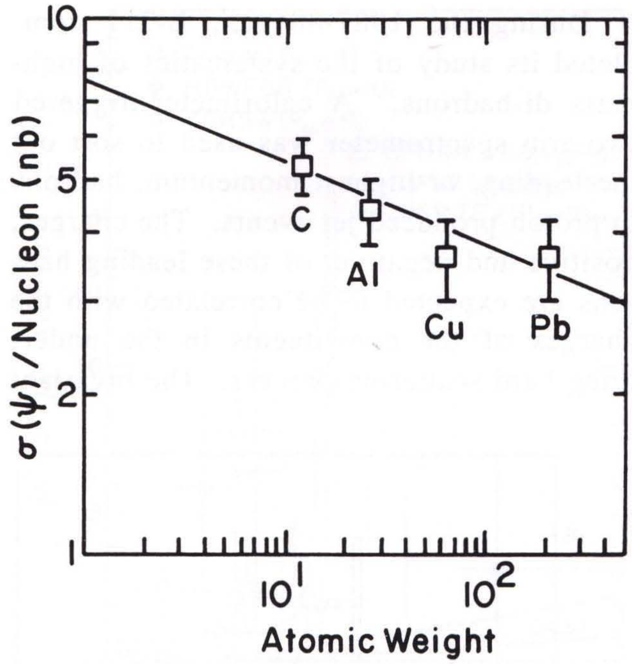


Fig. 12. The nuclear target dependence of J/ψ production as measured by E-672.

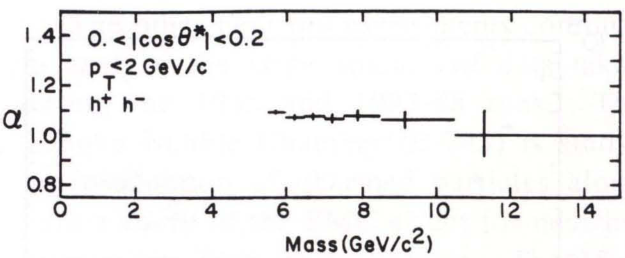


Fig. 14. The nuclear dependence parameter α_{+-} *for +-hadron pairs as a function of the invariant mass of the pair as observed by E-711.*

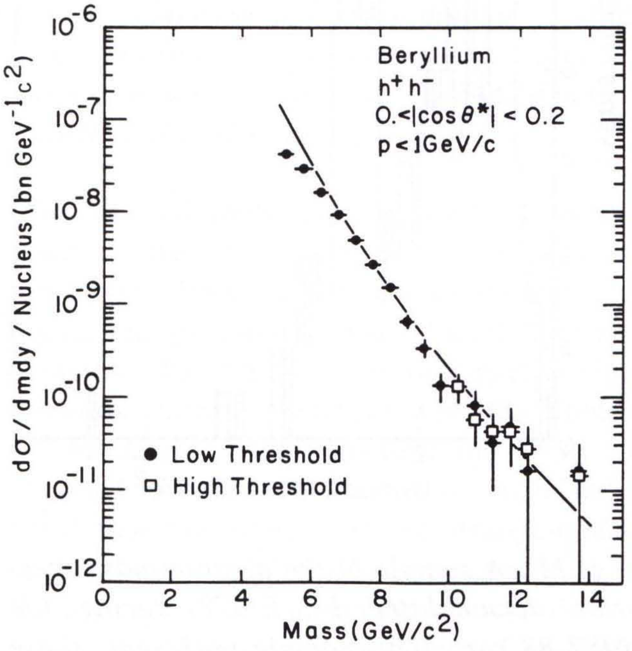


Fig. 13. The invariant mass spectrum observed by E-711 for proton-Beryllium collisions.

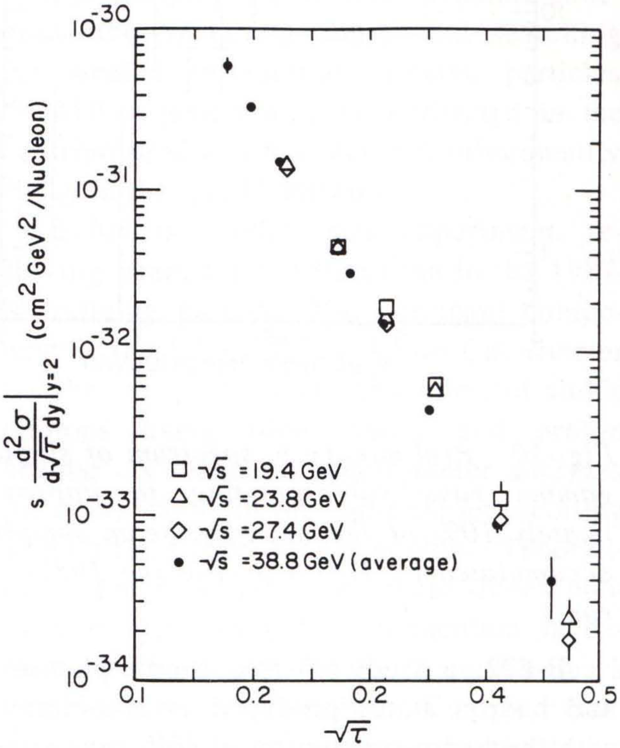


Fig. 15. The E-605 dimuon at yields at 800 GeV compared with the lower energy E-288 measurements.

mass and angular distributions of these hadron pairs produced near the kinematic limit should provide stringent tests of quantum chromodynamics. The initial analysis pass of these data has been completed using

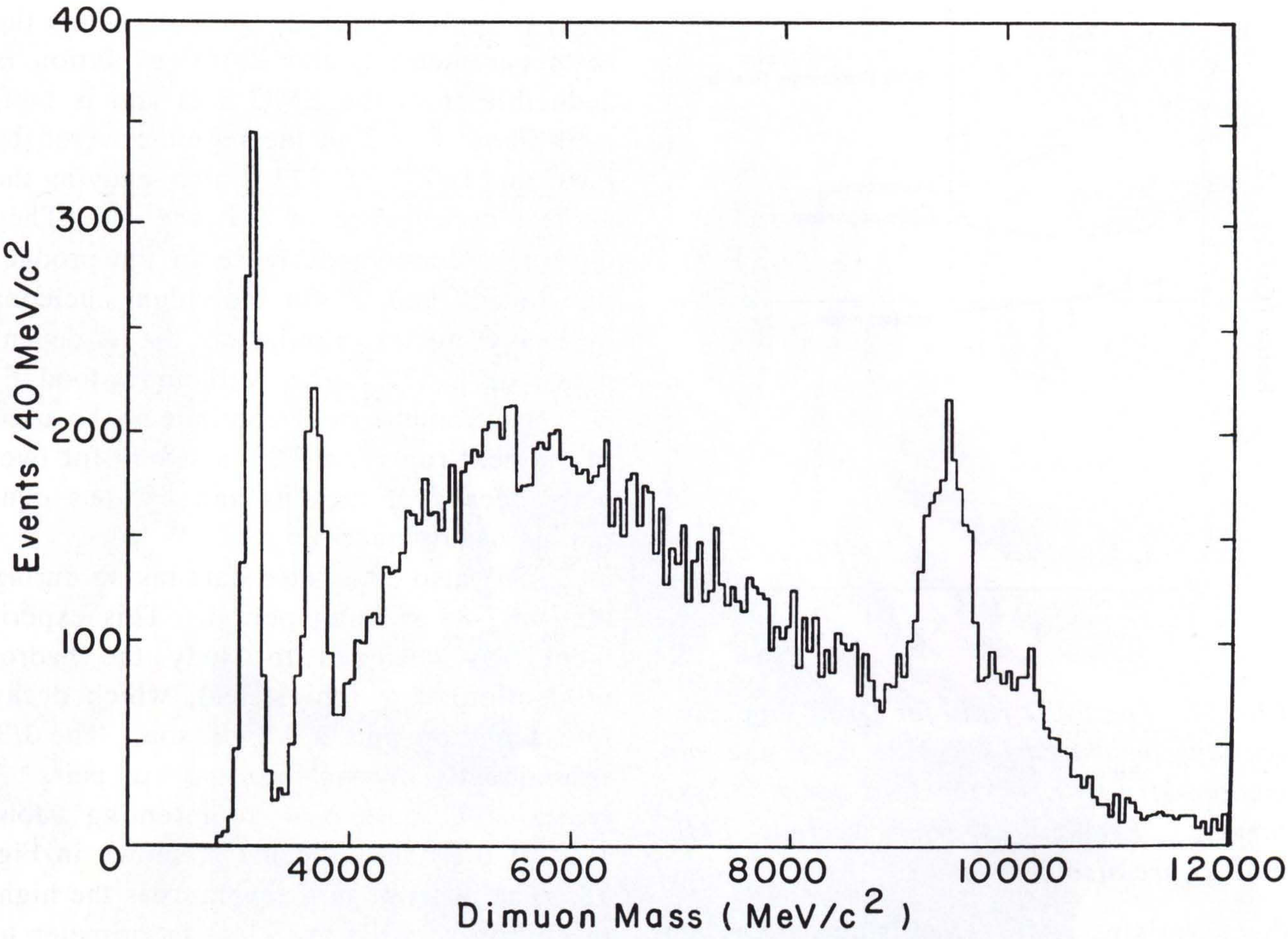


Fig. 16. The observed dimuon mass spectrum for E-772 accumulated over three spectrometer settings.

the Florida State University Cyber 205 and ETA 10 supercomputers. Examples of the invariant mass distribution for positive + negative hadron combinations and the measured A-dependence parameter α+- are shown in Figs. 13 and 14.

The large two-particle spectrometer in Meson East has served E-605 and E-772 in past runs, and is being upgraded for the upcoming E-789. E-605 has recently presented the continuum dimuon mass spectrum. Figure 15 shows the scaling spectrum for the dimuon invariant mass divided by the available energy in the center of mass for the 200-, 300-, and 400-GeV data of E-288 along with the new 800-GeV data.

E-772, an experiment designed to measure the distribution of sea anti-quarks in complex nuclei, completed data taking during the 1987-88 run. The production of forward dimuon pairs produced via the Drell-Yan mechanism is dependent on the valence quark distribution of the beam protons and the anti-quark distribution of the target nuclei. Such Drell-Yan dimuon production is closely related to the inelastic muon or neutrino scattering for which complex target nuclei data has recently produced surprising results known as the EMC effect. The dimuon data of E-772 allows a clean measurement of the anti-quark sea distributions for the nuclear targets, thereby checking if

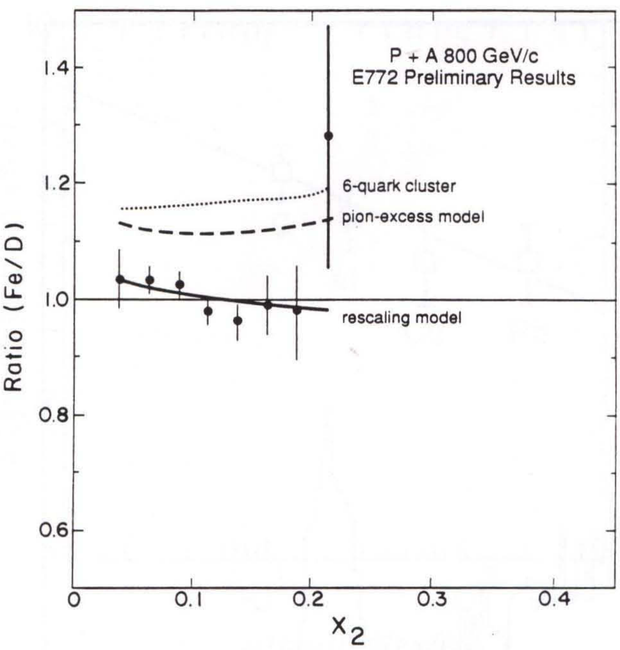


Fig. 17. The Fe/D ratio for Drell-Yan cross sections measured in E-772. x_2 is the momentum fraction of the anti-quark in the target. Predictions from various EMC models are also shown.

this surprising EMC effect is due to any unexpected modifications of the quark sea. Figure 16 shows a composite plot of the E-772 observed dimuon mass distribution, summed together for the three spectrometer settings. It is interesting to observe the J/Ψ, Ψ′, Υ, and Υ′ in a single plot. A preliminary yield ratio for iron to liquid deuterium targets of the dimuon pairs corresponding to a target quark x_2 value is shown in Fig. 17. This preliminary data shows that the Fe/D ratio is nearly independent of x_2 and is best represented by the theoretical rescaling model. This model notes the similarity between the x-dependences of two features of deep inelastic lepton scattering, namely the scale violation parameter for scattering from single nucleons and the EMC effect for complex nuclear targets. This similarity could suggest that the QCD scale is modified for heavy nuclei, such that Q_0^2 (nucleon) is scaled to $\zeta\ Q_0^2$ (nucleus) where the scale parameter ζ and its Q^2 evolution is deducible from the EMC data and is typically about $\zeta = 2$ in the region covered by EMC and E-772. E-772 is also studying the nuclear dependence of J/Ψ and Ψ′. They observe a relative decrease in the production of J/Ψ and Ψ′ for individual nucleons in heavy nuclei, similar to the A-dependence of E-672. The well understood E-605 spectrometer will continue to be used in the next run for E-789, a search for two-body decays of mesons and baryons containing beauty quarks.

E-705 also completed data taking during the 1987-88 running period. This experiment was designed to study the hadroproduction of χ (chi states), which decay into a photon plus a J/Ψ meson. The J/Ψ subsequently decays into a $\mu^+\ \mu^-$ pair. A typical J/Ψ mass peak representing about 10% of the data collected is shown in Fig. 18. The heart of this apparatus is the high-resolution scintillating glass calorimeter to

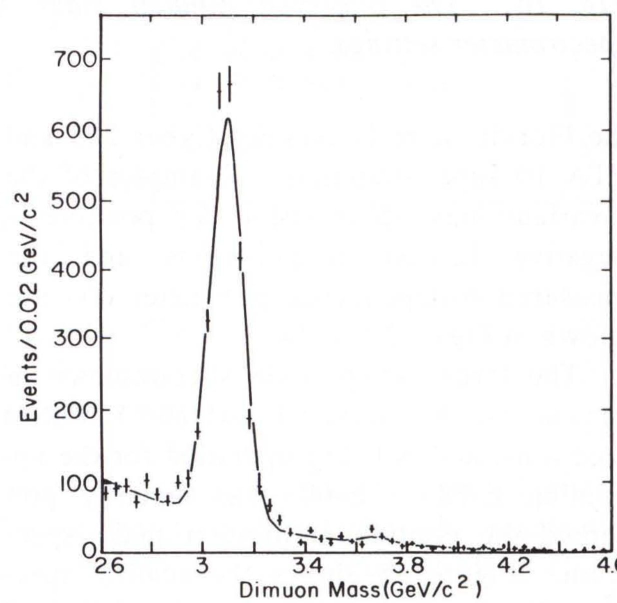
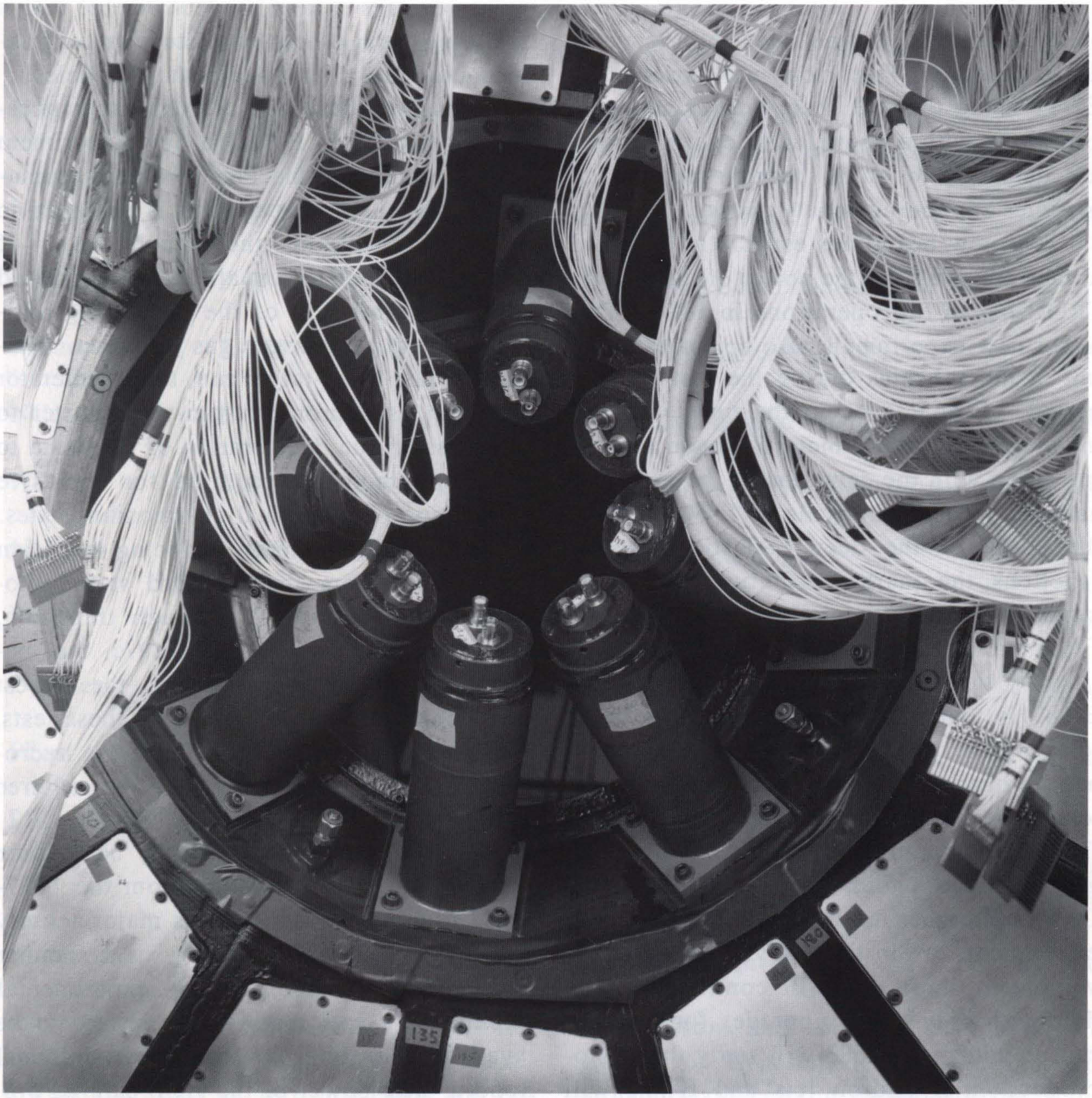


Fig. 18. The dimuon mass spectrum based on about 10% of the E-705 data. Both the J/ψ and ψ′ peaks are evident.



The E-760 central Cerenkov detector.

detect the photons. Analysis programs are being developed to find and measure the χ decay photons. This group will continue as E-771 using the J/Ψ spectrometer and trigger, along with a powerful silicon microvertex detector, to study hadroproduction of particles containing beauty quarks.

Two new beamlines especially designed to take advantage of the power of the TEVATRON began full operations in 1987. Two major new experiments also began data taking in these beams during the last running period. E-665 is using the new 500-GeV muon beam to study inelastic muon scattering along with the detection of the produced hadrons. The main goals of E-665 include the study of the deep inelastic structure functions, the quark distributions within the target nucleons, especially at the new low-Feynman x range just recently made accessible by the world's highest energy muons. E-687 is using the wideband photon beam to study the photoproduction of charm and bottom quarks. This experiment is designed to acquire a substantially larger data set than E-691 by operating at higher photon energies (average photon event energy = 225 GeV) and higher luminosities. Both of these experiments are in the analysis program development stage and will continue to take data with only minor upgrades for the next run. In addition, E-683 will study the photoproduction of hadron jets and E-774 will search for electromagnetic production of short-lived penetrating particles, both using the wideband photon beam. Finally, E-782 will bring a new muon beam into the Tohoku Bubble Chamber to study structure functions at low Q^2 for the next run.

After demonstrating its capabilities at Brookhaven National Laboratory, E-690 has moved to Fermilab and is preparing to take data during the next run. The experiment features a recoil spectrometer and a real-time event processor to study target fragmentation into charm and beauty particles.

Also considered as a fixed-target physics experiment is E-760, a new experiment being installed in the Pbar Source Accumulator Ring. This experiment is designed to study charmonium, the bound states of charm - anti-charm quark pairs, produced by the annihilation of the circulating antiprotons and a hydrogen gas jet target. During the last fixed-target run, the Accelerator Division used protons from the Booster to commission the deceleration of the beam to the exact momenta required for exclusive production of individual charmonium states. This required efficiently reducing the beam momentum from the standard stored momentum of 8.9 GeV/c through transition, continuously down to 3.6 GeV/c, the momentum corresponding to η_c, the lowest mass charmonium state. During these tests, the experimenters commissioned the hydrogen gas jet target and attained the required design luminosity.

Although there have already been some preliminary physics results from the 1987-1988 running period, there is major activity in analysis program activity and number crunching by almost every experimental group. We anticipate major results to be available in time for next year's annual report. The power of the ACP parallel processors are being extensively exploited to speed up these offline data analyses. In addition, a full program of experimental physics is planned for the next fixed-target physics run, including many new, or extensively upgraded experiments (Table 2).

So, we have examined the current snapshot of the Fermilab Fixed-Target Physics Program. We have noticed that the field of charm particle production and properties

Table 2
Fermilab Fixed-Target Physics Program for the Next Run

West	E-706	Direct Photon Production in Hadron Collisions	
	E-672	Hadronic Final States Associated with Jets and Dimuons	
MCenter	E-773	Phase Difference between η_{+-} and η_{00}	(NEW)
MPolarized	E-704	Physics with a Polarized Proton Beam Facility	
MEast	E-789	Two-Prong Decays of Neutral Beauty Particles	(NEW)
NCenter	E-782	Muon Scattering in the Tohoku Bubble Chamber	(NEW)
NEast	E-690	Study of Charm and Beauty in Target Fragmentation	(NEW)
NMuon	E-665	Muon Scattering with Hadron Detection	
PWest	E-771	Search for Beauty Decays into J/ψ	(NEW)
PCenter	E-761	Charged Hyperon Radiative Decays	(NEW)
PEast	E-791	Hadro-production of Heavy Flavors	(NEW)
PBroadband	E-687	Photo-production of Charm and Beauty	
	E-683	Photo-production of High Transverse Momentum Jets	(NEW)
	E-774	Electron Beam Dump Particle Search	(NEW)
Antiproton	E-760	Charmonium States using the Antiproton Ring	(NEW)

has progressed from the observation of a handful of events to large data samples allowing the study of rare processes and decays. The study of bottom physics is just taking its first steps. The neutrino and muon programs are producing definitive structure functions which are the quark distributions within the nucleons. Interactions involving either initial-state or final-state photons are elucidating the gluon distributions within both mesons and nucleons. High-statistics studies of hyperon decays and magnetic moments are helping to solidify the Standard Model. Polarization and spin phenomena are continuing to puzzle the theorists. We are at the brink of the first substantially new information concerning CP violation in over 20 years.

Exciting? You bet!

Pete

IV. Fermilab 1978-1988 - A Chronology

7/17/78 Robert R. Wilson, Fermilab's founding Director, leaves Fermilab to become a professor at the University of Chicago. Philip. V. Livdahl becomes Acting Director.

8/24/78 The Universities Research Association, Inc., (URA) Board of Trustees nominates Leon M. Lederman (LML) as Fermilab Director Designate. LML tentatively accepts directorship, postpones starting date to 6/1/79 in order to complete setup of new experiment at Cornell.

9/23/78 SAG (Scientific Advisory Group) appointed by LML begins consulting as "sounding board."

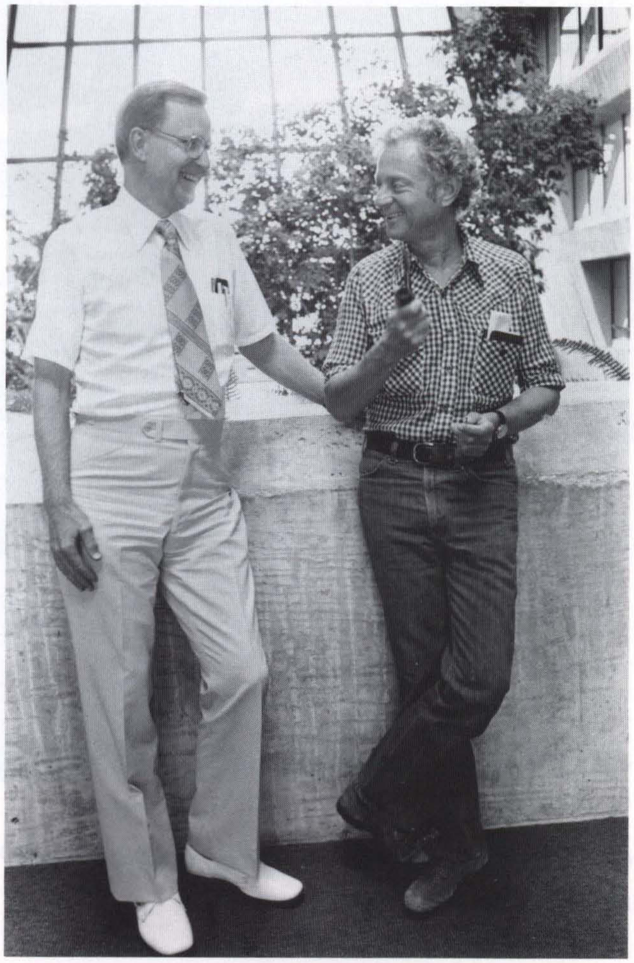
10/1/78 Energy Doubler becomes a construction project and is re-named the Energy Saver by Department of Energy (DOE).

10/19/78 Universities Research Association, Inc., and the U. S. Department of Energy announce the selection of Leon M. Lederman as Fermilab Director Designate. Acting Director Livdahl makes the decision known to Fermilab staff at a Director's Meeting.

LML appoints three "wise men," Boyce McDaniel of Cornell, Burton Richter of Stanford University, and Matthew Sands of the University of California, Santa Cruz, to advise on the Energy Saver.

10/30/78 LML welcomes People's Republic of China (PRC) delegation of high-ranking science administrators to Fermilab.

11/11/78 LML organizes the "Armistice Day Shootout" that sets the course for high-energy physics at Fermilab: the Saver is to be a 2-TeV $\bar{p}p$ collider as well as a fixed-target machine.



Acting Director Philip V. Livdahl and Director Designate Leon M. Lederman, August 1978.

12/21/78 Testing of 25 Energy Saver superconducting magnets begins at B-Sector.

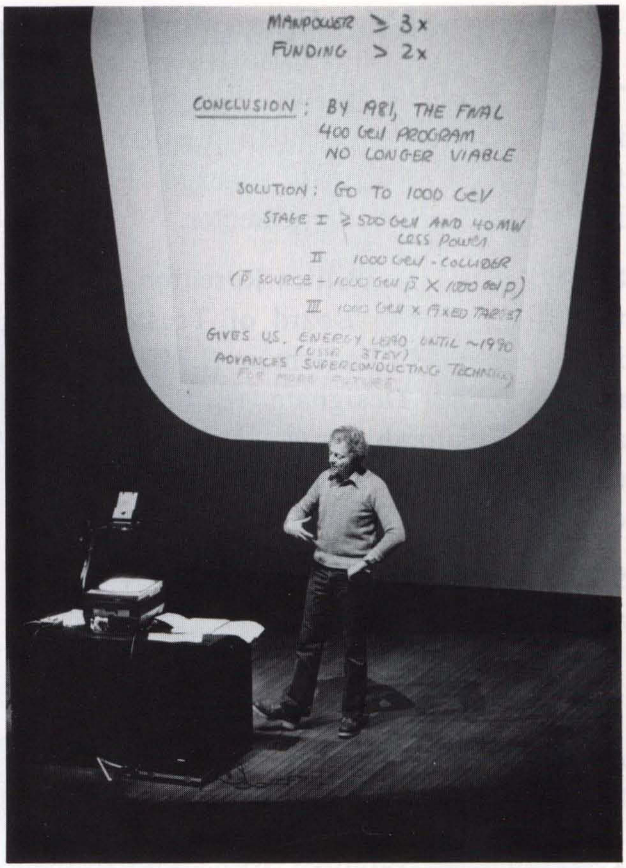
1/11/79 Beam transported through two Saver magnets in left bend of Switchyard.

2/1/79 B-Sector test is successful.

3/1 - 2/79 Norman Ramsey resigns as URA President, succeeded by Milton G. White.

4/79 Chez Leon opens. Tita Jensen is appointed Head Chef.

Tom Collins and LML, First Annual Run with the Director, June 1, 1979.



LML apprises Fermilab staff of the Lab's future plans at a Director's Meeting on February 11, 1980.

4/27/79 International Symposium in Honor of Robert R. Wilson is held at Fermilab.

6/1/79 LML assumes Directorship; first annual Run with the Director.

At the finish line, the Main Ring Pond Canoe Race, September 30, 1979.

7/5/79 DOE authorizes construction of the Energy Saver.

7/6/79 Party to celebrate beginning of Energy Saver construction.

7/23/79 LML, Mattmueller and Leiss of DOE, sign Energy Saver Project Management Plan.

8/23 - 29/79 International Symposium on Lepton and Photon Interactions at High Energies held at Fermilab.

8/30/79 LML appears on "Donahue."

LML announces DOE funding of the Saver project at a party held in Industrial Building 1 on July 6, 1979.

9/79 Beam successfully transported down half of the M-6 line (Meson Area), first line with superconducting components to become operational at Fermilab. J. D. Bjorken joins Fermilab Theory Department.

9/19/79 Two-way split of Meson's primary proton beam operational.

10/16/79 URA President Milton G. White passes away.

10/17 - 19/79 DOE Energy Management Symposium held at Fermilab.

11/79 B-12 Saver-magnet test begins. Sixteen dipole superconducting magnets and four quadrupoles will be tested for one year so that magnets and satellite refrigeration system behave as if in the Main Ring, without a beam.

11/79 Japanese begin physics collaboration at Fermilab.

12/79 URA past-president Norman Ramsey selected to complete term of M. G. White.

LML and Robert R. Wilson at the dedication of Robert Rathbun Wilson Hall, September 18, 1980.

Visiting experimenters from China participating in Fermilab's Arbor Day tree planting, May 8, 1980.

12/23/79 Main Ring sets new intensity record: 2.562 x 10^{13} protons at 400 GeV.

2/6/80 Construction of Energy Saver begins in A-2 sector.

3/28/80 Superconducting dipole put in operation to bend pion beam in Proton West high-intensity line.

4/18/80 Central Helium Liquefier produces liquid helium in first full-scale test.

4/22/80 Earth Day observed.

5/5/80 Fermilab-PRC Memorandum signed describing technical exchanges.

5/20/80 Agreement signed between U.S. and Japan for continued collaboration in high-energy physics through FY1981.

5/28 - 31/80 International Symposium on the History of Particle Physics held at Lab.

The panel at the International Symposium on the History of Particle Physics, May 28, 1980. Left to right: Herbert Anderson, Samuel Schweber, Victor Weisskopf, Paul Dirac, Gilberto Bernardini, Robert Seidel.

6/80 First segment of Saver helium-transfer line completed and successfully tested.

6/19/80 Agreement extending collaboration between US and PRC signed at Fermilab.

6/25/80 Accelerator run ends, achievements: highest operating efficiency for any 6-month period in Fermilab history, largest number of operating hours ever recorded in a week, and operation for long periods, successfully splitting high-intensity beam among three experimental areas.

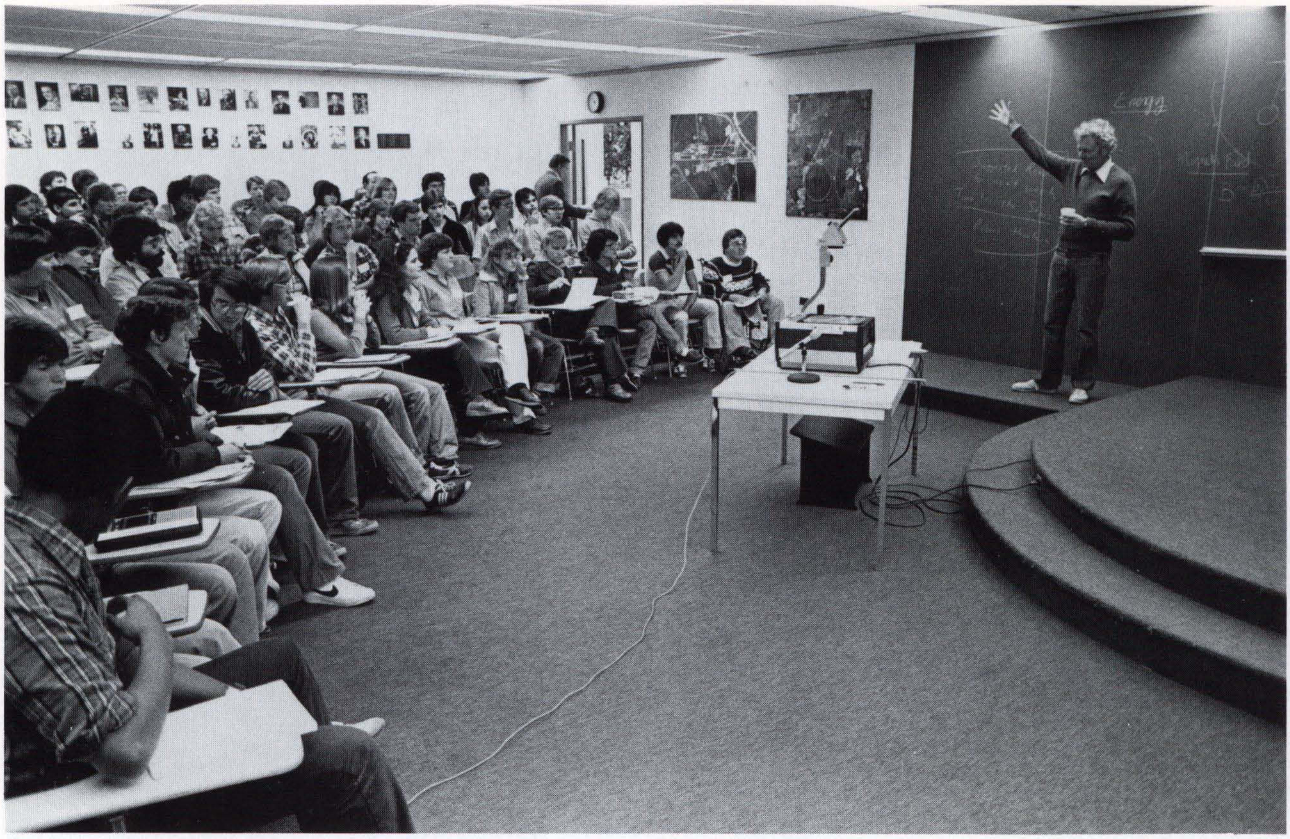
7/80 Fermilab awarded patent for superconducting magnet design by John Satti.

7/31/80 Fermilab awarded DOE citation for Energy Conservation.

8/14 - 9/26/80 A1-A2 cooling test successful.

9/18/80 Central Laboratory Building named in honor of Robert R. Wilson.

9/80 Neutron Therapy Facility's National Cancer Institute grant renewed for five years. Children's Day Care Center at Fermilab opens; DOE withdraws objections at last minute. I-R 100 Award presented to Fermilab for the Energy Saver dipole magnet and the negative hydrogen ion source.



The first Saturday Morning Physics class, October 4, 1980.

10/80 Saturday Morning Physics begins.

11/80 Successful resumption of 400-GeV accelerator operation. Energy Saver satellite refrigeration construction under way.

12/80 Installation of Saver magnets in A-sector begins.

12/12/80 Beam successfully transported through the superconducting left bends in the Switchyard to the F-1 manhole.

12/16/80 Superconducting left bend project in Switchyard commissioned; Fermilab now has the longest operational chain of superconducting magnets in world, and is the only laboratory with a chain of superconducting magnets transporting a primary proton beam (to the entire Meson Area).

12/80 Ongoing testing of Saver magnets at B-12 successful.

1/81 First superconducting spool piece successfully tested. President's Council for Energy Efficiency honors Fermilab with certificate for ''outstanding leadership in effectively promoting conservation.''

1/19/81 New intensity record set: 2.572 x 10^{13} protons per pulse out of the Main Ring at 400 GeV.

1/26/81 DOE conveys formal approval of TeV I project.

2/81 Fermilab begins Latin American scientific/technological cooperation.

2/15/81 Main Ring intensity record pushed to 2.9 x 10^{13} protons per pulse at 400 Gev. World record returns to Fermilab from CERN. Booster also sets record for injecting 4.11 x 10^{13} protons into the Main Ring.

2/21/81 Chicago Cyclotron magnet, now superconducting, operates at full field: 14.52 kg.

3/81 Testing final Saver magnets in B-12.

3/2/81 New intensity record, 2.890 x 10^{13} protons per pulse out of the Main Ring, delivered to the experimental areas.

3/15/81 New intensity record: 3.003 x 10^{13} protons per pulse at 400 GeV.

4/16/81 Lithium lens from Novisibirsk, U.S.S.R., arrives at Fermilab.

5/81 LML convenes a review of TeV program by Tigner Committee. Design changes for Antiproton Source are recommended. Installation of three-quarters of A-sector is complete. LML proposes Arms Control and International Security Seminars at Fermilab.

5/1/81 National Society of Black Physicists meets at Fermilab. Ninety local high school students attend.

5/5 - 7/81 Third DOE Site Development and Land Use Conference held at Fermilab.

5/20/81 Victor Weisskopf gives Fermilab colloquium.

5/28/81 First Fermilab Industrial Affiliates Meeting.

6/81 LML decides to re-start Antiproton Source design and R&D with an all-stochastic cooling system, appoints John Peoples as Head of TeV I project. Conceptual design for Antiproton Source delivered.

Dick Lundy (left), then Head of Technical Support, shows a TEVATRON cryostat to attendees of the first Fermilab Industrial Affiliates Meeting on May 28, 1981.

6/1/81 Groundbreaking for construction and improvements at Proton Area.

6/12/81 Workshop is held at Fermilab to plan/discuss the experiment at D0.

7/1/81 Formation of the new Accelerator Division combining Accelerator and Saver efforts into single division responsible for completion of Saver, operation of 400-GeV program in 1982, and commissioning and operation of the Energy Saver by extracting beam for fixed-target research and as a storage ring for colliding-beams experiments.

7/13 - 24/81 US Accelerator Summer School held at Fermilab.

9/81 DOE presents achievement award to Fermilab for exceptional performance contracting with small, disadvantaged businesses in FY1979.

Helicopter-aided installation of the Helium Transfer Line atop the Main Ring berm, July 10, 1981.

9/28/81 Wolfgang Panofsky delivers first Arms Control and International Security Seminar at Fermilab.

9/30/81 Director's Message to users and staff: funding, austerity, hope.

10/81 Trumpeter swans introduced into Main Ring cooling pond.

10/1/81 Fermilab Auditorium named in honor of Norman Ramsey.

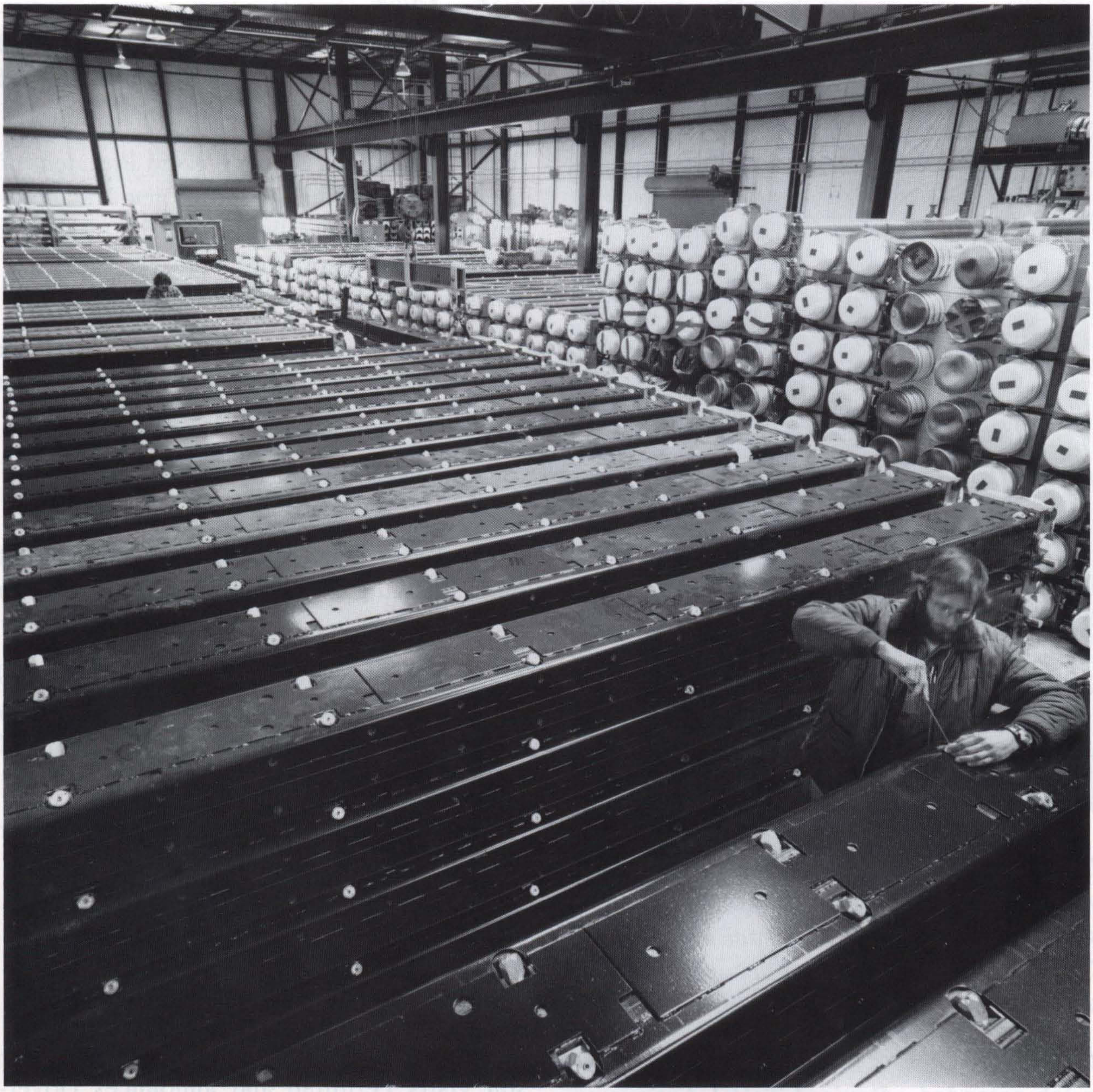
10/2/81 Users "Physics Town Meeting" at Fermilab.

11/19/81 Five more Saver magnets cooled to superconducting temperatures by Meson satellite refrigeration system.

1/1/82 Main Ring started up after 7-month shutdown for improvements to Linac and Booster, installation of Saver components. Beam available in experimental areas on schedule.

1/5 - 7/82 Pan American Symposium on High Energy Physics and Technology held near Mexico City, sponsored by Fermilab and Instituto de Fisica of University of Mexico, to advance the idea of hemispheric collaboration in HEP.

1/26/82 DOE conveys formal approval of TeV II project.



Saver magnets fill Industrial Building 4 awaiting installation, March 4, 1982.

Drasko Jovanovic shows Fermilab to Edward Teller on March 17, 1982, the occasion of the latter's visit to deliver an Arms Control and International Security Seminar address.

2/82 URA-DOE contract for operating Fermilab extended. Revised TeV I Antiproton Source Design Report presented to the Rees Committee and subsequently to DOE.

2/4/82 A-sector completely full of liquid helium.

2/19/82 A-Sector is cooled to operating temperature and energized to 2200 amperes (> 500 GeV).

3/1/82 Electron cooling system achieves design energy of 200-MeV protons.

3/17 - 18/82 Accelerator achieves new record intensity, 3.194 x 10^{13} protons at 400 GeV. Booster also achieves new record of 4.6 x 10^{13} protons per pulse.

5/82 H. Guyford Stever elected President of URA. Thomas Nash proposes new R&D program to build a parallel processor (Advanced Computer Program) for event reconstruction. Energy Saver cryostat #900 completed.

5/30/82 New world intensity record, 3.25 x 10^{13} protons per pulse at 400 GeV, set at Fermilab.

6/82 Research Division reorganization, formation of Experimental Areas Department.

6/14/82 150-GeV/c beam transported out of Main Ring and through Saver injection line.

6/18/82 Lab-wide party to celebrate 400 GeV, end of run, end of era, 15th birthday of Fermilab, A-sector testing, and start of TeV I and TeV II construction.

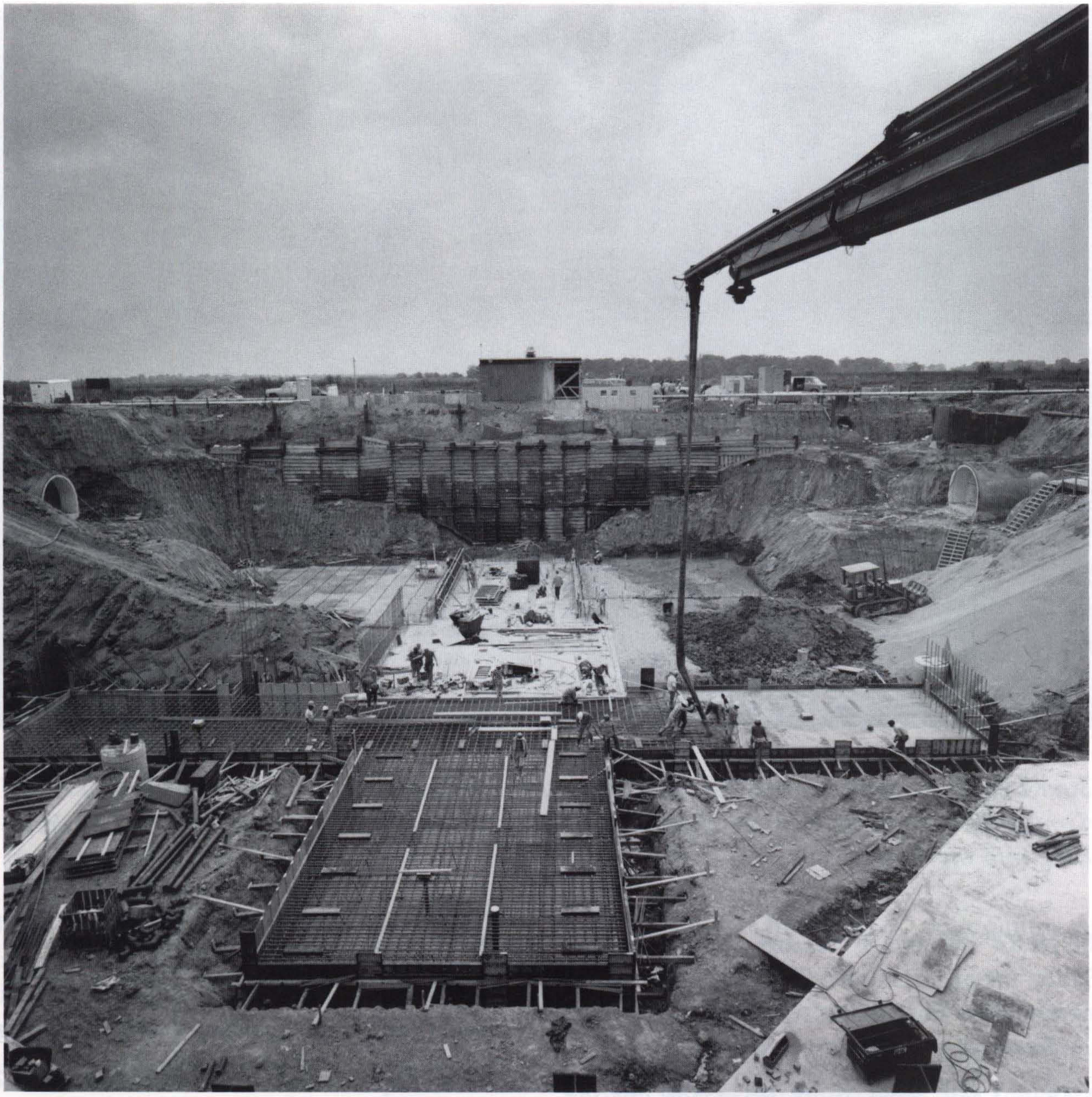
7/1/82 Groundbreaking for the Collider Detector at Fermilab (CDF) at B0.

7/15/82 LML festschrift at Fermilab.

9/82 Fermilab wins DOE Award of Excellence for 1981 Safety and Health performance.

10/82 Illinois Governor James R. Thompson visits Fermilab and announces Governor's Commission on Science and High Technology. LML and Frank Cole to serve on commission. Helium tanks in place for Saver; VAX computer systems brought online. Fermilab wins DOE Procurement Award for assisting small, disadvantaged businesses.

11/82 Bubble Chamber dome clad with copper.



Construction at B0 for the CDF experimental hall, September 24, 1982.

Stan Pruss, Helen Edwards, Rol Johnson, Bruce Hanna, and Dave Johnson in the Main Control Room on April 22, 1983, as the first low-intensity beam is injected from the Main Ring into the Saver.

11/19/82 E and F sectors of the Energy Saver installation complete; now in operation mode. This begins commissioning of the Saver.

12/82 LML wins Wolf Prize for upsilon discovery (E-288) at Fermilab. Advanced Computer Program group is formed.

1/17/83 Groundbreaking for Industrial Center Building.

2/83 Users Office presents Recreation Complex plans.

3/83 DOE Secretary Donald P. Hodel visits Fermilab.

3/18/83 Last magnet installed in the Energy Saver at A-49, ending 21-month effort.

4/9/83 Re-commissioning of Main Ring and commissioning of Saver begin.

4/16/83 Saver Sectors E and F powered to 500 GeV.

4/17/83 Proton beam in Main Ring accelerated to 150 GeV for first time since 6/82; sufficient energy for injection into Saver.

4/20/83 Joseph Cardinal Bernardin visits Fermilab at LML's invitation to discuss nuclear disarmament with staff.

The last Saver magnet is installed, March 18, 1983. Among those in attendance (l. to r.): LML, Dick Lundy, Thornton Murphy, Andy Mravca (DOE), John Matheny, Ray Hanft, Al McInturff, Dixon Bogert, and Hans Jöstlein.

4/22 - 23/83 Low-intensity beam injected from Main Ring into Saver at E0 straight section; following tuning and adjustments, beam transported to beam dump in Transfer Hall.

5/83 Entire Saver cooled to liquid helium temperature.

5/2/83 Final two spool pieces installed at A-47 and A-49 to "close" the Saver ring.

5/4/83 A-sector declared leak-tight.

5/7/83 Sectors C and D operated at Saver injection energy.

5/14/83 D-sector magnets successfully ramped with sectors E and F.

5/25/83 I. I. Rabi gives colloquium at Fermilab.

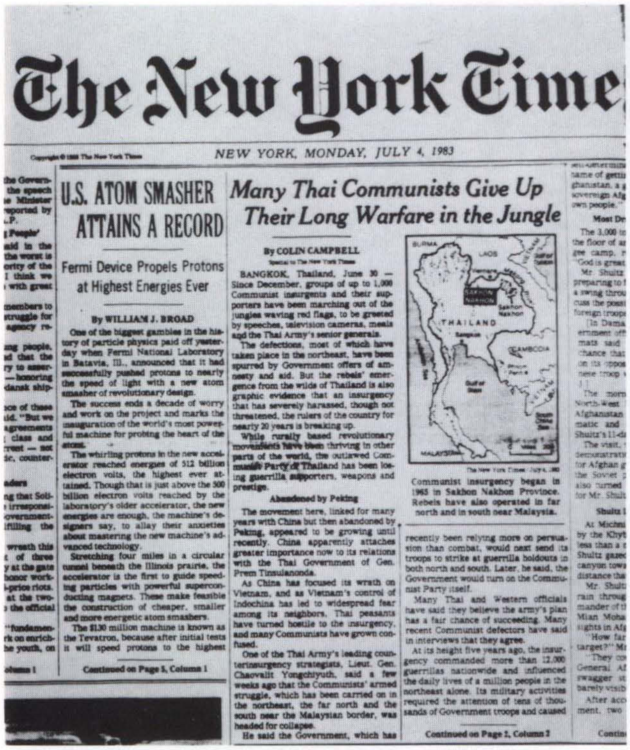
5/31/83 LML convenes Ballam Committee to advise on Lab's long-term computing needs.

6/2/83 Energy Saver achieves first complete revolution of proton beam at 100 GeV.

6/16/83 Saver successfully ramped to 500 GeV and multiple turns achieved.

6/20 - 7/15/83 First Summer Institute for Science Teachers sponsored by Friends of Fermilab (FFLA) for DOE Office of Energy Research.

6/26/83 First coasting beam in Saver.



The New York Times

NEW YORK, MONDAY, JULY 4, 1983

U.S. ATOM SMASHER ATTAINS A RECORD

Fermi Device Propels Protons at Highest Energies Ever

By WILLIAM J. BROAD

One of the biggest gambles in the history of particle physics paid off yesterday when Fermi National Laboratory in Batavia, Ill., announced that it had successfully pushed protons to nearly the speed of light with a new atom smasher of revolutionary design.

The success ends a decade of worry and work on the project and marks the inauguration of the world's most powerful machine for probing the heart of the atom.

The whirling protons in the new accelerator reached energies of 512 billion electron volts, the highest ever attained. Though that is just above the 500 billion electron volts reached by the laboratory's older accelerator, the new energies are enough, the machine's designers say, to allay their anxieties about mastering the new machine's advanced technology.

Stretching four miles in a circular tunnel beneath the Illinois prairie, the accelerator is the first to guide speeding particles with powerful superconducting magnets. These make feasible the construction of cheaper, smaller and more energetic atom smashers.

The $130 million machine is known as the Tevatron, because after initial tests it will speed protons to the highest

Continued on Page 5, Column 1

Many Thai Communists Give Up Their Long Warfare in the Jungle

By COLIN CAMPBELL

BANGKOK, Thailand, June 30 — Since December, groups of up to 1,000 Communist insurgents and their supporters have been marching out of the jungles waving red flags, to be greeted by speeches, television cameras, meals and the Thai Army's senior generals.

The defections, most of which have taken place in the northeast, have been spurred by Government offers of amnesty and aid. But the rebels' emergence from the wilds of Thailand is also graphic evidence that an insurgency that has severely harassed, though not threatened, the rulers of the country for nearly 20 years is breaking up.

While rurally based revolutionary movements have been thriving in other parts of the world, the outlawed Communist Party of Thailand has been losing guerrilla supporters, weapons and prestige.

Abandoned by Peking

The movement here, linked for many years with China but then abandoned by Peking, appeared to be growing until recently. China apparently attaches greater importance now to its relations with the Thai Government of Gen. Prem Tinsulanonda.

As China has focused its wrath on Vietnam, and as Vietnam's control of Indochina has led to widespread fear among its neighbors, Thai peasants have turned hostile to the insurgency, and many Communists have grown confused.

One of the Thai Army's leading counterinsurgency strategists, Lieut. Gen. Chaovalit Yongchiyuth, said a few weeks ago that the Communists' armed struggle, which has been carried on in the northeast, the far north and the south near the Malaysian border, was headed for collapse.

He said the Government, which has recently been relying more on persuasion than combat, would next send its troops to strike at guerrilla holdouts in both north and south. Later, he said, the Government would turn on the Communist Party itself.

Many Thai and Western officials have said they believe the army's plan has a fair chance of succeeding. Many recent Communist defectors have said in interviews that they agree.

At its height five years ago, the insurgency commanded more than 12,000 guerrillas nationwide and influenced the daily lives of a million people in the northeast alone. Its military activities required the attention of tens of thousands of Government troops and caused

Continued on Page 2, Column 2

Communist insurgency began in 1965 in Sakhon Nakhon Province. Rebels have also operated in far north and in south near Malaysia.

News that's fit to print on the front page: the newspaper of record announces the Saver's record energy of 512 GeV, July 4, 1983.

6/28/83 First lithium lens at Fermilab filled with lithium.

7/3/83 Saver reaches 512 GeV, exceeds design energy and sets new world record for high-energy accelerators.

7/7/83 LML awarded honorary degree from University of Chicago. Congratulatory telegram sent by DOE Secretary Donald P. Hodel to LML/Fermilab on achieving world record for accelerators.

7/12/83 Bersted Foundation presents $25,000 gift to FFLA for Summer Institute for Science Teachers.

8/2/83 512-GeV beam extracted to Switchyard dump.

8/11 - 16/83 12th International Conference on High Energy Accelerators held at Lab.

8/12/83 700-GeV beam extracted to Switchyard.

8/15/83 Saver circulating beam sets new record for accelerating protons: 700 GeV.

8/16/83 Groundbreaking for TEVATRON I Antiproton Source construction (the Accumulator-Debuncher tunnel).

8/19/83 Beam "stored" at 512 GeV.

9/83 Theoretical Astrophysics Group formed within Theoretical Physics Department of Research Division. NASA support for Group is secured.

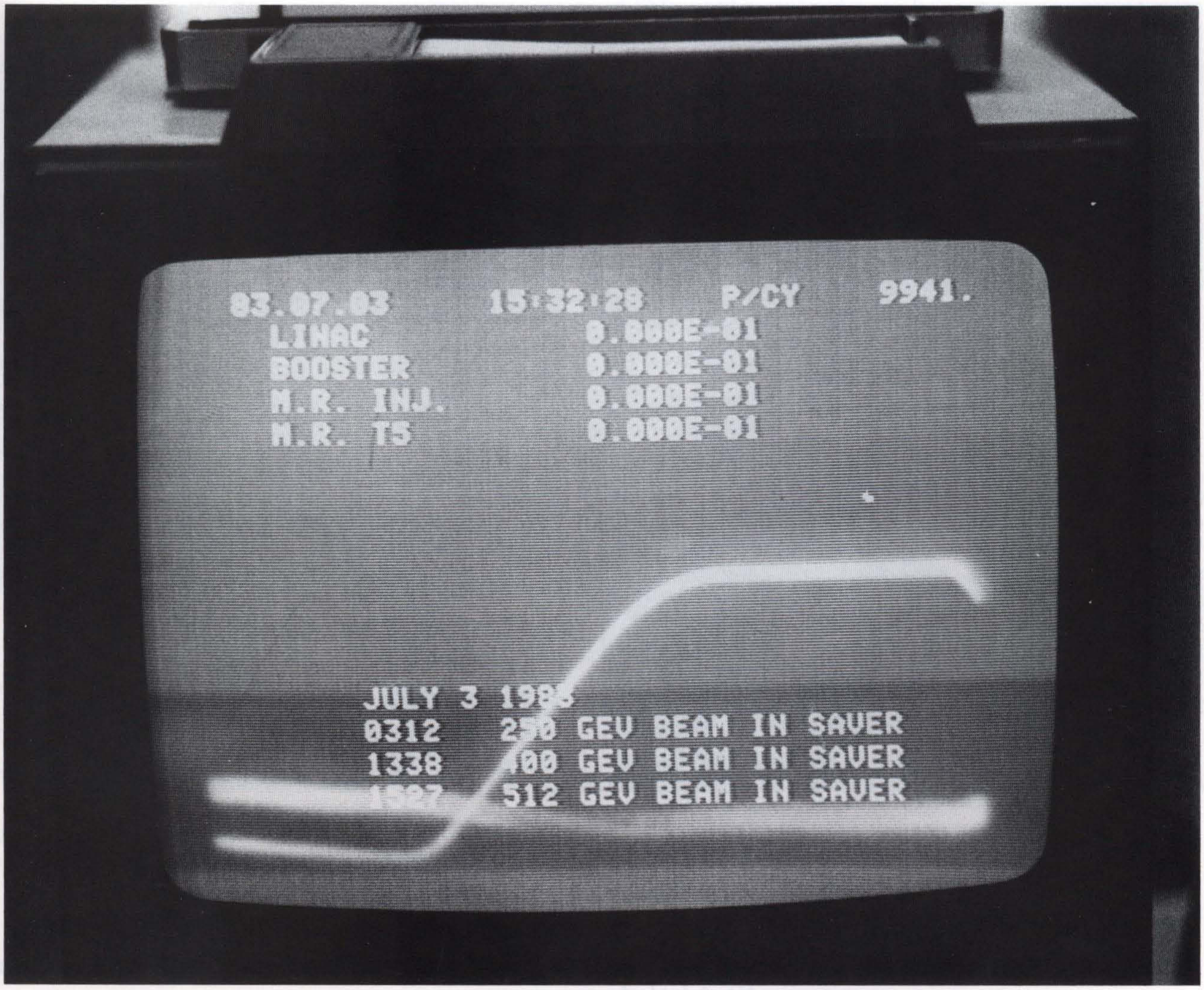
9/18/83 Fermilab Open House. 15,000 visitors overwhelm staff.

9/22/83 Fermilab wins four IR-100 awards for: TEVATRON helium line, ECL-CAMAC ultra-high-speed computer in Tagged Photon Area, slip-ring stepping motor of Bubble Chamber, and a precision electric current sensor for the Accelerator Division.

9/30/83 First Physics at the SSC (PSSC) meeting. PSSC formed by LML to institute regular open meetings on relevant SSC physics and detector issues.

10/83 At LML's suggestion, a feasibility study, sponsored by FFLA and the Corridor Partnership for Excellence in Education, is done for the Illinois Mathematics and Science Academy (IMSA). Proposal to be developed for Governor Thompson to submit to Illinois General Assembly in 1984.

10/1/83 Saver begins physics run at 400 GeV (TEVATRON era commences).



512-GeV beam in the Saver, 1527 hours, July 3, 1983.

10/4/83 Fermilab and Control Data Corp. sign contract for complex phased delivery of dual-CPU Cyber 875 system to begin in 12/83 and continue over next two years.

10/16/83 Beam is stored in the Saver for more than 30 hours.

10/21/83 Second PSSC meeting at Lab.

11/83 Second lecture series on Arms Control and International Security begins at Fermilab.

12/83 Ballam Committee publishes report on Lab's future computing needs.

12/6/83 Taiji Yamanouchi receives the Nishina Memorial Prize in Tokyo for distinguished work in atomic and nuclear physics.

1/84 Construction! Antiproton Source civil construction, CDF, Liquid Nitrogen Plant, drift chambers for E-652, etc.

2/14/84 400-GeV high-energy physics era ends, marking completion of Fermilab's commitments at that energy.

2/15 - 16/84 800-GeV ramp is extracted from the TEVATRON to the Switchyard Dump.

The Main Control Room at 3:27 a.m., July 3, 1983, the instant of 512-GeV Saver beam. Celebrating are (l. to r., standing) Linda Klamp, Bob Shafer, Roland Johnson, Dave Beechy, Bob Florian, Frank Nagy, and Dan Patterson. Seated: Ferdi Willeke, Frank Turkot, and Hans Jöstlein.

2/17/84 Commissioning of the low-beta insertion at B0 begins.

3/84 Antiproton Source magnet production under way.

3/17/84 Startup of 800-GeV experimental program.

4/84 FFLA receives $12,800 grant from the Aurora Foundation for science-education videotape library.

4/4/84 800-GeV protons transported to seven target stations.

4/27 - 28/84 Annual Users Meeting; George Keyworth, President Reagan's Science Advisor, and Alvin Trivelpiece, DOE Director of Energy Research, address users.

4/28/84 Dedication of the Energy Saver is attended by Governor Thompson, U.S. Senator Charles Percy, and other luminaries.

5/84 Norman Ramsey receives the 1984 Medal of Honor from the IEEE for "fundamental contributions."

5/2 - 5/84 Inner Space/Outer Space Astrophysics Conference held at Fermilab.

LML (with doppelgänger) addresses the 12th International Conference on High Energy Accelerators in the Ramsey Auditorium, August 11, 1983.

6/18/84 Summer Institute for Science Teachers organized by FFLA.

7 - 8/84 Day Camp for children of Fermilab employees offered for first time.

8/13 - 24/84 US Summer School on High Energy Particle Accelerators held at Fermilab.

10/84 Fermilab wins IR-100 Award for Spectrographic Nitrogen Detector.

10/25/84 Energy Saver awarded the Bald Eagle Award for outstanding accomplishment in energy conservation.

11/84 Robert R. Wilson receives Fermi Award from DOE.

2/85 Completion of last dipoles for the Antiproton Source Debuncher (TeV I). TEVATRON named winner of Outstanding Engineering Achievement Award by National Society of Professional Engineers.

3/85 New junior high school program, Beauty and Charm at Fermilab, developed by FFLA with grants from DOE and the Bersted Foundation.

3/9/85 Fermilab hosts Test of Engineering, Mathematics and Science Aptitude, a regional academic high school competition.

3/24/85 CDF solenoid magnet coil in the center of the B0 detector reaches its design field of 15 kG on the first try.

3/31/85 Proton beam transported from the Main Ring through AP-1 and AP-2.

4/85 FFLA receives $225,000 grant from NSF as funding for 1985-87 Summer Institute for Science Teachers.

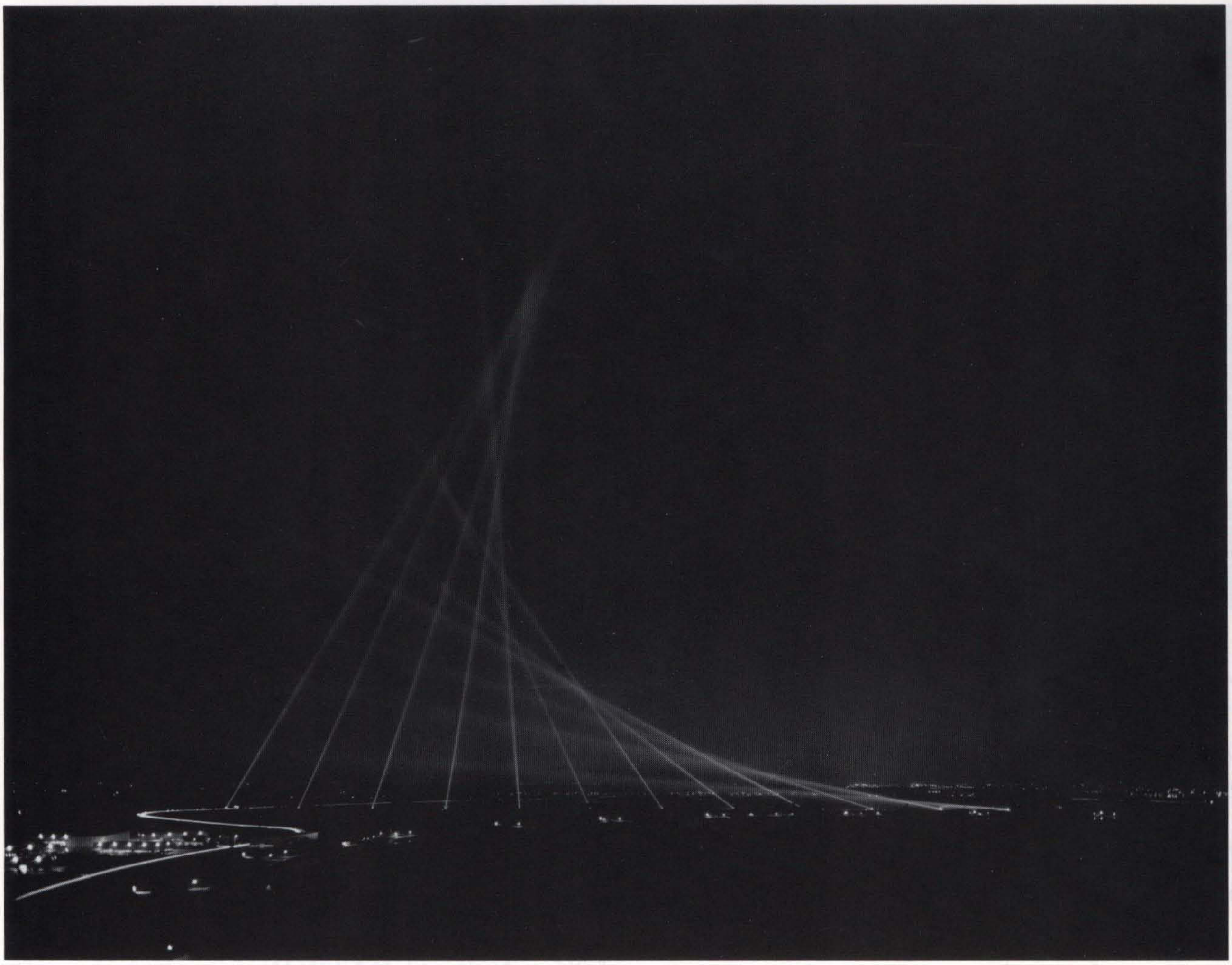
4/6/85 Commissioning of the Debuncher Ring of the Antiproton Source begins.

4/8/85 Last magnet installed in the Antiproton Source Accumulator.

4/21/85 8-GeV proton beam successfully circulated in Debuncher.

5/85 New TEVATRON intensity record: 1.375×10^{13}.

The line forms at Wilson Hall for Fermilab's Open House on September 18, 1983.



"The Parabola Project," an elaborate, one-night-only event created by artist Charles A. Derer at Fermilab concurrent with the 12th International Conference on High Energy Accelerators, August 12, 1983.

5/1 - 4/85 International Symposium on Particle Physics in the 50s held at Fermilab.

5/3/85 Stephen Jay Gould delivers inaugural lecture of Distinguished Speakers Series at Fermilab.

5/6/85 First operation of the 8-GeV multipurpose extraction system.

5/22/85 Cygnet (mute) swans brought to Fermilab.

5/30/85 William Bardeen awarded 1985 Guggenheim Fellowship.

6/12/85 Beam circulated in the Accumulator Ring for one full turn.

6/23/85 400-GeV electron beam transported to new Wide Band Experimental Hall for E-687 and E-683.

Groundbreaking ceremonies for the Pbar Source, August 16, 1983.

7/85 Fermilab proposes becoming a DOE National Environmental Research Park (NERP). IMSA authorization signed by Governor Thompson after approval by legislature.

7/25/85 Helen Edwards awarded Achievement in Accelerator Physics and Technology award at US Summer School on High Energy Accelerators. Robert R. Wilson receives historic award for High Achievement in Science.

7/29/85 Construction begins on D0 experimental hall.

8/85 DOE 5-year Appraisal rates Fermilab "Superior."

8/1/85 Edward A. Knapp succeeds H. Guyford Stever as URA President.

8/27/85 First injection of $\bar{p}$'s into Pbar Source Accumulator.

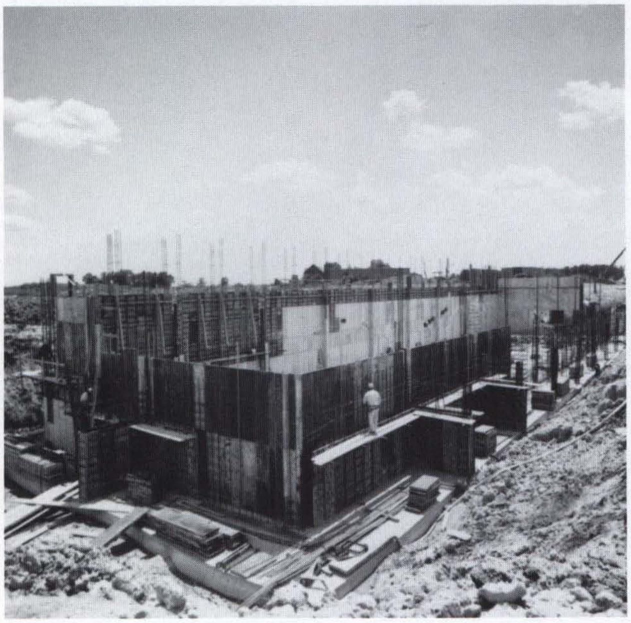
8/29/85 Fixed-target physics run ends.

9/85 Fermilab/BNL/LBL design for SSC magnet is chosen by SSC Magnet Selection Advisory Panel. IR-100 award to Fermilab Magnetic Wire Position Transducer for Antiproton Source.

9/10/85 CDF central detector rolled into collision hall to begin first (test) run.

9/13/85 CDF accepting beam.

9/27/85 Lab-wide party to celebrate end of 1985 TEVATRON run, forthcoming DOE support, new fiscal year, Enrico Fermi's birthday.



Construction progress at the Wide Band Lab, July 17, 1984.

10/85 Director's Special Colloquia on Topics in High-Energy Physics Series begins.

10/5/85 First injection of pbars into Main Ring.

10/11/85 Proton-Antiproton Collider (Tev I) Dedication at Fermilab.

10/12/85 10^{10} pbars stored in Accumulator. Protons and antiprotons injected, accelerated to 800 GeV, stored, and squeezed to a 1-meter β^*.

10/13/85 First 1.6-TeV center-of-mass collisions (13 in number) observed at CDF.

10/14/85 Shutdown begins for construction of CDF overpass at B0, construction of D0 collision hall, repair of TEVATRON magnets, and F17 extraction for Pbar Source.

1/17/86 Commissioning of AP4 beamline begins.

1/23/86 First proton beam extracted from the Booster, injected into Debuncher Ring.

1/25/86 Circulating beam in the Pbar Source Debuncher.

3/25/86 CDF successfully completes fifth and final review by DOE.

4/86 Science center at Fermilab (FermiCenter) proposed by FFLA to Director's Office; LML enthusiatically endorses idea.

4/17 - 18/86 FFLA Seminar on Problem Solving in Mathematics held at Fermilab to improve and enhance classroom experience for elementary and middle school programs.

4/24 - 27/86 Conference on Teaching Modern Physics held at Fermilab.

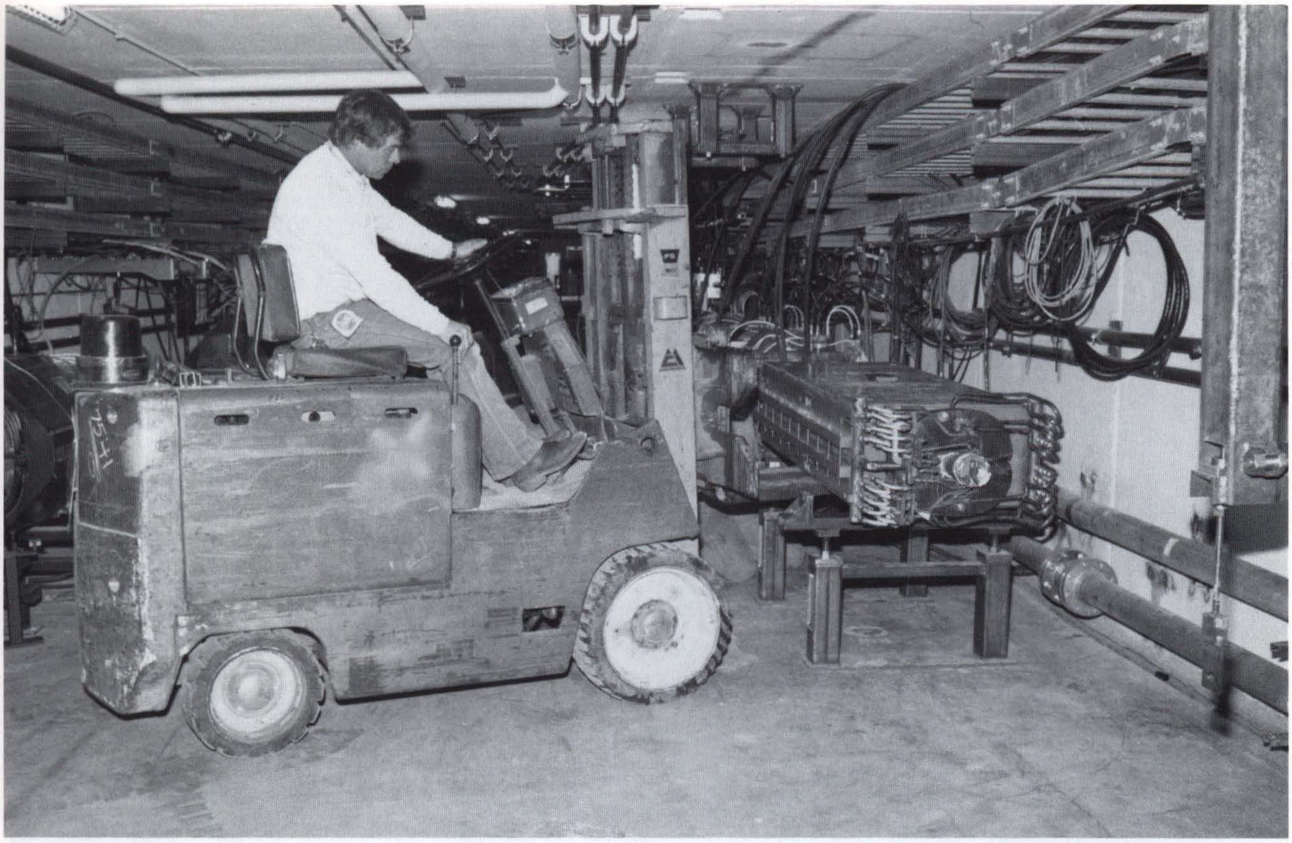
5/86 TEVATRON named one of the Top Ten Engineering Achievements in the last 100 years by the Illinois Society of Professional Engineers.

5/1/86 Booster and Pbar Source studies end; installation of new Booster control system begins.

5/2/86 Annual Users Meeting at Fermilab features panel on "How do we sustain good science?" Outline of 15-year Institutional Plan for Fermilab presented by LML.

6/86 "Design of a Proton Therapy Synchrotron," conceptual design study for 250-MeV proton synchrotron medical accelerator at Loma Linda University Medical Center, published. Advanced Computer Program starts successful 6-month analysis of data tapes from E-691.

6/16/86 Fermilab receives funding to form Environmental Advisory Committee and develop long-term environmental research plan preliminary to formal NERP designation.



The last magnet installed in the Pbar Source Accumulator Ring, April 8, 1985.

7/86 Helen Edwards receives 1986 Ernest O. Lawrence Award from DOE.

7/1/86 Groundbreaking for new Central Computing Facility.

7/18/86 Booster and Main Ring startup begins.

8/4/86 Beam transported to C0 abort dump.

9/2/86 Coasting beam in Main Ring.

9/7/86 Neutron Therapy Facility celebrates 10-year anniversary.

9/8/86 Main Ring beam accelerated to 120 GeV; cooldown of two sectors in TEVATRON begins.

9/11/86 TEVATRON power-supply testing begins.

9/19/86 Lab-wide party to celebrate completion of TeV II upgrades and accelerator repairs.

10/86 Advanced Computer Program and Video Data Acquisition System receive IR-100 Awards.

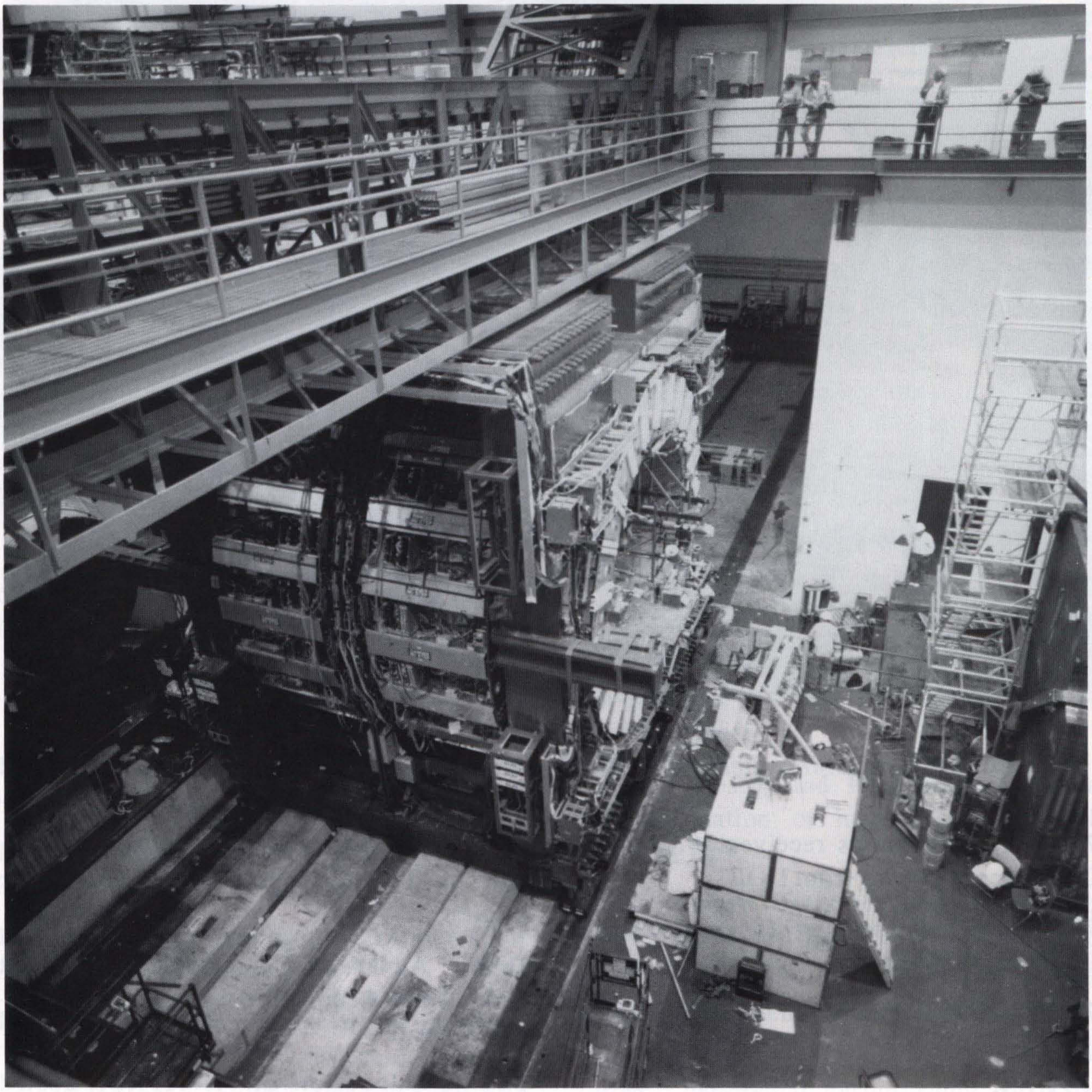
10/8/86 All sectors of TEVATRON cooled down and ramped.

10/14/86 TEVATRON-accelerated beam achieved.

10/20/86 Beam stored at 800 GeV.

10/21/86 First acceleration of TEVATRON beam to 900 GeV.

11/12/86 Antiproton stacking begins in Pbar Source Accumulator.



The Collider Detector at Fermilab rolls into the collision hall to begin its explorations, September 10, 1985.

Construction progress at the D0 experimental hall on September 13, 1985.

DOE Secretary John S. Herrington at the dedication of the Proton-Antiproton Collider, October 11, 1985. Among those in the Platform Group are (l. to r.) Harry Woolf (URA), John Peoples (Fermilab), LML, Helen Edwards (Fermilab), Illinois Governor James R. Thompson, and Dick Lundy (Fermilab).

11/26/86 Antiprotons reverse-injected into Main Ring and accelerated to 150 GeV.

11/30/86 Antiprotons accelerated to 900 GeV, stored, squeezed, and collided with 900-GeV protons. 1.8 TeV collisions in TEVATRON seen at CDF forward detectors.

12/14/86 Fermilab co-sponsors 13th Texas Symposium on Relativistic Astrophysics.

12/30/86 New five-year management contract signed between URA and DOE.

1/3/87 CDF observes $\bar{p}$-p collisions at total energy of 1800 GeV.

2/6/87 First 24-hour $\bar{p}$ store.

3/4/87 Pbar milestone luminosity of 10^{28} cm^{-2} sec^{-1} achieved.

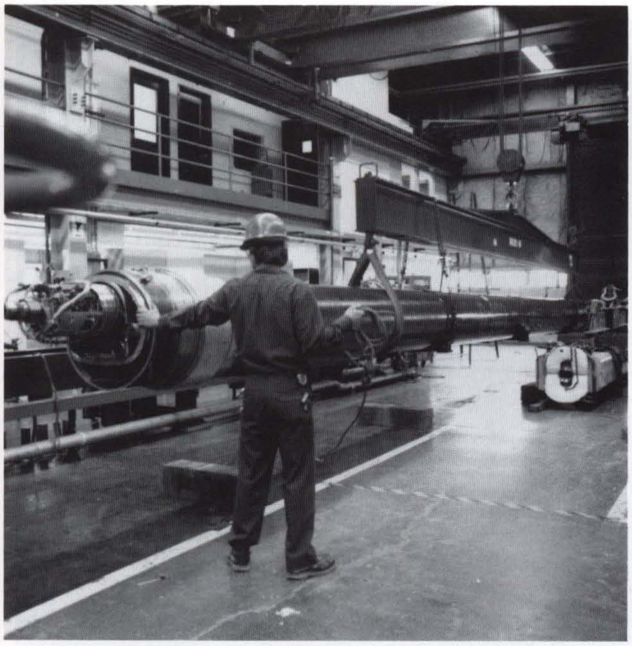
3/26/87 First "new-world" *W* event observed by the CDF detector.

5/8/87 Annual Users Meeting at Fermilab. T. D. Lee gives keynote address.

5/11/87 CDF physics run ends with total of 100 million $\bar{p}$-p collisions detected.

6/5/87 Fixed-target run starts as 800-GeV beam reaches experimental areas.

7/20/87 US Particle Accelerator School held at Fermilab. (Session I)



SSC cryostat #001 in the Magnet Test Facility, June 26, 1986.

Construction start on the Feynman Computing Center, September 16, 1986.

8/87 First graduate of Fermilab Accelerator Ph. D. Program, Michael Syphers.

8/3/87 US Particle Accelerator School held at Fermilab. (Session II)

9/87 Contract signed for Amdahl scientific computer.

9/17/87 Deputy Director Philip V. Livdahl retires to devote full time to Loma Linda medical accelerator.

11/87 Energy-efficient aspects of new Central Computing Facility earn DOE Energy Award for Fermilab.

1/8/88 Wallenmeyer Fest, "Homage to Bill," held at Fermilab.

3/22/88 Illinois Alliance for the Arts names Fermilab as recipient of their 1988 Service Award for supporting and furthering arts education in Illinois.

4/28/88 Delegation of physicists and high officials from U.S.S.R. visits Fermilab following the signing in Washington, D.C., of "memorandum of cooperation" between U.S. and U.S.S.R. formally re-establishing the 1973 Nixon-Breshnev agreement calling for cooperation in research, including HEP.

4/30/88 Wonders and Magic of Science sponsored by FFLA as part of Fermilab celebration of National Science and Technology Week.

5/88 URA signs first licensing agreement to allow industry to manufacture and market technology developed at Fermilab.

6/2/88 *Tractricious*, new Robert R. Wilson sculpture, rises in front of Industrial Complex.

7/88 John Peoples appointed Deputy Director Designate.

Stephen Hawking at the Quantum Cosmology Workshop, May 1, 1987.

1/89 Loma Linda Proton Therapy Accelerator, designed and built at Fermilab, achieves first successful operation at Industrial Building 2.

2/1/89 TEVATRON delivers 5 pb^{-1} to CDF.

4/5/89 Fermilab designated nation's sixth National Enviromental Research Park.

4/20/89 URA announces appointment of John Peoples as Fermilab Director Designate.

7/11/88 LML presented with DOE Distinguished Associate Award in Washington, D.C., "for his outstanding leadership and contributions to improving scientific education and public understanding of science."

7/19/88 Helen Edwards awarded MacArthur Fellowship "in recognition of her efforts as one of those instrumental in the successful construction and commissioning of Fermilab's TEVATRON."

8/88 Roberto Vega receives first Fermilab Summer Program for Minority Physics Students Ph.D.

9/7/88 TEVATRON reaches design luminosity of 10^{30} cm^{-2} sec^{-1}, first of the big colliders to reach this goal.

9/9 - 9/12/88 TEVATRON achieves record initial luminosity of 2.36 x 10^{30} $cm^{-2}sec^{-1}$.

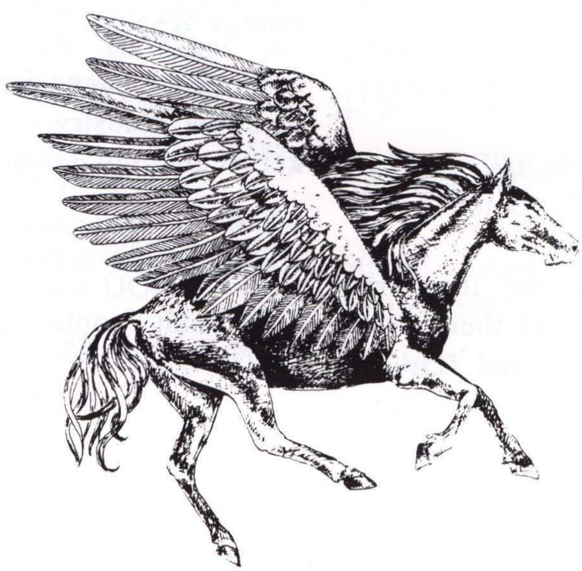
9/28/88 Helen Edwards inducted into National Academy of Engineering.

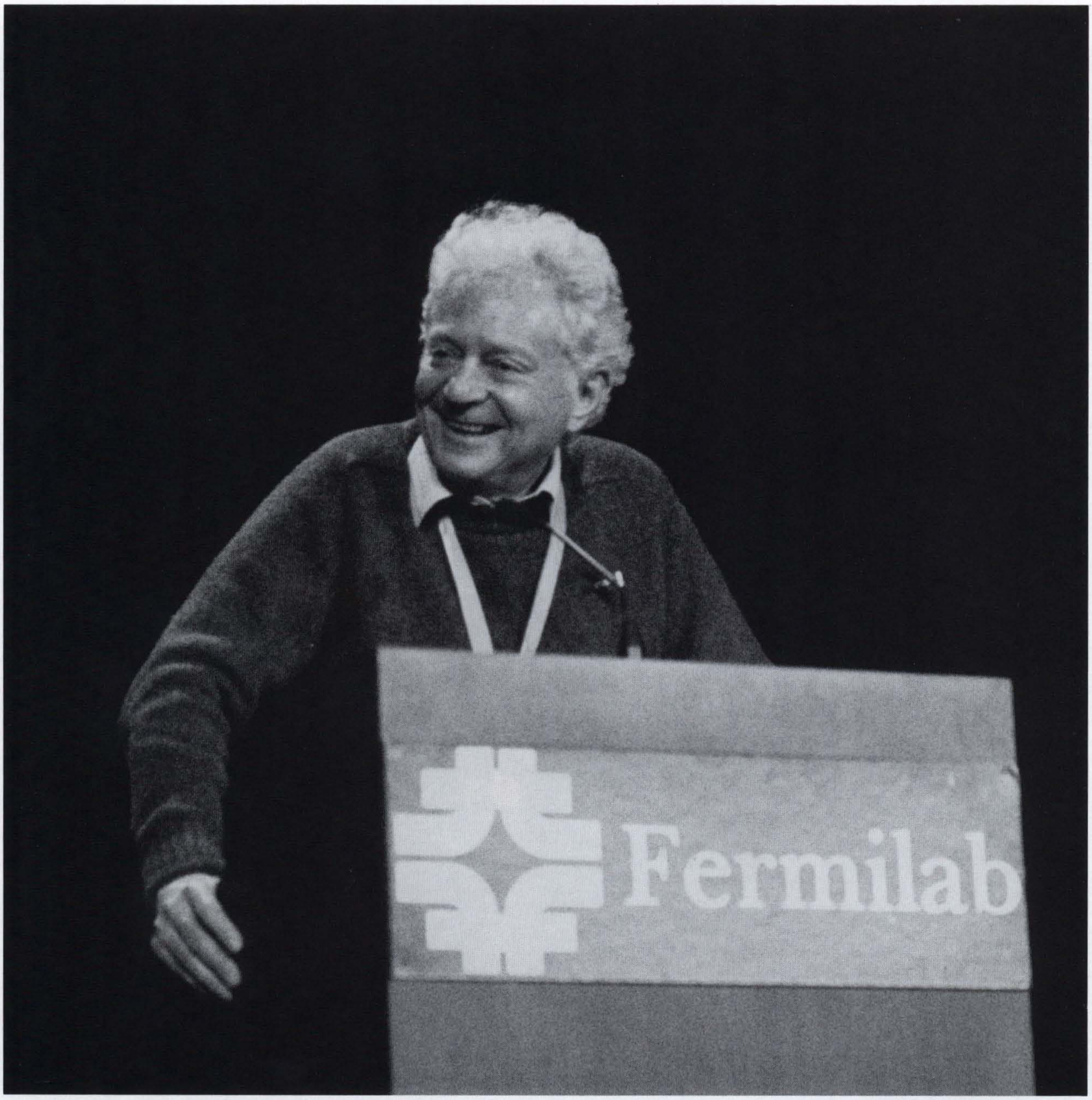
10/19/88 LML, Melvin Schwartz, and Jack Steinberger awarded 1988 Nobel Prize for Physics for 1962 discovery of muon neutrino at BNL. LML announces intention to retire on 7/1/89.

12/88 URA announces formation of Search Committee for Director of Fermilab.

12/2/88 20th Anniversary of Fermilab. Dedication of Feynman Computing Center.

12/8/88 TEVATRON achieves 2.09 x 10^{30} cm^{-2} sec^{-1}.





The Nobel Laureate, October 19, 1988.

V. Appendices

Appendix A. Fermilab Publications - 1988

Publications from Fermilab Experiments

Anti-Neutrino/H2&NE E-180

SEARCH FOR HIGHER CHARMED STRANGE STATES PRODUCED IN $\bar{\nu}_\mu$ N AND ν_μ N INTERACTIONS. A. E. Asratian et al., JETP Lett. **46** 62-65 (1987).

STUDYING ($\bar{c}s$) SPECTROSCOPY IN $\bar{\nu}$N COLLISIONS. A. E. Asratian et al., Z. Phys. C **40**, 483, (1988).

Emulsion/Protons @ 400 E-251

STUDY OF BARYON PRODUCTION AND ITS FEATURES IN 405-GeV/c PROTON-PROTON INTERACTIONS. T. Okusawa et al., Europhys. Lett. **5**, 509, (1988).

Particle Search E-400

OBSERVATION OF $D^0 \rightarrow K^0\bar{K}^0$. J. P. Cumalat et al., Phys. Lett. B **210**, 253 (1988).

MEASUREMENTS OF NEUTRON PRODUCTION OF LAMBDAS AND ANTILAMBDAS. J. Enagonio. Ph.D. Thesis, University of Colorado (1987).

PRODUCTION OF THE Σ_c^0 AND Σ_c^{++} BY HIGH ENERGY NEUTRONS. R. Ladbury, Jr., Ph.D. Thesis, University of Colorado (1988).

PRODUCTION OF CHARM MESONS BY HIGH ENERGY NEUTRONS. C. L. Shipbaugh, Ph.D. Thesis, University of Illinois, Urbana-Champaign, Illinois, 1988.

PRODUCTION OF THE $D_s^\pm$ BY HIGH-ENERGY NEUTRONS. C. Shipbaugh et al., Phys. Rev. Lett. **60**, 2117 (1988).

Nuclear Fragments E-466

DIFFERENTIAL RANGE MEASUREMENTS OF THE INTERACTION OF ^{238}U WITH 400 GeV PROTONS. D. L. Klingensmith and N. T. Porile, Phys. Rev. C **36**, 1051 (1987).

Emulsion/Protons @ 500 E-508

CORRELATIONS AMONG PARTICLES PRODUCED IN PROTON INTERACTIONS WITH EMULSION NUCLEI AT 800 GeV. L. M. Barbier et al., Phys. Rev. D **37**, 1113 (1988).

MULTIPLICITY IN PROTON-NUCLEUS INTERACTIONS IN EMULSION AT 800 GeV. A. Abduzhamilov et al., Z. Phys. C **40**, 223, (1988).

← *Paula Garrett, Fermilab's Head Librarian, amid the stacks.*

Neutrino E-531

THE PRODUCTION MECHANISM AND LIFETIMES OF CHARMED PARTICLES. S. G. Frederiksen, Ph.D. Thesis, University of Ottawa, Ottawa, Ontario, Canada (July 1987).

CROSS SECTIONS FOR NEUTRINO PRODUCTION OF CHARMED PARTICLES. N. Ushida et al., Phys. Lett. B **206**, 375 (1988).

PRODUCTION CHARACTERISTICS OF CHARMED PARTICLES. N. Ushida et al., Phys. Lett. B **206**, 380 (1988).

Di-Muon E-537

HIGH-MASS DIMUON PRODUCTION IN $\bar{p}N$ AND π^-N INTERACTIONS AT 125 GeV/c. E. Anassontzis et al., Phys. Rev. D **38**, 1377 (1988).

NUCLEAR-TARGET EFFECTS IN J/ψ PRODUCTION IN 125-GeV/c ANTIPROTON AND π^- INTERACTIONS. S. Katsanevas et al., Phys. Rev. Lett. **60**, 2121 (1988).

15-ft Neutrino//D2&HIZ E-545

NONSINGLET VALENCE-QUARK DISTRIBUTION FROM NEUTRINO-DEUTERIUM DEEP-INELASTIC SCATTERING. J. B. Cole et al., Phys. Rev. D **37**, 1105 (1988).

15-ft Neutrino/H2&NE E-546

COHERENT ρ^+ PRODUCTION IN NEUTRINO-NEON INTERACTIONS. H. C. Ballagh et al., Phys. Rev. D **37**, 1744 (1988).

15-ft and Emulsion Neutrino E-564

OBSERVATION OF DECAYS OF CHARMED D MESONS AND Σ_c^{++} (2450) BARYON PRODUCED IN NEUTRINO INTERACTIONS WITH NUCLEI IN NUCLEAR EMULSION. Yu. A. Batusov et al., Sov. J. Nucl. Phys. **47**, 639 (1988).

OBSERVATION OF PRODUCTION AND DECAY OF EXCITED $c\bar{s}$ STATE WITH A MASS ~2790-MeV/c^2 IN A NUCLEAR EMULSION. Yu. A. Batusov et al., JETP Lett. **47**, 569 (1988).

RESONANT PRODUCTION OF Λ_c^+ BARYONS IN NEUTRINO-NUCLEUS INTERACTIONS IN A PHOTOGRAPHIC EMULSION. Yu. A. Batusov et al., JETP Lett. **46**, 268 (1988).

30-in. Hybrid E-565

LEADING PARTICLE DISTRIBUTIONS IN 200 GeV/c p+A INTERACTIONS. K. Abe et al., Phys. Lett. B **200**, 266 (1988).

Polarized Beam E-581/704

ANALYZING-POWER MEASUREMENT IN INCLUSIVE π^0 PRODUCTION AT HIGH x_F. B. E. Bonner et al., Phys. Rev. Lett. **61**, 1918 (1988).

COMMISSIONING OF POLARIZED-PROTON AND ANTIPROTON BEAMS AT FERMILAB. A. Yokosawa, *Current Issues in Hadron Physics, Proceedings of the XXIIIrd Rencontre de Moriond - Hadronic Session*, Les Arcs, Savoie, France, March 13-19, 1988, ed. J. Tran Thanh Van, (Editions Frontières, Gif-sur-Yvette Cedex - France, 1988), p. 155.

POLARIZED PROTON AND ANTIPROTON BEAMS AT FERMILAB AND ASSOCIATED EXPERIMENTS. A. Yokosawa, Int. J. Mod. Phys. A **3**, 2753 (1988).

Particle Search E-584

SEARCH FOR NEW, LONG-LIVED, NEUTRAL PARTICLES. R. H. Bernstein et al., Phys. Rev. D **37**, 3103 (1988).

Neutrino E-594

AZIMUTHAL ENERGY FLOW IN DEEP-INELASTIC NEUTRINO SCATTERING. A. Mukherjee et al., Phys. Rev. Lett. **60**, 991 (1988).

High Mass Pairs E-605

HIGH-TRANSVERSE-MOMENTUM HADRON-HADRON CORRELATIONS IN $\sqrt{s}$ = 38.8 GeV PROTON-PROTON INTERACTIONS. D. E. Jaffe et al., Phys. Rev. D **38**, 1016 (1988).

HIGH-MASS PAIRS FROM E605. D. M. Kaplan (for the E-605 Collaboration), *Current Issues in Hadron Physics, Proceedings of the XXIIIrd Rencontre de Moriond - Hadronic Session*, Les Arcs, Savoie, France, March 13-19, 1988, ed. J. Tran Thanh Van, (Editions Frontières, Gif-sur-Yvette Cedex - France, 1988), p. 375.

Hadron Jets E-609

JET PRODUCTION FROM NUCLEI AT 400 GeV/c. H. E. Miettinen et al., Phys. Lett. B **207**, 222 (1988).

Beam Dump E-613

NEUTRINO PRODUCTION BY 400-GeV/c PROTONS IN A BEAM-DUMP EXPERIMENT. M. E. Duffy et al., Phys. Rev. D **38**, 2032 (1988).

Forward Search E-615

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Transition Magnetic Moment E-619

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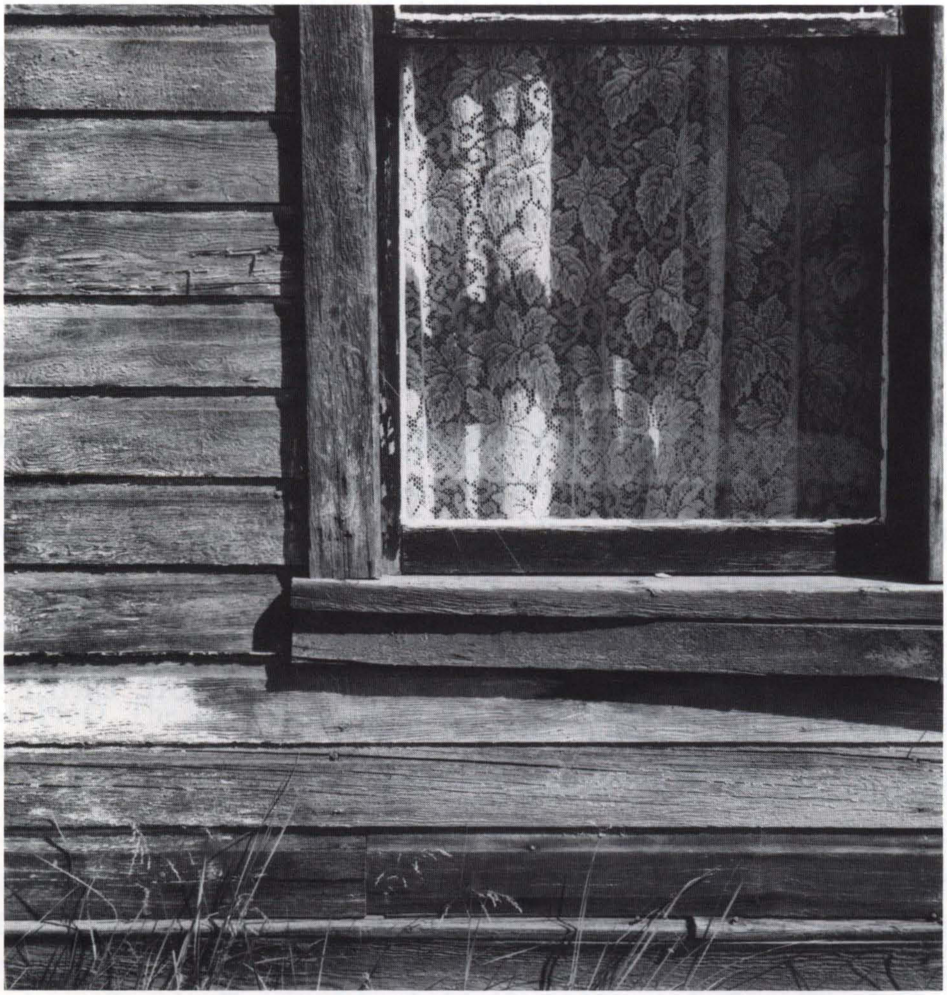

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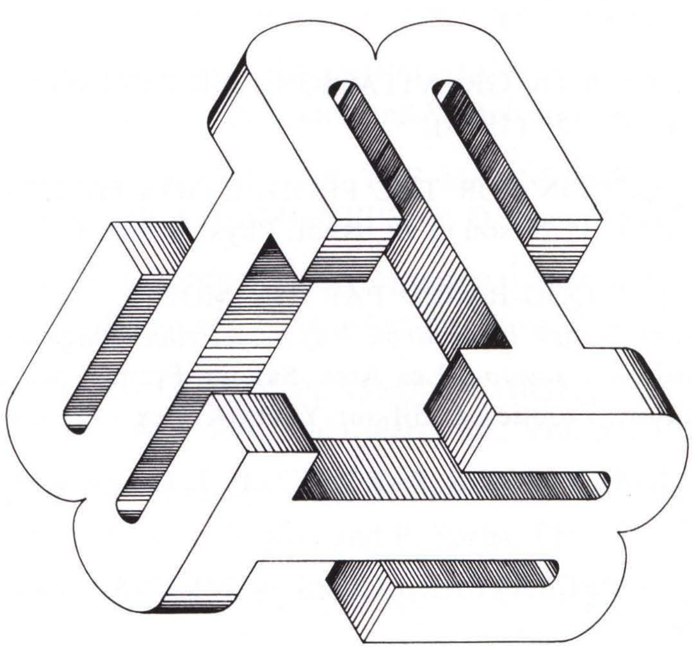

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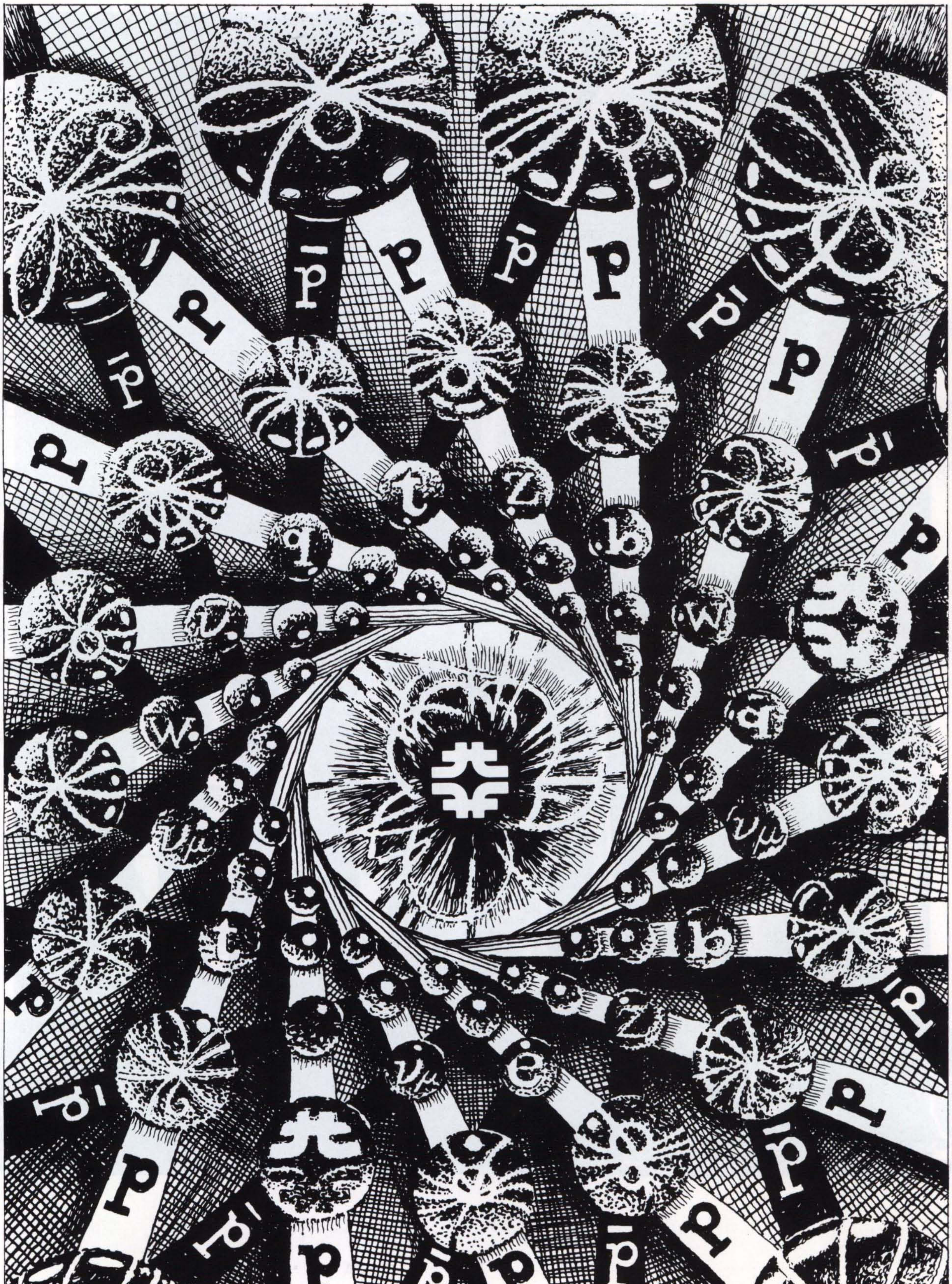


Appendix B. Fermilab Colloquia, Conferences, Lectures, Seminars, Symposia and Workshops - 1988

Fermilab Colloquia

H. Grunder, CEBAF, "CEBAF," January 27.

D. Toussaint, University of California, San Diego, "Lattice QCD at 10^{12} °K," February 24.

L. Wos, Argonne National Laboratory (ANL), "Automated Reasoning," March 2.

J. Ketterson, Northwestern University, "High T_c and Other Novel Superconducting Systems," March 9.

R. Ruffini, University of Rome, "Intermediate Large-Scale Structure of the Universe," March 23.

B. Barish, California Institute of Technology, "Monopoles, Astrophysics, and Cosmic Rays at Gran Sasso," April 6.

P. Boynton, University of Washington, "Experimental Search for a 5th Fundamental Force," April 13.

R. Kirschner, Smithsonian Center for Astrophysics, "SN-1987A: The Supernova of a Lifetime," April 27.

M. Riordan, Stanford Linear Accelerator Center (SLAC), "The Hunting of the Quark: History of the MIT-SLAC Experiments," May 4.

N. Ramsey, Harvard University, "Experiments on Time Reversal Symmetry and Parity," May 18.

R. Woodruff, Lawrence Livermore Laboratory (LBL), "Current Arms Control and Verification Issues," June 8.

M. Turner, University of Chicago/Fermilab, "Dark Matter in the Universe," September 7.

R. Sinha, VEC Centre, Calcutta, "Quark Matter Diagnostics, Earthly and Cosmological," September 21.

P. Langacker, University of Pennsylvania, "The Status of Electroweak Theory," September 28.

A. Dressler, Mt. Wilson and Las Campanas Observatories, Carnegie Institution of Washington, "Large-Scale Distribution of Matter in the Universe and Streaming Motions of Galaxies," October 5.

M. Shochet, University of Chicago, "Hadron Collider Physics," October 12.

J. Bjorken, Fermilab, "The Fifth Force," October 19.

V. L. Fitch, Princeton, "Fifth Force or Farce?" October 26.

R. Palmer, Brookhaven National Laboratory (BNL)/SLAC, "Prospects for TeV Positron-Electron Linear Colliders," November 2.

D. Dearborn, Los Alamos National Laboratory (LLNL), "The House of the Rising Sun," November 16.

H. Edwards, Fermilab, "TEVATRON Upgrade Plans," November 30.

V. Foley, Purdue University, "Leonardo and the Bicycle: Visual Thinking and Some Modern Neurosciences," December 7.

N. Swerdlow, University of Chicago, "Recent Research on the Astronomy of Ptolemy," December 13.

Special Seminars

A. Bamberger, Frieburg University, "Direct Photon Production in Pion-Parton and Proton-Proton Interactions at 300 GeV/c (CERN Experiment NA24)," May 31.

M. Werlen, CERN, "Direct Photon Production in WA70 and Determination of the Gluon Content of the Proton," July 22.

Y. Kubota, "Charmless B Decay Search at CLEO and Status of the CLEOII CsI Shower Counter," August 30.

C. Joseph, University of Lausanne, "Results from UA6: Measurement of Inclusive π^0, η, and γ Production at High P_t in pp and $p\bar{p}$ Collisions at $\sqrt{s}$ = 24.3 GeV," September 19.

Joint Experimental-Theoretical Physics Seminars

S. Oh, Duke University, "Multiplicity Dependence of the Transverse Momentum Spectrum at $\sqrt{s}$=1.8 TeV (C0 Collaboration)," January 15.

P. Schlein, University of California, Los Angeles, "First Results from UA8: Evidence for Partonic Structure in the Pomeron," January 22.

S. Mishra, Columbia University, "Inverse μ-Decay and Low y in ν_μ-N Interactions at the TEVATRON," February 12.

V. Telegdi, California Institute of Technology, "Drell-Yan Pairs Produced by Pions," February 19.

S. Somalwar, University of Chicago, "Room Temperature Induction Detector for Magnetic Monopoles," February 26.

R. Kephart, Fermilab, "Log S Physics at CDF, a Status Report," March 11.

R. Rameika, Fermilab, "Are the Omegas Polarized? Preliminary Results from E-756," March 18.

M. Oreglia, University of Chicago, "Neutrino Production of Opposite Sign Dimuons at the TEVATRON," April 1.

K. Kondo, Tsukuba University, "W and Z Physics at CDF," April 15.

W. De Boer, Max Planck Institute, "What Did We Learn About QCD in High Energy e^+ e^- Annihilation?" April 22.

B. Webber, University of Cambridge, "Monte Carlo Simulation of QCD Coherence in Hadronic Collisions," May 6.

M. Virchaux and A. Milsztajn, Saclay, "A High Statistics Measurement of the Nucleon Structure Functions by the BCDMS Experiment at CERN: A Significant Test of QCD," May 27.

P. Karchin, Yale University, "E-691 Results on D_s^+ and D^+ Decays to Non-Strange States, $\Sigma_c^0 \rightarrow \Lambda_c\pi^-$, and Observation of a New State Decaying to $D^+\pi^-$," June 10.

S. Kwan, CERN, "New Results on Charm in Hadroproduction," August 19.

W. Marciano, BNL, "New Directions in Neutrino Physics at Fermilab," September 16.

L. Maiani, University of Rome, "Prospects of Lattice Gauge Theories," September 23.

G. Dugan, Fermilab, "Tevatron Collider: Machine Performance and Prospects," September 30.

M. Purohit, Princeton University, "Status of Hadro- and Photo-Production of Charm and Comparisons with QCD Predictions," October 7.

H. Stroebele, University of Frankfurt am Main, "Charged Particle and Neutral Strange Particle Production in Nucleus-Nucleus Collisions at 60 and 200 GeV/nucleon," October 14.

S. E. Tzamarias, Northwestern University, "The A-Dependence of J/ψ Production with 125-GeV/c Pions and Antiprotons, Production Dynamics and the Gluon Structure Functions (E-537)," October 21.

T. Bowcock, Harvard University, "New Results on B Mesons from CLEO," October 28.

I. Bigi, University of Notre Dame, "After E-691 and Mark III, too - Is there Any Life Left in Charm Decays?" November 11.

S. Menary, University of Toronto, "Excited States of Charm in E-691," November 18.

I. Leedom, Northeastern University, "Charm Production Properties from E-743," December 16.

Special Joint Experimental-Theoretical Physics Seminar

A. Suzuki, KEK, "Recent Results of Neutrino Physics from Kamiokande," June 13.

H. Pessard, LAPP, "Neutrino Oscillations at Le Bugey Reactor: New Results and Future Prospects with a New Detector," June 15.

S. Kuhlmann, Purdue University, "Measurement of the Inclusive Jet Cross Section in p-pbar Collisions at $\sqrt{s}$ =1.8 TeV," June 17.

J. Kirkby, CERN, "The Tau-Charm Factory: 1000 SPEARS," November 17.

Theoretical Physics Seminars

B. Grinstein, LBL, "Effective Hamiltonian for Radiative B-Meson Decay," January 7.

H. Sonoda, LBL, "Simple Conformal Field Theories," January 14.

L. Dolan, Rockefeller University, "Four-Dimensional String Theory," January 21.

A. Hasenfratz, Florida State University, "What We Can Learn About the Higgs Mass from Lattice Calculations," January 28.

D. Kaplan, Harvard University/SLAC, "Thermodynamic Baryogenesis," February 4.

G. Gipner, Princeton University, "String Theory on Calabi-Yau Manifolds," February 11.

V. Petrov, IHEP, Protvino, "What Can We Learn from the Soft Processes?" February 16.

Z. Qiu, Institute for Advanced Study, "Chiral Current Algebra and Conformal Field Theory," February 18.

J. Maillet, Fermilab, "On Some Algebraic Structures Related to Integrable Field Theories," February 25.

A. Duncan, University of Pittsburgh, "Bosonizing Lattice Fermions," March 10.

E. Mottola, LANL, "Baryon and Lepton Number Violation in the Standard Model," March 15.

D. Dusedau, University of Michigan, Ann Arbor, "On Berry's Phase," March 17.

T. Morris, Southampton University, "Background Impedence of the Cubic String Action," March 24.

M Porrati, LBL, "Spontaneous Supersymmetry Breaking in String Theory," March 31.

B. Zumino, LBL, "Geometric Aspects of String Theory," April 7.

P.G.O. Freund, University of Chicago, "Arithmetic of Strings," April 14.

R. Holdom, University of Toronto, "Chiral Symmetry Breaking with Walking Couplings," April 21.

M. Mangano, Fermilab, "The Color Structure of Gluon Emission," April 28.

C. Zachos, Miami University, "A Presentation for the Virasoro Algebra," May 5.

J. Collins, Illinois Institute of Technology, "Muon Anomalies from Cosmic Rays: The Swan is Alive and Well, and Living in Hercules X-1," May 12.

G. Altarelli, CERN, "Heavy Flavor Production in QCD," May 19.

S. Ellis, University of Washington, "Associated Activity in Hard Scattering Events: The Pedestal Effect," May 26.

A. Moreo, University of Illinois, Urbana-Champaign, "Numerical Study of Bosonic Strings with Extrinsic Curvature," June 2.

H. Yamagishi, SUNY-Stony Brook, "Causality, Cohomology, and Chiral Symmetry," June 9.

W. Tung, Illinois Institute of Technology, "A Closer Look at Parton Distribution Functions and Their Implications for Collider and SSC Physics," June 16.

V. Visnjic, University of Crete, "The Weinberg-Salam Model in a Gauge Invariant Formulation," July 7.

J. Trampetic, University of Oregon, "Rare B Decays," July 14.

J. Trampetic, University of Oregon, "Rare B Decays," July 21.

P. Sorba, Annecy, France, "Vertex Operators for Affine Algebras and Super-Algebras," July 21.

G. Sterman, SUNY-Stony Brook, "Summing Large Corrections in Hadronic Cross-Sections," July 28.

In-Gyu-Koh, Korea Advanced Institute, "The Operator Product Expansion in Conformal Field Theory," August 4.

M. Moshe, Technion, Haifa, "Superstring Zero Modes and Superparticle Quantization," August 11.

H. Harari, Weizmann Institute, "Anomalous Couplings of W Bosons," August 18.

K. Ellis, Fermilab, "'The Status of Perturbative QCD' Plenary Session, Munich," August 26.

S. R. Das, T.I.F.R., Bombay, "Space of Two-Dimensional Quantum Field Theories and Morse Theory," September 1.

M. Marcu, DESY, "Order Parameters for Gauge Theories with Matter Fields," September 29.

B. Grinstein, Fermilab, "Wormholes and the Hierarchy Problem," October 6.

J. Shigemitsu, Ohio State University, "Can One Set Bounds on Yukawa Coupling Generated Fermion Masses?" October 13.

N. Glover, CERN, "Weak Boson Production via Gluon Fusion," October 20.

K. Lane, Boston University, "High Order Corrections to Walking Technicolor," October 27.

H. Steger, DESY, "Prospects for Measuring Particle-Antiparticle Mixing in the B_s-$\overline{B}_s$ System," November 3.

V. Korepin, Steklov Instititute, Leningrad, "Exactly Solvable Models for High T_c Superconductivity," November 10.

I. Sarcevic, University of Arizona, "Multiplicities and Minijets at TEVATRON Collider Energies," November 17.

O. Alverez, University of California, Berkeley, "Current Algebra Relations via Supersymmetry," November 22.

Z. Bern, LANL, "Renormalization in String Theory," December 1.

P. Griffin, Fermilab, "Bosonization of Parafermion Conformal Field Theories," December 8.

M. Porrati, LBL, "Perturbative and Non-Perturbative Spacetime Supersymmetry Breaking in String Theory," December 15.

O. Kalashnikov, Lebedev Physics Institute, "Nonperturbative Approach to the Chiral Phase Transition," December 22.

Special Theoretical Physics Seminars

J. Lykken, University of California, Santa Cruz, "Phenomenology-Inspired Superstrings," January 5.

M. Evans, Rockefeller University, "Symmetry in String Theory," January 12.

H. Itoyama, Fermilab, "The Vertex as a Bogoliubov Transformed Vacuum State in String Field Theory," January 19.

J. Labastida, Institute for Advanced Study, "Bosonic Strings in Background Massive Fields," February 2.

R. Pisarski, Fermilab, "Smooth Strings," March 8.

V. Gribov, Landau Institute, Moscow, U.S.S.R., "Anomalous Vector Current in QCD and Possible Solution of Infrared Instability Problem," May 24.

E. Dagatto, University of Illinois, Urbana, "A New Phase of QED," May 31.

B.L. Ioffe, ITEP-Moscow, "Structure Functions of Deep Inelastic Lepton-Nucleon Scattering in QCD," June 13.

Y.M. Makeenko, ITEP-Moscow, "Solving the Loop Space Equation by Polygon Discretization," June 14.

A.V. Radyushkin, JINR-Dubna, "Loop Space Formalism and Renormalization Group Analysis of Infrared Behavior in Perturbative QCD," June 14.

J. Liu, Carnegie-Mellon University, "Neutrino Magnetic Moment," June 28.

M. Shaposhnikov, Institute for Nuclear Research, Moscow, "Baryon Asymmetry Generation in the Standard Electroweak Theory," October 25.

Special Theoretical Physics Colloquia

G. Altarelli, CERN, "Collider Physics 1. Strong Interactions," May 17.

G. Altarelli, CERN, "Collider Physics 2. Electroweak Interactions," May 20.

Theoretical Physics Informal Seminar

A. Likhoded, IHEP, Serpukhov, "The Rise of the Inclusive Cross Section and the Nature of the Leading Pomeron Singularity," October 26.

Theoretical Astrophysics Seminars

A. Gould, SLAC, "WIMP Capture: Particle Physics Meets Geology," January 18.

Y. Pang, Columbia University, "Stability of Soliton Stars," February 1.

R. Flores, CERN, "Supersymmetric Dark Matter Detection," February 15.

D. Seckel, University of California, San Diego, "Neutron Diffusion and Big Bang Nucleosynthesis," February 25.

H. Kurki-Suonio, Drexel University, "Cosmic Nucleosynthesis and Baryon Inhomogeneity from the Quark-Hadron Transition," March 7.

H. Reno, Fermilab, "Primordial Nucleosynthesis: the Effects of Injecting Hadrons," March 14.

J. Halliwell, University of California, Santa Barbara, "Derivation of the Wheeler-DeWitt Equation Using Path Integrals of Mini-Superspace Models," March 21.

C. Hogan, University of Arizona, "The Cosmic Submillimeter Background," April 4.

R. Watkins, University of California, Santa Barbara, "Relic Densities of Dark Matter Candidates," April 11.

R. Brandenberger, Brown University, "Callan-Rubakov Effect for Strings," April 18.

P. Jetzer, Fermilab, "Dynamical Instability of Bosonic Star Configurations," April 25.

R. Burman, LANL, "Ultra-High Energy (1000 TeV) Signals from Hercules X-1," May 2.

E. Farhi, Massachusetts Institute of Technology, "Universe Creation in the Laboratory," May 9.

P. Shellard, Massachusetts Institute of Technology, "Superconducting String Simulations," May 16.

B. Lieberman, Massachusetts Institute of Technology, "Adiabatic Methods in the Functional Schro/'dinger Picture,' " May 23.

R. Gandhi, NIKHEF, "Neutrino Helicity Flips via Electroweak Mechanisms and Supernovae," September 12.

D. Schramm, University of Chicago, "The Large-Scale Structure of the Universe and Late Time Phase Transitions," September 19.

K. Griest, University of Chicago/Fermilab, "Neutralino Dark Matter and Its Detection," September 26.

F. Occhionero, Osservatorio Astronomico di Roma, "Double Inflation from Fourth Order Gravity," October 3.

J. Fry, University of Florida, Gainesville, "Voids, Scaling, and the Origins of Large-Scale Structure," October 10.

P. Haensel, CAMK/Princeton University, "Non-Equilibrium Processes in Neutron Stars' Crusts," October 17.

C. Stubbs, University of Washington, Seattle, "The Experimental Status of the Fifth Force: Was Newton Right?" October 24.

F. Accetta, Yale University, "Fun with the Wormhole Calculus," October 31.

G. Veneziano, Boston University/CERN, "Beam-Shaped Gravitational Waves: Properties and (Theoretical) Applications," November 7.

D. Dearborn, LLNL, "How Serious are Astrophysical Constraints?" November 14.

M. Duncan, CERN, "Time and Quantum Cosmology," November 21.

V. Petrosian, Stanford University, "Arcs in Clusters of Galaxies as Gravitational Lenses," November 28.

Special Theoretical Astrophysics Seminars

M. Hindmarsh, LANL, "Z2 Strings in Non-Abelian Gauge Theories," April 13.

H. Feldman, SUNY-Stony Brook, "Thermal Fluctuations in the Pre-Inflationary Phase," September 7.

L. Stodolsky, Institute for Advanced Study/Max Planck Institute, "Neutrino Mixing in a Stochastic Environment," October 25.

A. Migdal, Academy of Sciences, Moscow, "Random Surfaces and Strings: Analytical and Numerical Results," November 1.

G. Veneziano, Boston University/CERN, "Probing Quantum-String-Gravity by Gedanken Collisions," November 8.

G. Savvidy, Yerevan Physics Institute, "Co-Cycles of Area Preserving Diffeomorphisms. Anomalies in the Theory of Relativistic Surfaces. QCD and Membranes," November 15.

Accelerator Division Seminars

B. Brown, Fermilab, "Magnets and Measurements for European Accelerators - DESY, CERN, GSI," January 12.

A. Tollestrup and D. Finley, Fermilab, "Intrabeam Scattering and the Upgraded TEVATRON Collider," January 19.

J. Simpson, ANL, "Wake Field Acceleration Measurements," January 26.

M. Syphers and S. Holmes, Fermilab, "Recent Results of Main Ring 8-GeV/20-GeV Studies," February 2.

Y. Huang, Princeton University, "A Computer Study of Beam Extraction from the Princeton AVF Cyclotron," February 16.

R. Talman, SSC Central Design Group, "Million Revolution Accelerator Beam Instrument for Logging and Evaluation Implementation: C. Saltmarsh Application," February 23.

L. Coulson, Fermilab, "Fermilab Radiation Data and Experience for the SSC," March 1.

G. Jackson, A. McInturff, and D. Johnson, Fermilab, "Reports on Recent TEVATRON Studies," March 8.

S. A. Bogacz, Fermilab, "Coherent Instabilities - General Picture, Recent Examples (Booster and TEVATRON)," March 15.

R. Koul, BNL, "Theory and Simulation of a Low-Emittance Laser-Driven rf Electron Gun," March 29.

J. Marriner, D. Harding, and J. McCarthy, Fermilab, "Preparations for the Collider Run: Pbar Source, Accumulator to Main Ring Beam Transfer, rf, and Diagnostics," April 5.

P. Martin, D. Finley, and G. Dugan, Fermilab, "Preparations for the Collider Run: Main Ring, TEVATRON, Summary and Overview," April 12.

L. Michelotti, Fermilab, "Differential Algebra Without Blood, Sweat, Tears, and FORTRAN Using C++," June 7.

E. Eichten, S. Holmes, and J. Yoh, Fermilab, "Discovery Potential of Potential Fermilab Hadron Colliders vs. Energy and Luminosity," June 14.

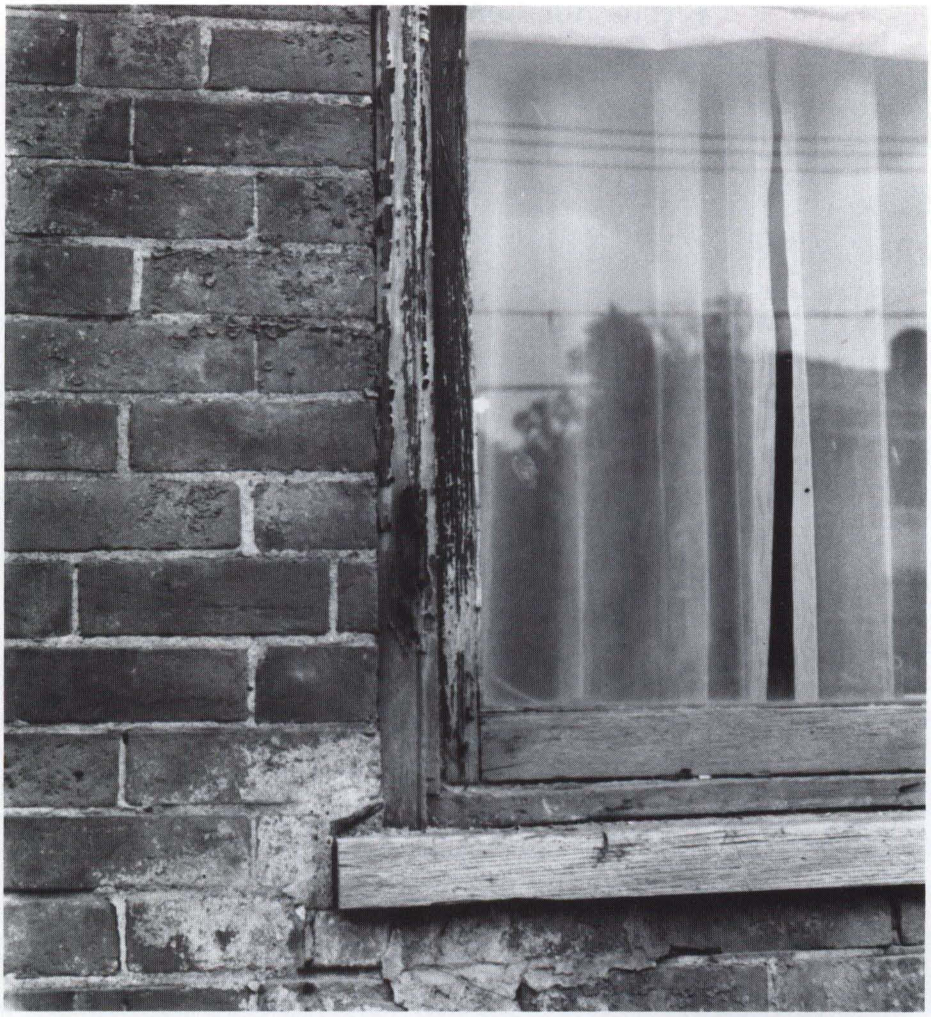
S. Kramer, ANL, "Accelerator Design for the Argonne Advanced Photon Source," July 19.

S. Holmes, Fermilab, "Summary of the Snowmass Hadron Collider Working Group," July 26.

G. Dugan, J. Marriner, D. Finley, and P. Martin, Fermilab: "TEVATRON Collider Performance, Present and Anticipated," August 2.

P. Mantsch, Fermilab, "High-Field Magnets for the TEVATRON Upgrade," August 23.

T. Nicol, J. Theilacker, and T. Peterson, Fermilab, "Magnet Cryostat Designs and Cryogenic Considerations for TEVATRON Upgrades," August 30.



R. Gerig and S. Mane, Fermilab, "Tracking and Reality in the Main Ring," September 6.

W.-C. A. Lin, University of Texas, and Ilya Prigogine, Center for Statistical Mechanics, "Quantum Resonance Zones, Quantum KAM Theorem and Quantum Resonance Overlap," September 13.

L. Teng, Fermilab, "What Does It Take to Get Polarized Beam in the TEVATRON?" October 4.

G. Goderre, Fermilab, "Results of Helical Orbit Studies in the TEVATRON," October 25.

H. Edwards, Fermilab, "Plans and Priorities for the Next Two Years," November 8.

J. Peoples and G. Dugan, Fermilab, "Division Reorganization," December 6.

C. Johnstone, Fermilab, "The 200-/400-MeV Transfer Line," December 20.

Accelerator Controls Seminar

L. Chapman, M. Frey, and A. Waller, Fermilab, "Current Issues and Object-Oriented Programming," November 14.

DØ Friday Seminars

J. Kohli, Panjab University, "Silicon Vertex Detector Possibilities for DØ," September 16.

S. Wimpenny, University of California, Riverside, "Heavy Flavors/UA1," October 7 and September 23.

H. Prosper, Fermilab, "The Grenoble Experiment on the Electron Dipole Moment of the Neutron," October 14.

R. McCarthy, SUNY-Stony Brook/Fermilab, "DØ Central Calorimeter Installation," November 11.

O. Callot, SUNY-Stony Brook, "Central Drift Chamber Premod Tests in DØ," December 16.

Research Division Seminars

R. Ruchti, University of Notre Dame: "Active Target Development for E-687," January 20.

G. Hallewell, SLAC, "Progress in the Construction of the SLD CRID," April 13.

S. Hansen, Fermilab, "New ADC's and TDC's for Fixed-Target Physics," May 10.

D. Cossairt, Fermilab, "Production and Transport of Muons in Thick Shields at the Junction, CASIM Calculations and Measurements," May 12.

P. Jarron, CERN-EF, "Existing VLSI Technology and Applications in HEP," May 25.

P. Jarron, CERN-EF, "Future Perspectives for VLSI Technology in HEP," May 26.

L. Christophorou, ORNL, "Gaseous and Liquid Media for Particle Detectors," July 19.

J. Kreuger, Hamburg, "High Resolution Hadron Calorimetry for the ZEUS Detector at HERA," August 8.

C. Johnstone, Fermilab, "The A-Dependence of Leading Particle Production," September 1.

A. Davis, CERN, "Fire Safety Planning for LEP," October 10.

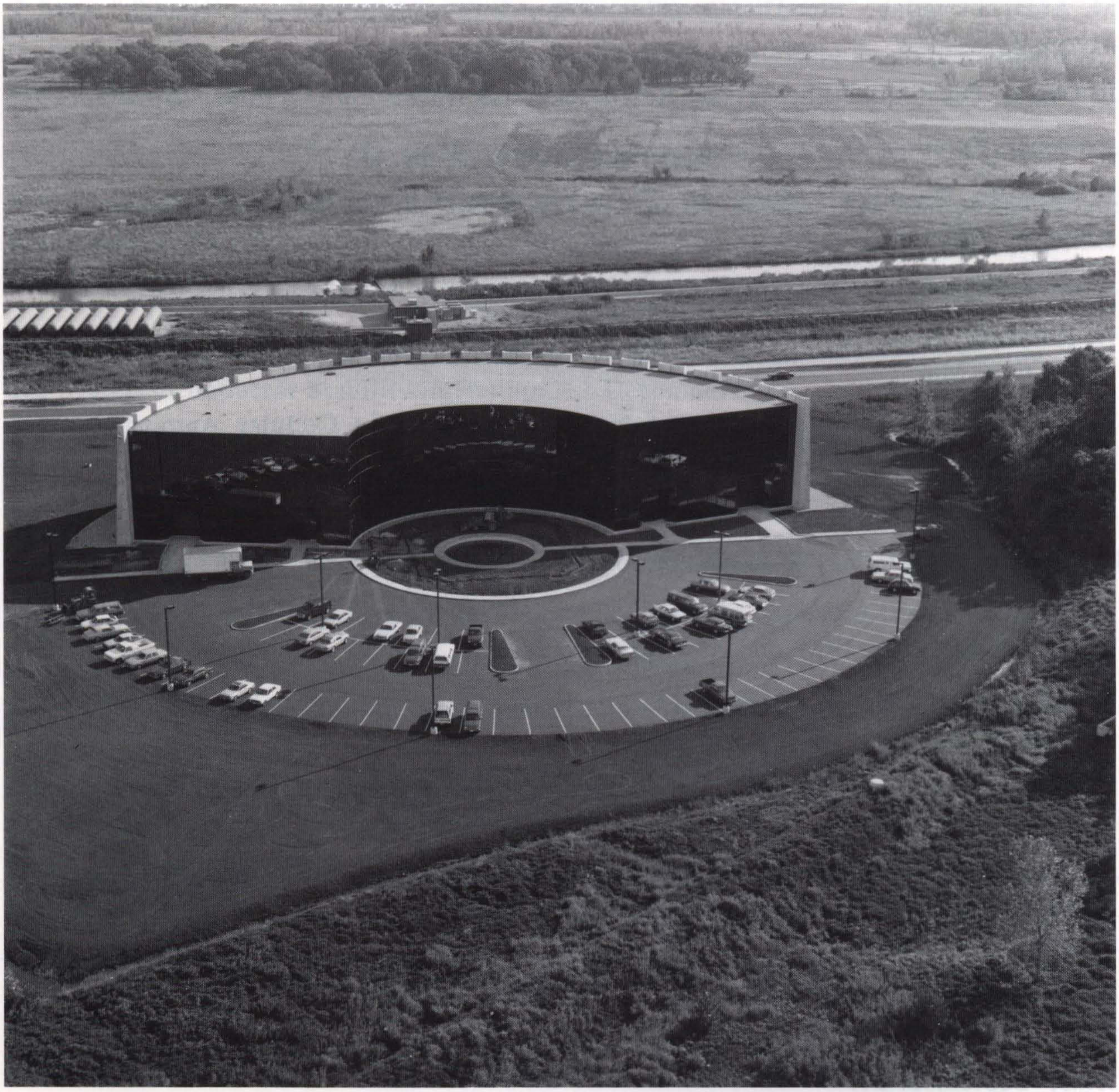
V. Zarucheisky and V. Kotov, IHEP, Serpukhov, U.S.S.R., "Status of UNK," October 11.

Special Research Division Seminar

D. Anderson, Fermilab, "Detectors for the Non-Physicist," September 7.

Computing Networking Special Seminar

H. Montgomery, Fermilab, "Computer Networking: Report of the HEPNET Review Committee," April 4.



Computing Techniques Seminars

D. Carlson, Illinois Institute of Technology, "Database Technology," January 12.

G. Chartrand, Fermilab, "Wide Area Networking in High-Energy Physics," January 26.

J. Hoftun, Brown University, "MicroVAX Farms," February 23.

T. Virgo, Fermilab, "DIGS to DI3000," March 8.

G. Manning, Active Memory Technology, "DAP: A New Massively Parallel Computing System," March 17.

M. Afdal, Fermilab, "Plot-Display (PLTDSP) of Physics Results Using DI3000," April 5, March 22.

P. Demar, Fermilab, "Ethernet and New Local Area Networking Options," April 12.

J. Pfister, Fermilab, "Central Computing Upgrade: Overview," April 19.

J. Nicholls, Fermilab, "Interlink: Communicating Between the VAX Cluster and the Amdahl," April 26.

J. Mack, Fermilab, "VM Overview: the Amdahl Environment," May 3.

A. Kreymer, Fermilab, "ACP Systems in the Fermilab Computing Environment: Status and Plans," May 17.

B. Denby, Saclay, "Applications of Neural Networks and Cellular Automata in Experimental High Energy Physics," May 19.

R. Thatcher, Fermilab, "FORTRAN on the Amdahl," May 24.

G. Chartrand, Fermilab, "Communications to the Amdahl System," May 31.

P. Sinervo, CDF/University of Pennsylvania, "The Management and Development of CDF Code for VAX, IBM, and Absoft Environments," June 7.

M. Leininger, T. Nicol, and U. Pabrai, Fermilab, "Workstation Evaluation for Mechanical Engineering Applications," June 14.

P. Kasper, Fermilab, "The E-687 Code Management System: A Solution to a General Problem," June 28.

M. Afdal, Fermilab, "Compatibilities and Incompatibilities of HBOOK3/HBOOK4 with HBOOK4/HPLOT5: Some Case Studies," July 12.

D. Ritchie, Fermilab, "Breaking Up is Hard to Do: Restructuring the FNAL Vax Cluster USR$ROOT File Base," August 16.

J. Biel, Fermilab, "Plans for the Second Generation of ACP Multimicroprocessor Systems," September 27.

J. Knobloch, Mainz University, "Data Reduction and Offline Software of the ALEPH Collaboration," November 1.

P. Constanta-Fanourakis and M. Votava, Fermilab, "Helical Scan Devices - EXABYTE, GIGASTORE," November 8.

P. Avery, University of Florida, "A New Multi-Processing Software System Using Workstations," November 18.

B. Denby, Fermilab, "The Fermilab Neural Networks Project," December 6.

H. Melanson, Fermilab, "E-665 Experience with the Amdahl," December 13.

Special Computing Techniques Seminar

C. Moler, Ardent Computer, "Scientific Visualization with Graphics Supercomputers," March 22.

Research Techniques Seminars

P. Sharp, Rutherford Laboratory, "Integrated Circuit Development in Europe for Future Experiments," July 8.

Cryogenics Seminars

R. Boom, University of Wisconsin-Madison, "Superconducting Magnetic Energy Storage Systems/Conductor Stability in Helium II," December 5.

J. Gonczy, Fermilab, "Superinsulation Systems and the SSC," December 22.

Helium Cryogenics Seminar

S. Stoy and R. Fast, Fermilab, "Liquid Helium II - The Superfluid Thermal Properties of Liquid Helium," November 21.

Engineering Seminar

Crystal Semiconductor Corporation, "Data Acquisition Techniques," February 25.

Mechanical Engineering Seminars

A. Holmes, "Threaded Fasteners," November 9.

J. Hosier, INCO International, "Inconnel 718 and Other High String Stainless Steel Alloys," December 14.

Special Technical Support Services Seminar

J. Clem, Iowa State University, "Magnetic Hysteresis and Flux Creep Effects in Superconductors," November 7.

Fermilab Academic Lecture Series

S. Solomon, Head Project Scientist, National Ozone Expedition, 1986-1987, "The Hole in the Sky," January 15.

A. Albrecht, Fermilab, "Cosmology for High-Energy Physicists," March 8, 10, 15, 17.

D. Green, Fermilab, "Particle Properties on an Abacus: Bound Systems of Hadron Constituents," March 28.

D. Green, Fermilab, "Particle Properties on an Abacus: Su(n) and Hadron Multiplets," March 30.

D. Green, Fermilab, "Particle Properties on an Abacus: Hadron Masses," April 1.

D. Green, Fermilab, "Particle Properties on an Abacus: Weak Decays of Hadrons," April 4.

D. Green, Fermilab, "Particle Properties on an Abacus: Electromagnetic Decays of Hadrons," April 6.

D. Green, Fermilab, "Particle Properties on an Abacus: Strong Decays of Hadrons," April 8.

S. Parke, Fermilab, "Neutrino Oscillations," May 9, 11.

H. Harai, Weizmann Institute/Fermilab, "Heavy Flavors - 88," July 25, 27, 29.

Lecture Series for College Students

D. Jovanovic, Fermilab, "The Standard Model," June 15.

L. Teng, Fermilab, "An Introduction to Particle Accelerators," June 22.

P.W. Lucas, Fermilab, "Accelerator Computer Control Systems," June 29.

S. Pordes, Fermilab, "Introduction to Particle Detectors," July 6.

J. Cooper, Fermilab, "Description and Status of CDF," July 13.

E. Treadwell, Fermilab, "Monte Carlo and Detector Simulation Techniques in High Energy Physics," July 19.

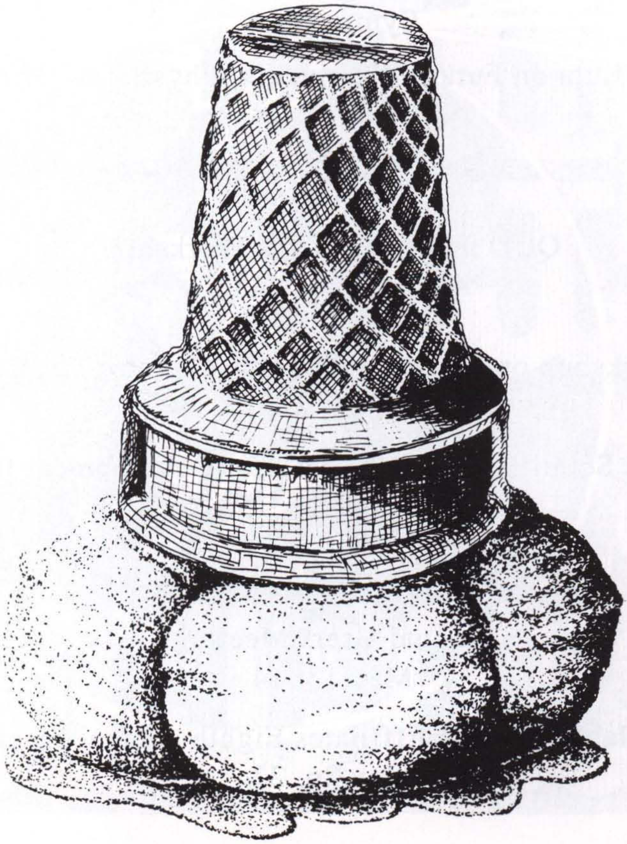
J. Bjorken, Fermilab, "The Fifth Force," July 21.

N. Turok, Fermilab, "The Big Bang and the Universe on Very Large Scales - a New Testing Ground for High-Energy Physics," August 3.

Academic Lecture Series

Haim Harari

Weizmann Institute/Fermilab



Heavy Flavors - 88

A series of lectures reviewing recent developments and future experiments on top and bottom physics, generation mixing, CP-violation, mass matrices, b-factories, neutrino masses, oscillations and decays, and related topics.

Fermi National Accelerator Laboratory
Curia II

•

Monday, July 25, Wednesday, July 27,
and Friday July 29, 1988
1:30 p.m. - 3:00 p.m.

•

Conferences

Conference on New Directions in Neutrino Physics at Fermilab
September 14, 15, 16

Lattice Gauge Theory Conference
September 22, 23, 24, 25

Symposium

Symposium on Future Polarization Physics at Fermilab
June 13, 14

Workshops

QCD in Astrophysics Workshop
April 29, 30, May 1

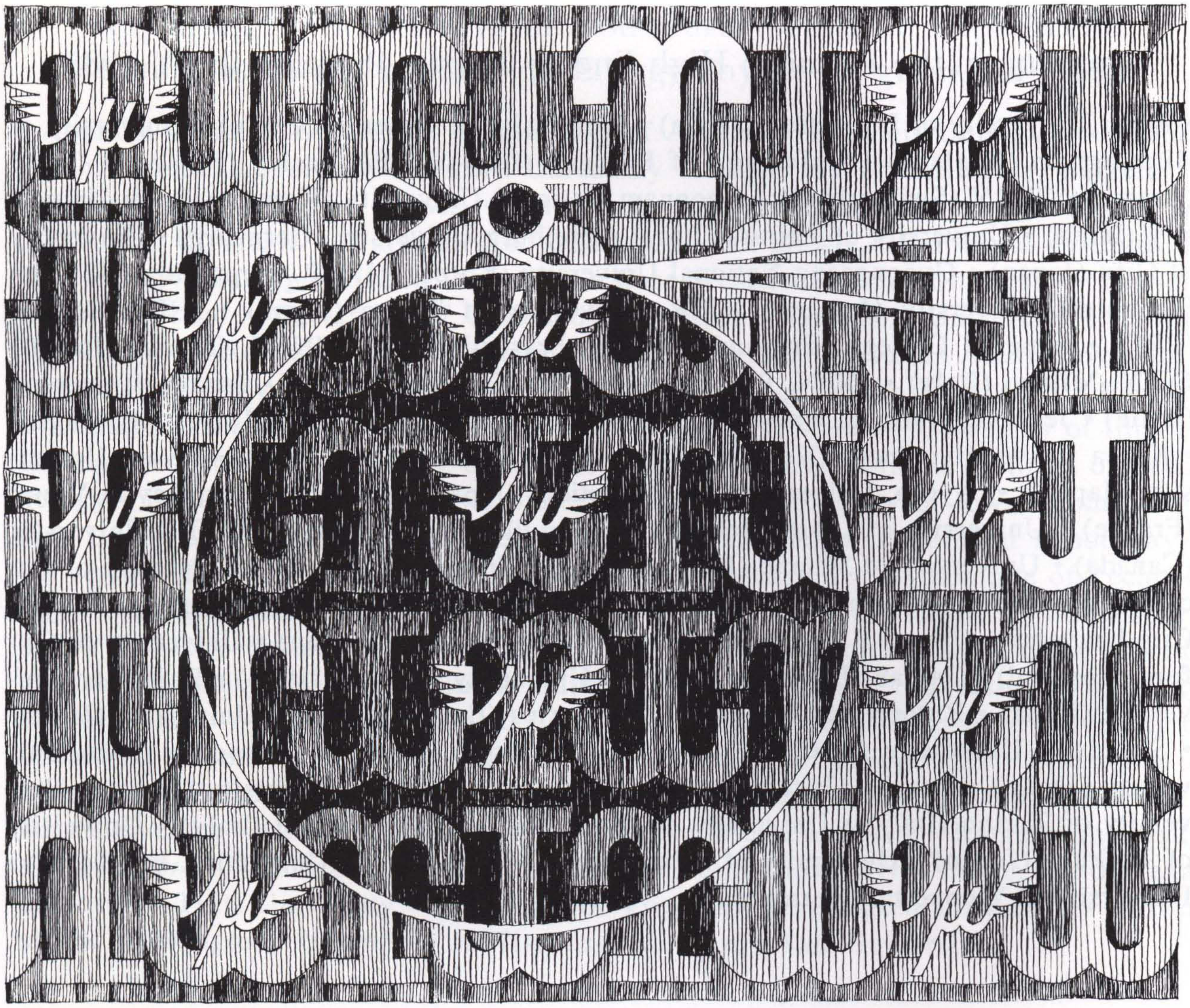
7th Topical Workshop on Proton-Antiproton Collider Physics (PBARP-7)
June 20, 21, 22, 23, 24

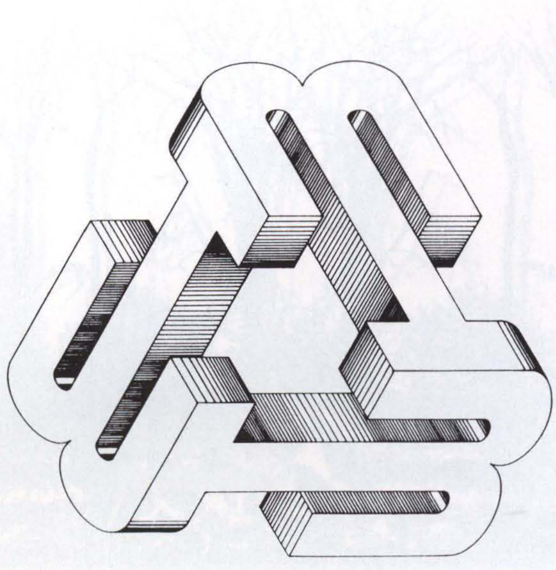
Workshop on Scintillating Fiber Detector Development for the SSC
November 14, 15, 16

Other

Annual Users Meeting
May 13, 14

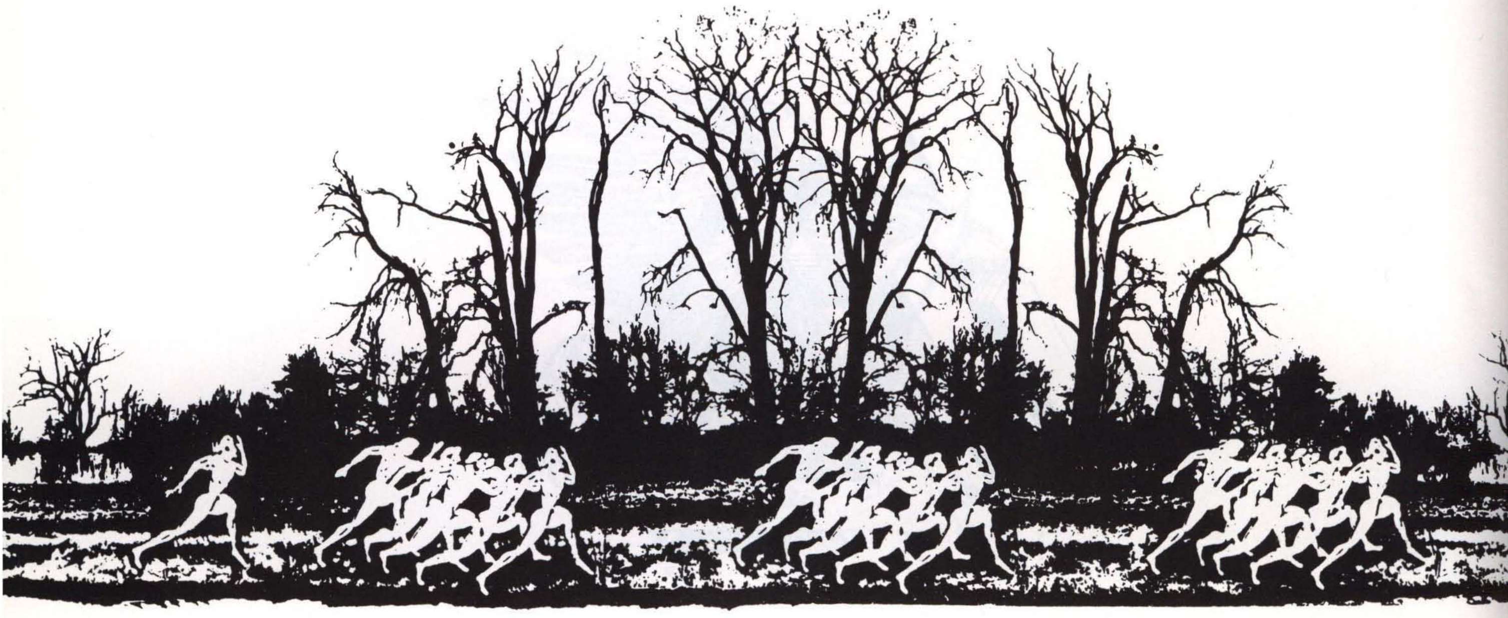
Fermilab Industrial Affiliates Eighth Annual Meeting
May 26, 27





Appendix C. Foreign Institutions Participating on Experiments Running in the Fermilab High-Energy Physics Program in FY 1988

• Aichi University of Education (Japan) • University of Athens (Greece) • University of Birmingham (England) • University of Bologna (Italy) • CEN-Saclay (France) • CBPF (Brazil) • CERN (Switzerland) • Chonnam National University (Korea) • Delhi University (India) • University of Ferrara (Italy) • Freiburg University (Germany) • University of Gifu (Japan) • Gyeongsang National University (Korea) • IHEP, Serpukhov (USSR) • Hiroshima University (Japan) • ICRR, University of Tokyo (Japan) • IHEP, Beijing (PRC) • Imperial College (England) • INFN, Frascati (Italy) • INFN, Genova (Italy) • INFN, Milano (Italy) • INFN, Pisa (Italy) • INP, Krakow (Poland) • Jammu University (India) • Jeonbug National University (Korea) • KEK (Japan) • Kobe University (Japan) • Korea University, Seoul (Korea) • Kyoto Sangyo University (Japan) • Kyoto University (Japan) • Kyoto University of Education (Japan) • LAPP, d'Annecy-le-Vieux (France) • University of Libre (Belgium) • Max-Planck (Germany) • McGill University (Canada) • University of Milano (Italy) • Nagoya University (Japan) • University of Occupational and Environmental Health (Japan) • Okayama University (Japan) • Osaka City University (Japan) • Osaka Science Education Institute (Japan) • University of Oxford (England) • Panjab University (India) • University of Pavia (Italy) • Rajasthan University (India) • Rutherford-Appleton Laboratories (England) • Saga University (Japan) • Shandong University (PRC) • Sookmyong Woman's University (Korea) • Toho University (Japan) • Tohoku Gakuin University (Japan) • Tohoku University (Japan) • University of Torino (Italy) • University of Toronto (Canada) • Trieste (Italy) • University of Tsukuba (Japan) • University of Udine (Italy) • Won Kwang University, Iri (Korea) • University of Wuppertal (Germany) •



Appendix D. Domestic Institutions Participating on Experiments Running in the Fermilab High-Energy Physics Program in FY 1988

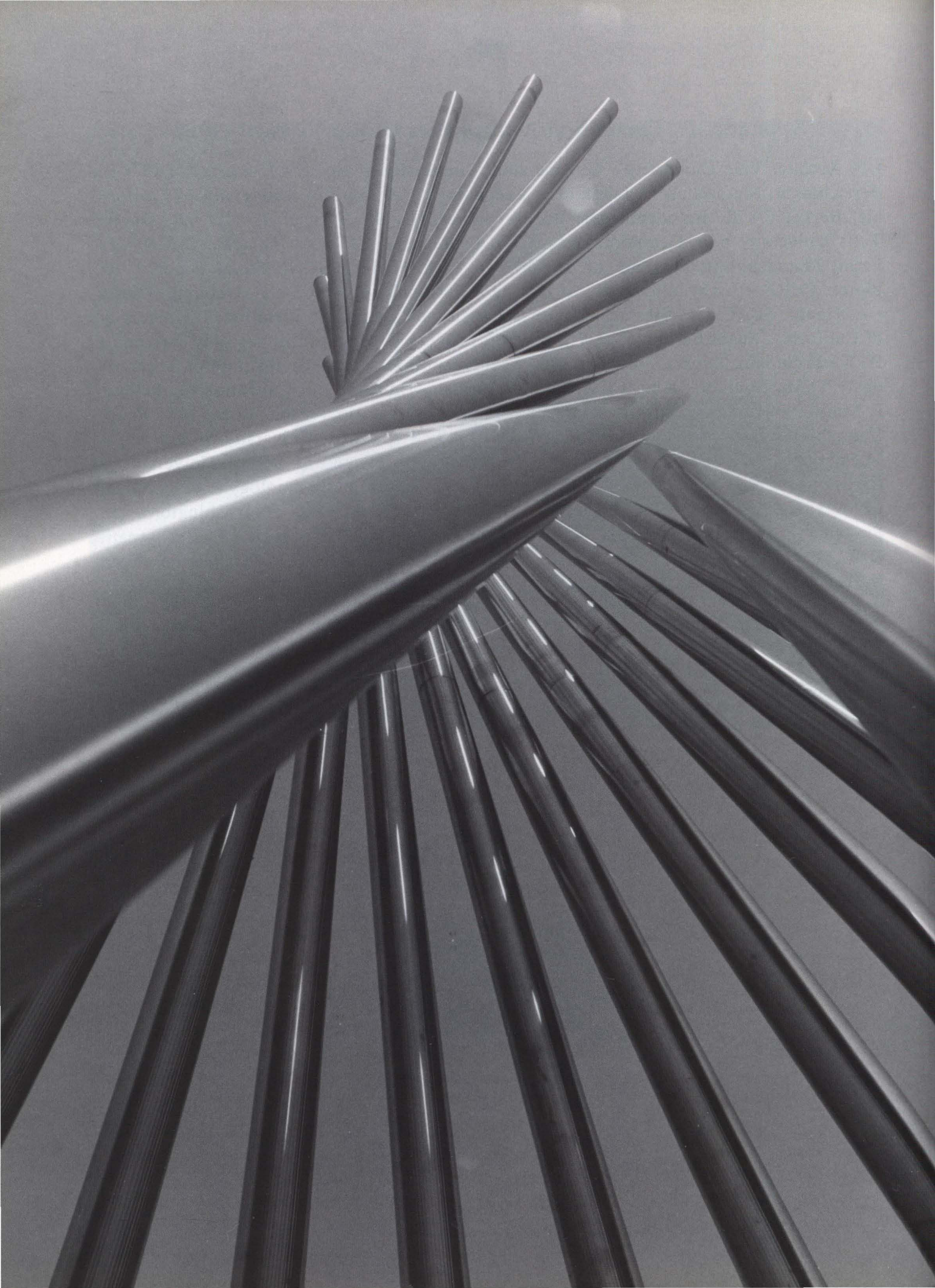
• Argonne National Laboratory • University of Arizona • Brandeis University • Brookhaven National Laboratory • Brown University • University of California, Berkeley • University of California, Davis • University of California, Irvine • University of California, Riverside • University of California, San Diego • California Institute of Technology • Carnegie-Mellon University • Case Western Reserve University • University of Chicago • University of Colorado at Boulder • Columbia University • Cornell University • Duke University • Elmhurst College • Fermilab • Florida A&M University • Florida State University • University of Florida • George Mason University • Harvard University • Haverford College • University of Hawaii at Manoa • University of Illinois, Champaign-Urbana • University of Illinois, Chicago Circle • Illinois Institute of Technology • Indiana University • Iowa State University • University of Iowa • Johns Hopkins University • Lawrence Berkeley Laboratory • Los Alamos National Laboratory • University of Louisville • University of Maryland • Massachusetts Institute of Technology • Michigan State University • University of Michigan • University of Minnesota • SUNY at Stony Brook • New York University • University of North Carolina • Northeastern University • Northern Illinois University • Northwestern University • University of Notre Dame • Oak Ridge National Laboratory • Ohio State University • University of Oklahoma • Pennsylvania State University • University of Pennsylvania • University of Pittsburgh • Prairie View A&M University • Princeton University • Purdue University • Rice University • University of Rochester • Rockefeller University • Rutgers University • University of Tennessee at Knoxville • Texas A&M University • University of Texas at Austin • Tufts University • University of Virginia • Washington University • University of Washington • University of Wisconsin-Madison • Yale University •

Appendix E. Theoretical Physics Department Visitors/Guest Scientists - 1988

• R. Akhoury, University of Michigan • C. H. Albright, Northern Illinois University • R. Baier, University of Bielefeld • Z. Bern, LANL • T. Bhattacharya, Tata Institute of Fundamental Research • N. Byers, University of California • L. Chatterjee, Jadavpur University • P. Chiappetta, Centre de Physique Theorique CNRS • T. Clark, Purdue University • T. Curtright, University of Florida • W. Czyz, U.S.S.R. • E. Dagatto, University of Illinois at Urbana-Champaign • A. Das, University of Rochester • S. R. Das, Tata Institute of Fundamental Research • C. DeTar, University of Utah • S. Ellis, University of Washington • S. Fajfer, Institut za Fiziku V. Putnika • F. Feinberg, Massachusetts Institute of Technology • G. I. Ghandour, University of Kuwait • N. Glover, CERN • S. Gottlieb, Indiana University • V. Gribov, Landau Institute • R. Grigoryan, ERPI • H. Harari, Weizmann Institute of Science • P. Hasenfratz, Universitat Bern • W.-S. Hou, Max Planck Institut • B. Ioffe, Institute of Theoretical Physics B. Cheremushkinskaya • A. Isaev, INR • O. K. Kalashnikov, Lebedev Physical Institute • A. Kennedy, Florida State University • I. Khan, Sultan Qaboos University • M. Kikugawa, Hiroshima University • I.-G. Koh, Korea Advanced Institute of Science and Technology • V. Krasnikov, INR • K. Lassila, Iowa State University • T. Leung, Purdue University • A. Likhoded, IHEP • L. Lipatov, Institute for Nuclear Physics Gatchina • J. Liu, Carnegie-Mellon University • W. Liu, University of California, San Diego • S. Love, Purdue University • J. Maharana, Universite′ de Paris XI • I. Makeenko, Institute of Theoretical Physics B. Cheremushkinskaya • M. Marcu, DESY • E. Marinari, Universita di Roma • G. Martinelli, CERN • S. D. Mathur, Tata Institute of Fundamental Research • J. McCarthy, Indiana University • J. McCarthy, SUNY/Stony Brook • D. McKay, University of Kansas • R. Mkrtchyan, ERPI • A. Moreo, University of Illinois at Urbana-Champaign • D. Morris, California Institute of Technology • M. Moshe, Israel Institute of Technology • F. W. Nijhoff, Clarkson University • V. Novikov, ITEP • R. J. Oakes, Northwestern University • G. A. Perez, Universitario National Autonoma de Honduras • R. Petronzio, Instituto Naz. Fiz. Nucleare • V. Petrov, Institute of HEP • L. Polley, Oldenburg University • M. Porrati, Lawrence Berkeley Laboratory • A. Radyushkin, JINR (Dubna) • A. Rosely, ITEP • I. Sarcevic, LANL • C. A. Savoy, Universite′ Louis Pasteur • G. K. Savvidy, Yerevan Physics Institute • J. C. Sexton, IBM • M. E. Shaposnikov, Institute for Nuclear Research of the Academy of Sciences • M. Sher, Washington University • J. Shigemitsu, Ohio State University • P. Sorba, LAPP • J. Szwed, Jagellonian University • J. Taylor, University of London • D. Toussaint, University of California, San Diego • J. Trampetic, University of Oregon • P. Van Baal, CERN • A. Vainstein, Institute of Nuclear Physics - Novosibirsk • V. Visnjic, University of Crete • H. von Gersdorff, University of Minnesota • B. Webber, University of California • E. Weinberg, Columbia University • H. Xiao-Gang, University of Melbourne • T. Yanagida, Toboku University • D. Yennie, Cornell University • M. Zaglauer, Washington University •

Appendix F. Theoretical Astrophysics Group Visitors - 1988

• F. Accetta, Yale University • L. Amendola, University of Rome • J. Bahcall, IAS • E. Bertschinger, Massachusetts Institute of Technology • F. Bouchet, University of California, Berkeley • R. Brandenberger, Brown University • R. Burman, LANL • R. Davis, Tufts University • D. Dearborn, LLNL • G. Djorgouski, CIT • M. Duncan, CERN • E. Farhi, Massachusetts Institute of Technology • H. Feldman,SUNY/Stony Brook • R. Flores, CERN • J. Fry, University of Florida • R. Gandhi, NIKHEF • G. Gelmini, Trieste • A. Gould, SLAC • P. Haensel, Copernicus Astronomy Center • J. Halliwell, University of California, Santa Barbara • M. Hindmarsh, LANL • C. Hogan, University of Arizona • H. Kurki-Suonio, Drexel University • B. Lieberman, Massachusetts Institute of Technology • T. Mastronikola, King's College • A. Meiksin, University of California, Berkeley • I. Moss, Newcastle University • F. Occhionero, Osservatorio Astron. Rome • Y. Pang, Columbia University • A. Patkos, Eotvos University • A. Perez, University of Valencia • V. Petrosian, Stanford University • R. Rivers, Imperial College • D. Seckel, University of California, Santa Cruz • P. Shellard, Massachusetts Institute of Technology • A. Stebbins, CITA • L. Stodolsky, Max Planck/IAS • C. Stubbs, University of Washington • L. Susskind, University of Texas at Austin • A. Szalay, Eotvos University • T. Vachaspati, DAMTP • G. Veneziano, Boston University • R. Watkins, University of California, Santa Barbara • R. Wilkinson, Imperial College • T. York, Cornell University •



Appendix G. Universities Research Association, Inc.

Universities Research Association, Inc.

Officers of the URA Council of Presidents - April 19, 1989

• Thomas E. Everhart, California Institute of Technology *(Council Chairman)* •
• Edward J. Bloustein, Rutgers University *(Council Vice-Chairman)* •

Executive Committee of the URA Council of Presidents - April 19, 1989

• Thomas E. Everhart, California Institute of Technology *(Chairman)* • Edward J. Bloustein, Rutgers University • James Corbridge, University of Colorado - Boulder • William H. Cunningham, University of Texas at Austin • John DiBiaggio, Michigan State University • Edward A. Knapp, Universities Research Association, Inc. • Robert M. O'Neil, University of Virginia • George Rupp, Rice University • John Silber, Boston University •

URA Council of Presidents - April 19, 1989

• Richard C. Atkinson, University of California, San Diego • Steven C. Beering, Purdue University • Edward J. Bloustein, Rutgers University • E. Grady Bogue, Louisiana State University • Derek C. Bok, Harvard University • Keith H. Brodie, Duke University • James Corbridge, University of Colorado - Boulder • G. E. Cornell, University of Toronto • Robert A. Corrigan, San Francisco State University • William H. Cunningham, University of Texas at Austin • Richard M. Cyert, Carnegie-Mellon University • William H. Danforth, Washington University • John DiBiaggio, Michigan State University • James J. Duderstadt, University of Michigan • Joseph D. Duffey, University of Massachusetts at Amherst • Gordon P. Eaton, Iowa State University • Melvin A. Eggers, Syracuse University • Thomas Ehrlich, Indiana University • Thomas E. Everhart, California Institute of Technology • William P. Gerberding, University of Washington • Hanna Holborn Gray, University of Chicago • Paul E. Gray, Massachusetts Institute of Technology • Vartan Gregorian, Brown University • F. Sheldon Hackney, University of Pennsylvania • Paul Hardin, University of North Carolina • Nils Hasselmo, University of Minnesota • Ira Michael Heyman, University of California, Berkeley • Edward H. Jennings, Ohio State University • David L. Johnston, McGill University • Bryce Jordan, Pennsylvania State University • Eamon Kelly, Tulane University • Donald Kennedy, Stanford University • William E. Kirwan, University of Maryland • Henry Koffler, University of Arizona • John Latourette, Northern Illinois University • Joshua Lederberg, Rockefeller University • Rev. Edward A. Malloy, C.S.C., University of Notre Dame • John H. Marburger, State University of New York at Stony Brook • Jean Mayer, Tufts University • James D. McComas, Virginia Polytechnic Institute • William H. Mobley, Texas A&M University • Steven Muller, Johns Hopkins University • W. H. Nedderman, University of Texas at Arlington • J. Russell Nelson, Arizona State University • Dennis O'Brien, University of Rochester • Robert M. O'Neil, University of Virginia • Jack W. Peltason, University of California, Irvine • Chase N. Peterson, University of Utah • Percy Pierre, Prairie View A&M University • Wesley W. Posvar, University of Pittsburgh • Agnar Pytte, Case Western Reserve University • Hunter R. Rawlings, III, University of Iowa • Jack E. Reese, University of Tennessee at Knoxville • Frank H.T.

Rhodes, Cornell University • George Rupp, Rice University • Kenneth G. Ryder, Northeastern University • Steven B. Sample, State University of New York at Buffalo • Roger Sayers, University of Alabama • Benno C. Schmidt, Jr., Yale University • Donna E. Shalala, University of Wisconsin at Madison • Harold T. Shapiro, Princeton University • John Silber, Boston University • Albert J. Simone, University of Hawaii at Manoa • Bernard F. Sliger, Florida State University • Michael I. Sovern, Columbia University • David Swank, University of Oklahoma • Richard L. Van Horn, University of Houston • Paul R. Verkuil, College of William and Mary • Arnold R. Weber, Northwestern University • Morton W. Weir, University of Illinois • Joseph B. Wyatt, Vanderbilt University • Charles E. Young, University of California, Los Angeles •

Officers of the URA Board of Trustees - April 19, 1989

• John H. Marburger, State University of New York at Stony Brook *(Chairman)* • Edward G. Jefferson, E. I. du Pont de Nemours & Company (retired) *(Vice-Chairman)* •

Executive Committee of the URA Board of Trustees - April 19, 1989

• Edward A. Knapp *(Chairman)* • J. Fred Bucy, Texas Instruments Corporation (retired) • Edward G. Jefferson, E. I. du Pont de Nemours & Company (retired) • Henry Koffler, University of Arizona • John H. Marburger, State University of New York at Stony Brook • Bernard F. Sliger, Florida State University • H. Guyford Stever, National Academy of Engineering (retired) •

URA Board of Trustees - April 19, 1989

Regional Trustees: *Region 1* - Henry Koffler, University of Arizona • *Region 2* - Hanna Holborn Gray, University of Chicago • *Region 3* - Bernard F. Sliger, Florida State University • *Region 4* - Wesley W. Posvar, University of Pittsburgh • *Region 5* - Joseph B. Wyatt, Vanderbilt University • *Region 6* - Harold T. Shapiro, Princeton University • *Region 7* - John H. Marburger, State University of New York at Stony Brook • **Trustees-at-Large:** J. Fred Bucy, Texas Instruments Corporation (retired) • William R. Frazer, University of California System • Edward G. Jefferson, E. I. du Pont de Nemours & Company (retired) • George R. Mitchell, Mitchell Oil Company • Robert C. Stempel, General Motors Corporation • H. Guyford Stever, National Academy of Engineering (retired) •

Corporate Officers

• Edward A. Knapp *(President)* • Ezra D. Heitowit *(Vice President/Secretary)* •

Fermilab Board of Overseers - April 19, 1989

• David H. Cohen, Northwestern University • Maurice Glicksman, Brown University • Robert E. Gordon, Notre Dame University • Jack M. Hollander, Ohio State University • Leland E. Holloway, University of Illinois • George R. Kalbfleisch, University of Oklahoma • William H. Kelly, Iowa State University • Joseph E. Lannutti, Florida State University • Vincent Z. Peterson, University of Hawaii • Charles E. Putman, Duke University • Albert Silverman, Cornell University • Paul F. Slattery, University of Rochester •

Visiting Committee for Fermilab

• Robert K. Adair, Yale University • Barry C. Barish, California Institute of Technology • Thomas J. Devlin, Rutgers University • Stephen D. Ellis, University of Washington • Jerome I. Friedman, Massachusetts Institute of Technology *(Chairman)* • Robert Gluckstern, University of Maryland • Herman Grunder, CEBAF • Ewan Patterson, SLAC • Martin L. Perl, SLAC • David N. Schramm, University of Chicago •

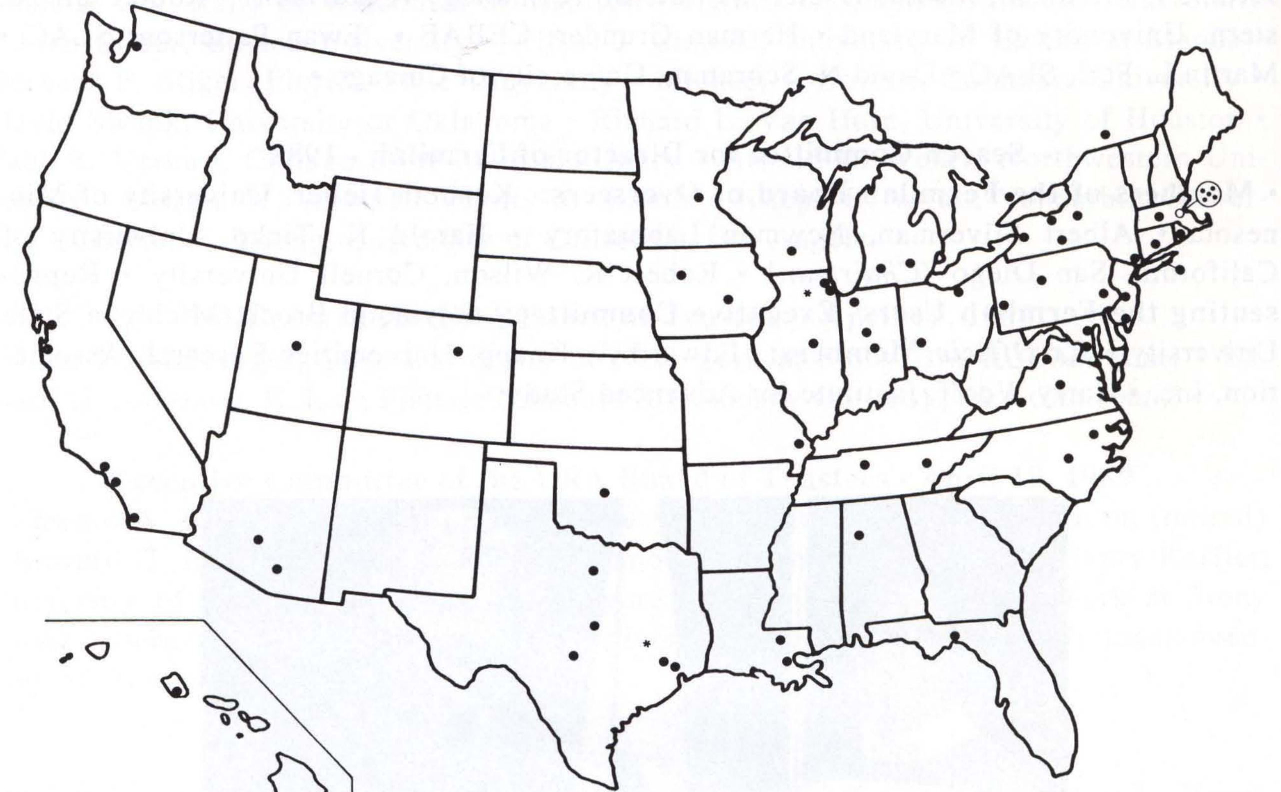
Search Committee for Director of Fermilab - 1988

• **Members of the Fermilab Board of Overseers:** Kenneth Heller, University of Minnesota • Albert Silverman, Newman Laboratory • Harold K. Ticho, University of California, San Diego *(Chairman)* • Robert R. Wilson, Cornell University • **Representing the Fermilab Users' Executive Committee:** Raymond Brock, Michigan State University • ***Ex-Officio* Members:** Edward A. Knapp, Universities Research Association, Inc. • Harry Woolf, Institute for Advanced Study •

John Peoples, Fermilab's Director Designate, and Leon Lederman in April 1988.

Universities Research Association, Inc., Member Institutions

Locations of member and associate member institutions of Universities Research Association, Inc., which operates Fermi National Accelerator Laboratory and the Superconducting Super Collider Laboratory as a contractor for the United States Department of Energy



Alabama
University of Alabama (Tuscaloosa)
Arizona
Arizona State University
University of Arizona
California
California Institute of Technology
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
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 Chicago
Northern Illinois University*
University of Illinois - Champaign-Urbana
Northwestern University
Indiana
Indiana University
Notre Dame University
Purdue University
Iowa
University of Iowa
Iowa State University
Louisiana
Tulane University
Louisiana State University
Maryland
Johns Hopkins University
University of Maryland
Massachusetts
Boston University
Harvard University
University of Massachusetts
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 University
New York
Columbia University
Cornell University
University of Rochester
Rockefeller University
SUNY at Buffalo
SUNY at Stony Brook
Syracuse University
North Carolina
Duke University
University of North Carolina
Ohio
Case Western Reserve University
Ohio State University
Oklahoma
University of Oklahoma
Pennsylvania
Carnegie-Mellon University
University of Pennsylvania
Pennsylvania State University
University of Pittsburgh
Rhode Island
Brown University
Tennessee
University of Tennessee, Knoxville
Vanderbilt University
Texas
Prairie View A&M University*
University of Houston
Rice University
Texas A&M University
University of Texas at Arlington
University of Texas at Austin
Utah
University of Utah
Virginia
Virginia Polytechnic Institute
University of Virginia
College of William and Mary
Washington
University of Washington
Wisconsin
University of Wisconsin-Madison
Canada
McGill University
University of Toronto

*denotes an associate member institution

Appendix H. High Energy Physics Advisory Panel - 1988

• Barry C. Barish, California Institute of Technology • Karl Berkelman, Cornell University • Alexander W. Chao, Lawrence Berkeley Laboratory • Jerome I. Friedman, Massachusetts Institute of Technology • Sheldon L. Glashow, Harvard University • Howard A. Gordon, Brookhaven National Laboratory • Anne Kernan, University of California, Riverside • Joseph E. Lannutti, Florida State University • Francis E. Low, Massachusetts Institute of Technology, *(Chairperson)* • Charles Y. Prescott, Stanford University • Paul J. Reardon, Science Applications International Corporation • Jonathan L. Rosner, Institute for Advanced Study • Kenneth C. Stanfield, Fermi National Accelerator Laboratory • Mark W. Strovink, Fermi National Accelerator Laboratory • Lawrence R. Sulak, Boston University • Stanley G. Wojcicki, Lawrence Berkeley Laboratory •

Appendix I. Physics Advisory Committee - 1988

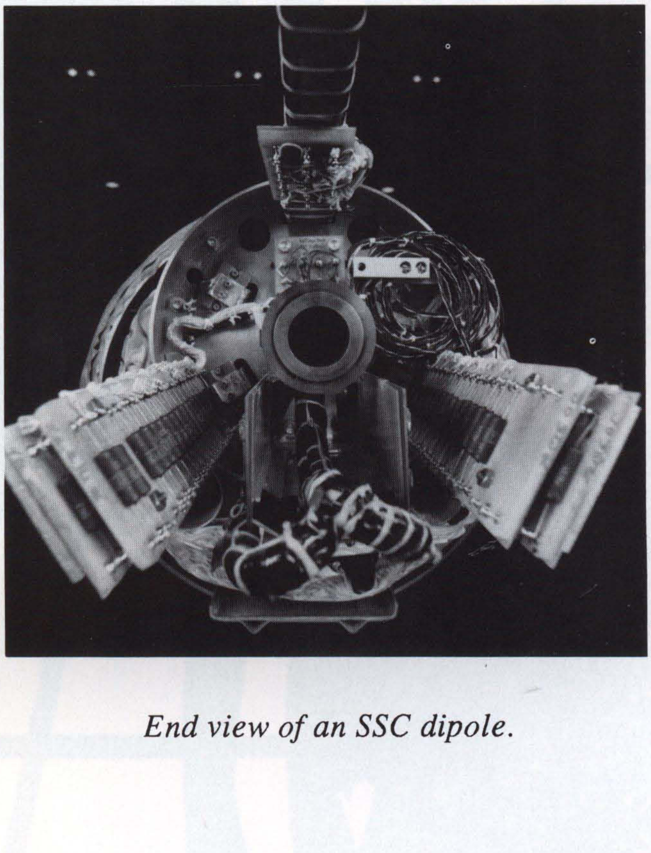
• Richard D. Field, University of Florida • Mary Kay Gaillard, Lawrence Berkeley Laboratory • Howard A. Gordon, Brookhaven National Laboratory • Anne Kernan, University of California, Riverside • William J. Marciano, Brookhaven National Laboratory • Francis M. Pipkin, Harvard University • Richard Prepost, University of Wisconsin-Madison • Charles Prescott, Stanford Linear Accelerator Center • John P. Rutherfoord, University of Washington • Michael Schmidt, Yale University • Melvin Jay Shochet, Enrico Fermi Institute, University of Chicago • Mark W. Strovink, Fermi National Accelerator Laboratory • Michael Witherell, University of California, *(Chairperson)* • Lincoln Wolfenstein, Carnegie-Mellon University •

Appendix J. Fermilab Users Executive Committee - 1988-1989

• Raymond L. Brock, Michigan State University • James H. Christenson, Fermi National Accelerator Laboratory • Marjorie Corcoran, Rice University • Eugene Engels, Jr., University of Pittsburgh • Steven Errede, University of Illinois *(Chairperson)* • Arthur Garfinkel, Purdue University • George D. Gollin, Princeton University • Stephen Holmes, Fermi National Accelerator Laboratory • Michael N. Kreisler, University of Massachusetts • Henry J. Lubatti, University of Washington • Regina Rameika, Fermi National Accelerator Laboratory *(Secretary)* • James Siegrist, Lawrence Berkeley Laboratory • Anna Jean Slaughter, Yale University •

Appendix K. Fermilab Industrial Affiliates - 1988

• AT&T Bell Laboratories • Air Products and Chemicals, Inc. • Allied-Signal Engineered Materials Research Center • Ameritech Development Corporation • Amoco Corporation • Babcock & Wilcox • CBI Services, Inc. • CVI, Inc. • Commonwealth Edison Company • Cray Research, Inc. • Digital Equipment Corporation • Digital Pathways, Inc. • R. R. Donnelley & Sons Company • Eaton Corporation • Environmental Monitoring Laboratories, Inc. (Waste Management, Inc.) • General Dynamics • General Electric Company • GTE Laboratories • W.W. Grainger, Inc. • Harza Engineering Company • Hewlett-Packard Company • Hutchinson Technology, Inc. • IBM • State of Illinois • Inland Steel Company • Intermagnetics General Corporation • Kinetic Systems Corporation • Litton Industries, Inc. • Major Tool & Machine, Inc. • Martin Marietta Denver Astronautics • NALCO Chemical Company • New England Electric Wire Corporation • NYCB Real-Time Computing, Inc. • R. Olson Manufacturing Company, Inc. • Omnibyte Corporation • Oxford Superconducting Technology • Phillips Scientific • Plainfield Tool and Engineering, Inc. • Schlumberger-Doll Research • Science Applications International Corporation • Sulzer Brothers • Swagelok Companies • Union Carbide Corporation • Varian Associates, Inc. • Westinghouse Electric Corporation •



End view of an SSC dipole.

Appendix L. Exhibits in the Fermilab Gallery - 1975-1988

No Date: SCIENCE THROUGH THE AGES, scientific books from the John Crerar Library • KITAOJI ROSANJIM CERAMICS, from the Art Institute of Chicago • JAPANESE PRINTS, from the Art Institute of Chicago •

1975: SCULPTURE BY SIR JACOB EPSTEIN, from the collection of the Museum of African Art, Washington, D.C. • TWO CHICAGO PHOTOGRAPHERS: HAROLD ALLEN AND ELLEN CARR FINE, from the collections of the artists • MAN RAY, PHOTOGRAPHICS (in Gallery Annex), from the collection of Arnold H. Crane •

1976: MARCEL BARDON, photography, from the collection of the artist • 100 YEARS OF CHICAGO ARCHITECTURE, from the Museum of Contemporary Art • DANKMAR ADLER AND LOUIS HENRY SULLIVAN ARCHITECTURE, from the collection of Chicago School of Architecture Foundation •

1977: JAPANESE PRINTS, from the collection of Dr. Robert R. Wilson • MARTHA RAY, CERAMICS AND PRINTS, from the collection of the artist • MARTYL, from the collection of the artist • PHOTOGRAPHY OF WALKER EVANS, from the collection of Arnold H. Crane • PAINTINGS BY ANGELA GONZALES, from the collection of the artist • BOTANICAL ILLUSTRATIONS, Nancy Hart and Anthony Tyznik, from the Publications of the Morton Arboretum •

1978: 16 TWENTIETH-CENTURY ARTISTS, from the Fairweather Hardin Gallery • CONTEMPORARY PRINTS, from the Joseph Randall Shapiro Collection • TWENTIETH-CENTURY ARTISTS, from the Richard Gray Gallery • PHOTOGRAPHY OF LINCOLN FAJARDO, (gallery annex), from the collection of the artist • SUMIE PAINTINGS BY MOTO KIMURA, (gallery annex), from the collection of the artist • MARCEL BARDON, from the collection of the artist • PAINTINGS AND SCULPTURE, from the Lillian H. Florsheim Collection •

1979: AFRICAN SCULPTURE, from the GSA Confiscated Collection • BARBARA A. BRIEN, from the collection of the artist • NOJIMA YASUZO PHOTOGRAPHY, from the Gilbert Gallery • MASON CREEK AREA FOSSILS, from the collection of Jerry Latshaw •

1980: WYNN BULLOCK, Gilbert Gallery • PRE-COLOMBIAN POTTERY, Art Institute of Chicago • MINERALS FROM THE FIELD MUSEUM, Field Museum of Chicago • GREEK VASES OF THE FIFTH CENTURY, B.C., Art Institute of Chicago •

1981: MARINE MOLLUSK SHELLS, from the Chicago Shell Club • SCIENTIFIC ILLUSTRATION, from the collections of six artists • EXHIBIT OF TECHNOLOGY, from the Fermi Industrial Affiliates •

1982: CLAY SCULPTURE, Exhibit A Gallery • SIX ARTISTS - SIX MEDIA, from the collections of the artists •

1983: NEW IRELAND, ART, LIFE, AND DEATH, Field Museum of Natural History • MARGO HOFF, Fairweather-Hardin Gallery • FROM THE COLLECTION OF MARJORIE AND CHARLES BENTON II, Benton Collection (Paintings and Prints) • JACQUES BARUCH PRESENTS - Anderle, Brunovsky, Butrymowicz, Gazovic, Krejci, Kulhanek, Rosiak, and Saudek, Baruch Gallery • HERB COMESS PHOTOGRAPHS, from the collection of the artist •

1984: ZAKIN/YOUNGER CERAMICS, from the collection of the artists • ART EXHIBIT IN HONOR OF THE ENERGY SAVER DEDICATION, Bailey, Caldwell, Derer, Dietrich, Hubbard, Mooney, Price, Scarff • MEXICAN TRADITIONAL AND CEREMONIAL ART, from the collection of the May Weber Foundation • GERARD ALTMANN, from the collection of the artist •

1985: CHARCOAL DRAWINGS (Mini-show), Anatomy Class from The School of the Art Institute of Chicago • MARTYL, from the collection of the artist • NATIONAL PARK PHOTOGRAPHS, on loan from the artist, Stan Jorstad •

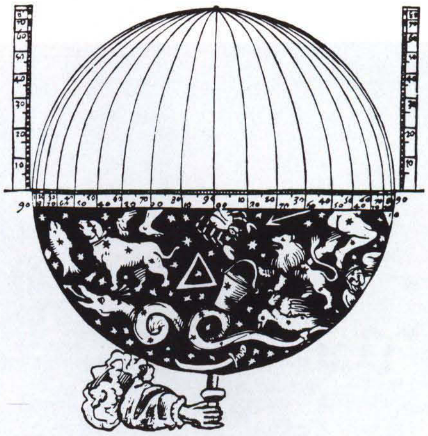
1986: SPACE 900, five artists • BLACK HISTORY, paintings and prints from a private collection • ROBERT MIDDAUGH, on loan from the collection of the artist • CONTEMPORARY PAINTING AND SCULPTURE, from the Broido Collection • DOUGLAS BUSCH, LARGE FORMAT PHOTOGRAPHY, from the collection of the artist • FERMILAB ARTS AND CRAFTS, various media, open show •

1987: ALBECHT-BUEHLER PENTOMINOES, inlaid wood from the artist • SHU JIA DING, Oriental painting • FERMILAB EXHIBIT COMMITTEE, various media • WEBER AFRICAN COLLECTION, sculpture from the Weber Foundation • FRONTIERS OF CHAOS, contemporary math as art, Goethe Institute • TORKEL KORLING, 50 YEARS IN PHOTOGRAPHY, botanical and industrial photography from the artist's collection • PHSCOLOGRAMS by (Art^n), sculpture, photos, holograms combined as art •

1988: WILLIAM CLIFT PHOTOGRAPHY, from the collection of the artist • VIRGINIO FERRARI SCULPTURE, from the collection of the artist • FACULTY FROM THE SCHOOL OF THE ART INSTITUTE OF CHICAGO, from the artists • EMPLOYEES' ARTS AND CRAFTS SHOW, from the employees • STAN JORSTAD: THE GOOD EARTH, from the collection of the artist • ELLEN CARR LEDERMAN, PHOTOGRAPHY, from the collection of the artist • D. CARY SCHRAMM, PAINTING, from the collection of the artist •

廣重

INTERNATIONAL CONFERENCE
IN HONOR OF ROBERT R. WILSON



SCIENCE THROUGH THE AGES

A Selection of Pioneer Works in Science, Technology, Medicine in the Collections of

THE JOHN CRERAR LIBRARY

INTERNATIONAL SYMPOSIUM
IN HONOR OF ROBERT R. WILSON

Prints from the Art Institute of Chicago

MARCEL BARDON

Fermilab December, 1978

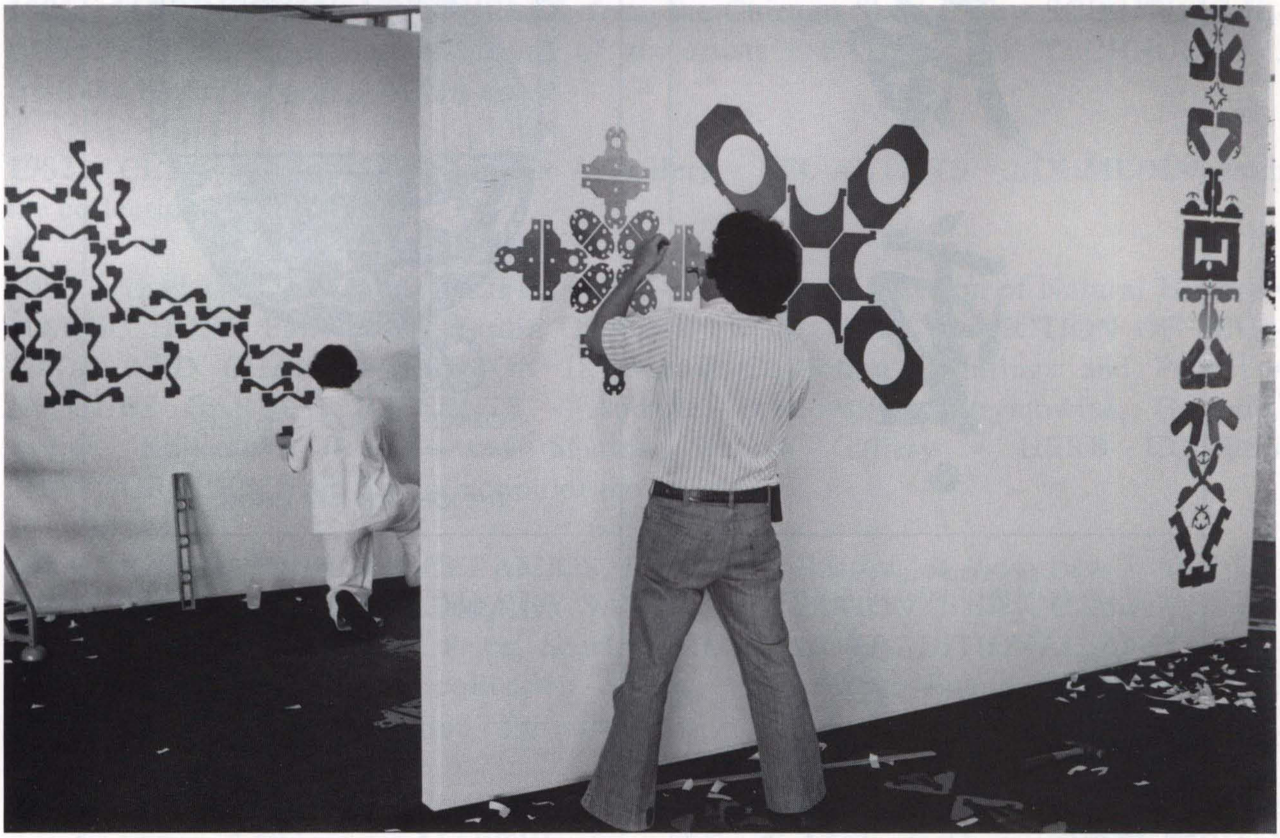
Eight Artists from the Midwest

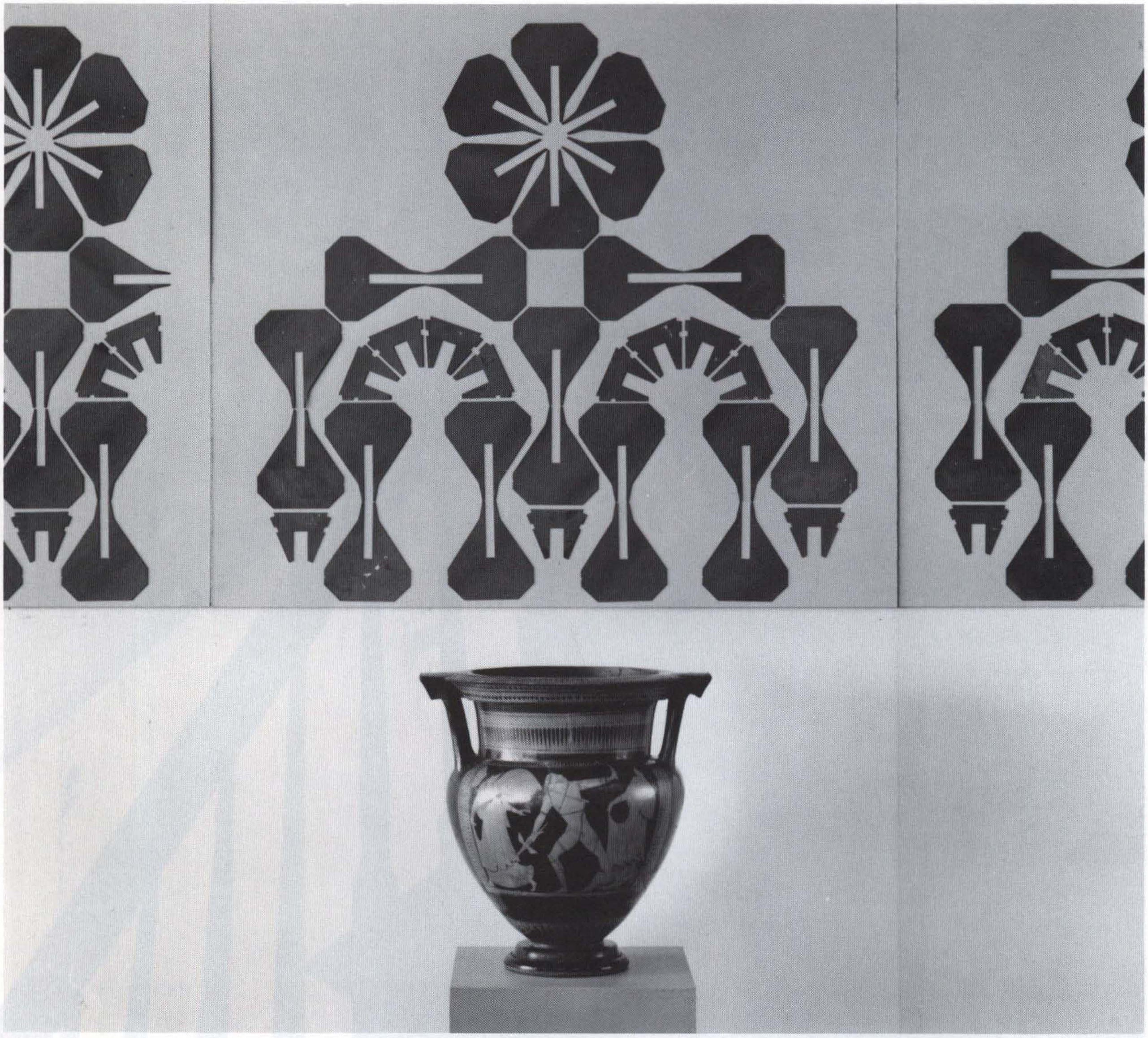
8

Fermilab, October, 1980

Precolumbian Pottery

Fermilab, January, 1980

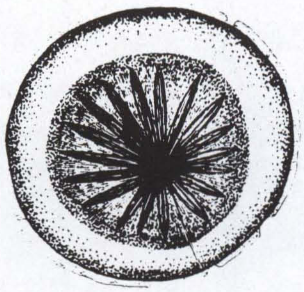




↑ *Fifth century B.C. Greek vases loaned from The Art Institute of Chicago were displayed with decorative arrangements of magnet laminations, March/April 1980.*

← *Exhibit Committee members using magnet laminations to decorate Gallery panels.*

Mazon Creek Area Fossils



Fermilab, October 1979

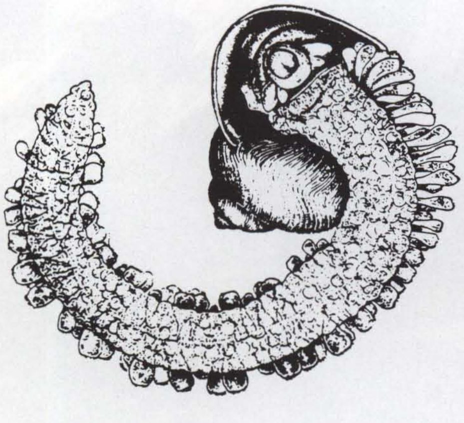
WYNN BULLOCK

Fermilab January, 1980

Greek Vases of the Fifth Century B.C.

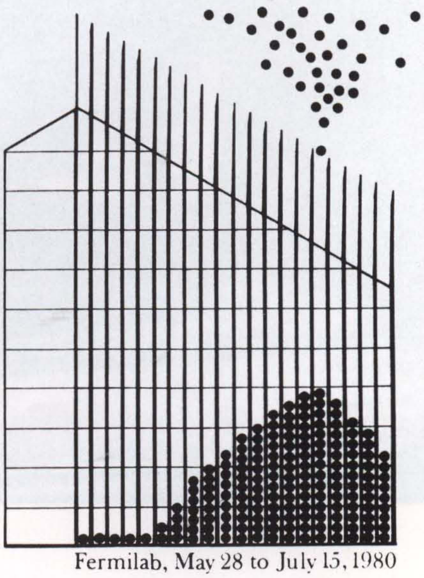
Fermilab March and April, 1980

Marine Mollusk Shells
from the Chicago Shell Club



Fermilab. April-May 1981

Memorabilia of Five Decades of Particle Physics

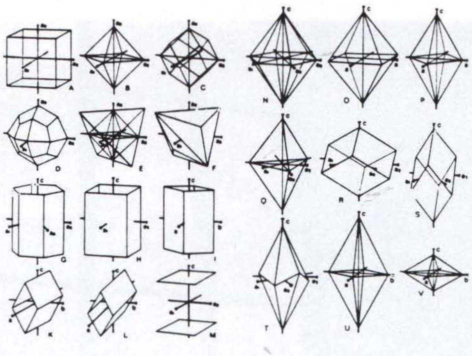


Fermilab, May 28 to July 15, 1980

↑ *The Gallery's first exhibit was a weekend display of Joseph Epstein sculpture on loan from The Museum of African Art, Washington, D.C.*

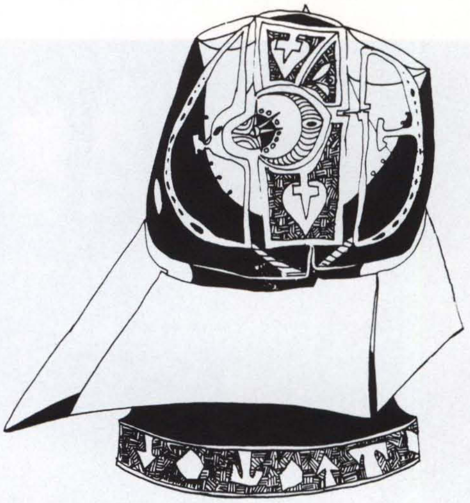
← *(Top) A collection of pre-Colombian Peruvian pottery being arranged for a January 1980 exhibit. (Bottom) One of the minerals on display in the ''Minerals from The Field Museum'' exhibit, January/February 1981.*

Minerals from the Field Museum



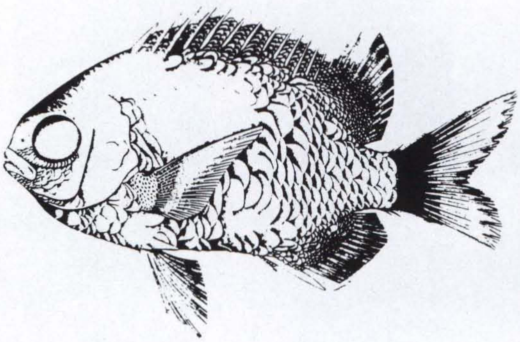
Fermilab, January and February 1981

Sculpture by
Geraldine McCullough



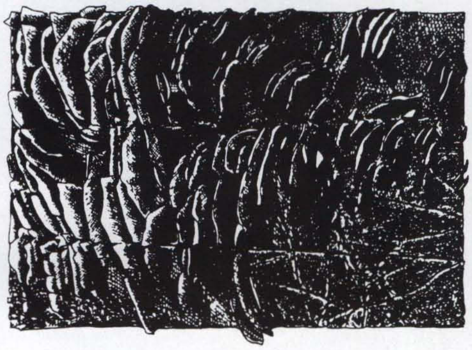
March, 1981

Scientific Illustration



Fermilab, June and July, 1981

Clay Sculpture, 1982

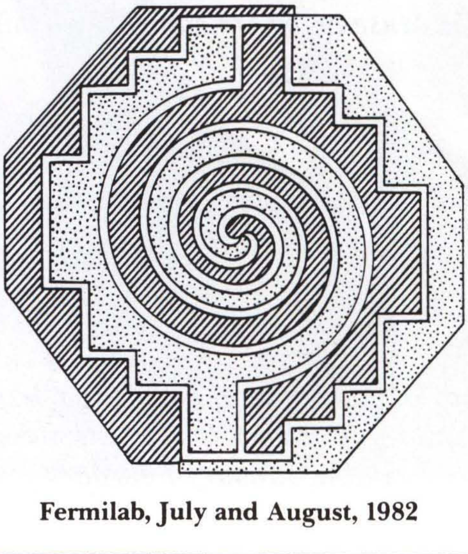


Fermilab, January and February, 1982

Twenty 19th Century Black Women

Fermilab, May 1982

Southwest Indian Pottery
800 A.D.—1977 A.D.



Fermilab, July and August, 1982

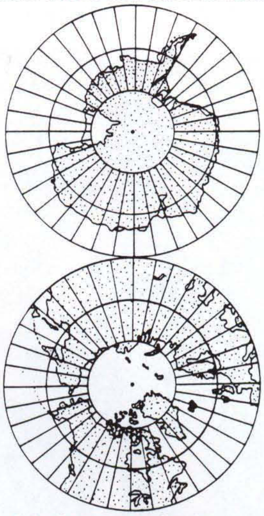
Jacques Baruch
Presents

Jiri Anderle • Albin Brunovsky
Zofia Butrymowicz • Vladimir Gazovic
Jan Krejci • Oldrich Kulhanek
Barbara Rosiak • Jan Saudek

Fermilab, September and October 1983

Eliot Porter

The Antarctic and Iceland



Fermilab, January and February 1983

New Ireland

Art, Life and Death

Fermilab, March and April, 1983

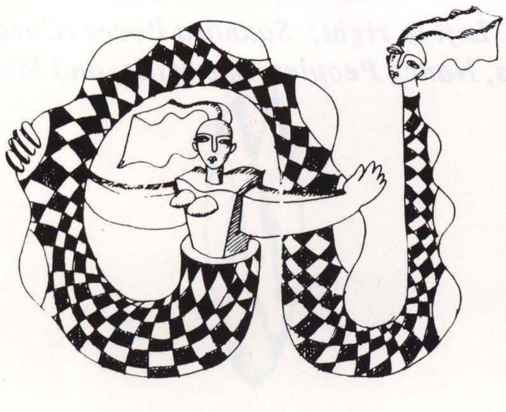
Mexican Traditional and Ceremonial Art

from the Collection of The May Weber Foundation

Fermilab, June and July, 1984

Sculpture and Stained Glass

Selected From The
Chicago Artist Coalition



Fermilab February - April 1985

The Plucked Chicken Press

Cynthia Archer and Will Petersen

Fermilab, November 1984 through January 1985

The 1989 Exhibit Committee with the Director. Left to right; Saundra Poces (Curator), Carol Denby, Leon Lederman, Angela Gonzales, Nancy Peoples, Sue Mills, and Mizuho Mishina.

Martyl

Fermilab, August and September 1985

Traditional Arts of Africa

from the Collection of The May Weber Foundation

Fermilab, June and July, 1987

Torkel Korling

From Wildflowers to Factories
50 Years in Photography

Fermilab, October 7th through November 1. 1987

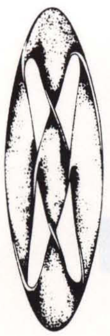
William Clift

Photography

Fermilab, January and February, 1988

Sculpture by Four Artists

Brent Collins • Robert Cumpston
David Lotton • Penn Stallard



Fermilab, February and March 1989

Ellen Carr Lederman

New Photography

Fermilab, October through November 1988

Audited Financial Statements

Fermi National Accelerator Laboratory - Universities Research Association, Inc.

September 30, 1988 and 1987

Ernst & Whinney

Appendix M. Audited Financial Statements
Fermi National Accelerator Laboratory - Universities Research Association, Inc.

Audited Financial Statements

FERMI NATIONAL ACCELERATOR LABORATORY -
UNIVERSITIES RESEARCH ASSOCIATION, INC.

September 30, 1988 and 1987

Ernst & Whinney

150 South Wacker Drive
Chicago, Illinois 60606

312/368-1800

REPORT OF INDEPENDENT AUDITORS

Board of Trustees
Universities Research Association, Inc.
Washington, D.C.

We have audited the accompanying balance sheets of Fermi National Accelerator Laboratory - Universities Research Association, Inc. as of September 30, 1988 and 1987, and the related statements of revenue and program costs and changes in fund balance, and of funded operating expenses for the years then ended. These financial statements are the responsibility of the Association's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly the financial position of Fermi National Accelerator Laboratory - Universities Research Association, Inc. at September 30, 1988 and 1987, and the results of its financial transactions for the years then ended, in conformity with generally accepted accounting principles.

Ernst & Whinney

November 28, 1988

BALANCE SHEETS

FERMI NATIONAL ACCELERATOR LABORATORY -
UNIVERSITIES RESEARCH ASSOCIATION, INC.

	September 30 1988	1987
ASSETS		
Cash	$ 222,655	$ 331,863
Prepaid expenses	79,383	77,511
Miscellaneous receivables	2,650,006	2,572,756
Due from Universities Research Association, Inc.	123,497	113,505
Inventories	22,608,530	21,680,072
Property and equipment:		
Construction in progress	35,909,014	32,910,087
Equipment and buildings	807,489,351	771,689,527
	843,398,365	804,599,614
Less allowances for depreciation	383,747,520	342,635,848
	459,650,845	461,963,766
	$485,334,916	$486,739,473
LIABILITIES AND FUND BALANCE		
Liabilities:		
Accounts payable	$ 18,584,672	$ 12,526,406
Employee compensation	9,567,304	8,888,662
Contract retentions	479,284	485,270
Deferred credits	1,080,550	1,999,442
	29,711,810	23,899,780
Fund balance	455,623,106	462,839,693
Commitments--Note B		
	$485,334,916	$486,739,473

See notes to financial statements.

STATEMENTS OF REVENUE AND PROGRAM COSTS AND CHANGES IN FUND BALANCE

FERMI NATIONAL ACCELERATOR LABORATORY - UNIVERSITIES RESEARCH ASSOCIATION, INC.

	Year Ended September 30 1988	1987
Transfers from United States Department of Energy	$188,632,338	$184,358,804
Program costs (credits):		
Funded operating expenses	151,319,949	135,888,087
Other program costs which did not require the use of contract funds:		
Provisions for depreciation	44,250,280	40,333,080
Other adjustments to property and equipment accounts which did not require the use of contract funds	270,615	(848,570)
TOTAL PROGRAM COSTS	195,840,844	175,372,597
REVENUE IN EXCESS OF (LESS THAN) PROGRAM COSTS	(7,208,506)	8,986,207
Net transfers to other federal agencies	(8,081)	(12,147)
Fund balance at beginning of year	462,839,693	453,865,633
FUND BALANCE AT END OF YEAR	$455,623,106	$462,839,693

See notes to financial statements.

STATEMENTS OF FUNDED OPERATING EXPENSES

FERMI NATIONAL ACCELERATOR LABORATORY -
UNIVERSITIES RESEARCH ASSOCIATION, INC.

		Year Ended September 30	
		1988	1987
Salaries, wages and related costs		$ 85,090,842	$ 79,342,866
Materials and supplies		27,255,561	20,627,799
Subcontracts and purchased services		18,695,174	13,641,513
Electric power		16,459,393	20,008,449
Inventory usage and adjustments		7,094,896	7,171,957
Travel, relocation and other employee expense allowances		3,037,478	2,430,942
Management allowance		1,094,100	1,015,200
Miscellaneous revenues, principally from universities and cafeteria and housing operations		(2,634,906)	(2,435,910)
	TOTAL	156,092,538	141,802,816
Less portion of operating expenses redistributed to other fund types		4,772,589	5,914,729
	TOTAL	$151,319,949	$135,888,087

See notes to financial statements.

NOTES TO FINANCIAL STATEMENTS

FERMI NATIONAL ACCELERATOR LABORATORY -
UNIVERSITIES RESEARCH ASSOCIATION, INC.

September 30, 1988 and 1987

NOTE A--ACCOUNTING ENTITY AND SUMMARY OF ACCOUNTING POLICIES

Under the terms of a contract between Universities Research Association, Inc. (the Association) and the United States Department of Energy (DOE), the Association has undertaken to organize, design, construct and operate Fermi National Accelerator Laboratory (Fermilab) at Batavia, Illinois. These financial statements include the accounts pertaining to Fermilab which are maintained at the Association's office at Batavia, Illinois. Other financial transactions, which are recorded in the corporate accounts of the Association maintained in its Washington, D.C. office, are reported separately and are not reflected herein.

Property and Equipment: The contract provides that assets acquired to carry out the contract become the property of the United States Government, although Fermilab has their use and custody. Certain equipment and buildings at the construction site have been furnished directly by the Government and have been included in the financial statements at cost less allowances for depreciation. The balance sheets set forth such assets, related liabilities and equity of the funding agency, the DOE, in Fermilab.

Property and equipment are stated on the basis of cost. Provisions for depreciation of equipment and buildings are computed principally on the straight-line method. Fermilab follows the DOE policy of capitalizing all equipment items costing more than $5,000.

Inventories: Inventories consist principally of replacement and repair parts and supplies which are valued at cost using the first-in, first-out (FIFO) method.

Vacation Pay: Vacation pay is accrued as it is earned by the employees.

NOTE B--CONTRACTUAL COST CEILINGS

The contract between the Association and the DOE establishes the total costs and commitments which may be incurred by Fermilab during the contract period (obligational authority). During the term of the contract, the DOE issues financial plans which establish annual cost ceilings for the various programs conducted by the Laboratory. Fermilab has exceeded the operating cost ceiling by approximately $1,620,000 for the year ended September 30, 1988. However, total obligational authority under the terms of the contract had not been exceeded at September 30, 1988.

NOTES TO FINANCIAL STATEMENTS--Continued

FERMI NATIONAL ACCELERATOR LABORATORY -
UNIVERSITIES RESEARCH ASSOCIATION, INC.

NOTE C--COMMITMENTS AND CONTINGENCIES

At September 30, 1988, Fermilab had issued purchase orders and other contracts for the procurement of goods and services. The noncancelable portion of these commitments pertain to various activities as follows:

Inventories	$ 3,904,000
Equipment	6,835,000
Plant	2,149,000
Operations	6,448,000
	$19,336,000

The Laboratory is involved in certain legal actions for which liability insurance exists. Management, after taking into consideration legal counsel's evaluation of such action and existing insurance coverage, is of the opinion that the outcome thereof will not have a material adverse effect on the financial position of the Laboratory.

NOTE D--RECLASSIFICATIONS

Certain 1987 amounts have been reclassified to conform with the 1988 financial statement presentation.


COMPUTER FACILITY

Acknowledgments

Heartfelt thanks to the many authors who contributed to the *Fermilab 1988 Annual Report*, and who, though they must have seen it coming, never ran and hid.

The chronology beginning on page 143 is the result of the tireless efforts of Adrienne Kolb, who works with Lillian Hoddeson on the Fermilab History Project. This particular chronology aims to hit the high points of Fermilab's previous ten years and makes no claim to thoroughness; that is best left to history in general and the History Project in particular.

Stephanie Novack of the Fermilab Publications Office provided indefatigable assistance in preparing this report.

Our gratitude, as always, to Universities Research Association, Inc., for their support.

Design and Art

• Angela Gonzales: illustrations on the outside front cover, pages ii, vii, the frontispiece, pages 9, 12, 13, 14, 16 (2), 47 (2), 50 (2), 59, 73, 77, 104, 118, 198, 200, 217, 219, 237, 241, 244, 245, 247, 259, the outside back cover, the vignettes that appear throughout, and the overall design of the book.

Photography Credits

• Reidar Hahn: pages 2, 3, 6, 24, 26, 32, 35, 36, 39, 43, 44, 48, 51, 52, 56, 60, 62, 65, 66, 80, 88, 91, 92 (top), 103, 110, 112, 124, 139, 142, 169, 170, 213, 229, 231 (top), 233, 234, and 246.

• Anthony Frelo: pages 163, 164, 165, and 166.

• Richard Fenner: pages 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 157, 158, 159, 160, 161, 162, and 168.

• Brian Eaves: pages 10, 114, 226.

• Ellen Lederman: the inside front cover, pages 22, 102, 123, 177, 195, 199, 211, 224, 231 (bottom), 240, and the inside back cover.

• Olivia Gonzales: pages 8, 25, 31, 55, 68, 71, 72, 84, 95, 117, 180, 207, 216, and 222.

Other

• Pages 21 and 54: Event as recorded by the Collider Detector at Fermilab.

• Pages 48, 51, and 234: Sculpture by Brent Collins.

• Page 74: Courtesy of Ralph Leighton, California Institute of Technology.

• Page 96: From *Struwwelpeter*, a 19th-century children's book by Heinrich Hoffmann.

• Page 101: Computer rendering of *Tractricious*, designed by Robert R. Wilson, here deconstructed by John Paulk and his faithful Macintosh. *Tractricious* itself, pictured on pages 10, 56, 66, and 226, stands in front of Fermilab's Industrial Complex.

R.F.