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Atom smasher may hold key to creation

CHICAGO (AP) — Scientists say they cannot study subatomic particles in finer detail than had verse began about 15 billion years ago with a

New atom-smasher produces record levels of energy

The New York Times

The world's most powerful at-

Fermilab takes lead with test of atom smasher

CHICAGO (AP) — Scientists say they cannot predict the practical

Fermi atom smasher creates record force

CHICAGO (AP) — The wor

Atom smasher pummels particles with record force, scientists report

CHICAGO (AP) — The world's smasher mic part record f

Lederman said.

A device called a detector — 25

U.S. atom smasher reaches record leve

CHICAGO — The world's mos owerful atom smasher yesterda rew subatomic particles into eac ther with record force, thrusting th nited States to the forefront o

Insight

Proton-Antiproton Collisions at Fermilab

Machine to probe quirks of quarks

By BOYCE RENSBERGER

The Washington Post

"It's all very profound.

Illinois Atom Smasher Gives Record-Breaking Performance

By LEE DEMBART, *Times Staff Writer*

Physicists at the Fermi National of fiddling with the machine to

A Triumph At Fermilab

52 CHICAGO SUN-TIMES, Monday, October 14, 1985

Big atom smasher is a bigger success

Atom smashers set world record

CHICAGO (AP) — Scientists say they cannot predict the practical way of controlling the atom Modern chemistry, transistors

Atom Machine a 'Smashing Success'

The Washington Post

Washington — Physicists at the Fermi National Accelerator Laboratory have succeeded Sunday in operating a newly upgraded $500-million atom smasher that is the world's most powerful device of its kind.

the ultimate nature of matter anyone has ever gone before.

The success, which was met

Nature's laws worth graspin

Biggest bang ever

Fermilab high-energy experiment a smash

By Tom Schlueter

Coincidentally, the historic collision oc-

the antiproton source, which took 300 m

Atom smasher rams particles at record leve

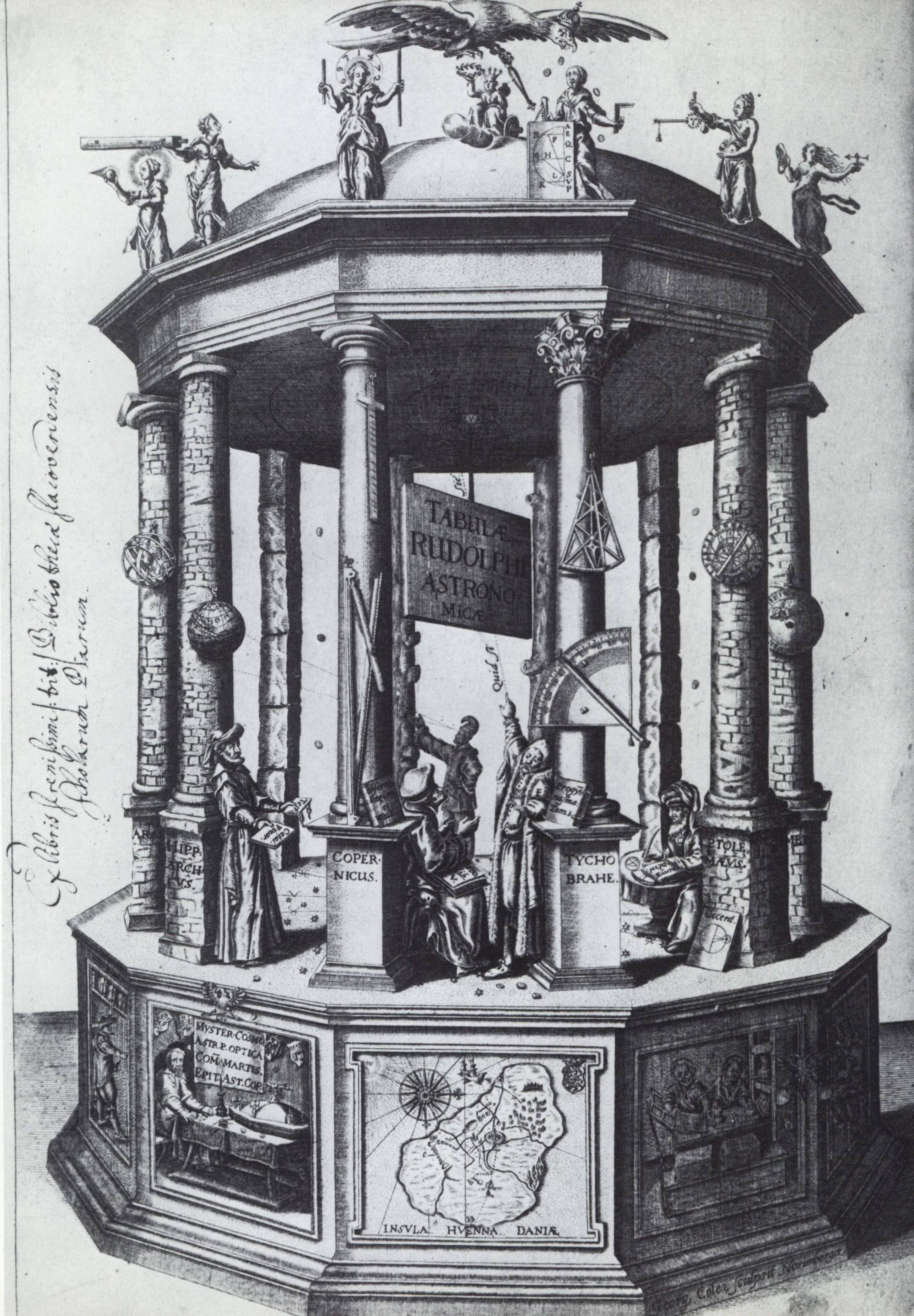
CHICAGO (AP) — Scientists say they cannot predict the pract-

consortium of researchers from a dozen European countries

tron volts, the lab announced. A flashlight battery produces

ogy of the 20th century," he "When we were trying to u

Fermilab 1985



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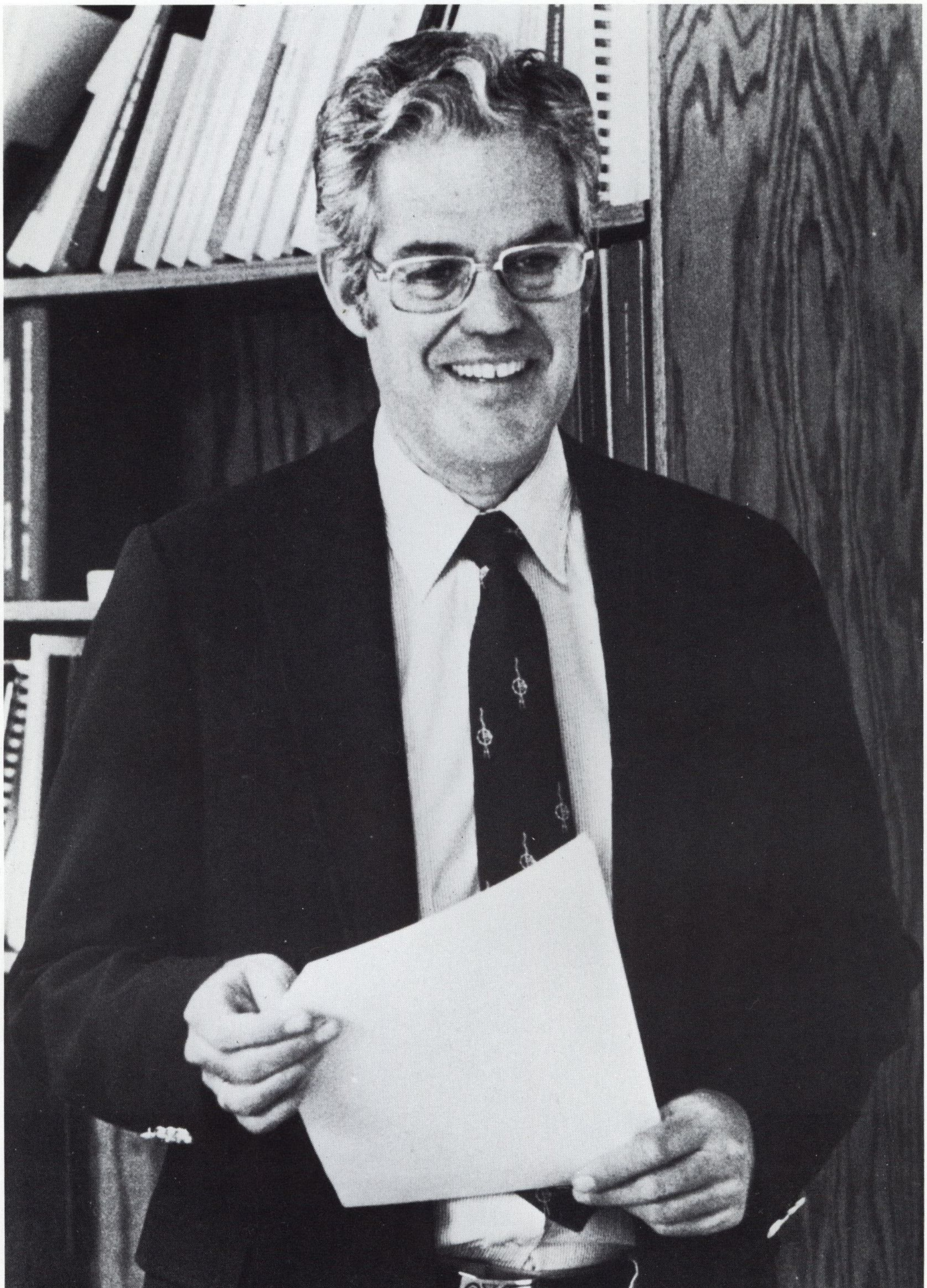
INSULA HUENNA DANIAE

Fermilab 1985

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



Edward A. Knapp, elected in 1985 as President, Universities Research Association, Inc.

UNIVERSITIES RESEARCH ASSOCIATION

1111 19th Street, N.W. Suite 400 Washington, D.C. 20036

(202) 293-1382

January 8, 1986

Dr. Leon Lederman
Fermilab, Director's Office
P.O. Box 500
Batavia, IL 60510

Dear Dr. Lederman,

This year has been a time of tremendous accomplishment and project completion for Fermilab. With the dedication of the Tevatron collider and the recording of the first proton-antiproton collisions in the CDF detector, a new era in American high-energy physics has been inaugurated, one which will lead to a deeper understanding of the fundamental interactions and constituents of nature, and ultimately, a better life for all of us. The Universities Research Association is proud to be the operating contractor for the Department of Energy for this vital and productive enterprise.

Fermilab is operated by the URA consortium to insure for the Department university involvement and control of the research programs at this major national facility. High-energy physics is a university-based science, and it has evolved into a field which requires substantial personal sacrifice in terms of travel, disruption of life, and general inconvenience for its participants. The URA will continue to emphasize the university nature of this scientific enterprise and work with the Department of Energy to optimize the American investment in this field.

It is clear that Fermilab has a bright future ahead, with the commissioning of TeV I and II, and the development of the detectors and experimental techniques necessary to exploit these major new facilities. Fermilab is also intimately involved in the future of high-energy physics on another front. By operating the world's first superconducting high-energy proton accelerator, it has shown the way to the next generation of instrumentation for this field. Fermilab is also an active participant in the R&D studies directed toward the next major accelerator needed by the field. Again, the university-based nature of the field is emphasized through this contractual arrangement. The effort to pool technical development by participants from the entire high-energy field and industry has been extremely successful over the past year, and Fermilab has been a major contributor and participant in this cooperative venture for American Science.

While the future is never completely clear, I see an era of great promise and productivity ahead for high-energy physics. The URA will continue to emphasize the university nature of this science and work with the Department of Energy to keep this most fundamental of the scientific fields productive and vital.

Sincerely,

Edward Knapp

Edward Knapp
President, URA

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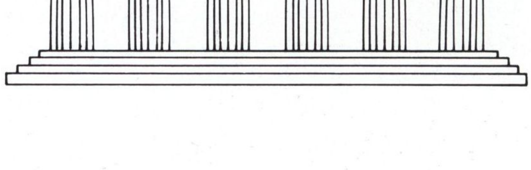

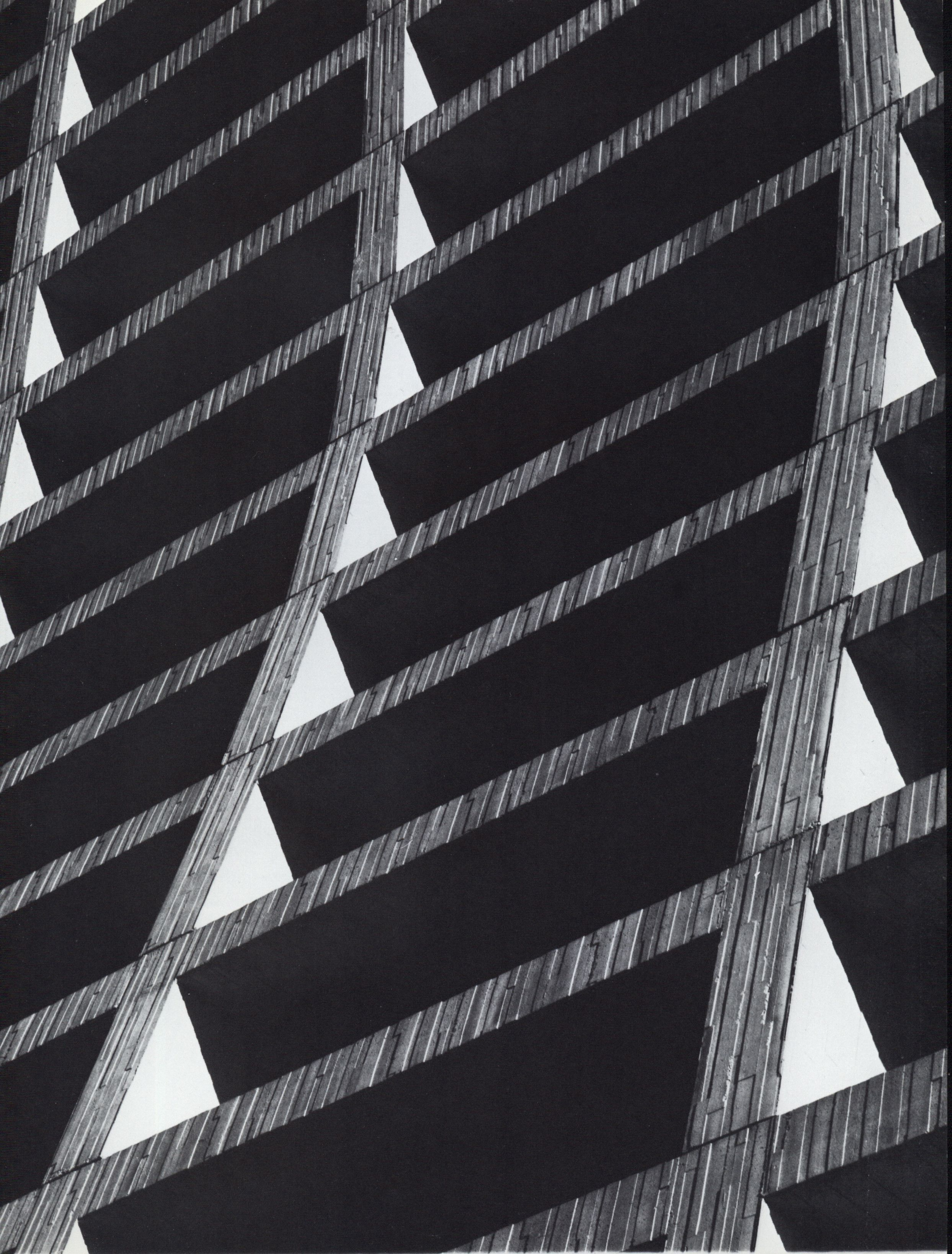

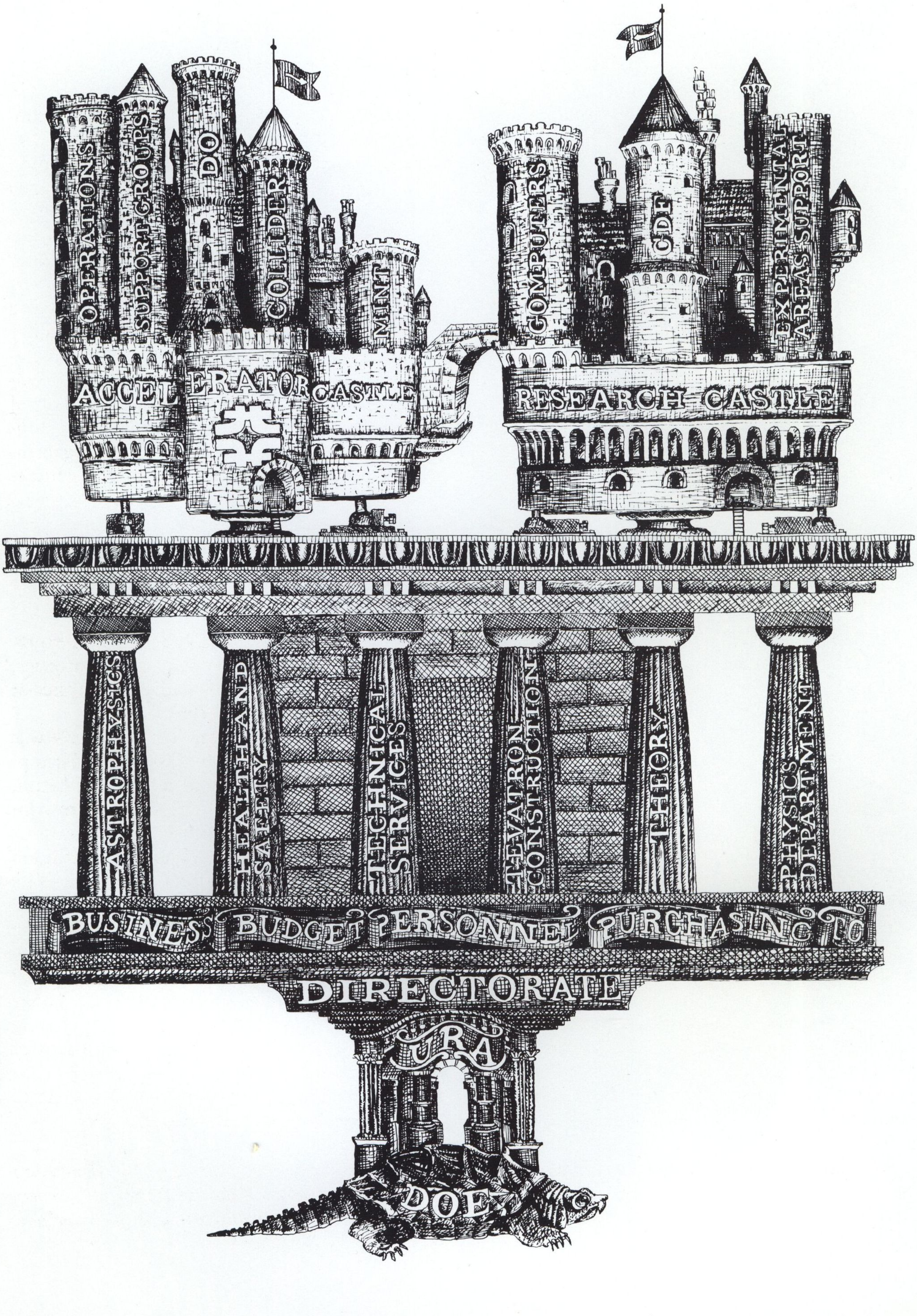

OPERATIONS
SUPPORT GROUPS
DO
COLLIDER
MINT
ACCELERATOR CASTLE
COMPUTERS
CDF
EXPERIMENTAL AREAS SUPPORT
RESEARCH CASTLE
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HEALTH AND SAFETY
TECHNICAL SERVICES
TEVATRON CONSTRUCTION
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TO
DIRECTORATE
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I. The State of the Laboratory

How to characterize the year 1985 at Fermilab? The highpoints:

1. A rather successful run of the fixed-target program which began moving in January, was at full speed by April, and was terminated in August;
2. A commissioning test of the antiproton ($\bar{p}$) collider which emerged from parasitic operation on September 1 and terminated spectacularly with collisions being observed by the Collider Detector at Fermilab (CDF) on October 16. This story is told, *Rashomon*-like, from three different vantage points: The Accelerator, the Antiproton Source, and the CDF detector;
3. The subsequent shutdown in order to build the overpass at B0 and the collision hall at D0, the last phase of the TEVATRON construction program.

In the following report we will supply some details, we will try to expose the foundations and structures which make high-points possible. For the sake of clarity, we refer to the accompanying True Organizational Chart (TOC) of the Laboratory as the guide to this *Report*. We see the two Divisions, veritable castles of activity, upheld by columns resting on a classical stylobate. The lower frieze celebrates the activities which support the columns. At the core, the symbol of the universal support, the hard-shell tortoise, ageless, implacable. It is good to have a True Organizational Chart of Fermilab in matching architecture.

The Accelerator Division Castle

The 1985 Run

In 1984, the TEVATRON ran 18 weeks at 400 GeV and 10 weeks at 800 GeV. In 1985, the machine came on for physics in January, the coldest month, as it turned out, in recorded history in northern Illinois. Rich Orr, Accelerator Division leader, begins the Accelerator story:

This cold probably contributed to two major transformer failures which kept the accelerators off for almost the entire month. After repairs, the run for fixed-target physics started in earnest in February. The requirements on proton intensity, beam splitting, and on spill diversity increased steadily as more and more experiments came on line. By April, we were delivering up to 1.5×10^{13} protons to 12 experiments. By August 29, the last day of the run, some 1.3×10^{18} protons had been delivered. We had 35 weeks of scheduled running which represents a satisfactory improvement in duration and in quality over the 1984 run. Of course this included machine study time, maintenance and repairs, etc. However, some 3000 hours were available for physics at an average efficiency of 70%.

The beam spill from the TEVATRON was exceptional. During the 23-second flattop, slow-spill users received 20 seconds of beam, and fast-spill (neutrino) recipients were sent three pulses of 1- to 2-milliseconds duration.

The overall machine reliability continued to improve over the course of the run. The entire complex, from ion source through the Switchyard, delivered beam for 60-80% of the scheduled time. Proton intensity began at approximately 10^{12} protons per pulse (ppp) and rose steadily to a peak of 1.5×10^{13}ppp. These numbers are respectable for a machine in its second year, but both reliability and intensity remain a major concern.

The physics experiments that ran in 1985 are discussed later in this *Report*.

"So, during the first six-thousand years of the world's history, from the time of the pagoda of Hindustan to that of the cathedral of Cologne, architecture has recorded the great ideas of the human race . . . every human thought has its page in that vast book . . . 'til Gutenberg's time, architecture was the principal, universal form of writing." (The Bellringer of Notre Dame, *Victor Hugo*)

Original Main Ring tunnel sections, buried in 1970-71, replaced this year with larger sections to accommodate the B0 overpass currently under construction.

Shutdown Highlights

The shutdown was scheduled to permit the construction of colliding-beams experimental areas at straight sections D0 and C0 as well as an overpass at B0. This construction required the removal of more than 8% of the Main Ring and TEVATRON (including the magnets, cryogenics, water systems, cables, cable tray, etc.). When the Main Ring is restored, it will arch more than 21 feet over the center of the CDF detector.

All of the accelerators are receiving major facelifts. The Linac is having some of its drift-tube assemblies repaired and aligned. The Booster is getting a modern control system, new beam monitors, and a smoother beam tube. A new beam is being constructed from the Booster to the Debuncher as a commissioning aid.

The existence of two overpasses in the Main Ring has mandated the construction of a new 8-GeV beamline to properly match the Booster and Main Ring.

The Main Ring is getting magnet-to-magnet bellows smoothers to reduce its impedance and new fixtures to facilitate alignment.

The TEVATRON is also receiving some attention. About 25 dipoles which have inferior quench currents are being replaced by better magnets. In addition, some of the spool pieces are being replaced because their correction magnets are no longer working. All the guide-field power supply transformers are being replaced with a transformer of a type less likely to fail in the mode that caused much of the Accelerator downtime in January. New quench-protection heater-firing units will be installed to reduce the likelihood of spurious quenches.

The Switchyard will have new beam-position monitors to facilitate beam set-up and changes in the split ratios. The beam to the Meson Lab will be changed slightly in order to reduce beam losses when running at energies above 800 GeV.

These changes will make the Accelerator start-up more difficult than usual — but should lead to improved performance in the long run.

The Accelerator as a Sink for Refrigeration: Central Helium Liquefier

A secret weapon of Fermilab, and as essential to its operation as electricity, has been our Central Helium Liquefier (CHL). We tell visitors this plant has more than doubled the world's capacity to liquefy helium. Once upon a time there were grave concerns about the reliability of this huge complex. No longer! We make up for years of neglect by this rather detailed report from CHL proprietor Ron Walker:

The Fermilab Central Helium Liquefier is an industrial-type complex installed in a 70-meter by 15-meter building. The complex is located 183 meters from the Accelerator ring and is connected to the ring by a liquid-nitrogen-shielded transfer line which transports liquid helium and nitrogen from the CHL, around the 6.4-kilometer ring, and back to the CHL.

The primary function of the CHL is to supply liquid helium and nitrogen to the TEVATRON. This liquid is used in conjunction with 24 satellite refrigerators distributed around the Accelerator ring to provide 24 kW of refrigeration to operate the superconducting magnets in the beam tunnel. The Accelerator cannot reach full energy unless the CHL is at 80% of full capacity. Therefore, the first priority is to keep the plant as reliable as possible and, to this end, a number of improvements and additions have recently been commissioned.

A complete TEVATRON control console with a link to the Accelerator controls network (ACnet) has been installed in the CHL control room. ACnet processes many of the important parameters at the CHL. It is now possible for CHL operators to observe, log data, and plot trends in many of the ring and CHL parameters. A color printer has been added which is used to make hard copies of interesting plots and data generated by ACnet.

In May of 1984 a third main helium compressor (C-compressor) was put into operation. This machine is identical to the two original compressors (A and B) which are required to maintain sufficient flow. The third compressor was originally intended to provide flow for a nitrogen reliquefier, but a decision was made to use it as a helium compressor to provide redundancy.

C-compressor was used to test a planned upgrade in controls at the CHL using the Texas Instruments PM550 process controller. The PM550 has been reliable and effective, and there has been no downtime associated with it during 4000 hours of operation. It has provision for a link to ACnet which will result in more complete use of ACnet for analysis and monitoring of CHL functions. The PM550 has analog input and output capacity and contains menu-driven process loop control programs. It performs various scaling, conversions to engineering units, and special calculations. Data, alarms, and status messages generated by the PM550 are displayed on a dedicated color video screen. The PM550 is not dependent on ACnet, and the CHL can operate with ACnet down.

The CHL crew spent the latter part of 1985 beginning an extensive rework of the plant controls. The existing controls on compressors A and B, the cold box, and the cryogenic distribution were replaced by PM550 units. The new controls are expected to generate fewer trips, improve communications with ACnet, and provide the operators with more information on process variables.

The effectiveness of the CHL and the refrigeration system in general has been improved significantly by installing a liquid-helium pump to boost the flow in the ring transfer line by pumping liquid from the liquid-helium dewars. The liquid-helium pump currently operating at the CHL is an early model of a satellite expander that has been converted to a single-acting pump. A crank mechanism manufactured by CVI Incorporated is used to drive a vertical shaft that is sealed by a Teflon bellows. The stainless-steel pump piston has four compression rings which are made of carbon-filled Teflon. This piston runs in a stainless-steel cylinder.

The use of a liquid pump and dewar as an additional supply and backup is a very practical and useful improvement. The ability to satisfy large, short-term demands has reduced the time required for cooldown of magnet strings and quench recovery. The amount of Accelerator downtime due to the CHL has diminished dramatically since the pump has been on line.

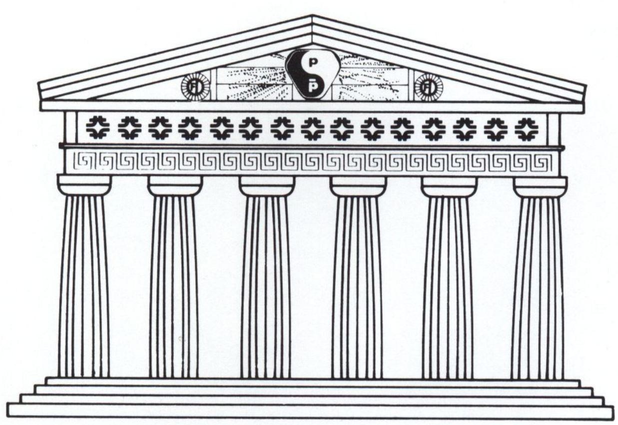
A major addition to the complex has been a 100-ton-per-day nitrogen reliquefier which is designed to supply 90% of the liquid-nitrogen requirements of the TEVATRON refrigeration system. The plant is expected to save enough in liquid nitrogen costs to pay for the equipment in a three-year period. The cost of liquid nitrogen is reduced by approximately 50%. Furthermore, the operating reliability is increased by having a larger total supply of liquid nitrogen available. To date, the nitrogen reliquefier has provided liquid nitrogen for the TEVATRON for approximately 2000 hours.

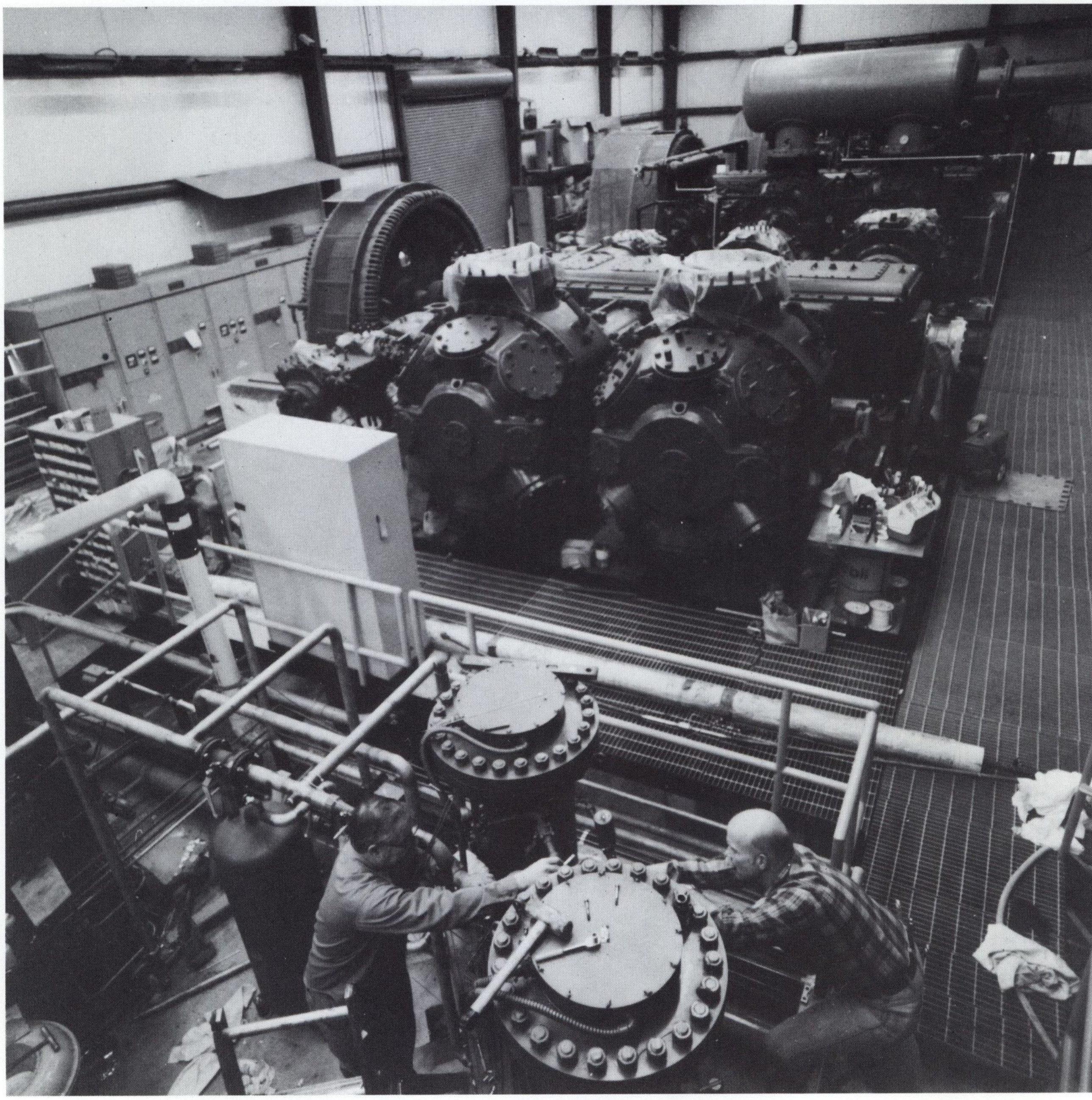
Plans are being made to install a second helium cold box and a fourth main helium compressor in a new building addition. A large effort is underway to modify the existing equipment so that the new additions can be turned on without extensive downtime at a future date. These efforts include the design and construction of a new cryogenic distribution box, modification of the compressor piping to provide isolation for the new cold box and compressor, required improvements and additions to various cryogenic transfer lines, and the construction of a second liquid-helium pump. The second pump will incorporate significant improvements and will be used to further development of pump technology at Fermilab.

The reciprocating compressors, although they are very old, have given reliable service. With three compressors available, one compressor can be used as a reserve. This has provided sufficient backup, with the result that the compressors have caused very little downtime, except for the one water leak that occured in April 1985. The seriousness of a major water leak was well demonstrated, and careful monitoring to eliminate the possibility of water leaks has been assigned high priority.

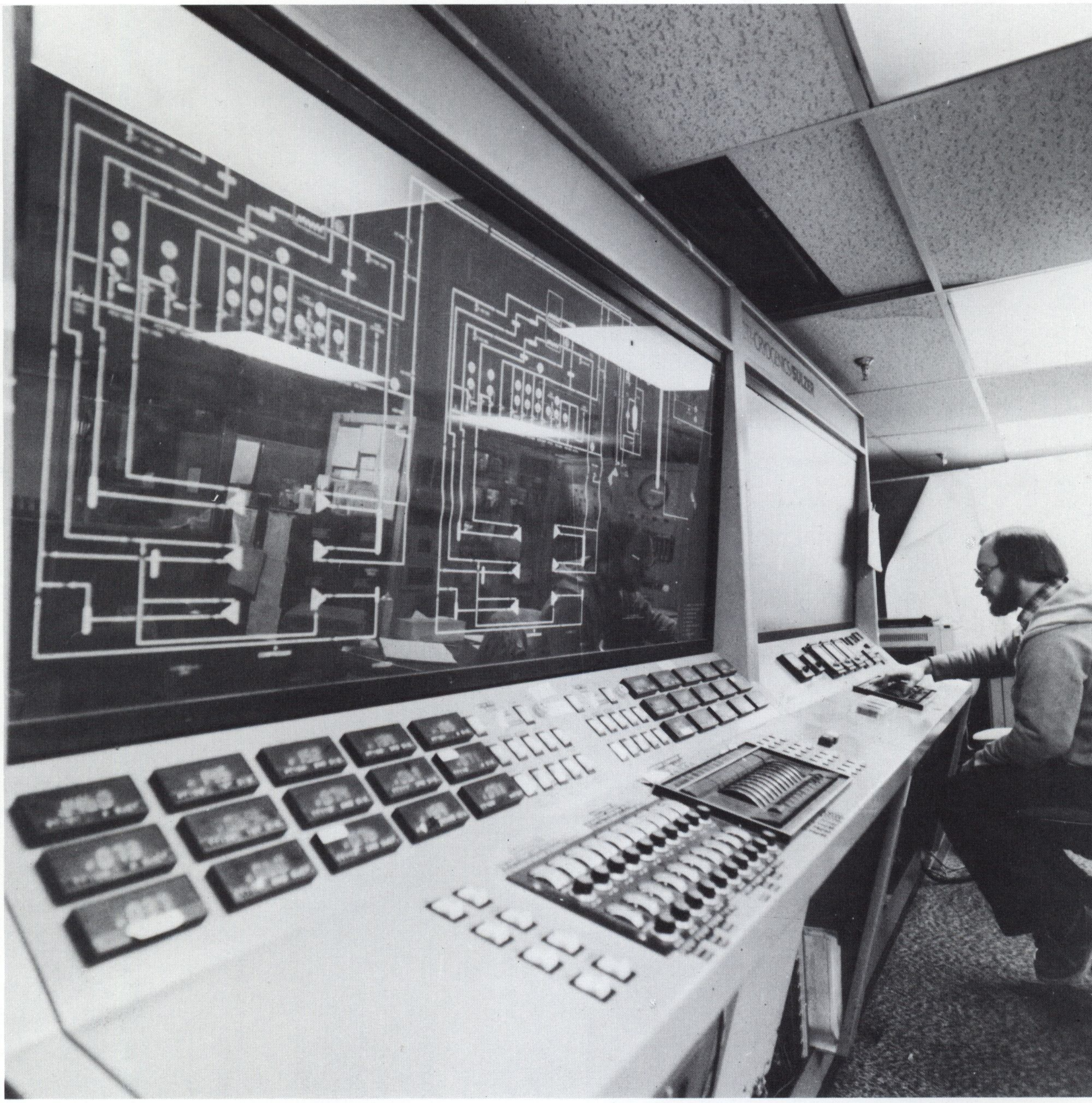
The capacity of the CHL is well matched to the requirements of the Accelerator, and the combined operation of the satellite refrigerators and the CHL has become routine and reliable.

The CHL has logged a total of 21,000 hours of operation from April 1980 to October 1985, with a total of 560 hours of unscheduled downtime. Operating efficiency is defined as the ratio of *successful* operating time to the *scheduled* operating time. With this definition, the lifetime operating efficiency of the CHL is 97.3%. Due to improvements in crew training, increasing redundancy, and the use of the liquid-helium pump, the CHL logged only three hours of downtime in the last four and one-half months of operation. This represents an operating efficiency of 99.9% for the last 137 days of operation.





George Athanasiou (left) and Reid Rihel at work on a helium dryer inside CHL.



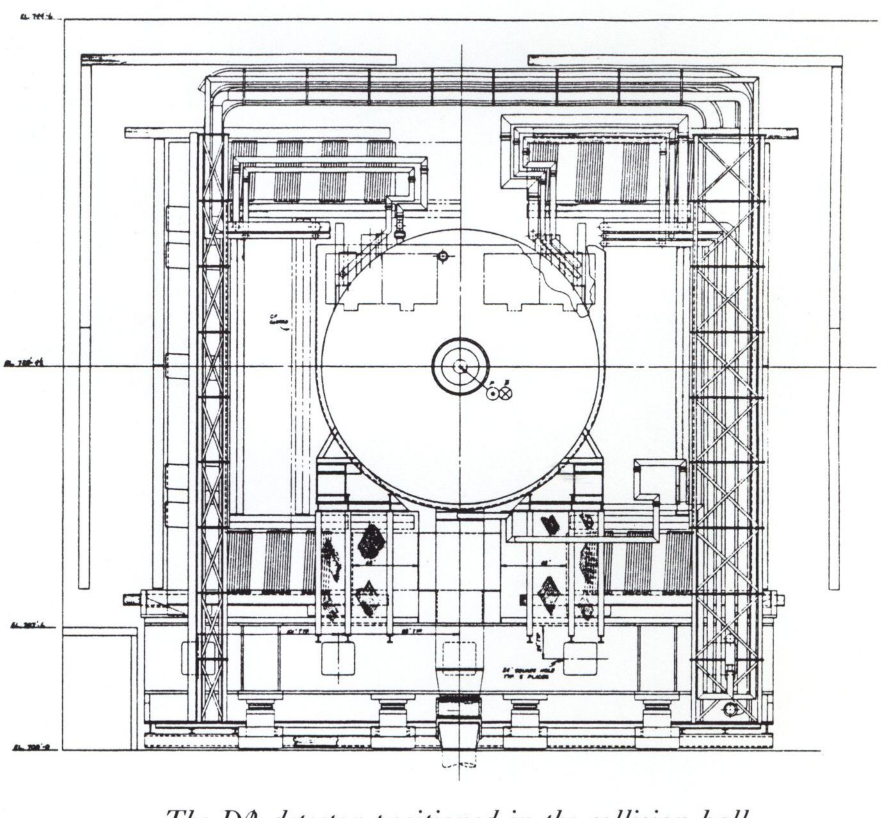
Rick Bossert at the CHL control panel.

The Accelerator as Host to the DØ Collider Detector

A scanning of 1983-84 *Annual Reports* indicates that we need to briefly review the history of DØ. The original (1979) proposal for the Energy Saver envisioned one of our six long straight sections (B0) as available for the observation of proton-antiproton collisions. Each of the others had a crucial function which would inhibit the installation of a major detector. Almost as an afterthought, it was noted that D-sector contained the apparatus for extracting beam for the fixed-target program and, when operating in the collider mode, these devices could in principle be removed and a serious detector rolled in.

In 1982, the Laboratory and its advisors determined that some effort should be made to broaden the Collider program and proposals were called for the D0 straight section. Studies carried out by the Accelerator Division had determined that the changeover at D0 would not be excessively troublesome. The initial philosophy was to encourage a very inexpensive yet ingenious detector that could be changed after a few runs. The resulting proposals were deemed unacceptable by the 1982 Physics Advisory Committee (PAC) and the Laboratory was encouraged by them, by the Department of Energy (DOE), and by the High Energy Physics Advisory Committee (HEPAP), to call for a major detector, designed to be complementary to CDF. By this time, the UA1 and UA2 interplay at CERN was teaching us the value of complementary observations of the complex $\bar{p}p$ collisions.

In 1983, PAC, faced with three somewhat similar proposals (P-714/P-728, P-724, and P-726) took a very unusual step. They rejected all three proposals but gave a blind acceptance to a detector that would contain the best features of all three proposals! The features stressed were those that were complementary to CDF. They further suggested that the Director appoint a Project Head and have him submit a design to the PAC for its further con-



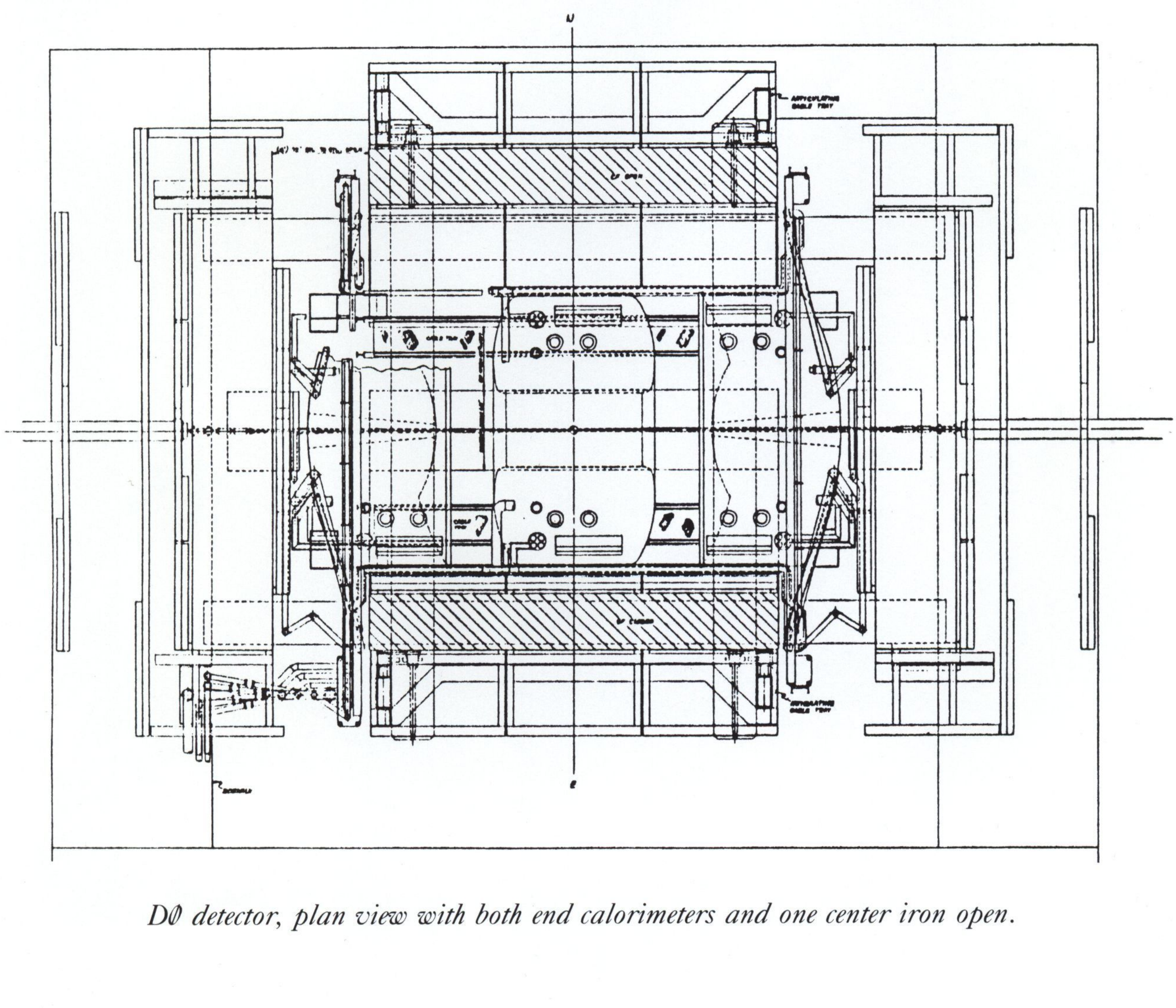
The DØ detector positioned in the collision hall.

currance. The Director followed orders, appointed Professor Paul Grannis of SUNY/ Stony Brook.

In 1985, after the requisite number of internal and DOE reviews, the DØ project is "go." It has been nestled in the Accelerator Division, the objective being to give that division some more intimate familiarity with major detector technology and to bring more physicists into contact with the Accelerator. The co-leaders are Paul Grannis and Peter Koehler, who, as Head of the Experimental Support Department, also looks after the smaller collider experiments (E-710, E-735, E-713).

Paul Grannis, the scientific spokesman for the DØ experiment, reports:

The DØ project was given formal funding approval early in 1985. Much of the effort since then has gone into refinement of the design of the experiment, guided by a variety of research and development activities. The experiment has been conceived with the knowledge gained from the CERN $\bar{p}p$ collider. It has placed particular emphasis upon the measurement of three fundamental aspects of very-high-energy collisions: jets, leptons, and missing transverse energy. The emergence of jets at large transverse momenta as a more fundamental entity than the collection of hadrons which comprise them gives a new simplicity to hadron collisions. They are interpreted as being the realizations of the basic hadron constituents — quarks and gluons. Identification of leptons (electrons and muons) is essential for discovering many of the new massive particles which may lurk in TeV I's energy domain. Most of these new states should have distinctive decay modes involving leptons. These leptonic modes allow more sensitive searches because they are much freer from



DØ detector, plan view with both end calorimeters and one center iron open.

background than are the hadronic decays. The missing transverse energy measurement allows one to infer the presence of neutrinos (or other non-interacting particles).

An example of the interplay of these signatures is found in the current hunt for the top quark through the decay $W \rightarrow t\bar{b}$; ($\bar{b}$ = jet 1; $t \rightarrow eb\nu$ = e + (jet 2) + (missing energy). The final products of two jets, electron and missing energy should sum to the parent W mass, while jet 2, electron and missing energy sum to the top quark mass.

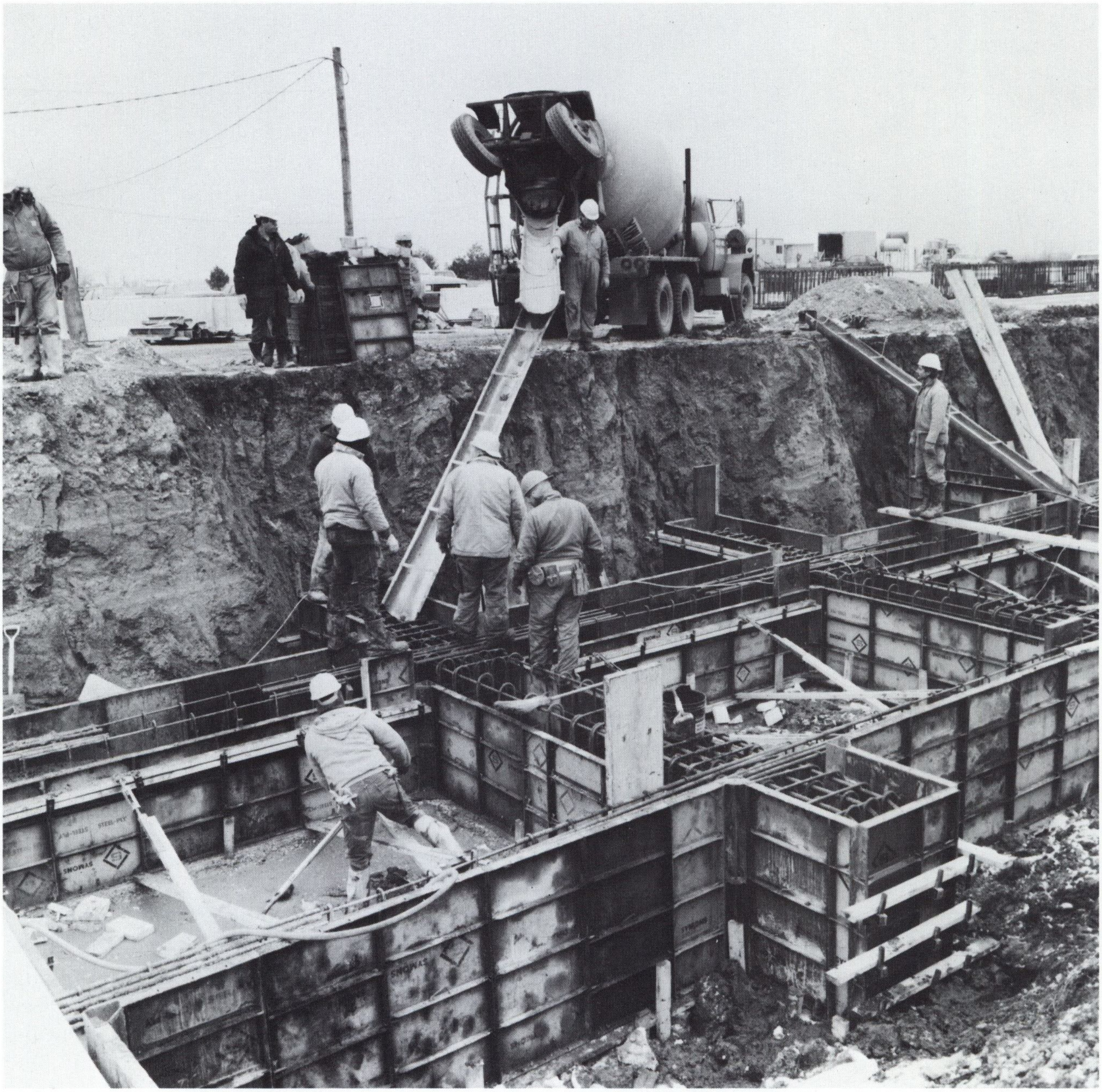
The DØ detector stresses the use of calorimeters to measure the energy of all hadrons, electrons, and photons. This energy measurement is done on a unified basis for all particles and with a precision exceeding that achievable from magnetic analysis for high-energy particles. The calorimeters absorb the particle energies in thin uranium or copper plates interspersed with liquid-argon gaps for energy sampling. This combination was chosen for its uniform response to electromagnetic and hadronic energy deposits, its radiation hardness, its ease of calibration, and the possibility that the readout can be finely subdivided. In order that the calorimetry have no gaps in coverage and remain relatively compact, the detector design has no central magnetic field. Missing transverse energy measurement is made with the observed calorimeter energy and position information, coupled with knowledge of the initial energy and momentum brought into the collision.

Lepton measurements are realized several ways. In combination with the traditional role of providing particle track angles and positions, the central detector system inside the calorimeters enhances electron identification. Three transition-radiation detector shells flag the passage of electrons by detecting low-energy x-rays emitted from close-spaced foils of polypropylene. The outer layer of chambers measures the amount of ionization so as to distinguish electrons from conversion pairs. Muons, the most penetrating of observable particles, are identified by their ability to pass through the full depth of calorimetry and surrounding shells of magnetized iron without significant interaction. The bending of the muon trajectory in the iron allows the measurement of their energy and sign. Altogether, 125,000 channels of electronic signals are derived from the detector elements.

Overall, the detector weighs about 5500 tons. Since its location in the Accelerator is shared with fixed-target beam extraction magnets, the DØ detector must roll on and off of the beamline, trailing its cables and services behind it. Construction of the DØ Experimental Area began in July 1985. The building includes a collision hall (65 ft × 44 ft × 44 ft) separated from a somewhat larger assembly hall by a removeable concrete-block shield wall. Areas for electronics, computers, liquid-argon storage, and work space are also incorporated.

The DØ collaboration has grown to about 110 physicists from 17 institutions, including 13 university groups and 4 national laboratories (Brookhaven [BNL], Fermilab, Lawrence Berkeley Laboratory [LBL], and Saclay in France). A unique feature of the team is the recent joining of a group from CBPF, Brazil. Much of the activity in the past year has centered upon prototype R&D. Three separate beamline tests were conducted. The Saclay group, working at CERN, tested transition-radiation detector performance and demonstrated excellent electron-hadron differentiation. A test in a BNL beam measured many properties of the DØ tracking-chamber prototypes. A major study in a Fermilab beam demonstrated the feasibility of uranium-liquid argon calorimetry, confirmed the equality of electron and hadron response, and measured details of energy and position resolution. Other major prototype activities included studies of the muon chamber system in a cosmic-ray setup, a system test of parallel microprocessors for data acquisition and event filtering, tests of prototype electronics for the calorimeters and muon chambers, and development of Monte Carlo simulations of the detector performance.

← *A geologist's puzzle, revealed by the excavation for the DØ Experimental Area.*



Concrete forming for the DØ Experimental Area.

The Experimental Support Department (ESD) within the Accelerator Division has been established to provide the centralized support for DØ (and several other smaller experiments at TeV I). Within ESD, major progress has been made on design of the support platform, iron toroids, cable handling, cryogenic services, electrical services, and calorimeter mechanical design.

The DØ experimenters, challenged and encouraged by the first success of TeV I and CDF, are working on a schedule which calls for start of installation in late 1986, first physics with a partial detector in 1988, and full assault on TeV physics in 1989.

The Accelerator as a Treatment for Cancer: the Neutron Therapy Facility (MINT)

Neutron therapy has been available to cancer patients at Fermilab since 1976. More than 1400 patients have been referred since then, and a large volume of medical research has been conducted at Fermilab using the Neutron Therapy Facility (NTF). The year 1985 marked a turning point in the operation of NTF. Deputy Director Phil Livdahl explains:

There are several reasons why neutron irradiation is particularly useful for treating cancer, and these advantages relate to the high linear energy transfer (LET) of neutrons in tissue. Neutrons typically deposit 20 to 100 times more energy in matter per unit path length than does a megavolt x-ray, and this high LET gives rise to the radiobiological properties of importance in cancer treatment. High-LET radiation is less dependent on the presence of oxygen to accomplish its cell-killing effect than are low-LET x-rays and, thus, is a more effective killer of the oxygen-deficient cells found in tumors which have grown faster than the available blood supply could accommodate. Almost all large tumors fall into this category, as do some relatively small tumors. Secondly, the type of radiation damage inflicted by a neutron on a tumor cell is less readily repaired than damage caused by a photon. This characteristic allows neutrons to be given in fewer increments than are necessary when using photons. Finally, there is less variation in radiosensitivity throughout the cell cycle with neutrons than with conventional x-rays or chemotherapy. This is especially important because relatively slow-growing tumors, such as prostate tumors, have a high percentage of cells in a resting phase at any one time. These cells often survive the damage inflicted by a treatment which effects dividing cells.

Robert R. Wilson proposed as long ago as 1947 that proton accelerators could be used to treat cancer victims. In 1974, Don Young and Miguel Awschalom were given the task of designing and building a facility for the treatment of patients at Fermilab. Financial constraints made it necessary to use the exisiting hallway parallel to the Linac rather than build a free-standing clinic on the west side of the Accelerator. The extracted beam had to be of a suitable energy to adequately treat tumors deep inside a human body while sparing the skin overlaying the tumor to some extent. In addition, a way had to be found to bring the patient to the level of the Linac. Awschalom and Young decided to build the Neutron Therapy Facility around a freight elevator which was conveniently located adjacent to tanks 4 and 5 of the 9-tank Linac. A proton beam could be diverted at this point using 58° and 32° bending magnets. (The energy of the proton beam is 66 MeV at this point. The protons strike a beryllium target housed inside a shielding wall to produce a 49-MeV neutron beam.) This system satisfied all of the requirements which existed. Awschalom remained with NTF as deputy department head, and shepherded the facility through the ensuing decade of research work.

Four people were responsible for the medical research conducted at NTF: Frank Hendrickson and Lionel Cohen were the Co-Principal Investigators, JoAnne Mansell was the Clinical Research Coordinator, and Ivan Rosenberg was the Facility's first Medical Physicist. The Neutron Therapy Facility has entered more patients into national neutron clinical trials than any other participant. Some of the trials involved randomly assigning eligible patients to receive either the best standard treatment for their cancer, or neutrons, which at the time were considered to be the experimental arm. This was done only with the patient's permission. Other studies used slightly differing doses of neutrons in order to determine the optimum dose. The National Cancer Institute (NCI) funded the operation of the facility from June 30, 1975, until October 1, 1985.

In keeping with the tradition set by the rest of the Fermilab community, NTF has achieved a number of "firsts" and "bests."

- The targetry developed here, p(66)Be(49), has become the standard for modern neutron facilities.
- NTF was the first neutron facility in the

world to plan and treat patients in an isocentric manner.

- More patients have been treated at NTF, and at a smaller cost per patient, than at any other facility in the United States.
- Our department has achieved consistently outstanding ratings for complete and accurate clinical data submission to the national headquarters group.
- We have been the major contributor to several of the national studies.
- Over the past ten years, we have lost fewer treatment days due to equipment problems than has any other U.S. facility.
- More than 50 manuscripts authored by NTF staff have been published in national and international journals.
- Most importantly, many people who had little hope of survival without neutron irradiation have been cured of their cancer.

These accomplishments do not belong to the NTF staff alone. Indeed, none of these things could have occurred without the support, encouragement, and easy accessibility of the experts available only at Fermilab.

Medical research conducted here and elsewhere over the past decade has documented that, in some types of cancer, neutrons have been proven to be more effective than alternative types of therapy and that neutron therapy is at least as effective as conventional radiotherapy in treatment of other forms of cancer. Some of the tumors which respond best to neutrons are those which are categorized as radioresistant to photons. These also tend to be tumors which are inoperable, or are those in which the surgery necessary for removal of all of the cancer would leave the patient very disfigured and/or with impaired function. Because of the size of such tumors, chemotherapy would not be curative. Although we have been unable to achieve 100% local control in any type of cancer treated here, the proportion of patients who remain cancer-free in the area treated with neutrons is higher than would be expected if these patients had standard treatment. Only patients who have cancers of such a type, size, and extent that neutron irradiation is believed to be appropriate for them are accepted for therapy.

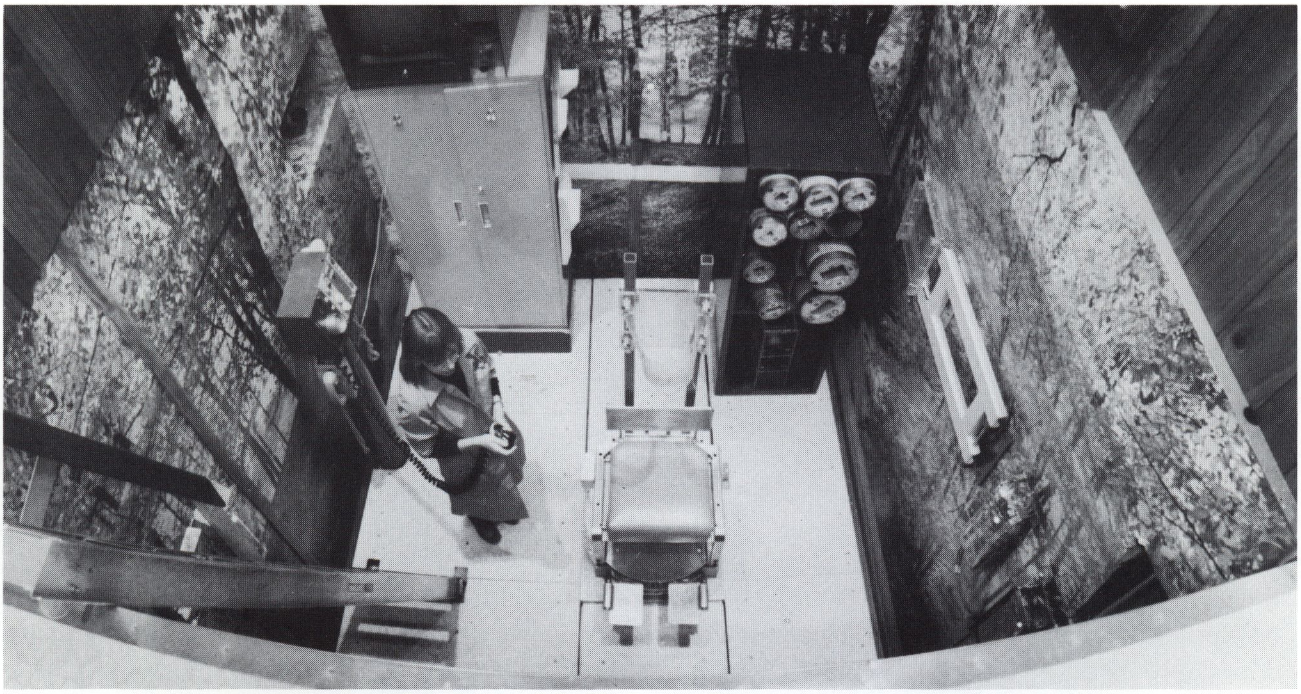
The results of neutron therapy as compared to more conventional treatment are shown in Table I.

As a result of these studies, neutron irradiation is now the treatment choice for non-resectable radioresistant tumors. After having provided funds for the operation of the neutron facility at Fermilab for almost a decade, the National Cancer Institute is no longer paying for what is now considered to be routine therapy. A few hospital-based neutron facilities continue to have some federal funding to conduct randomized trials, and it is our intention to review results of treatment in the hope that even better methods of administering therapy will be identified. The treatment itself is no longer experimental, and payment for treatment is being made by major insurance companies, Health Maintenance Organizations, and Medicare.

As part of the facility's transition from being governmentally funded to being self-supporting, a group of physicians have formed the Midwest Institute for Neutron Therapy (MINT) at Fermilab. MINT has entered into a contract with Fermilab, which has been approved by the Department of Energy, to buy the beam time, personnel, supplies, and equipment necessary to continue to treat patients. MINT guarantees full cost recovery to the Laboratory through its business activities. Frank Hendrickson and Lionel Cohen continue to perform the necessary functions of prescribing and directing the patient treatments.

The typical cost to patients is similar to that of conventional radiation therapy and is significantly less than surgery or chemotherapy. MINT came into existence to fund the actual costs of treating patients at the Neutron Therapy Facility and if an eventual profit is made, plans are to upgrade the facility and possibly, in the future, donate money to URA in order to foster research and educational activities.

The Laboratory's commitment to allow this exciting work to continue has been very gratifying, and we hope to be able to treat patients here for years to come.



The NTF treatment level as seen from the upper (x-ray diagnostic) level. NTF Chief Technician Barbara Bennett holds the control which rotates and adjusts the chair (center) until patients are precisely aligned with the beam.

Table I

Percent of Patients Having Local Control

Type of Cancer	*Neutrons*	*Standard Treatment**
Salivary gland	71%	36%
Soft tissue sarcoma	50%	5-60%
Osteogenic sarcoma	67%	5-20%
Chondrosarcoma	56%	25-51%
Clinically positive neck nodes	46%	33%
Prostate	93%	78%
Malignant Melanoma	71%	13.8-23.4%
Rectum and sigmoid colon	53%	21-52%
Bladder	58%	26%

*When these data were available as part of a randomized clinical trial, the figure represents the results for the control group treated with photon irradiation. When no randomized control group was used, the ranges of percent having local control quoted are from *Clinical Oncology for Medical Students and Physicians*, Philip Rubin, M.D., ed., (American Cancer Society, Sixth Edition, 1983).

The Accelerator as Collider — Room A

Here we begin the Fermilab version of *Rashomon* or the observation of proton-antiproton collisions from three different control rooms. Rich Orr continues his report on the Accelerator, and begins the 1.6-TeV collision narrative:

The first step in the Accelerator's role as a collider is to make p̄'s. During the 60 seconds of acceleration and flattop of the TEVATRON, the Main Ring was ramped to 120 GeV and beam extracted to hit the antiproton target. Some five cycles were so used each minute, completely parasitically. This permitted extensive commissioning of the Antiproton Source as soon as the Source rings and associated beamlines were ready for testing. Before this was successful, considerable work had to be done to decouple the two rings magnetically. Commissioning proceeded from April through August.

In early September the Fermilab accelerators switched from their familiar role of providing protons for the fixed-target program to a new role as participants in the Collider program. The Linac and Booster were required, as usual, to provide 8-GeV protons to the Main Ring. Main Ring beam was extracted at 120 GeV and guided to the antiproton-production target. After the Antiproton Source (its story comes later) had accumulated a sufficient stack of 8-GeV antiprotons ($>1.0\times10^{10}$ in this case), part of the stack was extracted and sent back to the Main Ring, accelerated to 150 GeV, coalesced into a single bunch, and passed to the TEVATRON. The Main Ring then picked up a Booster batch of 8-GeV protons, accelerated them to 150 GeV, and coalesced them to a single bunch which was also injected into the TEVATRON. Both beam bunches were accelerated to 800 GeV, synchronized, and squeezed into a 1-meter interacting region β^* at the center of the B0 straight section where the CDF detector lurked.

A short history of this first test of the complete Collider system follows (this is the Accelerator point-of-view):

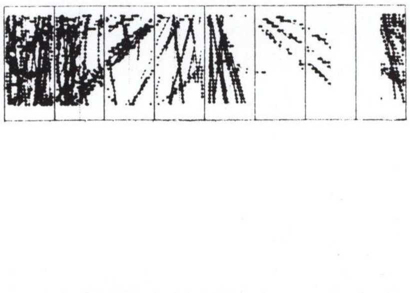
Oct. 5 — First injection of antiprotons into the Main Ring. These were obtained from an accumulated store of 0.4×10^{10}.

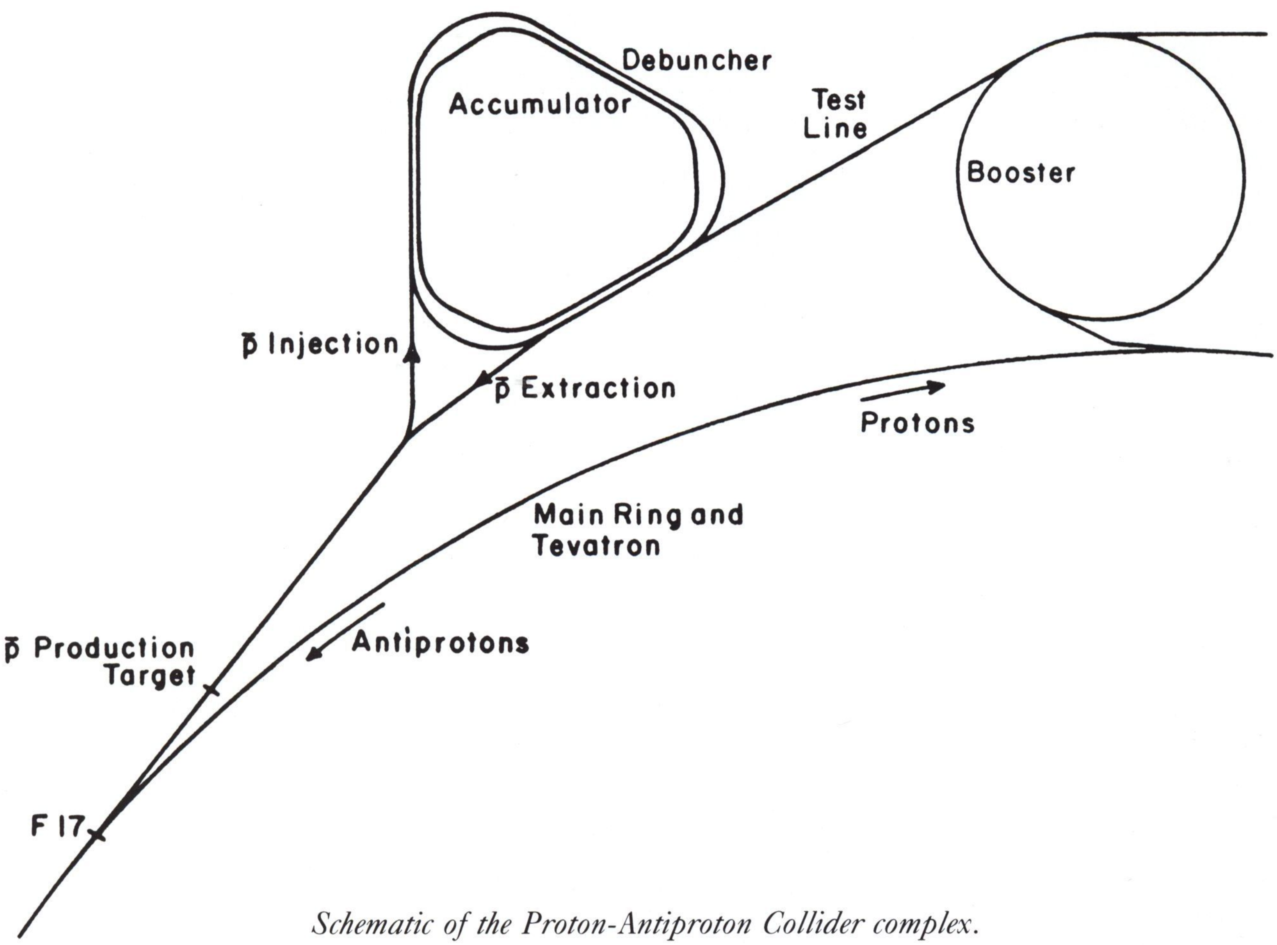
Oct. 8 — About 0.9×10^{10} antiprotons had been stored in the Accumulator. A 19-point checkout procedure was initiated in order to insure that the devices responsible for the transfer of antiprotons from the Accumulator to the Main Ring and from the Main Ring to the TEVATRON were properly adjusted. This check was made by transferring protons in the opposite direction. Three shots of antiprotons were attempted. Beam was transferred to the Main Ring on the second and third attempts, but no beam was seen in the TEVATRON.

Oct. 10 — Seven shots were attempted. Beam was seen in the TEVATRON.

Oct. 12 — More than 10^{10} antiprotons were stored in the Accumulator. Protons and antiprotons were successfully injected, accelerated to 800 GeV, stored, and squeezed to a 1-meter β^*. In the wee hours of October 13, 1.6-TeV collisions were observed in the CDF detector. Bingo!

The purpose of this run was to prove that all of the complex systems needed to accomplish proton-antiproton collisions were in place and working together in a consistent fashion. This goal was accomplished in grand style.





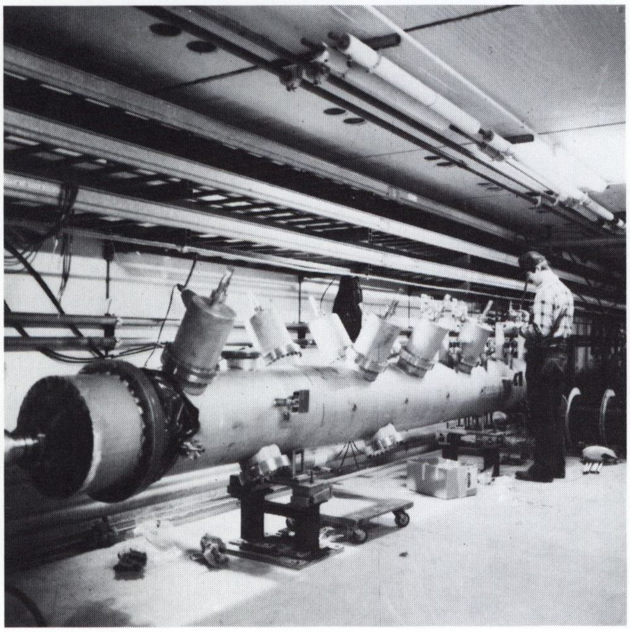
Schematic of the Proton-Antiproton Collider complex.

The Antiproton Source — Room B

In 1981, we threw out one design of an antiproton source (TeV I) and resubmitted a new design to DOE. The detailed design of Debuncher and Accumulator rings began in 1982 under the direction of John Peoples, who now reports on the 1985 work:

April may be the cruelest month for the poet but it was a joyous month for those of us building the Antiproton Source. Early in April the first proton beam was injected into the Debuncher, marking the beginning of an intense period of commissioning. It did not mark the end of an equally intense effort of construction and installation. For the next six months we continued construction and installation during the day, and commissioned the Antiproton Source during nights and weekends. By the end of April, protons had been stored in the Debuncher for up to an hour. During May the initial tests of $\bar{p}$ production using the lithium lens were carried out. At the same time, the sequence of bunch rotation of protons in the Main Ring followed by bunch rotation of antiprotons in the Debuncher was demonstrated. While these tests exposed a variety of problems, the problems pointed the way to the solutions. In June the pace quickened. The installation of the Accumulator was sufficiently complete to allow us to inject protons in the reverse direction through the extraction line. By the end of June, circulating beam had been achieved in the Accumulator. Then, it happened. Something was wrong. It wasn't possible to accelerate beam in the Accumulator without losing most of it.

There was very little time to stop and gain an understanding. Many parts of the Accumulator had not been installed and the commissioning of the Debuncher was far from com-



Wesley Mueller of the Antiproton Source Department makes microwave connections during installation of part of the stack tail kickers in the Accumulator at Sector 30. The kickers are inside the pictured vacuum vessel.

plete. We had fallen behind the schedule to reach colliding beams in September. Deliveries of critical components had slipped badly, making operation difficult but not impossible. We learned to master the dubious art of turning the Antiproton Source on at six in the evening and turning it off at six in the morning. Frequently, only an hour or two of useful beam was obtained. We and the equipment were neophytes and the newness was apparent all too often. Gradually, we became experts at extracting an 8-GeV proton beam from the Main Ring, transporting it to the Debuncher and Accumulator, and then determining the properties of these rings with 8-GeV protons.

During July the first tests of the Debuncher stochastic cooling system were successfully carried out. Bunch rotation and p̄ production studies led to improvements. We discovered that the effective aperture of the Debuncher was too small. We embarked on a careful study of the injection line. It pointed the way to improvements, which were then made. The improved injection line led to a better understanding of the Debuncher. That understanding was followed by a few hard-won improvements in the Debuncher acceptance. By August the Debuncher was beginning to work the way we had envisaged when we designed it in 1982.

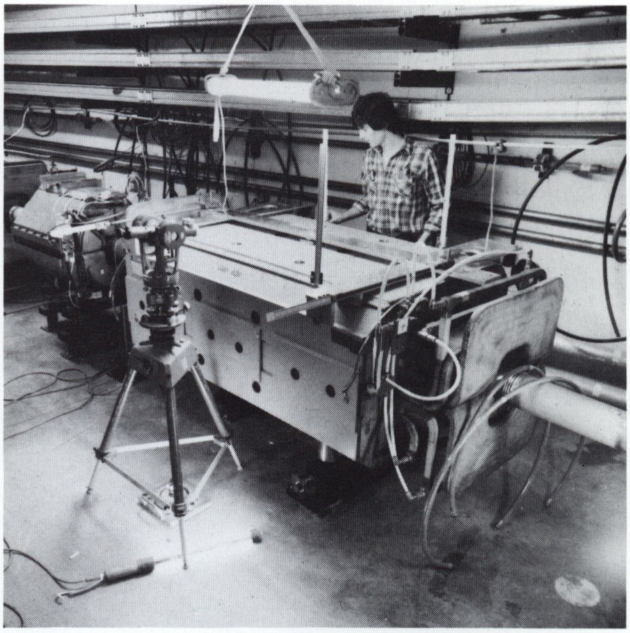
The Accumulator remained a mystery and a disappointment. Such a state was hardly surprising, since it was still not complete. August came and the irrevocable shutdown date of September 23 came inexorably closer. We had not captured a single p̄ in the Accumulator. The Accumulator cooling systems and vacuum system were still being installed. Early in August, the first bakeout was attempted. It was our cruelest month. The Accumulator aperture vanished. It was no longer possible to inject beam on a reasonable orbit, and once injected on an unreasonable orbit it could not be decelerated to the core orbit.

Nearly two weeks of round-the-clock measurements followed. Each night a new solution for the problem was proposed and then disposed of by the objective eye of measurements. By August 21, it was clear that there was an aperture restriction in the injection straight section in the center of the aperture, but not at the edges. Unfortunately, the restriction was in a spot where it was awkward to open the vacuum chamber, but there was no other choice; September had come closer. On August 22, two collapsed elliptical bellows, forming distorted figure eights, were found. They were removed only after dismantling eight quadrupoles in the tunnel. Two long, 16-hour workdays were needed to dismantle and restore the magnets and vacuum chamber. Two more days of pumping, baking, and cooldown followed before it was possible to condition the injection and extraction kickers. Since the first conditioning of the injection septum had taken two weeks, we feared that it might take as long the second time. It didn't: only 12 hours were needed. The waiting was painful but it was over. Still, September had come closer. In the meantime we went on improving the Debuncher and the injection line at night and on weekends. Time was not wasted, only its passage was rued.

On August 27, injection into the Accumulator was tried. It worked. The injection orbit was reasonable, the lifetime, roughly two hours, was acceptable for the time being. Beam was then decelerated to the stacking orbit without loss. There was hope. The pace of our work quickened. The tune and operating point were established. The horizontal and vertical betatron motions were decoupled. The Accumulator behaved as designed except for the aperture, shrunk by misalignment to only a third of the design values. There was no time to align the machine. More equipment was added to the Accumulator. The Accumulator cooling systems were tried. They worked. Then the slow, laborious measurements of open loop gain were started and completed. Baking of each sector was done selectively as time permitted. The lifetime improved slowly.

Then came September. Heretofore, we had been using protons. With September came antiprotons. Our diagnostics did not detect the minuscule numbers at first. It required an act of faith to believe that the system was working. Small adjustments were made to find the elusive $\bar{p}$'s. During the evening on September 7, there was a weak signal; perhaps a $\bar{p}$ had been seen. A few hours later it was undeniable. The signal on the spectrum analyzer showed that there were 2×10^6 particles with a negative charge and the mass of a proton circulating in the Accumulator. Slowly the signal grew in intensity, and by the following morning it had grown to more than a microamp, 10^7 antiprotons. It was beautiful! All we had to do was improve the accumulation rate by a thousand to make colliding beams possible.

September 7, 1985, was marked by yet another test of our mettle to achieve colliding beams. It was the hottest September day on record in northern Illinois. Power supplies took note of it by tripping off. The magnets got hot and the Booster Pond grew hotter. A magnet hose ruptured and the tunnel became a subterranean river. The river receded. By the afternoon of September 8, accumulation had to be stopped because of the heat. Only the Debuncher could be operated. The shutdown to allow CDF to roll its detector into place started



A member of the survey team prepares a Debuncher dipole for final alignment.

on the morning of September 9. We used the opportunity to install a new adiabatic debunching cavity in the Debuncher, hoping that it would reduce the $\bar{p}$ momentum spread so that it could be contained within the Accumulator injection aperture. A more sensitive current monitor was put into the Accumulator to measure the feeble $\bar{p}$ currents. Throughout the week the vacuum chamber was baked slowly, reducing the pressure.

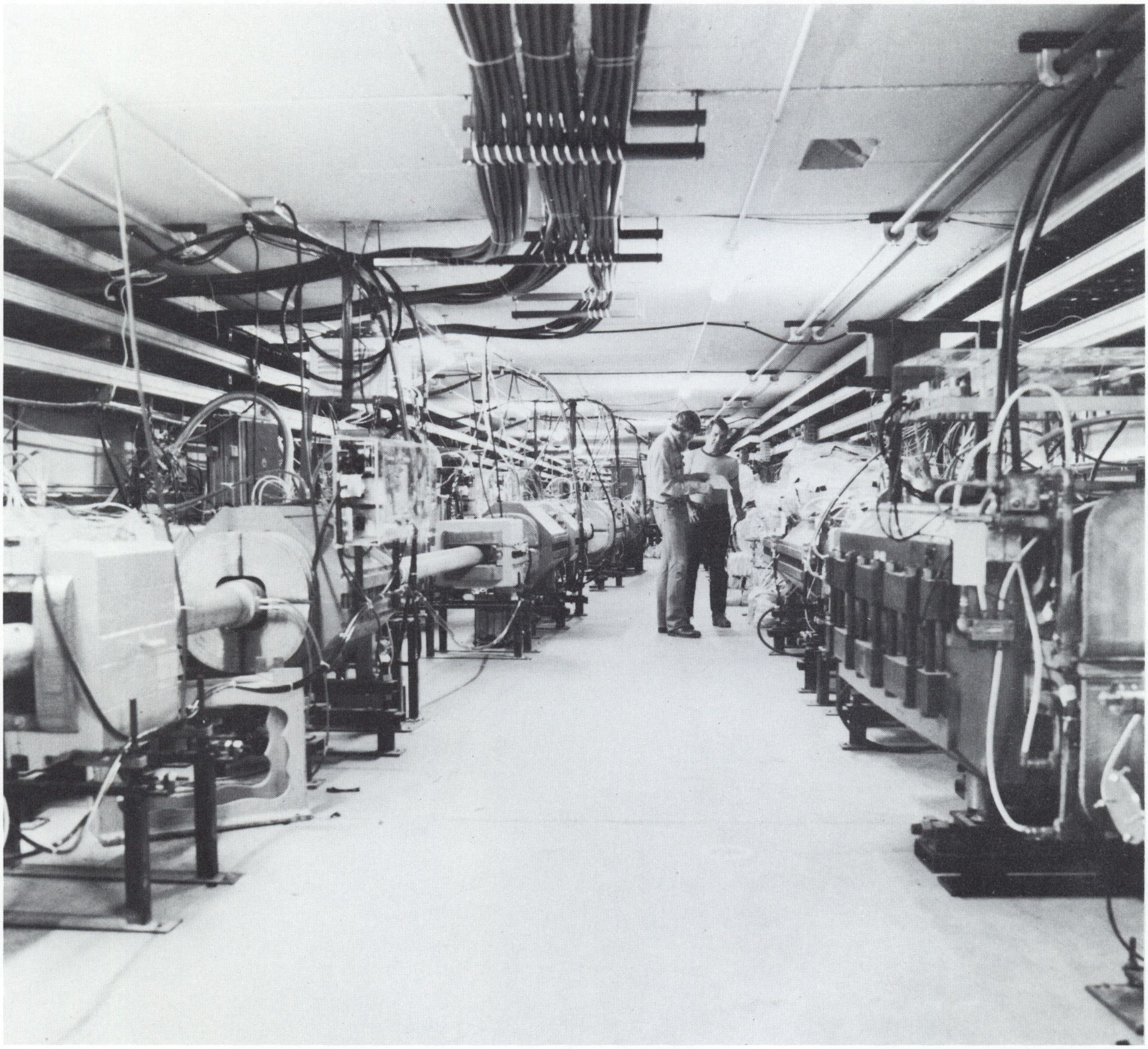
On September 14 we started again. The lifetime of the beam in the Accumulator had increased to six hours. The accumulation rate reached 10^8 $\bar{p}$'s/hour by September 22 and stopped. Not enough. Improvements began to come. September 23, shutdown day, arrived. It was hardly the time to quit. The irrevocable was revoked. Bulldozers and scrapers were relentlessly scraping the earth away at the D0 and B0 construction sites.

The polarity of both rings and the injection line were changed to allow us to return to cooling the more copious 8-GeV protons on September 26. More slow, painstaking, open loop gain measurements were made. When there was no beam, more additions were made to the diagnostics. After four days, back to antiprotons. We went on and they went on. Autumn brought cool, clear nights and cool magnets and power supplies. The accumulation rate reached 2×10^8/hour and the stack reached 10^9. Each little improvement added something. By late September the stacking rate reached 4×10^8/hour and the stack reached 2×10^9. Finally, we were ready to send p̄'s back. The shutdown date? Postponed again.

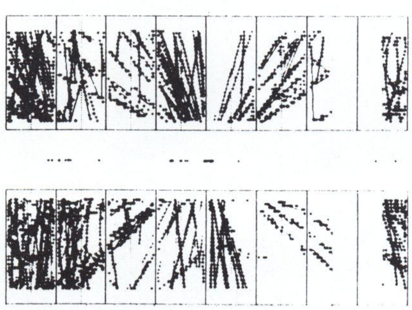
By October 5, 3×10^9 p̄'s had been accumulated, enough to try sending them to the Main Ring. The first try worked: p̄'s were extracted, traversed AP-3, and disappeared into the Main Ring. We tried again the next day and this time enough p̄'s survived injection into the Main Ring to be detected as a circulating beam. The next day the stacking rate reached 6×10^9 p̄'s/hour. Accumulation was becoming dependable, although very slow compared to the design. Each night the p̄'s penetrated a bit further into the Main Ring and TEVATRON.

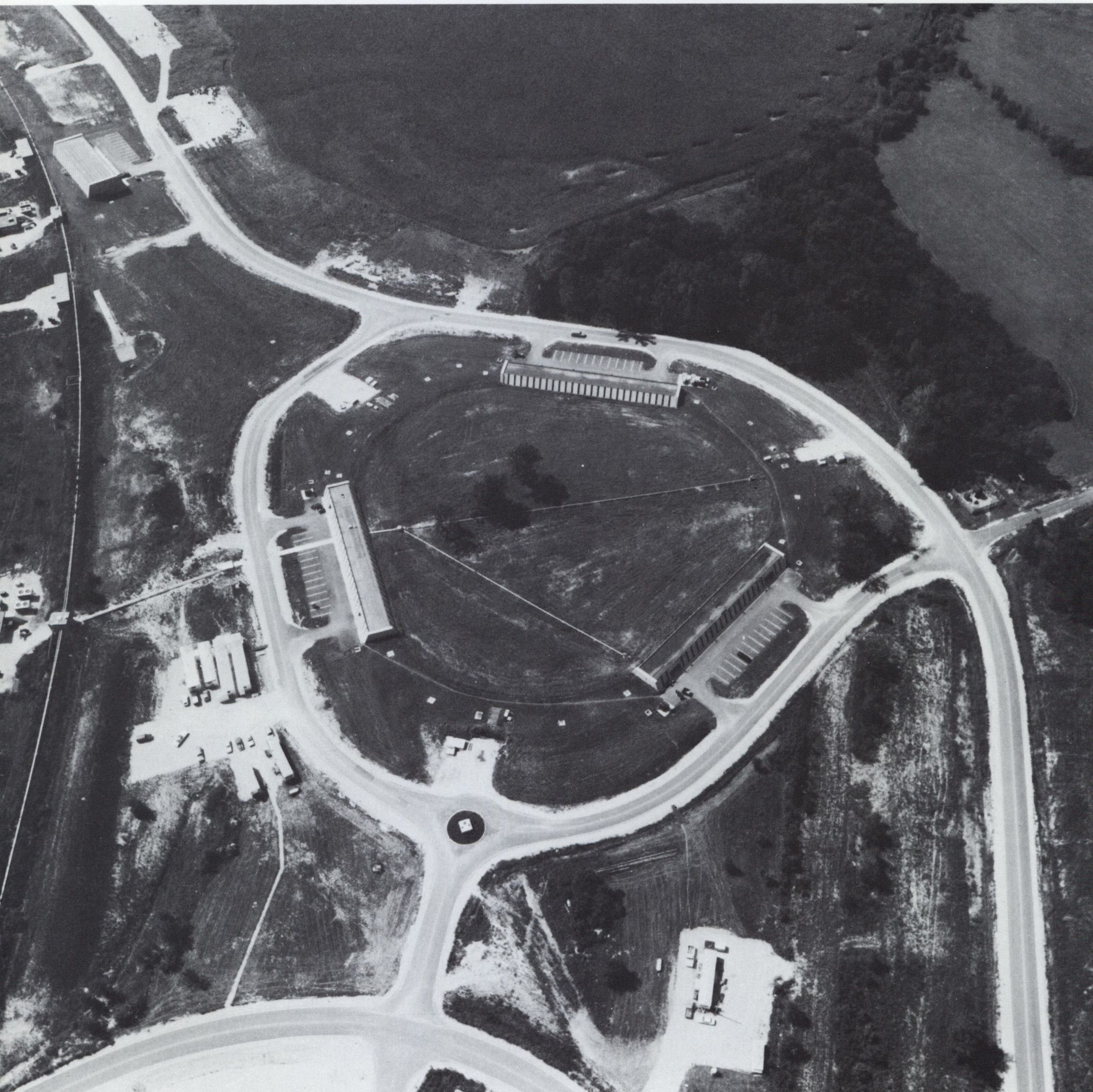
October 11 was time to rest and be Dedicated. While we were dedicated we had never been Dedicated. Annointed, we returned to making p̄'s. By midnight on October 11, the accumulation rate reached 10^9/hour, a thousand times better than the first accumulation on September 7. The moment of triumph appeared to recede when the Debuncher dipole power-supply tripped off. The source of new p̄'s went dry. We had accumulated 10^{10} p̄'s. Their lifetime in the Accumulator was more than 100 hours. There was still time to take them out, and one more chance before shutting down for a year.

Hours went by. The first shot was tried on the morning of October 12. An hour later another was made and then another. Finally a few p̄'s made it to the TEVATRON and were seen circulating. Adjustments were made. The next few shots were unsuccessful. The store of p̄'s had declined to less than 3×10^9 as each shot diminished the stack by 7×10^8. October 13: Another shot was tried at 2:25 a.m., the last chance to get a good one off. The Accumulator was nearly empty. Success. It went all the way to the TEVATRON. Protons and antiprotons were circulating through each other. The two little bunches were gradually moved into position for observation. The low beta squeeze began. CDF had an event! It is time to celebrate.



A view of the Debuncher to Accumulator transfer line showing Kerry Mellott and Lee Benson of the Mechanical Support Department enjoying a rare moment of leisure during installation of the Accumulator bakeout system.





An aerial view of the Antiproton Source. The three long buildings are the service buildings which contain the Antiproton Source power supplies and electronics. The building in the upper left is the target service building, the point at which antiprotons are produced by collisions of 120 GeV protons with tungsten nuclei.

The Collider Detector at Fermilab — Room C

The Collider Detector at Fermilab is part of the Research Castle, but in the interest of continuity, we transport it here to present Roy Schwitters' version of the events that led to the EVENT:

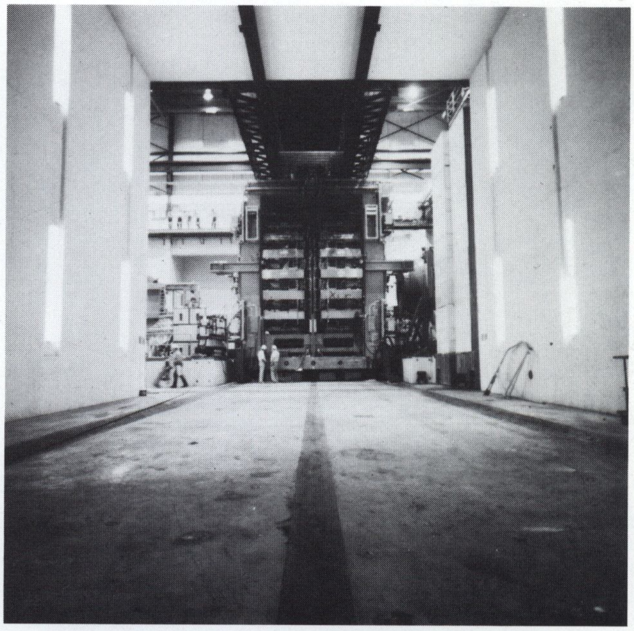
Early Sunday morning on October 13, 1985, operators and physicists working on the TEVATRON, the Antiproton Source, and the Collider Detector witnessed 23 events arising from proton-antiproton collisions at 1.6 TeV, the highest energy ever achieved in a laboratory experiment. With this, Fermilab lands on the shore of a new world of particle physics that will begin to be explored starting in 1986. We have every reason to believe that this new world will yield the kinds of riches and surprises in our understanding of nature that followed similar advances in scientific instrumentation.

For CDF, the successful observation of these first collision events marked a major milestone in a year that was filled with important accomplishments. The original goal of the short test-run was to test representative parts of detector, electronics, data acquisition, and trigger systems under realistic conditions so that the full detector could begin physics measurements as soon as possible in 1986. CDF also needed to verify that no unexpected backgrounds accompanied the TEVATRON beams and that the enormous weight of the detector did not disrupt the delicate alignment of the TEVATRON.

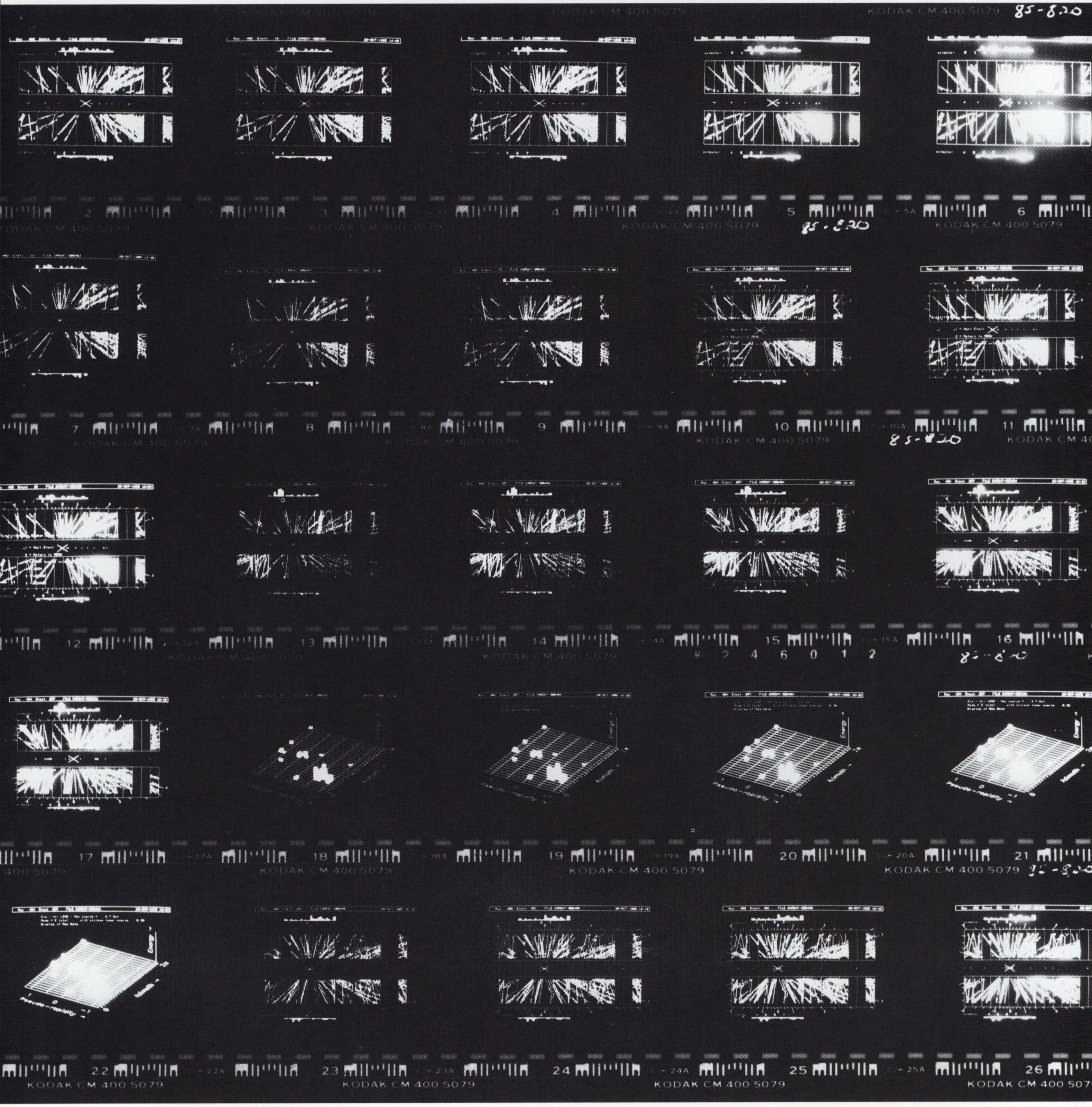
These goals were fully met during single proton beam running in September; the great achievement of successfully colliding a beam of antiprotons with a proton beam was an added bonus that gave even more information about the detector and provided a most satisfying reward to the many scientists, students, engineers, and technicians from all over the U.S., Japan, and Italy who have been working on CDF for many years.

Almost every month during 1985 signaled the completion of important detector components, some of which had been under construc-

The view looking south through the access tunnel into the BO collision hall prior to rolling-in of the CDF detector.



The view looking north through the access tunnel from the BO collision hall into the CDF assembly area with the CDF detector visible in the background.



Photographs of the event displays of the first 1.6 TeV proton-antiproton collisions at CDF. Two views are shown: the tracks from the Vertex Time Projection Chamber, and (frames 18-22) the "Lego" plots showing energy deposition in the calorimeter segments.

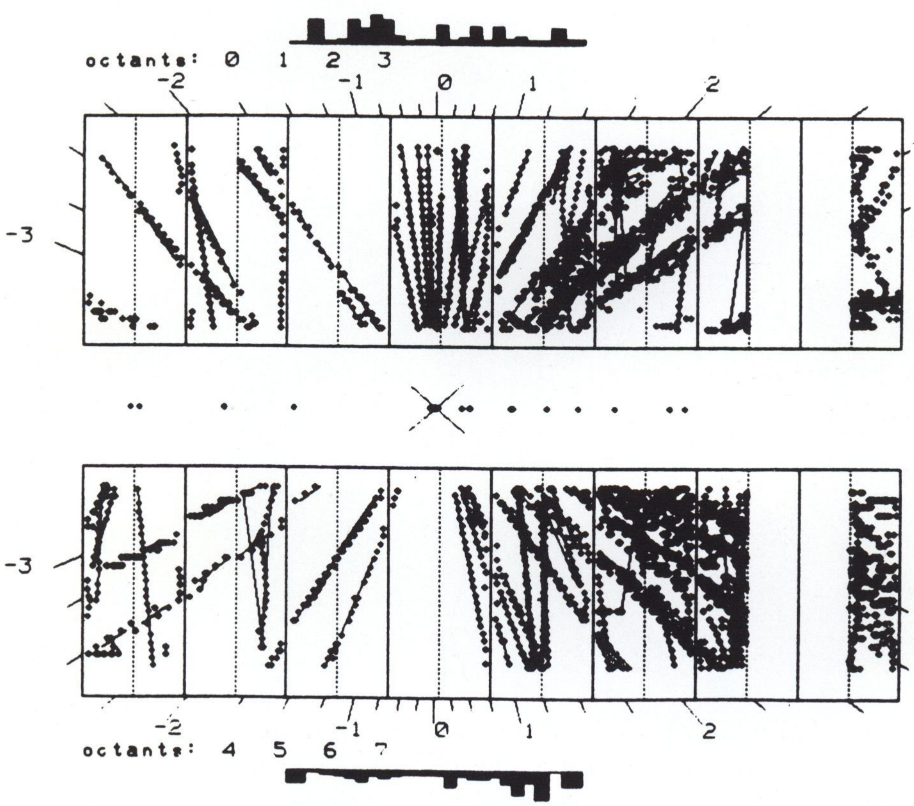
tion for years. For example, the last of the 50 central calorimeters and shower-counter modules, which contain elements from Italy, Japan, and several U.S. laboratories, was installed in CDF, bringing to a close a worldwide assembly line that had been operating for more than two years.

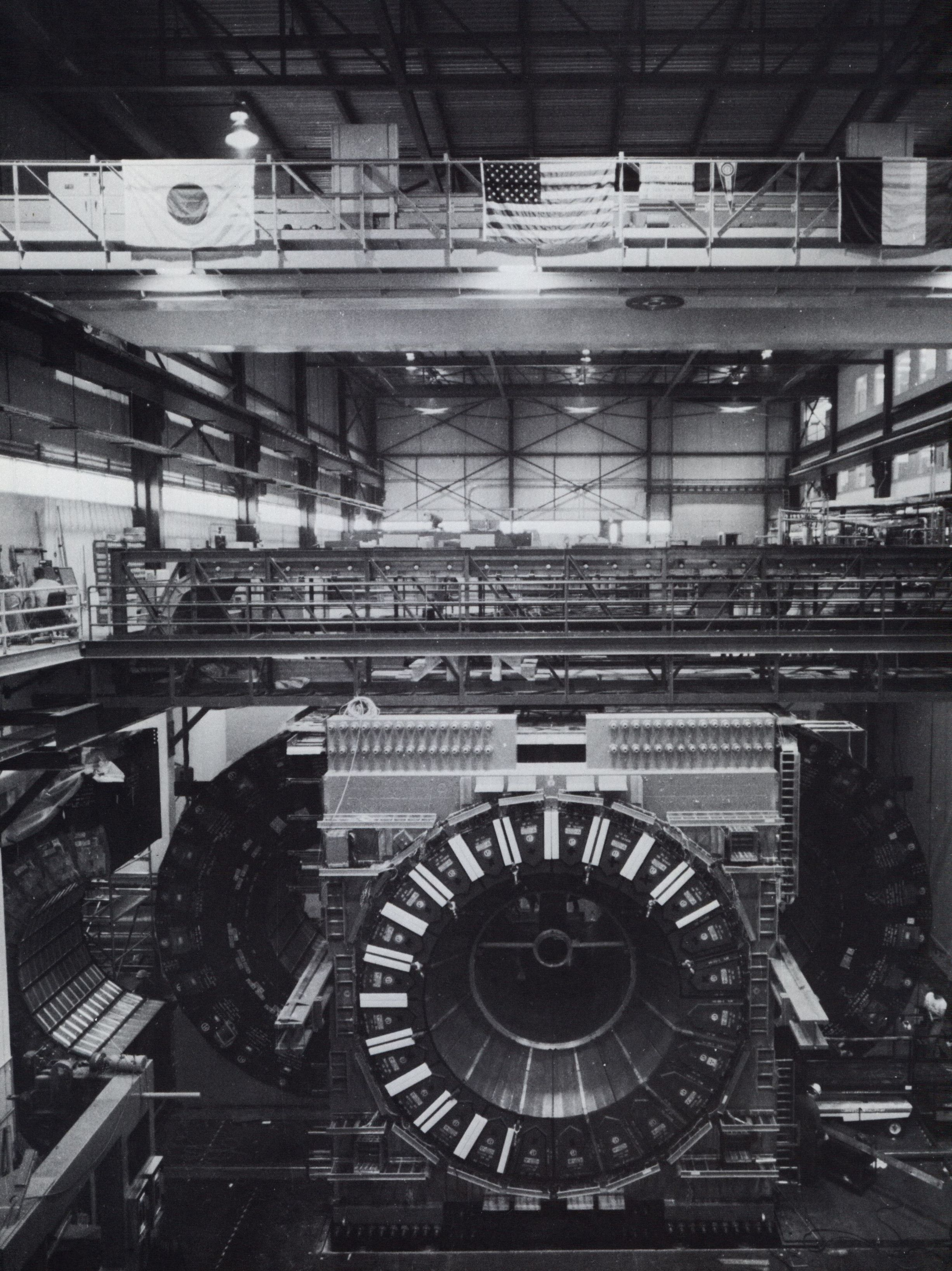
Another highlight of the past year was the very successful initial operation of the CDF superconducting solenoid magnet. This was a joint project by Fermilab, Tsukuba University (Japan), and the Japan National Laboratory for High Energy Physics. The coil for this magnet measures 3 meters in diameter by 5 meters long and it was built by Hitachi Ltd. of Japan. It was flown to Chicago in 1984 and matched to its 2200-ton iron yoke and cryogenics system in the CDF Assembly Building in early 1985. Cooldown and power tests went very smoothly. The solenoid magnet system met all of its design goals and appears to be very stable and reliable.

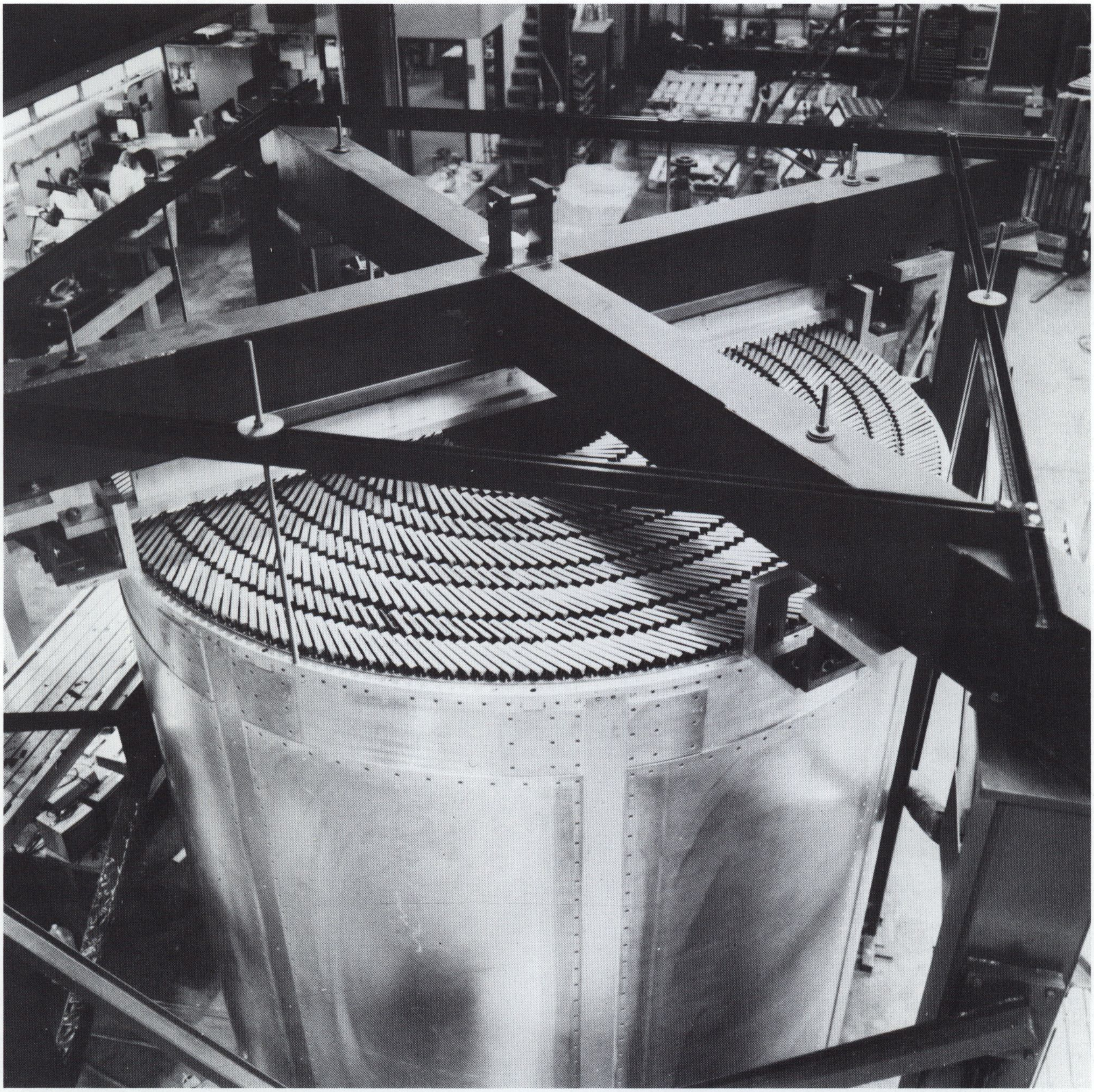
CDF made use of two test-beams during the fixed-target running for testing and calibrating detector components. By the end of the fixed-target run, the performance of all CDF calorimeters and shower counters had been verified in test beams and full calibration was completed on most systems.

By summer 1985, a great deal of energy and effort was being focussed on assembly and checkout of the part of the detector to be rolled into the TEVATRON for the September-October beam tests. This was the first opportunity to bring together the full multitude of detector, electronics, and software systems that would be needed for CDF. It, of course, brought together all the people expert in these systems, and the parking lots at CDF were full at all hours of the day and night and over weekends. This tremendous effort was rewarded by the collisions of October 13.

Following the test run, CDF has returned to the task of completing all the other detector systems needed to start physics measurements with the TEVATRON Collider in 1986.







Assembling the CDF central track chamber prior to wire stringing.

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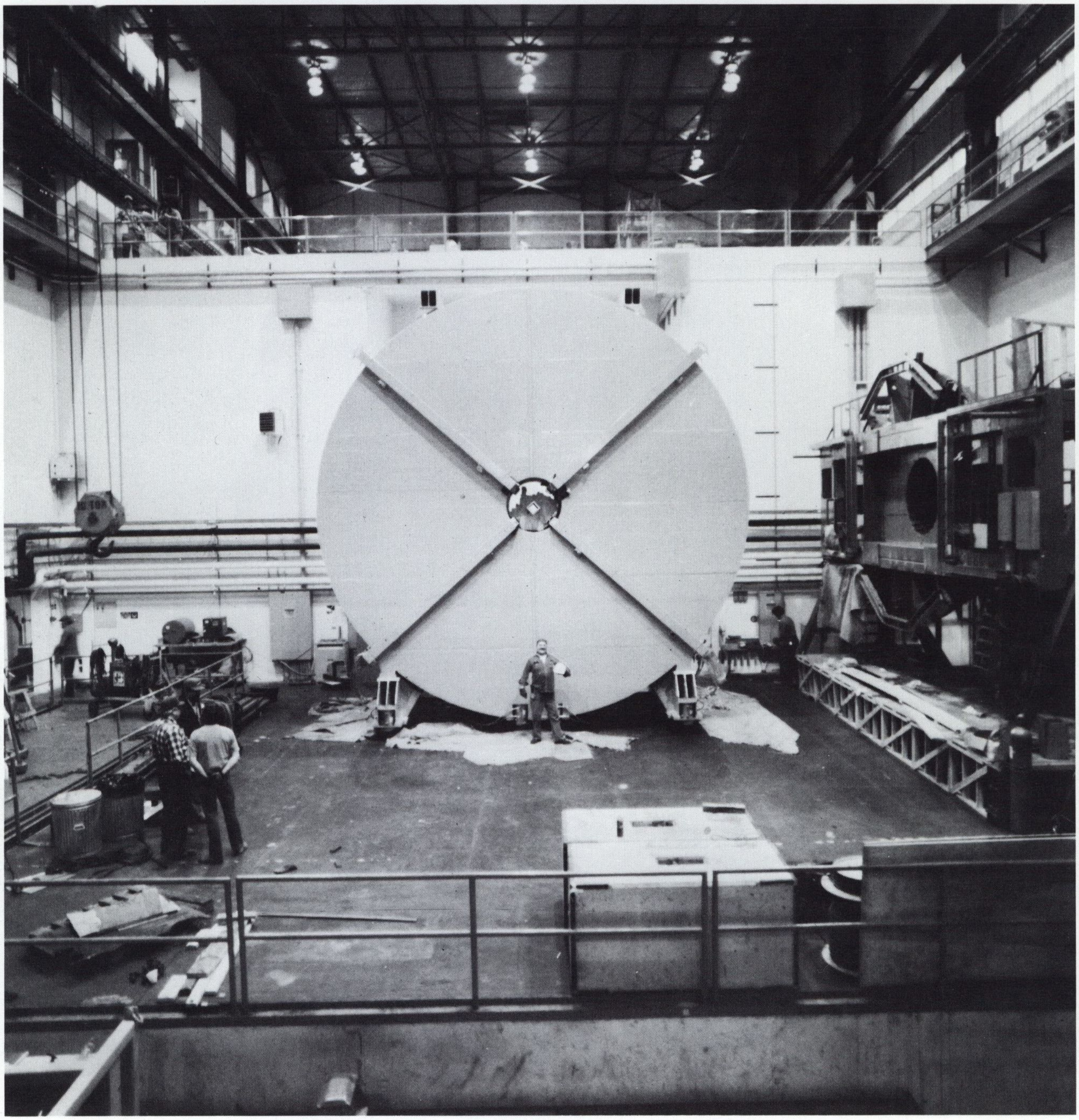
The CDF central detector in the assembly hall. The crane is hung with the flags of Japan, Italy, and the United States — the three nations in the CDF collaboration. Immediately over the detector is the cable mover which carries the cables between the detector and the counting room, and which allows the detector to be moved without uncabling. The detector itself has three of its four calorimeter arches visible in retracted positions. The large round tube in the center of the detector is the inside of the superconducting solenoid magnet; the smaller tube holds the Vertex Time Projection Chambers.



The completed CDF forward muon toroid dwarfs a proud worker.

The CDF detector rolls into the B0 collision hall for the first time on September 9, 1985. ⟶

The Research Division Castle

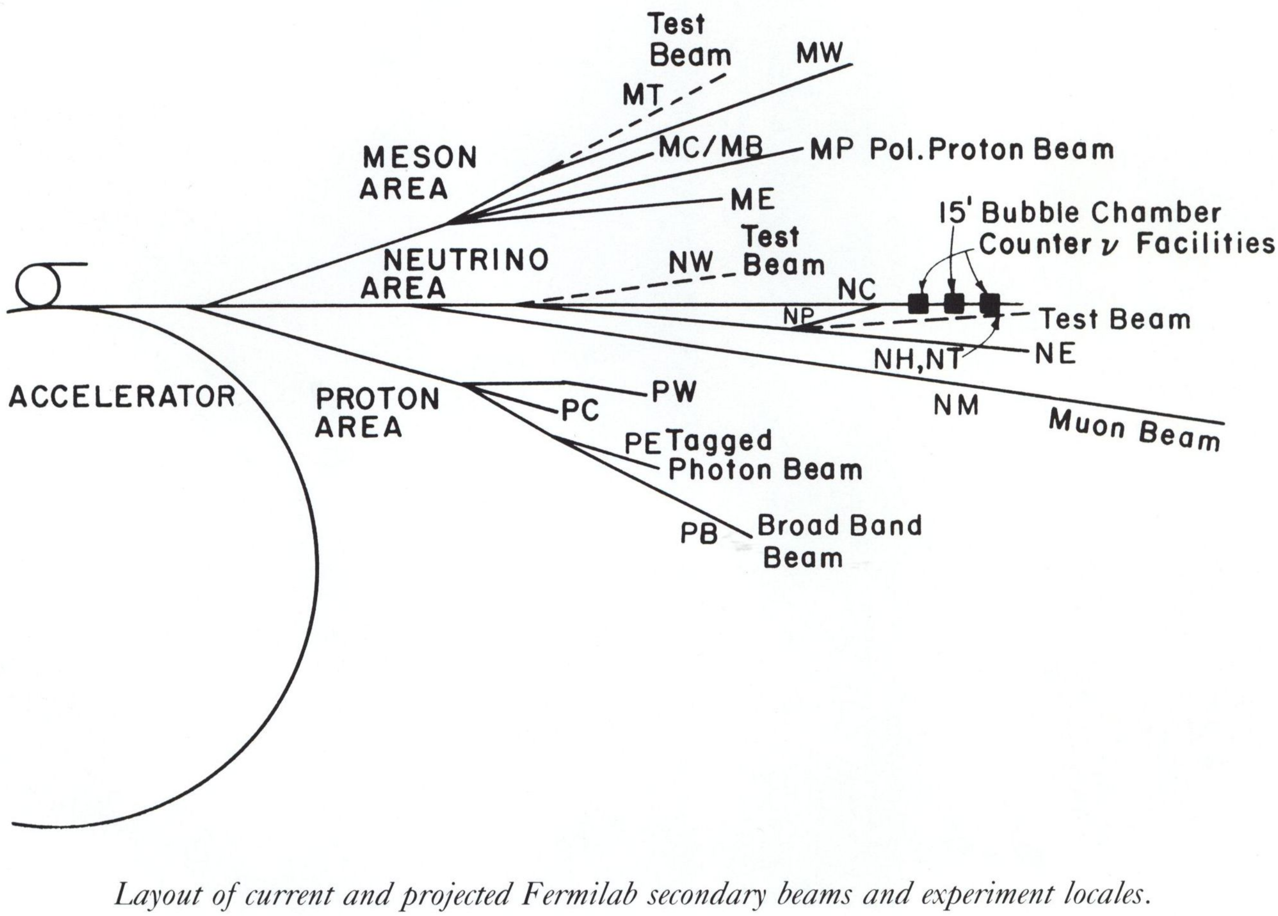
This multifaceted conglomerate administers the Computing, CDF, and Theory Departments. The Research Division also administers six support departments which are designed to allow the fixed- target users to make most efficient use of the protons that emerge from the Switchyard. This includes the operation of all the beamlines and facilities that are Fermilab's responsibility, e.g., the 15-ft Bubble Chamber, Multiparticle Spectrometer, etc.

Ken Stanfield, Head of the Research Department, reports:

Highlights of 1985

A major accomplishment was the installation and commissioning of the new Wide-Band and Muon beamlines. The Wide-Band beam was commissioned on June 23, 1985, when 400-GeV/c electrons were successfully transported to the new Wide-Band Experimental Hall. Following the commissioning, electron beams with energies ranging from 50 to 650 GeV/c were transported to the Wide-Band Hall. In the Muon Beamline, construction of all 26 enclosures was completed by late March 1985, and the installation of beamline components was begun. Unfocussed muons were detected in the Muon Experimental Hall in mid-July and the beamline was officially commissioned during the first week of August, with an intense beam of well-focussed muons entering the hall. The shape of the beam was exactly as expected and the intensity and halo were within the anticipated limits.

In the Meson Area, the construction of two new beams (MP and MW) is part of the final



Layout of current and projected Fermilab secondary beams and experiment locales.

phase of the TeV II project. Currently, both the M-West and M-Polarized Experimental Halls are 90% completed. This also includes the counting house and service building. The enclosures leading to the halls are 60% completed and are scheduled to be finished in early 1986. Further upstream in the Front-End Hall, beamline components are being rearranged to accommodate the new beams. This year, the M-West target pile was completed and work on the M-Polarized target pile is underway and scheduled for completion in July 1986.

Details of the physics program in the fixed-target areas are presented in the article "The Fixed-Target Run of 1985" which appears later in this *Report*.

Operations Department

The 1985 run was the first in which all transport systems were operated from the new centrally located Operations Center. Personnel in this department provided 24-hour-a-day service to all fixed-target users. During 1985, the group commissioned two new beamlines, developed new status monitoring for interlocks and cryogenic systems, tested faster processors for the PDP11 controls system, and developed an improved monitoring program for the Neutrino Area data logging.

Experimental Areas Support Department

This department helped to install the new beamlines and installed experiments E-731, E-743, E-745, E-653, and E-711. One of their chores is to provide air conditioning to keep the experiments going during summer months.

The Mechanical Department

This department handled all mechanical operations, e.g., the installation of magnetic elements in the new beamlines. During 1985, this department designed and constructed a target pile for M-Center and M-West. Installations were made for the secondary beams for M-Center (E-731), N-East, and N-Test beams which provided protons for E-711 and E-653.

The Facilities Department

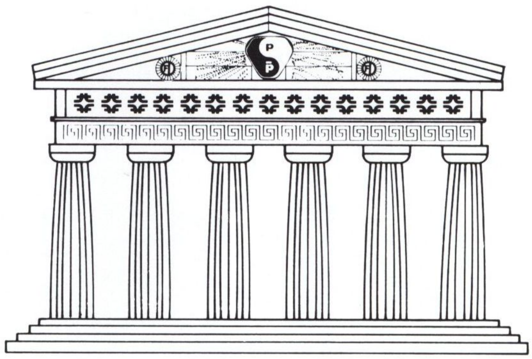
The Facilities Department installed the new external muon identifier (EMI) and internal picket fence (IPF) systems at the 15-ft Bubble Chamber. They carried out major modifications of the Tagged-Photon Spectrometer (E-691) and the Multiparticle Spectrometer (E-743). The department supported the important test beams in N-West and M-Bottom, used to calibrate the wedge modules of the CDF central calorimeter.

Electronic/Electrical Department

This department installs and commissions all the power, interlock systems, and vacuum controls and so contributed to the Wide-Band and Muon beamlines. They are called on to give electronics and electrical support for the experimenters. For example, they designed a power distribution system and state-of-the-art surface mount technology for the CDF electronics systems.

The Cryogenics Department

Cryogenic magnets play an increasing role in the beamlines either because of lack of space or because of economics. By the end of 1985, the Experimental Areas had 293.5 meters of cryomagnets supplied by five refrigerators. In addition, the 15-ft Bubble Chamber, the Chicago Cyclotron Magnet, the Tohoku Bubble Chamber magnet, the CDF superconducting solenoid, and the upcoming large liquid-argon calorimeter (E-706) are part of the workload. This department also maintained all of the Experimental Area cryogenics in 1985 and installed the superconducting magnet string in the Wide-Band Beamline.



The Computing Department

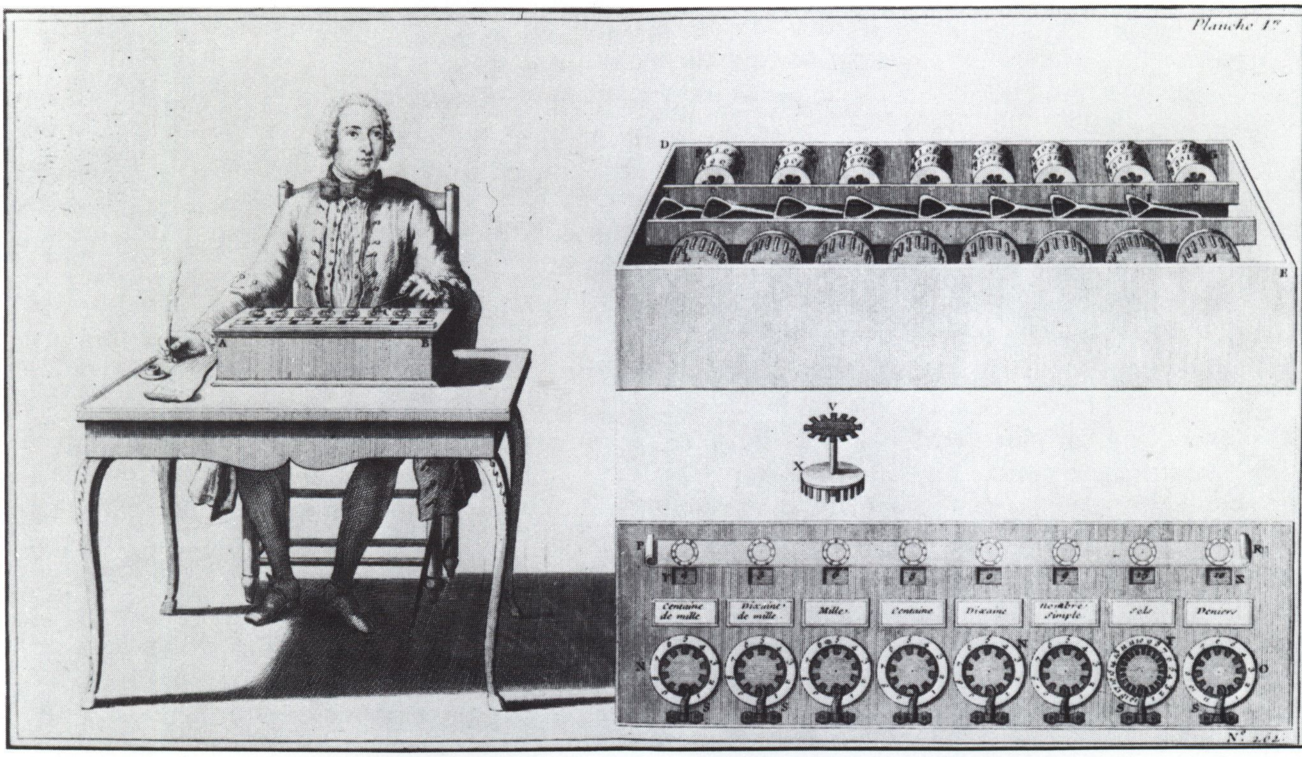
Hugh Montgomery, Head of the Computing Department, outlines 1985 achievements:

Acquiring the data is not enough. Fermilab's policy has been to serve the users with the computing power for design, on-line data acquisition, fast turn-around analysis, and number crunching. In 1983, we commissioned a study of computer needs under the chairmanship of Joe Ballam, and in 1985 we have seen the results of a blend of our long-planned evolution now channeled by the recommendations of the Ballam Committee.

The Past Year

Computing in high-energy physics continues to expand not only in terms of the raw computing cycles necessary for data analysis, but also in terms of its role in the everyday life of the physicist. On the one hand, the processing power of modern microprocessors pervades the arena of data-acquisition modules and systems; on the other, communication between often widely dispersed collaborators increasingly depends on sophisticated worldwide computing networks. Faced with this scenario, the challenge to Fermilab is, at one and the same time, to provide a comparatively stable environment for the production computing associated with experiments that have taken data since the advent of the new TEVATRON era, and to plan for continuing expansion of both the capacity and capability to meet the needs of, among others, the large Collider experiments.

At the beginning of 1985 the system of three CYBER 175 and one CYBER 875 central processors were providing more than 100 hours of CYBER 175-equivalent hours of computing per day. The time was shared among the experiments attempting to reap the fruits of the first operation of the TEVATRON for fixed-target physics during 1984. The new TEVATRON run during the course of 1985, with new experiments loading the system with quasi-online analysis of their current data samples, maintained pressure on the computer center to the extent that the delivery of the second CYBER 875 CPU, originally planned for late 1985, was



Pascal's machine, an eighteenth century computer.

advanced and installation completed in July/August with minimal disruption of normal service. Immediately, the extra cycles available were consumed as the large fixed-target experiments had their last month of data taking. The end of the Accelerator run saw little slackening and a steady consumption of more than 125 hours of CYBER 175 equivalent per day, which has become the norm.

The newer and more modern component of the computer center is represented by the VAX Cluster. At the beginning of 1985 this consisted of two VAX 11/785 machines operating in an essentially independent manner. Over the course of the year, this system has grown by the addition of the two CDF offline VAX 11/780 machines and the acquisition of two new VAX 8600s (the latter are new machines announced by Digital Equipment Corporation only a year ago). The six machines, along with appropriate ancilliary equipment, are coupled under the VMS4 operating system so that a user on any of the machines experiences a common environment, operating system, and file base. The motivation for this development is the desire to provide, in the short term, adequate interactive computing to permit the development of software for the new large fixed-target and collider experiments and to provide the large (virtual) memory environment necessary for the production work associated with the CDF program. This installed capacity is, of course, only sufficient for the early phases of CDF.

While it is important that the computer hardware be sufficient unto the needs, it is only so much silicon without the appropriate software and support for its users. Therefore, there has been a significant bent towards enhancing the services available from the Computing Department by way of installed software, software support, and software development. The changing character of both the uses of the computing system by the physicist and the development of business uses of computers permits many items to be obtained in the commercial market. A good example of this is in the field of graphics where, traditionally, Fermilab (and almost every other comparable laboratory) relied on in-house development of software. The acceptance of standards has permitted the purchase of a graphics package which, it is hoped, will replace the outdated home-grown package. It is, of course, necessary to ensure that there is good in-house support for this purchased software and the many other packages available on the central computers.

Industry, however, is not a viable source of specialized high-energy physics software, and for many purposes custom software is produced by the physicists themselves. Within the Computing Department, effort is being made to address some of the subjects which lack the appropriate suite of tools. One of these subjects is that of magnetic field measurement, analysis, representation, and modeling. Another is pattern recognition, which is anachronous in that it is a dominant component of the analysis problem but has never enjoyed an acceptable general package. This is also one of the areas where the availability of massive memory space and vector processors suggest that a considerable payoff may result from a thorough understanding of the problem by the community. By their nature such projects as these have an associated long lead-time to results and uncertainty as to their utility. This year, only a start has been made.

In the field of data-acquisition computing, tremendous changes have been made in the last few years and continue to be made. The characteristics of on-line computers have changed from the rather limiting 16-bit machines to 32-bit VAX machines which have opened up new horizons for on-line monitoring and analysis. Perhaps the major change is that there is the capability for the ordinary physicist to contribute to the on-line system where a few years ago only the "guru" had the intimate knowledge of the data-acquisition system. There are now almost 20 VAX machines installed in experiments, and both the Computing Department and the physicists have made significant progress during the last year in exploiting their richesse. A considerable commonality is discernable and efforts are being made to ensure that development done in one experiment is propagated to the others in a supportable way. This is not the end of the line however, and the development of powerful microprocessors and their incorporation as almost general computing engines in the data-acquisition system is already at hand ("We are confronted by insurmountable opportunities": Pogo).

Closer still to the detectors, 1985 saw the operation of E-653 which, as one of the first experiments to rely on large-scale utilization of commercial FASTBUS products, was a challenge to the Prep/Hardware Repair Group of the Computing Department. We are happy to report survival and a successful run by the experiment. At the frontier, a project was essentially completed to demonstrate the use of optical disks for data taking; this is one of the routes towards higher data-recording densities and, hopefully, higher rates in the future.

The diverse array of capabilities described above has begun to be integrated into what we hope is a larger whole. At the beginning of the year, none of the fixed-target experimental machines were connected to the world. By the end of the year only one VAX was not connected through DECnet to the central cluster, other machines on site, and indeed the world. Since the VAX Cluster is connected on the same Hyperchannel network as the CYBER system, the world is becoming larger. The experimenter may now get a phone call at home from his colleagues, connect his terminal via telephone lines to the central port selector, logon to the central cluster, in turn "set host" to his experimental VAX, investigate the problem there or pass through to a PDP11, solve the problem, modify his files, archive his files on the central system, VAX, or CYBER, logoff, and go to bed having solved a problem without the time delay normally associated with driving into the counting room during an Illinois winter night. This is one local example of the advances seen during 1985 in our networking capabilities. No less important, but for the moment less visible, is the active participation with other major U.S. high-energy physics laboratories in the progress towards a nationwide high-energy physics network (HEPnet) with appropriate ease of connection for all universities and laboratories to the scene of their current experiments and to Europe and Japan. The opportunities are, to say the least, stimulating.

Prospects: New Acquisitions

It has been recognized for some time that the currently installed computing system does not conveniently expand, either in capacity, capability, or in physical space, to meet the needs of the next ten years. A project was conceived to provide both a new computing system and the building to house it. There is now funding for this project to start in earnest and the parameters of both building and computer are being honed to finer detail each week. The building construction will start in the spring of 1986 and will take rather more than a year to complete, permitting computers to be installed during 1987. A year from now the progress of this project should be visibly manifest and will be a spur in our efforts to provide computing capabilities worthy of the Laboratory and its goals.

The Advanced Computer Program

Last year, the Advanced Computer Program (ACP) made the cover of our *Annual Report.* This did not deter the efforts in 1985. Tom Nash, Head of the ACP Group, brings the project up to date:

Last year's *Annual Report* cover story gave us nowhere to hide. There was nothing else to do but go out and build what we promised. All pieces are working now, and we are in the process of integrating the system.

The ACP was formed to develop new ways of using computers in high-energy physics to meet the large computer requirements in the field at affordable costs. During 1985, the ACP group made significant progress towards the goal of building a full-scale 140 processor system which is scheduled to be completed in the spring of 1986.

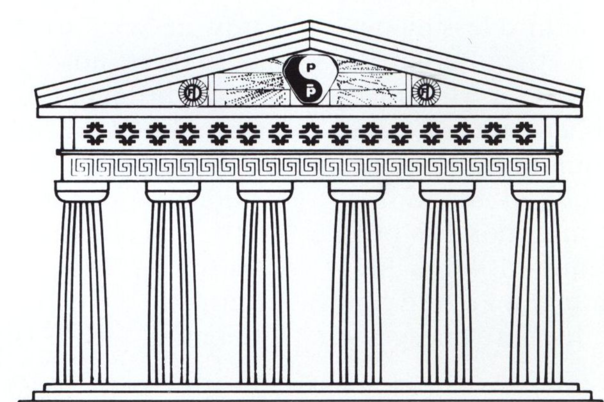
Thanks to a buyer's semiconductor market in 1985, the ACP Group was able to produce single-board computers for a third less money, and with more memory, than originally planned. Our CPUs are based on Motorola's 68020 and AT&T's 32100 microprocessors and are designed with the maximum performance and minimum features required for multiprocessor applications. The intention has been to demonstrate what is required when hundreds of processors are run together, and how conventional designs intended for "onesy and twosey" situations can be streamlined. The ACP Group's efforts in this area seem to be having the desired impact, aiming industry at the right product. Frequent idea interchanges have been conducted with chip and board designers at Motorola and AT&T. They, and others, are, perhaps hesitantly, testing out the multiprocessor market. ACP software is being used as a specification standard by at least one major, three-letter-name computer company.

Omnibyte Corporation, of West Chicago, Illinois, a well-known specialist in single-board computers, has been a particularly close collaborator. They are already selling our CPUs and will shortly be selling the rest of the components of the ACP multiprocessor system. They and we have been (almost) beseiged by what we call our "anxious clients," a scattering of groups who, with varying levels of desperation and impatience, are demanding real hardware tests to decide whether the system meets their most fervent desires.

In addition to Fermilab's Computer Department and CDF, other groups working at Fermilab, LAMPF, HERA, CERN, SIN, and the National Superconducting Cyclotron Lab are on the "anxious clients" list. Rutgers, the University of Massachusetts, Yale, Toronto, Montreal, Ecole Polytechnique (Paris), Friebourg, CBPF (Brazil), and the University of New Delhi are either strongly interested in, or committed to, the system. At least three LEP and LEAR experiments are likely users. At LEP, as well as in the Fermilab fixed-target program, ACP modules will be used in data acquisition and monitoring, applications beyond the original concept of a system for high-level triggering and offline computing. Outside the realm of physics, we have had intensive inquiries from the U.S. Geological Survey and from the National Center for Atmospheric Research/National Oceanic and Atmospheric Administration, the latter for a real-time wind-shear warning system for airports. (Talk about practical spinoffs!) Of course, not all of these groups are committed to using the ACP system, but the strong interest they and others have shown tell us that, at the very least, we are on the right track.

The ACP group is excited about the opportunities for R&D into new architectures and co-processors using building blocks from the basic system. A connector on each CPU allows us to mount an auxiliary "daughter board" which can be used in a number of ways. An array-processor daughter board will carry out floating point calculations for theoretical and accelerator problems in a blinding flash. We can also use a daughter board to connect CPUs directly to their nearest neighbors in a "hypercube" architecture appropriate for lattice gauge calculations of quantum chromodynamics. Together with the Theory Department, we have determined that even before building a real hypercube connection, our present system has enough data-handling capacity to embed a pseudo-hypercube in it without, at least for some time, saturating the bus. Lattice gauge calculations will start early, and a collaboration of Fermilab theorists and the ACP could become a leader in this field.

There is also the promise of mating the present system with small "write once" optical disks (similar to audio compact disks). This should reduce, from a week or more to about half an hour, the turn-around time for physics analysis to drag through the reconstructed data of a large experiment. Combined with modern AI-style human interfacing software, the impact on physicist productivity in getting physics results out would be revolutionary. We find that very exciting.



The Support Columns

Continuing the State of the Lab, we go to the support structures.

Physics Department Column

Fresh from his successful wars on the TeV II front, Tom Kirk now reports as Head of the Physics Department:

Question: What has 206 legs, two heads, no arms, a college education, and turns over about once every three years? Answer: the Fermilab Physics Department. That's one way of looking at an unarmed agglomeration of 103 souls (about half of whom are scientists and engineers) that is headed by a pair of physicists with no training for management. This same organism experiences a constant turnover of personnel as post-doctoral fellows come and go and as temporary workers appear and disappear.

Well, is this gypsy outfit a troublesome embarrassment to the Lab? No! It's a featured ornament. It is the professional and intellectual home for all the experimental post-doctoral fellows and those staff scientists who are actively involved in high-energy physics experiments. It is responsible for other intellectual and educational activities that Fermilab sponsors, as well. Among these are the weekly Fermilab Colloquia, the aperiodic Academic Lecture Series, the famous Saturday Morning Physics classes, various special seminars, monthly dinner lectures for research associates, and various special physics meetings and workshops.

The Physics Department also aids staff scientists in the preparation of papers for publication and pays their journal page charges. Most of the travel to conferences, workshops, and group meetings for the purpose of fostering progress in physics is also sponsored and supported by the Physics Department. The provision of (more or less) quiet office space and computer terminals for the reduction of experimental data is an important adjunct of its mission.

Oh, then the Physics Department is a tweedy, marble column with pipe-smoking eggheads strolling about 'midst the soothing, quiet clicking of computer terminal keys. Well . . . not exactly. We also have the responsibility for designing, fabricating, installing, and maintaining a mind-boggling array of detectors and apparatus for high-energy physics experiments; this on behalf of the Fermilab staff scientists and post-doctoral research associates. To carry out this mission, the department employs a technical staff of engineers and technicians who solder and saw, drill and draw, push, pull, paint, survey, and service the myriad of exotic (and humble) devices that sense and record subnuclear particles as they interact and transform themselves in high-energy collisions.

For this design and fabrication work, the department occupies laboratory space in Wilson Hall and at several sites in the Fermilab Village. Part of the work, for example, involves the department in operating full-fledged assembly lines for the construction of wire proportional chambers and detector planes for a liquid-argon shower calorimeter. This sort of activity, staffed by technicians and temporary workers, has a pronounced industrial atmosphere and contrasts markedly with the analysis activities noted earlier. No, we are not just an ivory column.

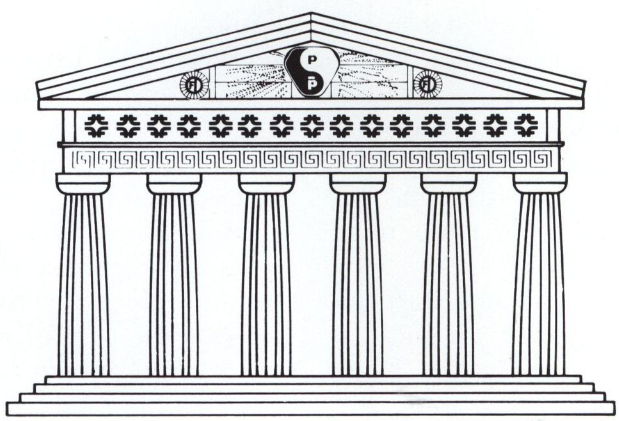
In addition to analysis in Wilson Hall, and to running production lines in the Village, a third important activity area for the department is the careful maintenance and upgrade of installed detectors in experiments throughout the fixed-target (and soon the colliding-beams) experimental areas. With the exception of the CDF detector, and several fixed-target experiments with no Fermilab collaborators, the Physics Department has apparatus in each of the experiments set up at Fermilab. Looking after all this equipment, plus repairing broken parts and upgrading or replacing components, is more than a full-time job for a small, dedicated corps of senior technicians who are assigned, experiment by experiment, to this work. The ground here is rather thinly covered in places. In recent experience, however, our customers report satisfaction with the results, so it must not be *too* thinly covered.

The biggest challenges to the Physics Department usually come in the design and fabrication of entirely new apparatus and detectors. This work involves mechanical, electrical, optical, and electronic components and systems, and often results in entirely new types of detectors or in state-of-the-art realizations of already invented ones. Recent examples of new Physics Department devices include design and construction of a set of giant (2m × 6m active area) drift chambers and over 100 precision, printed-circuit charge collection planes for a giant liquid-argon hadron calorimeter. Design of a new ring-imaging Cherenkov counter is now getting underway and prototype models of very large, high-precision proportional-tube detectors for the DØ experiment's Muon Detector are well along the design stage.

The designers and engineers who spearhead this work are an especially talented bunch who supervise well-trained drafters and technicians. They also keep a careful eye on the production of needed components and sub-assemblies produced elsewhere in Fermilab or in outside vendor job-shops. They always remember the patriot's watchwords: "Eternal vigilance is the price of freedom [from vendor error]".

For all but strongly list-oriented readers, this survey should round out a picture of the 1985 Fermilab Physics Department. For dedicated list readers, there is contained elsewhere in this *Report* a publication list for the year, the list of Colloquia, and the Academic Lecture Series list.

In short, for a partly revolving-door operation, the Physics Department plays a valuable and valued role in the life of the Laboratory.



A meeting of the Accademia del Cimento (Academy of Experiment) during the time of the Medicis. The Accademia stressed experiments on magnetism, the vacuum, and temperature measurement.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Theoretical Physics Column

The Theory Head, Chris Quigg, taking time from his schedule of research, SSC talks, and tennis, reports on Theory:

During 1985, members of the Theoretical Physics Department have contributed to a broad range of problems in the theory of elementary particles, and have continued to play a central role in the intellectual life of the Laboratory. The group has grown to include seven permanent members, four associate scientists with five-year appointments, and eight post-doctoral fellows. Several faculty members from nearby universities make Fermilab the focus of their research, and the traditional visitors' program continues to provide hospitality and support for nearly two hundred theorists each year. This brings new ideas to Fermilab, and makes the stimulating environment of the Laboratory — the experimental program and the (mostly intellectual) ferment of the third floor of Wilson Hall — available to many of our colleagues in other institutions.

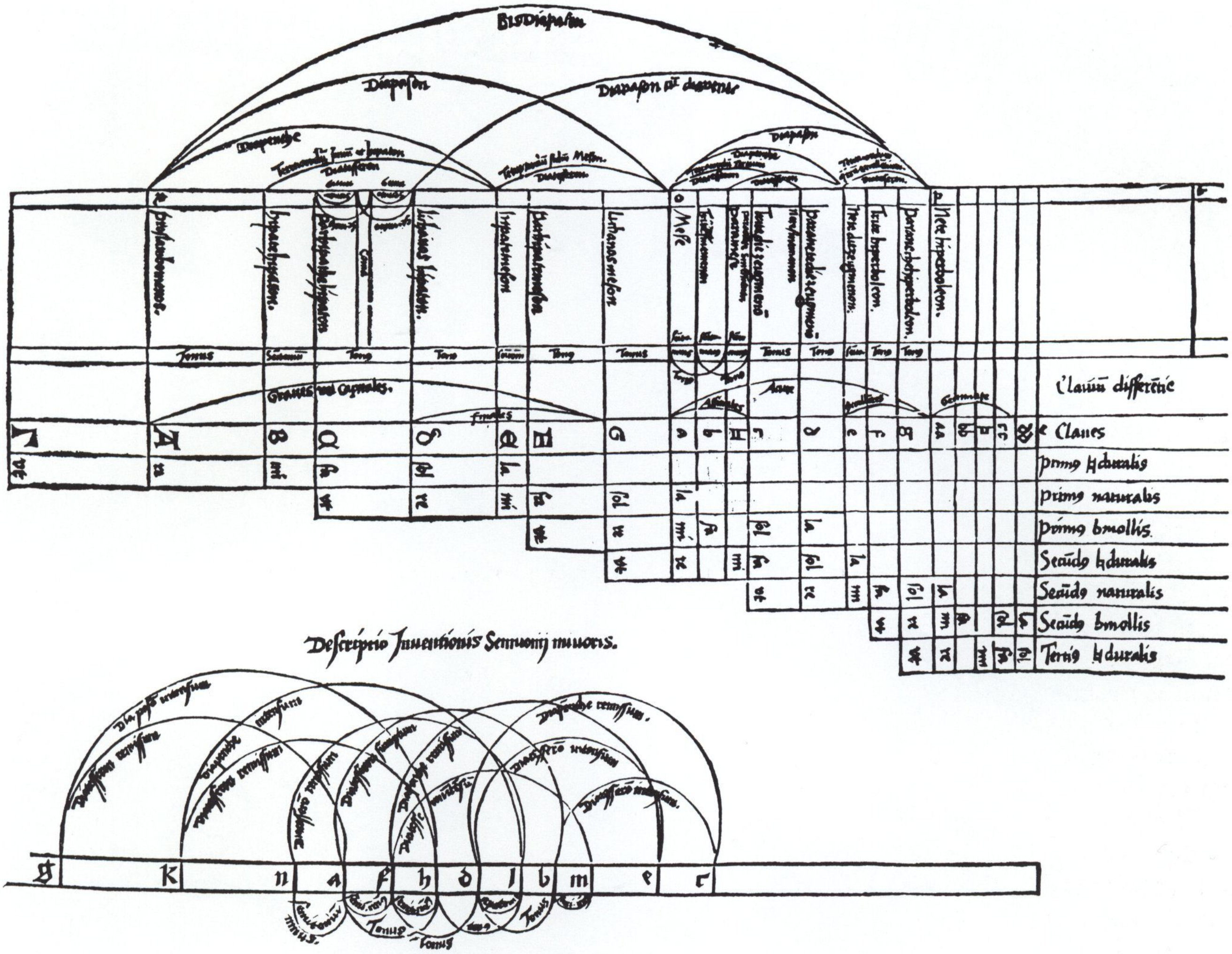
The organized activities of the group include the weekly Theoretical Physics Seminars and Joint Experimental-Theoretical Seminars. Each year, members of the group devote two sessions per week during the cruelest months to a Winter Workshop, a cooperative exercise in self-education intended to make all participants literate in some topical subject. Past Winter Workshops have concerned lattice gauge theories, supersymmetry, and gravity. The subject for 1985, anomalies, geometry, and topology, was a prelude to a conference of the same title sponsored in March by Fermilab, Argonne, and the University of Chicago, and organized by Bill Bardeen of Fermilab, together with colleagues from other institutions around Chicago. The 1986 Winter Workshop will focus on superstring theories.

Research highlights in 1985 range from fundamental problems in field theory to supercollider phenomenology. One particularly active area has been perturbative calculations in quantum chromodynamics (QCD), the gauge theory of the strong interactions. Stephen Parke and Tom Taylor have developed a new technique for the evaluation of multiparticle amplitudes, based on an application of supersymmetry, and have computed two-parton to four-parton cross sections in a manner which is suitable for fast numerical evaluation. Keith Ellis and Jim Sexton have calculated $2 \rightarrow 2$ and $2 \rightarrow 3$ parton scattering processes to order α_s^3. All these results will find immediate application to the experimental study of hadron jets at the CERN S$\bar{p}$pS and TEVATRON colliders, and are important for the understanding of backgrounds to exotic phenomena at the Superconducting Super Collider (SSC).

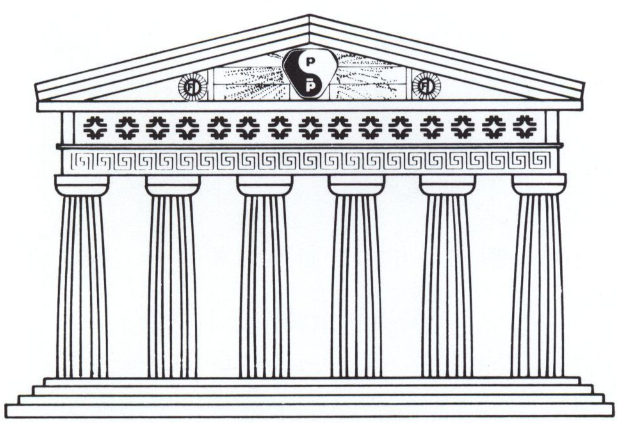
Hank Thacker and collaborators (including Jim Sexton) have been using the varied computing resources of the Laboratory (the VAX Cluster and the FPS-164 Array Processor) together with the MFE Cray-XMP machine at Livermore for their numerical simulations of quantum field theories on the lattice. Work during 1985 has addressed the phenomenological issues of decay constants of unstable mesons and baryons and the stability of a conjectured $\Lambda\Lambda$ dibaryon, and theoretical issues associated with length scales on asymmetric lattices.

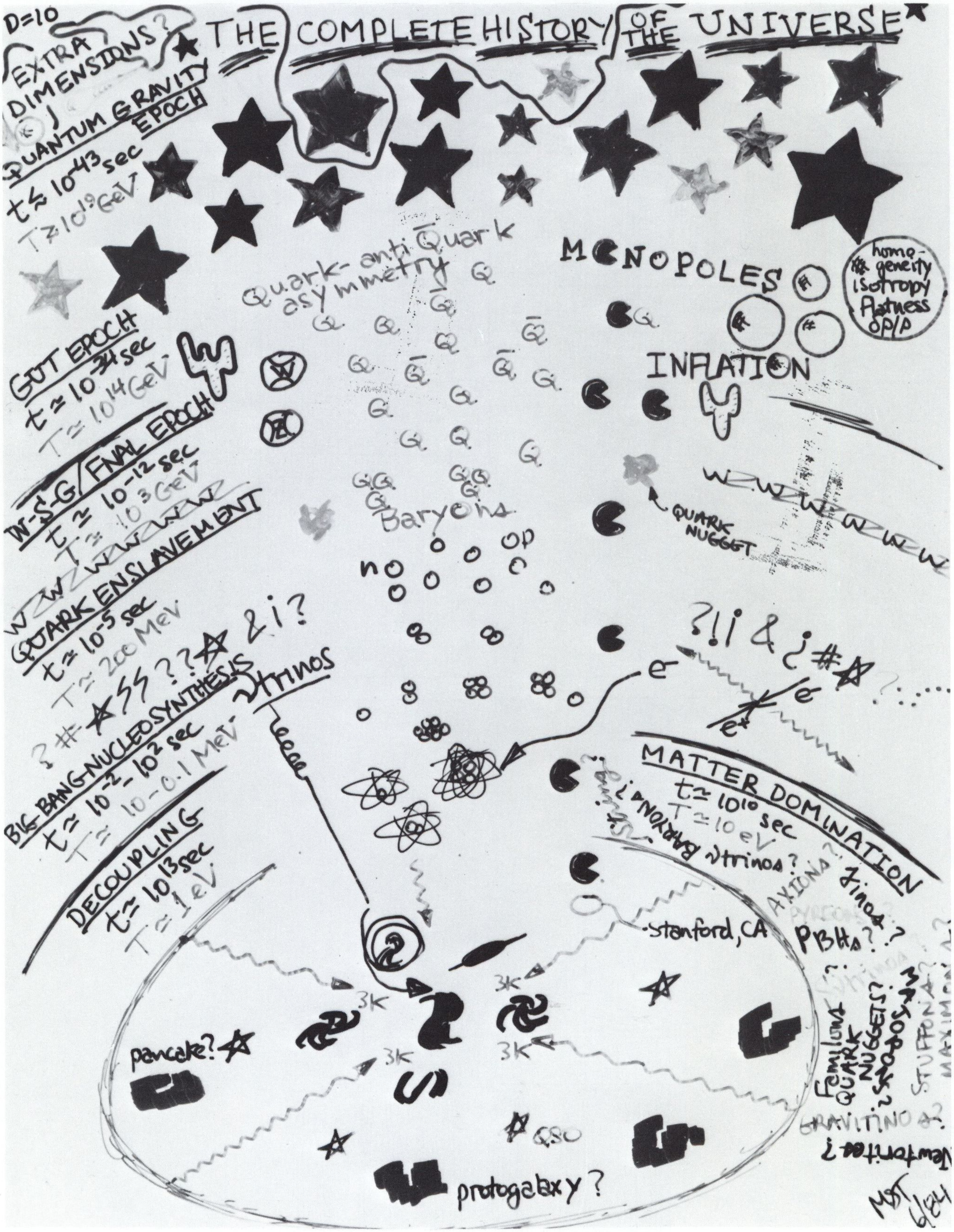
Among more formal efforts carried out within the group, it is appropriate to take note of some of the work on string theory and anomalies. Sumit Das and Mark Rubin constructed extended configuration spaces for string field theories, and are at work on the application of these spaces to string theory in curved space-time. Tom Taylor has analyzed the issue of dynamical symmetry breaking in superstring models in terms of an effective Lagrangian formalism.

The other subjects which have occupied the attention of Fermilab theorists are indicated by the seminar titles and list of publications included elsewhere in this *Annual Report.*



Music theory from the Margarita Philosophica, *A.D. 1517.*




THE COMPLETE HISTORY OF THE UNIVERSE
D=10
EXTRA DIMENSIONS?
QUANTUM GRAVITY EPOCH
t ≲ 10-43 sec
T ≳ 1019 GeV
GUT EPOCH
t ≃ 10-34 sec
T ≃ 1014 GeV
W-S-G/FINAL EPOCH
t ≃ 10-12 sec
T ≃ 103 GeV
QUARK ENSLAVEMENT
t ≃ 10-5 sec
T ≃ 200 MeV
BIG BANG NUCLEOSYNTHESIS
t ≃ 10-2 - 102 sec
T ≃ 10 - 0.1 MeV
DECOUPLING
t ≃ 1013 sec
T ≃ 1 eV
Quark-anti Quark asymmetry
Baryons
MONOPOLES
INFLATION
home-geneity
isotropy
flatness
δρ/ρ
QUARK NUGGET
νtrinos
e
e+
MATTER DOMINATION
t ≃ 1010 sec
T ≃ 10 eV
BARYONS?
νtrinos?
AXIONS?
Stanford, CA
PBHs?
3K
pancake?
QSO
protogalaxy?
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Astrophysics Column (NASA/Fermilab)

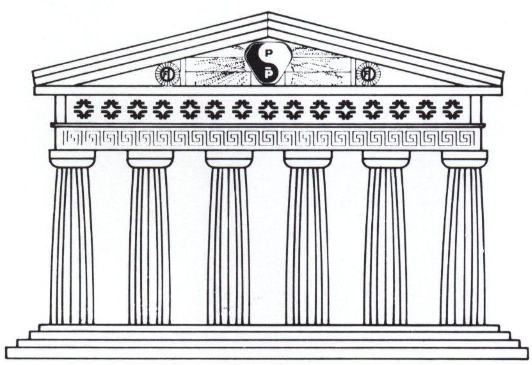
The west side of the third floor of Wilson Hall is Astro turf. Edward (Rocky) Kolb writes about the Astros:

The Theoretical Astrophysics Group at Fermilab is jointly funded by a grant from the Innovative Research Program (IRP) of the Office of Space Science and Applications of the National Aeronautics and Space Administration (NASA), and by Fermilab. The end of 1985 marks the third year of the existence of the Group. In these three years the Fermilab group has emerged as a world center at the interface of particle physics and cosmology.

The Group has grown over the three-year period to include three permanent staff members (E. Kolb, M. Turner, and A. Szalay), four post-doctoral fellows (at present, D. Lindley, R. Holman, L. Jensen, and J. Stein-Schabes), and numerous visitors, as listed in the appendices to this *Annual Report.* The center plans to make an additional appointment at the assistant professor level in the near future. The group is augmented by several members of the Fermilab Particle Theory Department who have similar interests in cosmology or astrophysics.

The foremost goal of the Theoretical Astrophysics Group is to do exciting and visible science at the interface of particle physics and cosmology/astrophysics. The prospects for the immediate future seem excellent. In 1986, Fermilab will begin to explore the structure of matter at center-of-mass energies of 2 TeV. At these energies it may be possible to start to explore the electroweak Higgs sector, and to start to uncover low-energy supersymmetry. Whatever may be found in this energy range is sure to have an impact on our picture of the origin of the Universe.

The scientific accomplishments of the group would be best summarized by listing the papers written and/or published by the Group in calendar year 1985. This list can be found in the Publications section of this *Report.* A complete progress report would include descriptions of the content of the papers listed. In the interest of brevity we will highlight work in three areas:

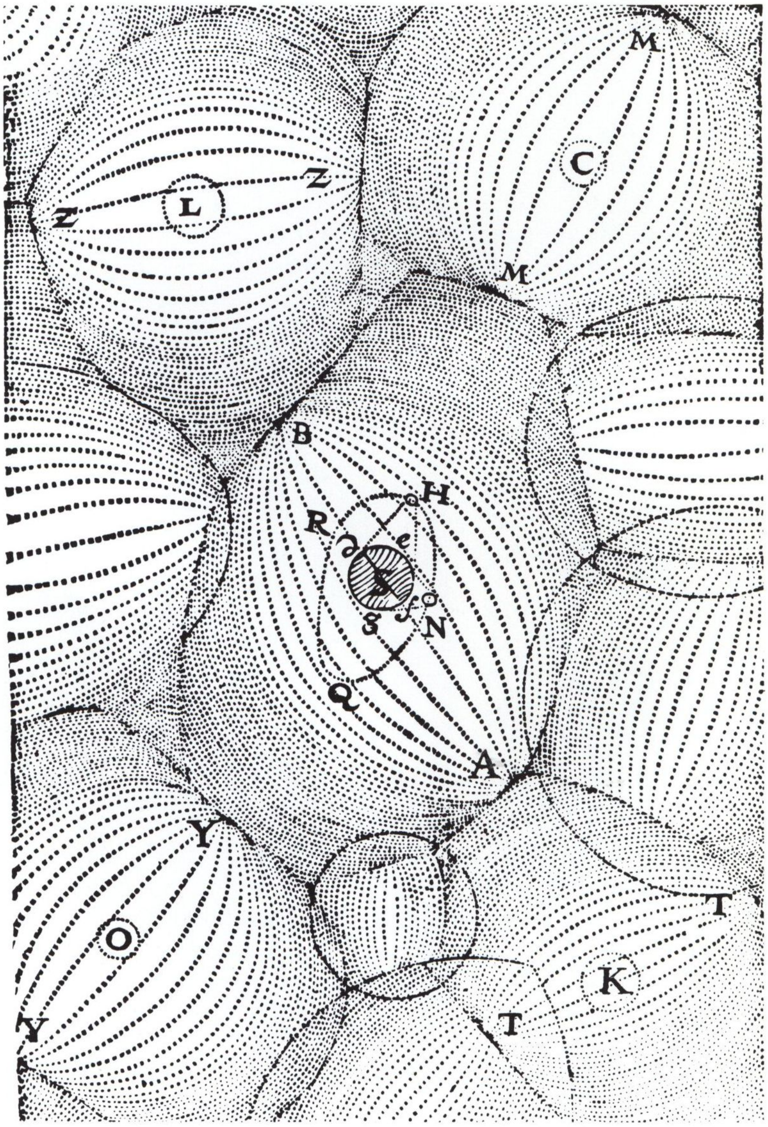


A Complete History of the Universe (courtesy of the Fermilab Astrophysics Group). Notable events include: The Quantum Gravity Era ($t \lesssim 10^{-43}$ sec), when the Universe may have had ten (rather than the current four) dimensions; The GUT Epoch ($t \approx 10^{-34}$ sec), when the symmetry between the strong, weak, and electromagnetic forces was broken, and the cosmic asymmetry between matter and antimatter, and monopoles arose, and cosmic inflation may have occured; Quark Enslavement ($t \approx 10^{-5}$ sec), when the Universe made the transition from a hot soup of free quarks and leptons to nucleons and leptons; Matter Domination ($t \approx 300$ yrs), when matter in the Universe became the dominant component — the $64,000 question is: what type of matter. We suspect that it is not ordinary nucleons, but rather exotic relic particles such as axions, photinos, or pyrgons. — M. S. Turner

Cygnus X-3

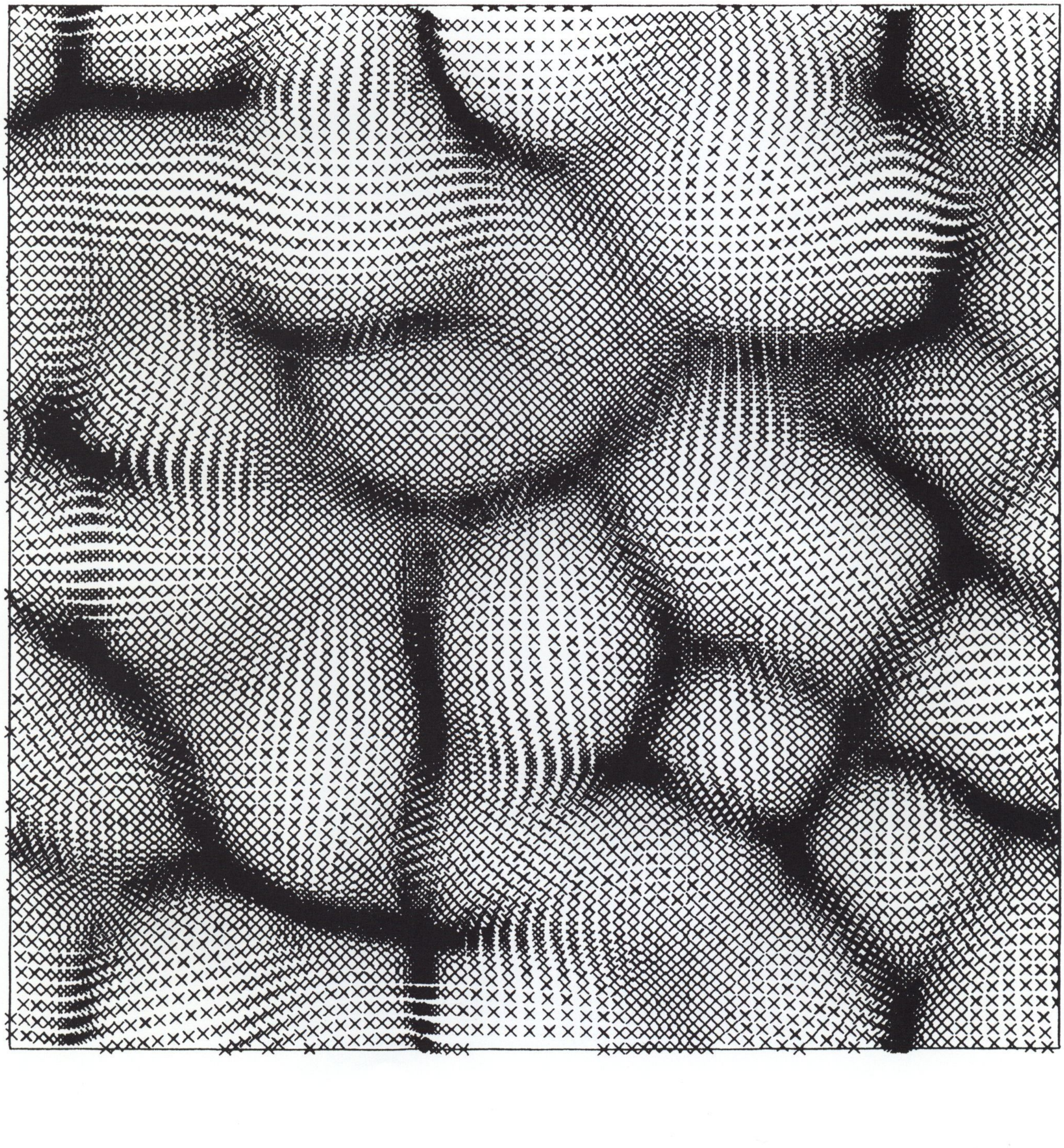
In 1985, two groups toiling deep underground have reported the observation of energetic muons in proton-decay detectors. They report an excess number of muons modulated with the 4.8^h orbital period of Cygnus X-3 coming from the general direction of Cygnus X-3. Kolb, Turner, and Walker of the Fermilab Astrophysics Group calculated the flux and zenith angle dependence of muons that would result from primary cosmic-ray neutrinos from Cygnus X-3. The result of the calculations of the Fermilab Group (and other groups) is that the reported signal cannot be explained by neutrino primaries.

The identity of the primary particle remains a mystery. Kolb and Walker, along with Larry McLerran of the Fermilab Particle Theory Group, Gordon Baym, an astrophysicist from the University of Illinois, and Robert Jaffe, a theorist from MIT, suggested that the primary particle from Cygnus (dubbed "Cygnet") is an H particle. The H particle, proposed by Jaffe in 1977, is a tightly bound, six-quark system with the quantum numbers of a di-lambda. The existence of the H particle is amenable to discovery at present-day accelerators. If the H is the Cygnet, the production mechanism proposed would revolutionize our view of neutron star structure and cosmic ray physics.



Detecting Dark Matter

Astronomical observations suggest the existence of a component of the mass density of the Universe that is dark. The identity of this ubiquitous dark matter is one of the fundamental questions in cosmology. It seems unlikely that the dark matter could be nucleonic, so cosmologists have to admit that they don't know what the Universe is made out of. In the past few years, particle physicists have been remarkably generous in proposing new particles as candidates for the dark matter. The most direct way to test the viability of a candidate particle is to produce and study it at accelerators. It is conceivable the $p\bar{p}$ collisions next fall at Fermilab will produce evidence of low-energy supersymmetry. If low-energy supersymmetry exists in nature, the lightest supersymmetric particle should be stable, and hence is a candidate for dark matter.



Another possible way to search for dark matter is through its present-day astrophysical effects. Keith Olive of the Fermilab Astrophysics Group, along with Joe Silk (University of California, Berkeley) and Mark Srednicki (University of California, Santa Barbara) have pointed out that if the Universe contains a near-critical density of photinos which are also assumed to constitute the dark matter in our galactic halo, then gravitational trapping by the sun and ensuing photino annihilations in the solar core yields a significant flux of 250-MeV neutrinos. This neutrino flux may be detectable in underground detectors. By detecting high-energy solar neutrinos we may be able to uncover the matter of the Universe.

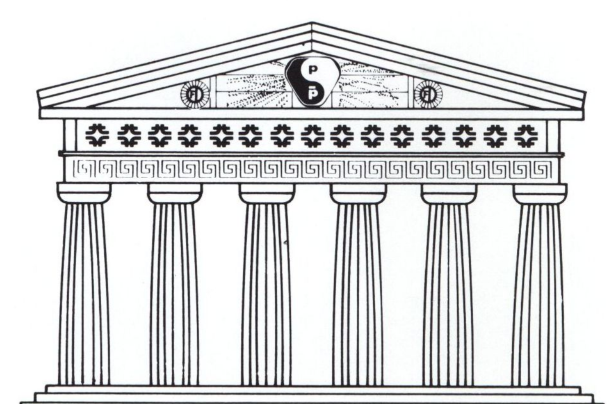
Extra Dimensions/Inflation

The search for a consistent quantum theory of gravity seems to lead to the requirement that the dimensionality of space-time is greater than four. In order to reconcile this requirement with our everyday experience of three spatial dimensions, it is necessary that the extra spatial dimensions today are small and compact. Superstring theories require that the typical size of extra dimensions is about the Planck length, $L_{PL} = G_N^{1/2} \approx 10^{-33}$ cm. This length is more than 60 orders of magnitude larger than the typical size of the three observed spatial dimensions, the Hubble length of $L_H = H_0^{-1} \approx 10^{28}$ cm. The usual question is, why are the extra dimensions so small? However, a better question is, why are the observed dimensions so large? If dimensions have anything to do with gravity, the only reasonable scale is the Planck scale.

One possible solution to the problem of large dimensions is the inflationary Universe proposal of Alan Guth. In this proposal the Universe went through a phase of exponential expansion. F. Accetta and D. Zoller of the University of Chicago, and M. S. Turner of Fermilab have studied inflation in models of induced gravity. Lars Jensen and Keith Olive have studied inflation in non-minimal supergravity models.

The question of inflation with extra dimensions is more complicated, since it is necessary that only three dimensions expand, while the other spatial dimensions either remain static or contract. The role of inflation with extra dimensions was reviewed by Kolb, and Frieman and Kolb explored problems of keeping the extra dimensions static.

The inflationary Universe will continue to be a major effort of the Fermilab Astrophysics Group.

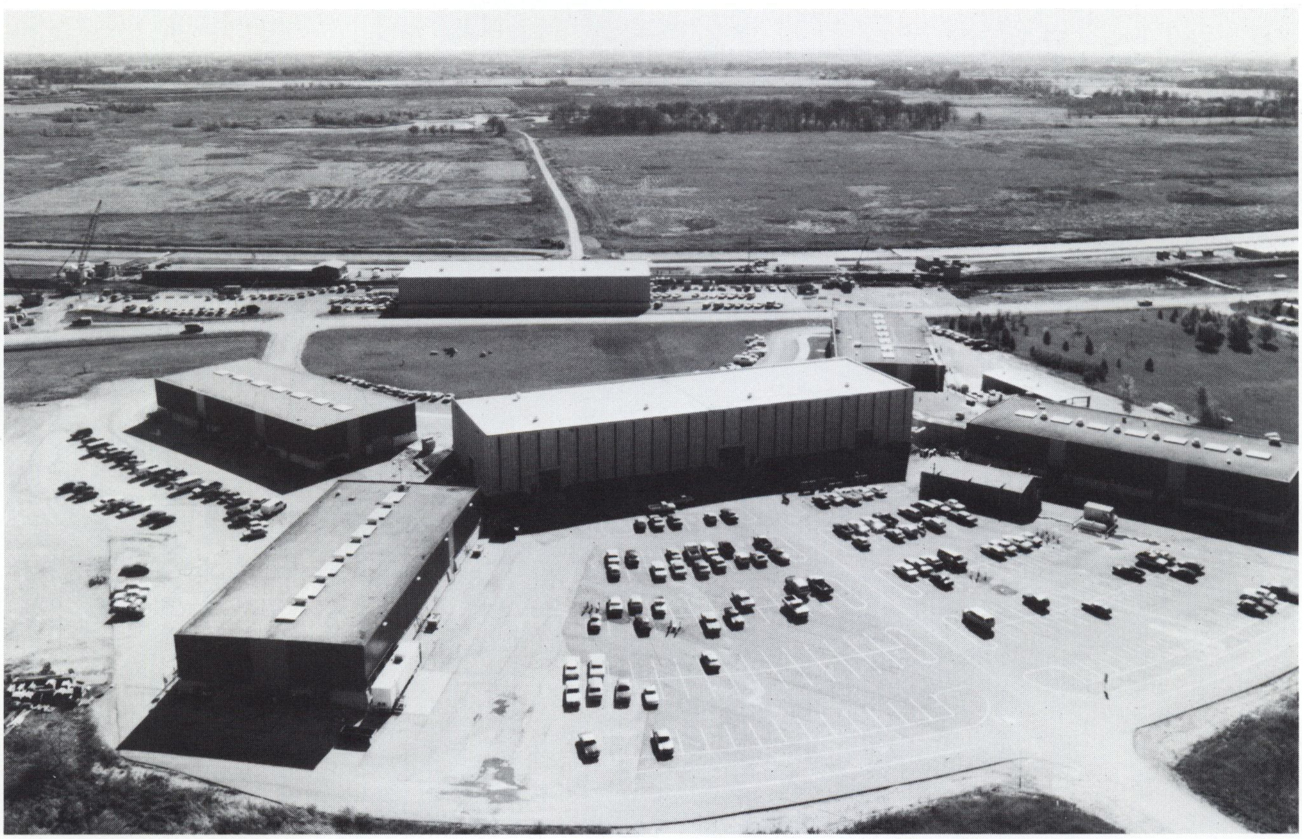


Technical Support Column

The Technical Support Section incorporates the Magnet Facility and related services including magnetic measurements, mechanical engineering, design, drafting, and shop services. This particular group was assembled to efficiently carry out the production of magnets and other vital components, first for the TEVATRON and then for the TeV I Proton-Antiproton Collider. With those two projects complete, finely-honed design and fabrication skills are being directed toward the new collider detector at D0 and the SSC. These projects, together with continuing services for the accelerators and experiments, constitute a vigorous level of activity for the foreseeable future. Paul Mantsch, Head of the Technical Support Section, supplies some details:

Magnets for the Proton-Antiproton Collider

The Technical Support Section contributed in a major way to the spectacular success of the Fermilab Proton-Antiproton Collider. Having produced over 1200 superconducting magnetic components for the TEVATRON, the magnet-assembly facility turned out another 700 conventional magnets for the Antiproton Source Accumulator and Debuncher rings. The last of the Accumulator magnets were painted, measured, and shipped during the early spring of 1985. The large-scale production experience gained from the TEVATRON and Collider projects will equip Fermilab to make unique contributions to the design and procurement of the magnetic components for the SSC.



The Magnet Facility complex. The tallest structure, Industrial Center, is also the newest. The B0 Experimental Area, home to CDF, is the upper-most structure in this photograph.

The main work floor of Industrial Center. To the left are three levels of enclosed labs, drafting facilities (both manual and CAD), and offices.

Magnets for Experiments

Early 1985 also saw delivery of the last in a series of over 200 beam-transport dipoles and quadrupoles which were part of the TEVATRON II program to upgrade external beamlines for the higher-energy beams of the TEVATRON. Since these magnets were not subject to the rigid requirements of those for the accelerators, some subassemblies, such as coils, could confidently be made in industry. Final assembly of the magnets, generally of an existing design, was carried out in the Technical Support Magnet Facility.

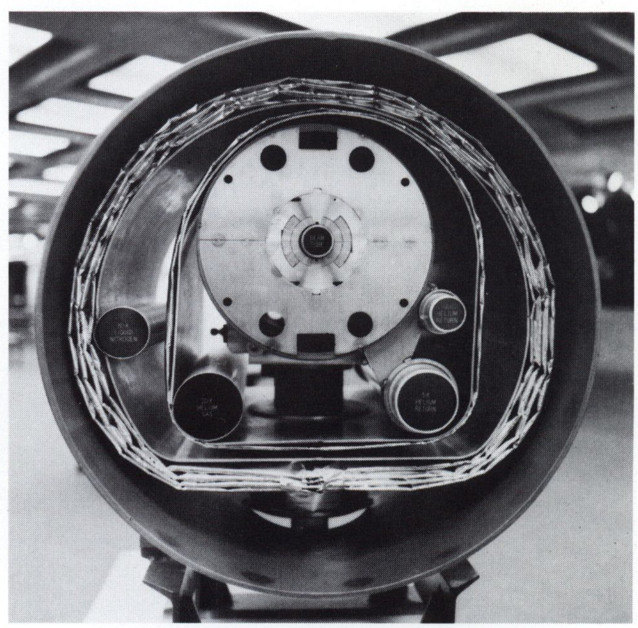
A major project of the Magnet Facility during the past year was the assembly of coils for three large spectrometer magnets for use in the Wide-Band Photon Experimental Hall. The 65 coils, containing over 90 tons of copper, were wound in industry and shipped to Fermilab for insulating and assembly. The coils were hand-wound with epoxy-impregnated tape, nested together, and cured in a mold to final shape.

Magnets for the SSC

The proposal for a 20-TeV on 20-TeV proton-proton collider (the SSC) was first seriously made at the 1982 Division of Particles and Fields' Summer Study on Elementary Particle Physics and Future Facilities at Snowmass, Colorado. Since the dipole magnets composing the proposed 60-mile-diameter ring account for a third of the project cost, initial effort was focussed on developing a reliable, low-cost magnet design. Magnet R&D programs were started at the national laboratories with superconducting magnet experience: BNL, LBL, and Fermilab, and later at the Texas Accelerator Center north of Houston. Although different ideas were pursued at each laboratory, the designs had converged, by late 1984, into two distinct styles. The national laboratories collaborated on a high-field (6 tesla) design while Texas tried to adapt a conceptually simpler, iron-dominated low-field magnet to the task. A special committee was convened in October of 1985 to select a final magnet style so that the meager resources available for development could be concentrated on a single design. These deliberations resulted in the selection of a high-field magnet.

The high-field magnet as currently conceived has a Fermilab-style "cosine theta" collared coil surrounded by an iron yoke at liquid-helium temperature. The cryostat is designed to have a heat leak less than one-tenth that of the TEVATRON dipole. The ends are very simple and can be joined with automatic welding techniques. To further minimize end costs, the magnets are made 16.5 meters long, about the practical upper limit for handling and transport.

Present plans call for the completion of four prototype magnets beginning in early 1986. These magnets will be cold tested and then set up in a string for tests and system development. The coils for these models will be made at Brookhaven National Lab and sent to Fer-



Cross section of a prototype SSC Reference Design D magnet and cryostat.

milab. The coils will be assembled into cryostats now being designed and built at Fermilab.

Fermilab has had a continuing intimate involvement with research and development for the SSC. A program was carried out to develop conductor, coils, and cryostats. A series of models were made to test new design concepts and to measure performance. In the national SSC prototype-magnet program, Fermilab is responsible for the cryostat, final magnet assembly, and testing. Tasks include the development of a low heat leak suspension, thermal radiation shields, containment vessel, and the magnet-to-magnet interface. The cold mass suspension uses a re-entrant post made of thin tubes of fiberglass-reinforced epoxy and stainless steel. The post features simplicity and low cost together with low thermal conductivity.

Magnets for Others

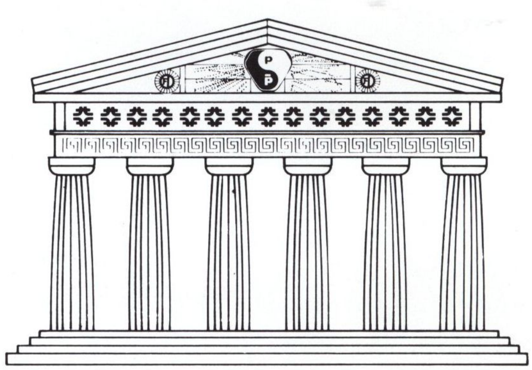
As the reputation of the Fermilab Magnet Facility has spread far and wide, a steady stream of requests for very specialized magnets and other unique magnet-related services has come in. Fermilab has been able to help other labs, university groups, and industrial concerns when our special facilities are required.

Three high-gradient superconducting quadrupole triplets are being made for the Stanford Linear Collider final focus. Twelve dipole magnet yokes are being stacked for the University of Indiana. Magnetic measurements were made of a quadrupole for Michigan State University. Consultation on magnets has also been provided to the designers of the Continuous Electron Beam Accelerator Facility (CEBAF) to be built in Newport News, Virginia.

Magnetic Measurements

Making reliable magnetic measurements to a precision of one part in ten thousand is a challenging enterprise. Making such measurements quickly and confidently in production compounds the difficulty. A great deal was learned, often painfully, in the measurement of the TEVATRON magnets. Anticipating that the measurement of the dipoles and quadrupoles for the Antiproton Accumulator and Debuncher would be even more demanding, the Magnet Test Facility group designed a highly automated system.

The new VAX-based measurement system depends on real-time data checking and analysis. The measurer is presented with results in a way that clearly indicates the quality of the measurements. A calibration database is keyed to the appropriate probe by a hard-wired identifier. Motions of the probe, changes of polarity, and magnet current monitoring are done by the computer. The measurements provide the reliable feedback necessary to ensure the quality production of the magnets and are no doubt an important factor in the success of the Collider. The TeV I measurement system has worked very well and will be a model for future projects, particularly SSC.

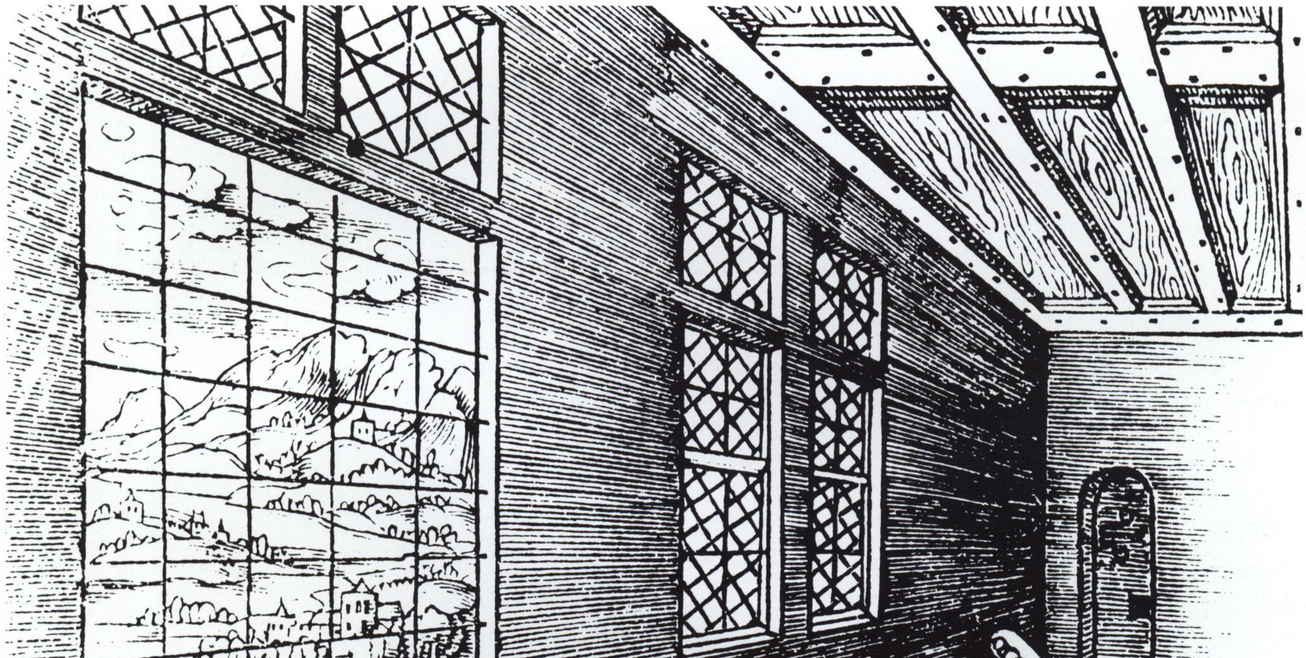


Automated Engineering, Design, and Machining

The use of computers as a tool in engineering, design, and machining has made important advances in the past few years at Fermilab in general and in the Technical Support Section in particular.

Although finite element analysis has been used extensively in structural analysis, it has been used only recently in thermal analysis. Development of the design for the SSC magnet cold mass suspension, for example, has used both of these tools.

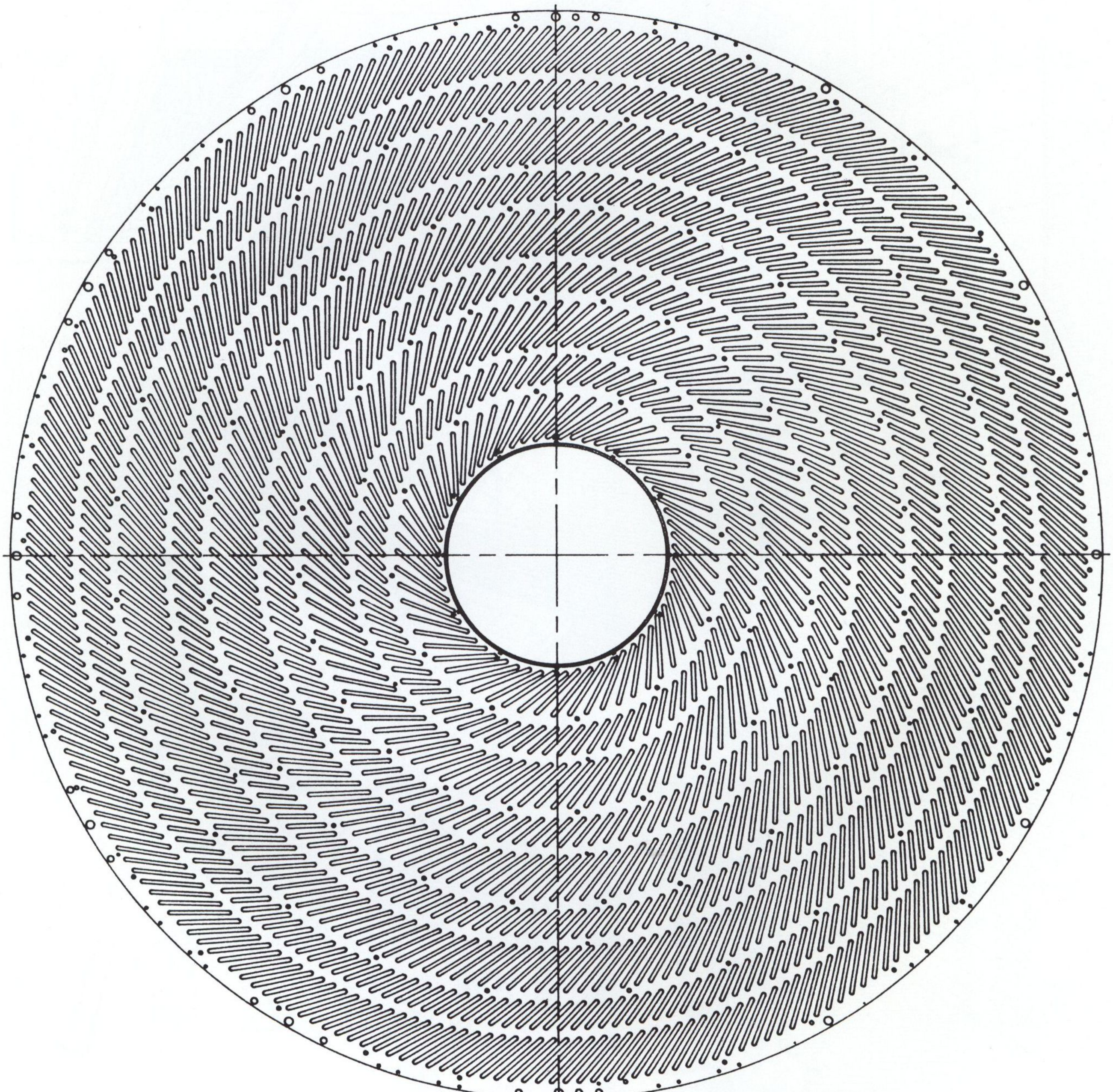
The use of computer-aided drafting has assumed an ever increasing fraction of drafting activity. Of the 30 designers and draftsmen in



Automated drafting in 1531: "drawing in perspective" using a grid for reference.

the Drafting and Design Group, more than half have training in computer-aided design (CAD). There are presently ten high-resolution color-graphic terminals which allow designers to access the CD2000 CAD programs in the Fermilab computer center. As the use of this system has matured, more and more advantage is being taken of its powerful features. Complex parts for the CDF central tracking chambers would, for example, have been extremely difficult without CAD.

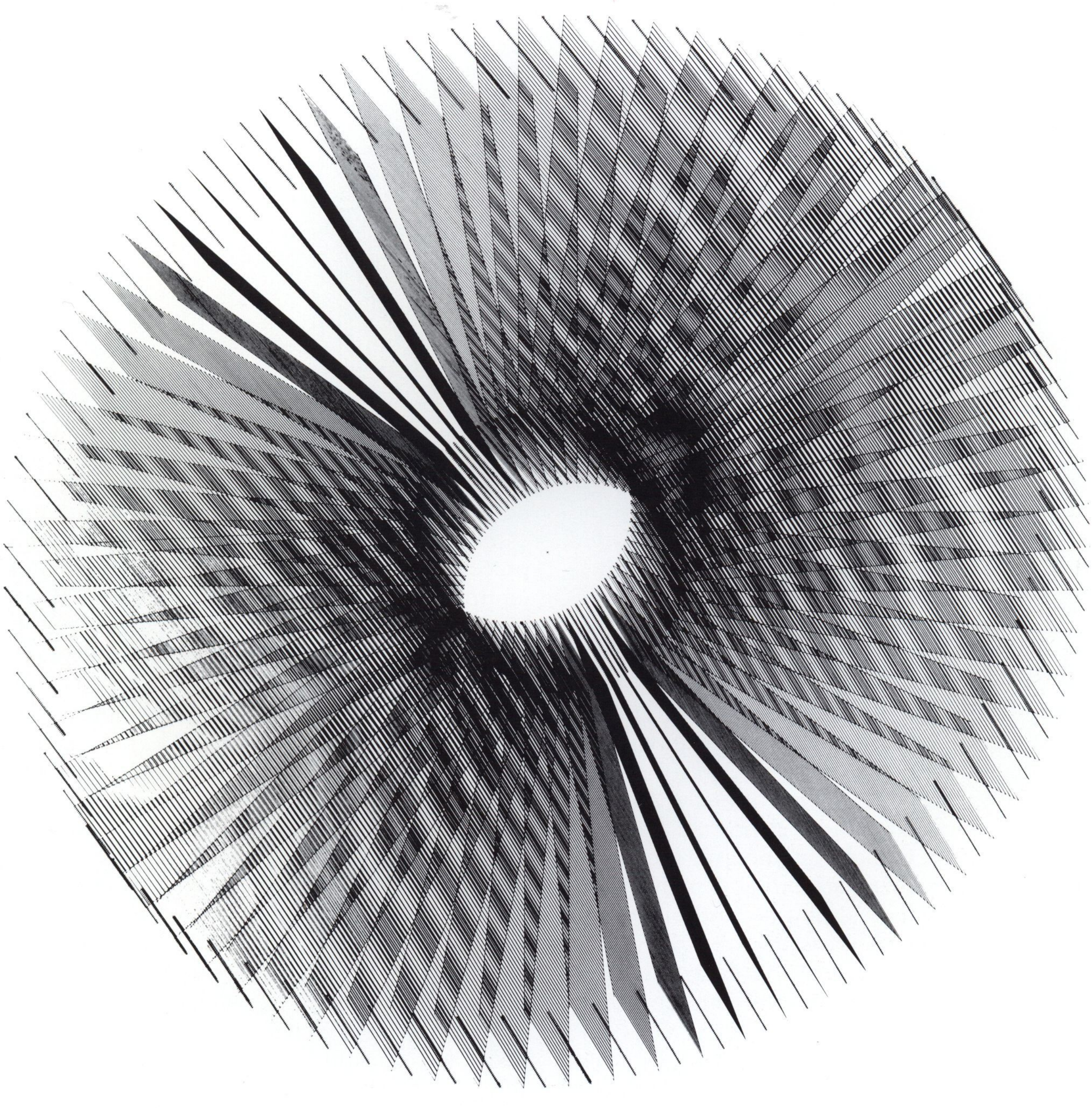
The next step in computer-aided design and fabrication is in taking CAD-generated files directly to the machine tools via computer-aided machining (CAM). The first tentative steps have been taken to make the CAD/CAM interface at the Fermilab machine shops. Mixing silicon chips with metal chips has been an



A computer-aided drawing of a CDF central tracking chamber endplate.

interesting and, in many ways, gratifying experience. Computerized machining brings together rather diverse groups of people: designers, machinists, and computer programmers. The response of the Fermilab machinists to this revolution in their trade is remarkable. Although the shop has only one CNC milling machine, an NC horizontal mill and NC plasma torch, nine machinists already have sought training on computer-controlled machine tools.

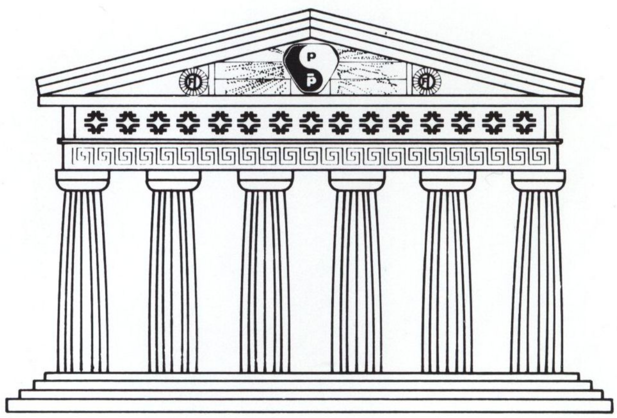
Complex supports for the coil ends of superconducting magnets were the first parts successfully machined from CAD data files. As the CAD/CAM interface becomes simpler and more standard, new applications of this technique will become evident.



A computer-aided drawing of a CDF radial wire drift-chamber configuration.

The last step in the engineering-design-fabrication cycle is inspection of the resulting part. As the parts become more complex, so does the inspection task. The Technical Support Inspection Group needs access to the CAD files in order to compare the part with the design. Interfacing the CAD files to Inspection's computerized coordinate measuring machine (CORDAX) is now under study.

Physics experiments and the accelerators that support them require innovative methods and instruments. Data acquisition, data reduction, and data control have challenged the frontiers of electronics and computers. The rapid fabrication of precision, complex, mechanical apparatus also has an important impact on the quality of our science. Integration of computers into engineering, design, and machining will greatly enhance that capability.



Construction Engineering Services Column

The fifth column is famous in history and justly so at Fermilab. This used to be called the TEVATRON Construction Group and as such, it was responsible for the civil construction of structures worth $55 million. Wayne Nestander, who heads Construction Engineering Services, was present at the very beginning. He dwells on the history of Fermilab construction since this is, to our knowledge, not recorded anywhere:

Civil or conventional construction at Fermilab includes a diverse blend of civil and geotechnical engineering, architecture, and specialized structural design. In addition, large electrical-power distribution systems and complementary air/water cooling systems ultimately dissipate the energy needed in the various Fermilab accelerators and experimental areas.

Since civil construction may be a substantial fraction of an accelerator construction budget, both innovative and practical engineering and design leading to cost-effective construction is essential. Often, the civil construction design preceeds the development of the accelerator equipment or systems that will be contained by the construction. Hence, operating flexibility and adaptability must be included in many areas of the civil design.

Civil engineering and construction has been carried out by many organizations both inside and outside of Fermilab during the past eighteen years. Initially, the architect-engineer consortium, Daniel, Urbahn, Seelye, and Fuller (DUSAF), provided the civil design during the 200-BeV Accelerator construction era. Later, other outside engineering firms, as well as Fermilab personnel, have continued the civil design work. As needs have changed through the years, the Fermilab organizational names relating to civil design have ranged from Plant Modifications, Architectural Services, and TEVATRON Construction to, at present, Construction Engineering Services.

Fermilab Director Emeritus Robert R. Wilson with the model of the new Central Computer Facility which he designed.

No matter what the organizational designation, the role of civil engineering and design at Fermilab is to provide the conventional facilities and services required for the scientific programs. The following review presents some of the construction history at Fermilab and describes civil engineering and construction work presently underway.

200-BeV Site Planning at Weston

The 200-BeV site provided by the state of Illinois included 6800 acres of farmland and the small village development of Weston. At the outset, the task of DUSAF was not only to site-plan for the 200-BeV Accelerator, but also to provide the services and utilities normally associated with a city of moderate size. Parallel with these efforts, DUSAF was required to provide offices and shops at the site for a scientific staff of ever increasing size.

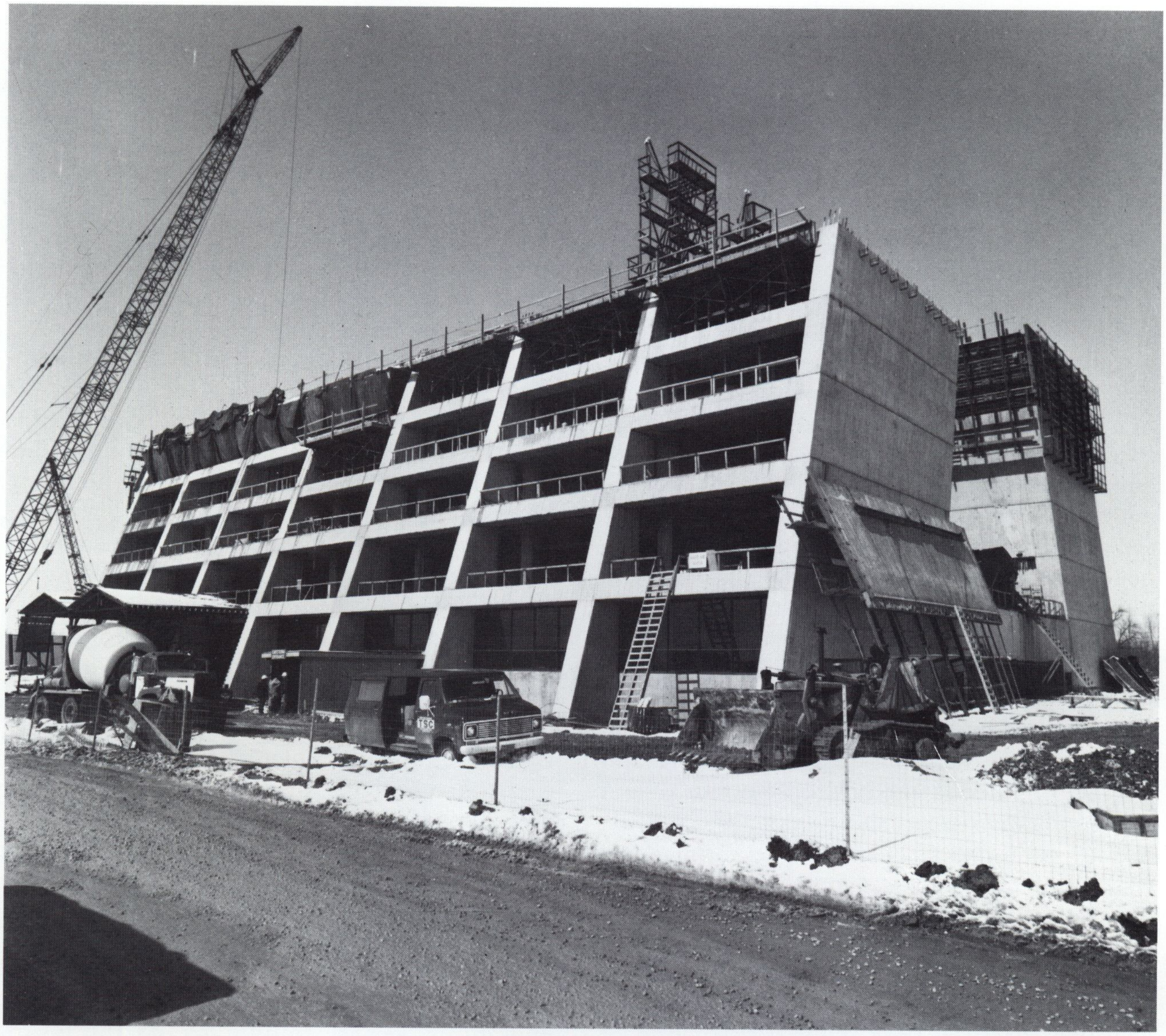
Initial site planning was given considerable emphasis and attention by Robert R. Wilson, the first director of Fermilab. Under his leadership, the basic relationship of the Accelerator ring and Experimental Area beamlines were drawn and redrawn to achieve a balance in required accelerator geometry, topography, effect on neighboring cities, historical and archeological features, road systems, and site drainage. Special attention was given to preserving forest areas, marshlands, streams, and even existing farms with unusual barns, homes, or silos. In driving about the site today, one finds roads or ponds that veer away to miss a stately grove of oaks, or an old Dutch-style barn next to a new beamline enclosure. Several

Main Ring tunnel sections in place, but not as yet covered, in 1970.

farmsteads complete with houses and barns are preserved and used for housing, offices, or maintenance facilities.

Many building structures at Fermilab are completely underground or covered with earth shielding at grade. To mark the location of these structures, related facilities such as roads, ponds, and berms were constructed parallel to the buried structures. Fermilab is readily identified from passing airplanes, and the Main Ring Road and Ponds are even discernable on high-altitude satellite photography of northern Illinois.

Since the Weston site, now designated the Fermilab Village, included a housing development, it was natural that these homes became the offices for the first employees on the site. Many of the homes were subsequently moved about the Village to be joined into larger, more useful office groups. Some of these homes were later reconverted to on-site housing for visiting scientific staff. A number of new pole-buildings were quickly erected in the Village next to the house/offices, and these buildings continue to be used as shops and laboratories. Many of the farm homes scattered about the



Construction progress on Wilson Hall, circa 1972.

6800-acre site were moved and clustered around several farm houses adjoining the Village. These houses are also used as dormitory and apartment space for visitors.

200-BeV Civil Construction

The civil design of the Accelerator structures and facilities was done in parallel with the site development and the technical design of the Accelerator components. As the parameters for the Preaccelerator, Linac, Booster, Main Ring, and Experimental Areas were defined and refined, the DUSAF organization produced the detailed drawings and specifications for the construction contracts. Field inspection, scheduling, and construction management functions were also done by DUSAF. The DUSAF construction manager, E. Parke Rohrer, and his capable organization provided superb and timely engineering design and construction management effort during this 200-BeV construction period.

The architectural appearance of Fermilab was also given considerable emphasis and attention by Robert R. Wilson. His talents as avocational sculptor and architect show through in the designs of many Fermilab buildings as well as related equipment items and systems. Wilson Hall, the 16-story-high office building, rises above the Illinois prairie and indicates the Fermilab site from many miles distant. Other low-rise buildings relate to each other, and to the general prairie site, through a common architectural style. Parking areas, roads, and cooling ponds are designed to complement the design of the adjacent buildings as well as to provide technical functions and personnel conveniences. Technical equipment such as substations and cooling towers are placed by buildings to enhance overall appearance and, at the same time, provide the required services. Electrical transmission lines entering the site are carried on pole structures combining function with pleasing line and form. The general style of civil construction promulgated by Wilson, and continuing to the present, is to incorporate the scientific and engineering needs into both cost-effective and eye-appealing design solutions.

The civil construction of the 4-mile-long Main Ring enclosure had major impact on both construction costs and schedules. As a basis for design, extensive geotechnical explorations were done by DUSAF and other consultants. The resulting data were analyzed in detail by Tom Collins in order to relate the Accelerator alignment and stability criteria to the civil engineering parameters. Earlier conceptual ring enclosure designs had posited deep caissons or pile foundations to bedrock under the entire 4-mile ring circumference. Based on Collins' analysis, the Main Ring was placed on a structural concrete mat approximately 20 feet below grade and into a stiff glacial till stratum. No piles or caissons were used and considerable construction cost economies and schedule improvements were achieved. The long-term stability of the ring enclosure in this glacial till has proved the wisdom of these decisions.

The construction schedule was also improved by using precast concrete arch sections for substantially all of the 4-mile circumference instead of the conventional cast-in-place methods. An on-site casting yard produced approximately 2000 precast arch sections. As these sections were placed and sealed on the cast-concrete base mat, the backfilling and completion of the Main Ring enclosure proceeded rapidly. Considerable cost reductions over cast-in-place concrete were also achieved.

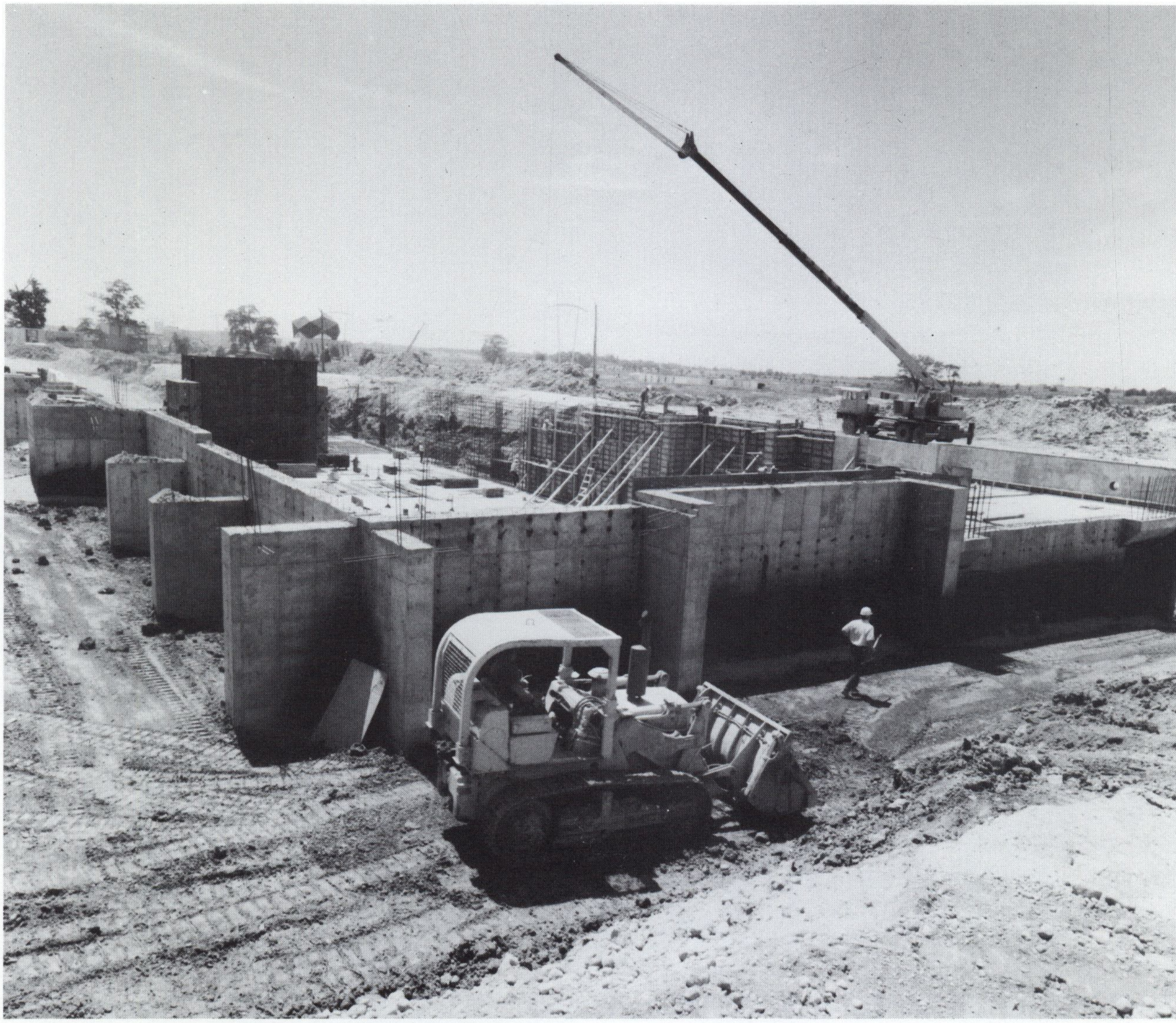
TeV I/TeV II Civil Construction

After completion of the initial 200-BeV facilities, in 1972-1973, civil construction at Fermilab continued on a much reduced scale to provide additions and extensions to existing facilities in the Experimental Areas. However, in the late 1970s Fermilab embarked on three major improvement programs, Energy Doubler/Saver, TeV I, and TeV II. The TeV programs both required extensive civil construction. TeV I was to provide the facilities and equipment for producing, accelerating, and colliding antiprotons with protons. TeV II was to improve the Experimental Areas to utilize the higher-energy beams provided by the Energy Doubler/Saver.

The TeV I civil construction that provided for antiproton production and acceleration included the F-17 Extraction Hall, the Antiproton Target Hall, the Antiproton Source Rings enclosures, service buildings, and the beamline enclosures connecting these structures. Additions and extensions to primary power distribution and cooling systems were also required. The total civil construction for the Antiproton Source segment approximated that of a completely new accelerator of modest size.

The TeV I civil construction that provided for the antiproton-proton collisions included the B0 Experimental Area, the B0 Beam Overpass, the D0 Experimental Area, additions to several Main Ring service buildings, and extensions and additions to power and cooling systems.

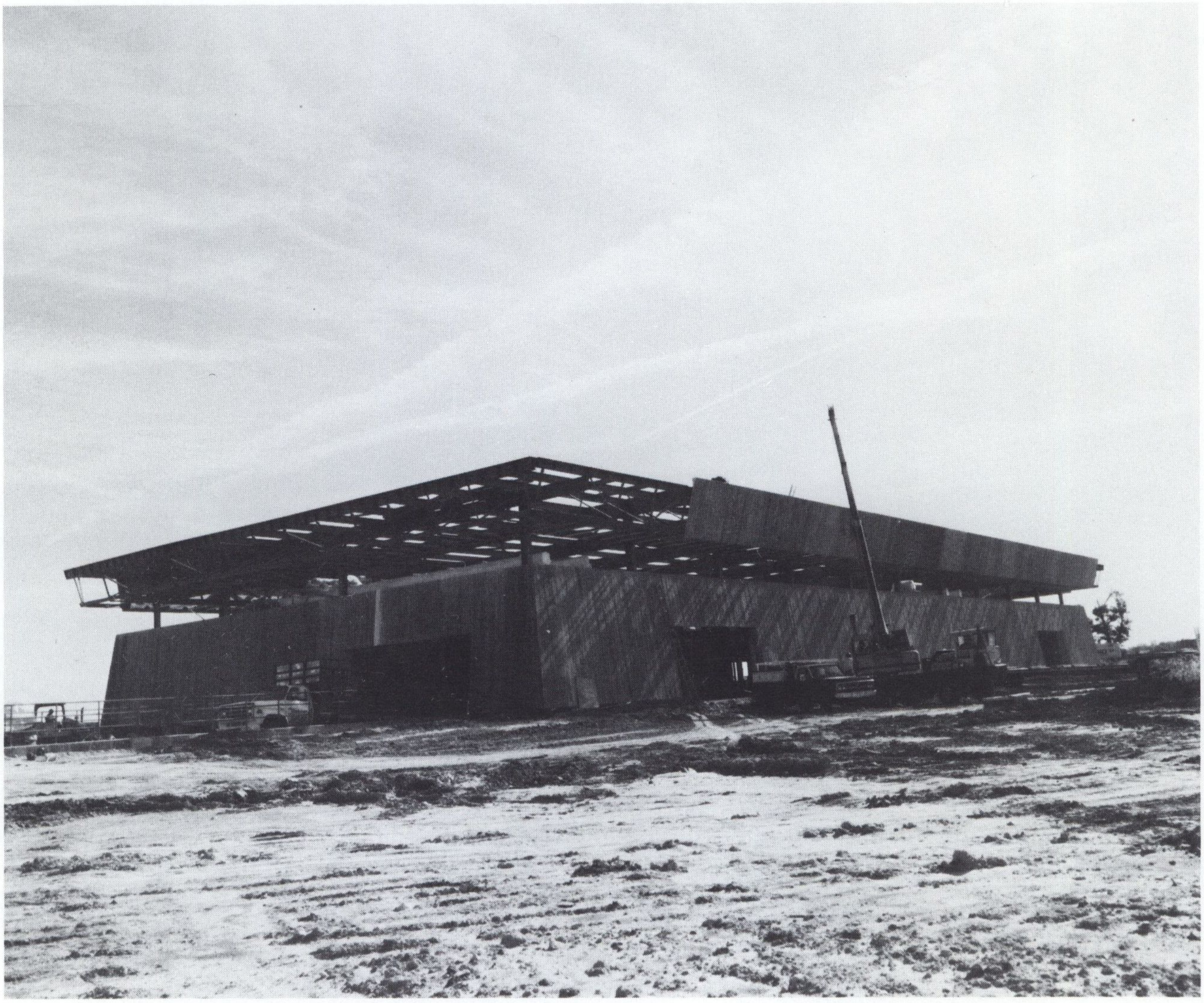
The TeV II civil construction included four new beamlines, the Muon, Wide Band, MW, and MP Beam Lines, as well as upgrades on



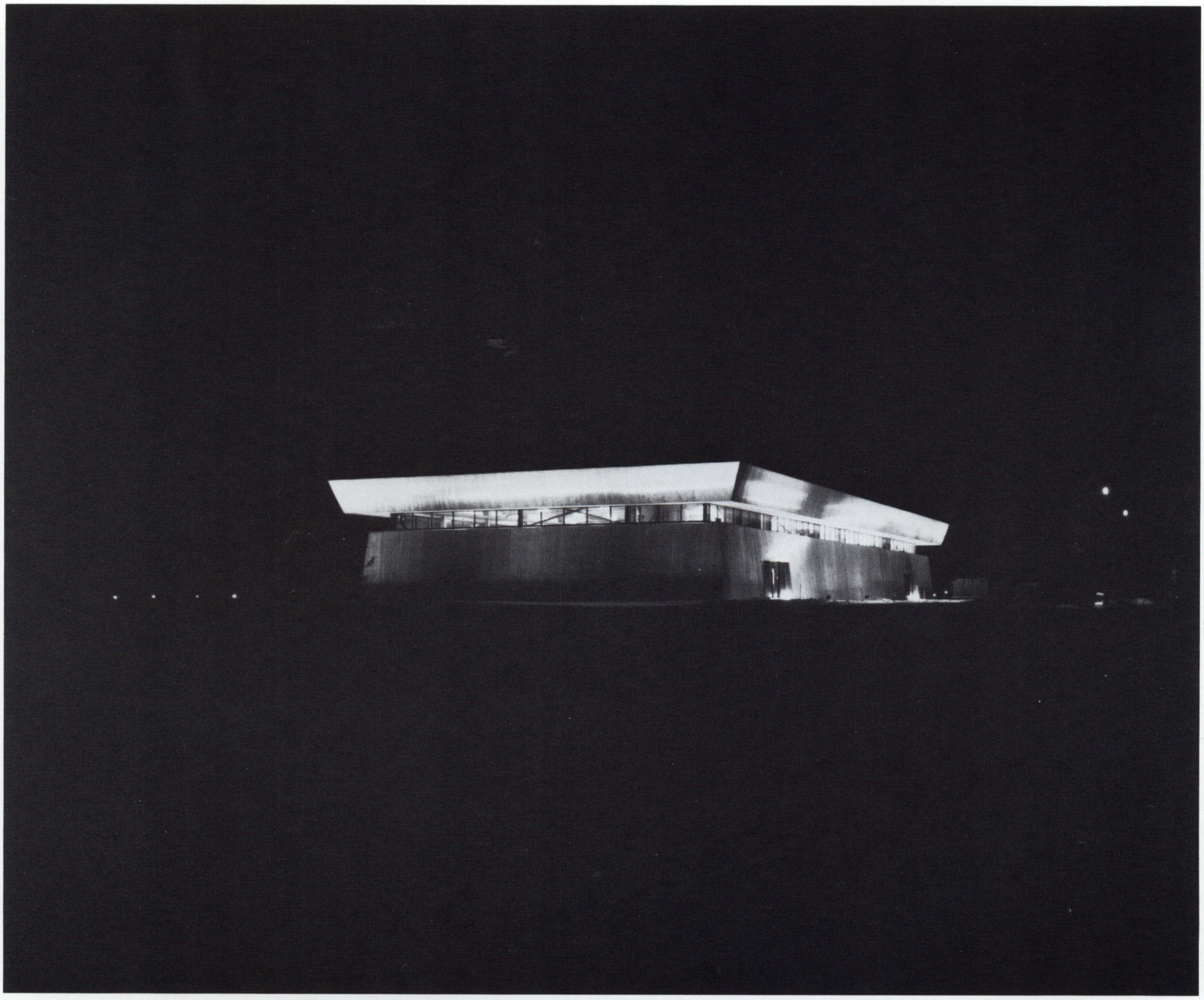
Foundations for the Muon Laboratory. The 2000-ton Chicago Cyclotron Magnet, around which Muon Lab was constructed, is visible in the background.

portions of existing beamlines. At the end of or adjacent to the four new beams, were Lab F, Lab G, Muon Lab, MW, and MP Experimental Halls. A shop facility, Industrial Center, was also built for the production of TeV II magnets. Extensive changes and additions to site roads, drainage, shielding berms, and underground utilities were required for most of the new TeV II buildings.

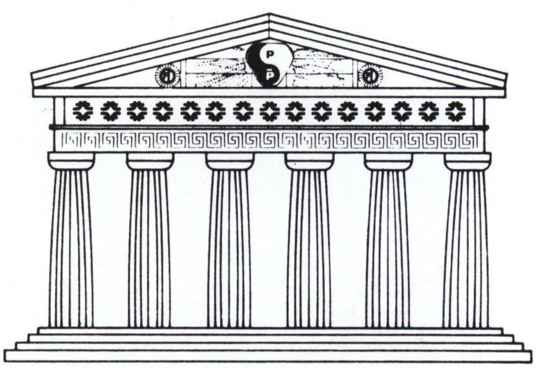
The coordination of Fermilab civil construction has changed considerably in keeping with the maturing of an operating laboratory. Construction in the late 1960s typically started in a recently harvested cornfield. In the 1980s, numerous interfaces with existing buildings, utilities, and scientific equipment must be resolved. In addition, schedule interfaces with Accelerator and Experimental Area operations have become an important ingredient of any construction effort. Much of current civil design must be based on what can fit into existing space and what can be built during a limited shutdown period. In addition, completion of civil construction often overlaps with the extensive reinstallation work of accelerator equipment.



The Muon Laboratory, still under construction in early 1985. In this photograph, precast concrete fascia panels are being hoisted into place.



The completed Muon Laboratory, its graceful lines accented by night illumination.




BC 33
CLEO IRON WORKS, INC.

Joint occupancy of the MW-MP labs in the Meson Area.

← *Construction work on the Booster Labs.*

Health and Safety Column

One of the most important columns supporting our Divisions is Safety. We have found that this subject requires continuous attention in a laboratory with so many diverse technologies. Larry Coulson, Head of the Safety Section, writes:

The last few years have seen the creation of a whole new high-energy physics laboratory at Fermilab. In retrospect, the "old" Fermilab seems to have been a relatively simple, conventional (but large), high-energy physics laboratory with traditional accelerator safety problems. During the years of construction, there was the dual challenge of maintaining the safety of an existing facility while working with design, construction, and operating personnel to insure that each new facility met our standards of safety. A listing of the changes that have produced the "new Laboratory" is also a listing of the challenges to our safety program.

These challenges include:

- Radiation safety for the new accelerators and beamlines, complicated by the near-limitless ability to store and transfer beam from ring to ring.
- Cryogenic safety for the TEVATRON and many other systems of cryogenic magnets and cryogenic experimental equipment.
- Mechanical safety for the much larger and more complicated experiments.
- Pressurized- and flammable-gas safety for the much larger detector systems.
- Construction safety for the many construction projects.
- Vacuum safety for the larger detectors.
- Chemical safety for the large variety of new chemicals the new Fermilab uses.
- Radiation considerations for the handling of uranium for the new generation of calorimeters.

A large number of people have worked on these safety problems. In addition to our highly dedicated staff of safety professionals, many physicists, engineers, and others have provided invaluable support by their service on safety committees.

Specific examples of successes in our safety program during 1985 include a reduction in injury rates and the continued reduction in personnel radiation exposures. The success of our emphasis on reducing injuries is evidenced by significant reductions in both the number of cases and lost work days. Comparison between first- and fourth-quarter statistics show a 74% decrease in cases and an 83% decrease in lost work and limited-duty days. Other efforts in this area included the creation of a computer database to permit rapid identification of trends, and correlation of safety and health problems with occupational hazards. This innovation has helped to identify areas where Safety Section manpower should be directed to further reduce injuries.

There have also been numerous changes in the emphasis of directives from the Department of Energy in the areas of radiation safety, chemical safety, and environmental protection. These changing regulatory standards are a reflection of current public safety concerns.

In response to DOE's renewed interest in accelerator health physics — at least partially stimulated by discussions about the SSC — we have begun programs designed to help us better understand and characterize the radiation environment of the Laboratory. Current efforts include extensive measurements of neutron spectra, a re-evaluation of personnel dosimetry with particular emphasis on neutron dosimetry, and the effects of environmental factors on the response of radiation-measuring instruments. This improved understanding and characterization should lead to even further reductions in the cumulative radiation dose to Laboratory personnel.

The Occupational Safety and Health Administration's new Hazardous Communication Standard stimulated an aggressive program to obtain manufacturer-provided material-safety data sheets for all chemicals known to be used at Fermilab. In order to make the information on these sheets more useful, a numerical rating scheme was developed to characterize the hazards of each chemical by toxicity, flamma-

bility, and reactivity. The ingredients and numerical ratings are stored in a computer database which allows for rapid trend analysis. New regulations were issued for chemical waste labeling, storing, and disposal reporting. An existing computer database proved invaluable in meeting these new challenges. In all, 33,000 gallons of regulated chemical wastes were properly disposed of or recycled in 1985.

Renewed interest in the National Environmental Policy Act has resulted in a closer analysis of proposed construction projects. For example, the presence of endangered species and cultural resources are now checked by qualified professionals as part of a formal review. If a project might have an adverse impact, steps are taken to prevent damage by mitigating the resource or moving the project.

The next few years will most certainly see more detailed regulatory requirements in all three of the above areas. The challenge will be to allocate resources in order to comply with these new directives while still maintaining the existing programs and staying alert to the changing needs within Fermilab.

Administrative Sections — The Nuclear Frieze

Business Services Section

Jim Finks was appointed Head of the Section, thereby qualifying to join one of the most prestigious clubs at Fermilab — the ex-Business Managers, one of whom happened to be Jim, who served a previous term as interim Business Manager. At last count, the club also included Don Poillon, Paul Reardon, James Campbell, Rich Orr, Dick Lundy, Bruce Chrisman, and Ken Stanfield, giving Jim and the Laboratory a deep resource of experience on how to keep the entire operation going as legally as possible. Finks rapidly began encouraging Business Services Section members to provide more service with less manpower and funding, but with increased planning and logical analysis of problems and alternative cost-cutting actions. As one result, the Facility Operations and Engineering Department was merged with Site Services and streamlined into the Facilities Management Group. This allowed total consolidation of all sitewide maintenance functions under one head and has eliminated duplication of effort, centralized administrative and budgetary functions, and increased efficiency. Jim Finks continues:

During 1985, Facilities Management: rescued the Accelerator schedule by replacing, under adverse weather conditions, a failed 100-MVA main power transformer; initiated an energy management project which includes replacing air towers, enlarging Casey's Pond, and rerouting the return of cooling water to the pond to conserve this valuable resource and to better regulate temperature. Another energy project involved the installation of thermostatic valves in the heating system at Wilson Hall. We also procured new paging equipment and added 600 new telephone lines and three FTS lines to keep pace with the Lab's growth. Several roofing projects were also completed, including adoption of a new pool liner concept for the previously troublesome Ramsey Auditorium roof. Several landscaping, paving, and tree planting projects were completed, and asphalt curbing was installed around parking lots and planting areas.

Purchasing, Contracts, and Support Services were reorganized into the Materials Group. During FY85, the Purchasing and Contracts Departments processed 27,861 procurement actions totalling $84 million, of which 75% of the dollars were awarded to small businesses while 5.3% went to businesses owned by disadvantaged individuals. Over 400 contracts, totalling $21 million, were awarded for civil construction. After many years of effort, we now have computerized commodity and vendor lists, requisition logging, purchase-order entry, and property management capability, all due to the procurement portion of the Purchasing, Accounting, Receiving System (PARS) integrated database finally coming on line. In Support Services, over 74,000 line items were received totaling 87 million lbs., 284,000 issues were made by Stores, over $500,000 in excess property was obtained, the vehicle fleet logged over 1.2 million miles, and over 46,000 passengers were carried by the Lab's taxi service.

The scattered elements of the Information Systems Department were combined at one location and placed under a modified MBO management style. Under this new philosophy, the department has dramatically improved its ability to provide design, analysis, programming, and support for computerized business applications and other systems of common interest throughout the Lab. Information Systems' major FY85 accomplishments included: (1) completion of a purchase- order system for online entry and reporting; (2) purchase of end-user computing tools; (3) Lab-wide training on current system software; (4) feasibility studies for a new payroll system and a new micrographics operation; (5) development of a Personal Computer Distributed processing network; and (6) completion of the installation of the Information Center itself.

On the legal and accounting fronts, Business Services prepared the groundwork for the Laboratory's first "work for others" in the form of an agreement with MINT for the continuation of treatment of patients at the Lab's Neutron Therapy Facility. Also, Fermilab's banking service was competitively bid and a substantial cost reduction to the U.S. Treasury was thereby obtained.

Laboratory Services Section

The significant technical goals and achievements during 1985 were matched stride-for-stride by extraordinary service activity. Chuck Marofske, Head of Laboratory Services (see Personnel on the TOC), takes note of these activities:

During 1985 we reached an all-time high in employment, but by the end of the year, total employment actually decreased by over 50 persons from the peak activity generated by the TeV I and TeV II projects. There were over 180 persons added to the payroll in 1985 and over 225 who left the organization. As staffing needs changed, there were numerous employee transfers in order to match human resources to the tasks at hand. There were more retirees in 1985 than in any previous year. Personnel changes do not include temporary appointments and student workers sponsored by the Laboratory.

We directed particular attention to the problem of providing quality health care benefits in a market place where costs continue an upward spiral in excess of general inflation. There were a number of group insurance changes introduced and two new Health Maintenance Organizations (HMOs) added as options. Employee enrollments in HMOs tripled during the open-enrollment period.

The Lab's maintenance mechanics and electricians voted to be represented by the International Association of Machinists, and a number of other labor agreements were renegotiated.

The Office of Federal Contractor Compliance and Performance conducted an on-site audit of our affirmative action program and issued a favorable report. The Laboratory continued summer learning/work opportunities for students at secondary and undergraduate levels of education attainment. From time to time the human-relations staff was called upon to investigate and resolve employment problems. A wide range of studies and reports were prepared, extending from absenteeism to overtime and retirement.

Due to the extended Accelerator run and other projects, there was an all-time-high demand for temporary housing. Most of our housing facilities were fully occupied for a large portion of the year. Service support was stretched to maintain quality while coping with the influx of persons utilizing Laboratory facilities. For example, the cafeteria averaged about 1700 customers per month exclusive of special-event programs.

An Activities Office was established during 1985. This new office will oversee major renovations planned for the Lab's Users Center next year in addition to coordinating ongoing efforts to provide recreational activities and guest support.

The Public Information Office's self-guided and group tour programs were extremely active, reflecting a high level of public interest in the Laboratory. There were also a number of video programs produced which used taped footage from the Laboratory as well as staff interviews. Many newspaper and magazine articles giving international coverage to the Lab's accomplishments appeared in magazines such as *National Geographic*, *New Scientist*, *Newsweek*, *Science News*, *Time*, *Chemical and Engineering News*, *Physics Today*, *Scientific American*, *Discover*, *Sierra*, and *Research & Development*; and in newspapers ranging from the *Chicago Tribune*, the *Chicago Sun Times*, and the *Washington Post* through the *New York Times* and the *Boston Globe*. Dozens of local papers nationwide carried Fermilab-related stories as a result of AP and UPI wire-service stories.

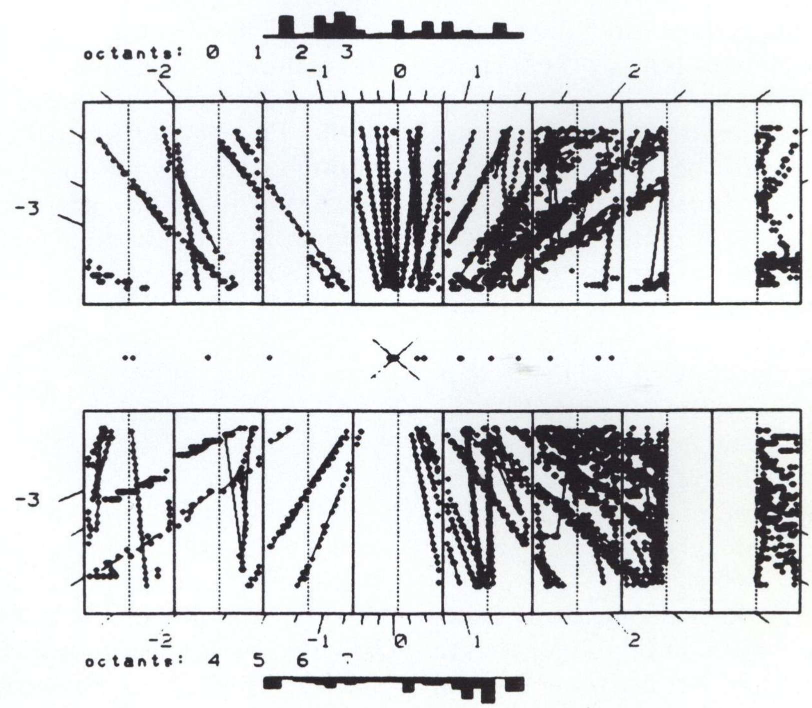
We continue to produce the monthly *Fermilab Report* and the bimonthly *FermiNews*. Publication assistance is made available for conference proceedings, technical papers and reports, and books. Library shelving was increased to accommodate our growing collection of reference materials. Photography service was provided to record the progress on numerous Laboratory projects.

With the assistance of many, and the support of the Director, we assembled a gala end-of-run/Happy Fiscal New Year event.

fermilab report

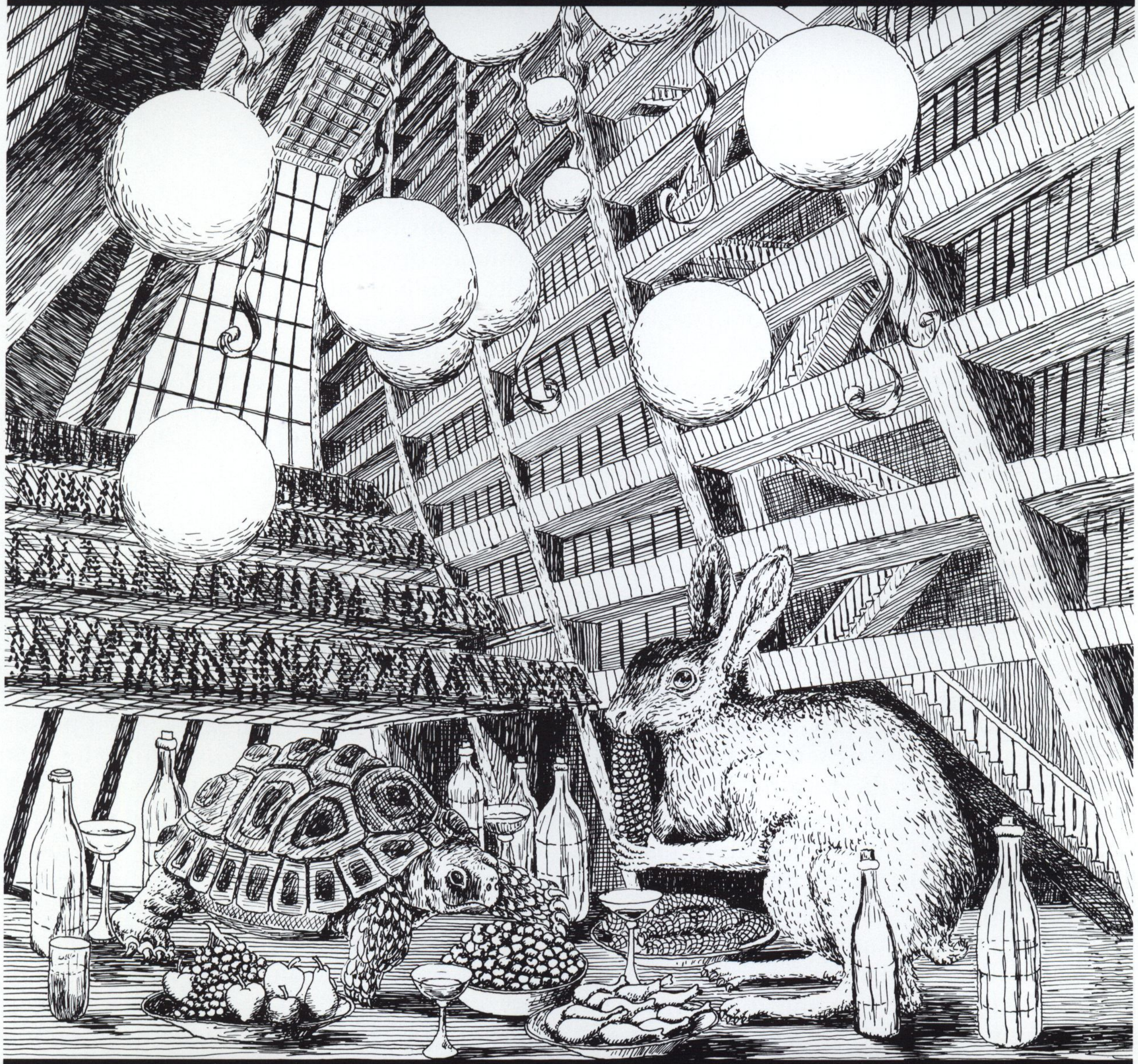
Fermi National Accelerator Laboratory Monthly Report

October 1985



Lab-Wide

End-Of-The-Run Party



All Fermilab People are Invited

To a Grand Party

Celebrating the End of a Very Successful Year (Fiscal Year 1985) Of Operations of the Tevatron

Fermi National Accelerator Laboratory
Wilson Hall Horseshoe/Atrium
September 27, 1985, 3:00 - 6:00 p.m.

Food Drink Surprises Music

We do have some important activities which don't fit in the True Organizational Chart. We'll call them "gargoyles."

Gargoyle 1:

Technology Transfer at Fermilab

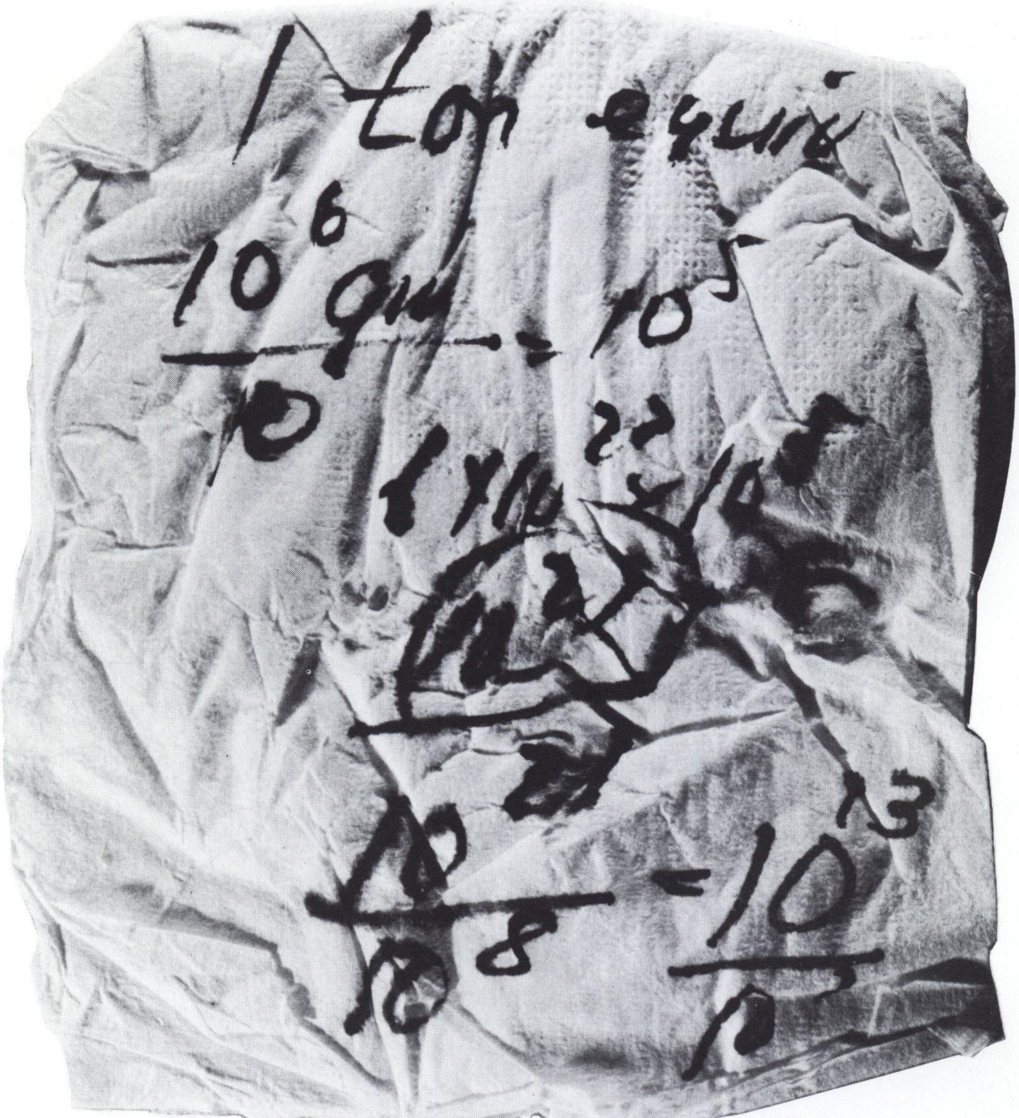
Dick Carrigan, who oversees Fermilab's Office of Research and Technology Applications, comments on the Laboratory/industry interface:

A superficial observer of a laboratory engaged in very basic research, Fermilab for instance, might jump to the conclusion that there were too few superconducting toothbrushes and quark power generators coming out of the program. A more insightful picture is that technology transfer, even though congressionally mandated, is a subtle process which does not yield readily to institutionalization. Although the Director wrote a long article (*Scientific American*, November 1984) on the subject, what has long been needed is a quantification of the process as only trained economists can do. Happily, such a program has been initiated by two Stanford economists and we eagerly await the results.

The major thrust of the technology transfer program at Fermilab is the Fermilab Industrial Affiliates. The Affiliates organization is comprised of 40 industrial concerns interested in the research and development work underway at the Laboratory. Affiliates receive a monthly, tailored distribution of technical reports. An annual meeting gives the Affiliates an opportunity to visit the Laboratory and review ongoing work and future projects. The 1985 meeting had as its major topic "Applications of Particle Physics, Out on the Limb of Speculation." This Round Table attracted outstanding participants. Sheldon Glashow of Harvard University discussed neutrino exploration of the earth. George Zweig of Los Alamos National Laboratory reviewed possibilities of room-temperature fusion catalysis. Robert Fleischer of General Electric speculated on magnetic monopoles, while Robert Forward of the Hughes Research Laboratory outlined the possibilities of antiproton rocket propulsion. Stephen Jones, then at Idaho National Engineering Laboratory and now at Brigham Young University, presented an update on the enormous progress in muon catalysis of fusion. Walter Sullivan of the *New York Times* served as moderator of the program. At the banquet, Dr. Gerard O'Neill, author of *The High Frontier*, spoke on "The Technology Edge." An "Intense Briefing on Superconductivity" was held in February. This was well attended by interested industries in the cryogenics and superconductivity fields. That meeting helped to illuminate the practical side of large-scale superconductivity.

The Laboratory is also involved in the more traditional forms of technology transfer. Many published technical articles and papers presented at meetings are based on the work carried out at Fermilab. These papers represent an effective means for transferring the work of the Laboratory. The field of particle physics is also an exporter of highly trained manpower to other technical areas. Physicists, engineers, and technicians compose a steady trickle to industrial labs near and far.

These activities are superimposed on another traditional, on-going, and historically very effective natural process of technology transfer. This is the process whereby Fermilab specifications are met by vendors only after considerable effort, usually collaborative, between Laboratory and industry. The result is often a new product, or a new skill which results in a new product. The development of the Fermilab TEVATRON, selected as one of the ten outstanding engineering achievements of 1984 by the National Society of Professional Engineers, provides many examples of this process. One of the best is the development of superconducting cable. That cable solidified and aggregated the present superconducting cable industry. It is this "standard" activity that probably accounts for an overall payback which is a significant fraction of the



annual budget of all the basic-research laboratories.

A current activity at Fermilab that shows this process in action is the Advanced Computer Program. One important element of this program, as detailed earlier in this *Report*, has been to maintain close working relationships with microprocessor-chip manufacturers and software developers. The thrust of the Fermilab program, in turn, acts back on the suppliers. To quote comments received from a person at a prominent corporation in the computer field, "I applaud your progress on the Advanced Computer Program microprocessor. You deserve credit for helping us all realize the benefits of multiprocessing systems."

Progress has also been made in exploiting some of the individual inventions at the Laboratory. This year the Laboratory has started to use the Technology Commercialization Center at the University of Illinois-Chicago to assess some of these inventions. Currently, a design class at the university is studying an interlocking component system, devised by Carl Lindenmeyer in the Fermilab Physics Department, for drift-chamber fabrication. Interestingly, one of the applications they are considering is for decorative panels. A Laboratory-developed modification on a coordinate measuring machine by Greg Kobliska and his colleagues in the Technical Support Section was featured recently in the magazine *Quality*, the trade publication of the quality control industry. This fall the Laboratory was awarded an IR-100 Award for a magnetic wire-position transducer developed by Hans Jöstlein. A real-time video data-acquisition system developed by Fermilab and Notre Dame for recording and processing data from a scintillating glass fiber-optic target has been spun-off into a new activity almost before the solder cooled. It is now being used to look at Halley's comet for second-to-second fluctuations in the comet's tail.

Proud as we are of these spin-off effects, we are of course primarily committed to the advancement of pure knowledge. In this, we found relevant statements from three hard-nosed industrial managers.

Henrik G. B. Casimir, Director of the Research Laboratories for N.V. Philips Industries of Holland, at the 1966 "National Symposium on Technology and World Trade" at the National Bureau of Standards:

"I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsense it has been my fortune to stumble upon.

"Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in, and had not contributed to, wave mechanics or the theory of electrons in solids. It so happened that inventors of transistors were versed in and contributed to the quantum theory of solids.

"One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the '30s by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics. One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps — only it didn't happen that way, and there were the Curies and Rutherford and Fermi and a few others.

"One might ask whether an electronics industry could exist without the previous discovery of electrons by people like Thomson and H. A. Lorentz. Again, it didn't happen that way.

"One might ask whether induction coils in motor cars might have been made by enterprises which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that.

"Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasized the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of 20th century innovation which is not indebted in this way to basic scientific thought."

George Pake, Group Vice President, Corporate Research Group, Xerox Corporation, speaking to the Materials Research Society in May 1985:

"In view of my own vested interests in condensed-matter physics and in commercialization of technology, you may well ask why I support a taxpayer subvention of $3 billion to construct the world's largest, most powerful particle accelerator [SSC] . . .

". . . It is simple: For the near-term and long-range future vigor and benefit of the U.S. industrial and even military economy, the most pragmatic posture I can imagine is one that opts by overt choice for the most advanced knowledge and deepest understanding . . . Nothing is more pragmatic than the broadest and deepest knowledge-base mankind can attain. And I am just chauvinistic enough to believe that the welfare and economic vigor of the United States is best assured if we lead the world in advancing knowledge and in developing that broad, deep knowledge base."

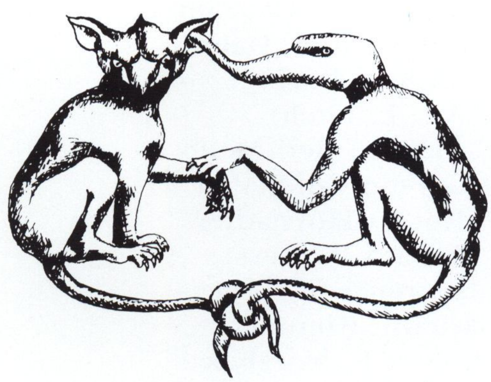
Lewis Branscomb, Vice President and Chief Scientist, IBM, at the TEVATRON I Collider Dedication at Fermilab, October 1985:

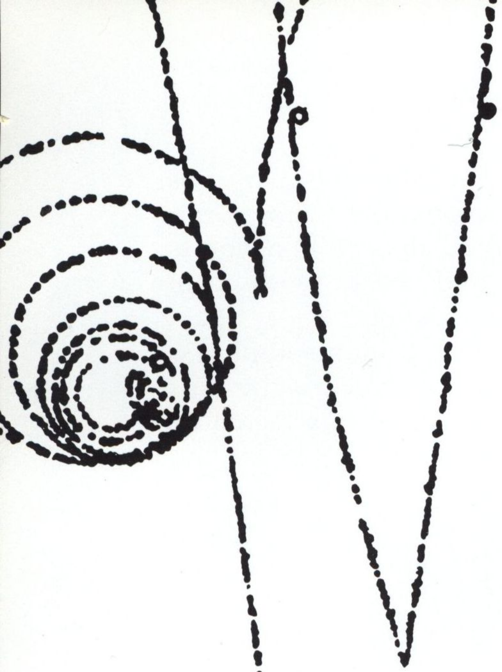
". . . When we choose as targets of this scientific and technological muscle-building the investigation of seemingly abstract and very fundamental questions, it is because these goals provide the most strenuous tests and bring out the most powerful motivations . . .

". . . We can catalog a number of practical, immediate benefits that have real value from a project like the TEVATRON:

- New ideas and technology in cryogenics, computing, and electrical engineering.
- Challenges for the vendor industries that support Fermilab.
- And, most of all, an exceptional educational experience for hundreds of young scientists who will find their way into our universities, companies, and government laboratories. After this experience, they will never be satisfied with second best, with compromised goals or easy work.

"What applies to those students applies to our nation as a whole and explains the most important reason for supporting scientific laboratories like Fermilab . . ."





Pions to Quarks

International Symposium on Particle Physics in the 1950s

Fermi National Accelerator Laboratory
Evening May 1 – Noon May 4, 1985

Particle physics from discovery of the pion and strange particles and the building of the first large accelerators to the introduction of symmetry concepts and proposal of the quark.

Physicists

Edoardo Amaldi
Ugo Amaldi
Owen Chamberlain
Geoffrey Chew
William Chinowsky
Ernest D. Courant
Richard H. Dalitz
Sidney Drell
Val L. Fitch
Murray Gell-Mann
Gerson Goldhaber
Robert Hofstadter
Donald W. Kerst
Lawrence W. Jones
Michiji Konuma
Robert E. Marshak
Louis Michel
Yoichiro Nambu
Abraham Pais
W. K. H. Panofsky
Donald H. Perkins
George Rochester
Abdus Salam
Matthew Sands
Emilio Segrè
Jack Steinberger
E. C. G. Sudarshan
Valentine Telegdi
Sam Treiman
Robert L. Walker
Victor F. Weisskopf
Robert R. Wilson
C. N. Yang

Historians

Alan D. Franklin
Peter Galison
John L. Heilbron
Armin Hermann
Andrew Pickering
Silvan Schweber
D. Hywel White

For further information write, by March 1, 1985, to:
Judy Zielinski
Symposium Secretary
Fermilab Mail Station 105
P.O. Box 500, Batavia, Illinois
Fermilab Telephone: 312-840-3211
FTS: 370-3211 Telex: 720-481

Photo: Courtesy Nicholas Samios

Gargoyle 2:

The Second Fermilab History of Particle Physics Symposium.

Particle physics research is ethnically future-oriented but an occasional pause to examine our heritage is illuminating, inspiring, and, as we learned recently, sometimes embarassing. In 1980, under the energetic initiative of our resident historian, Lillian Hoddeson, we had the first symposium, which resulted in a book, *The Birth of Particle Physics*, (Eds. Laurie Brown and Lillian Hoddeson; Cambridge Press, 1983). This covered the period of 1930-1950, and we were privileged to listen to such giants as Dirac, Weisskopf, Anderson, Bernardini, Le-Prince Rinquet, Pierre Auger, Bruno Rossi, Julian Schwinger, Willis Lamb, and many others.

In May of 1985, we held the second symposium. This one covered the period 1950 to 1965 and was entitled "International Symposium on Particle Physics in the 1950s: Pions to Quarks." Again, the Laboratory paused from its fascination with quarks and counters to listen to the scientists and historians. Coming closer to modern times, there are clear tensions in the presentations. Objective scholarship needs time but this is just the value of these symposia. Lillian is working hard on the book; perhaps we'll hold a third symposium in 1990 or so. Meanwhile, Hoddeson and her archivist buddy, Adrienne Kolb, keep our History of Accelerators Library up to date, the current emphasis being to document the progress of SSC.

Gargoyle 3:

Praise

The U.S. Department of Energy is our sponsor and here, in fact, is a word from our sponsor. Every five years, whether we need it or not, they make a comprehensive assessment of the management of the Laboratory. The year 1985 was one of those years, and our five-year report card is shown below.

Performance Area	Unsatisfactory	Marginal	Satisfactory	Good	Excellent	Superior
o Management						X
o Programmatic						X
o Projects						X
o Support Functions					X	
o OVERALL RATING						X

We took strong exception to several of the subelements of our assigned ratings, made eloquent appeals, but we did not succeed in changing any of the subelement ratings. The review is a complex and time-consuming process and strongly involves the DOE Batavia Area Office staff, and proceeding to the local maximum: Mr. Hilary Rauch, manager of the Chicago Operations Office. Incidentally, with his permission, we reprint a portion of his letter accompanying the Summary Appraisal Report:

Department of Energy
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439

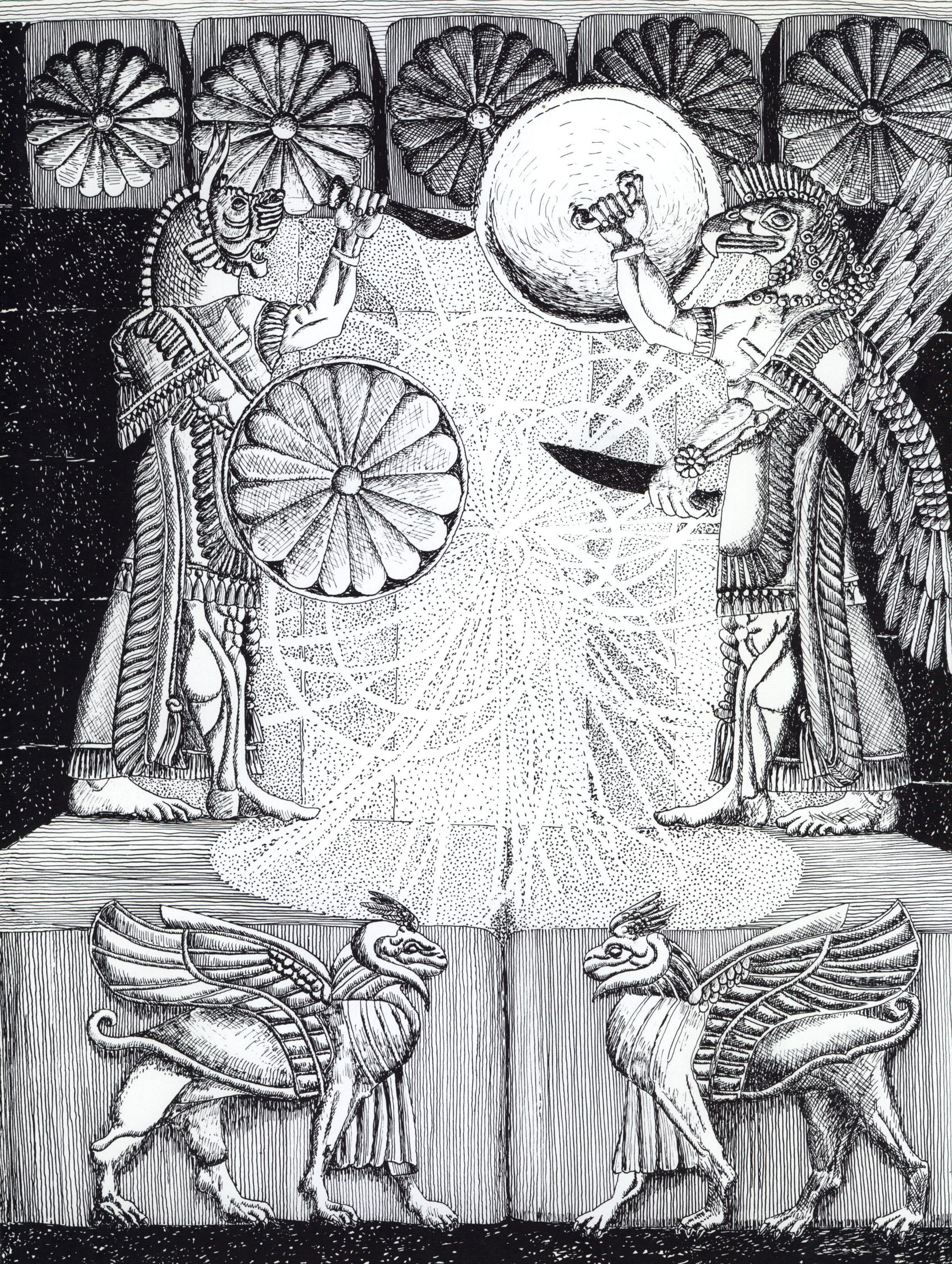
Dr. Leon M. Lederman, Director
Fermilab
P.O. Box 500
Batavia, Illinois 60510

Dear Dr. Lederman,

SUBJECT: SUMMARY APPRAISAL REPORT OF UNIVERSITIES RESEARCH ASSOCIATION, INCORPORATED (URA) AND FERMI NATIONAL ACCELERATOR LABORATORY (FERMILAB)

Enclosed are five copies of the subject appraisal report. I am pleased that URA/Fermilab's overall performance in managing and operating Fermilab during this period has received the highest rating achievable within this process, and to know that you plan to continue to make improvement and substantial advances as indicated in your letter of July 9, 1985.

Final comment: Even with our good rating, we *must* do better next time!



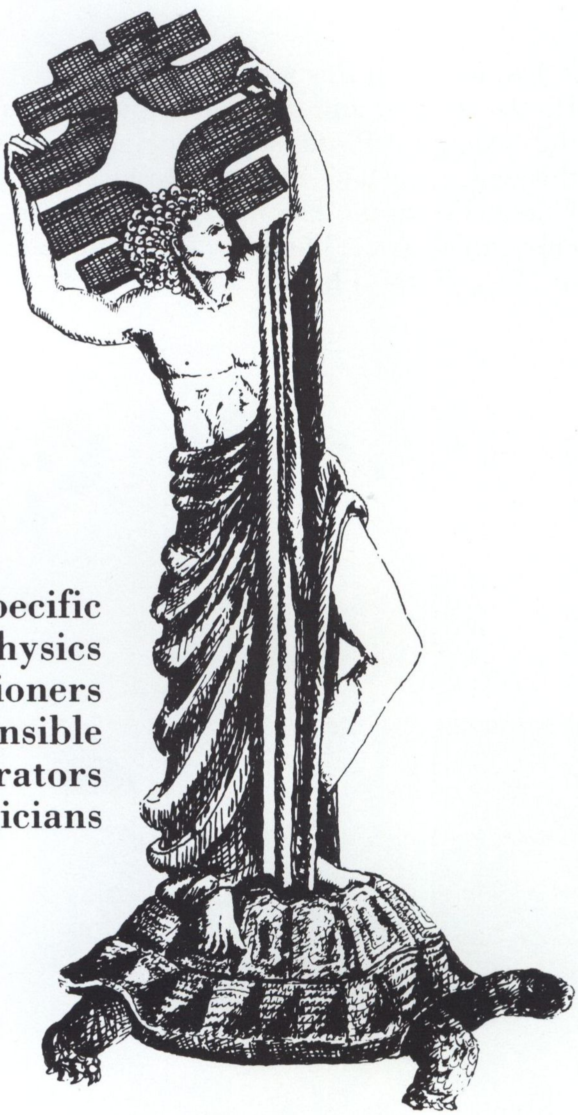
Gargoyle 4:

More Praise

Elsewhere in this *Report* we mentioned our IR-100 Award, and the honor given to us by the Society of Professional Engineers, but in this space we take note of the award to Dr. Helen Edwards, Deputy Head of our Accelerator Castle. This was for Achievements in Accelerator Physics and Technology for 1985, and was presented by the US Particle Accelerators School for her work in bringing on the Energy Saver. The citation lauds Helen for her "essential contributions in making the world's first superconducting synchrotron a reality."

Helen Edwards.

Director's Special Colloquium



Being a series of colloquia on specific topics in high energy physics given by outstanding practitioners and designed to be comprehensible to graduate students, administrators and abstract string theoreticians

Gargoyle 5:

Director's Special Colloquia

On October 13, we shut the machines down for the final construction phase of the TEVATRON program. This meant that our visitor population decreased and the atmospherics that are associated with a laboratory that is doing physics began to fade. As an aid to restoring this, we instituted a series of special colloquia given by some of the most outstanding practitioners, and covering some of the most provocative subjects. The 1985 series included:

"Towards a Unified Theory of All Interactions," by John Schwarz (California Institute of Technology).

"A Supercomputer for Lattice Gauge Theory: Results and Prospects," by Norman Christ (Columbia University).

"Supersymmetry, Gravity, and Unification," by Bruno Zumino (Physics Department, University of California, Berkeley).

"The Ongoing Search for Dark Matter Candidates," by Frank Wilczek (Institute for Theoretical Physics, Santa Barbara, California).

"Superstrings," by Edward Witten (Physics Department, Princeton University).

The series will continue in 1986 with speakers including Jim Cronin, Val Fitch, John Peoples, Burt Richter, Andrew Sessler, and Israel Singer.

Gargoyle 6:

Users!

It is well known that some colleagues share the view of the famous professor who was overheard to remark: "College would be a great place if it wasn't for all those students." Not so at Fermilab, which is managed by the universities for the universities from whence most users come. Not all; some come from other laboratories, many from abroad, and some even come from Fermilab. But no matter, they are the reason we exist and the fact that they do not appear on our True Organizational Chart is just one of the things wrong with TOCs. We interact with users through a variety of channels. One is a multitude of workshops, often organized by the users themselves. Another is the Users' Executive Committee (UEC), the membership of which is listed in the appendix to this *Report*, and which meets monthly. Then there is the Users Annual Meeting, held in May, and spiced by as much high-power oratory as we can muster. In 1985, we had approximately 300 attendees. We also maintain a Fermilab Users Office (UO) run by Phyllis Hale:

1985 has been another very productive year for the Fermilab Users Office. More than 600 visiting scientists have entered these portals from over 39 countries during the course of 1985. As one of the first stops a visitor, especially a foreign visitor, makes at Fermilab, the Users Office serves as a resource for visas, medical and dental assistance, driver's licenses, and other non-physics services. As of the end of 1985, our office has amassed a database of 3955 users (every visitor who has ever obtained a Fermilab I.D.) from which we compile and distribute a Directory of Researchers, as well as various other cross-referenced lists such as users by I.D. number, by country, by citizenship, etc.

On the subject of databases, the UO maintains the 1300-name mailing list for the Fermilab Users Organization. Administrative and secretarial assistance for the bi-monthly UEC meetings include organizing group meetings and luncheons, surveying the membership, compiling and mailing minutes to the membership, and gathering resource materials. The Annual Users Meeting is organized and administered by the Users Office.

The Users Office also provided support to various user-related committees, including the Facilities Committee and the Quality of Life Committee. In addition, the Users Office provided administrative and secretarial support to the TEVATRON Association of Fixed Target Spokespersons (TAFTS) which met six times during 1985. The care and well-being of Fermilab's contingent of graduate students is an on-going special concern of our office.

Innumerable special mailings originate from the Users Office. One of our most gratifying projects during the past year was the organization and shipment of over 100 boxes of used technical journals and various science-related publications to Latin American universities as part of the "Books for Latin America" project.

Workshops, and publications derived from those workshops, occupied a central role in Users Office activities for 1985. The Heavy Quark Workshop, the Gas Sampling Calorimetry Workshop II, the Triggering, Data Acquisition and Computing for High Energy/High Luminosity Hadron-Hadron Colliders Workshop, each of which were attended by well over 100 participants, were organized through the Users Office.

Users far from home need TLC as well as HEP, and we have reorganized the Lab desks devoted to "quality of life" by establishing a Fermilab Activities Office (AO), which can be found somewhere in the Personnel frieze and was mentioned earlier by Chuck Marofske. Under Marilyn Paul's firm hand, the AO sees to the local ambiance (and could, therefore, be called the Ambiance Office without disrupting the alphabetical nuances of the True Organizational Chart). Under AO auspices, the Reception Desk steers the weary traveler to the Guest Office, which dispenses aid and comfort, no small part of which includes various Recreation activities, followed by shop talk at the Users Center, and working dinners at Chez Leon. 1985 has seen the beginning of URA-funded, trustee-approved renovations to the Users Center, an ambitious plan to make the Center much more effective as an after-hours locus for cultural, conversational, and relaxational activities.

Gargoyle 7:

The Misty Vision of the Future

Here we are, up to our eyeballs in the tremendous effort to turn on the TEVATRON with a smooth and ever-increasing efficiency in alternating between collider and fixed-target physics. Here we are, entangled in the effort to cope with a complication called Gramm-Rudman-Hollings, which reduces our budget and which must not be permitted to block our intent to get physics out of this enormous investment in effort and money. And here we are, plotting our future, i.e., what is Fermilab doing in 1992?

We are part of a community committed to the SSC — the collider which will achieve 40 TeV in the center-of-mass. We now expect physics to begin in 1995 ± 1 and to reach its potential over the following 3 to 5 years. Our present capabilities, and our present understanding of the status of HEP, dictate the following set of priorities: (1) We must increase the energy of the TEVATRON to approximately 1 TeV; (2) We must increase the reliability of both modes to greater than 80%; (3) We must achieve the design luminosity of the Collider, i.e., 10^{30} cm^{-2} sec^{-1}; (4) We must increase the proton intensity of the TEVATRON to approximately 3×10^{13}ppp; (5) We must then work on the luminosity of the Collider — achieving greater brightness, more bunches, lower beta, so as to exceed 10^{31} cm^{-2} sec^{-1}. This will open up new physics by extending the *observable* effective mass range; (6) We must continue to upgrade the detectors of both programs, looking forward to at least one major new fixed-target detector and major revisions of the collider detectors.

In this way we can exploit the TEVATRON idea and prepare the community for facing the great adventure and the formidable challenges of SSC. It goes without saying that we must provide the test beams and contribute to the instrumentation R&D that SSC detectors will require. In the ideal world, the R&D will be in the form of fixed-target research.

Beyond this, the view gets mistier, so much depends upon the physics being uncovered here, at SLC, and in the European and Japanese machines coming on line between now and 1990. Of course, theory also plays a role, and we especially look toward the superstrings phenomenology so that we can somehow contribute to the fun and games at the Planck mass.

Gargoyle 8:

The Theory of Everything.

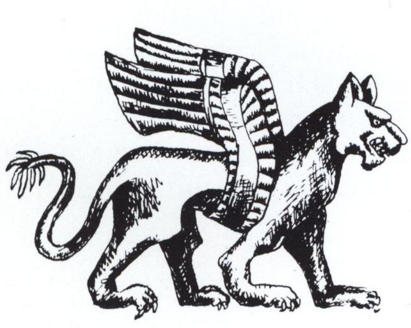
High-energy physics, these days, is being serenaded by haunting chamber music — seductive, exciting; now a violin solo, now the crescendo of a string quartet. We cannot close this State of the Laboratory without some comment on the Superstring Phenomenon — that is, the intensity and expectation that is radiated by some subset of our theorist colleagues that NOW we really have it. I reproduce here the Preface to a recent meeting, written by our own Bill Bardeen:

Mathematics and particle physics have often gone their separate ways in an attitude of mutual "benign neglect," diverging in both methodology and language. This uncomfortable gap was bridged to a unique degree at the Argonne/Chicago/Fermilab-sponsored "Symposium on Anomalies, Geometry, and Topology," which took place at Argonne National Laboratory and the University of Chicago on March 28-30, 1985. More than 300 theoretical physicists and mathematicians met together to discuss problems of current excitement and to report on recent progress in an atmosphere of remarkably unguarded optimism. While the meeting had many high points, the focus of much of the excitement and optimism concerned superstring theories. In an overview, John Schwarz described how superstring theories are now making dramatic strides towards achieving the ultimate goal of a unified quantum theory of all interactions including gravity.

Of course, superstrings are not isolated theoretical constructs but sit naturally at the peak of a large pyramid of theoretical concepts developed during the past few years, none seeming to be the whole truth but each having elements of formal beauty and aspects of physical reality. These developments include GUTS, low-energy supersymmetry, supergravity, Kaluza-Klein compactification, and finally superstrings. Each of these developments has motivated the next, addressing some of the remaining problems while making possibly more radical assumptions. Several speakers at the Symposium expressed the opinion that with this last doubling of the ante involving superstrings, winning the theoretical jackpot is all but a "sure thing!"

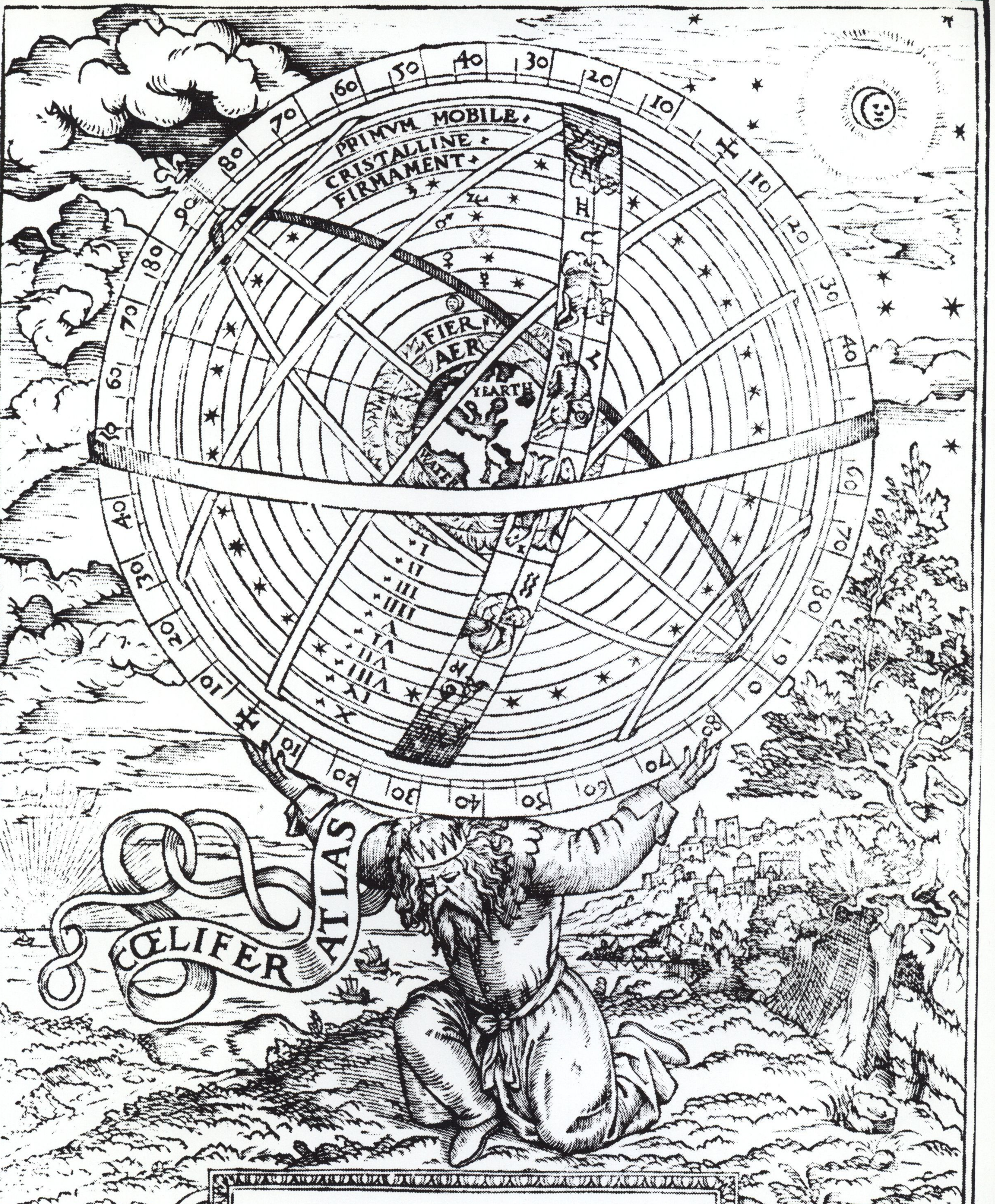
The breakthrough achieved in superstring theory and the impact of the Symposium can perhaps be summarized by the following comments. Mike Green remarked, "I feel the symmetry groups found for the superstring are very important but I am not yet convinced that one particular superstring theory is correct." Ed Witten commented, "This was the first widely attended conference since the (superstring) revolution. Before this meeting the significance of the developments had not really sunk in for many people." David Gross expressed the greatest optimism and said "it is remarkable how easily recognizable features of low-energy physics emerge from superstrings. While I don't believe we have yet found the right route to low energy, there appear to be no insuperable obstacles to deriving all known physics from the $E_8 \times E_8$ heterotic string."

That there is some connection between these developments and what may happen at the Fermilab collider or the SSC, we are not sure but we would not be surprised . . .

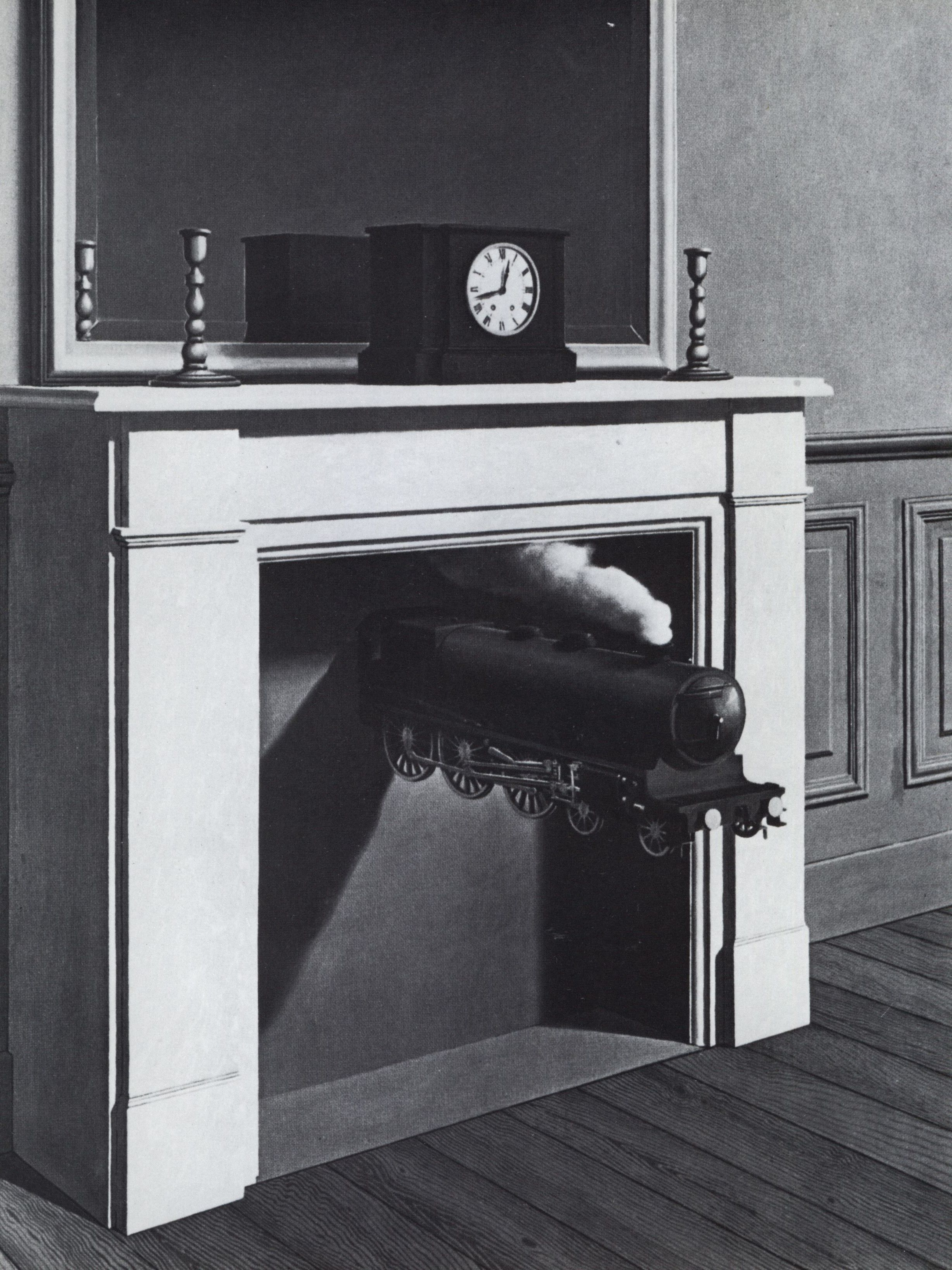


... a good place to end the overview.

Leon M. Lederman



An Earlier Theory of Everything



II. The Fixed-Target Run of 1985

". . . promises, promises . . ."

In the not-so-distant past, an accelerator operating at 70 GeV was mapping new territory in comparison to the existing 30-GeV machines. In the same manner, a factor of two in energy was a significant advantage of the 25- to 30-GeV machines over those which ran at 12.5 GeV. Doubling the energy always opened new horizons.

It is in this spirit that we shall discuss the *first* run of the Tevatron at an energy of 800 GeV. This energy is twice the energy of the two existing proton accelerators: the CERN SPS and the Fermilab Main Ring (see J.D. Bjorken's article, "Fixed-Target Physics at 800 GeV," in the *1984 Fermilab Annual Report*).

E-743: Charm

An experiment which directly exploited the energy-doubling feature of the Tevatron was E-743, the Little European Bubble Chamber (LEBC). This device, specially designed for this type of experiment, was shipped to Fermilab from CERN shortly after it was used there in a successful run of a similar experiment carried out at 400 GeV. The Fermilab Multiparticle Spectrometer was reconfigured to accommodate the needs of E-743, which included two new Cherenkov counters, a large transition radiation detector, and many additional tracking chambers. About 1.3 million triggers were recorded at 800 GeV in pursuit of a precision charm cross section measurement and a better understanding of how charmed particles decay. Analysis is proceeding well, with all scanning expected to be completed during the next year, and the first publications due in early 1986.

Figure 1 shows an example of a charm event. A D° is produced along with six charged particles, and decays into four charged particles after travelling a distance of 1.4 mm. The diagram shows the event in perspective transformation. This diagram uses digitized information from the CERN ERASME measuring system.

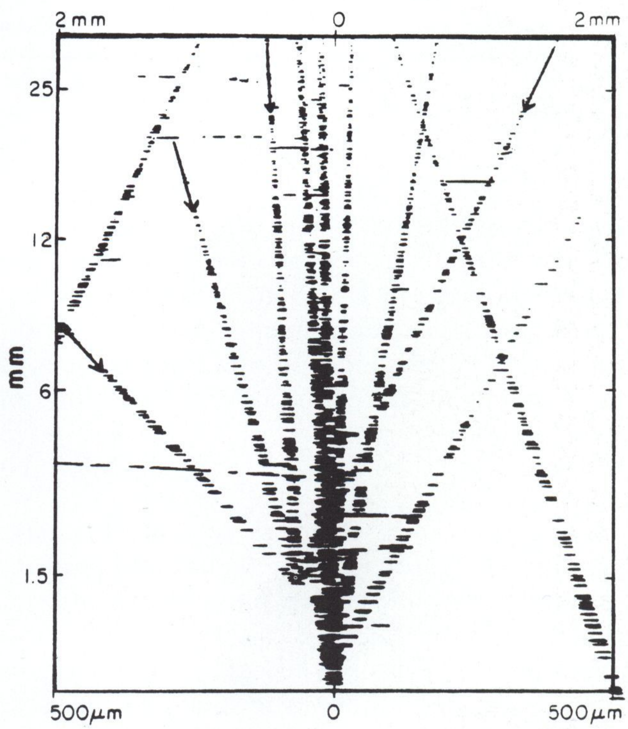


Figure 1

E-605: Dimuons

This collaboration of Columbia, University of Washington, KEK, Kyoto, Fermilab, SUNY/Stony Brook, Saclay, and CERN devoted the 1985 run to dimuons. To do this, they modified the focussing spectrometer by erecting a "thin" lead screen (48 in.) to decrease the detector loading by sea of soft photons. This enabled the experiment to take up to 5×10^{12} protons in a 1% acceptance bite optimized at approximately 10 GeV/c. About 20,000 upsilons with a mass resolution of 0.25% were accumulated. Figure 2 shows a

Rene Magritte, "Time Transfixed" 1939, oil on canvas, 57½ x 38⅜ in., Joseph Winterbotham Fund Collection,

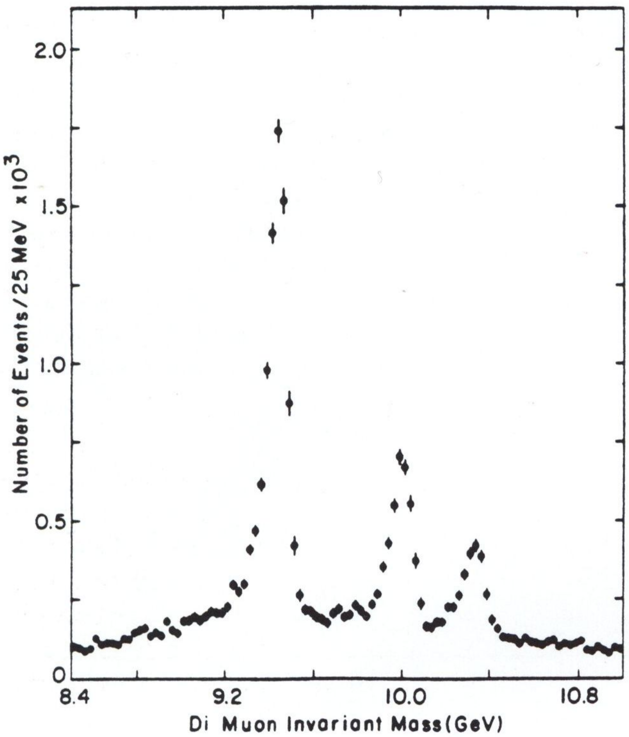


Figure 2

sample of the data with the upsilon peaks. These three states were discovered, but not fully resolved, in E-288 at Fermilab and they have also been seen at e^+e^- collider experiments. The absence of other resonances in this spectrum places important constraints on the spectroscopy of the upsilon family as well as on the proposed properties of other exotic particles discussed in extensions of the standard model, such as Higgs scalars or technipions.

The continuum of dimuon pairs in this spectrum is understood as a product of quark-antiquark annihilation in the interacting nucleons, the Drell-Yan mechanism. These data, combined with the detailed production dynamics of the upsilon s-states, will provide an important test of QCD predictions within the standard model. Experiment 605 also recorded extensive data on the production of hadrons at high transverse momentum in their 1984 run at 800 GeV. The ensemble of lepton and hadron yields at high fractional transverse momentum, x_T, in E-605 will be compared with the predictions of QCD-based scattering programs such as ISAJET and the LUND Monte Carlo and should provide a good contrast to the $\bar{p}p$ collider data which only test the calculations at lower x_T.

Tertiary beams also benefit greatly from the doubling of primary particle energy. Examples are photon and neutrino beams. There is an increase in energy and more than doubling in intensity in these beams. A tagged-photon beam experiment, E-691, took data in 1985.

E-691: Tagged Photons

The goal of E-691 was to collect a large sample of cleanly identified charmed particles produced by high-energy photons. The trigger for E-691 was based on the E_T sum from calorimetry. This is very efficient for charm events, independent of the specific final state. Using the data acquisition system designed to take advantage of the higher duty cycle of the Tevatron, E-691 collected 100 million events, of which 3% contained charm.

As of December 1985, about 2% of the data has been processed through the entire analysis chain, including vertex finding. It is already clear that the experiment has succeeded in accumulating a clear charm sample much larger than previous fixed-target experiments. Charm peaks seen in this small fraction of the data make reliable estimates for the full experiment possible. Figure 3 is a $K^-\pi^+$ mass spectrum for 1.7% of the data, requiring the two tracks to come from a common downstream vertex. There are 80 events in the D° peak, which implies a total of 4800 events in the full data sample. The secondary vertex cut used for this plot keeps 60% of the signal while suppressing the background by a factor of 80. Figure 4 shows the $K^-\pi^+$ mass spectrum for events which have an additional π^+ with $M(K^-\pi^+\pi^+) - M(K^-\pi^+)$ between 0.143 and 0.148 GeV, consistent with D^* decay. The data sample contains 1200 $D^{*+} \rightarrow \pi^+D^\circ$, $D^\circ \rightarrow K^-\pi^+$ with vertex cuts, 2000 without. For all of these channels, the background can be made much smaller (at some loss in signal) by

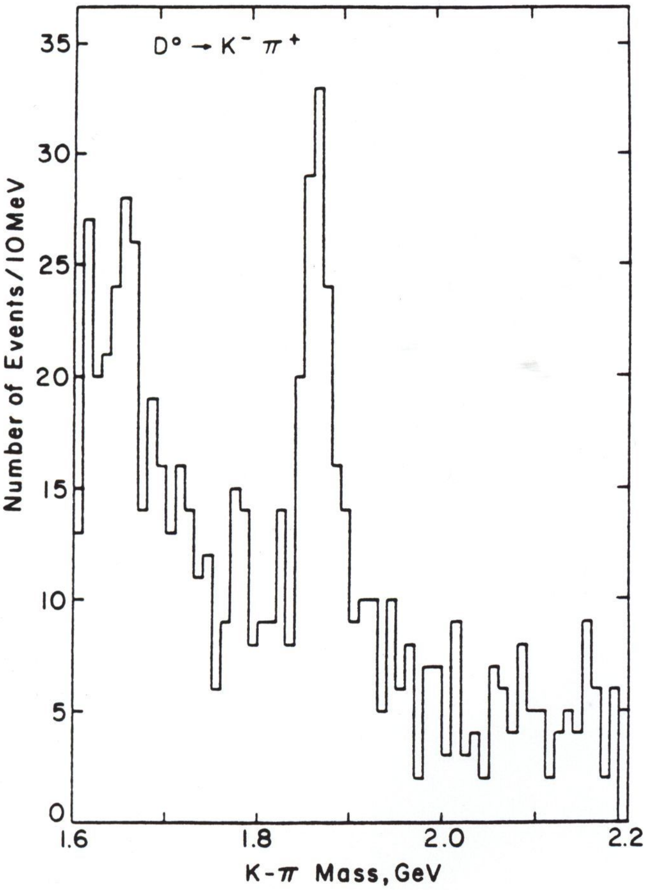


Figure 3

making tighter vertex cuts. Figure 5 shows a $K^-\pi^+\pi^+$ mass plot with similar cuts for a data sample corresponding to 1.4% of the total. In this 3-body channel the suppression of non-charm background is much larger, about a factor of 400. The signal for the full experiment will be about 2000 D^+ decays in this channel alone. All of these plots were made with a preliminary version of the vertex analysis.

These large charm signals open up many areas of interesting physics. There will be 6000 $D^{*+} \rightarrow \pi D^\circ$ events which can be used for studying the D° lifetime. Previous experiments with comparable resolution had fewer than 60 events. This sample of D° events tagged by the D^* decay will allow the first search for D°-$\bar{D}^\circ$ mixing below the 1% level. The lifetime measurement helps separate mixing from misidentified decays and from doubly Cabibbo-suppressed decays, which are themselves interesting. With thousands of events per decay mode for D° and D^+, one expects about 100 per decay mode of F^+ and Λ_c^+, with good signal-to-background ratio. Branching ratios and lifetimes for these particles are major goals of E-691 analysis. Searches for excited states decaying into F^+ and Λ_c^+ also look interesting.

Including the decay modes that are common and easy to detect, there will be about 15,000 D decays with low background. This will provide an unprecedented opportunity to look for excited charmed mesons decaying into D + π or D^* + π. In addition, detailed charm studies will be carried out with a sample one hundred times as large as previous experiments. For the first time, both D and $\bar{D}$ will be measured in a substantial number of events.

In addition to the open-geometry running, there was a short run to collect a large sample of $\psi \rightarrow \mu^+\mu^-$ events produced on H, Be, Fe, and Pb targets. This will allow a study of the

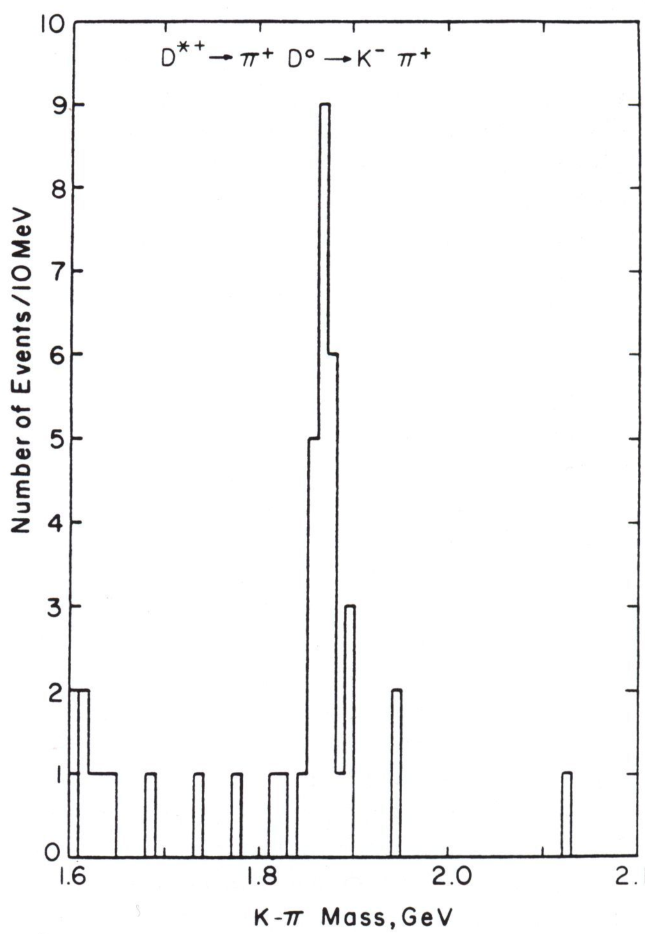


Figure 4

A-dependence of the ψ cross section with high statistics and good control of systematic uncertainties.

In summary, E-691 has collected a large sample of charm events which can be selected very cleanly by the vertex detector. It will contribute new results in the areas of charm spectroscopy, lifetimes, mixing, and production dynamics. The production versions of reconstruction programs are ready, and the processing of the 10^8 events is beginning. Tune in next year!

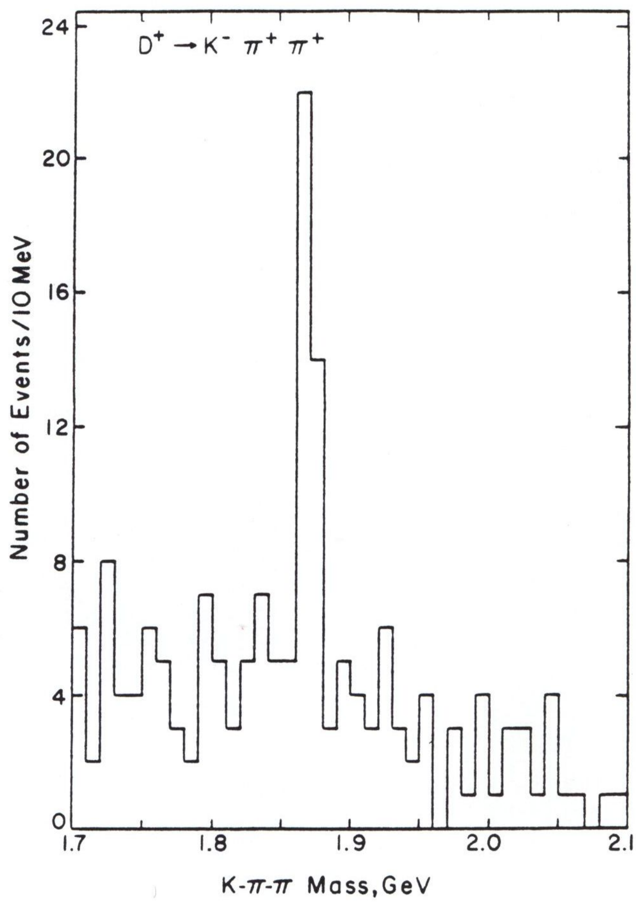


Figure 5

Neutrinos

The neutrino program in the 1985 run had four experiments utilizing the "quad triplet" neutrino beam. Two of these were bubble-chamber experiments and two were counter-electronic detectors. The successful extraction of fast-spill "pings" of approximately 1-millisecond duration was accomplished in the multiple mode. Three such pulses, each 2-3 $\times\ 10^{12}$ protons, were extracted and targeted on the pion and kaon production target. Fast extraction is a very difficult task in superconducting accelerators. The main difficulty stems from the necessity of keeping the extraction losses to an absolute minimum. During slow-spill extraction, the fractional loss of 1% or so can be absorbed in the superconducting magnets when spread over a long spill time. The requirement that a beam spill be of 1-msec duration imposes very severe restrictions on high-quality extraction. Nevertheless, three and sometimes four "pings" per cycle were routinely extracted during the 60-sec machine cycle and throughout the 8-month run.

In addition, the beam switchyard managed a very complicated array of hadron or muon beams operating concurrently with the pings and thus provided continuing calibrations for the electronic detectors.

The 15-ft Bubble Chamber experiment, E-632, an American-European- Indian collaboration, utilized the high-energy neutrino quad triplet beam. This was a first look at neutrinos in the energy domain greater than 300 GeV. The beam composition was about 75% neutrinos and 25% antineutrinos.

E-632: The 15-ft Bubble Chamber

155,000 photographs were taken in each of three cameras of the 15-ft chamber filled with a heavy neon-hydrogen mix. 100,000 photographs were taken with a high-resolution camera with classical optics which allowed events in the center of the chamber to be studied in greater detail. Development work was done in holographic optics, which has the potential for higher resolution over a larger volume than classical optics. Some holograms of events were obtained and a new arrangement is being prepared for the next run. Several holographic replay systems have been built and are working well.

The 13,000 charged-current events are now being scanned and measured. These are being studied particularly for new effects. One interesting objective is the famous "same-sign dilepton" signal. A very small number of events displayed with bubble-chamber clarity could solve the problem.

The EMI/IDF counters worked very well and muons of momentum greater than 4 GeV/c were identified with 93% efficiency. To study

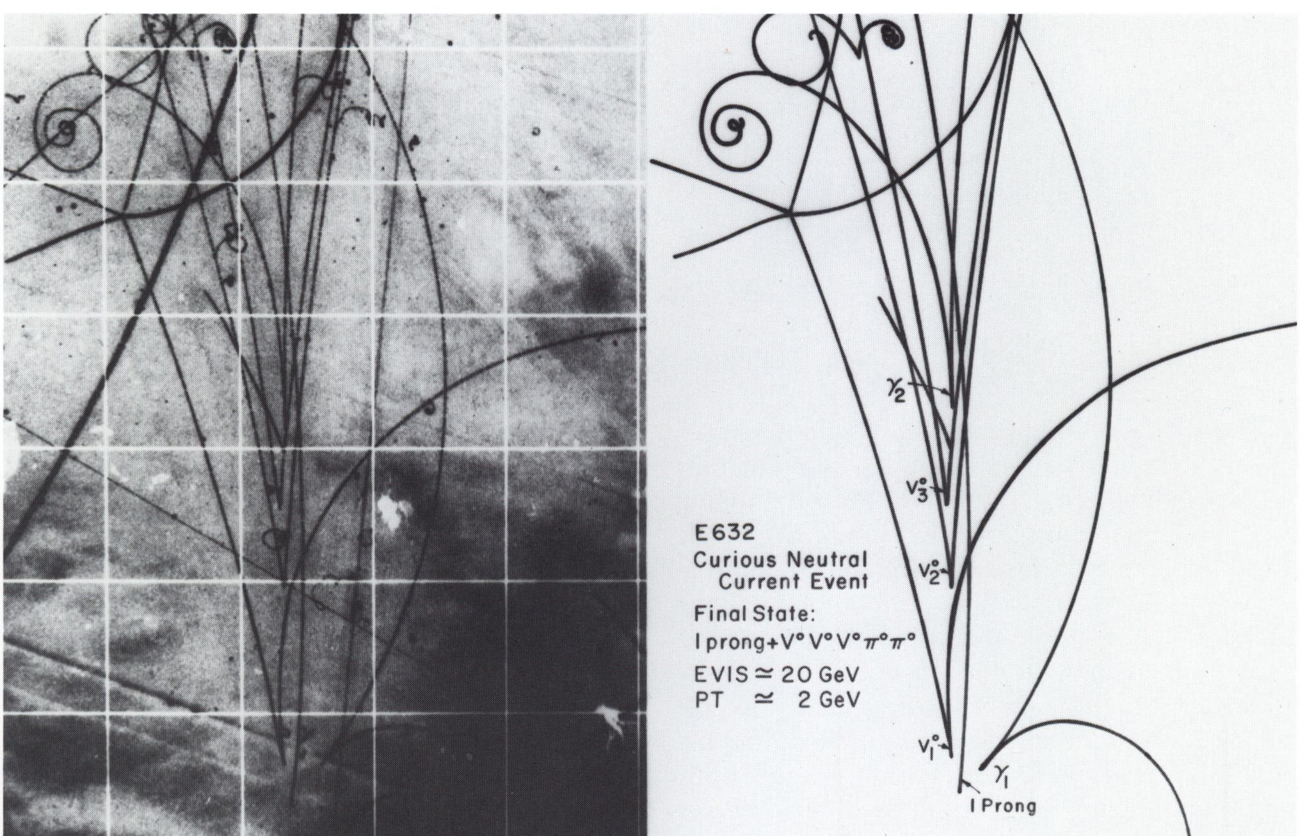


Figure 6

like-sign dileptons, the $\mu\mu$ candidate events are being selected using the EMI/IDF counters while the μe events are being selected using both the counter data and film scanning. Two interesting events are shown in Fig. 6 and Fig. 7.

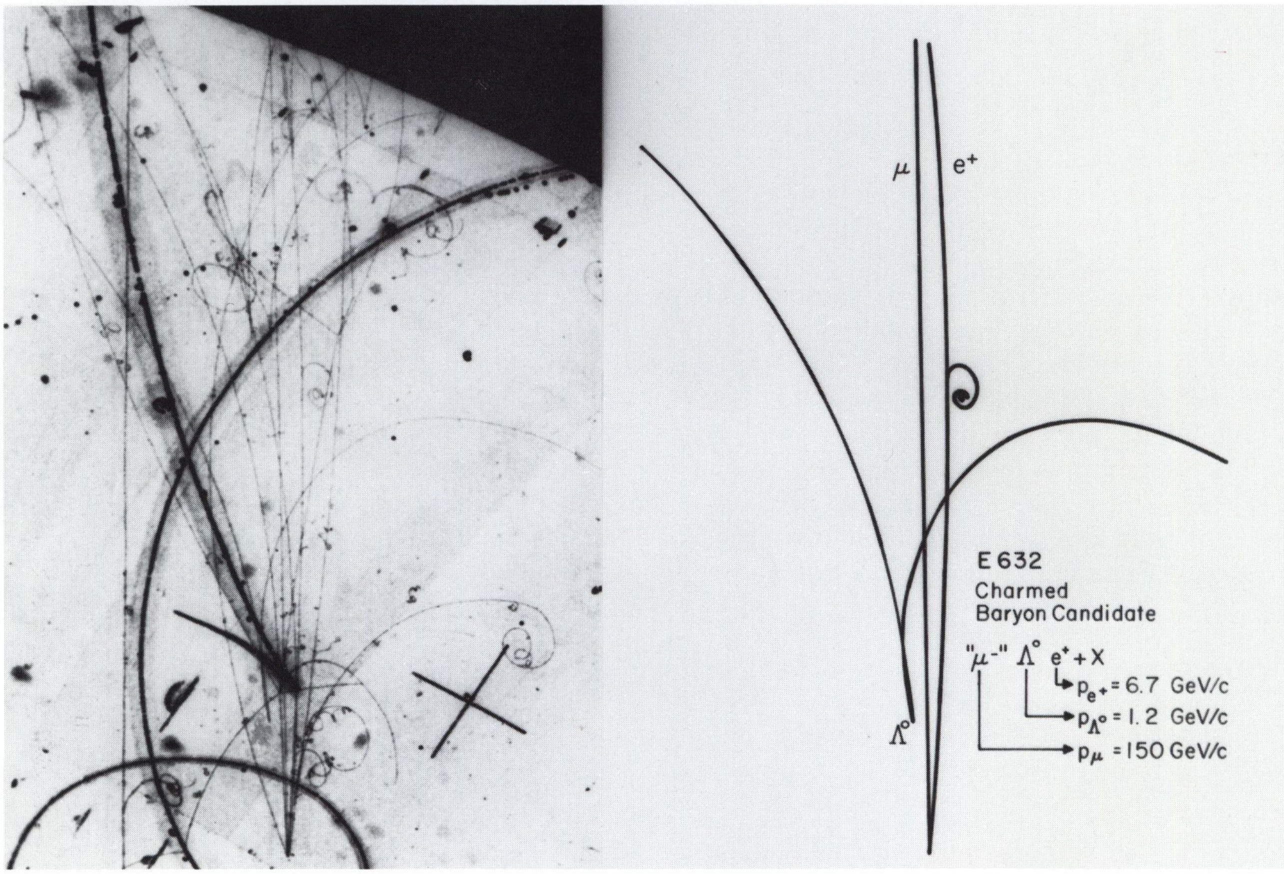


Figure 7

E-745: Tohoku Bubble Chamber

The other bubble chamber in the neutrino run was the new Tohoku 1-m, heavy-Freon chamber. Experiment 745 is a Brown University, IHEP (Beijing), MIT, Nagoya, Oak Ridge, Technion (Israel), Tel Aviv, Tennessee, Tohoku University collaboration. Experiment 745 began as an engineering test, but good physics data were obtained. The experiment, using the 1-m, high-resolution Freon bubble chamber with a hybrid muon-detection system, was used to study high-energy neutrino interactions and the physics of short decays.

Experiment 745 had a smooth run in the four months from April to August. 200,000 normal bubble-chamber pictures and 63,000 holographic pictures were taken. The unique feature of the experiment, holographic photography, was developed successfully and projection machines for reconstruction of holograms are in routine operation in two laboratories. Processing of data is about 40% complete and the first pass of analysis will be completed by spring 1986. Figure 8 shows the first identified charm event in this run, $D^\circ \rightarrow K^\circ\pi^+\pi^-$.

Figure 8

E-744: Electronic, Heavy

The large (approximately 1000 tons) electronic detector for E-744 is a University of Chicago, Columbia, Fermilab, Rochester collaboration. The 600-ton target calorimeter was instrumented with scintillation counters sampling every 10 cm of steel and multiwire drift chambers with 20 cm of steel sampling. With the aid of fast, buffered electronics built at Columbia University's Nevis Labs, the experiment was capable of recording upwards of 30 events during a single millisecond spill. Throughout the run the apparatus performed flawlessly and accumulated 1.7×10^6 charged-current events produced by neutrinos and antineutrinos. In addition, a corresponding number of neutral-current events was also collected.

The main thrust of the experiment is to study rare neutrino events, specifically dimuons. It is estimated that the experiment collected approximately 4000 dimuons of opposite sign and 200 like-sign dimuons before momentum and fiducial cuts. In the quad triplet run, the mean neutrino event energy was 150 GeV and some 10% of events had energy between 300 and 600 GeV. This number of events was the largest number ever collected in a single neutrino experiment at Fermilab. This sample corresponds to 5×10^{17} protons on target. Typical like-sign and opposite-sign dimuon events are shown in Fig. 9.

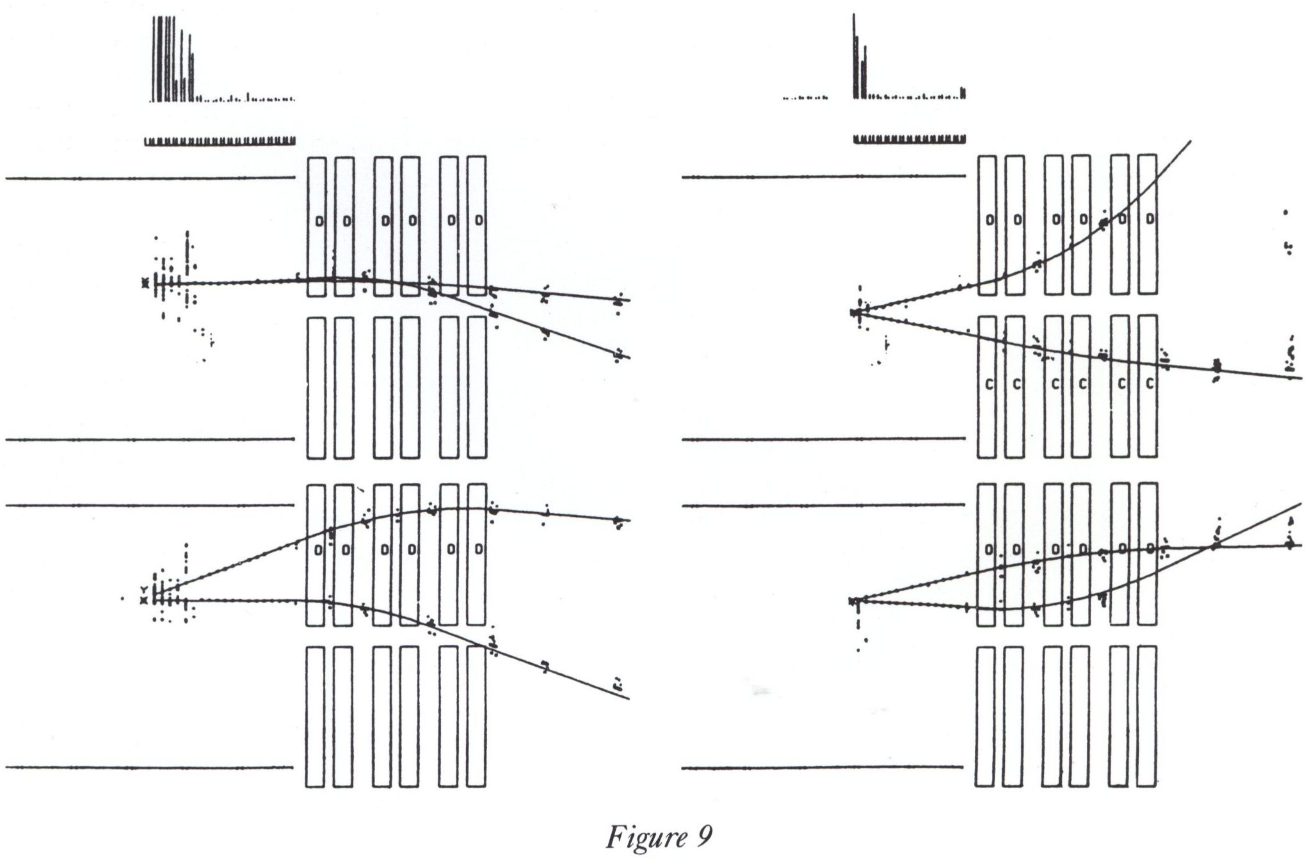


Figure 9

E-733: Electronics, Fine Grain

The second electronic detector which took data during the 800-GeV Tevatron run was E-733, a Fermilab, Florida University, MIT, and Michigan State collaboration. This 300-ton, fine-grain detector is capable of measuring the direction as well as the energy of hadronic showers. Some 220,000 triggers were taken. A fraction of these triggers had a dimuon enhancement; thus, one expects a rich opposite-sign dimuon and like-sign dimuon sample of events contained therein. In addition to running in the neutrino beam, the experiment utilized a slow-spill hadron beam providing continuous calibration throughout the run.

E-731: CP Violation

This is a University of Chicago, Elmhurst, Fermilab, Princeton, Saclay collaboration. To date there is no evidence for milliweak ($\Delta S = 1$) CP violation, although such predictions arise naturally in many forms of the standard model of electroweak interactions. A signature for milliweak CP violation is a non-zero value of the parameter ε'/ε to a precision of 0.1%. This will require the detection of approximately 10^5 $K_L^\circ \rightarrow \pi^\circ\pi^\circ$ and 4.10^5 $K_L^\circ \rightarrow \pi^+\pi^-$ decays. Such a measurement will either demonstrate the existence of milliweak CP violation or, at the very least, severely constrain the models that describe it. The most accurate previous result (from Fermilab E-617) had an error of about $\pm$ 0.006. To achieve its goal, E-731 requires a high-rate/low-background neutral kaon beam and a detector with high acceptance and good background suppression.

During the 1985 Tevatron run, the new neutral-kaon beam at M Center was successfully commissioned. It combines both the high energy and high duty-cycle of the Tevatron to produce a neutral K long beam which has five times more useable (100-GeV region) flux than ever before at Fermilab. Soft neutrons and photons, which had been limiting factors in previous experiments, have been significantly reduced. The spectrometer, consisting of an 800-element lead-glass array, a new 2000-wire high-rate drift-chamber system, an analysis magnet with a 60-in. gap, a 1mm-thick triggering hodoscope in vacuum, and several planes of triggering hodoscopes was installed and tested. In addition, a series of $K - \rightarrow 3\pi$ veto counters outside the decay fiducial, but within the vacuum chamber, an active regenerator also in the vacuum, and a beam anti-counter were commissioned. The entire integrated spectrometer system was in place and collecting data for the last six weeks of the run.

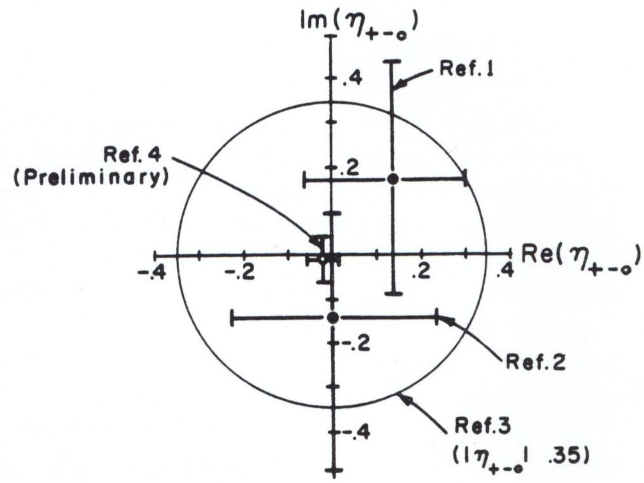
The 1985 run was very successful; approximately 10,000 neutral $K_L^\circ \rightarrow \pi^\circ\pi^\circ$ have already been collected. This corresponds to a statistical precision nearly twice as good as the E-617 result. Additionally, the background suppression counters have worked quite well: the systematic errors have also been improved. These data are now being analyzed. As a result of experience gained in the 1985 running period, the experimenters plan to build a hardware cluster finder for the lead glass and upgrade the data acquisition system. With these changes, the full goals of E-731 should be achieved.

E-621: CP Violation

In E-621, a collaboration from Michigan, Minnesota, and Rutgers universities is making a measurement of η_{+-o}, the CP-violation parameter describing $K_s^\circ \rightarrow \pi^+\pi^-\pi^\circ$ decays. By collecting $\pi^+\pi^-\pi^\circ$ decays with a Vee spectrometer located close to the kaon production target, CP violation is seen as an interference between K_s° and K_L° decays. In 1984, when Fermilab began operating at 800 GeV/c, a test run collected 200,000 $K_{\pi 3}$ decays. The analysis of these data is proceeding; backgrounds and systematic errors are negligably small, and one is able to confidently state that $|\eta_{+-o}| < 0.03$ (the previous upper limit was 0.35). The complete analysis should reduce the error by a factor of two.

During the 1985 fixed-target run, improvements were made in the beamline, in the shielding of the spectrometer, and in the trigger. The experiment collected 3.2 million $K_{\pi 3}$ decays. This data set is now under analysis. If we assume that systematic errors will remain manageable, and scale by statistical precision alone, this should yield a measurement of $|\eta_{+-o}|$ to an accuracy of $\pm$ 0.003.

The state of the current understanding of $|\eta_{+-o}|$ is illustrated in Fig. 10, which shows preliminary results from the 1984 test run, two other experiments with large statistics, and the Particle Data Group's upper limit.



Complex η_{+-o} Plane

References:

1. *M. Metcalf et al., Physics Letters 40B, 703 (1972)*
2. *V.V. Barmin et al., Nuovo Cimento 85A, 67 (1985)*
3. *Particle Data Group, Rev. Mod. Phys. 56, S37 (1984)*
4. *This experiment: Preliminary results from 1984 test run*

Figure 10

E-653: Emulsion

Experiment 653 is an Aichi (Japan), Davis, Carnegie-Mellon, Chonnam (Korea), Gifu (Japan), Gyeongsang (Korea), Jeonbug (Korea), Kobe (Japan), Nagoya (Japan), Ohio State, Okayama (Japan), Oklahoma, Osaka City (Japan), Osaka Prefecture (Japan), Sookmyong, Seoul (Korea), Toho (Japan), Won Kwang (Korea), Yokohama (Japan) universities collaboration, a study of charm and beauty using a new form of hybrid emulsion spectrometer. As given in the proposal, the purpose of this experiment was to obtain a low-background sample of 10,000 charm and 100 beauty-associated decays selected by decay lengths rather than branching modes. Desired physics included precision measurement of lifetimes, measurement of branching ratios, discovery of new states, a search for exotic four-quark meson states, a study of the $F \rightarrow \tau$ decay, mixing measurements, and a variety of lesser goals.

For E-653, 1985 was a full-system maiden run. A series of emulsion modules, scanned through the 800-GeV proton beam under computer control, were exposed to track intensities varying between 0.5×10^4 and 2×10^5 per square centimeter. Interactions in the vicinity of the emulsion resulting in a penetrating muon with greater than 5-GeV/c momentum were recorded using a highly precise electronic spectrometer. Emulsion targets typically were 6-8% of an interaction length, and 5% of interactions resulted in a muon trigger. Most of these triggers came from pion and kaon decays within the free drift space of the spectrometer.

Solid-state microstrip detectors located the beam to within 5 microns and secondary charged tracks to within 14-20 microns. Multiple-sampling drift chambers with 100-micron resolution completed a short but powerful spectrometer. Particle identification apparatus included a 70-picosecond time-of-flight hodoscope, a liquid-argon calorimeter with 1-mm resolution and 1-cm two-shower separation, a hadron calorimeter, and a muon magnetic-toroid spectrometer. Data were recorded via a FASTBUS system suitable for a wide variety of emulsion and all electronic running.

5.6 million triggers, representing approximately 0.71×10^8 interactions within the fiducial volume of the emulsion, were recorded, roughly 80% of the 1981 prediction for the first run.

Currently, individual systems have been calibrated to precisions quoted previously and vertex finding is commencing. Initial contact has been made between electronic predictions and interactions within the emulsion, and the hope is to begin finding charm by spring. Assuming an A^1 nuclear dependence, a 25-microbarn-pair cross section, and a 70% overall efficiency, experimenters could find almost 5000 charm pairs, though because of uncertainties they would be happy with half that number. Based on a 5-nanobarn cross section, they expect to find perhaps four associated beauty events.

Other Highlights

As part of the doubling of the energy of the Fermilab fixed-target program, four new beamlines were designed and under construction in 1985. Perhaps most important of these four were the new Muon Beamline and the Wide Band Photon Beamline. At the end of those new beamlines, new detectors are being constructed for runs in 1986.

Getting some beam down these two new lines to test for beam halos and intensities, and to debug some elements of the new apparatus, was considered important, although of lower priority. The race to complete the construction of the tunnels and beam enclosures, and install and connect beam-transport magnets before the end of the running cycle, was fortunately won. Below are the reports from the two beamlines.

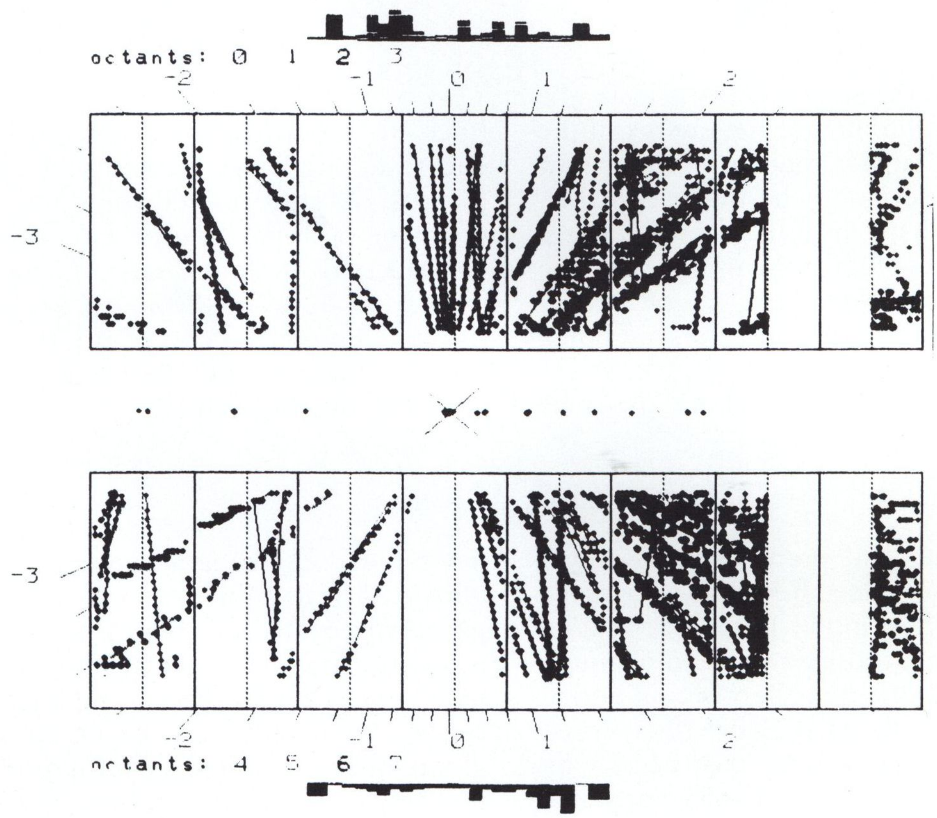
E-665: Muons

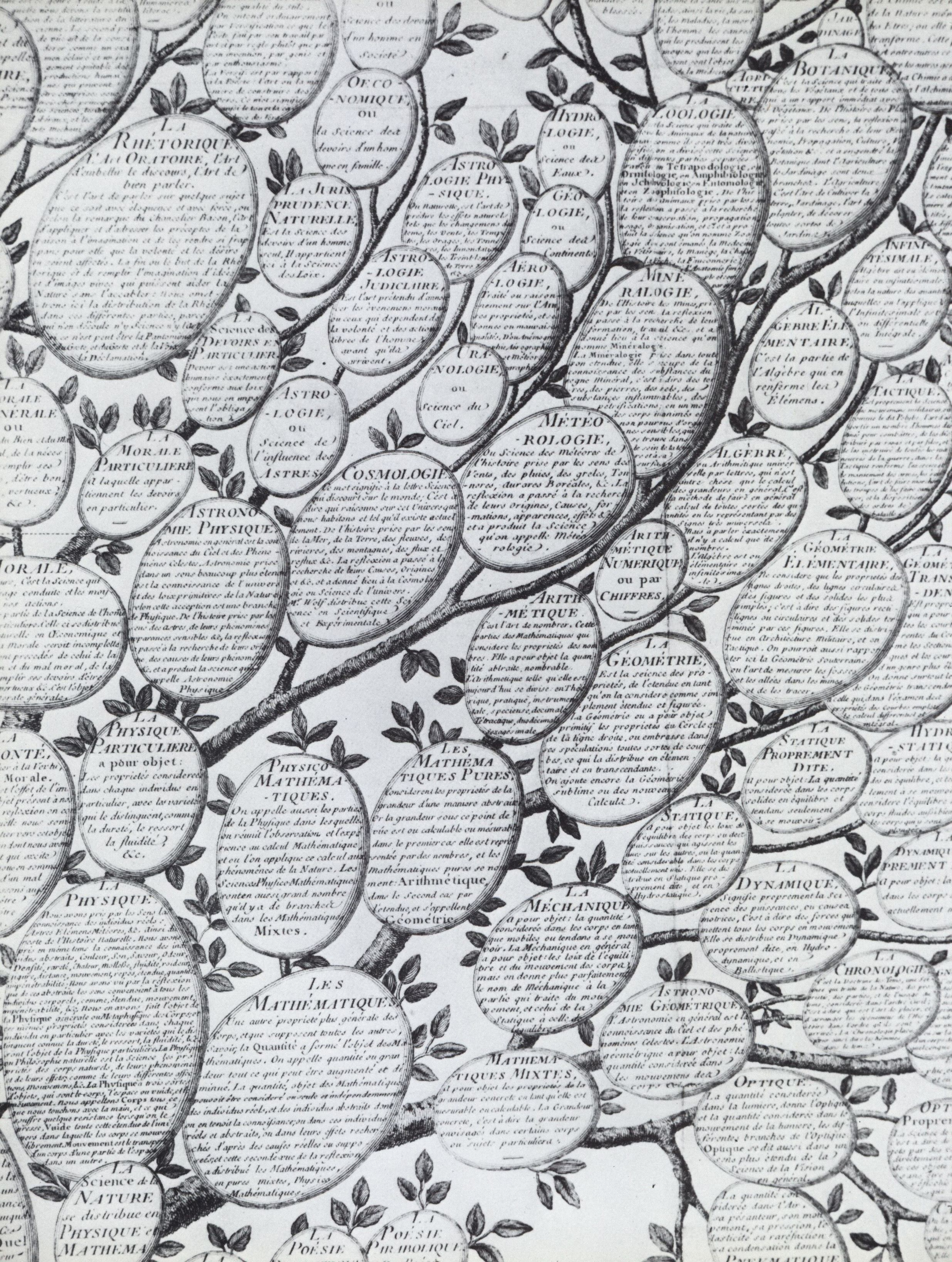
Experiment 665 did pretty well for never making it onto the official Fermilab long-range schedule! The new muon beam needed for the experiment was mostly a set of cold muddy holes in the ground when the running period started in January. By early September, when the run ended, the new beam had been commissioned and tests of the E-655 apparatus had begun. Useful measurements were made of overall beam and halo yields, a crude beam phase space measurement was made, several proportional wire detectors were tested, and a halo trigger established using the full muon spectrometer scintillation counter array. The group looks forward to a useful run for physics in 1987.

E-687: Photons

The following items were accomplished between June 23, 1985, when the wide-band beam was first successfully transported, and the end of the run in late August.

1. Beam studied: the beam was operated in electron/photon mode at momenta up to 650 GeV/c and as low as 15 GeV/c. Measurements of electron yields, charged-hadron contamination of the electron beam, and neutral-hadron contamination of the photon beam were made. Beam optimization, both of the magnetic tune and collimator settings as well as radiator and converter studies, were completed. Some measurements of muon backgrounds were completed. The electron-sweeping system was commissioned and used to calibrate the electron shower-counters which will be used to measure the electron energy after the radiator.
2. Spectrometer Analysis Magnet: The first of the two new large analysis magnets was constructed and operated. It achieved the design field.
3. Experimental equipment: Major components of the detectors were operated in conditions approximating actual running conditions.





La Rhétorique l'Art Oratoire, l'Art d'embellir le discours, l'Art de bien parler.
Oeconomique ou la Science des devoirs d'un homme en famille
Hydrologie, ou Science des Eaux.
La Zoologie
La Botanique
La Jurisprudence Naturelle, Est la Science des devoirs d'un homme seul, Il appartient à la Science des Loix.
Astrologie Physique
Géologie, ou Science des Continents
Astrologie Judiciaire
Aërologie
Minéralogie
Infinitésimale
Algèbre Élémentaire, C'est la partie de l'Algèbre qui en renferme les Élémens.
La Science des Devoirs en particulier
Uranologie ou Science du Ciel.
Astrologie, ou Science de l'influence des Astres
La Morale Particulière à laquelle appartiennent les devoirs en particulier.
La Morale Générale ou
La Tactique
Météorologie
Cosmologie
Algèbre
Astronomie Physique
Arithmétique Numérique ou par Chiffres.
La Géométrie Élémentaire
Morale
Arithmétique. C'est l'art de nombrer.
La Géométrie
La Physique Particulière a pour objet: Les propriétés considérées dans chaque individu en particulier, avec les variétés qui le distinguent, comme la dureté, le ressort, la fluidité &c.
Physico Mathématiques. On appelle aussi les parties de la Physique dans lesquelles on réunit l'observation et l'expérience au calcul Mathématique et où l'on applique ce calcul aux phénomènes de la Nature. Les Sciences Physico Mathématiques sont en aussi grand nombre qu'il y a de branches dans les Mathématiques Mixtes.
Les Mathématiques Pures
La Statique Proprement Dite.
Hydrostatique
La Statique
La Dynamique
La Physique
La Méchanique
La Chronologie
Astronomie Géométrique
Les Mathématiques
Mathématiques Mixtes
Optique
La Science de la Nature se distribue en Physique et Mathématiques
La Poésie
Poésie Parabolique

III. Educational Activities at Fermilab

Friends of Fermilab Association

Fermilab's commitment to the enhancement of science education was demonstrated in 1985 by continuing support of a number of in-house programs for teachers and pre-college students sponsored by the Friends of Fermilab Association (FFLA).

FFLA is a not-for-profit corporation. It is a membership organization, with members drawn from both the Fermilab community and the general public. Stanka Jovanovic is FFLA's president; Marge Bardeen is the vice-president and program coordinator. During Mrs. Bardeen's absence in 1985-86, Barbara Grannis is serving as program coordinator.

The FFLA marked its third year of operation in 1985, and has continued to develop and conduct pre-college science education programs for teachers, students, and the general public. With funding assistance from the National Science Foundation (NSF), the U.S. Department of Energy, Abbott Laboratories Fund, and the following foundations: The Bersted Foundation, The Forest Fund, Furnas Foundation, Inc., The Grainger Foundation, Chauncy and Marion Deering McCormick Foundation, and the Robert R. McCormick Charitable Trust, and with the invaluable help and cooperation of regional educators and Fermilab staff, FFLA has mounted new programs and improved some programs implemented in previous years.

Discussing future plans for the Friends of Fermilab Summer Institute for Science Teachers, following receipt of a grant from the National Science Foundation, are (left to right, seated) Fermilab Director Leon Lederman; James Ruebush, Science teacher at St. Charles High School; Marge Bardeen, vice-president of FFLA; Judy Zielinski, member of the FFLA Board of Directors; and (left to right, standing) Stanka Jovanovic, president of FFLA; and Robert Riley, president of the Batavia Bank and FFLA board member.

1985 Summer Institute for Science Teachers

The past year saw the initiation of a three-year National Science Foundation grant which provided major funding for the 1985 Summer Institute for Science Teachers sponsored by FFLA. The four-week institute drew high-school teachers from the nine-county northeastern Illinois area. Forty-five biology, chemistry, and physics teachers participated in the program, which consisted this year of intradisciplinary and plenary lectures at Fermilab, and science and computer labs at a local high school.

Physics West/Chemistry West

One of the great benefits of the institute is the opportunity which it offers to science teachers to share information. Physics West, a spin-off of the 1984 Summer Institute, was created to provide a framework for area teachers to continue to exchange professional news and views. Physics West is now well established, with monthly meetings in various locations in Kane and DuPage counties. It was joined this year by Chemistry West, a forum where chemistry "graduates" of the Summer Institutes can share innovative teaching methods and classroom materials.

Resources for the Science Classroom

A teacher's manual listing regional facilities for tours and materials available for the K-12 science classroom, *Resources for the Science Classroom*, was developed with FFLA sponsorship in 1984. In 1985 a supplement to the original manual was produced and distributed to over 650 area schools. The response to the manual and supplement has been extraordinary, with requests for copies arriving almost daily from schools throughout Illinois and neighboring states.

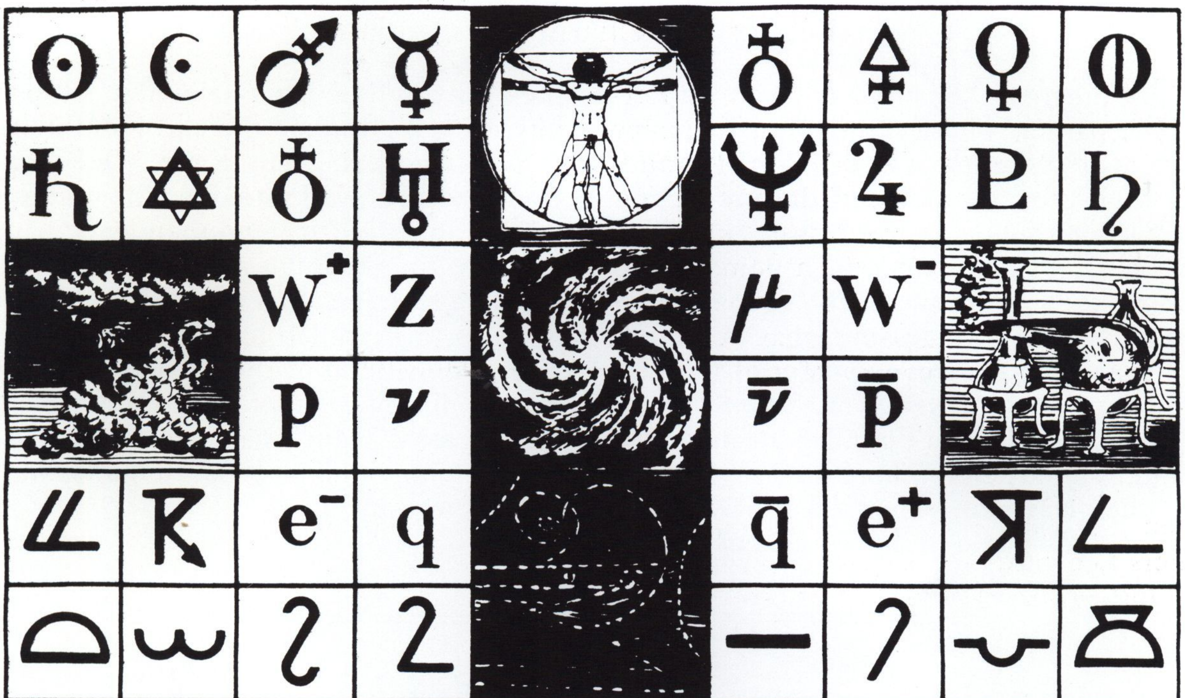
Discovery and Invention Poster Contest

FFLA celebrated National Science Week in May 1985 by sponsoring a Discovery and Invention Poster Contest for third to sixth grade students in Kane and DuPage counties. The challenge was to create a scientific invention for which the student would like to be famous in the year 2010.

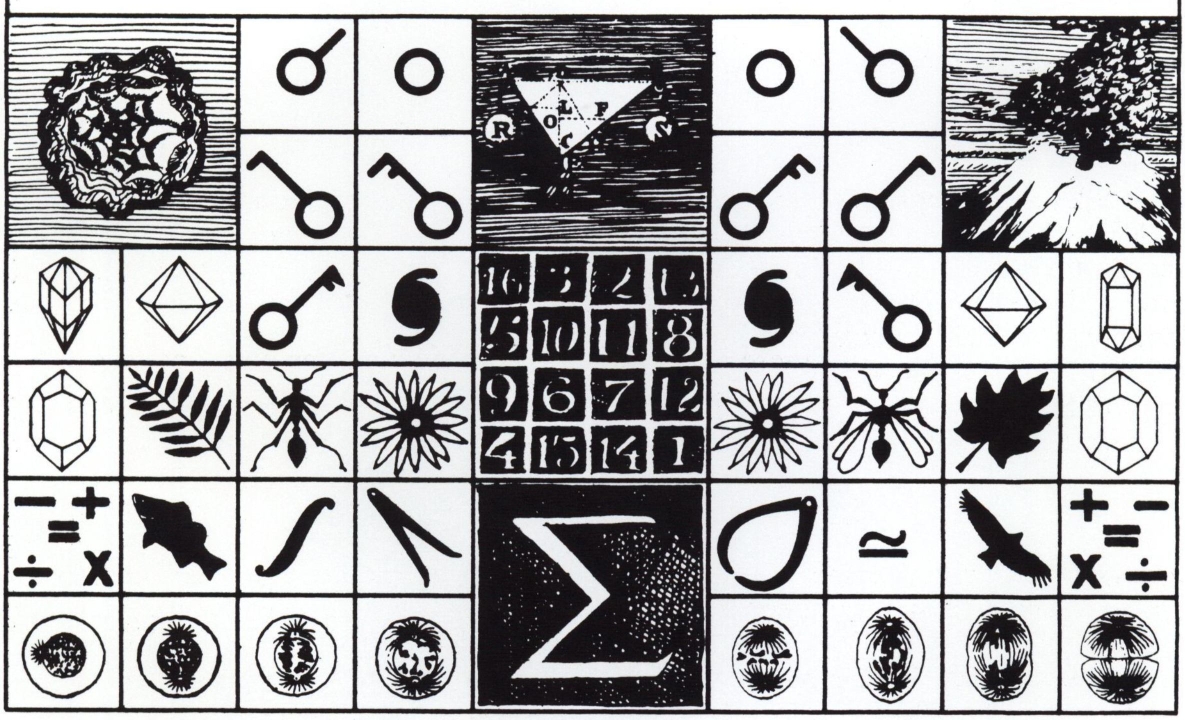
Fifty-two posters were submitted for judging and display at Fermilab after having won "pre-contests" in the schools. Prizes were awarded to the top six winners. The poster contest was highly successful and FFLA has been asked by the NSF to make a report on "How to Organize a Poster Contest" which will be included in an NSF publication and distributed throughout the U.S.

Target — Science and Engineering

A program for gifted minority students, "Target — Science and Engineering," is an apprentice program which has been held at Fermilab since 1980. Between twenty and twenty-five students selected from applicants from the Chicago metropolitan area have taken part in the six-week program each summer, working with a Fermilab staff member in the mornings and spending the afternoons preparing a science research project. In 1985, FFLA assisted with this program by securing a private-sector grant to supplement program funding.



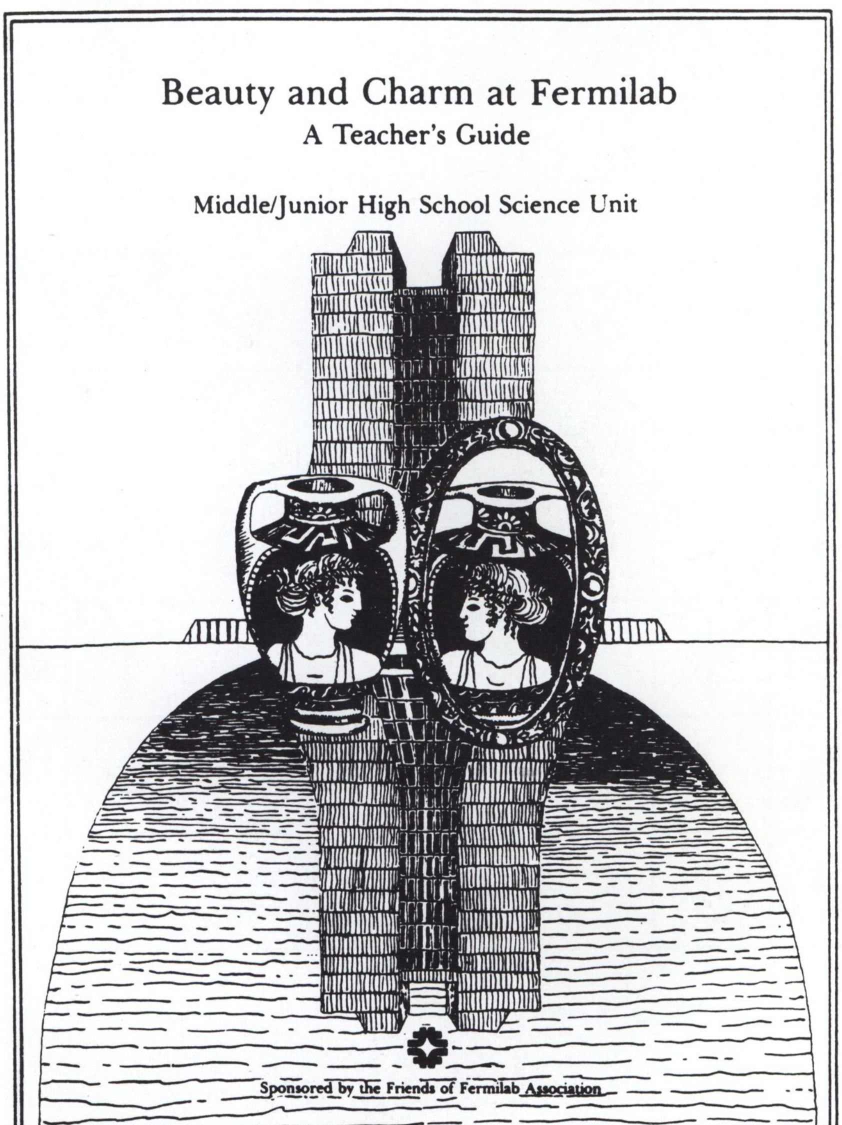
Resources for the Science Classroom



Beauty and Charm at Fermilab

A new program, "Beauty and Charm at Fermilab," a particle-physics curriculum for junior high-school students, was developed during 1985. The program included the production of a teacher's guide, a five-lesson "kit unit" with simple experiments which demonstrate concepts such as "how small is small" and "how to observe and measure what we cannot see." Following the development of the prototype curriculum, a series of three Saturday workshops were held at Fermilab to familiarize a group of junior high-school science teachers with the classroom materials. Seventeen teachers participated in the workshops, where they received a brief overview of particle physics and critiqued the classroom unit.

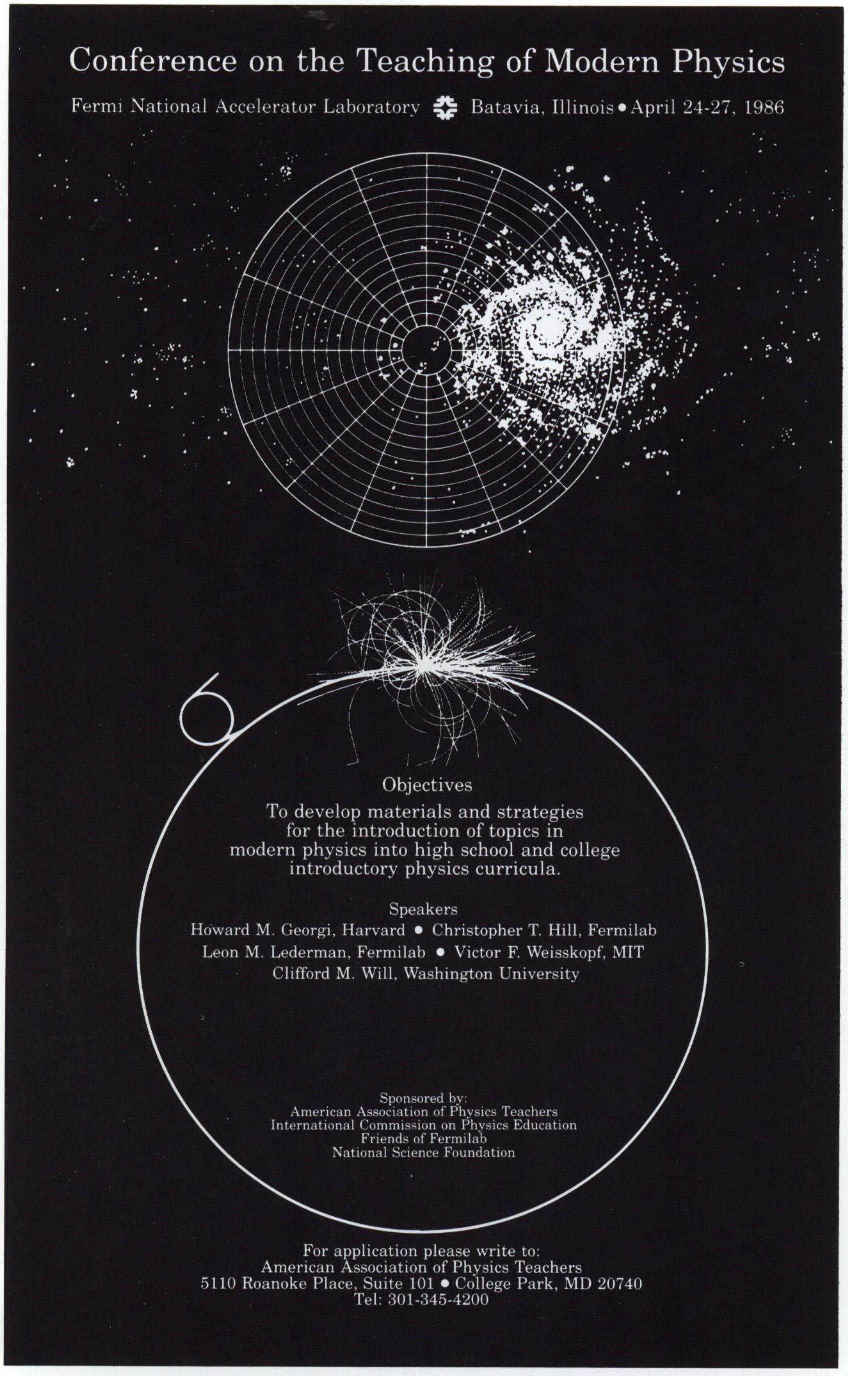
The teachers, from Kane, DuPage, and Cook counties, will introduce the unit in their schools in early 1986 and then assist with the revisions in the pilot curriculum. The first round of this program culminates with a series of visits to Fermilab by the teachers and approximately 1000 of their students. The students will view a videotape of Fermilab experimental areas, which has been produced specially for junior high-school students, and visit various working areas.



Additional Conferences and Workshops

In 1986, FFLA will co-sponsor an international "Conference on the Teaching of Modern Physics" to be held at Fermilab. Also in 1986, FFLA will inaugurate a program for K-8 teachers, "Problem Solving in Mathematics Teacher Training Workshop," and will establish a regional videotape library based on videotapes of the Saturday Morning Physics lectures and funded by the Aurora Foundation.

In December 1983, FFLA sponsored the "Curriculum Design Workshop" for the Illinois Mathematics and Science Academy, which was then in its initial planning stage.



Illinois Mathematics and Science Academy

The Illinois Mathematics and Science Academy was proposed to the Illinois General Assembly in an address by Governor James R. Thompson in early 1984. In 1985, the General Assembly enacted an Educational Reform Bill. Through the efforts of State Senator Forest Etheredge (R.-Aurora), a provision for the establishment of the proposed Mathematics-Science Academy was appended to the bill. The bill was duly signed into law by Governor Thompson, creating the Academy, which is scheduled to open in Aurora, Illinois, in close proximity to Fermilab, in 1986.

Fermilab scientists, FFLA members, and Fermilab Director Leon Lederman played an active role in the design and promotion of the Academy concept: a three-year boarding school for gifted students who would enter as high-school sophomores and graduate into the sophomore year of college. A very large number of curriculum innovations were devised to make this the pre-eminent school in the nation. It is expected that Fermilab will continue to play an important role in the Academy.

The US Particle Accelerators School

The US Particle Accelerators School began operation in 1981 following a recommendation made by a subpanel of the High Energy Physics Advisory Panel that convened in 1979-1980 to study the state of accelerator R&D. The purpose of the school is to help educate the young as well as those wanting to expand their knowledge in accelerator physics, and to enhance the professional stature and pedagogic capabilities of accelerator scientists. To accomplish these goals on a national scale, with the school changing its location from year to year, the US School Office was established at Fermilab in 1984. The office opened under the direction of the creator of the school, Mel Month of BNL. With a central management in place, it became possible to influence the complex process of education within a much broader cultural framework. The result was the introduction of a wide array of school-related activities, with the school office providing the administrative coordination and support necessary for organization and implementation. The list of office activities includes:

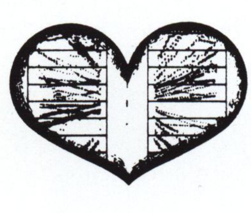
- An intensive Accelerator School each year
- Cultural symposia (high-energy physics, other accelerator-based sciences, etc.)
- Publication of school texts
- International courses on specialized topics (jointly with the CERN Accelerator School)
- Prizes for achievement in accelerator physics and technology
- History symposia and historical awards
- Organization of the American Physical Society (APS) Topical Group on Particle Beam Physics

The student population for the annual two-week school has grown from 120 in 1981, to 260 in 1985. This very large growth in demand reflects a deep interest within the science community. Although the full extent of this interest in accelerator science and technology is not known, the expansion of accelerator use in the accelerator-based sciences as well as in industry, medicine, and defense suggests that we may only be seeing the tip of the iceberg.

The Fermilab Ph.D. Program in Accelerator Science

In 1985, Fermilab started a joint program with universities to try to help alleviate the current shortage of accelerator physicists. The Laboratory offers the opportunity for graduate students to carry out accelerator research toward a university Ph.D. degree. The student carries out thesis research at Fermilab, with a sponsor (probably a member of the high-energy physics group) in the student's university physics department. A Laboratory staff member is the student's supervisor during the research work here. Thesis topics can be in either theoretical or experimental accelerator work.

Response to this program by university physics departments has been enthusiastic; already, two students are here working toward their Ph.D.'s, and there have been many inquiries and expressions of interest by others. Michael Syphers is working on a thesis topic involving computer simulation and subsequent hardware construction of a new 8-GeV transfer line between the Booster and Main Ring to accurately match the phase spaces of the two accelerators. Enrique Henestroza is studying the application of perturbation theory to non-linear accelerator Hamiltonians. Although the program is still new, all indications point to its success and value to our field.



Physics in Latin America; the NSF/APS Grant, and More

Since mid-1984, Fermilab has been administering a grant from the NSF to the American Physical Society to aid physics in Latin America. The initial idea arose at a Symposium on Pan American Collaboration in Experimental Physics in Rio de Janeiro, Brazil, in mid-1983; considerable concern was expressed there at the effects of the economic crisis on the growing scientific infrastructure of the most developed countries in Latin America. It became obvious that a relatively small amount of money would be enormously helpful in tiding Latin American physics over the difficulties caused by the hard-currency shortages.

In July 1984, NSF approved a grant of $300,000 to the APS for assistance to physics in Argentina, Brazil, Chile, Mexico, and Venezuela; the two principal investigators are Leon Lederman (Fermilab) and Leo Falicov (University of California, Berkeley). The grant is to be used in four areas: (1) library subscriptions to U.S. scientific journals; (2) payment of page charges for articles by Latin American authors submitted to refereed U.S. journals; (3) spare parts and maintenance items for existing equipment in Latin American physics laboratories; and (4) per diem support for Latin American physicists visiting the U.S. for short periods of time.

Grant representatives in each of the five countries collect requests in their countries and send lists of approved items to the U.S.; these are then considered under guidelines set up by a U.S. committee for the grant. Fermilab, which has had a history of interactions with Latin America over a number of years, was designated to administer the grant; this involves placing orders with manufacturers, paying for the orders, issuance of per diem checks, and so forth. By agreement with DOE, the services of Fermilab's Purchasing and Accounting Departments, administrative and secretarial assistance, computerized record-keeping, telephones, etc., were provided at no cost to the grant and were essential to the smooth administration of the grant.

Following some trial and error, procedures evolved for processing the requests, and the operation has become reasonably routine. Although the fractions of expenditures in the different categories varied from country to country, a typical breakdown is: per diem 15%, journal subscriptions 25%, page charges 15%, and equipment 45%. To date, there have been over 700 separate transactions processed, and about 75% of the funds have been disbursed.

The feedback we have received from the five Latin American countries has been uniformly positive; the relatively small amount of money and effort involved in this program has indeed had a significant impact. For example, libraries have been able to obtain forefront physics journals that they could not otherwise afford, and replacement parts became available that allowed broken research equipment to become operational again. Hopefully the success of this modest program will lead to others aimed at similar problems in other parts of the world.

As a direct result of Pan American symposia sponsored by Fermilab and the University of Mexico (1981) and by Fermilab and the Brazilian Physical Society (1983), Fermilab has hosted many Latin American visitors, principally from Mexico, Brazil, and Argentina. Out of this came two new groups engaging in experimental HEP. One, from the Institute of Physics, (UNAM), Mexico, is involved in E-690, a collaboration with Columbia University and the University of Massachusetts, scheduled to run in the '87 running period. The other, from CNPQ in Rio de Janiero and from the University of Sao Paolo, Brazil, worked with E-691 (see "The Fixed-Target Run of 1985" elsewhere in this *Report*). A third Pan American symposium is scheduled to be held in Argentina sometime in 1986.

Simposio Panamericano de
Panamerican Symposium on

Física de Partículas Elementales y de Tecnología
Particle Physics and Technology

Enero 5, 6 y 7 de 1982 Cocoyoc, Morelos, México
January 5, 6 and 7, 1982 Cocoyoc, Morelos, Mexico

Entre los Participantes Estaran
Partial List of Participants

J. D. Bjorken • G. Cocho • J. Cronin • R. P. Feynman • C. Garcia-Canal • S. Glashow • L. Lederman
J. Leite-Lopes • R. Marshak • M. Moravcsik • W. Panofsky • B. Richter • R. Salmeron • R. R. Wilson

Para Toda Información:
For Information Please Write to:

Dr. M. Moreno, Secretario Científico • Instituto de Física, UNAM
Apdo. Postal 20-364, México 20, D.F.

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Saturday Morning Physics

This now-six-year-old program continues to be the core pre-college activity at Fermilab. We have graduated about 1300 students, and Saturday Morning Physics (SMP) Principal Drasko Jovanovic plans to begin a follow-up program to see where these survivors of our 10-week lecture series and tour end up — how many are following a scientific career and how important was SMP? Our lecture series for 1985, which we repeated three times for three different classes during the course of the year, looks like this:

- Introduction: What is an Elementary Particle? From Molecules to Quarks, with a Pause at the Hydrogen Atom. *Lecturer:* L. Lederman
- How Do We Make Particles? Accelerators, Beam Transport, and Assorted Technologies. *Lecturer:* D. Jovanovic
- Special Theory of Relativity. *Lecturer:* T. Nash
- How Do We See Particles? Interaction of Radiation with Matter. *Lecturers:* G. Fisk, C. Kerns
- The Connections of Particles with Cosmology: How the World Began. Massive Neutrinos, Pulsars, Neutron Stars, and Black Holes. *Lecturers:* E. Kolb, M. Turner
- Particle Physics Spin-offs: Technology and Applications to Other Fields, Current Problems, and Future Prospects. *Lecturer:* E. Malamud
- Conservation Laws and Symmetry Principles: Energy, Momentum, Rotation, Left-Handedness and Right-Handedness, Time, and Antimatter. *Lecturer:* C. Hill
- Quantum Theory; Particles and Waves; Quantum Numbers and the Intrinsic Properties of Elementary Particles, i.e., Charge, Spin, Mass, Strange, etc. *Lecturer:* S. Parke
- Leptons and Quarks: Electrons, Muons, Taus and Neutrinos of the Lepton World, Mesons and Baryons and Their Constituents: the Quark Model. *Lecturer:* P. Rapidis
- The Forces of Nature and Their Carriers: Photons, W's, and Gluons. *Lecturer:* J. Butler

The Summer Program for Minority Students

The first Fermilab educational program was the Summer Program for Minority Students, which began in 1970 while most of the Laboratory was still in the Village. Ken Williams, the founder of our Equal Employment Opportunity (EEO) office, was the spark behind the original program. Scientific and technical people began to be much more active in the program in 1974 and the entire program is now steered by a volunteer committee largely composed of scientists and engineers, working with the EEO office.

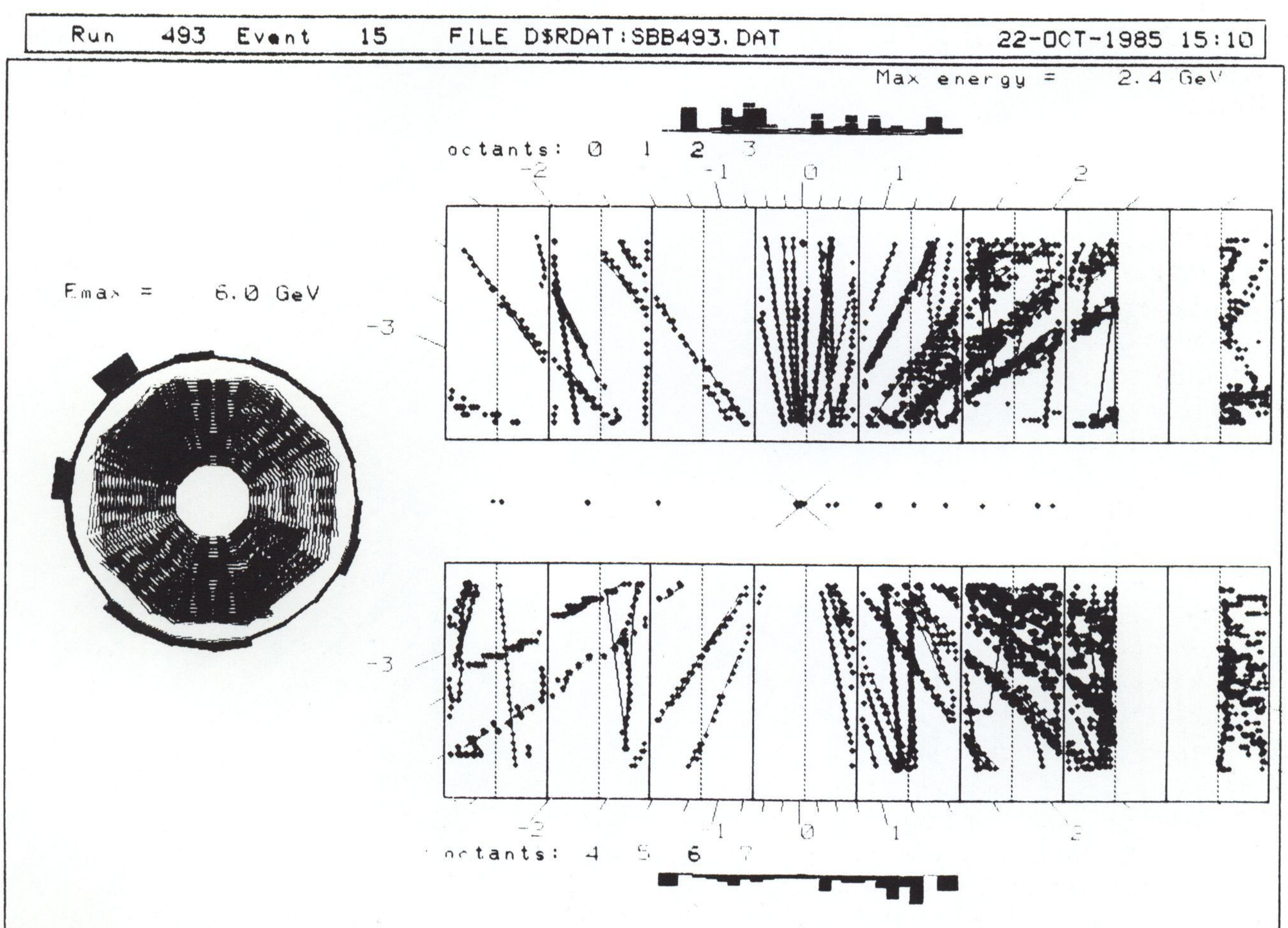
The Summer Program is still going strong. Its goal remains the same, to help able minority students toward careers in science. To further this goal, each summer we bring approximately 20 undergraduate students to Fermilab to work in Laboratory technical projects. They work directly for a supervisor, who guides them in their specific work and, more generally, shows them how to be scientists by the best methods of all, example and participation. After 11 weeks, the students go back to their colleges and universities, each having completed a project that is part of the Laboratory's scientific effort, given a talk, and written a report on it. The experience of work in a real laboratory is enormously valuable to a student, especially if he or she is from a smaller institution where there is only limited contact with research.

We find these students by going out to look for them. Each year, committee members visit many predominantly black and Hispanic colleges and universities to interview students for the program. We also take some minority students from majority institutions. Over the years, we have developed close relationships with many of the deeply dedicated faculty members of the institutions we visit. We rely heavily on their advice in selecting students.

One dedicated faculty member who has had major influence on the program is James

Davenport of Virginia State University, who has come to the Laboratory for many summers to coordinate and guide the students and the program. He watches over the students' work and leads them through the preparation of their talks and papers. He has been a great positive influence on the students and the entire program.

We have had some success in our continuing goal. More than half of the almost 200 students we have had in the program are active in scientific and technical careers, including teachers, researchers, engineers, and computer scientists. More than half a dozen have earned Ph.D.'s in science. Maybe that's only a drop in the bucket, but it's a drop we're proud of. We will continue working to make more drops.



IV. The Post-Doctoral Program at Fermilab

"*. . . lowly beasts of burden.*" – *I.I. Rabi*

Post-doctoral research associates, "post-docs" as they are universally known, play a linchpin role in the scientific life of Fermilab. They come in two categories of affiliation, university and Fermilab, and four flavors: experimenter, theorist, astrophysicist, and accelerator physicist (in approximate descending population order). On any given day, when the accelerator is running for high-energy physics, there may be more than one hundred of these folks on site, building particle detectors, logging data in experiments, processing data tapes on computers, calculating theoretical and phenomenological quantities, and inventing new ways for accelerators to perform better. Without them, the research enterprise at Fermilab (the main reason we are here!) would quickly grind to a halt. So, who are these people? What are they like? Where did they come from?

Most of the research associates are university-associated experimenters who are here on a relatively short-term basis. Some commute from their home institution (as do their professor colleagues), but a majority live in the Batavia area and function as full-time scientific representatives of their groups. Since they are recent Ph.D. graduates, they are usually young (in their late twenties or early thirties), and they come from all over the world. They are bright, friendly, hard working, and they bring a zest and flavor to Fermilab that helps give this institution its atmosphere of liveliness and challenge. They are just beginning to flower as scientists and they provide an injection of new insight, a sometimes unorthodox viewpoint, and the dogged labor that moves our scientific enterprise ahead. They are, in short, a treasure to Fermilab, to the U.S. scientific effort, and to the world science community.

Within the whole research associate population, there is the subset of people (approximately half the total number) who are Fermilab post-docs. They will be the focus of this article. At the time of writing, there are twenty-one Fermilab post-docs in experimental high-energy physics, eight in particle theory, four in astrophysics, and three in accelerator physics. In addition, there is a small group, the Wilson Fellows, whose duties are similar to those of research associates, but who are generally further along in their careers. More on this elite group later.

We first consider the largest of these groups, the twenty-one experimenter research associates. They are recruited from all over the world. The last three to arrive were Fridolin Dittus from Switzerland, Yee Bob Hsiung from Taiwan, and Stephen Delchamps of the U.S. Other recent arrivals include Taku Yamanaka from Japan, Ian Leedom from Michigan, and Carol Johnstone from Texas (some consider the famous Lone Star State the equivalent of a foreign country!). Among the Fermilab research associates working here during the past year, we also number citizens of Argentina, India, and Norway. Truly an international crowd.

We are also pleased and encouraged by the rising number of women who are represented among our experimenter post-docs. There are two women currently employed, Carol Johnstone and Wyatt Merritt, and two more who left us within the past six months, Loretta Dauwe to assume an assistant professorship in Flint, Michigan, and Regina Rameika who joined the Fermilab scientific staff. In a field that has traditionally not appealed to women these are encouraging trends, and it is apparent from our ongoing recruitment experience that the fraction of women in the field of high-energy physics will continue to rise in the future.

Fermilab experimenter post-docs typically come to us fresh from earning their Ph.D.'s. Each receives a two-year appointment that can be renewed, year by year, up to a maximum of five years. The usual stay at Fermilab is three to four years. By the time their post-doctoral interval is over, most of the people are ready to make the next step up their career ladders. Some become assistant professors of physics, some join Fermilab or other laboratories as scientific staff members, and a

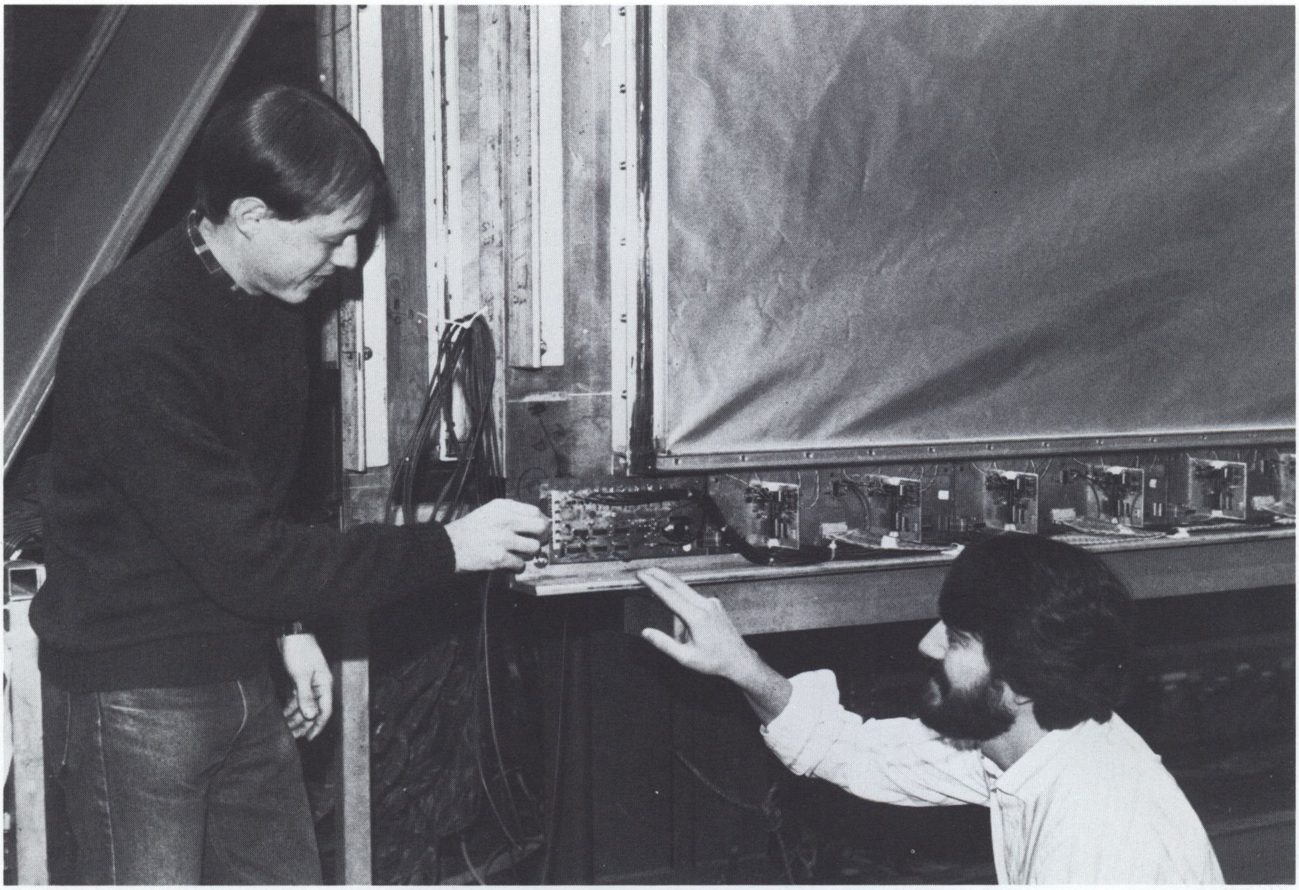
Dave Christian (left) and Steve Gourlay (right).

few leave high-energy physics for positions in industry. Though we are sad to lose direct contact with these friends, we are also happy to know that they are useful and happy in industry. We have yet to grow our first Stephen Jobs or Edwin Land, but we know from feedback sources that Bell Telephone Laboratories and Schlumberger, Inc. are better off because of our post-doctoral alumni.

Let's look at some of the current Fermilab post-docs and their activities. Forrest Davenport joined us in March 1985, and elected to work with experiment E-687 in the Wide-Band Photon Beam. His current principal activity is building a set of multi-wire proportional chambers with the expert help of Technical Specialist Karen Kephart and her Physics Department team of technicians. The accompanying photo shows Forrest, Karen, and Wanda Newby completing the soldering on a plane of cathode wires that will become one electrode in a chamber with 12 similar wire planes.

Steve Gourlay, shown in a photo conversing with Wilson Fellow Dave Christian, is also a research associate on E-687. He is responsible for designing a multi-cell Cherenkov counter and getting it built in the next few months. Dave Christian has *twice* as much Cherenkov counter work to do, since he must design and build two such counters for Fermilab E-690, also in the near future. Were they involved in a discussion of the finer points of mirror optics? Maybe. On the other hand, maybe they were discussing the Chicago Bears' chances to win the Super Bowl in 1986!

In another photograph, Harry Melanson and Steve Wolbers contemplate the recently completed electronic hookup of a very large drift chamber they will use in Fermilab muon experiment E-665. This chamber is one of a group of eight completed or under construction for that experiment. Steve has taken responsibility for the mechanical construction, wire placement, electrical hookup, and gas-supply



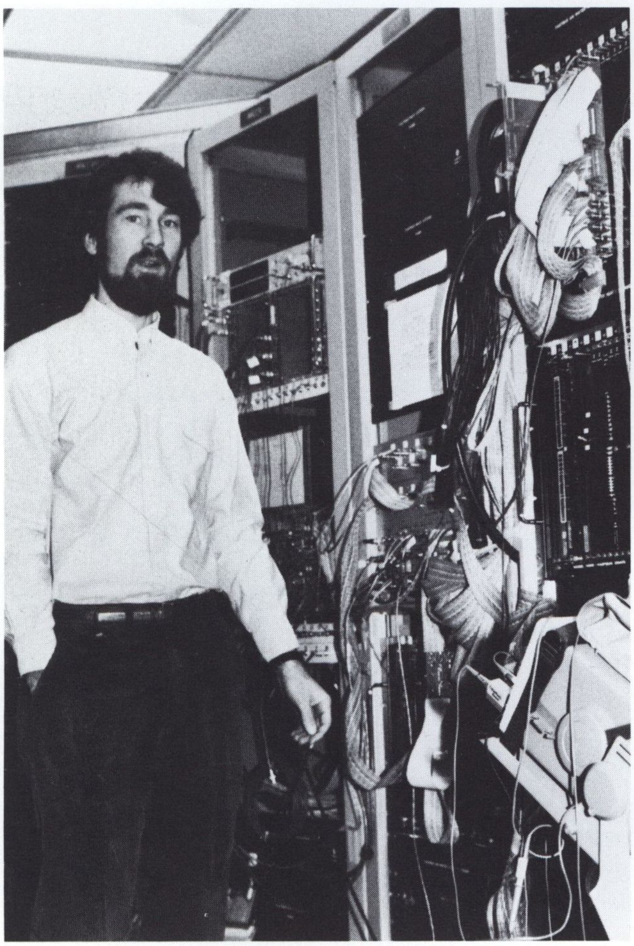
Steve Wolbers (left) and Harry Melanson (right).

system for the chambers. Harry holds responsibility for the electronic signal processing, testing, and data readout. Not apparent in the photograph is the fact that these chambers exhibit amply the intrinsic perversity of inanimate objects and will absorb lots of Steve's and Harry's time during the next year. Good luck, guys!

Carol Johnstone came to Fermilab in June 1985. She joined the direct photon experiment E-706 as its first Fermilab post-doc and gave that effort a terrific shot in the arm. Carol came to us from Los Alamos where she was the spokesperson for the experimental group from which her thesis came. She was already an experienced, take-charge manager when she arrived, and she commenced to imbue E-706 with her enthusiasm and energy from that moment on. In an accompanying photograph, Carol is seen next to the large, steel gantry that will support the liquid-argon calorimeter which constitutes a crucial part of the experiment. Carol's main job is organization and implementation of the E-706 online data-acquisition system, but she has a lively interest and involvement in calorimeter construction and testing as well. With Carol around, E-706 has an energy supply that renders electric power almost redundant.

The flagship experiment for Fermilab in the next couple of years will be E-741, widely known as CDF, the Collider Detector at Fermilab. At the present moment, there are three Fermilab research associates in the CDF enterprise. They are, in order of their arrival, Jim Patrick, John Huth, and Gong-Ping Yeh. Jim is shown in an accompanying photograph standing in front of one of the FASTBUS electronics racks that connects the particle detectors in the gigantic CDF detector with the event trigger system and data readout. It may look like everything is complete and functional, but a few minutes of conversation with Jim Patrick points up the fact that there is a

Taku Yamanaka.



Jim Patrick.

great deal of work still to be done between the moment recorded on film and the cornucopia of new physics that will flow from the completed, operating CDF experiment.

Jim, John Huth, and G.-P. Yeh will all play important roles in this unfolding process. John, for example, is simultaneously working on the central vertex time projection chamber and conducting R&D on exciting new materials with 1-dimensional conduction properties. His extensive training at the University of California, Berkeley in the subtle mysteries of free-electron propagation in gases and their subsequent multiplication in strong electric fields will stand him in good stead at CDF.

G.-P. Yeh has been heavily involved with the Monte Carlo simulation of physics events in the CDF detector and will be well placed to analyze and understand the real data when it comes in. In October 1985, following the TeV I Collider triumph, he had already seen a handful of real events. Fermilab Director Leon Lederman, with his unerring sense of public relations, called these first events "the lowest-bias events in history!" G.-P. is now counting on the next few million events to reveal new mysteries in the core of matter. He should get them before 1986 is over.

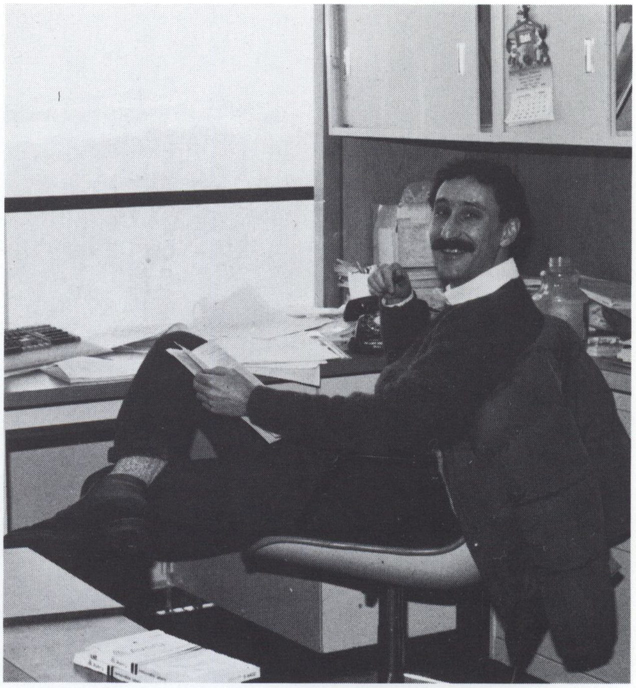
The Fermilab neutrino physics program has traditionally been a high-visibility, high-priority research activity. In very recent times, the home team, CCFR, has scored some points against the CERN-based opposition, a circumstance that stimulates and reinforces the efforts of two Fermilab-based CCFR post-docs, Mike Lamm and Wyatt Merritt. In the case of the Merritts, Wyatt's husband Frank, a physics professor at the University of Chicago, is also a member of the same neutrino experimental group. The Merritts have a new baby boy who, if rumors have it right, is already studying ways to upgrade the experiment in the new century.

In this brief snapshot it is only possible to mention the specific activities of a sampling of the post-docs. There are many others who are also doing a great job for their experiments: Mike Sokoloff, Milind Purohit, and Wilson Fellow Kris Sliwa with E-691; Gaston Gutierrez and Wilson Fellow Dave Christian with

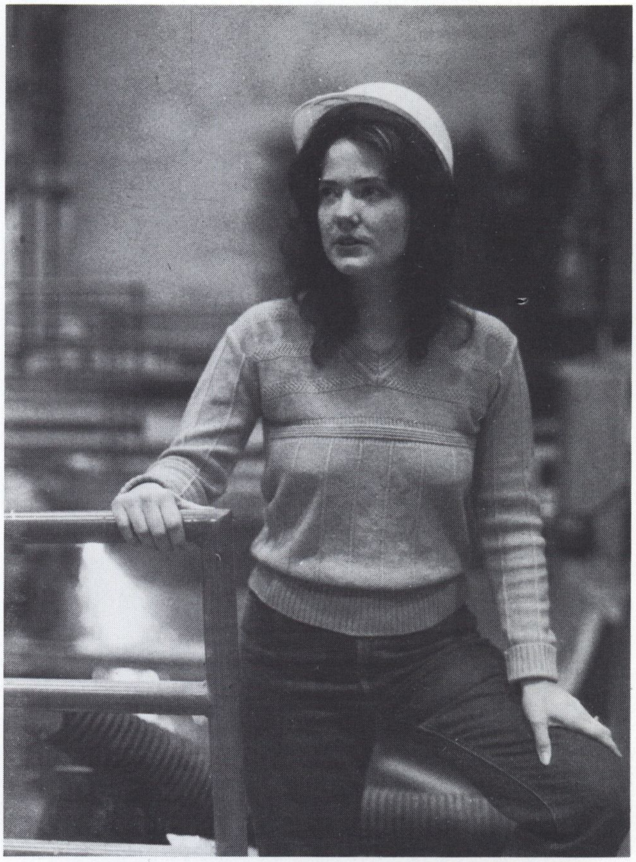
E-690; Taku Yamanaka with E-731; Mike Crisler with E-711; Merrill Jenkins with E-705; and George Coutrakon with E-665. By this time next year, new arrivals Steve Delchamps, Yee Bob Hsiung, and Fridolin Dittus are expected to be in the thick of things and similarly valued.

Now, on to the Theory Department post-docs. There are only eight of them, but two are women, an impressive 25%! Admittedly, the statistical precision is questionable, but it's still indicative of very successful recruiting work by Chris Quigg, urbane Theory Department Head. Sumathi Rao, one of the women theorists, has been at Fermilab for two years. During the past year she worked on several aspects of topology, anomalies, fractional charges, and related topics. She studied non-abelian gauge theories in three dimensions in the perturbative regime and proved a global Ward identity, working together with Rudy Pisarski. Her theorist colleague Halsey Reno, shown at work in her office, has spent the past year working on the enigmatic problem of particle families (or generations). Ideas pertaining to the existence of the three known families of quarks and leptons, plus their familial relationships, are among the more challenging problems in recent particle theory. The 0(18) gauge group is a currently active candidate for relating the fermions and for pointing the way to a possible understanding of proton decay and other rare processes.

Mark Rubin has spent his time during the past year working with the recently revived higher-dimensional world view, first put forward in the 1920s by Kaluza and Klein. Mark also accomplished a neat technical piece of work by pointing out an apparent contradiction in the prescription of Fujikawa for calculating anomalies. Working with Sumit Das, he also constructed configuration spaces for string field theory. The two are currently studying the application of these spaces to string theory in curved space-time. Hiroshi Itoyama, a native of Japan who came to Fermilab after doing his Ph.D. at Columbia, has been working on the structure of anomalies and their physical consequences. He is also working on the related topic of superstring theory, the newest



Mike Sokoloff.



Carol Johnstone.

Left to right: Forrest Davenport, Karen Kephart, and Wanda Newby.

hope to avoid some of the most pernicious anomalies and divergences of field theory. In particular, he is investigating higher-mass string modes and multi-loop diagrams.

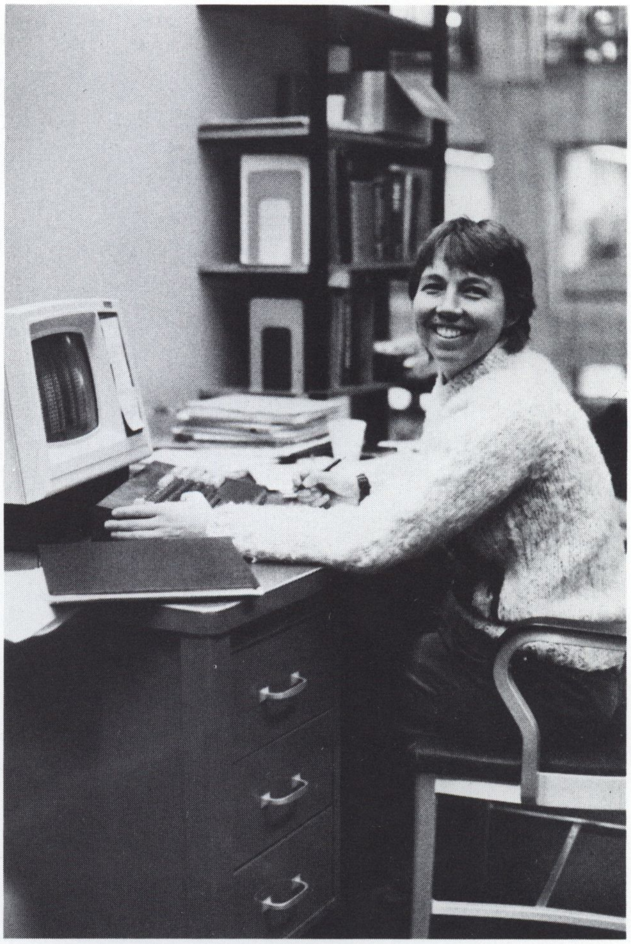
Jim Sexton, a native of Ireland, worked with Keith Ellis during the past year on QCD radiative corrections to all parton-parton processes and used the results to calculate one-hadron inclusive cross sections to order alpha cubed. They are presently preparing to study one- and two-jet inclusive cross sections. He has also studied pure SU3 on asymmetric lattices with Hank Thacker. Kirk Olynyk, a Canadian post-doc, has also spent a large part of his time in the past year working on a lattice. He has investigated the properties of scalar particles that transform under adjoint representations of both global and local SU(N) symmetries. Another European native, Joachim van der Bij from Holland, has concerned himself mostly with the effects of heavy particles on low-energy physics.

To people who are not themselves theoretical physicists, a natural question might be: "Where in the world do such hard-to-comprehend (even pronounce!) ideas come from?" As we have just seen, they come from the U.S., from Europe, and from Japan. That's where they come *from*, but Fermilab is where they are coming *to*: a world center of theoretical physics and one of the main places where the big advances are made. These young people are here to help make these advances possible.

The Astrophysics Group is relatively small in personnel, but it deals with the birth and evolution and death of the whole Universe. With such grand themes for their work, the Astro post-docs are stimulated to tackle and conquer exciting and esoteric problems. For example, Keith Olive, who recently departed to become a professor at the University of Minnesota, worked on a topic bridging the fields of astrophysics and particle physics by studying the implications of photino-photino annihilation into neutrinos as an experimental mechanism for asking the question (a hot one in recent years): Where is the 90% of all matter in the Universe? We can only account for 10% by tabulating stars and galaxies. Is the rest taken up by photinos of non-zero mass? David Seckel worked on an even more esoteric question while he was here: Is there a "shadow universe" totally intermingled with our known one, but whose existence can only be known by its gravity field? David has now left us to become a CERN fellow, but he left us with a very interesting idea to contemplate, namely what are the consequences to our known Universe of the existence of its shadow? Can we ever expect to find out?

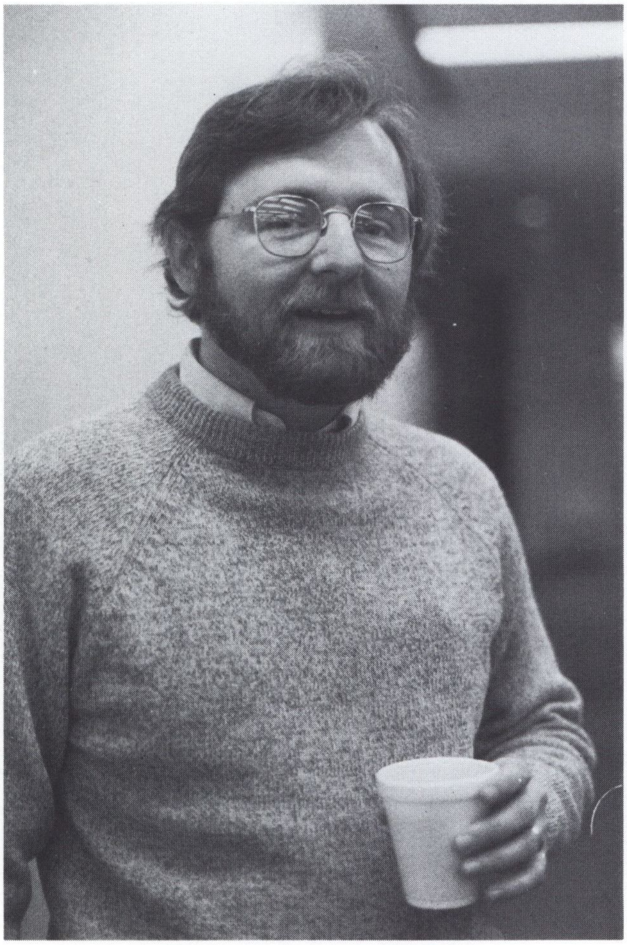
Two more current Astrophysics post-docs are Lars Jensen, a Dane who came here from the University of Pennsylvania, and David Lindley, an Englishman from Cambridge. Lars is working on a study of the consequences of gaussian statistical fluctuations in the nearly perfect homogeneous fluid that followed the first inflation phase of the Universe. He wants to explain how such fluctuation phenomena could result in the rather inhomogeneous Universe we now perceive when we look up into the night sky. David is studying the primordial nucleo-synthesis of the matter in our Universe today, and how its quantitative and qualitative features are influenced by the hypothesized presence of evanescent neutral particles that played their role briefly at an early stage in the big bang. In the accompanying photo, Dave is surprised coming out of a primordial terminal session in his office.

Finally, we note the recent arrivals of Richard Holman from Florida and Jaime Stein from Sussex, England. Richard is working on superstring cosmology and its phenomenological consequences, while Jaime prefers to play with chaotic behavior in the cosmology of extra dimensions. Extra dimensions? Shadow world? Superstrings? Is this "Amazing Stories" or a new charismatic cult religion? Except for the few fellows who play the game themselves, most of us have to believe that it is what these folks say it is: real science. Speculative, yes, but not wacko. Good stuff!



Halsey Reno.

The smallest post-doc group at Fermilab is, paradoxically enough, in the area of accelerator physics, where two new Ph.D.'s hold research associate appointments in the Accelerator Division. Nearly all accelerator physicists are grown from people whose Ph.D.'s came in other fields. Take Dejan Trbojevic, who received his degree two years ago in surface physics and who has been involved in studying the desorption of gases from the walls of the proposed SSC accelerator by the intense synchrotron radiation generated by this 20-TeV machine. Dejan joined a group who went to Brookhaven National Laboratory, where they used the BNL Synchrotron Light Facility to study the desorption experimentally. Now he is moving further toward classical accelerator physics by involvement with a redesign of the Fermilab Main Ring orbit-correction system. The second accelerator physics post-doc is



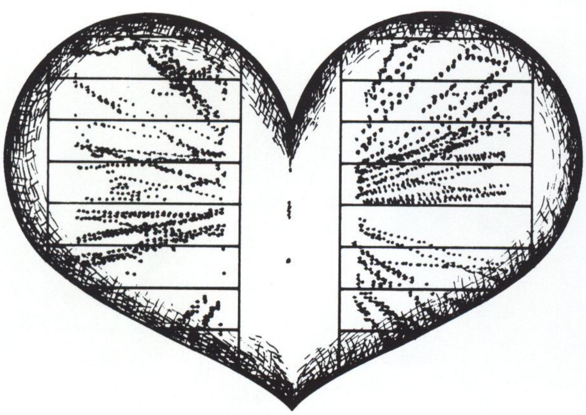
Mike Lamm.

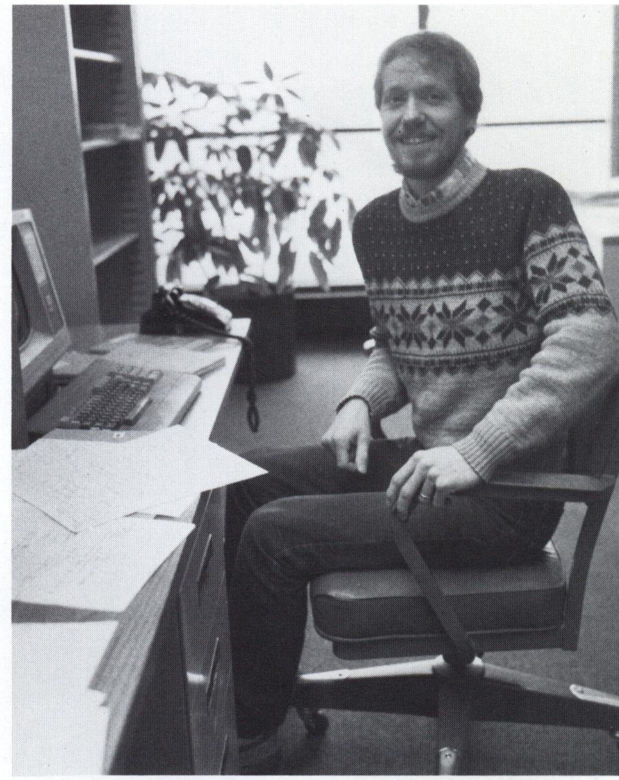
Sejin Qian who came to Fermilab from the Peoples Republic of China a few months ago. Sejin is working on questions of beam loss and radiation of hadron secondaries in the Fermilab Tevatron and the SSC.

Similar to the Fermilab research associates in their duties, but further along in their scientific careers, is the small but prestigious group of Wilson Fellows, named for Fermilab's charismatic founder and Director Emeritus, Robert Rathbun Wilson. Since the program's inception in 1979, these young scientists have been chosen from among their contemporaries as people of special promise with very strong potential for scientific creativity and leadership. Appointed for five-year terms, they have as their duty only to pursue high-energy physics as creatively and relentlessly as they can. Current Wilson Fellows include Dave Christian, the Fermilab leader and sparkplug on E-690, a novel experiment designed to detect and study samples of millions of hadro-produced charmed particles; Bill Foster, a key member of CDF; and Kris Sliwa, the productive and imaginative young physicist who brought the new drift-chamber detector for E-691 to fruition. If the current Wilson Fellows follow the paths of their predecessors, they will be among the next generation of leaders in the field of high-energy physics. We at the Laboratory are proud of the record of all the Wilson Fellows and of their contribution to our work here as well as of their accomplishments after leaving Fermilab.

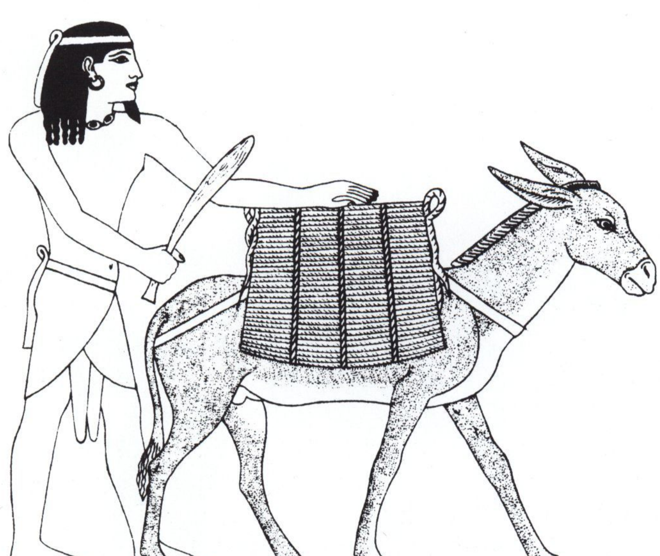
One big post-doc challenge we have at Fermilab arises from the large number of highly varied activities, both experimental and theoretical, in which our post-docs are involved. It would be perfectly possible for a theory post-doc to come here, spend two years, and never even see, much less meet and interact with, half of the experimenter post-docs. It's also conceivable that two experimenters could work here three years apiece and never meet. Tom Kirk and Dan Green, who currently head the Fermilab Physics Department, think they have made inroads on this problem by inventing "Food for Thought," a series of monthly early-evening dinner meetings. All Fermilab post-docs and Wilson Fellows are invited for a free meal (the food is gradually improving) and for an edifying physics talk afterwards. The talks rotate among the attending post-docs, and have an informal character that stimulates questions and comments that might be inhibited in the formal setting of a daytime seminar. Or maybe it's the wine with dinner! But, who cares; it mixes the cast and enhances communication . . . and that is what was intended. Attendance has fluctuated, reaching a low point near the hectic end-of-run period in September, but the idea is working and looks like a successful initiative. So far the only drawback has been five- and seven-pound weight gains by Tom and Dan, respectively. A small price to pay for increased communication among the research associates!

So this is the Fermilab post-doc world at a glance. They are all different, but they have in common the inner fire in the belly that drove them through to Ph.D.'s in one of the most esoteric human activities — high-energy physics. It didn't turn them out as brilliant but mechanical robots, either. They are husbands and wives, moms and dads, neighbors and voters. They pay their taxes, buy their groceries, and save for a better car. But they also push back the darkness at the edge of our knowledge of nature. And they love it. And we are really proud of them.





Dave Lindley.



V. Appendices

Appendix A

Publications

Experimental Publications

Photomeasurements #87A

INCLUSIVE PRODUCTION OF Ω^- AND $\bar{\Omega}^+$ BY K_L^0-CARBON INTERACTIONS IN THE ENERGY RANGE 80-280 GeV/c. E. P. Hartouni et al., Phys. Rev. Lett. 54, 628 (1985).

Muon #203

MUOPRODUCTION OF J/ψ(3100). T. W. Markiewicz, Ph.D. Thesis, Lawrence Berkeley Laboratory, University of California, October 1981.

Dimuon #326

A STUDY OF THE PRODUCTION OF MASSIVE MUON PAIRS IN 225 GeV π^- NUCLEUS COLLISIONS. H. B. Greenlee, Ph.D. Thesis, Enrico Fermi Institute, the University of Chicago, Chicago, Illinois, June 1985.

Charged Hyperon #497

CHARGED-HYPERON PRODUCTION BY 400-GeV PROTONS. T. R. Cardello et al., Phys. Rev. D32, 1 (1985).

MEASUREMENT OF Σ^- PRODUCTION POLARIZATION AND MAGNETIC MOMENT. Y. W. Wah et al., Phys. Rev. Lett. 55, 2551 (1985).

SEARCH FOR HEAVY CHARGED PARTICLES AND LIGHT NUCLEI AND ANTINUCLEI PRODUCED BY 400-GeV PROTONS. J. L. Thron et al., Phys. Rev. D31, 451 (1985).

Photoproduction #516

STUDY OF INCLUSIVE K_s^0, Λ, AND $\bar{\Lambda}$ PRODUCTION IN DIFFRACTIVE γp INTERACTIONS. S. Bhadra et al., Phys. Rev. Lett. 55, 2749 (1985).

A LARGE AREA LIQUID SCINTILLATION MULTIPHOTON DETECTOR. V. K. Bharadwaj et al., Nucl. Instrum. Methods 228, 283 (1985).

Dimuon #537

CONTINUUM DIMUON PRODUCTION IN $\bar{p}$ − W COLLISIONS AT 125 GeV/c. E. Anassontzis et al., Phys. Rev. Lett. 54, 2572 (1985).

Hadron Jets #557

A STUDY OF HIGH TRANSVERSE ENERGY EVENTS IN PROTON-PROTON AND PROTON-NUCLEUS COLLISIONS AT s = 27.4 GeV. R. S. Holmes, Ph.D. Thesis, University of Maryland, June 1985.

This list was compiled using 1984 (not in Fermilab 1984*) and 1985 journal articles, theses, and conference papers. Some conference papers were submitted to a conference prior to 1985 but were not published until 1985. If there are changes, omissions, or comments, please notify the Publications Office.*

30-inch Bubble Chamber #565/570

INCLUSIVE K^+K^- PRODUCTION IN REACTIONS π^+p, K^+p, AND pp AT 200 GeV/c. V. Suchorebrow, Ph.D. Thesis, Massachusetts Institute of Technology, February 1985.

30-inch Hybrid #570

INCLUSIVE PARTICLE PRODUCTION IN π^+, P, K^+P, AND PP INTERACTIONS AT 200 GeV/c. T. A. J. Frank, Ph.D. Thesis, Massachusetts Institute of Technology, February 1985.

Particle Search #580

$K^{*\pm}$ (892) PRODUCTION IN π^-N INTERACTIONS AT 200 GeV/c. A. Napier et al., Phys. Lett. 149B, 514 (1985).

INCLUSIVE RESONANCE PRODUCTION IN SINGLE-VEE EVENTS IN π^-N INTERACTIONS AT 200 GeV. S. Mikocki, Ph.D. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, August 1985.

Particle Search #591

NUCLEAR CHARGE DISPERSION IN THE FRAGMENTATION MASS REGION AND THE THERMAL LIQUID DROP MODEL. N. T. Porile et al., Phys. Lett. 156B, 177 (1985).

Neutrino #594

DETERMINATION OF $SIN^2\theta_W$ AND ρ IN DEEP-INELASTIC NEUTRINO-NUCLEON SCATTERING. D. Bogert et al., Phys. Rev. Lett. 55, 1969 (1985).

DETERMINATION OF THE NUCLEON STRUCTURE BY MEANS OF THE WEAK NEUTRAL CURRENT. D. Bogert et al., Phys. Rev. Lett. 55, 574 (1985).

TOTAL CROSS SECTION MEASUREMENTS FOR MUON NEUTRINO AND ANTINEUTRINO CHARGED CURRENT DEEP INELASTIC SCATTERING. T. F. Eldridge, Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, June 1985.

A COMPARISON OF NEUTRAL TO CHARGED CURRENT, NEUTRINO-NUCLEON INTERACTIONS IN A WIDE BAND NEUTRINO BEAM AT FERMILAB. J. A. Slate, Ph.D. Thesis, Michigan State University, East Lansing, Michigan, 1985.

NEUTRAL CURRENT AND CHARGED CURRENT STRUCTURE FUNCTIONS OF THE NUCLEON. G.-P. Yeh, Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1985.

High Mass Pairs #605

A DEPENDENCE OF THE INCLUSIVE PRODUCTION OF HADRONS WITH HIGH TRANSVERSE MOMENTA. Y. B. Hsiung et al., Phys. Rev. Lett. 55, 457 (1985).

RATIOS OF SINGLE HADRONS PRODUCED AT HIGH TRANSVERSE MOMENTUM IN 400 GeV/c PROTON-NUCLEON COLLISIONS. H. D. Glass, Ph.D. Thesis, SUNY/Stony Brook, New York, August 1985.

Hadron Jets #609

MEASUREMENT OF THE DIJET CROSS SECTION IN 400-GeV/c pp INTERACTIONS. M. W. Arenton et al., Phys. Rev. D31, 984 (1985).

MEASUREMENT OF THE SINGLE-JET INVARIANT CROSS SECTION AT FERMILAB. L. R. Cormell et al., Phys. Lett. 150B, 322 (1985).

Particle Search #610

PERFORMANCE OF A LEAD GLASS SPECTROMETER AT HIGH ENERGIES. A. T. Laasanen et al., Nucl. Instrum. Methods A236, 307 (1985).

CHARGE DISTRIBUTIONS OF HADRONS ASSOCIATED WITH HADRONIC J/ψ PRODUCTION. H. S. Budd et al., Phys. Rev. D31, 1132 (1985).

Chi-Meson Production #610/673

FORWARD CHARGE FLOW IN HADRONIC J/ψ PRODUCTION. W.-G. Li, Ph.D. Thesis, University of Illinois, Urbana, Illinois, August 1985.

Photon Dissociation #612

DIFFRACTIVE PHOTON DISSOCIATION IN A HIGH PRESSURE HYDROGEN TIME PROJECTION CHAMBER. G. R. Snow, Ph.D. Thesis, The Rockefeller University, November, 1983.

DIFFRACTION DISSOCIATION OF PHOTONS ON HYDROGEN. T. J. Chapin et al., Phys. Rev. D31, 17 (1985).

Beam Dump #613

A DEPENDENCE OF CHARM PRODUCTION. M. E. Duffy et al., Phys. Rev. Lett. 55, 1816 (1985).

Forward Search #615

PION STRUCTURE AS OBSERVED IN THE REACTION $\pi^- N \rightarrow \mu^+ \mu^- X$ AT 80 GeV/c. S. Palestini et al., Phys. Rev. Lett. 55, 2649 (1985).

FORWARD PRODUCTION OF HIGH MASS MUON PAIRS IN PION-NUCLEON INTERACTIONS. S. Palestini, Ph.D. Thesis, Princeton University, December 1984.

A STUDY OF J/ψ PRODUCTION IN 260 GeV π^-—NUCLEUS COLLISIONS. C. Adolphsen, Ph.D. Thesis, Enrico Fermi Institute, the University of Chicago, December 1985.

A STUDY OF MASSIVE MUON PAIR PRODUCTION AT HIGH X_F. J. P. Alexander, Ph.D. Thesis, Enrico Fermi Institute, the University of Chicago, March 1985.

CP Violation #617

A MEASUREMENT OF THE K^0 (890) RADIATIVE WIDTH. D. L. Carlsmith, Ph.D. Thesis, the University of Chicago, December 1984.

A DETERMINATION OF THE BRANCHING RATIO OF K_L TO GAMMA GAMMA. H. W. M. Norton, Ph.D. Thesis, the University of Chicago, December 1984.

A STUDY OF CP-VIOLATION THROUGH A PRECISION MEASUREMENT OF η_0/η_{+-}. R. H. Bernstein. Ph.D. Thesis, the University of Chicago, December 1984.

Particle Search #623

OBSERVATION OF THE CABIBBO-SUPPRESSED DECAY $D^{\pm} \rightarrow \phi\pi^{\pm}$. C. H. Georgiopoulos et al., Phys. Lett. 152B, 428 (1985).

OBSERVATION OF DOUBLE PHI MESON PRODUCTION IN 400 GeV/c PROTON-NUCLEON INTERACTIONS. T. F. Davenport, Ph.D. Thesis, Florida State University, Tallahassee, Florida, December 1984.

Direct Photon Production #629

LARGE TRANSVERSE MOMENTUM DIRECT PHOTON, π^0 AND η PRODUCTION WITH A CARBON TARGET. S. R. W. Cooper, Ph.D. Thesis, Michigan State University, East Lansing, Michigan, 1985.

Charm Particle #630

CHARM PRODUCTION IN NEUTRON-NUCLEON INTERACTIONS. L. Tzeng et al., Phys. Rev. Lett. 55, 1172 (1985).

Channeling #660

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APPLICATION OF A CRYSTAL SEPTUM TO REPLACE A MAGNET IN A CHARGED PARTICLE BEAM AND STUDY OF DECHANNELING AND FEEDING-IN EFFECTS IN A SINGLE SILICON CRYSTAL. R. L. Wijayawardana, Ph.D. Thesis, SUNY/Albany, May 1985.

Chi Meson #673

DIFFERENCES BETWEEN PROTON- AND π^- -INDUCED PRODUCTION OF THE CHARMONIUM χ STATES. D. A. Bauer et al., Phys. Rev. Lett. 54, 753 (1985).

Neutrino Interactions/Narrow Band #710

NEUTRINO PRODUCTION OF LIKE SIGN DIMUONS. K. Lang et al., Perspectives of Electroweak Interactions, Proceedings of the Leptonic Session, Twentieth Rencontre de Moriond, Les Arcs, Savoie, France, Vol. 2, March 17-23, 1985, Ed. J. Tran Thanh Van, (France: Editions Frontieves, 1985), p. 87.

Chi Meson #705

A MEASUREMENT OF THE RESPONSE OF AN SCG1-C SCINTILLATION GLASS ARRAY TO 4-14 GeV/c PIONS. B. Cox et al., Nucl. Instrum. Methods A238, 321 (1985).

MEASUREMENT OF ELECTROMAGNETIC SHOWER POSITION AND SIZE WITH A SATURATED AVALANCHE TUBE HODOSCOPE AND A FINE GRAINED SCINTILLATION HODOSCOPE. R. Rameika et al., Nucl. Instrum. Methods A236, 42 (1985).

A MEASUREMENT OF THE ENERGY RESOLUTION AND RELATED PROPERTIES OF AN SCG1-C SCINTILLATION GLASS SHOWER COUNTER ARRAY FOR 1-25 GeV POSITRONS. D. E. Wagoner et al., Nucl. Instrum. Methods A238, 315 (1985).

Direct Photon #706

A LARGE LIQUID ARGON PHOTON/HADRON CALORIMETER FOR FNAL. F. Lobkowicz et al., Nucl. Instrum. Methods A235, 332 (1985).

Sigma Beta Decay #715

MEASUREMENT OF THE ELECTRON ASYMMETRY IN THE BETA DECAY OF POLARIZED Σ^- HYPERONS. S. Y. Hsueh et al., Phys. Rev. Lett. 54, 2399 (1985).

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Gravitational Detector #723

SEARCH FOR ANOMALOUS LONG RANGE INTERACTIONS AT HIGHLY RELATIVISTIC VELOCITIES. P. J. Reiner, Ph.D. Thesis, The University of Rochester, Rochester, New York, August 1985.

Collider Detector Facility #741

CONSTRUCTION AND TESTING OF A 3m DIAMETER $\times$ 5m SUPERCONDUCTING SOLENOID FOR THE FERMILAB COLLIDER DETECTOR FACILITY (CDF). H. Minemura et al., Nucl. Instrum. Methods A238, 18 (1985).

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HYPERON EXPERIMENTS AT FERMILAB. L. G. Pondrom, Phys. Rep. 122, Nos. 2 & 3, 57 (1985).

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Colloquium

Spurgeon Keeny

Executive Director
The Arms Control Association
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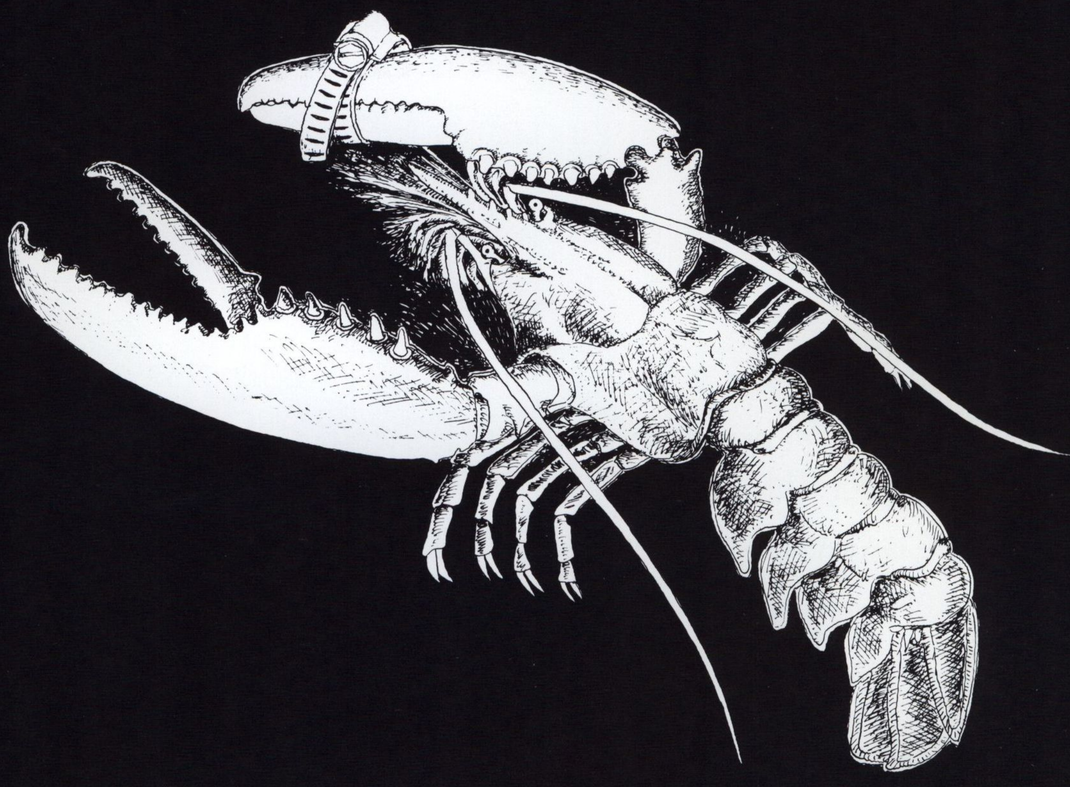
Senior Associate
The Carnegie Endowment
For International Peace



Current Status and Future Prospects of Arms Control

Fermi National Accelerator Laboratory

Norman Ramsey Auditorium

Wednesday, September 11, 1985, 4:00 p.m.

Appendix B

1985 Workshops, Seminars, and Colloquia

Theoretical Physics Seminars

J. Bagger, Stanford Linear Accelerator Center: "Heavy Families in Unified Theories," January 8, 1985

G. Bodwin, Argonne National Laboratory: "Factorization of the Drell-Yan Cross-Section in Perturbation Theory," January 15, 1985

M. Soldate, Stanford Linear Accelerator Center: "Searching for the Intermediate Mass Higgs," January 17, 1985

A. Niemi, The Institute for Advanced Study: "Fermion Fractionization and Some New Index Theorems," January 22, 1985

Z. Yi-Cheng, Brookhaven National Laboratory: "Time Dependent Kink Solution and Metastability," January 29, 1985

E. Predazzi, Torino University: "E.M.C. Effect," February 5, 1985

R. Hughes, Caltech: "QED in 2+1 Dimensions, Fermion Fractionization, Topological Photon Mass and the Quantum Hall Effect," February 8, 1985

A. D. Kennedy, Institute for Theoretical Physics, Santa Barbara, California: "Recent Developments in Lattice QCD," February 12, 1985

E. Van Beveren, University Nymegen: "QCD Inspired Strong Curvature (A Hadron Model)," February 15, 1985

M. Dine, The Institute for Advanced Study, Princeton: "A New Mechanism for Baryosynthesis," February 19, 1985

A. Nelson, Harvard University: "To be announced," February 26, 1985

V. Baluni, University of Michigan: "Gauge Boson Composites," February 28, 1985

S. Barr, University of Washington, Seattle: "Solving the Strong CP Problem Without Axions," February 21, 1985

A. Kostelecky, Los Alamos National Laboratory: "Evidence for Phenomenological Supersymmetry in Atomic Physics," March 1, 1985

L. S. Brown, University of Washington, Seattle: "How the Seattle g-2 Experiment Works and What is its Line Shape," March 5, 1985

A. N. Schellekens, State University of New York at Stony Brook: "Compactification by Higher Dimensional Instantons," March 4, 1985

H. Thacker, Fermilab: "Lorentz Invariance on a Lattice," March 12, 1985

A. Soni, University of California, Los Angeles: "Lattice Calculation of Hadronic Weak Matrix Element," March 25, 1985

D. Boyanovsky, Stanford Linear Accelerator Center: "Axial and Parity Anomalies at Different Perspective," March 26, 1985

A. Hodges, University of Texas: "An Introduction to Twistor Theory," March 27, 1985

H.-Y. Guo, Peoples Republic of China: "Topological Understanding of Anomalies," April 2, 1985

S. Parke, Fermilab: "Perturbative QCD Using Extended Supersymmetry," April 9, 1985

C. Savoy, CERN: "Phenomenological Constraints on Supergravity Models," April 23, 1985

Z. Kunszt, University of Bern, Switzerland: "Gluino Pair Production at the Collider," April 30, 1985

G. Chapline, Lawrence Livermore Laboratory: "Unification of Gravity and Elementary Particle Interactions in 26 Dimensions," May 7, 1985

L. L. Chau, Brookhaven National Laboratory: "Integrability Properties of Supersymmetric Yang-Mills Theory," May 8, 1985

C. Orzalesi, Scientific Attachè, Italian Embassy, Washington, D. C.: "Compactification Mechanism in Kaluza-Klein Theories," May 16, 1985

D. Nemeschansky, Stanford Linear Accelerator Center: "Holonomy Anomaly," May 21, 1985

J. Shigemitsu, Ohio State University: "Lattice Gauge-Higgs System," May 28, 1985

M. Karliner, Stanford Linear Accelerator Center: "The Baryon Spectrum of the Skyrme Model," June 4, 1985

D. D. Wu, University of Chicago: "The Rephasing Invariance of the K-M Matrix," June 5, 1985

E. Mottola, University of California, Santa Barbara: "Why Does the Vacuum Weigh Nothing?" June 11, 1985

G. Lasher, IBM: "A New Algorithm for Topological Charge in SU(2) Lattice Gauge Field," June 18, 1985

D. R. Yennie, Cornell University: "Integer Quantum Hall Effect," June 24, 1985

K. Bitar, American University of Beirut, Lebanon: "Renormalization Flow on the Lattice and Deconfinement," July 9, 1985

J. L. Rosner, Enrico Fermi Institute, University of Chicago: "Exotic Fermions in E^6," July 16, 1985

P. Mackenzie, The Institute for Advanced Study: "Hadronic Coupling Constants in Lattice QCD," July 23, 1985

K. Tanaka, Ohio State University: "Kaluza-Klein Monopoles in 5 Dimensions," July 25, 1985

M. Rubin, Fermilab: "Reparametrization and Gauge Transformations in String Field Theories," July 30, 1985

A. Das, University of Rochester: "Fujikawa's Method and Solutions of Two-Dimensional Models," August 6, 1985

D. Petcher, NIKNEF, Amsterdam: "Field Theory in a Finite Volume: Can You Get Big Results by Thinking Small?" August 13, 1985

T. Sjöstrand, University of Lund, Sweden, and Fermilab: "Multiple Parton-Parton Scatterings in Hadronic Events," August 20, 1985

U. Sarkar, University of Texas, Austin: "Superstrings and Neutrino Masses," August 27, 1985

B. Grossman, Rockefeller University: "Three Co-cycles in Quantum Mechanics and Field Theory," September 3, 1985

J. Tran Thanh Van, University de Paris Sud, Orsay, France: "Theoretical Approach to Low-p_t Physics," September 5, 1985

J. J. Van der Bij, Fermilab: "Some Two-Loop Corrections to Weak Interaction Parameters," September 10, 1985

M. J. Perry, Princeton University: "Superstrings and Geometry," September 17, 1985

M. H. Reno, Fermilab: "Phenomenology of 0(18)," September 24, 1985

P. Candelas, University of Texas at Austin: "Yukawa Couplings in Superstring Theories," October 1, 1985

A. Axelrod, Florida State University: "Dinucleon Decay in GUTS," October 8, 1985

C. Davies, Cornell University: "Langevin Simulations of QCD," October 15, 1985

O. Alvarez, Lawrence Berkeley Laboratory: "Conformal Field Theory and String Models," (to be continued), October 22, 1985

O. Alvarez, Lawrence Berkeley Laboratory: "Conformal Field Theory and String Models," October 24, 1985

M. Dine, City College of New York: "Is the Superstring Weakly Coupled?" October 29, 1985

P. Moxhay, Indiana University: "Infinity Cancellations in 0(32) Superstrings," October 31, 1985

H. Itoyama, Fermilab: "Supersymmetry Anomalies," November 5, 1985

O. Alvarez, Lawrence Berkeley Laboratory: "(Yet More) Conformal Field Theory and String Models," November 7, 1985

G. Kane, University of Michigan: "Nonminimal Supersymmetry at Low Energies: Spectrum, Signatures, and LISPs," November 12, 1985

M. Peskin, Stanford Linear Accelerator Center: "Gauge Invariant Strings and Superstrings," November 14, 1985

D. Soper, University of Oregon: "Theory of Heavy Particle Production," November 19, 1985

M. Gross, Oxford University: "Fermion Doubling and the Continuum Limit on a Random Lattice," November 21, 1985

A. H. Mueller, Columbia University: "Small x Behavior in QCD," November 26, 1985

D. Friedan, University of Chicago: "Problems in String Field Theory," December 3, 1985

R. Pisarski, Fermilab: "Quantization of Topologically Massive Chromodynamics," December 5, 1985

H. Minakata, Tokyo Metropolitan University: "A Non-Perturbative Approach to Super-Critical QED," December 12, 1985

Y. Meurice, CERN: "Covariant Quantization of the Boson String," December 17, 1985

Joint Experimental-Theoretical Physics Seminars

A. Vorobyov, Leningrad Nuclear Physics Institute, USSR: "Muon Catalysis of Nuclear Fusion Revisited," January 4, 1985

G. Smith, Pennsylvania State University: "The Physics Program at LEAR," January 11, 1985

B. Durand, University of Wisconsin: "Multiplicity Distributions as a Test of Dynamics," January 18, 1985

J. Panman, CERN: "High Precision Measurements of sin2-theta," January 22, 1985

S. Errede/I. Leedom, University of Illinois: "Detection of Exotics at SSC," January 25, 1985

R. D. Schamberger, State University of New York at Stony Brook: "Upsilon Physics Above Threshold and Search for the Higgs," February 1, 1985

S. Heppelmann, University of Minnesota: "90-Degree Exclusive Scattering at Brookhaven," February 22, 1985

J. Rohlf, Harvard University: "To Be Announced," March 1, 1985

T. Gaisser, Bartol Research Foundation: "Neutrino Physics from Cosmic Rays," March 8, 1985

F. Close, Rutherford Laboratory: "Quarks in Nuclei," March 14, 1985

B. Cabrera, Stanford University: "Bolometric Detection of Neutrinos," March 15, 1985

P. Sokolsky, University of Utah: "Recent Results from the Fly's Eye," March 22, 1985

E. Stern, State University of New York at Stony Brook: "Recent Results of Elastic Scattering of Neutrinos at Brookhaven," March 29, 1985

M.-C. Touboul, Pierre & Marie Curie University, Paris: "Recent Results on Charm Hadroproduction in π-p at 360 GeV," April 5, 1985

J. Steinberger, CERN: "LEP Detector: ALEPH," April 11, 1985

L. Branscomb, IBM: "New Technology for Frontier Science: Where Will It Come From?" April 12, 1985

D. Müller, University of Chicago: "Cosmic Ray Astrophysics at High Energies: The Case for a Large Magnet Spectrometer in Space," April 19, 1985

W.-D. Nowak, CERN: "Review of Deep Inelastic Charged Lepton Scattering," April 26, 1985

J. Steinberger, CERN: "Review of Neutrino Scattering," April 25, 1985

P. Kunz, Stanford Linear Accelerator Center: "The 3081/E Processor," May 17, 1985

K. Lang, University of Rochester: "Neutrino Production of Dimuons by CCFRR," May 24, 1985

O. Piccioni, University of California, San Diego: "Concepts and Misconceptions About the Einstein-Podolsky-Rosen Paradox," May 31, 1985

J. Conway, University of Chicago: "Muon Pair Production at Large x: First Results from E-615," June 7, 1985

C. Naudet, Rice University: "Higher Twist Effects in Large pT Pion-Proton Interactions at 200 GeV (E-609)," June 14, 1985

E. Leader, Birkbeck College, University of London: "pp vs. $p\bar{p}$: From SPS to SSC," June 28, 1985

S.-U. Chung, Brookhaven National Laboratory: "Status of Glueball Candidates: New Results on E/iota Meson," July 12, 1985

R. Lipton, Fermilab: "Hadronic Charm Production: Results From E-515," July 19, 1985

P. Weilhammer, CERN: "Recent Results on F-mesons from NA-32," July 26, 1985

R. Raja, Fermilab: "W/Z Production and Decay Properties," August 2, 1985

F. Fidecaro, S.N.S. Pisa: "Pion Form Factor in the Timelike and Spacelike Regions," August 16, 1985

G. Carboni, CERN: "Direct Observation of the Decay of Beauty Particles into Charmed Particles," August 20, 1985

K. Young, University of Washington, Seattle: "Search for Photinos, the Anomalous Single Photon Experiment (ASP) at PEP," August 30, 1985

D. DiBitonto, Texas A&M University: "Diffractive Heavy Flavor Production at Collider Energies: Experience from UA-1," September 6, 1985

M. Marshak, University of Minnesota: "Muons From Cygnus X-3," September 20, 1985

T. Yamanaka, Fermilab: "Search for Right-Handed Currents in Kaon Decay," October 4, 1985

B. V. Sreekantan, Tata Institute of Fundamental Research, Bombay: "Search for Very High Energy Gamma Rays from Possible Cosmic Ray Sources," October 18, 1985

P. Petersen, Rutgers University: "Σ-Λ Transition Moment (E-619)," October 25, 1985

J. Marriner, TeV I, Fermilab, and CDF speaker to be announced: "Status Report on TeV I and CDF Projects," November 8, 1985

G. Zapalac, University of Chicago: "A New Determination of the Σ^- Magnetic Moment Using Both Leptonic and Hadronic Decay Modes (E-715)," November 15, 1985

C. N. Yang, State University of New York at Stony Brook: "The Origin of KNO Scaling in Hadron-Hadron Collisions and the Prediction That KNO Scaling Does Not Obtain in $\varepsilon+\varepsilon-$ Collisions," November 22, 1985

A. Para, Fermilab: "New Results from CDHS," December 3, 1985

C. Wilkinson, University of Wisconsin: "Polarization and Magnetic Moment of the $\Sigma+$ Hyperon (E-620)," December 13, 1985

Theoretical Astrophysics Seminars

J. Silk, University of California, Berkeley: "Schemes for Biased Galaxy Formation," January 22, 1985

R. Brandenberger, Institute for Theoretical Physics, University of California, Santa Barbara: "Realization of New Inflation," January 28, 1985

N. Iwamoto, Washington University, Israel: "Superweak Particle Emission from Neutron Stars," February 4, 1985

Y. Rephaeli, Tel Aviv University: "To be announced" February 11, 1985

J. Harvey, Princeton University: "An Introduction to Superstrings — The Theory of Everything?" February 15, 1985

P. Trower, Virginia Polytechnic Institute: "Large Area Detector Dedicated to Monopole Search Astrophysics, and Cosmic Ray Physics at the Grand Sasso," February 18, 1985

C. Hill, Fermilab: "Applications of a Covariant Functional Schroedinger Formalism," February 25, 1985

S. Sarkar, CERN: "Cosmology of Decaying Gravitinos," March 4, 1985

T. Gaisser, Bartol Research Foundation: "Non-Accelerator Physics at Energies of 40 TeV," March 7, 1985

M. Geller, Harvard University: "Shane-Wirtanen Counts and the Large-Scale Galaxy Distribution," March 11, 1985

A. Dekel, Yale University: "Origin of Dwarf Galaxies, Cold Dark Matter, and Biased Galaxy Formation," March 14, 1985

M. Fall, NASA Space Telescope Institute: "Origin of Globular Clusters," March 18, 1985

A. K. Drukier, Max Planck Institute, Munich: "Low Temperature Detection Techniques for Elementary Particles and Astrophysics," March 20, 1985

H. Tye, Cornell University: "Informal Discussion of Superstring Cosmology," March 25, 1985

G. Efstathiou, Institute of Astrophysics, Cambridge University: "Can We Measure Ω?" April 8, 1985

Q. Shafi, Bartol Research Foundation: "Superconducting Extended Structures," April 15, 1985

S. Hawking, Cambridge University: "Origin of Structure in the Universe," April 22, 1985

J. C. Wheeler, University of Texas at Austin: "Classical and Peculiar Type I Supernovae," May 6, 1985

E. Vishniac, University of Texas at Austin: "Explosive Formation of Lyman Alpha Clouds," May 9, 1985

M. Ruderman, Columbia University: "High Energy Radiation from Neutron Stars," May 13, 1985

A. Guth, Massachusetts Institute of Technology: "The Dynamics of False Vacuum Bubbles," May 20, 1985

M. Yoshimura, KEK: "Cosmology in More Than Four Dimensions," May 23, 1985

M. Teper, Annecy, France: "The Physics of Quantized Magnetic Monopoles: A Lattice Monte Carlo Study of the SU(2) Georgi-Glashow Model," May 30, 1985

M. Turner and T. Walker, Fermilab: "What's Coming from Cygnus X-3 (If Anything)?" June 10, 1985

J. F. Valle, Rutherford Laboratory: "Fitting Simpson's Neutrino into the Standard Model," June 17, 1985

R. Cowsik, Tata Institute for Fundamental Physics, Bombay: "The Invisible Universe," August 29, 1985

S. Kulkarni, University of California, Berkeley: "Geminga: An Old X-Pulsar?" September 9, 1985

J. Fry, University of Florida: "Statistics of Voids in Hierarchical Universes," September 23, 1985

D. Koo, NASA Space Telescope Institute: "Evolution of Quasars," September 30, 1985

C. Will, Washington University: "Approximation Methods in Gravitational Radiation Theory," October 7, 1985

N. Vittorio, University of California, Berkeley: "Galaxy Formation and the Microwave Background," October 14, 1985

P. Shapiro, University of Texas at Austin: "Primordial Molecules, Cosmological H_2 Regions, and Galaxy Formation," October 21, 1985

G. Gelmini, Harvard: "Dark Matter in the Solar Neutrino Problem and in Double-β-Decay Experiments," November 4, 1985

M. Srednicki, University of California, Santa Barbara: "Particle Emission of Cosmic Strings," November 11, 1985

A. Melott, University of Chicago: "Issues in the Modelling of the Large-Scale Structure in the Universe," November 18, 1985

B. Tully, University of Hawaii: "How Large is the Local Supercluster?" November 21, 1985

D. Müller, University of Chicago: "High Energy Particle Astrophysics: Current Questions and the Prospects of a Space Station," November 25, 1985

A. Stebbins, University of California, Berkeley: "Cosmic Strings and Cold Matter," December 9, 1985

P. Anderson, University of Florida: "Closing the Universe with Vacuum Energy," December 16, 1985

Research Technique Seminars

F. Miyasaki, Idaho National Engineering Laboratory: "The INEL Scientific Data Management System," February 7, 1985

A. Bross, Lawrence Berkeley Laboratory: "Detector R&D at Lawrence Berkeley Laboratory — Are We Having Fun Yet?" February 18, 1985

D. Snider, Idaho National Engineering Laboratory: "The INEL Scientific Data Management System," February 28, 1985

G. Hanson, Stanford Linear Accelerator Center: "The New Drift Chamber for the MARK II Detector at SLC," March 6, 1985

J. Huth, Lawrence Berkeley Laboratory: "High Resolution Tracking Chamber Using Avalanche Localization," April 11, 1985

A. K. Drukier, Max Planck Institute: "Low Temperature Detection Techniques for Elementary Particles and Astrophysics," March 20, 1985

P. Weilhammer, CERN: "Test Results of DELPHI Silicon Microstrip Vertex Detector with VLSI Readout," July 25, 1985

S. Palanque, Saclay, France: "Studies and Development of Scintillating Fibers at Saclay," June 6, 1985

R. McLaren, CERN, DD Division: "The CERN Computer Interfaces," June 20, 1985

M. Johnson, Fermilab: "Use of the ANSYS Program for Electromagnetic Calculations," August 1, 1985

T. Gentile, University of Rochester: "The CLEO Vertex Detector, Construction and Performance," August 15, 1985

C. Todd, Siemens, Inc.: "8 bits, 100-MHz Flash ADCs," September 17, 1985

J. Cosley, Source 3: "High Speed Digital Circuits in Semi-Custom VLSI ICs," December 5, 1985

Advanced Computer R&D Seminars

W. Bledsoe, Microelectronics and Computer Technology Company (MCC): "Directions in Artificial Intelligence Research at MCC and Elsewhere," October 9, 1985

C. Moore, Micro Services: "Forth and the NC4000 Symbols," October 28, 1985

T. Koschman, Xerox Corporation: "Object Oriented Programming Strategies," December 2, 1985

E. Lusk, Argonne National Laboratory: "Computerized Deduction," December 9, 1985

Academic Lecture Series

D. Green, Fermilab: "Particle Physics Detectors," January 14 & 16, 1985

J. Lach, Fermilab: "Hyperon Physics (E-715)," January 21 & 23, 1985

T. Kirk, Fermilab: "Charmonium Production (E-610/E-673)," January 28, 1985

C. Brown, Fermilab: "Dimuons & Upsilons (E-70/E-605)," January 30, 1985

E. Fisk, Fermilab: "Neutrino Scattering (E-21/E-652)," February 4 & 6, 1985

J. Yoh, Fermilab: "Physics at CDF," March 4 & 6, 1985

M. Marx, Fermilab: "Solutions at the DØ Detector," March 11 & 13, 1985

D. R. O. Morrison, CERN: "Structure of Proton, Isoscalar Nucleon & Nucleii (EMC effect)," March 20 & 25, 1985

D. R. O. Morrison, CERN: "Tests of Quark-Parton Model, QCD," March 20 & 25, 1985

D. R. O. Morrison, CERN: "Measurement of $\mathrm{Sin}^2(\theta_w)$," March 20 & 25, 1985

D. R. O. Morrison, CERN: "Neutrino Masses, Results and New Experiments," March 20 & 25, 1985

W. Bardeen, Fermilab: "Superstrings," July 8 & 10, 1985

H. Harari, Fermilab: "Let the Desert Bloom from TeV to Planck," July 22, 24, 29 & 31, 1985

E. Kolb, Fermilab: "The Large-Scale Structure of the Universe," August 5, 1985

E. Kolb, Fermilab: "The Early Universe," August 7, 1985

E. Kolb, Fermilab: "Relic Particles from the Big Bang," August 12, 1985

E. Kolb, Fermilab: "Phase Transitions," August 14, 1985

D. Edwards, Fermilab: "Introduction to Accelerator Physics," Oct. 28, 30 & November 4, 1985

G. Dugan, Fermilab: "Introduction to the Antiproton Source," November 18 & 20, 1985

Fermilab Colloquia

D. Larbalestier, University of Wisconsin: "The Metallurgical and Superconducting Design of NB-Ti Composites," January 3, 1985

S. Gronemeyer, Siemens, Inc.: "Clinical Magnetic Resonance Imaging," January 9, 1985

J. Jewell, Bell Laboratories: "Digital Optical Computers," January 16, 1985

W. Bingham, Illinois Natural History Survey: " 'Optimizing' Siting for the SSC: A Computer-Based Landscape Model," January 23, 1985

J. Snow, Department of Geosciences, Purdue University: "Geophysical Columnar Vortices," January 30, 1985

B. Kayser, National Science Foundation, Washington, D.C.: "What is a Majorana Particle?" February 6, 1985

M. Scully, University of New Mexico: "Quantum Optics and General Relativity: A New Frontier," February 13, 1985

N. Pickering, Bowed Instruments, New York: "Computer-Assisted Violin Research," February 20, 1985

R. Blandford, California Institute of Technology: "Fermat's Principle and Gravity Lenses," February 27, 1985

B. Margon, University of Washington: "The Origin of the Cosmic Diffuse X-ray Background Radiation," March 6, 1985

S. Garoff, Exxon Research and Engineering Co., New Jersey: "Molecular Aspects of Wetting on Surfactant Coated Surfaces," March 13, 1985

M. E. Bickford, University of Kansas: "Nature — An Origin of Continental Crust," March 27, 1985

O. Gingerich, Harvard University: "Tycho and the Mystery of Master Witt: A Historical Scientific Detective Story," March 28, 1985

G. Matloff, Pratt Institute: "Populating the Galaxy," April 3, 1985

C. Levinthal, Columbia University: "Parallel and Special Purpose Computing in Biology: Both in Animals and in Hardware," April 17, 1985

C. M. Noble, Jr., Alcar Software, Inc.: "Theory vs. Phenomenology in the Business World - The State of the Art," April 24, 1985

S. Block, Stanford University: "How Bacteria Swim: A Biophysicist's View of the World's Smallest Motor," May 1, 1985

G. Chapline, Lawrence Livermore National Laboratory: "In Defense of Star Wars," May 8, 1985, (A continuation of the Arms Control and International Security Seminar Series)

A. B. Carter, Harvard University: "Technical Aspects of Nuclear Command, Control, Communications, and Intelligence," May 16, 1985, (A continuation of the Arms Control and International Security Seminar Series)

M. Hirsch, University of California: "Chaos and Convergence in Dynamical Systems," May 22, 1985

J. Taylor, Princeton University: "Pulsars, Clocks, and Gravity," May 29, 1985

B. Parker, A.I.R. Laboratories: "Art Meets Science (or is it the other way around?)," June 12, 1985

H. I. Bjelkhagen, Fermilab and the Royal Institute of Technology: "Holography in Art and Science," July 3, 1985

G. Suski, Lawrence Livermore National Laboratory: "A Major Fusion Project Comes On-line: The NOVA Project at Lawrence Livermore National Laboratory," July 24, 1985

S. M. Keeny, Jr., Arms Control Association, Carnegie Endowment for International Peace: "The Current Status and Future Prospect of Arms Control," September 11, 1985, (A continuation of the Arms Control and International Security Seminar Series)

N. DeWolf, ONEAC: "Making Dreams Happen (While Having Yet Another Dream)," September 12,. 1985

J. E. Doran, Chicago Police Department: "Latent Fingerprint Development Procedures," October 2, 1985

W. Bledso, Microelectronics and Computer Technology Corporation: "Directions in Artificial Intelligence at MCC and Elsewhere," October 9, 1985

G. Reber, Reber Observatory: "The Beginnings of Radio Astronomy," October 16, 1985

R. J. Wood, McDonnell Douglas Astronautics Co.: "Electrophoresis Operations in Space Manufacturing in Microgravity," October 23, 1985

C. H. Bennett, IBM Research: "On the Role of Irreversibility in Stabilizing Complexity," October 30, 1985

J. Schwarz, California Institute of Technology: "Towards Unified Theory," November 7, 1985

N. Christ, Columbia University: "Lattice Gauge Computer," November 14, 1985

C. Morin, Packer Engineering: "Accident Investigation and Accident Prevention through Multidisciplinary Approaches," November 20, 1985

F. Wilczek, University of California, Santa Barbara: "Dark Matter Candidates," December 10, 1985

Workshops

Heavy Quark Workshop
May 6-7, 1985

Workshop on the History of Particle Theory in Japan (1935-1960)
May 6-7, 1985

Gas Sampling Calorimetry Workshop
October 31-November 1, 1985

Workshop on Triggering, Data Acquisition and Computing
for High Energy/High Luminosity Hadron-Hadron Colliders
November 11-14, 1985

Other

International Symposium on Particle Physics in the 1950s:
Pions to Quarks
May 1-4, 1985

Fermilab Annual Users Meeting
May 10-11, 1985

Fermilab Industrial Affiliates Annual Meeting
May 21-22, 1985

Dedication of Tevatron I
October 11, 1985

Appendix C

Approved Experiments in the Fermilab Fixed-Target and Collider Programs

Electroweak

E-632 WIDE BAND NEUTRINOS IN THE 15-FT BUBBLE CHAMBER (UC/Berkeley, Birmingham, Brussels, CEN/Saclay, CERN, Chandigarh, Fermilab, Hawaii, IIT, Imperial College, MPI/Munich, Oxford, Rutgers, Rutherford-Appleton, Stevens, Tufts)
E-635 SEARCH FOR AXION-LIKE OBJECTS (Fermilab, VPI)
E-636 STUDY OF BEAM DUMP-PRODUCED NEUTRINOS (Beijing, Brown, Fermilab, Haifa, Indiana, MIT, ORNL, Seton Hall, Tel-Aviv, Tennessee, Tohoku, Tohoku Gakuin)
E-646 STUDY OF PROMPT-NEUTRINO PRODUCTION (UC/Berkeley, Fermilab, Hawaii, IIT, Rutgers, Stevens, Tufts)
E-649 NUCLEON STRUCTURE FUNCTIONS AT HIGH Q^2 (Fermilab, Florida, MIT, Michigan State)
E-652 NEUTRINO PHYSICS AT THE TEVATRON (Chicago, Columbia, Fermilab, Rochester)
E-665 MUON SCATTERING WITH HADRON DETECTION (Argonne, CERN, Cracow, Fermilab, Freiburg, Harvard, Illinois/Chicago, Maryland, MIT, MPI/Munich, UC/San Diego, Washington, Wuppertal, Yale)
E-733 NEUTRINO INTERACTIONS WITH QUAD TRIPLET BEAM (Fermilab, Florida, MIT, Michigan State)
E-745 NEUTRINO PHYSICS WITH QUAD TRIPLET BEAM (Beijing, Brown, Fermilab, Haifa, Indiana, MIT, Nagoya, ORNL, Tel-Aviv, Tennessee, Tohoku, Tohoku Gakuin)
E-770 HIGH STATISTICS STUDIES OF CHARGED CURRENT INTERACTIONS USING THE TEVATRON QUAD TRIPLET BEAM (Chicago, Columbia, Fermilab, Rochester)

Decays and CP

E-721 CP VIOLATION (Arizona, Athens, Duke, Fermilab, McGill, Northwestern, Shandong)
E-731 MEASUREMENT OF ε'/ε (CEN/Saclay, Chicago, Fermilab, Princeton)
E-761 PROPOSAL TO STUDY HYPERON RADIATIVE DECAY (Fermilab, Iowa, Leningrad, Yale)

Heavy Quarks

E-653 HADRONIC PRODUCTION OF CHARM AND B (Aichi, Carnegie-Mellon, Chonam, UC/Davis, Gifu, Gyeong Sang, Jeonburg, Kobe, Korea, Nagoya, Ohio State, Okayama, Oklahoma, Osaka City, Osaka Sci. Ed. Inst., Sookmyong Womans, Toho, Wonkwang, Yokohama)
E-687 PHOTOPRODUCTION OF CHARM AND B (Colorado, Fermilab, Illinois, INFN/Frascati, INFN/Milano, U. Milano, Northwestern, Notre Dame)
E-690 STUDY OF CHARM AND B PRODUCTION (Columbia, Fermilab, Massachusetts, Mexico)
E-705 CHARMONIUM AND DIRECT PHOTON PRODUCTION (Arizona, Athens, Duke, Fermilab, McGill, Northwestern, Shandong)

E-760 A PROPOSAL TO INVESTIGATE THE FORMATION OF CHARMONIUM STATES USING THE ANTIPROTON ACCUMULATOR RING (Fermilab, Ferrara, Genova, Northwestern, Penn State, Torino, UC/Irvine)

E-769 PION AND KAON PRODUCTION OF CHARM AND CHARM-STRANGE STATES (Brazil, Fermilab, UC/Santa Barbara, Toronto, Tufts)

Hard Collisions

E-672 HIGH P_T JETS AND HIGH MASS DIMUONS (Caltech, Chicago Circle, Florida State, Indiana, Michigan/Flint, Serpukhov)

E-683 PHOTOPRODUCTION OF HIGH P_T JETS (Arizona, Fermilab, Lehigh, Rice, Vanderbilt, Wisconsin)

E-704 EXPERIMENTS WITH POLARIZED BEAM FACILITY (Argonne, Austin, CEN/Saclay, Fermilab, Kyoto, LAPP/France, LBL, Northwestern, Rice and Serpukhov, Trieste)

E-706 DIRECT PHOTON PRODUCTION (Dehli, Fermilab, Michigan State, Minnesota, Northeastern, Pennsylvania State, Pittsburgh, Rajasthan, Rochester)

E-711 CONSTITUENT SCATTERING (UC/Davis, Fermilab, Florida State, Michigan)

pp Collider

E-710 MEASUREMENTS OF ELASTIC SCATTERING AND TOTAL CROSS SECTIONS AT THE FERMILAB ANTIPROTON COLLIDER (Bologna, Cornell, Fermilab, George Mason, Maryland, Northwestern)

E-713 PROPOSAL FOR A SEARCH FOR HIGHLY IONIZING PARTICLES FOR THE DO AREA AT FERMILAB (UC/Berkeley, Fermilab, Harvard)

E-735 SEARCH FOR A DECONFINED QUARK GLUON PHASE OF STRONGLY INTERACTING MATTER IN ANTIPROTON-PROTON INTERACTIONS AT SQUARE ROOT OF S EQUAL TO 2 TEV (Duke, Fermilab, Iowa State, Lawrence Livermore, Notre Dame, Purdue, Wisconsin)

E-740 STUDY OF PROTON-ANTIPROTON COLLISIONS USING A LARGE DETECTOR AT DO (Brookhaven, Brown, CEN/Saclay, Columbia, Fermilab, Florida State, LBL, Maryland, Michigan State, SUNY/Stony Brook, Northwestern, Pennsylvania, Rochester, VPI)

E-741 STUDY OF PROTON-ANTIPROTON COLLISIONS USING A LARGE DETECTOR AT BO (Argonne, Brandeis, Chicgao, CBPF/Brazil, Fermilab, Fukui, Harvard, Haverford, ICRR/Tokyo, Illinois, INFN/Frascati, INFN/Pisa, KEK, LBL, Pennsylvania, Purdue, Rockefeller, Rutgers, Saga, Texas A&M, Tsukuba, Wisconsin)

Others

E-466 NUCLEAR FRAGMENTS (Argonne, Chicago, Chicago Circle, Purdue)

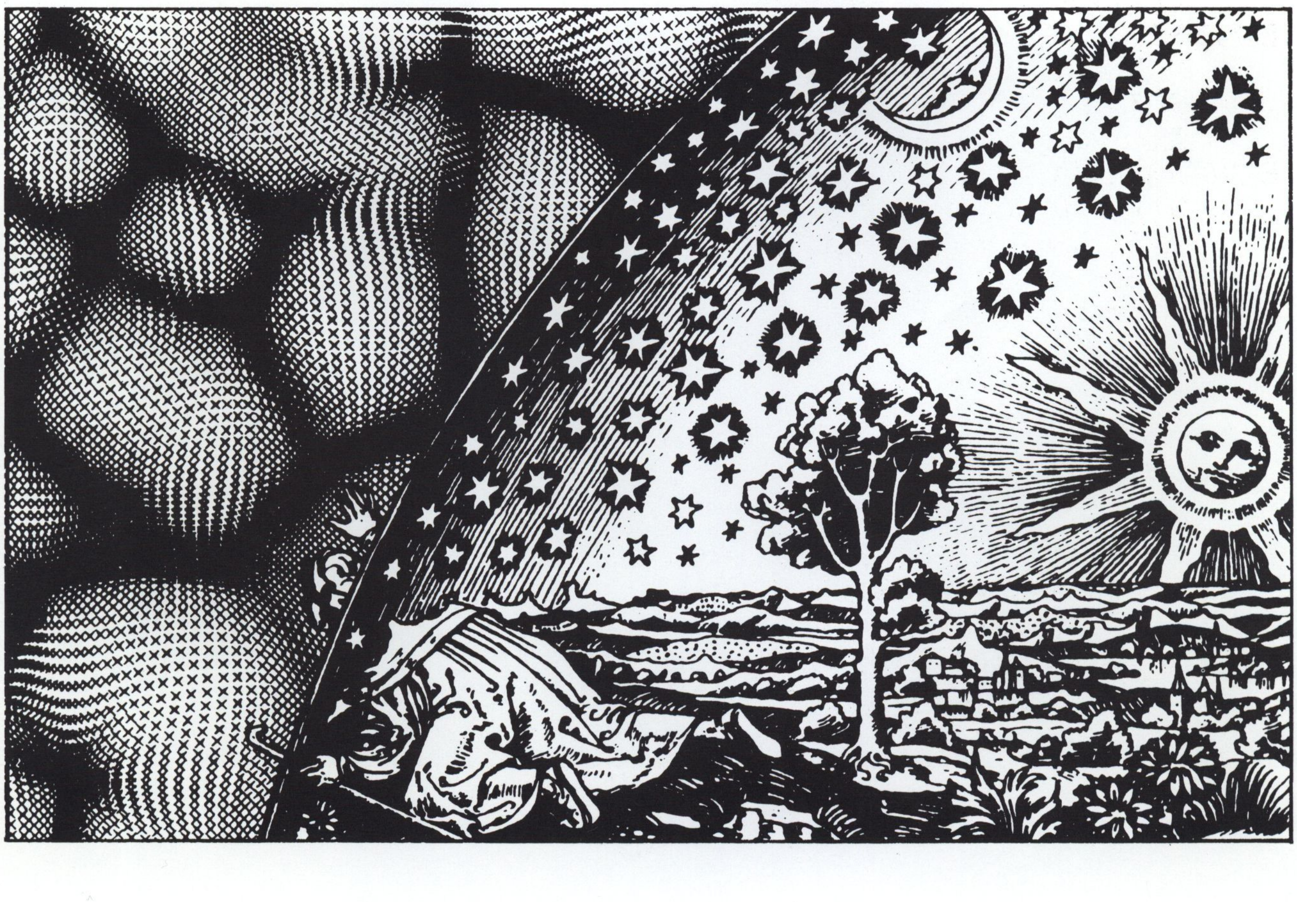
E-754 CHANNELING TESTS (Case Western Reserve, Fermilab, GE R&D Center, Sandia, SUNY/Albany)

E-756 MEASUREMENT OF THE MAGNETIC MOMENT OF THE OMEGA MINUS HYPERON (Fermilab, Michigan, Minnesota, Rutgers, Washington)

Appendix D

Visitors to the Fermilab Astrophysics Group — 1985

P. Anderson, University of Florida • I. Angus, California Institute of Technology • R. Bond, Canadian Institute for Theoretical Astrophysics • R. Brandenberger, Institute of Theoretical Physics, Santa Barbara • R. Cowsik, Tata Institute, India • A. Dekel, Yale University • A. K. Drukier, MPI f. Physik, West Germany • J. Dykla, Loyola University of Chicago • G. Efstathiou, Institute of Astrophysics, University of Cambridge • M. Fall, Space Telescope Science Institute • J. Fry, University of Florida • T. Gaisser, Bartol Research Foundation • M. Geller, Harvard University • G. Gelmini, Harvard University • M. Gleiser, King's College, England • A. Guth, Massachusetts Institute of Technology • J. Harvey, Princeton University • S. Hawking, University of Cambridge • N. Iwamoto, Washington University • D. Koo, Space Telescope Science Institute • S. Kulkarni, University of California, Berkeley • A. Melott, University of Chicago • D. Müller, University of Chicago • N. Neto, CBPF, Brazil • M. Panek, CAC, Poland • J. Peebles, Princeton University • Y. Rephaeli, Tel Aviv University, Israel • M. Ruderman, Columbia University • S. Sarkar, CERN • Q. Shafi, Bartol Research Foundation • P. Shapiro, University of Texas at Austin • J. Silk, University of California, Berkeley • M. Srednicki, University of California, Santa Barbara • A. Stebbins, University of California, Berkeley • G. Steigman, Bartol Research Foundation • M. Teper, CERN • P. Trower, Virginia Polytechnic Institute and State University • B. Tully, University of Hawaii at Honolulu • H. Tye, Cornell University • J. F. Valle, Rutherford Lab, England • E. Vishniac, University of Texas at Austin • N. Vittorio, University of Rome, Italy • C. Will, Washington University • S. Willenbrock, University of Texas at Austin • M. Yoshimura, KEK.



Appendix E

Universities Research Association, Inc.

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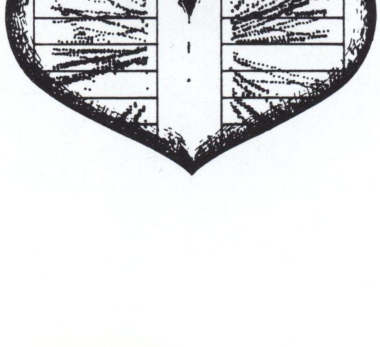

Appendix F

Physics Advisory Committee

Hugh Williams, University of Pennsylvania, *Chairman* • John Cumalat, University of Colorado • Thomas Devlin, Rutgers University • Gary Feldman, Stanford Linear Accelerator Center • Richard Field, University of Florida • Howard Gordon, Brookhaven National Laboratory • David Hitlin, California Institute of Technology • Alfred Mueller, Columbia University • Francis Pipkin, Harvard University • Melvyn Shochet, University of Chicago • Martinus Veltman, University of Michigan • Michael Witherell, University of California, Santa Barbara.

Appendix G

Fermilab Users Executive Committee

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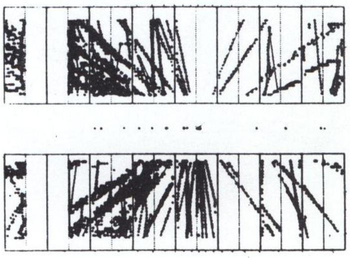
Appendix H

Fermilab Industrial Affiliates

AT&T Bell Laboratories • Ameritech Development Corporation • Borg-Warner Corporation • Brunswick Corporation • Commonwealth Edison Company • Control Data Corporation • Convair — General Dynamics • CVI • Deere & Company • Digital Equipment • Digital Pathways • Eaton Corporation • Fluor Engineering, Inc. • General Electric • General Motors • Goodyear Tire & Rubber Company • W. W. Grainger, Inc. • Harshaw Chemical Company • Harza Engineering Co. • Hewlett-Packard Company • IBM • State of Illinois • Intermagnetics General Corporation • Kinetic Systems Corporation • Litton Industries, Inc. • NALCO Chemical Company • New England Electric • Nuclear Data, Inc. • NYCB Real-Time Computing, Inc. • Omnibyte Corporation • Oxford Airco • Plainfield Tool and Engineering • Shell Development Company • Signal UOP Research • Standard Oil Company (Indiana) • Sulzer Brothers • Sunbeam Appliance Company • Union Carbide Corporation • Varian Associates • Westinghouse Electric Corporation.



Acknowledgements

The front cover painting, the True Organizational Chart facing page 1, and the illustrations on pages 65, 69, 74, 76, 78, 80, 103, 104, 105, 106, 109, 121, 122, and 148 are reproductions of original works by Angela Gonzales . . . as are the gargoyles.

The front cover painting depicts the "Temple of Achievement." It is styled after the Doric order. A representation of the Event (proton-antiproton collisions at 1.6 TeV) surrounds the Antiproton Source logo on the tympanum. The institutions participating in the Fermilab Collider program are engraved on the stylobate. The program's sponsors, DOE and URA, are acknowledged by the inscriptions on the bases of the two foremost portrait sculptures. The sculptures themselves represent Fermilab management and staff, and the project leaders and staff of the Accelerator Division, the Antiproton Source, CDF, and DØ. The pendulum seeks a resting point on the Standard Model. The gargoyles speak for themselves, and the Canadian geese are, as always, omnipresent.

First frontispiece: *Tabulae Rudolphinae* by Johannes Kepler, 1627.

Second frontispiece and photographs on pages 10, 62, and 63: Olivia Gonzales.

Page 33: From *Machines et inventions approuvées par l' Academie Royale des sciences*, 1735.

Page 39: Illustration by G. Vascellini from *Serie di ritratti d' uomini illustri toscani*, 1773.

Page 41: Illustration by Gregor Reich from *Margarita Philosophica.*

Page 42: *Complete History of the Universe* by M. S. Turner, Fermilab Astrophysics Group, 1985.

Page 51: Illustration by Hieronymus Rodler from *Eyn schön nützlich büchlin*, 1531.

Pages 52 & 53: Computer-aided drawings by Ayfer Atac, Fermilab Technical Support Section, 1985.

Page 85: *Cosmography* from *The Cosmographical Glasse* by William Cunningham, 1558.

Page 99 :Photograph taken at the University of Chicago by James L. Lasenby.

Page 100: *The Tree of Knowledge* from *Encyclopedie*, artist unknown.

The back cover shows a reproduction of the CDF logbook page signed by all present at the creation of 1.6-TeV proton-antiproton collisions.

All photography, except where noted, by the Fermilab Photography Unit.

Skilled and diligent efforts in the production of this *Report* were provided by Angela Gonzales, and Susan Winchester and Peggie Roberts of the Fermilab Publications Office.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Cooldown is Cold Fact
TeV I Antiproton Source
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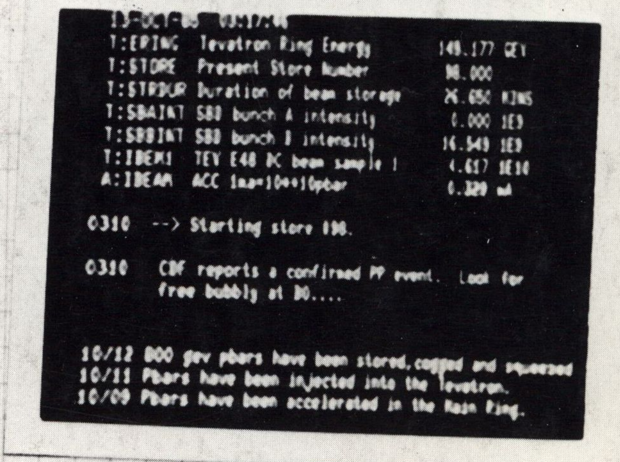

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