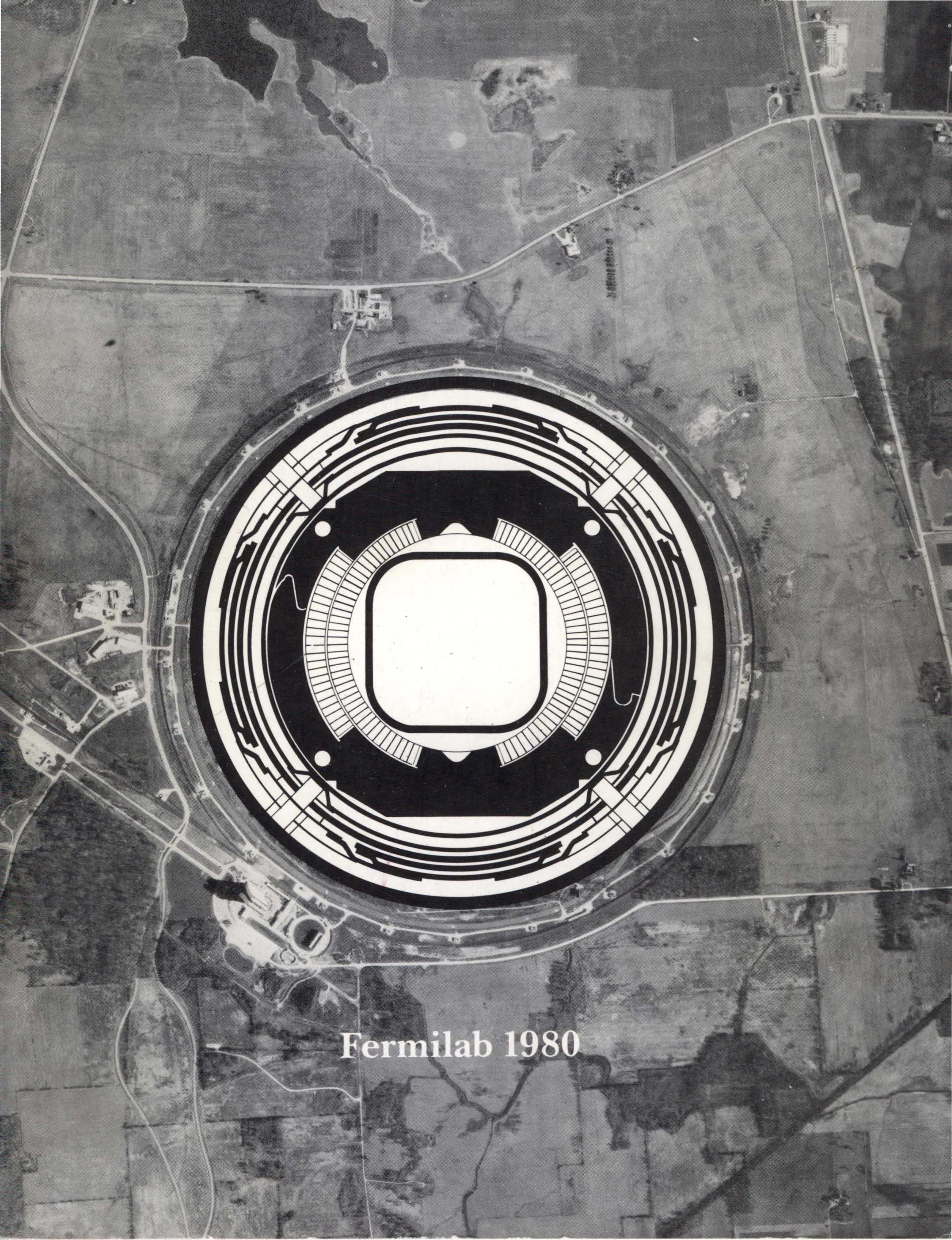


Fermilab 1980

Universities Research Association, Inc.

Trustees

Officers

Fermilab Visiting Committee

Member Institutions

The University of Arizona, Brown University, California Institute of Technology, University of California, Berkeley, University of California, Los Angeles, University of California, San Diego, Carnegie-Mellon University, Case Western Reserve University, University of Chicago, University of Colorado, Columbia University, Cornell University, Duke University, The Florida State University, Harvard University, University of Hawaii, University of Illinois, Indiana University, The Iowa State University, University of Iowa, The Johns Hopkins University, University of Maryland, Massachusetts Institute of Technology, The University of Michigan, Michigan State University, University of Minnesota, University of North Carolina, Northeastern University, Northwestern University, University of Notre Dame, The Ohio State University, University of Pennsylvania, Princeton University, Purdue University, Rice University, The University of Rochester, The Rockefeller University, Rutgers The State University, Stanford University, State University of New York at Buffalo, State University of New York at Stony Brook, Stevens Institute of Technology, Syracuse University, The University of Texas at Austin, University of Toronto, Tulane University, Vanderbilt University, University of Virginia, Washington University, University of Washington, University of Wisconsin, Madison, Virginia Polytechnic Institute and State University, Yale University

Fermilab 1980

Annual Report of the Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory
Batavia, Illinois

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

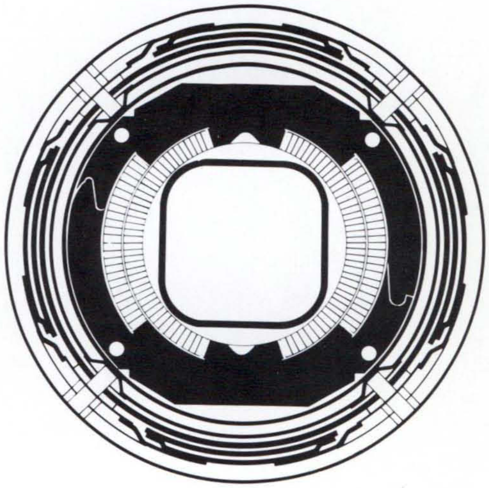


Table of Contents

The State of the Laboratory

The state of the Laboratory can never be better than the state of the science so I begin my second Annual Report with a subjective view of our field, high-energy particle physics. This is the study of the fundamental constituents of matter and of their interactions. We know, as a result of prodigious efforts of the past three decades in the laboratories around the world, that matter is composed of two apparently elementary constituents, the quarks and the leptons. The interactions among these constituents produce the more complex things that make the world in its infinite variety. One interaction is the strong force which binds the quarks into protons, neutrons, pions, i.e., hadronic or nuclear matter. The electromagnetic force has the task, among others, of binding the leptonic object, the electron, to the nucleus to make the atoms. The weak interaction generates reactions such as the radioactive decay of particles and processes involving leptons called neutrinos. The forces of interaction described above have, in the decade of the 70's, been found to have remarkably similar form in spite of a vast disparity in apparent strengths and ranges. A unified theory of the weak and the electromagnetic interactions has had great success in accounting for a large variety of data. The strong theory, called quantum chromodynamics (QCD) has also achieved wide general acceptance, although calculational difficulties impede quantitative confrontation with experiment and some fundamental puzzles remain to be understood. All the theories mentioned require the existence of force carriers, quantum states of the force fields. The electromagnetic quanta are photons; the quanta of the weak force are massive objects $W^{\pm}$ and Z^0. Unification implies that $W^{\pm}$, Z^0, and photons constitute a family of force carriers.

The strong-force carriers are called gluons. Although substantial indirect evidence exists for the reality of gluons, the $W^{\pm}$ and Z^0 are outside of the range of currently operating accelerators. Nevertheless, there has been considerable effort and excitement in the possibility of a grand unification of the three interactions. So much for history. We come to 1980.

The notion that we are in a revolutionary period persists although perhaps this revolution does not fit any of the categories listed in Thomas Kuhn's relevant book.[1] The search for elementarity is very old--to be on the verge of apparent success should then not alter one's world view--or should it? Nevertheless progress in 1980 continues to encourage the belief that the **things** are quarks and leptons and the forces are gauge fields carried by photons, W's, Z's, and gluons. No doubts have been cast on the electroweak theory; QCD continues to gain slowly and grand unification makes considerable theoretical progress, even though experimental tests are still in the future. Probably the most interesting new data of 1980 have come from the work at the Cornell e^+e^- collider, CESR, which is effectively devoted to following up the Fermilab discovery of three upsilon states. This exotic spectroscopy is not generating any surprises, but is providing crucial data towards refining the quark-quark force.

The various approaches towards grand unification are strewn with open questions that probe extensively into our understanding of the nature of matter. Almost every aspect of QCD predictions need sharper confirmation. The numerical values of the parameters, for example, α_s (Q^2), need refined measurement. Structure functions of the hadrons need to be determined over the entire range of x and Q^2. Accurate measurements of scaling-violation predictions are very important. Quark and gluon spin effects in polarization measurements open a new domain. How does the tau neutrino behave? Are there large (more than 10 eV) neutrino mass differences? What are the properties of objects containing the b-quark? Current ideas imply the existence of masses that are unreachable with planned accelerators of 10-50 TeV. One approach is to do precision experiments at energies far below thresholds. An example is a very precise measurement of $\sin^2 \theta_W$ to probe grand unification models. Searches for very rare decay modes are other examples. Decay systematics of baryons containing heavy quarks must be studied. How quarks fragment and the visualization of quarks and gluons via jets are another topic requiring quantitative measurement. Processes that vary as a high power of atomic number are not understood and may shed light on the behavior of aggregates of quarks in the atomic nucleus.

All these questions (and many more) are addressed uniquely by Tevatron II, the fixed-target 1000-GeV program with its wide variety of beams and spigots. In almost all of the cited problems the difference between 400 GeV and 1000 GeV is crucial! Were Tevatron II to expire, the next look at these problems would be by the Soviet UNK (3 TeV) accelerator circa 1990.

Taking a more philosophical view, we see a theory perhaps encumbered by too many objects and too many forces still to unify, but we must remember that we are doing experiments at very low energies compared to what is important in the universe. There is the expectation that at extremely high energies, things will display their ultimate simplicity. For this we must look up.

The interaction of our subject with cosmology deepens. Astrophysicists have always been our best customers, hot for particle-physics results. More recently, the flow has reversed somewhat; superdense and superhot bulk matter involve conditions that cannot be easily duplicated in accelerator laboratories. Some of the most dramatic cosmological observations, such as the absence of antimatter in the universe and the ratio of baryons to photons, depend crucially on the properties of particles and their interactions at energies of the order of 10^{14} GeV, a temperature characteristic of the early (when it was only 10^{-27} years old) universe. The current cosmological literature is routinely filled with concepts such as baryon-non-conserving forces, CP violation, grand unification theories, gauge and Higgs bosons--these are the grammar and vocabulary of Fermilab scientists. Thus we are trying to press our astro- colleagues (with a series of seminars) for hints as to what we can expect at 2 TeV in the center of mass, i.e., Fermilab's Tevatron I project.[2]

The year was notable for a growing confidence on the part of some leading theorists that we will soon have enough energy (of order 100 GeV in the center of mass) to test the last crucial aspects of theoretical predictions and that theory really needs no new phenomena until something like 10^{15} GeV! In the decade of the 80's, Fermilab's 2-TeV collider should provide a significant challenge to this confident prediction.

In a different vein, 1980 was the year of the Woods Hole Panel of the DOE, a continuation of a tradition for the high-energy community to adjourn to a quiet place in order to plan for its future. Previous Woods Hole panels (1974-1977) have set the field on the course in which the major laboratories would engage in construction to provide those facilities that are deemed vital towards the advancement of the science. The 1980 Woods Hole study met in the environment of funding shortages and significant changes in the world scene in high-energy physics. The Fermilab program, both the on-going 400-GeV research and the status and plans of the superconducting accelerator program (Energy Saver, Tevatron I, and Tevatron II) were presented in detail. I think it is fair to say that this program found considerable favor in the Panel's view and its full support by the DOE was strongly recommended.[3]

Another relevant happening that will impact our future was the FY 1981 high-energy physics budget which, although a bit higher than the President's submission is nevertheless some \$15-\$20 millions **below** the OMB-DOE "agreement" (Deutch "floor"). This agreement suggested that a DOE budget of \$300M in constant 1979 dollars was a minimum level that could support the construction and operation of the three DOE laboratories and the university users. When compounded by the failure of 1980 to meet this goal, the net burden faced by the program is about \$30M. Fermilab's FY 1981 budget was \$7M below the minimum need to carry out Saver-related research, development and operation, conduct a respectable 400-GeV running period of 33 weeks, and carry out vigorous R&D on the antiproton source. As a consequence, the run period was reduced to 22 weeks and resources from the Research and Accelerator Divisons assigned to necessary Saver tasks. The antiproton work was significantly slowed. We hoped that this third year of Saver-induced austerity would be relieved by the FY 82 budget. At this writing we do not have grounds for much optimism. What is at stake is the application of the Saver to do physics.

Let's look at what kind of physics we did in 1980. The accelerator ran from January to June 16 and started up again in mid-November. Some of the major experiments that took data are listed in Table I. The "summer" Saver shutdown was considerably extended because of fiscal austerity. A great deal of planning went into this shutdown in order to expend the available resources with maximum efficiency.

The Accelerator Division was given the go-ahead to proceed with the superconducting conversion of the Left Bend (which sends 400-GeV protons to the Meson Laboratory). The virtues of this decision were that (1) we save power (2) it permits 1000-GeV operation and must be done eventually (3) we gain valuable experience in running a high intensity beam (more than 10^{12} ppp) through a string of 20 superconducting magnets, and (4) We free up 48 conventional magnets which are slated for the antiproton-targeting R&D program. The fear was that, should the system be delayed, the Meson Laboratory physics program would suffer and this is where the bulk of our customers live. As of this writing, the project has had some success. The Left Bend has transported 2×10^{12} protons per pulse to Meson Hall and all beam lines have been activated. It is too early to judge reliability. Clearly this program will give us invaluable operating experience.

In the Research Division, the major activity was a long-overdue improvement in the neutrino shield using 14,000 tons of surplus Argonne steel and accelerator improvement project funding. The results as observed by the neutrino experiments in the November startup were spectacular. Where previously about 300 muons per pulse would penetrate the shield with 300-GeV protons incident, now only 1 to 3 muons appear with 400-GeV incident.

Start-up of a complex accelerator after a long shutdown is always difficult. Add the fact that extensive installation work was going on in the tunnel and ingredients for catastrophe abound. We used techniques evolved during the 1979 shutdown and achieved an excellent start-up with reliable beam of more than 2×10^{13} ppp within a week of the official start-up time.

Physics results published in CY 80 are listed in our Publications List at the end of this report and in general reflect data taken considerably earlier. Some very precise elastic scattering data [Phys. Rev. **D21**, 3010 (1980)] were taken in 1976 as E-69. Similarly, a spate of hadronic interaction papers published by the 30-in. Hybrid Bubble Chamber collaboration are based on 1976 runs. The list includes increasingly incisive experiments using high-energy photons as probes and these serve to point towards the now-running tagged-photon spectrometer (E-516) and a third-generation broad-band photon-beam experiment (E-400), which aims toward producing massive numbers of charmed particles. Statistically significant data are just now coming out of the

15-ft bubble chamber and these appear in six papers. High transverse momenta inclusive data of great precision come from the prolific Chicago-Princeton group [Phys. Rev. Lett. **44**, 511 (1980)]. How quarks emerge from hard collisions is a fundamental issue and spectrometer studies (E-260 and E-395) provide such data. Great precision again appears in the program of magnetic-moment measurements (E-440) capitalizing on the discovery of polarization in the production of hyperons at modest transverse momenta. Some of the most dramatic results are derived from the successful application of the fine-grained nuclear-emulsion technique (E-531) to the production and decay of charmed mesons by neutrinos. These are the first measurements of identified charmed-particle lifetimes. The instrumentation required to study very short lifetimes is a fundamental problem and addressed by a workshop on holography and by joint efforts with Yale on the development of fine streamers (E-630) and with Charpak at CERN on refined wire chambers (E-605). The Director has offered a reward of $100,000 or all of his personal surplus cash (whichever is less) for the invention of an economical detector plane (larger than 1 m^2) which achieves 10μ resolution.

A brief summary of other major activities follows:

Energy Saver. We entered the year full of concerns about the stability of the magnet mounting in the cryostats and with much to be learned about refrigerators, magnetic measurements, correction-coil requirements and large-systems performance. We are now confident that we are making accelerator-quality magnets. We have a great deal of operating experience with our refrigerators, and we are slowly mastering the systems aspect, although there are many trials ahead. The correction coils are in production. Among many hurdles still to come is the doubling of magnet production with no degradation in quality. In summary, although we know of no deep technical problems, there is a continuous strain on the staff, due to the difficulty of the tasts, the tightness of funding, and the dependence on vendor performance. The need for stringent quality control at all stages of the assembly of magnets requires continuous and anxiety-ridden attention.

Tevatron I. The colliding-beams program made substantial progress in demonstrating the two types of cooling that are involved in forming an intense source of antiprotons. Conceptual designs of precoolers and a variety of scenarios for accumulation and further cooling are being hotly pursued. Study weeks are a useful mechanism. Serious problems of target blowup have been alleviated by a number of new strategies. A new Program Management Group for TeV I, under the chairmanship of J. D. Bjorken, monitors the program on a biweekly basis. As we proceed into the construction phase, we expect a continuous flow of people from other parts of the Laboratory to join the program of achieving 2 TeV in the center of mass. Collaboration with LBL, ANL, INP, Novosibirsk, and the University of Wisconsin continues in a fruitful manner.

Tevatron II. Fixed-Target 1000-GeV Program--the years of planning, discussion, open workshops, and user feedback have culminated in a design report and a proposal for FY 82 funding. The first real test of the soundness of the idea was the call for proposals in the neutrino-muon area. The results were a flood of over 30 proposals. Intense interest from Western Europe was indicated by 6 proposals with major European participation. We expect an even larger response to our call (deadline February 1981) for hadron-beam proposals. A summer workshop on Tevatron II physics was studded with new ideas for exploiting this facility. Probably no better testimony to the scientific merit of this program can be found than the enormous response of the high-energy physics community--in quality and quantity.

Miscellany. Among the uncountable number of diverse activities which came to the attention of the Director, a few stand out vividly. Our Cancer (now renamed Neutron) Therapy Facility is the leading center for radiation beam treatment of tumors. This matches the many letters that come in, full of praise and appreciation. We started a Saturday Morning Physics program for good high-school students, which has proved so delightful for all concerned that we are more than occasionally tempted to expand this and chuck all the rest. We are still deeply involved in technology transfer via our Industrial Affiliates program, public education in science via any medium that is available, an ever-growing visitors program, some effort at addressing problems of science and technology in developing countries, and a proposal for a dramatic fellowship program to protect and enhance that scarce resource, the brilliant, young investigator. Concern with this dwindling species has led to the quest for "mini-experiment" facilities--opportunities for small groups with modest resources but ample imagination to do significant research in far less than the average time per experiment. Fermilab must be capable of providing such facilities among the variety of beam lines.

We stumbled upon a device for the examination of an approved experiment somewhere in-between the time of approval and the time of data taking. This period may take as long as two years! The review is attended by all the collaborators (often the first time they are in a room together), the Director, and four or five henchmen who have briefed themselves on the experiment. The sessions usually begin at 10 a.m. on Saturdays and run until 3 or 4 in the afternoon.

All aspects of the research are reviewed. Is it still good physics? Will the software be ready? A typical program is appended in Table II. This gives the Laboratory an opportunity to hear the students and postdocs who do the work and (usually) tell the truth rather than their professors (who may not do either!). It gives us an opportunity to help by adding resources. The mere act of preparing for these reviews, they all say, has been enormously fruitful. It is also a unique pedagogic experience and in fact the word has got around--it is well attended by students and by Laboratory and visiting physicists.

That Greatest Miscellany of All: Theoretical Physics. Theoretical physics plays a dual role--it must of course do theory and the vigor of the activity is described herein. But it does much more. In addition to the close coupling of theorists and experimentalists working in the same laboratory, other features appear at Fermilab. There is the joint "Wine and Cheese Seminar." There is the biweekly Journal Club. There are the Academic Lectures addressed to graduate students and postdocs (young and old). There is the Soirée for physics in the pre-proposal state. There is the entrapment of theorists into interesting problems in accelerator physics, Accelerator Journal Club, and service on Project Management Groups. There is the active role of Fermilab theorists in all phases of Program Advisory Committee activities and Director's Reviews of Experiments in the construction phase. All of this has fostered an environment of intellectual quality and moves us toward the goal of achieving the kind of atmosphere enjoyed by the great laboratories which have played so important a role in the history of our subject, e.g., Göttingen, Copenhagen, Berkeley.

The noted author of **Lives of a Cell** Lewis Thomas comments in a recent essay[4]:

> This is, in real life, the way basic research is done. It seems, in the telling, a disorderly and unorganized way of working, an occupation based on making the right mistakes, but it is not. Instead, it is a way of working with the human imagination as the central and indispensable instrument. . . . The work is done, mainly, by making up stories about nature. . . . Once in a while, if the work is going very well and the air is right, the story turns out to be a very funny story. . . . Some of the profoundest insights . . . have their beginnings in a burst of laughter. There is an important element of humor in basic research . . . it has something to do with astonishment at the outrageous simplicity of mechanisms in nature when . . . they are finally comprehended.

Leon M Lederman

References

[1] Thomas Kuhn, **The Structure of Scientific Revolutions** (University of Chicago Press, Chicago, 1970).
[2] Tevatron Phase I Design Report, Fermilab, February 1980.
[3] Woods Hole Panel Report, HEPAP: Report of the 1980 Subpanel on Review and Planning of the U. S. High Energy Physics Program, July, 1980.
[4] Lewis Thomas, Essay in **Discover**, January, 1981, p. 43.

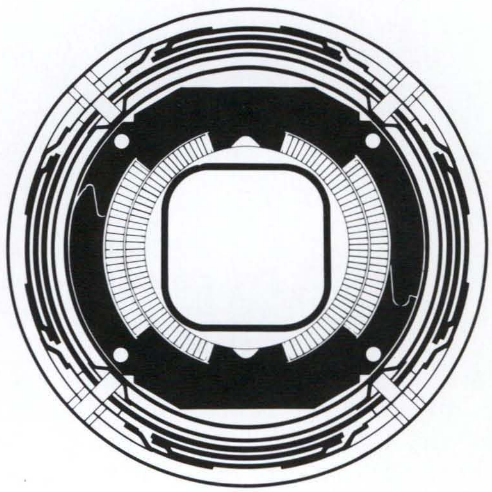


Table I. Experiments That Took Data in CY 1980.

E-515 (Rosen). This experiment is attempting to study charm production with pions.

Carnegie-Mellon University
Fermi National Accelerator Laboratory
Northwestern University
University of Notre Dame

E-629 (Ferbel). This proposal is to measure the γ yield in p-Be collisions for $p_t > 3$ GeV/c and compare the yield from π^+Be and p Be collisions.

Fermi National Accelerator Laboratory
Michigan State University
University of Minnesota
University of Rochester

E-613 (Jones). This is a beam dump experiment to measure the production of prompt neutrinos as a function of production angle and target material. E-613 is currently in progress.

Universita di Firenze, Firenze (Italy)
University of Michigan
Ohio State University
University of Washington
University of Wisconsin

E-585 (Francis). This experiment measures KN charge exchange reactions.

University of California, Davis
University of California, San Diego
Carleton University (Canada)
Michigan State University

E-557 (Malamud). This experiment will attempt to identify jets produced in πp interactions and then to identify their properties. The experiment will utilize the multiparticle spectrometer and a large calorimeter to measure the jet energies.

California Institute of Technology
Fermi National Accelerator Laboratory
University of Illinois, Chicago Circle
Indiana University
University of Maryland
Rutgers University

E-577 (Rubinstein). This experiment measures πp elastic scattering up to $|t| = 8$ $(GeV/c)^2$. The experiment is currently taking data.

University of Arizona
University of California, San Diego
Cornell University
Fermi National Accelerator Laboratory
North Central College
Northeastern University

E-580 (Lannutti). This experiment is searching for resonances decaying into two V's ($\Lambda\bar{\Lambda}$, $K\bar{K}$, . . .).

University of Arizona
Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Florida State University
Georgia Institute of Technology
Michigan State University
University of Notre Dame
Tufts University
Vanderbilt University
Virginia Polytechnic Institute & State University

E-516 (Nash). This experiment in the Tagged Photon Laboratory is designed to study high mass final states and in particular the photoproduced charm states.

University of California, Santa Barbara
Carleton University (Canada)
University of Colorado
Fermi National Accelerator Laboratory
National Research Council of Canada
University of Oklahoma
University of Toronto (Canada)

E-497 (Lach). This experiment has received an initial approval to measure the flux of hyperons coming from their hyperon channel and to search for massive long-lived charged particles of 5-6 GeV/c^2.

Fermi National Accelerator Laboratory
Iowa State University
Yale University

E-326 (Piroue, Shochet). This is an experiment to measure high-mass dimuon cross sections at high p_t.

University of Chicago
Princeton University

E-537 (Cox). The dimuon spectrum produced with an incident antiproton beam will be measured in this experiment. The antiprotons are a tertiary beam from anti-lambda decay. The experimental apparatus is set up and the beam has been established.

University of Athens (Greece)
Fermi National Accelerator Laboratory
McGill University (Canada)
Michigan State University
Shandong University (China)

E-650 (Webb). This proposal is for a continuation of E-567. The previous experiment has given a tantalizing but inconclusive 2 standard-deviation signal for the D meson.

Brookhaven National Laboratory
Centre de Recherches Nucleaires de Saclay (France)
Princeton University
Universita di Torino (Italy)

E-53 (Baltay). This experiment is an exposure of the 15-ft bubble chamber filled with a heavy Ne-H_2 mixture. The major objective of this exposure is to provide additional data on νe scattering.

Brookhaven National Laboratory
Columbia University

E-564 (Voyvodic). This experiment will put an emulsion stack in the 15-ft bubble chamber. Neutrinos interacting in the emulsion produce particles which make tracks in the bubble chamber. These tracks can be traced back into the emulsion to locate the origin of the interaction. The volume around the interaction will be scanned for particle decays. The length of the decay track plus the data from the bubble chamber on the decay tracks will yield a measurement of the lifetime of the decaying particle.

Fermi National Accelerator Laboratory
Institute of Theoretical and Experimental Physics, Moscow (USSR)
Institute of High Energy Physics, Serpukhov (USSR)
Institute of Nuclear Physics, Krakow (Poland)
Joint Institute for Nuclear Research, Dubna (USSR)
University of Kansas
University of Washington

E-531 (Reay). This experiment uses an emulsion target in a neutrino beam with a downstream electronic spectrometer to analyze the downstream tracks. The measurements in the spectrometer are used to locate the vertex for the event in the emulsion. The emulsion is then scanned for the primary vertex and for a decay vertex. In this way the lifetime of charmed particles will be measured.

Aichi University of Education, Kariya (Japan)
Fermi National Accelerator Laboratory
Kobe University (Japan)
Korea University, Seoul (S. Korea)
McGill University (Canada)
Nagoya University (Japan)
Ohio State University
Okayama University (Japan)
Osaka University (Japan)
Universite d Ottawa (Canada)
Science Education Institute of Osaka Prefecture (Japan)
University of Tokyo (Japan)
University of Toronto (Canada)
Virginia Polytechnic Institute & State University
Yokohama National University (Japan)

E-594 (Taylor). This experiment uses a flash tube detector in a neutrino beam to study the structure of semileptonic neutral currents. In addition, they wish to use broad-band beam to study νe scattering.

Fermi National Accelerator Laboratory
Massachusetts Institute of Technology
Michigan State University
Northern Illinois University

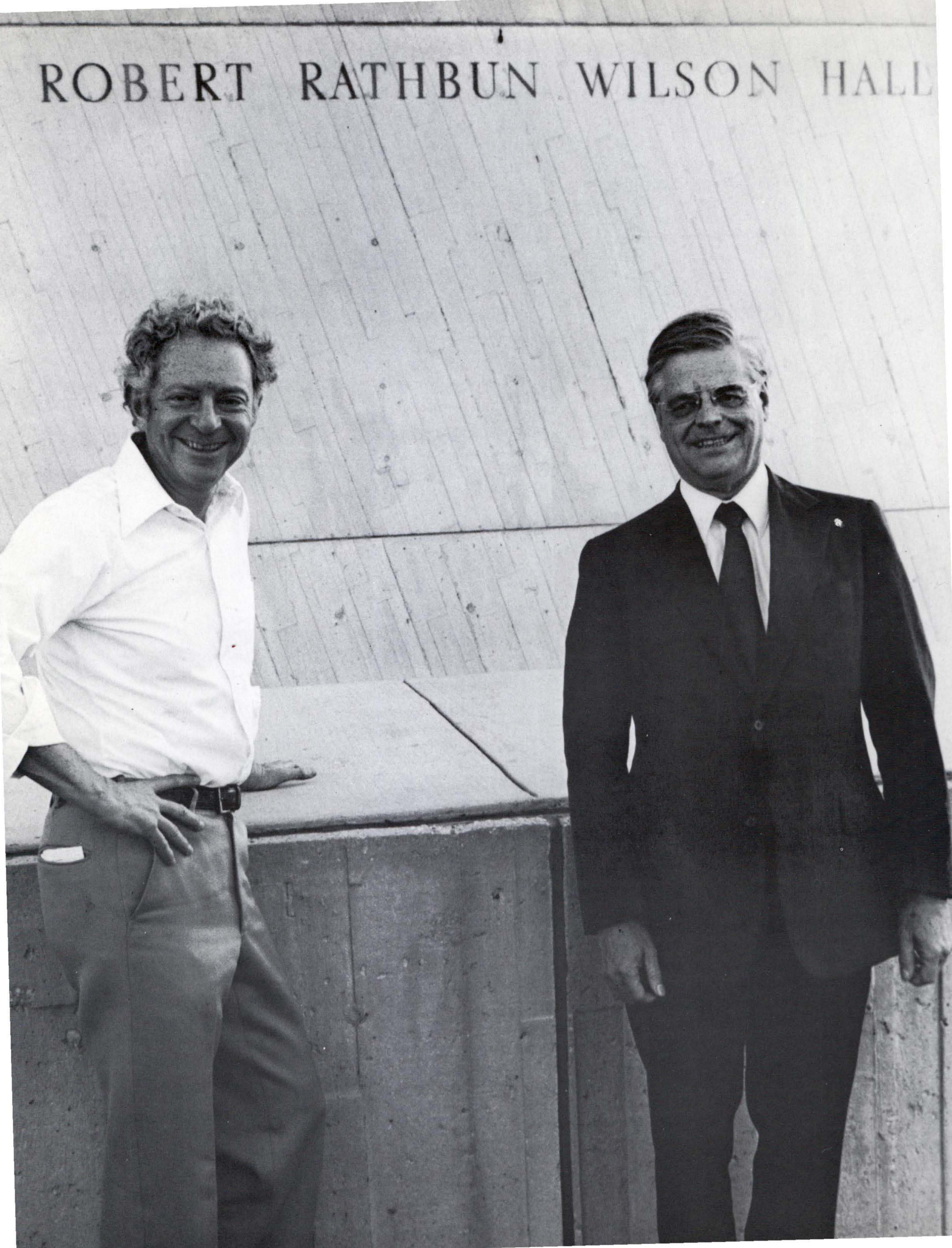
Table II.

Director's Review -- E-557

March 29, 1980

Agenda

10:00	Introduction and Physics Background and Goals	Terry Watts
10:30	Description and Operation of the Spectrometer	Don McLeod
11:00	Experiment Simulation	Clive Halliwell
11:30	Track and Vertex Reconstruction	Jack Martin
11:50	Calorimeter Design and Performance	Pat Rapp
12:20	Calorimeter Calibration System	Alex Dzierba
12:45 - 1:30	Lunch	
1:30	Beam and Incident Particle Identification	Bob Ellsworth
1:50	Strip Chambers (γ detection)	Fred Lopez
2:00	Secondary Charged Particle Identification System	Bruce Brown
2:30	Conclusions and Experimental Goals	Ernie Malamud


ROBERT RATHBUN WILSON HALL

Central Laboratory Named In Honor of Robert Wilson

Fermilab's architecturally significant Central Laboratory Building was renamed Robert Rathbun Wilson Hall, in honor of Fermilab's Director Emeritus Robert Rathbun Wilson, during a brief ceremony in front of the building in September.

In 1975 the 16-story building was given an award by the Society of American Registered Architects of the Illinois State Council for its "superior achievement and for design and professional excellence."

Fermilab's Director Emeritus Robert Wilson (right) stands with Leon Lederman in front of the new inscription on Robert Rathbun Wilson Hall.


OSU
HIGH ENERGY
PHYSICS
32

Chronology of an Experiment, E-613

The purpose of the Laboratory is to provide facilities and particle beams to study the basic nature of matter by carrying out experiments in high-energy physics. The product produced by Fermilab is not practical objects or electric power, but new knowledge.

Scientists from Fermilab and many different countries propose experiments and come to the Laboratory to perform them. They bring or build much of their own equipment and in addition use Laboratory equipment.

An experiment at Fermilab is a large enterprise, usually involving people from a number of institutions and taking several years from start to finish. There are some instances where a collaboration and its apparatus have evolved through a whole series of related experiments, using the results of one to suggest new lines of investigation. There are groups that have been doing experiments more or less continuously since the accelerator began operation in 1972.

A new experiment begins with the collaborators writing a proposal, a document that discusses the importance to science of the possible results, the method and feasibility of doing the experiment, estimates of the beam time required, and commitments of people and resources. In this stage, the working of the collaboration and the importance of the work are hammered out in vigorous, free-wheeling debate among the dozen or more members of the group. The proposal that comes from this effort is frequently as long as a book and filled with precise detail to withstand the scrutiny needed to get approval. Even a follow-on experiment of the same group using the same apparatus needs new approval, because it occupies beam space that could be used by another experiment.

All proposals are reviewed by the Physics Advisory Committee. The committee meets several times a year and they review each proposal thoroughly. A spokesman for the experiment appears before the committee to undergo a friendly, but intense grilling. The committee must satisfy itself that there are no insuperable difficulties with the experiment and that it will fit in with other experiments in beam time, location in an experimental area, and the committee's judgment of its place in the Laboratory's priorities. Their goal is to enable the Laboratory to make the best possible contributions to he advancement of knowledge.

The Physics Advisory Committee makes a recommendation to the Director. The Laboratory schedules approved experiments for places in an experimental area and work begins to build the equipment.

There are some experiments, such as those using the 15-foot bubble chamber as the detector, where the equipment is already complete. There are others, such as those using one of the large spectrometer facilities where the new equipment needed is minimal, but most experiments require considerable building of equipment, which takes time and people.

Almost all experiments involve astonishing amounts of electronic equipment. Rack after rack will be filled with electronic boxes of all sorts, to turn the equipment on and off within tiny fractions of microseconds, to sort out the signals from any parts of the detector, and to add them up and store them. Painstaking weeks or months are needed to hook up all the forest of cables to and from these boxes and to check it all out. Trailers and portable shacks are brought in to house the electronic equipment and they become almost a home to the experimenters. In the last stages of the checkout, the accelerator provides test beams to be sure that the experiment is really detecting the right particles.

Finally the experiment is ready. Beam is provided by the accelerator and there is considerable consultation by telephone between the control room and the experiment to get the beam intensity right and the beam exactly on the target. At any moment, the accelerator operators need to satisfy 15 or more experiments, almost always with conflicting desires for beam.

Time is too precious to turn off the accelerator at 5 o'clock and take the night off. If that were done, all the time would be spent retuning, so the accelerator and experiments run around the clock. Someone has to be at each experiment whenever it is running, to monitor progress and to repair equipment that breaks down.

Who does all the work? The scientists who participate in the planning, building, checking out, running, and analysis of the data are from many different institutions and at many different career stages. Some are faculty members with teaching responsibilities at their universities. On days when their classes don't meet and on weekends, they fly to Fermilab to work on their experiments.

They are also teaching at Fermilab, because others in the group of experimenters are graduate students in science at universities. When these students have completed the classroom requirements for their degrees, they move to Fermilab and participate in the experiment, learning the arcane lore of experimental research and working toward completion of their thesis requirements. They live in housing on the site.

After they write their theses and earn the Ph.D., some young researchers stay on at the Laboratory as post-doctoral research associates, beginning to shape their careers in physics. As time goes on, they move to university departments or join the Fermilab staff.

The demanding pace eases off somewhat when data-taking is done. Continual checks on the data have been made during the course of running, using the Fermilab computer facility. Many experiments require many hours of time on large computers to put the data into a form in which it can be interpreted. Usually, computers at universities are used for this work. This data analysis takes months after the running is completed.

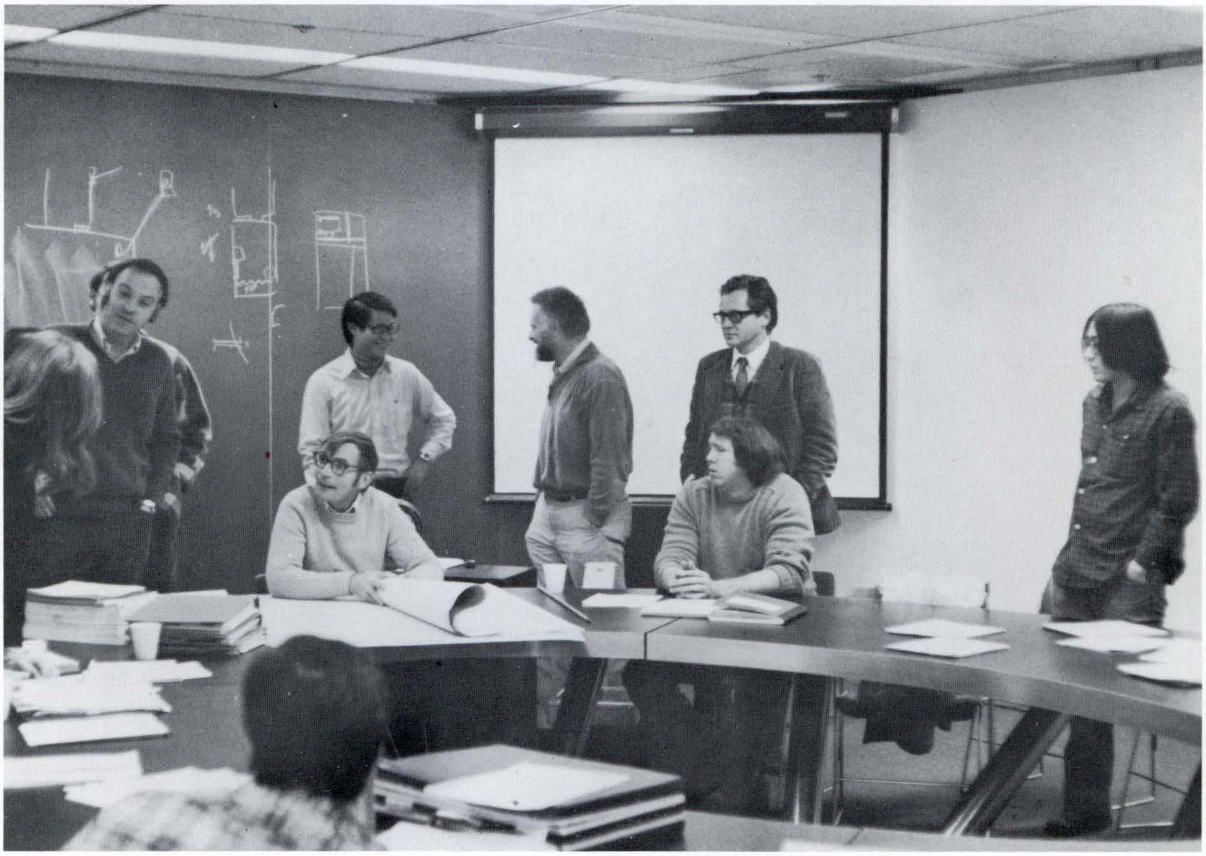
Finally the experiment is done. Hints of the results have been given at the informal biweekly experimenters meeting, but now a full seminar is given and the results are written for publication in a scientific journal. Frequently a short version for quick publication and a longer version with more details are both prepared.

Except for results so important that a laboratory director or university department head is willing to ask for special treatment, the paper is sent out for review by referees, other scientists in the field who must agree that it is useful, valid work presented in a comprehensible form. The process of refereeing, setting in type, proofreading, and printing can take several months.

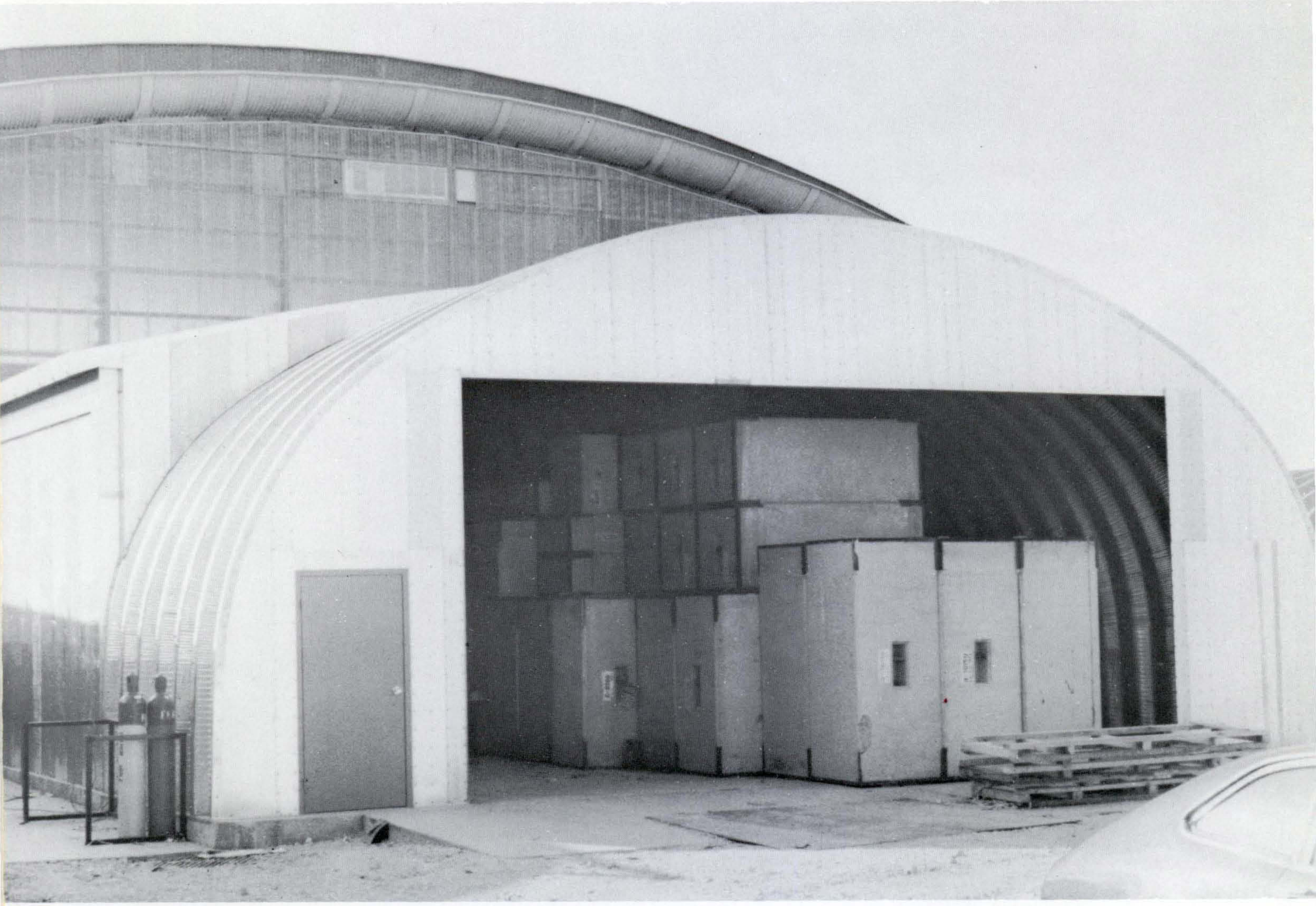
The whole process of publishing results, of subjecting them to criticism in seminars, by referees and by the readers of scientific journals, is the life blood of science. A scientific result is only true if it can be verified by other experiments. The testing, the scrutiny, the criticism all help to sharpen the results and make them better.

E-613 was the first neutrino experiment to be done in the Meson Laboratory. In this experiment a Firenze (Italy), Michigan, Ohio State, Washington, and Wisconsin group is studying interactions that produce prompt neutrinos. The experiment has sufficient sensitivity to seek previously undetected sources. The magnetized beam dump 160 feet upstream of the neutrino detector consists of two dump magnets, the old 275 ton "hyperon" magnet, rotated 90° so muon deflections are in the vertical plane, and two spoiler magnets. The detector located in a new building is a 200-ton electron calorimeter followed by a large toroidal-magnet muon spectrometer using drift chambers. All of the equipment for this large experiment was designed, built, assembled, and installed in only a few months and by June the experiment was running with about half the detector active and taking preliminary data. Beam intensities in excess of 10^{12} protons per pulse were targeted safely in the Meson Detector Building. During the summer the few missing items in the apparatus were completed, modifications made to reduce the muon background at the neutrino detector, and data taking resumed in the fall.

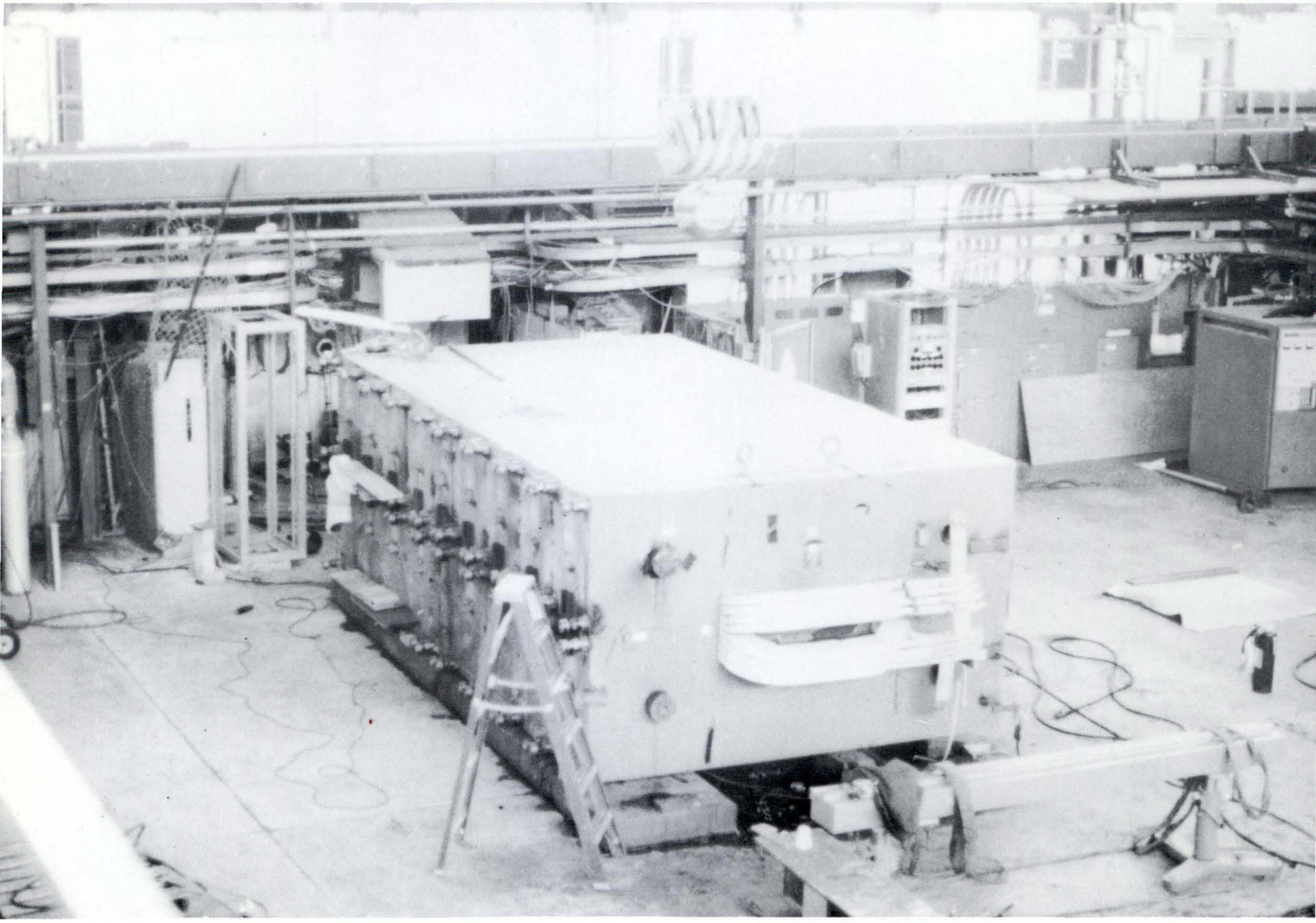
The photographs presented here show the steps and complexities involved in setting up and running a Fermilab experiment, from the initial planning stages to final data taking. The photographs, except where noted, were taken by Lawrence Jones from the University of Michigan, spokesperson for the experiment, and Jan Hoftun, one of the collaborators from Ohio State University. This experiment is featured because photographs were readily available for all stages.



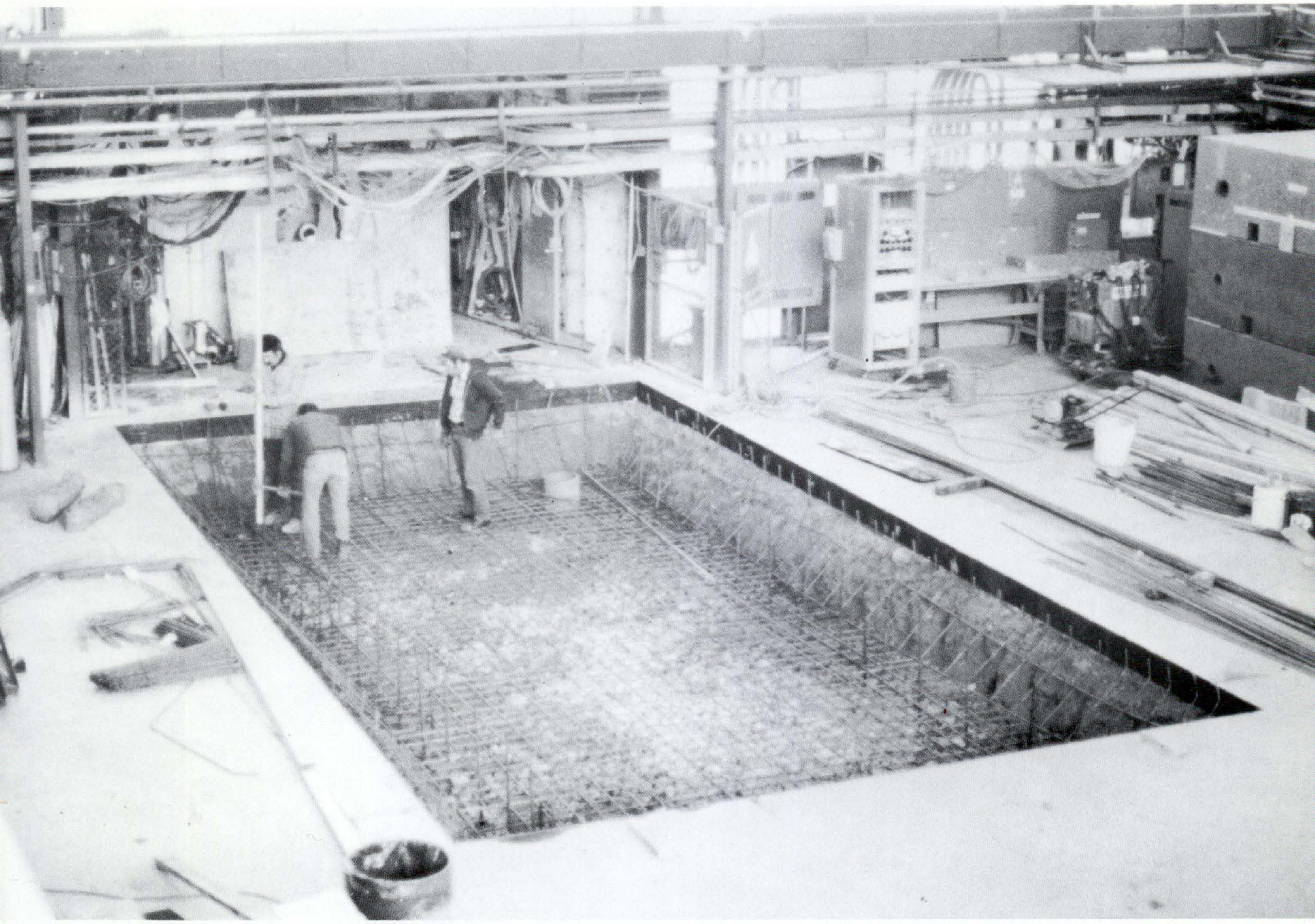
In the fall of 1979, much effort was put forth on the design of the dump system (targets, magnets, etc.) and the experimental configuration. Pictured discussing the design are (seated, left to right) Dave Eartly and Sam Childress; standing (left to right) are Don Reeder, T. Y. Ling, Tom Romanowski, Gianni Conforto, and Ed Wang.



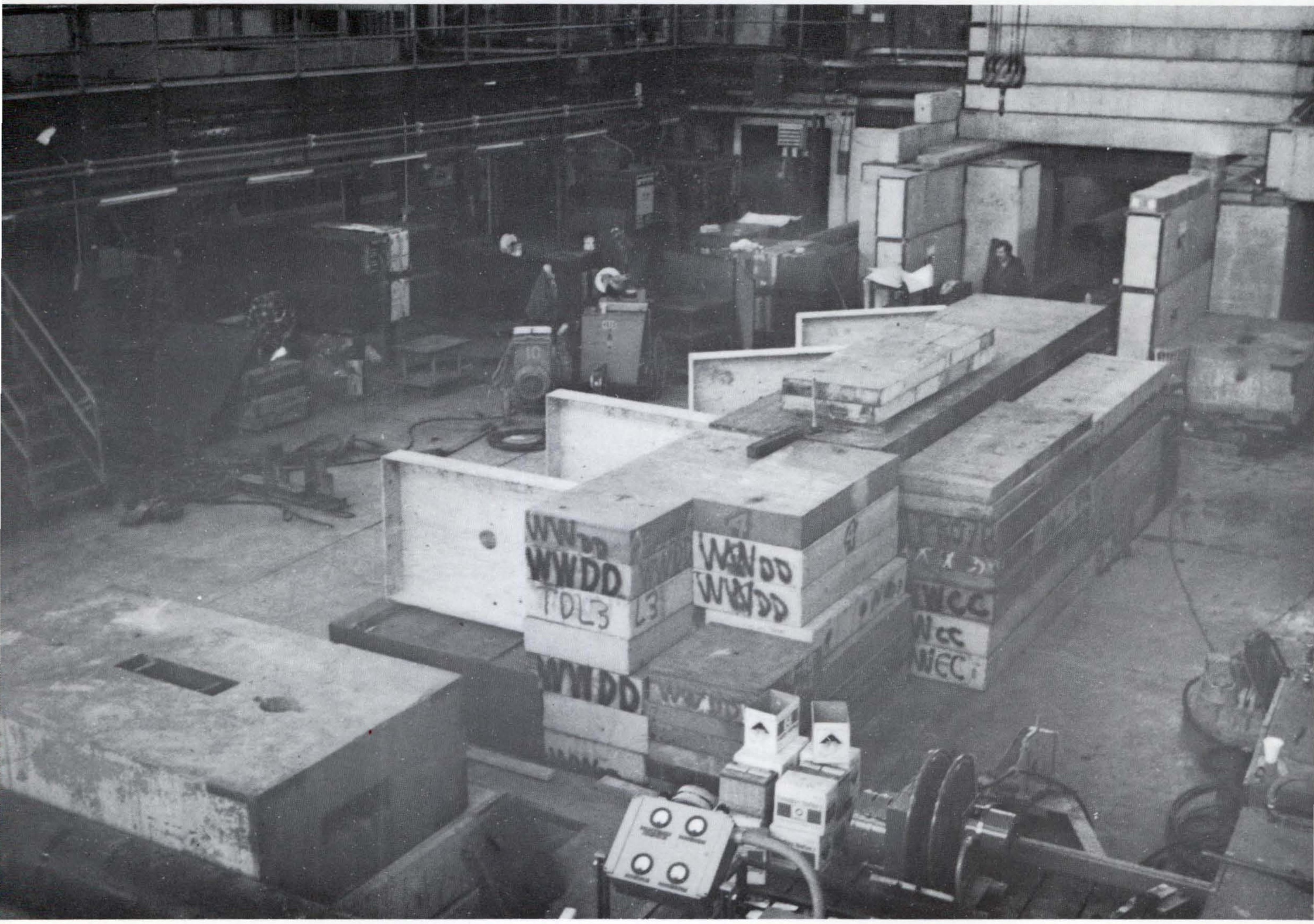
1 - The initial phase of the installation began with the construction of the calorimeter-spectrometer building.



2 - The 275-ton hyperon magnet (hoizontal position) was disassembled and modified for vertical assembly. This magnet has been used in a series of Wisconsin, Michigan, Rutgers experiments and will probably be used again in the future.

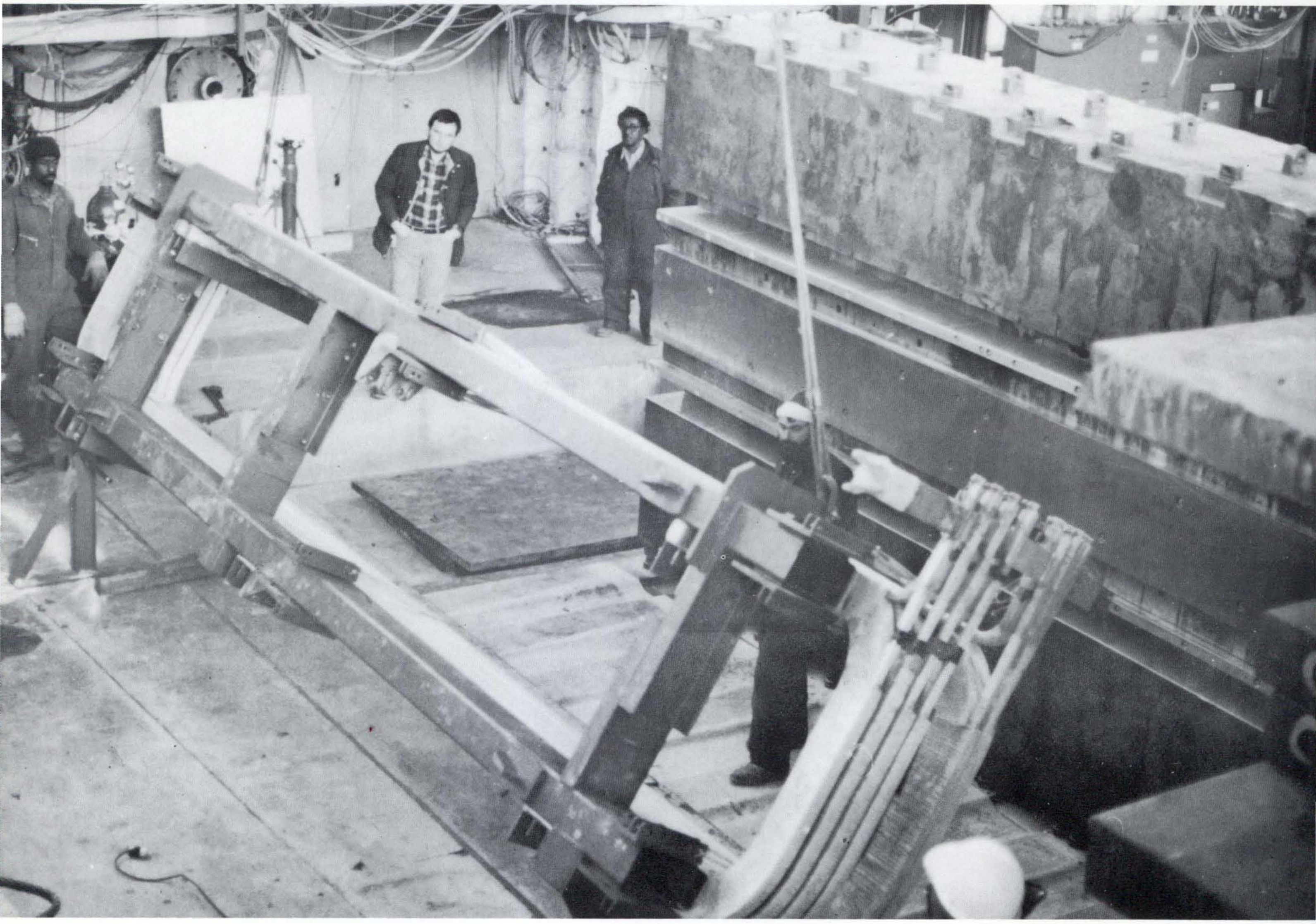


3 - A pit to hold the hyperon magnet in its vertical position was dug and poured in concrete.

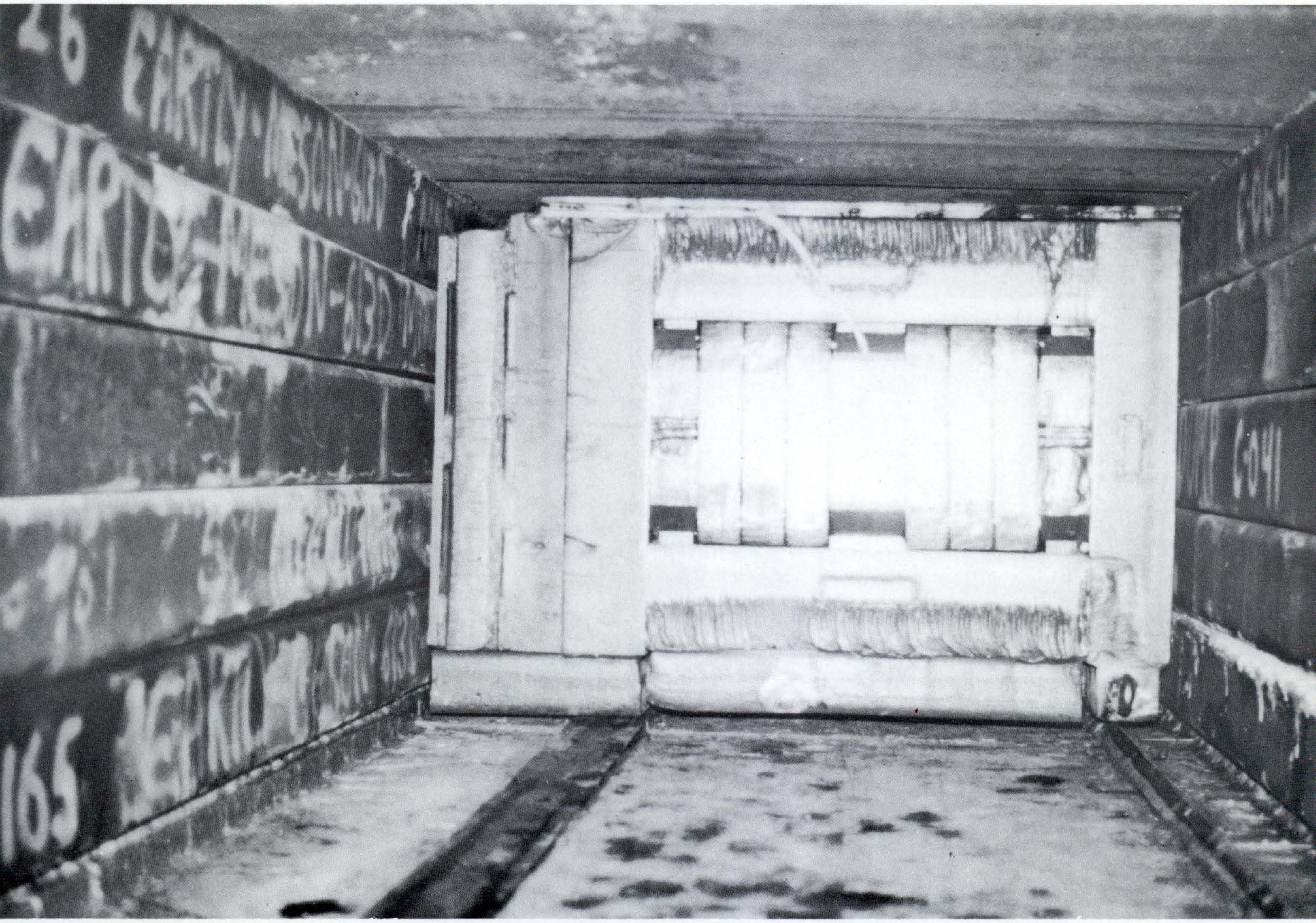


4 - During the pit construction, the primary beam dump magnets and spoiler magnets were assembled, with the pit complete the assembly of the beam dump shield began.

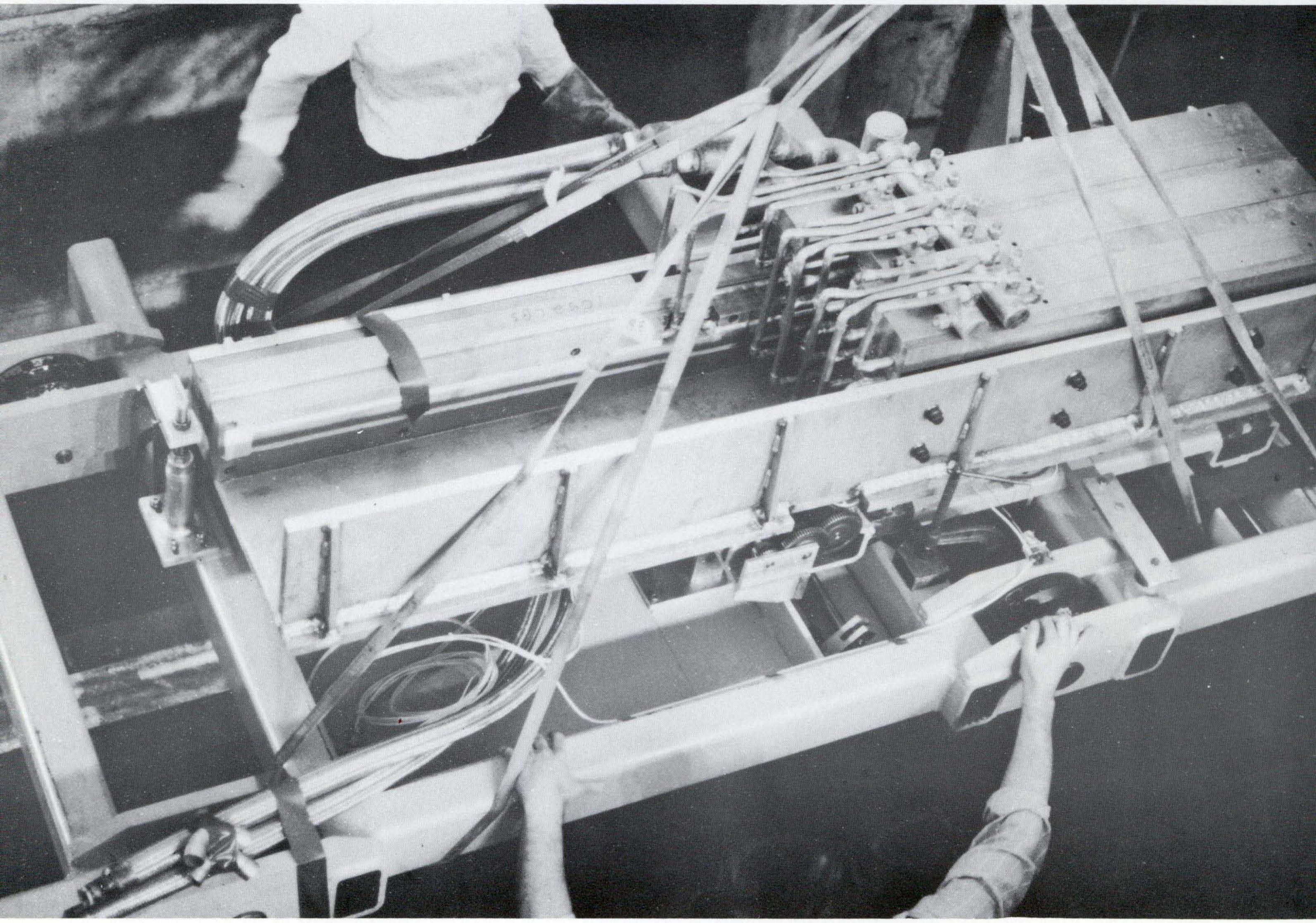
5 - The 1000-ton iron core for the beam dump was completed.



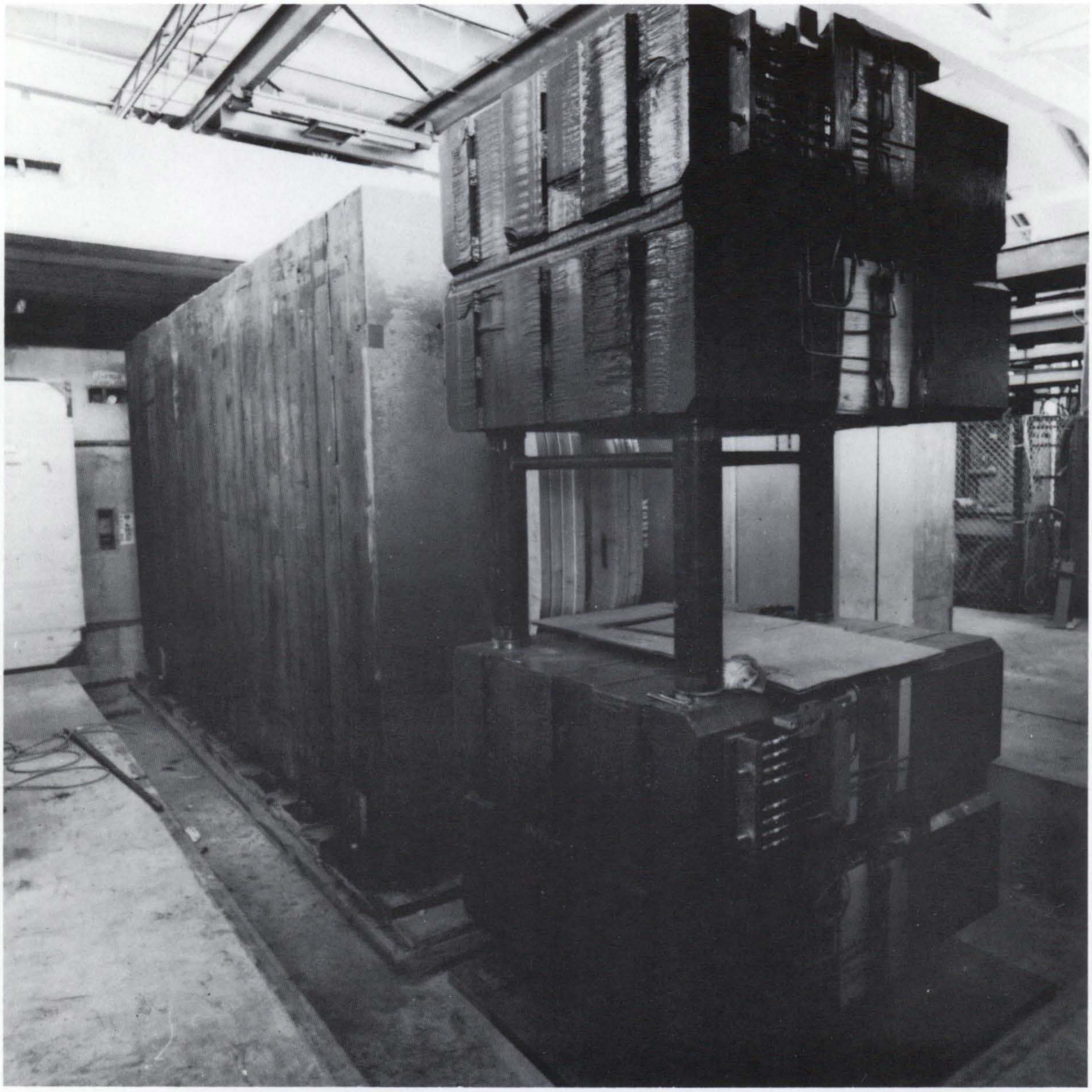
6 - During the completion of the dump pile, the reassembly of the hyperon magnet in the vertical position proceeded. Special fixtures for lifting the fragile aluminum coil assembly were developed. Installation of the coils in the vertical position is shown. Stan Sobczynski (center) and John Williams (right) of the Meson Department are observing the installation.



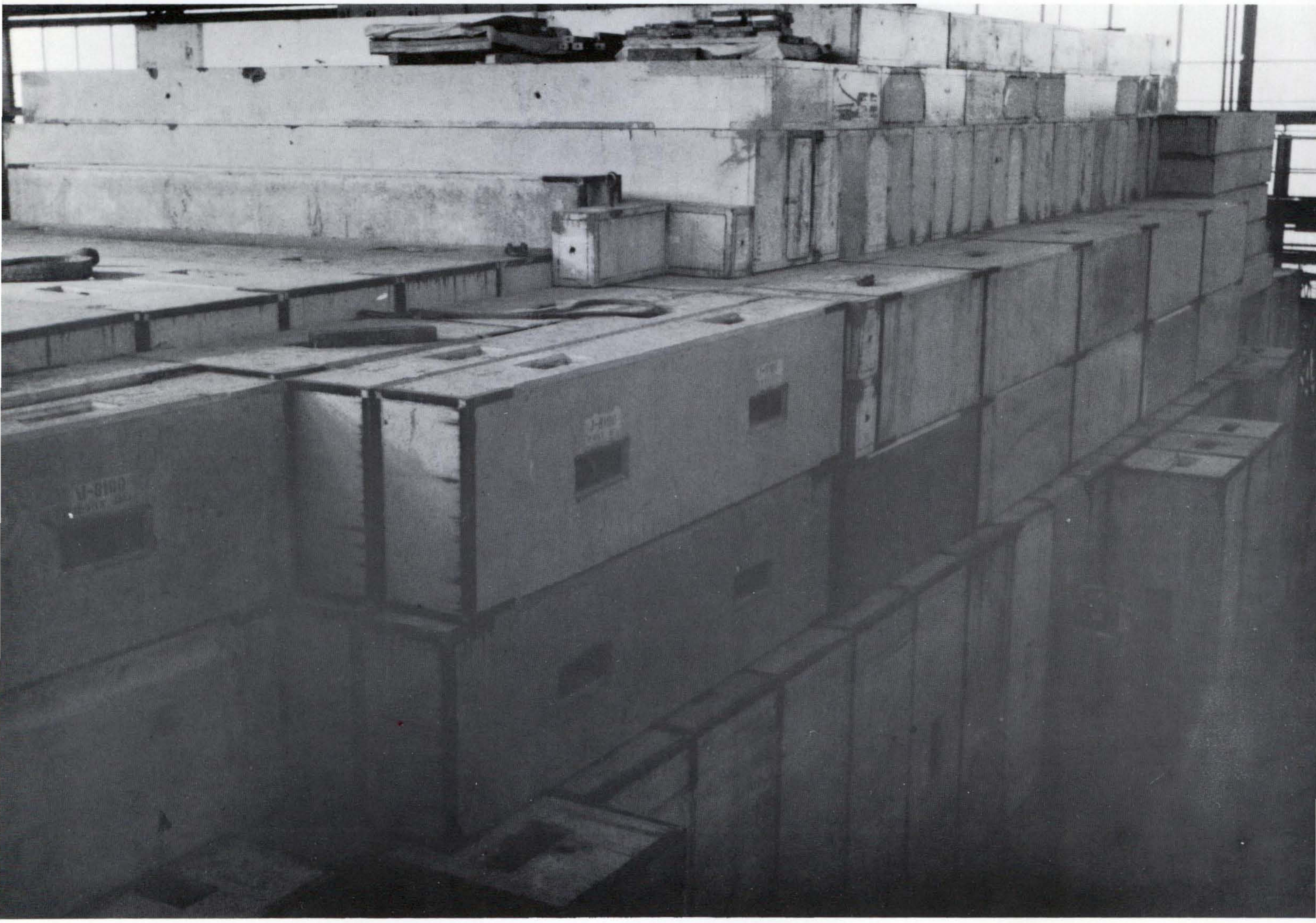
7 - The primary toroid dump magnets which are housed (behind the targets) in a cave inside the beam dump pile. A rail system allows their removal.



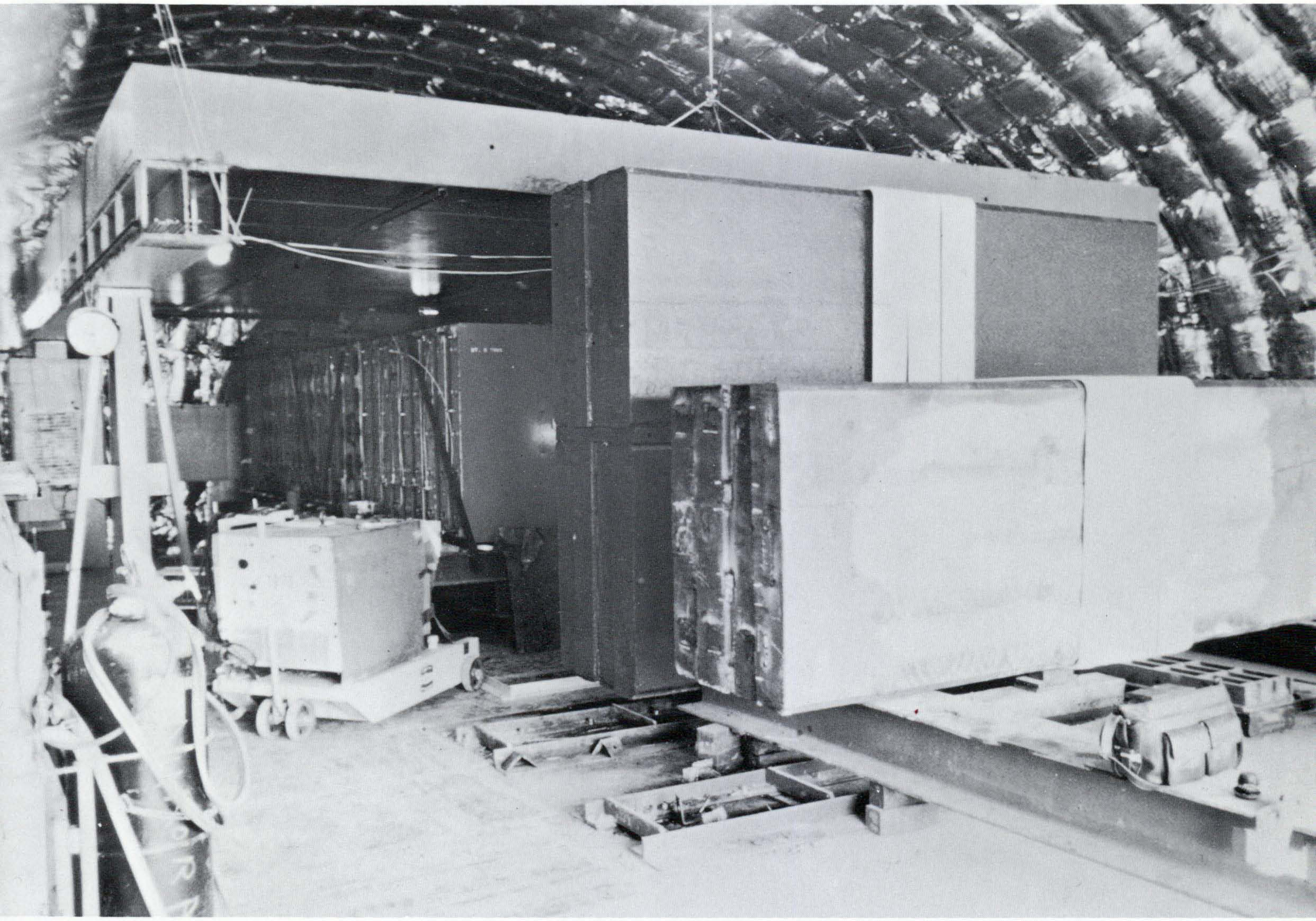
8 - The water-cooled target manipulator with multiple element and density targets. It is also housed in the beam dump cave on rails.



9 - The assembled vertical hyperon and spoiler magnets behind the beam dump. (Photograph by Fermilab Photo Unit)



10 - Installation of the concrete shielding over the beam tunnel, beam dump, hyperon, and spoiler magnets.

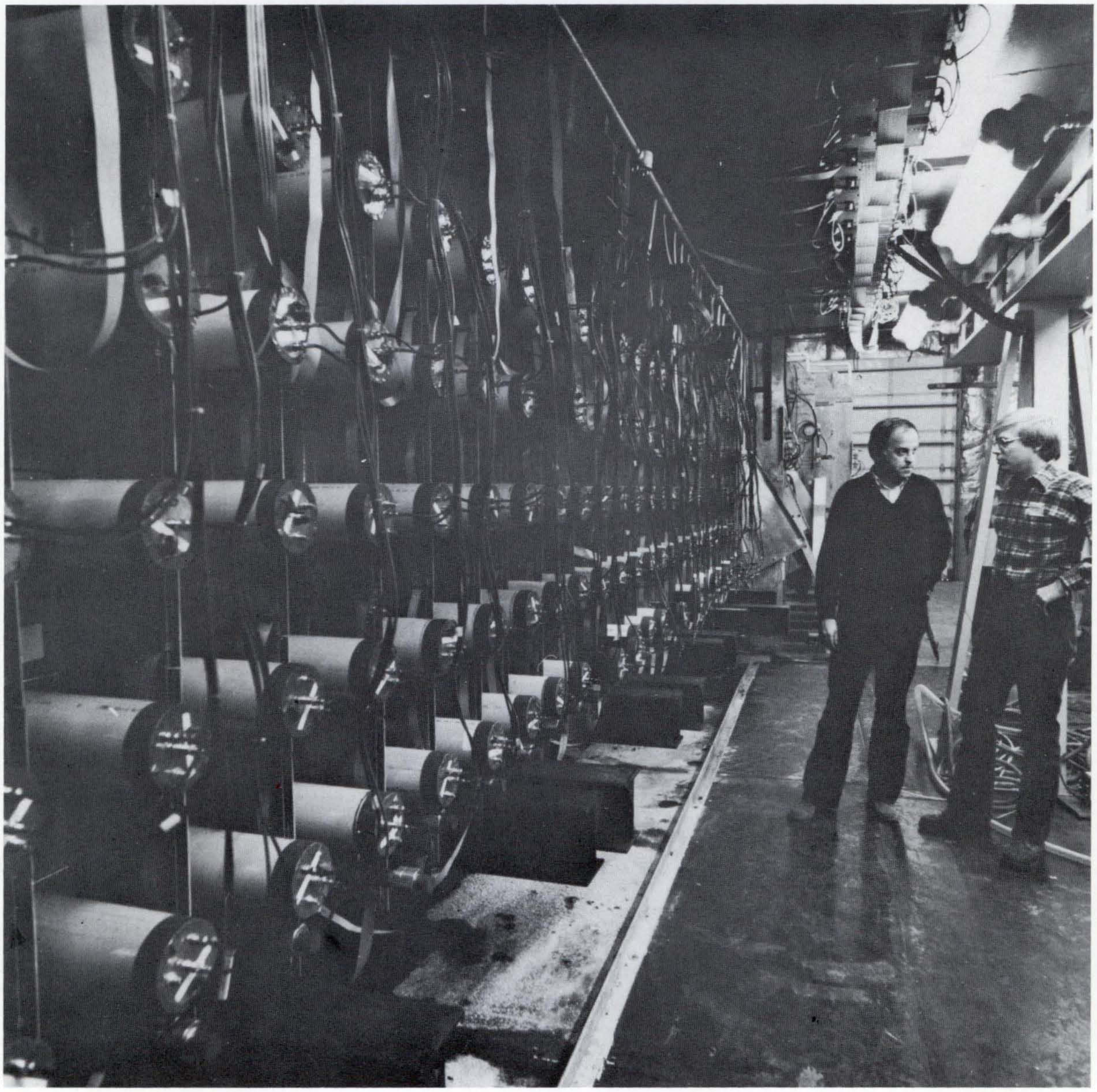


11 - Installation of the calorimeter modules, cosmic-ray shield, and the construction of the toroid analyzing magnets for the muon spectrometer.

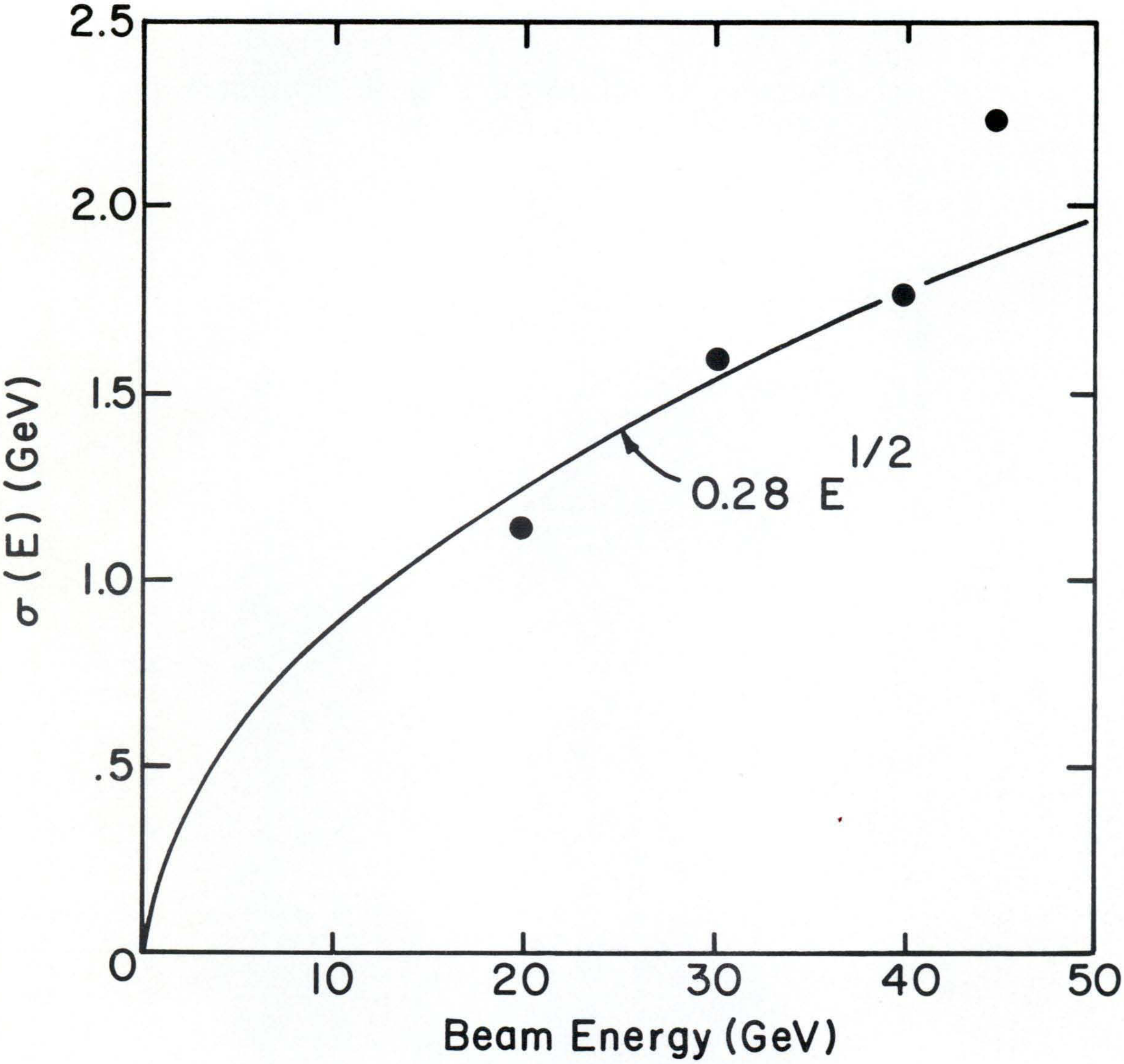
12 - The partially-completed instrumented liquid scintillator-lead plate calorimeter with analog proportional chambers. Summer student Debbie Mills is stringing cable.

13 - The drift chambers in the muon spectrometer come in modules and are being installed by a group from Ohio State University, on the bottom T. A. Romanowski (left), T. Y. Ling and S. Volk a little higher, and M. Crisler. ⟶

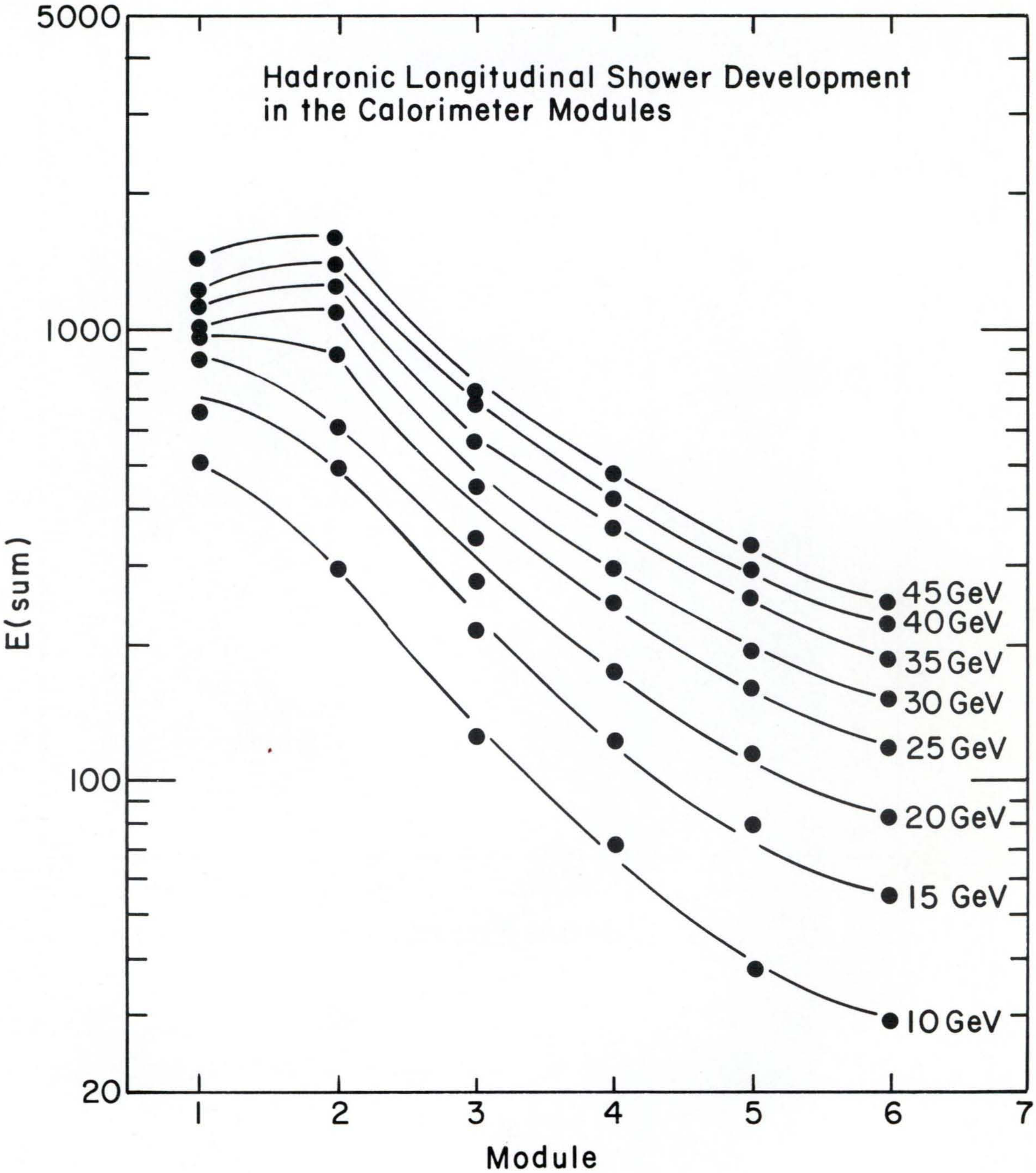

OSU
HIGH ENERGY
PHYSICS
32



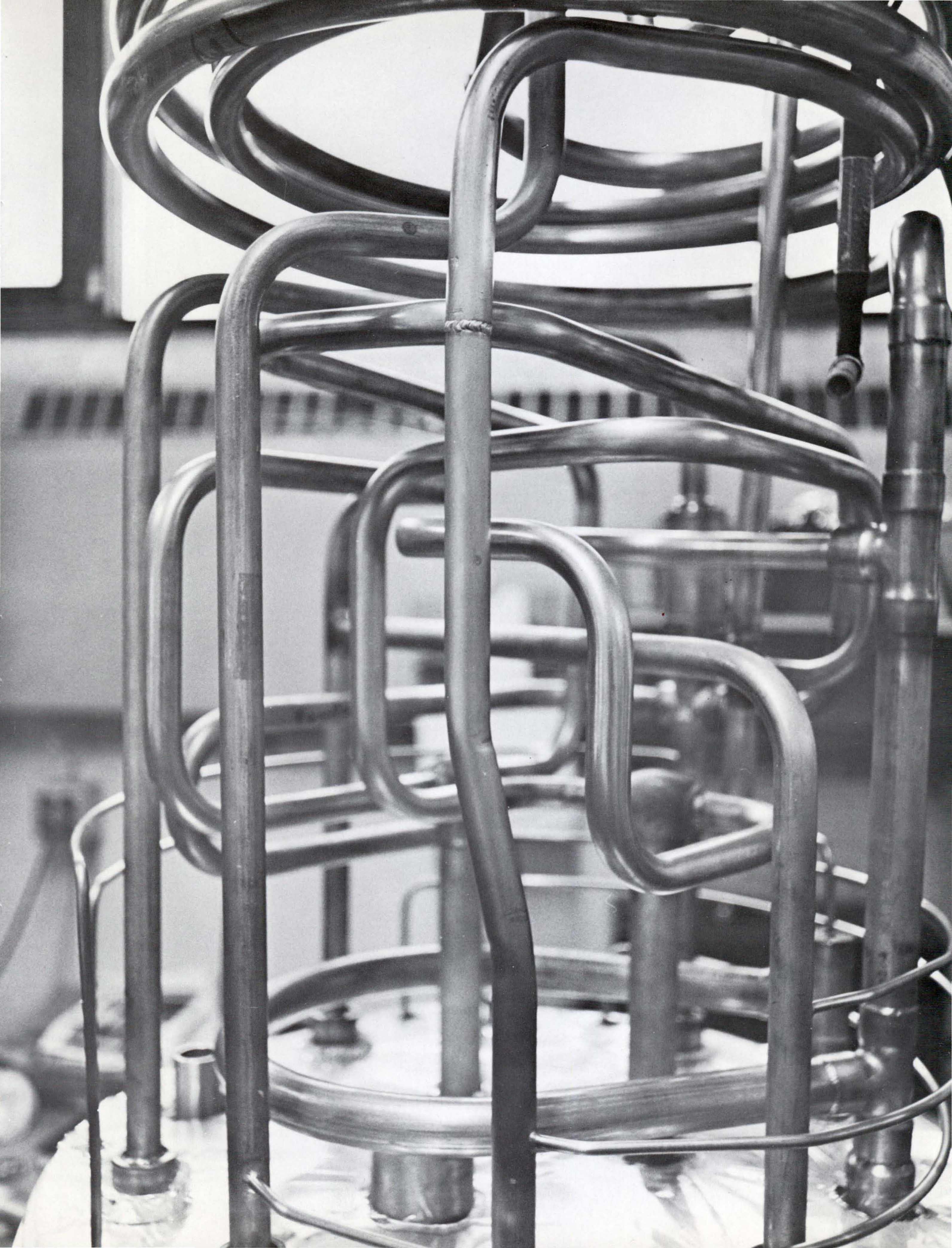
14 - The nearly complete detector consisting of the calorimeter plus drift chamber - toroid magnet muon spectrometer. Don Reeder (left) and Mark Duffy, both from the University of Wisconsin, discuss future plans.

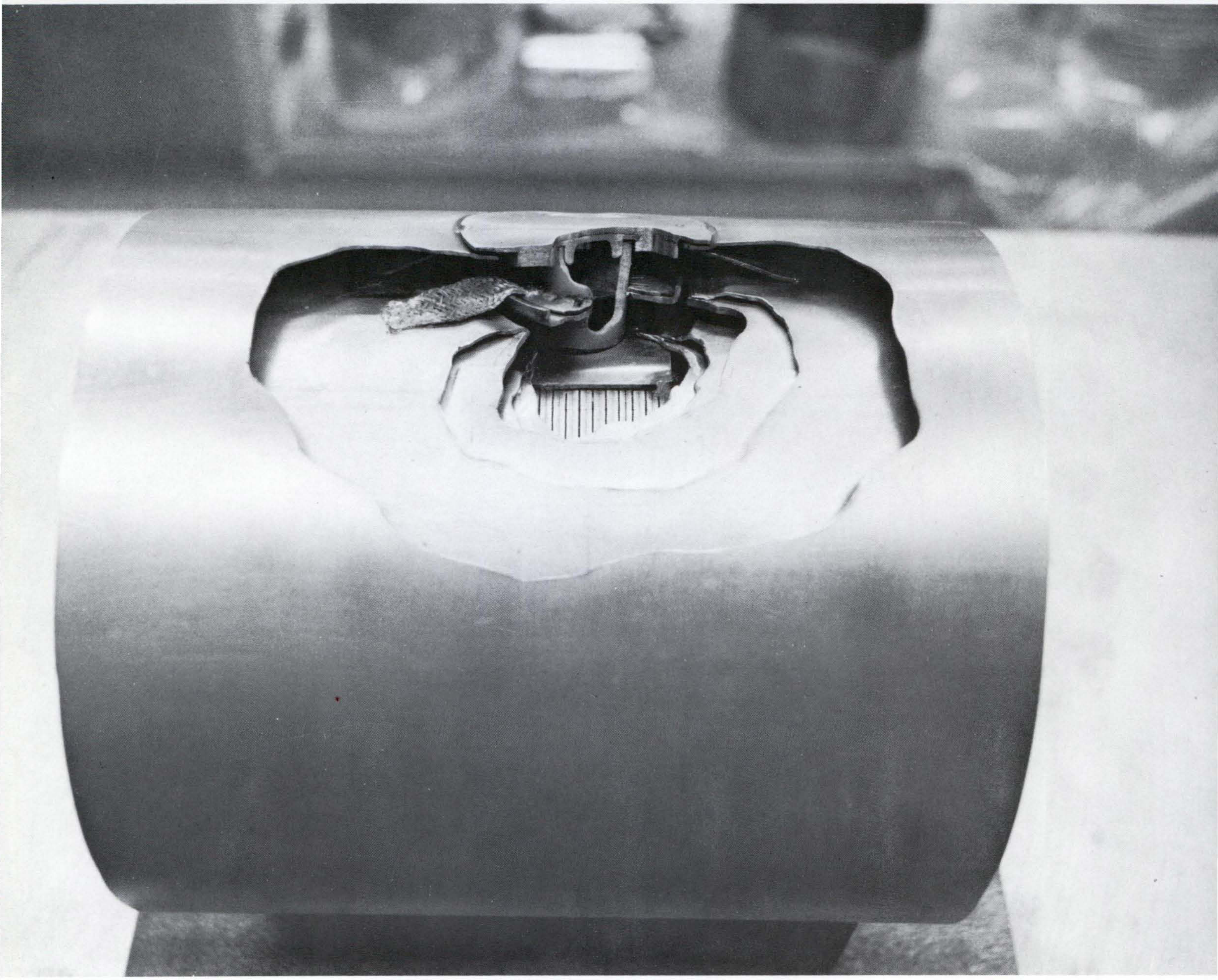


15 - Electron energy resolution as measured in the lead plate-liquid scintillator calorimeter module; rms uncertainty (width) vs. energy.



16 - Hadronic longitudinal shower development in the calorimeter modules; visible energy vs. longitudinal depth in the calorimeter.





Cutaway view of the cryostat showing the revised anchor.

Energy Saver Division

1980 has been a year of solid accomplishment for the superconducting accelerator. We have been hard at work on the Energy Saver, the first part of the Tevatron project. The dipole-magnet difficulties discovered in 1979 were cured by a new suspension system and the cure was proven in 1980. Following this, dipole production began in earnest in the fall. Quadrupole-magnet production also began. The Central Helium Liquefier was commissioned and came into full operation in 1980. Significant milestones were also reached in construction and operation of satellite refrigerators and in tests of magnet installation, cooldown, and operation both in the tunnel and in the B12 test facility.

Magnets

The problem of the motion of the vertical plane during cooldown was a difficult one to solve. The solution finally arrived at uses four opposed anchors at the center of the cryostat and a series of "smart" bolts containing spring-loaded pistons to maintain the cryostat preload at a constant pressure (see the section on technical innovations elsewhere in this report).

Exhaustive tests were carried out at the Magnet Test Facility on a number of magnets to prove out this design. Individual magnets have been thermally cycled between room temperature and operating temperature more than 60 times, with a total measured vertical-plane excursion of less than 0.5 milliradians, within specifications.

Production of collared coils had continued through the period of redesign, so that we are now well up to schedule in coil production. In addition, a great effort was made to salvage components and assemblies from old-style cryostats. It has been possible to swing into production of dipoles relatively quickly. We are now in process of raising the production rate from five to ten per week.

In parallel with the dipole redesign, work to bring the quadrupole to a state of readiness for production was going on. This design and testing has now progressed to a point where quadrupole production has also begun. The correction-magnet package is closely related to the quadrupole because of its proximity. Most of the correction magnet types have now been taken out of the quadrupole bore and designed into the "spool piece" next to the quadrupole. Correction magnets are now being wound in quantity.

We have learned over the years that the most careful attention to quality control is needed in building good superconducting magnets. In 1980, we improved our quality-control system and applied it to every magnet.

Full-scale production necessitates an increase in our magnet-measuring capabilities and we have expanded our facility to meet the need. The facility has matured and become very reliable in the last year.

Refrigeration

The Central Helium Liquefier came into operation on March 28. It has subsequently reached a rate of 3,000 liters of liquid helium per hour, doubling the world's capacity. Operation has proved in practice to be smooth and trouble-free.

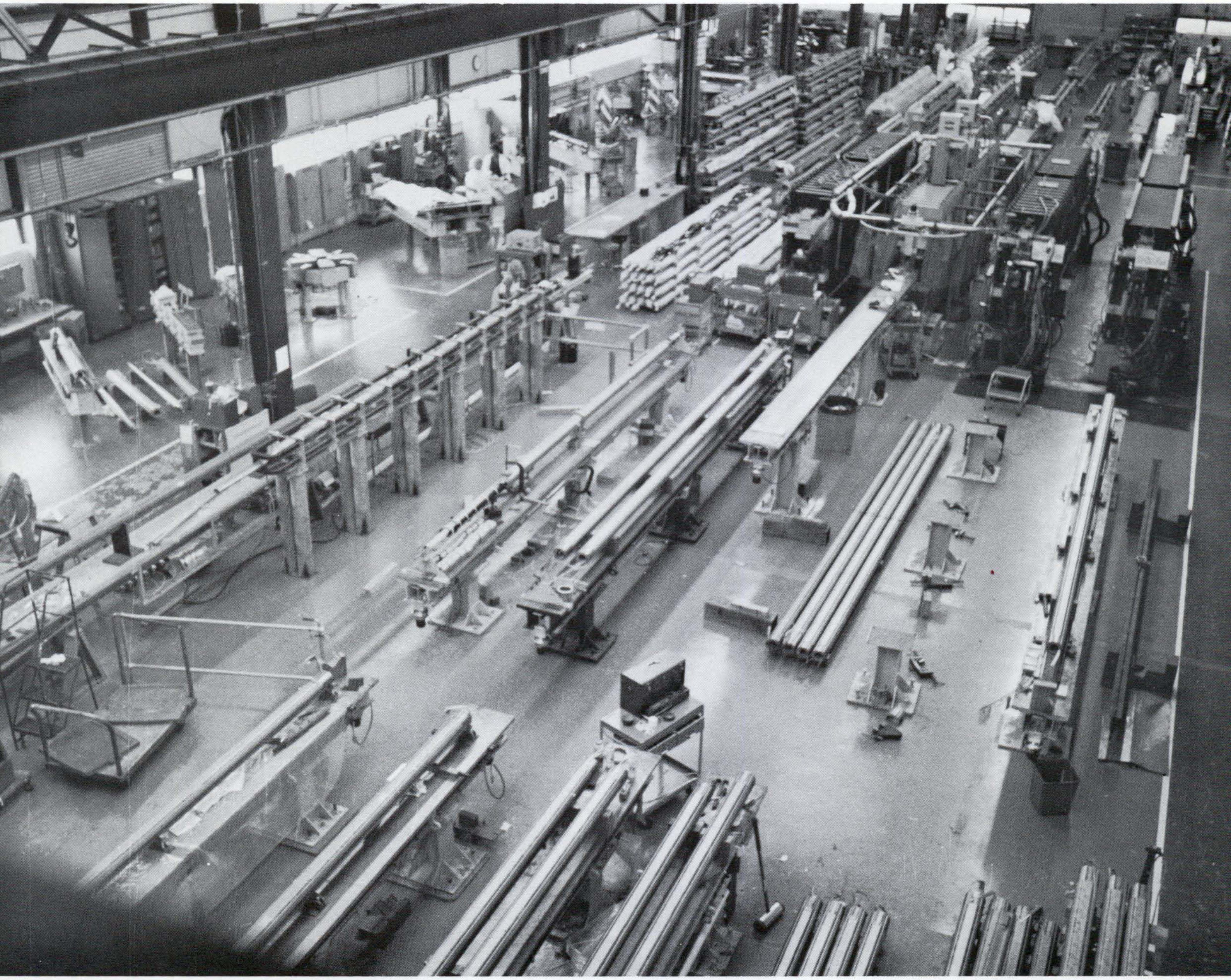
The first production satellite-refrigeration systems have been installed at A3 and A4 and have been undergoing system shakedown tests. Compressor installations have been commissioned in almost half the ring. Helium-transfer lines are moving along in construction. The A2 refrigerator has been operated for long periods in satellite mode being fed liquid helium from the A1 refrigerator.

System Tests

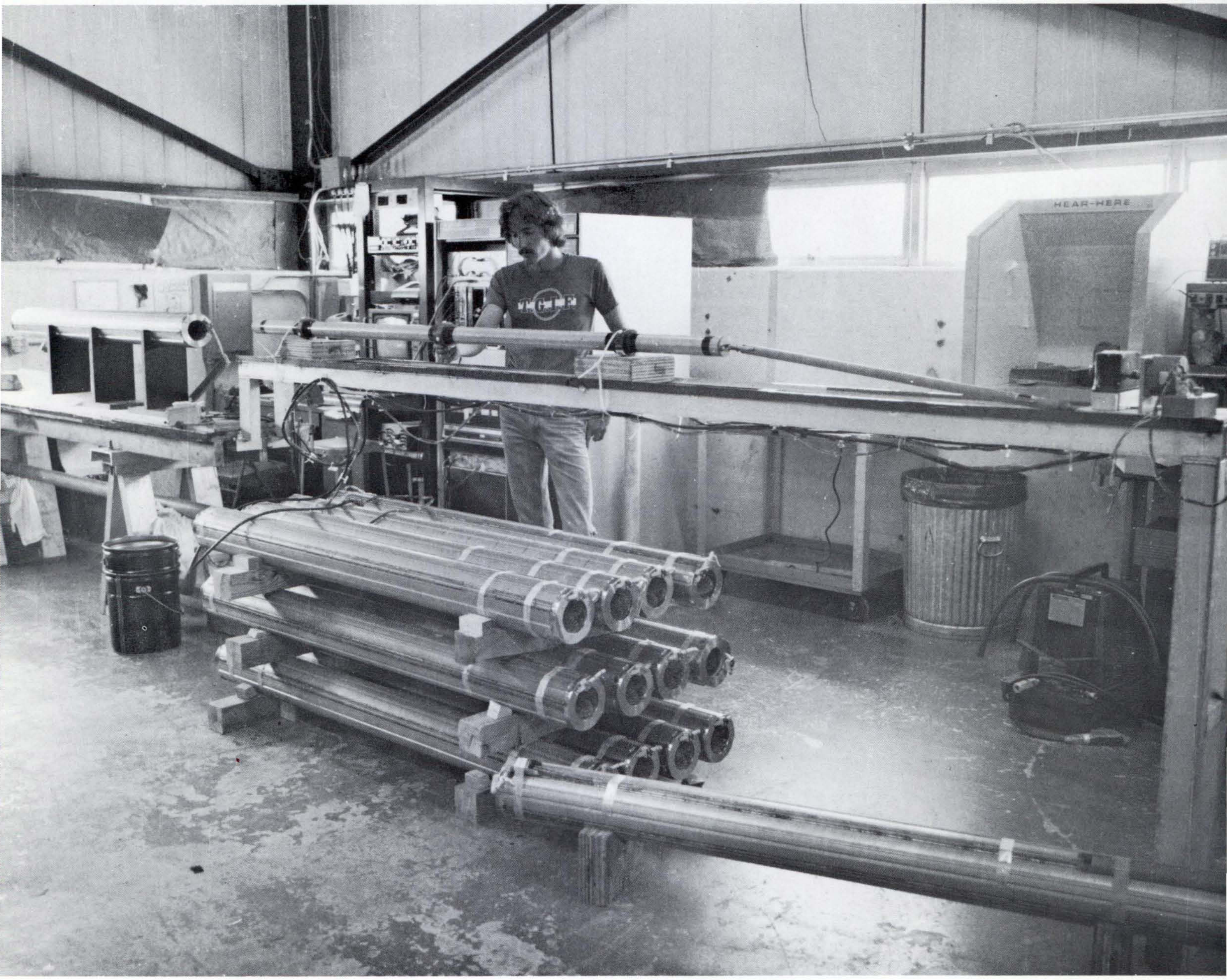
The A2 refrigerator was used to cool a cryogenic loop of 40 magnets installed in the tunnel. The system operated well above specifications and the experience gained in installation, including alignment, connection, pumpdown, hipot, and leak check, is invaluable.

The above-ground test system at B12 has been worth its weight in niobium-titanium. We have learned a great deal by having a system with easy and continuous access. A string of 20 magnets has been installed, cooled, and powered. The system can be kept for very long times in a superconducting state with little monitoring. The B12 system is used to test quench-protection systems, cryogenic-control systems, coil-bus configuration and to measure heat losses. The B12 system is now being converted to new-style magnets.

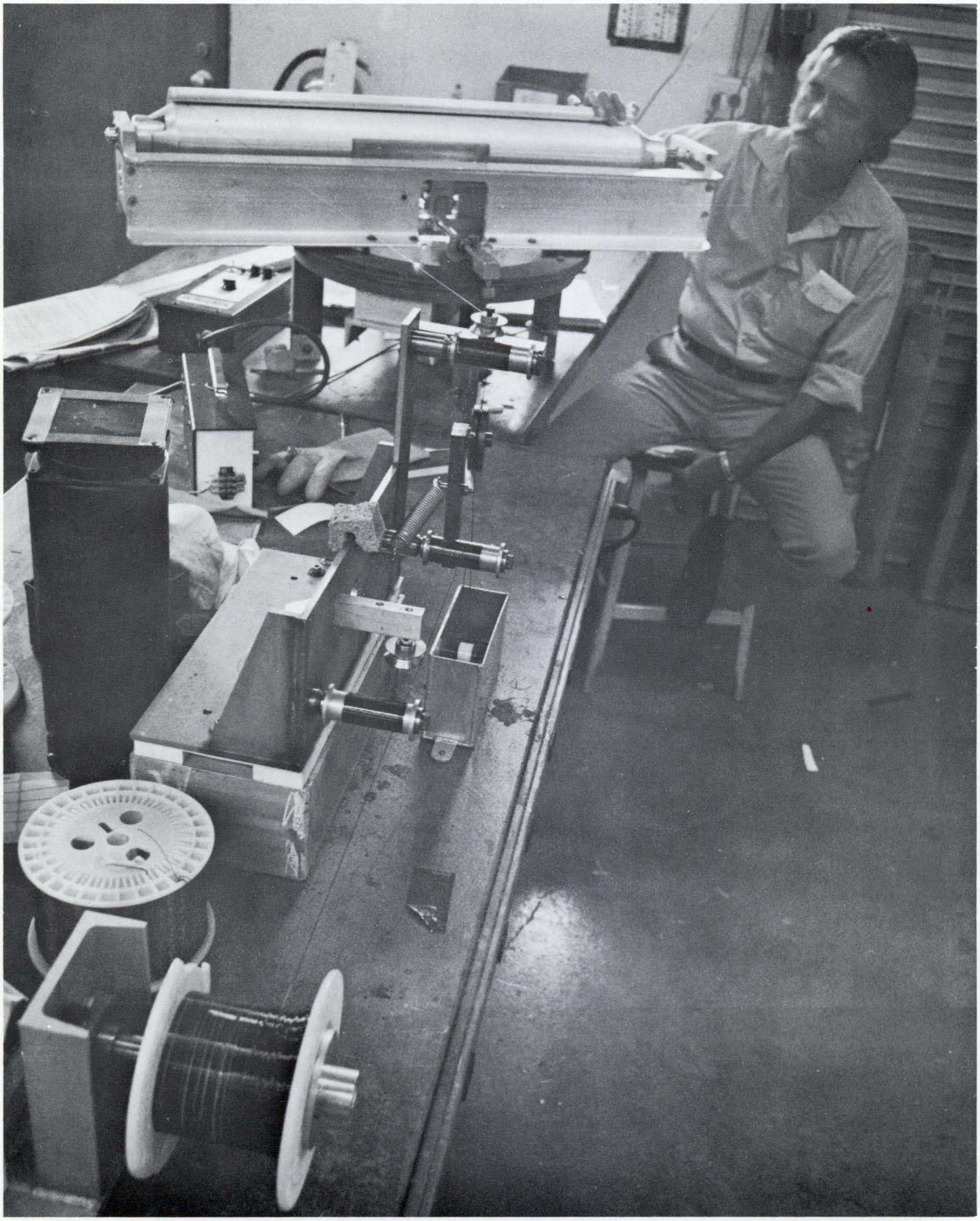
In recognition of the Energy Saver's importance to Fermilab's future, it was given divisional status in 1980. A very large fraction of the Laboratory's effort is devoted to this greap leap forward into the superconducting age.



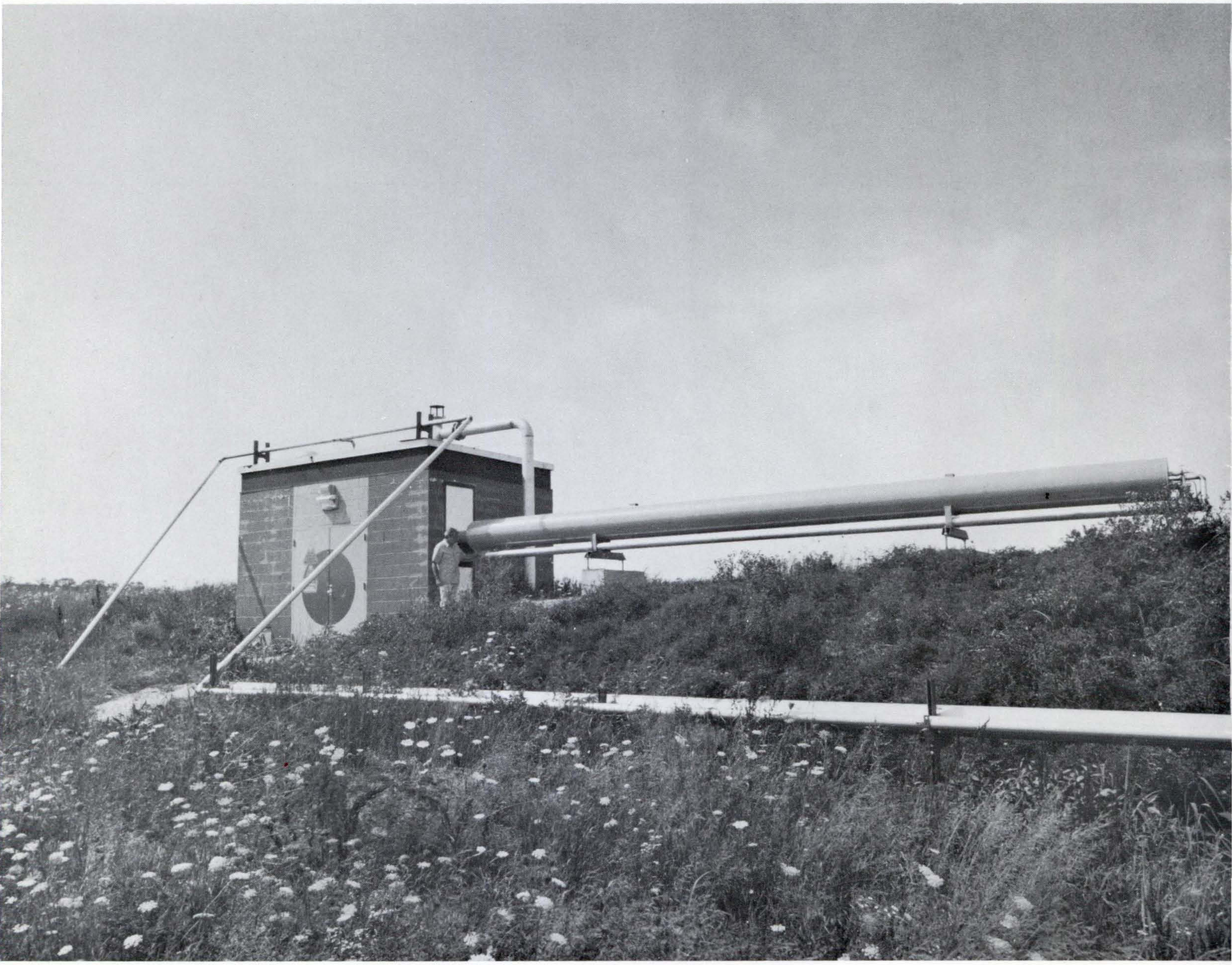
The magnet factory; many coil assemblies are stacked, awaiting cryostats.



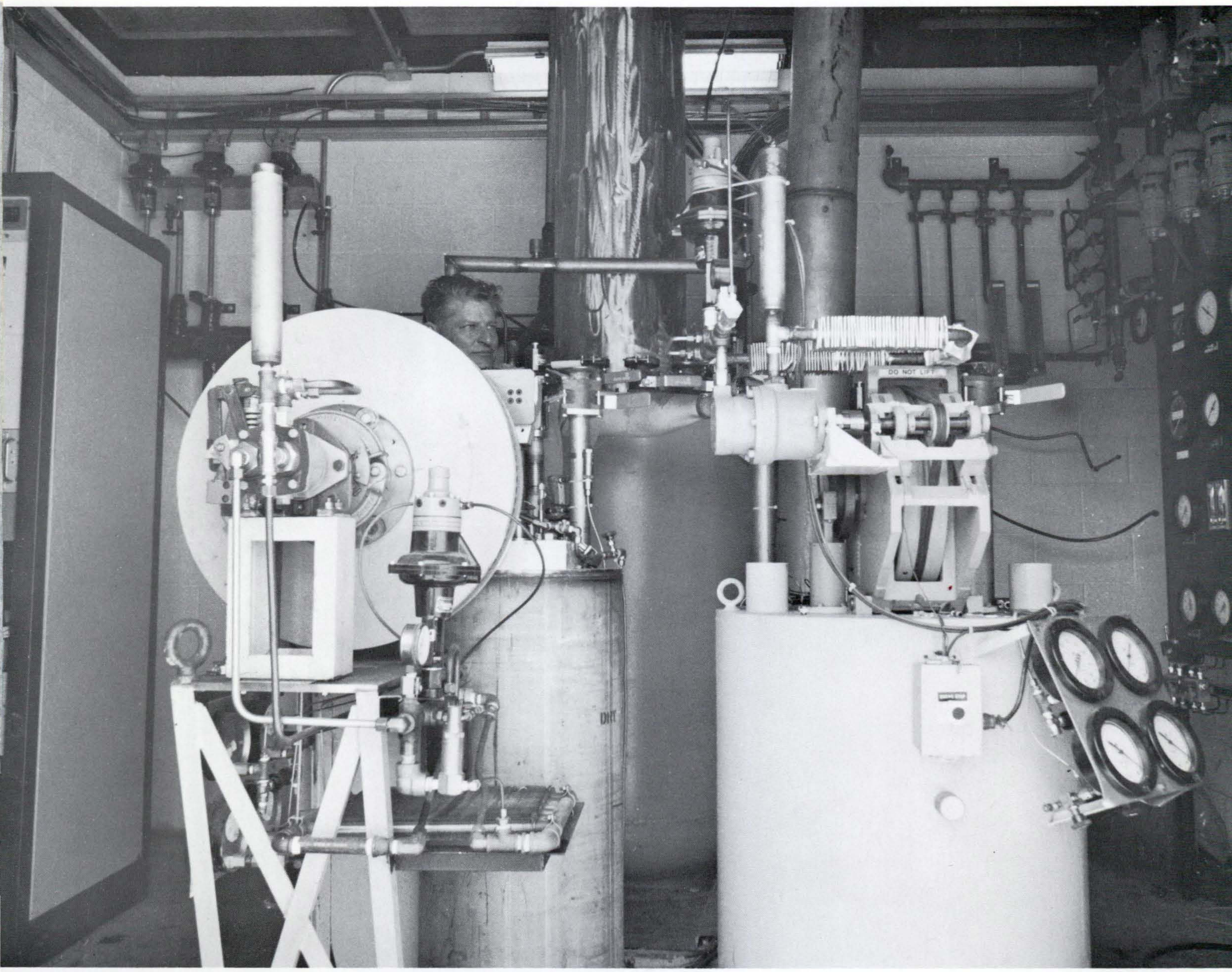
Room temperature quadrupole magnetic measurement apparatus. Completed collared coils in foreground; Ned Cummins in background is part of the quadrupole fabrications staff.



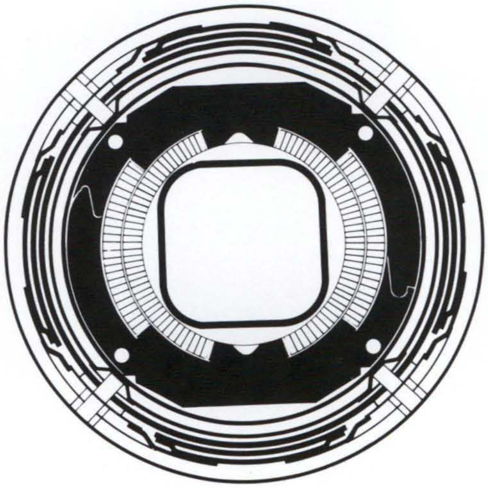
Walter Wojak winds correction coils.

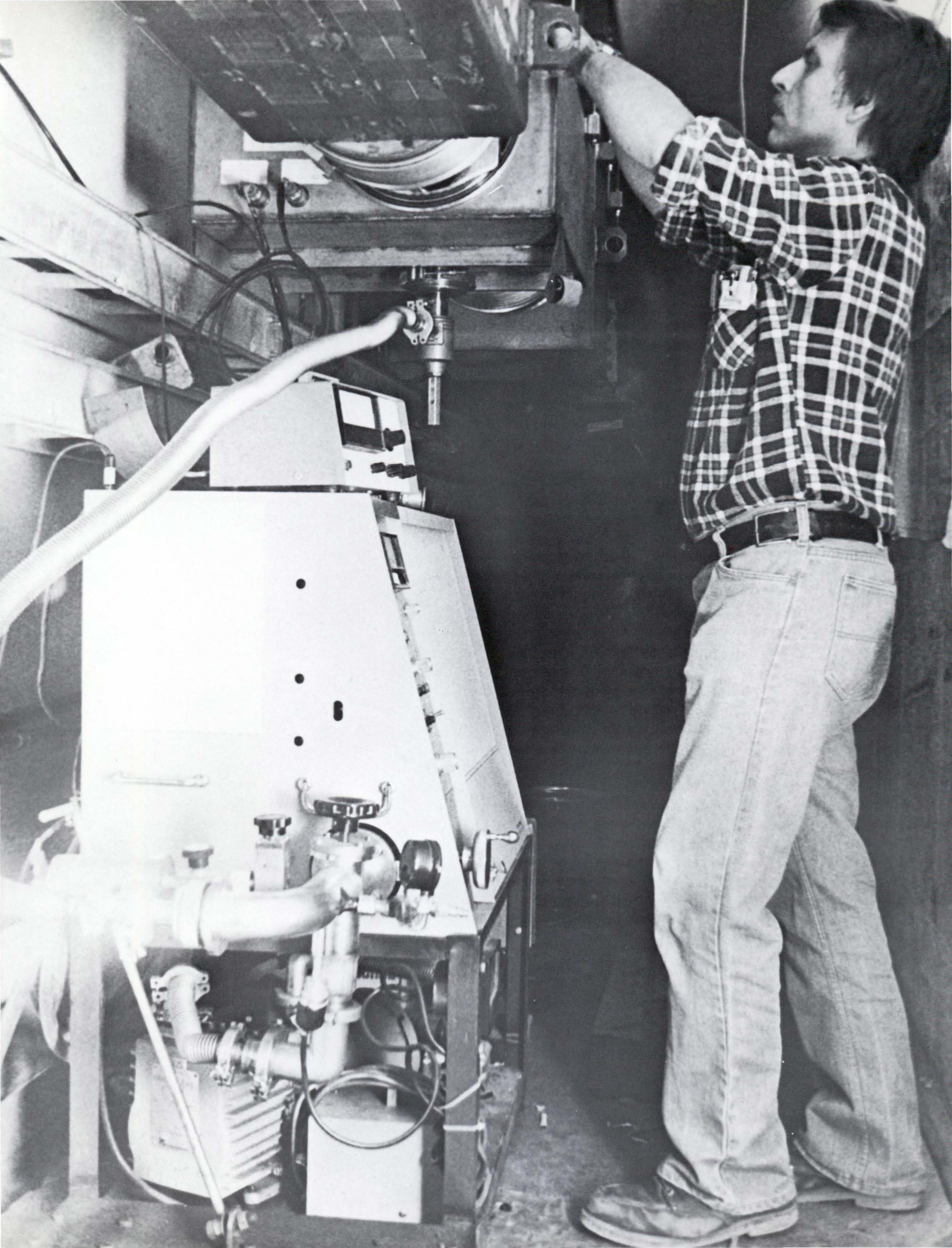


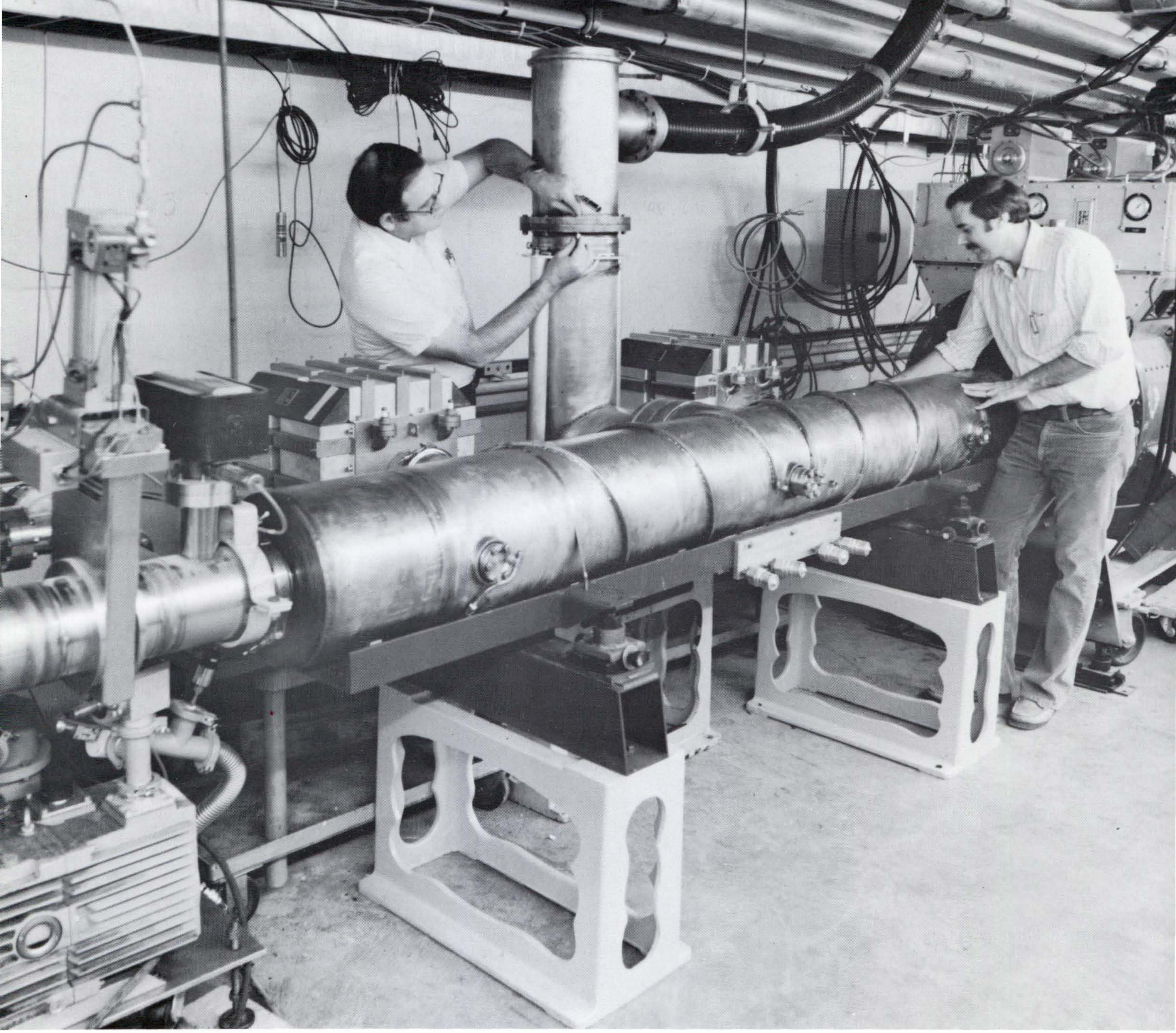
First production model of the heat exchanger installed at the A4 refrigerator building.



Satellite refrigerator installation at A2. Paul Furio can be seen in the background.







Bill Miller (left) and John Reid inspect the installation of the prototype Energy Doubler rf cavity on its test stand in the RF Building.

Mike Ziomek of the Accelerator Division's Mechanical Support group connects a superconducting magnet in the Left ← Bend.

Accelerator Division
Operations and Improvements

It has again been a busy year in the Accelerator Division, with a number of significant accomplishments. The major activities can be divided into accelerator operation, maintenance and development during shutdown periods, and activities and projects in the Accelerator Division. The Colliding-Beams project, part of the Accelerator Division, is reported separately.

The accelerator operated at both 400 and 350 GeV during the year. The year began with a smooth start-up, with running periods during January at 400 GeV and from March through June at 350 GeV. During the second running period, all the beam was delivered to the experimental areas in the slow-spill mode, which made splitting of the beam difficult and consequently limited intensity to less than 2×10^{13} ppp. Despite this limitation, new accelerator records were set during this period in high-energy physics efficiencies, number of hours of operation realized per week, and the number of protons per pulse in the slow spill. During the summer and early autumn, the accelerator had an extended period of maintenance and development, with 400-GeV operation resuming in November and lasting until the end of the year. There was a 27% utilization of the accelerator for FY 80.

During the February-March shutdown, a number of projects were completed. The Linac Group accomplished a successful switchover from the first negative-ion source (see Awards Section elsewhere in this report) to the second. In addition, the Linac Group constructed a negative-ion source for the Beijing accelerator. During the shutdown this source was installed in the H^- area for testing. It will be sent to the People's Republic of China. An additional negative-ion source was constructed for Brookhaven National Laboratory. The Main Ring Group performed major work on the accelerator to prepare the Main Ring for the Energy Saver. Various pieces of equipment were rearranged and new connections for facilities for the Saver were installed. Finally, the Extraction and Switchyard Group began preparations for installations of 21 superconducting magnets in the Left Bend, the area of the Switchyard that delivers protons to the Meson Experimental Area.

The summer and early fall shutdown was a period of intense activity. The Left Bend was given the highest priority and the Extraction and Switchyard Group worked throughout the shutdown and into the fall running period in order to complete the project. The installation of these superconducting magnets is related to the overall Energy Saver program to augment the Main Ring by a superconducting synchrotron. The Extraction and Switchyard Group also completed work on Enclosure C to provide added space for additional beam lines. The Main Ring Group completed a number of projects. These include:

(i) Modifying the tunnel at C12 for the new Main Ring-Tevatron Abort System that was installed by the Energy Saver Division.

(ii) Disconnecting the Main-Ring power supplies at A2 from the Main-Ring system and turning them over to the Energy Saver project.

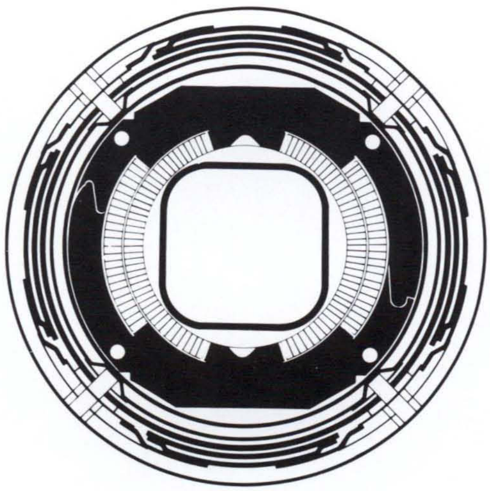
(iii) Modifying the Main-Ring tunnel from F17 to F25 to allow installation of $\bar{p}$ production-backward injection line for the Colliding-Beams project.

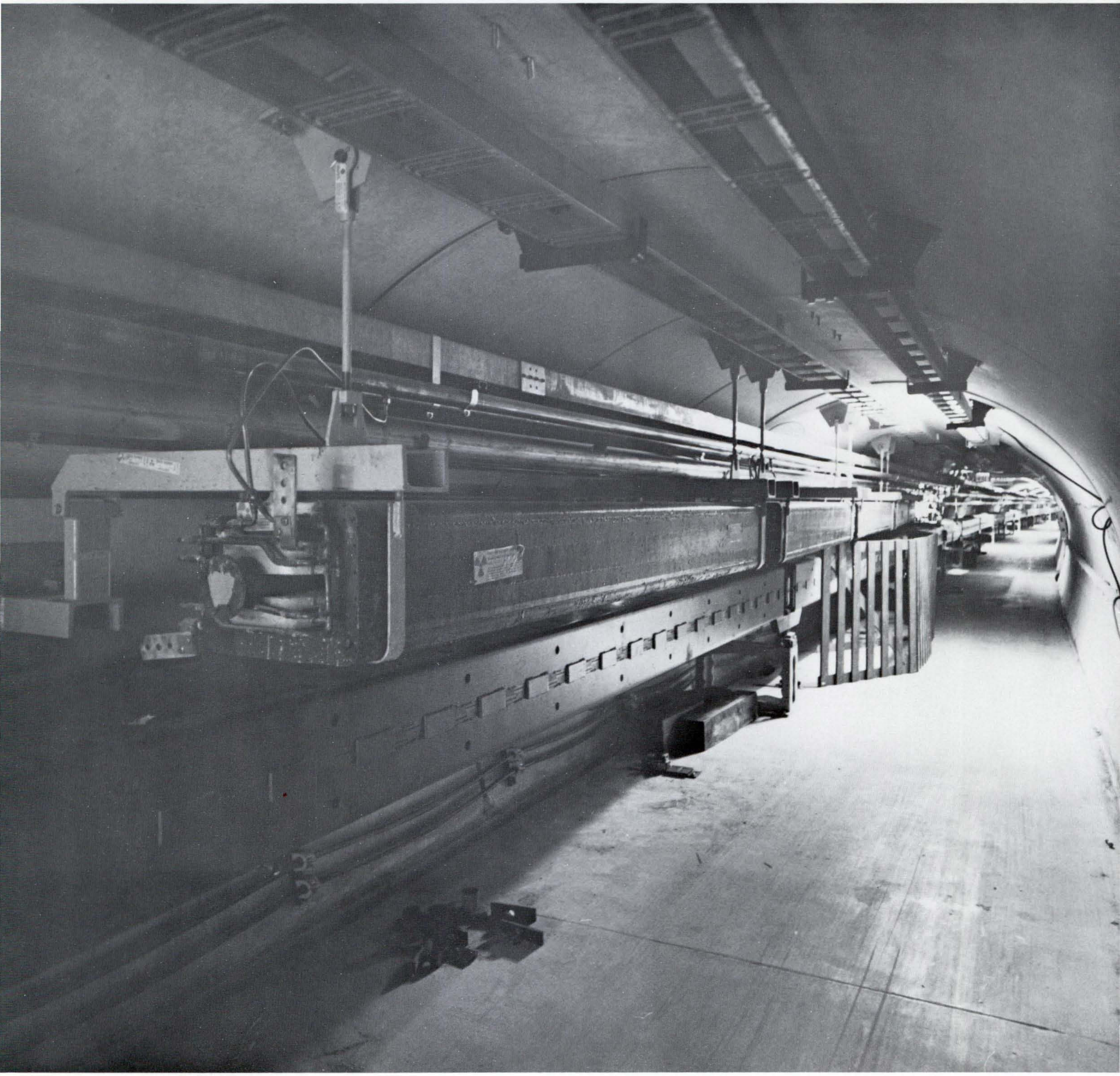
(iv) Modifying the Main-Ring bus and vacuum systems and the rf cavities to eliminate conflicts with the Energy Saver system.

The Operations Group modified the Main Control Room to prepare for operation of the superconducting accelerator.

The Accelerator Division participated in a number of activities and projects during the year. The project in the Accelerator Division that had the highest priority during the year was the Left Bend, discussed above. The first Saver rf cavity was constructed by the Accelerator Division and then tested at F0 for use in the superconducting accelerator (see section on technical innovations elsewhere in this report). The properties and characteristics of the Saver rf cavity were analyzed during accelerator studies with beam circulating in the Main Ring. Work also proceeded on the Doubler Beam-Position System. The Booster Group modified both the injection straight section and extraction areas. These improvements resulted in better reliability and intensity of the proton beam in the Booster. Finally, the Controls Group has begun the process of acquiring and installing a new computer system to replace the Xerox 530's for the Main Control Room.

Thus 1980 marks the beginning of a new era for the Accelerator Division with the preparation of the accelerator for the Saver and the first installation of superconducting magnets in the Left Bend. In addition, the Division has been conducting both active 400-GeV and acccelerator studies programs. The Accelerator Division is working to maintain the research program and to complete the goal of making the Energy Saver a reality for Fermilab.





Recently installed 80-GeV extraction line at F17 in the Main Ring. This line will provide protons for the antiproton-production target station for the proton-antiproton collider.

Accelerator Division
Colliding Beams

A system for producing proton-antiproton collisions with a luminosity of greater than 10^{30} cm^{-2} sec^{-1} at approximately 2 TeV center of-mass energy in the Fermilab superconducting magnet ring is being designed by the Colliding Beams Department in the Accelerator Division. This energy and luminosity will permit the study of a wide range of new phenomena, far beyond what is possible at any other high energy physics laboratory. To further these plans, a research and development program is in progress in preparation for construction of a "bright" anti proton source and several major advances have been made during the past year.

The plan for achieving proton-antiproton colliding beams in the superconducting ring requires the construction of a source of antiprotons. The design of this antiproton source is being carried out. Currently it is planned to extract a proton beam of approximately 80 to 100 GeV from the Main Ring and focus this beam onto a target for antiproton production. Antiprotons from the target, at an energy of approximately 5 GeV, will be collected in a large-aperture magnet ring called a Precooler, where they will be stochastically cooled to reduce their momentum spread. The antiprotons may then be decelerated in the Precooler after or during precooling, so that they can be transferred to a lower-energy ring where further cooling will take place using an electron beam. The cooling processes will reduce the dimensions of the antiproton beam so that accumulation of many pulses can be achieved. After several hours of accumulation, a sufficient intensity of antiprotons will be available so that the beam can be reaccelerated to 1000 Gev in the superconducting ring. Collisions between this beam and a counter-circulating proton beam will allow physics experiments to be performed at 2 TeV center of mass energy in either of two colliding-beam experimental areas to be constructed in Main Ring straight sections.

Experiments are in progress to study the processes of electron and stochastic cooling. These studies are being carried out in a 200-MeV storage ring using protons from the linear accelerator. During February through May, 1980, Fermilab, in collaboration with Lawrence Berkeley Laboratory and Argonne National Laboratory, succeeded in demonstrating that the momentum spread and vertical size of the circulating proton beam can be reduced by a stochastic cooling system. This system detects the random fluctuations of the beam at one location and amplifies the detected signal so that it can be reapplied as a corrective kick to the particles at a downstream location. A multitude of these small corrections given to the beam in succeeding revolutions cause the beam to become smaller and denser. In addition to reduced beam size, the most dramatic effect of stochastic cooling was to increase the lifetime of the stored beam in the ring by a factor of five or more.

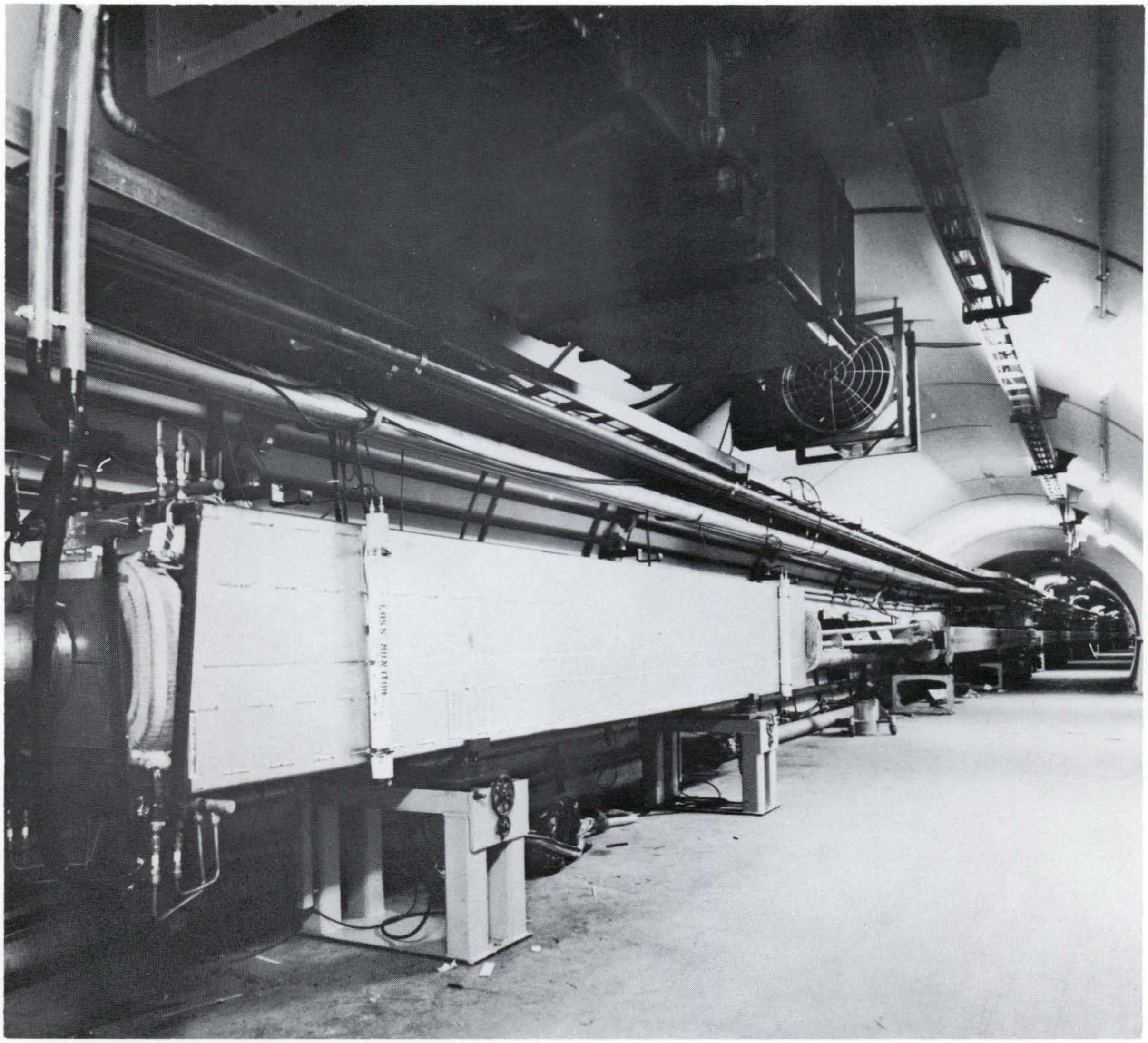
A second method of cooling a "hot" beam of particles was demonstrated on October 17 when the first successful cooling using an electron beam was observed. In this process a cold electron beam of closely the same velocity as the proton beam is made to travel together with the proton beam over a portion of the path of the proton beam in the ring. By collisions of the two beams, the excess transverse and longitudinal momenta of the protons or antiprotons are transferred to the electrons until the two beams reach "thermal" equilibrium. The hotter proton beam thus is cooled by heating the cooler electron beam. Reducing the transverse and longitudinal size of the heavy particle beam will allow more particles to be stored and accumulated, which is necessary for greater luminosity in proton-antiproton collisions. These first experiments were done at a proton energy of 115 MeV because of difficulties in achieving a higher voltage in the electron system. Improvements in the electron system are underway so that these experiments can be continued at 200 MeV.

Considerable progress was made during the summer shutdown on the installation of magnets and other components in the 80-GeV proton extraction line from the Main Ring and the antiproton target station. In addition, two power supply buildings have been constructed close to the target vault in sector F of the main ring. The first 80-GeV extracted beam through the septum magnet in the main ring is expected in January 1981 and the first targeting studies are scheduled for later in 1981.

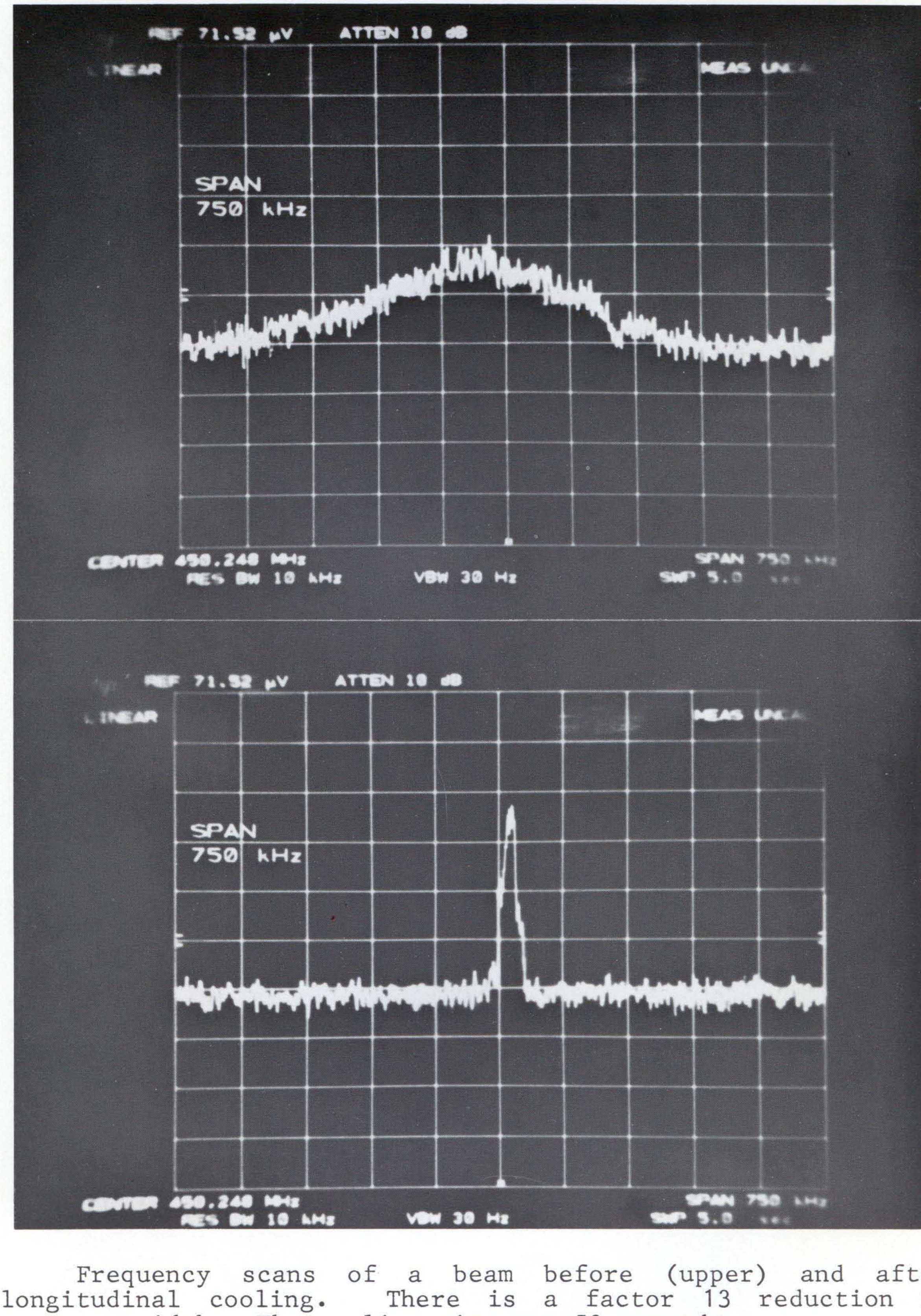
For high-luminosity collisions, it is necessary to rebunch the proton beam in the Main Ring to a few bunches of much greater intensity. Successful experiments have been performed to coalesce four bunches into one. The efficiency of this process depends upon the size and quality of the Main Ring bunches and the capability of the rf rebunching cavity. The bunching requirements for colliding beams will place new demands on the performance of the Main Ring and a continuing effort is underway to study Main Ring performance and develop the required capability.

A number of study weeks and workshops were held at Fermilab during the year to analyze and review various topics connected with colliding beams. A study week from February 18-22 considered the topic of beam-beam interactions in the specific case of proton-antiproton colliding beams. Discussions were held regarding a recent theory proposed at Fermilab that is based on the assumption that the observed beam-beam effects are enhanced by diffusion mechanisms in the storage ring. Two workshops were held during the month of April. The first one took place from April 7-11 and was devoted to beam storage in the Tevatron. The emphasis was placed on single-particle problems of long-time beam storage. The second meeting was held from April 28-30 and covered the topic of "High Temperature and Energy Density in Target Materials." One of the most significant results of the workshop was provided by computer simulation studies on the evolution of the target density as a function of energy deposition. New schemes were proposed to handle the problems of an antiproton target source. A study week was held from November 10-14 to update the design of the antiproton sources.

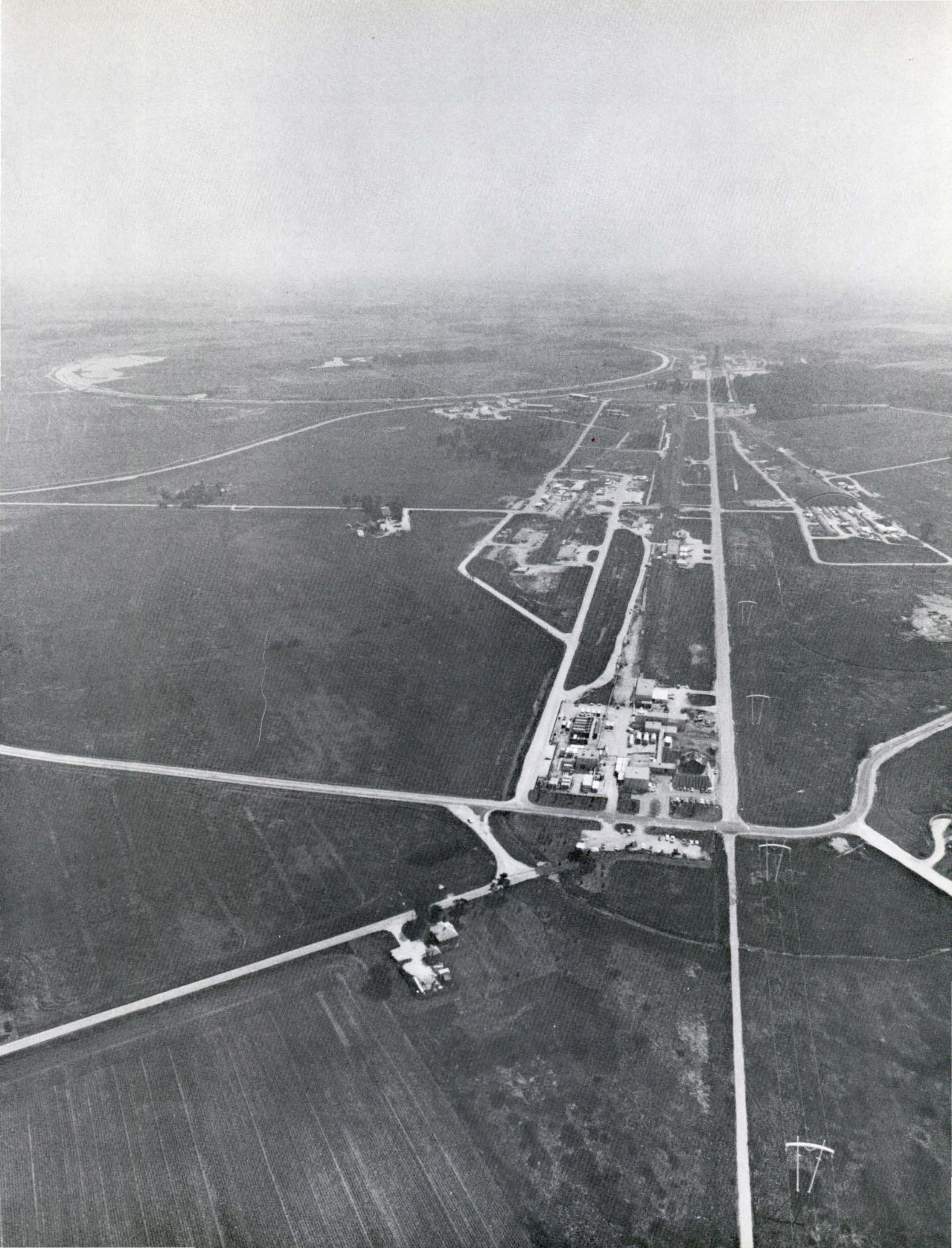
The colliding beams program at Fermilab has received considerable assistance from several institutions who are collaborating in the effort. The participating institutions are Argonne National Laboratory, The Institute of Nuclear Physics at Novosibirsk, USSR, Lawrence Berkeley Laboratory, and the University of Wisconsin.

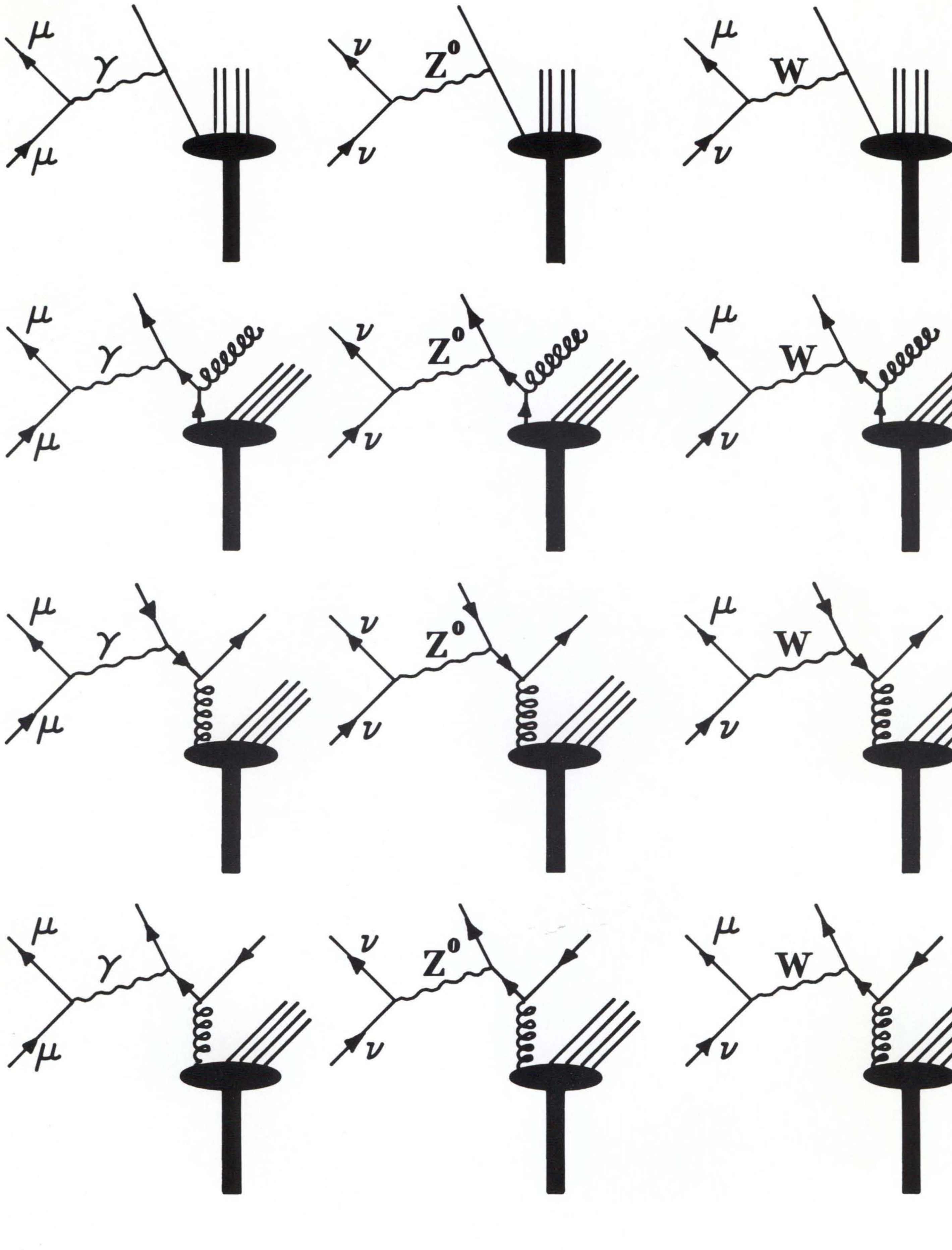


The Lambertson magnet for the 80-GeV extracted proton beam that will produce antiprotons for the proton-antiproton collider.



Frequency scans of a beam before (upper) and after longitudinal cooling. There is a factor 13 reduction in momentum width. The cooling time was 50 seconds.




μ
γ
μ
ν
Z°
ν
μ
W
ν
μ
γ
μ
ν
Z°
ν
μ
W
ν
μ
γ
μ
ν
Z°
ν
μ
W
ν
μ
γ
μ
ν
Z°
ν
μ
W
ν

High-Energy Physics Research Activities

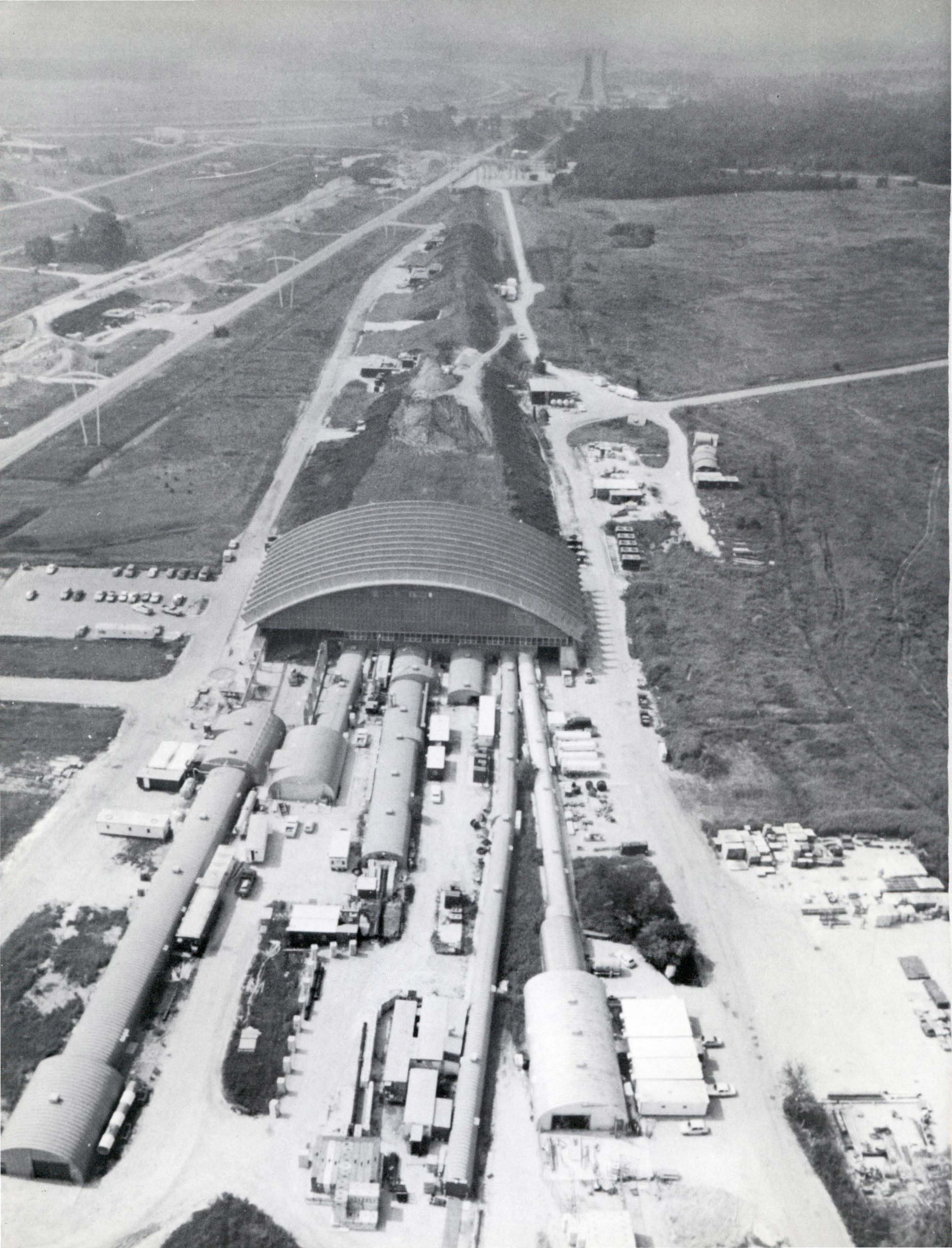
This was a year of hard work on several fronts, with a good operating period in the first half of 1980 and noteworthy progress on construction for the 1-TeV era that will be coming to Fermilab soon. The following sections tell the work of each area in more detail.

The new construction is the advance guard of what will be a major new project, TEVATRON PHASE 2, to provide extracted 1-TeV proton beams and experimental-area facilities for a fixed-target research program in the new energy range. Conceptual design work on this project was completed and brought together in a design report in 1980.

The project includes 1-TeV extraction and Switchyard construction together with improvements and construction of new experimental facilities in each external experimental area. Neutrino targets and shielding will be improved and a new muon beam and laboratory constructed. The Proton West and Proton Central beams will be improved to 1 TeV and completely independent target stations will be built for the two photon beams in Proton East. A Target Service Gallery and a polarized-proton beam will be added to the Meson Area, as well as improvements for 1-TeV capability in all beam lines.

A proton beam of 1 TeV energy will be an intense source of muons, electrons, neutrinos, photons, mesons, and baryons with which to study the emerging picture of the weak, electromagnetic, and strong interactions. The gain in the event rate of energetic interactions and the doubled energy of the proposed muon beam will allow detailed measurements of quark structure functions of nucleons and sensitive tests of quantum-chromodynamics predictions of their energy variation. Careful measurement of high-energy neutrino charged and neutral-current interactions will test the unified description of the weak and electromagnetic interactions of leptons, including the predicted damping of the total cross sections from the postulated effect of the intermediate vector boson.

In addition to the three external experimental areas, the Research Division is also the home of the Theoretical Physics Department, the Computing Department, the Colliding Beam Facility, and Research Services. Each of these departments has made major advances in 1980 and these are discussed below.



Meson Department

In the Meson Area, 1980 has been a year combining operation for present experiments and construction for the future. A total of five experiments were completed even though the area was in operation for only half the year.

By January of 1980, recovery from the 1978-79 Meson Pause was complete. The vigorous and exciting experimental program carried out during the January-June running period was able to benefit from the improvements made during the Meson Pause. One improvement was the installation of a new radiation monitoring and interlock system, using modern solid-state technology, that was more reliable and operationally simpler than the system it replaced.

In M6, the westernmost Meson beam line, E-577, a collaboration from the University of Arizona, University of California at San Diego, Cornell University, and Fermilab, set up and took data on elastic scattering at high t. The objective is to see if the dip structure observed in high t pp scattering is also observed in reactions with other incident hadrons. This experiment, while concentrating primarily on π^-p, has also collected significant data on π^+p, $K^\pm p$, and $\bar{p}p$ elastic scattering.

The data runs for this experiment and for E-515 in M1 benefited greatly from the two-way split installed during the Meson Pause. Variable and independent horizontal targeting on MC and MW was used to enhance the flux of 200 GeV π^- required by both experiments. Although the primary proton energy was limited to 350 GeV during this period, intensities in both M1 and M6 of 5×10^6 per pulse were attained by reducing the primary production angle to approximately 1 mrad.

In the other branch of the M6 beam, the Multiparticle Spectrometer was the scene of active efforts by two groups of experimenters. E-580, a collaboration of seven institutions, Arizona, Fermilab, Florida State, Notre Dame, Tufts, Vanderbilt, and Virginia Polytechnic Institute, have implemented a multiplicity trigger on the MPS to collect events of the type n charged particles $\rightarrow$ n + 4 charged particles. In events of this topology they are searching for new massive states decaying into $\Lambda^0\bar{\Lambda}^0$ or $K_s{}^0K_s{}^0$. This group is the first to use the MPS as a facility and had their first successful data run in spring 1980.

E-557, a collaboration of experimenters from Fermilab, Illinois (Circle Campus), Indiana, Maryland, and Rutgers will use the MPS with a large calorimeter serving as both trigger and neutral particle detector to select high p_T events in hadron-hadron collisions. During the summer of 1980, the calorimeter was completed and the first data run is planned for early 1981.

During an E-557 test run, 400-GeV protons were transported to the MPS. This doubling of the maximum M6 beam line energy was made possible by the installation of a string of three Energy Saver dipoles in the front-end hall, connected to two helium liquefiers. This string ran reliably through the January-June running period. This system is the first step in a program to convert all the major bend points in M1, M2, and M6 to superconducting (Energy Saver) magnets.

The next step started in the summer. A building with room for four satellite refrigerators was constructed on the west side of the Meson berm at 800 feet and the first refrigerator was installed. This refrigerator will initially be used to cool a string of five Energy Saver dipoles in M6 at 1300 feet. After M6 is converted, work will start on conversion of the front-end hall portion of M1 and M2 as part of an energy-management project approved for FY 81.

Cryogenics components and transfer lines for these conversions are designed and built by the Meson Department. Some of this capability will be used to make components for the Energy Saver during shutdown periods.

The low-intensity ($< 10^5$ particles per pulse) low-energy (10 to 50 GeV) test beam M5 continues to be popular and heavily subscribed by users. Some of the equipment tested in 1980 is (i) calorimeters and chambers for the Colliding Detector Facility Department, (ii) calorimeters for a hadron jet experiment, E-609, to be carried out in M6 by a group from Argonne, Fermilab, Lehigh, Pennsylvania, Rice, and Wisconsin, (iii) extensive tests on the energy and spatial resolution of the E-613 electromagnetic calorimeters before their installation in M2, (iv) test of "CRISIS," an ionization-sampling particle-identification device built by MIT as part of the 30-in. bubble-chamber downstream spectrometer, (v) evaluation of phototubes for use in the E-557 (atmospheric-pressure, multi-celled) and E-605 (ring-imaging) Cherenkov counters.

Next to the east, in M4, a University of California at Davis, University of California at San Diego, Carleton, and Michigan State group has been doing a systematic measurement of the charge-exchange reaction $K^-p \rightarrow \bar{K}^0 n$ (E-585). In the January-June period data taking at 68 and 116 GeV K^- energy was comand the 165-GeV data run is at the end of 1980.

In M3, E-533 (study of π-μ atoms) and E-584 (search for new long-lived neutral particles) were completed and then M3, the high-intensity neutral beam, was idle while preparations were started for E-617 in which a group from Chicago and Stanford will measure with high precision the ratio of the rates of the CP-violating decays of $K_L^0 \rightarrow \pi^0\pi^0$, $\pi^+\pi^-$. One technical problem in M3 was caused by the lack of straightness of the vacuum pipes in which the beam is transported between 700 and 1300 feet. These pipes are buried in the Meson shielding berm and have probably become distorted over the years because of the M4 beam directly underneath. The 1000 to 1300 foot pipe was replaced during the Meson Pause and in the summer of 1980 the 700 to 1000 foot pipe was unburdened and straightened. Construction of equipment to set up a dual K_L^0 beam and some installation work were other preparations for E-617 during 1980.

E-613 in the M2 line is described in "Chronology of an Experiment," elsewhere in this report.

Before concluding with M1 it is worth mentioning some recent physics results from experiments completed in late 1979 or early 1980. Before E-613 was installed in M2, the neutral-hyperon beam setup was modified to a charged hyperon beam and the group from Wisonsin, Michigan, Minnesota, and Rutgers (E-620) carried out beautiful, precise measurements on the magnetic moments some of the charged hyperons.

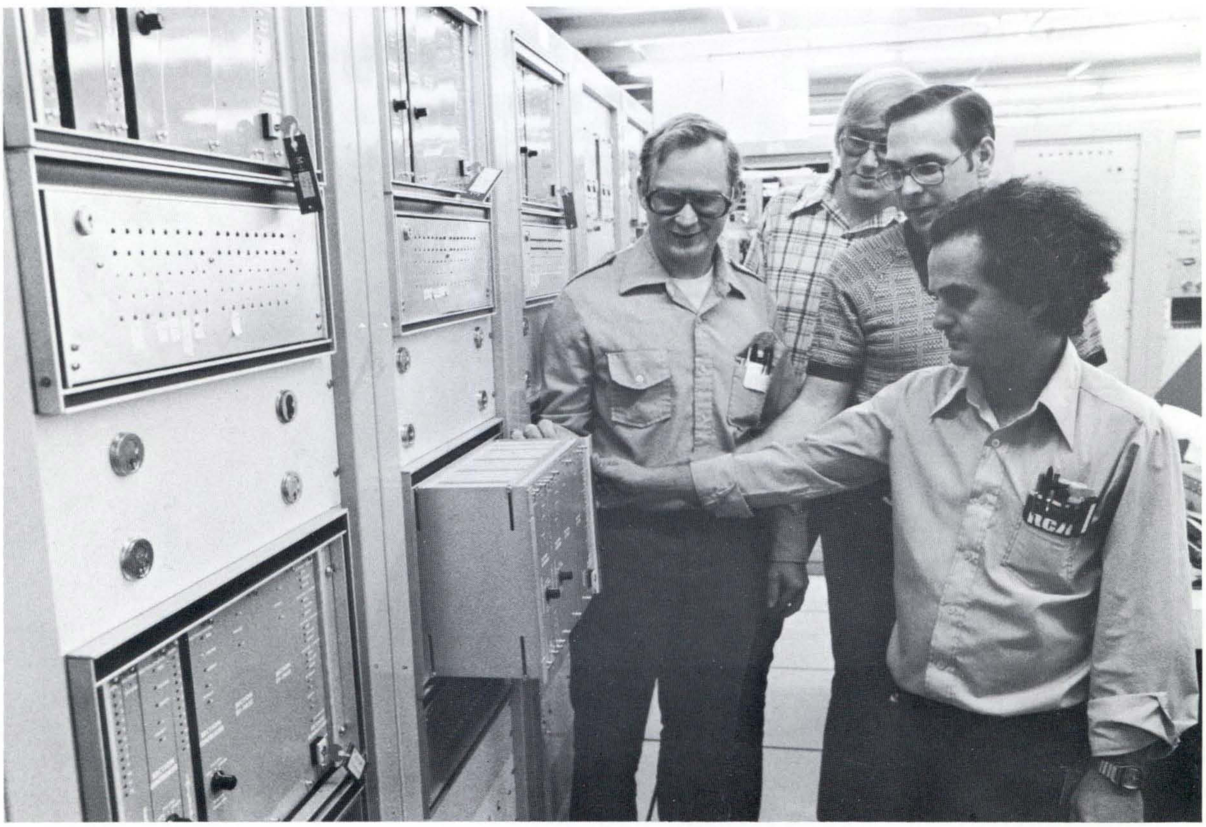
E-272 in M1 was an experiment on diffractive Coulomb dissociation using incident kaons. This experiment, carried out by a Brookhaven, Fermilab, Minnesota, and Rochester collaboration, obtained detailed information on the radiative widths of the K* (890) and other excited states of the $q\bar{q}$ system forming the K^+ meson.

The M1 line was the scene of much activity in 1980. Installation of a major new spectrometer was completed for E-515. This powerful setup, built by a Fermilab, Carnegie-Mellon, Northwestern, and Notre Dame collaboration is designed to study charmed-particle production by hadrons. It uses a large liquid-argon calorimeter and a prompt muon trigger to obtain an enriched sample of charmed events. This group obtained over a million triggers in their first data run.

As soon as summer arrived, the north wall of the Detector Building and a 100-foot section along the M1 line were torn down to make way for a major new construction effort, the M1 extension to house E-605, a hugh dimuon (or di-hadron) spectrometer designed to look for new quark flavors with a primary proton beam of up to 3×10^{12} protons/pulse. E-605 is a successor to the famous E-288 where the upsilon was discovered and is being carried out by many of the same experimenters. The institutions participating in E-605 are Saclay, CERN, Columbia, Fermilab, Kyoto, Ibaraki, Stony Brook, and Washington. E-605 is regarded as a transition experiment between the present 400-GeV accelerator and the Energy Saver; it will run with whatever energy protons are available. E-605 will also have much greater sensitivity than E-288. The first step in building E-605 was to build an enclosure and install a new 30-ton crane. Using this crane, blocks cut from the retired Nevis Cyclotron will be assembled into the two large analysis magnets required for the E-605 spectrometer.

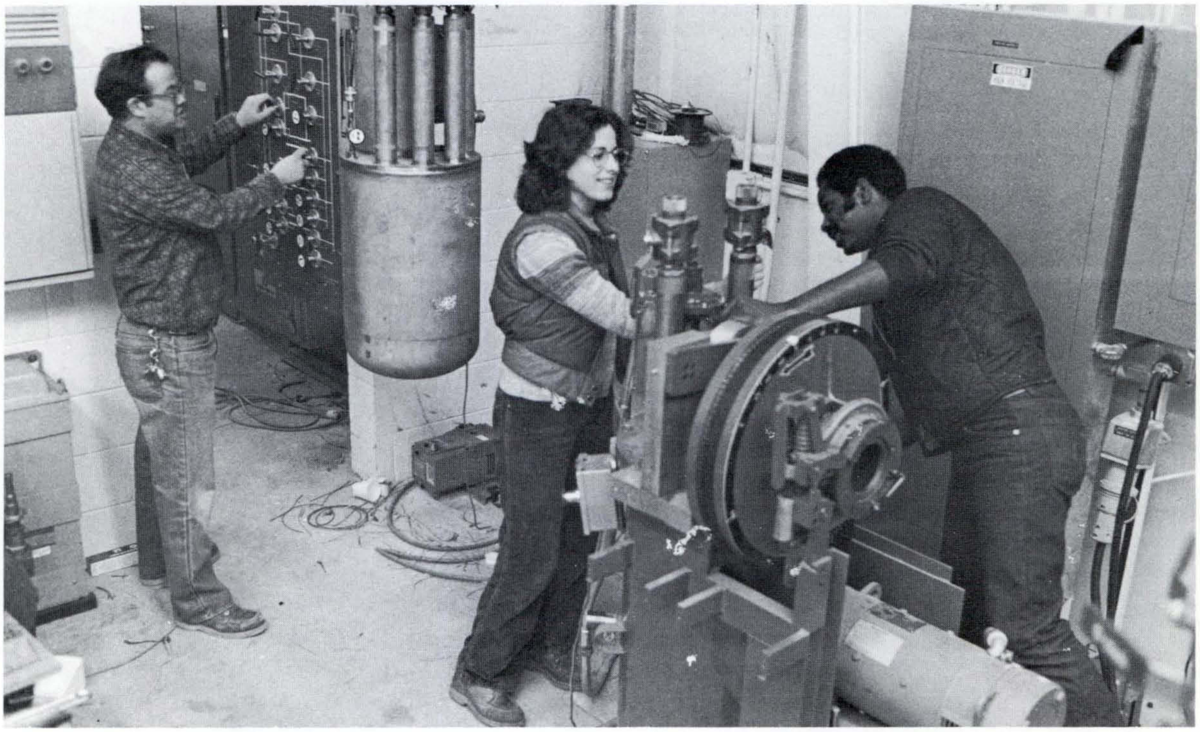
No sooner was the contractor finished with the Detector Building part of the M1 extension construction than experimenters from Fermilab, Michigan State, Minnesota, and Rochester started setting up E-629 in the M1 line. This experiment uses the successful liquid-argon calorimeter from E-272 and will be run as a test of the feasibility of studying single high-p_T photon production at Tevatron energies.

Although the Meson Area with its large number of beams and setups continues to be a very dynamic area with frequent changes in experiments, there has been a trend during 1980 towards fewer but larger and longer-lasting experimental setups. The experimental program is an exciting one and quite diverse in the kinds of physics explored.

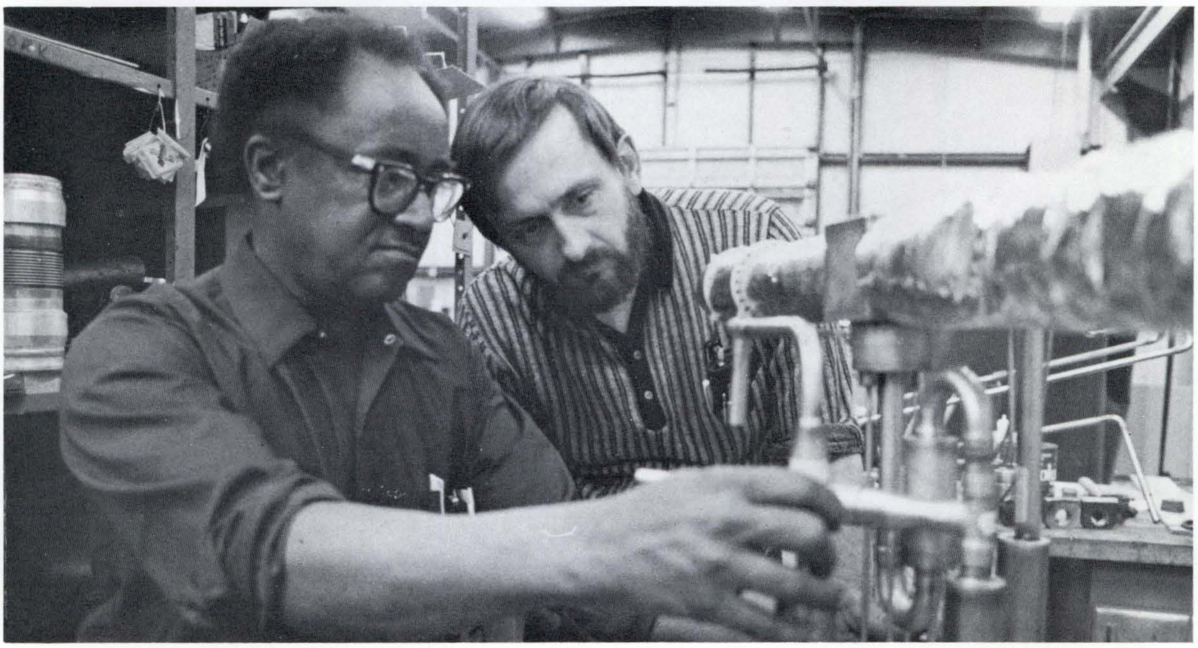


In the Meson Area control room, (left to right) Paul Czarapata, Glenn Federwitz, Jerry Dyche, and Skip McGuire examine the racks containing the electronics for digital readout of radiation monitors and the new optical door status sensors.

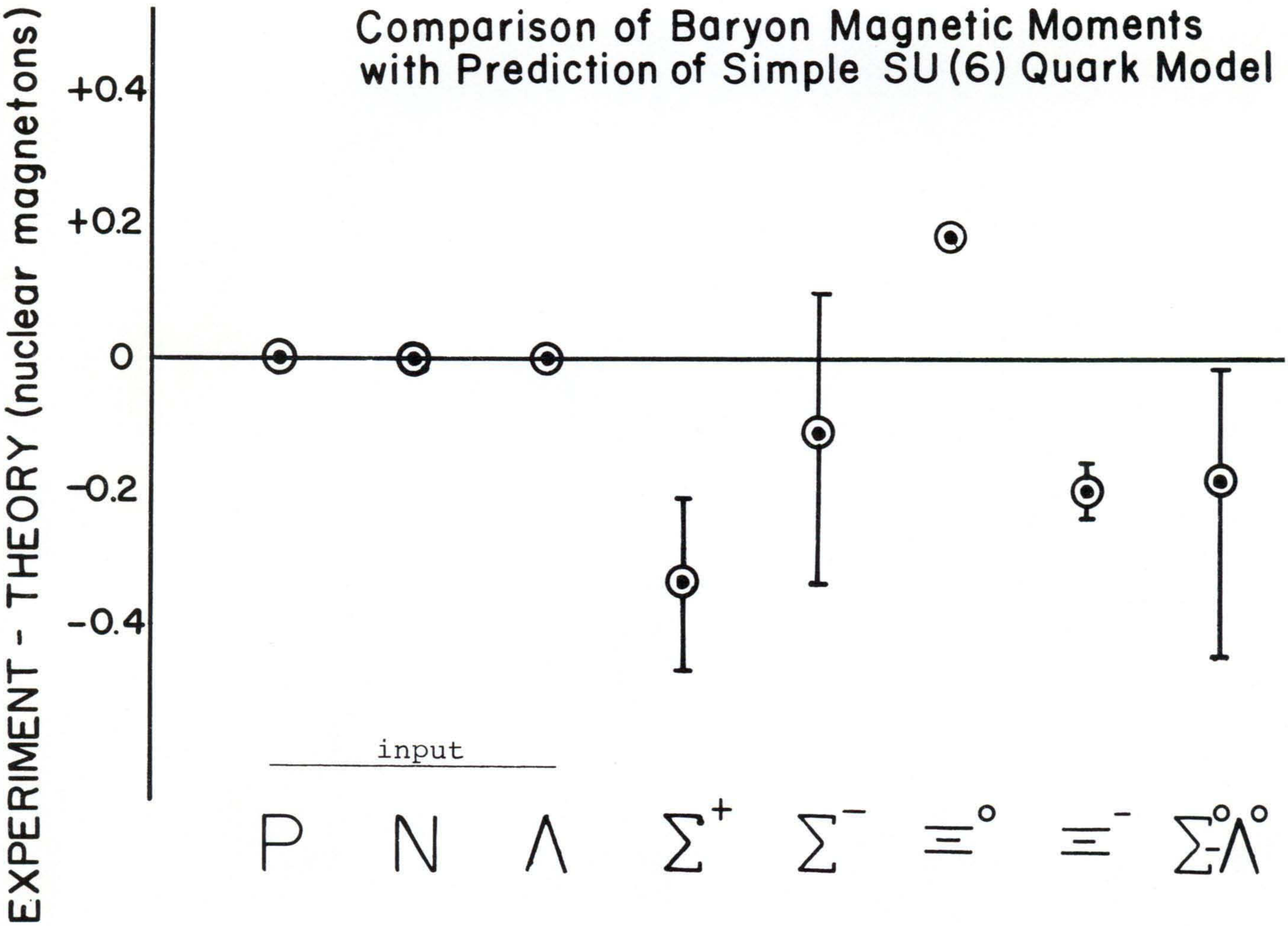
The E-557 calorimeter combines large coverage with reasonable granularity and resolution. It is built from acrylic scintillator and wave bars; the total number of channels is 280. The large computer-controlled tables allow each module to be placed in the beam for calibration. Pictured are (left to right) Vickie Frohne, Rich Cantal, Dan Green, and Sten Hanson (on ladder). Not pictured is Pat Rapp, Research Associate, Physics Department, who designed and constructed the calorimeter.



First satellite refrigerator in the Meson Cryogenics Building. Pictured are Terry O'Brien, Teresa Sobocki, and Ed Justice of the Meson Cryogenics Group.



John Williams and Bud Koecher (left to right) of the Meson Experiment Components Group work in Lab 6 in the Village on a feed box for the M6 cryogenic conversion. Not pictured are Cal Grayson and Jerry Sasek of the same group.

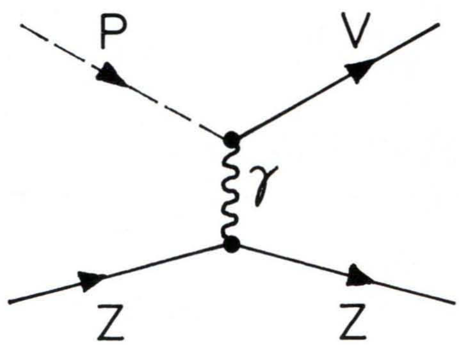


NOTES:

Λ	World average dominated by E440 final results
Σ^+	World average dominated by CERN HYBUC Experiment
Σ^-	World average including very preliminary data from E620
Ξ°	E440 and E495 final results
Ξ^-	E620 preliminary result
$\Sigma^\circ\Lambda^\circ$	Transition moment - CERN result

Recent results from the M2 neutral hyperon group, E-440 (Rutgers, Michigan, Wisconsin, and Minnesota), measuring the magnetic moments of neutral and charged hyperons.

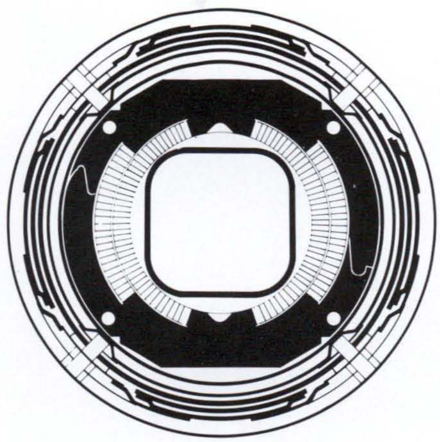
Radiative Widths of Vector and Tensor Mesons
E 272



PRIMAKOFF EFFECT

REACTION	WIDTH (KeV)	
$\rho^- \rightarrow \pi^- \gamma$	67 ± 7	D. Berg, et al., PRL 44, 706 (1980)
$K^*(890)^- \rightarrow K^- \gamma$	62 ± 14	D. Berg, et al., PL (in press)
$A_2^- \rightarrow \pi^- \gamma$	~ 400	Preliminary
$\rho^+ \rightarrow \pi^+ \gamma$	~ 65	Preliminary (agrees with ρ^-)
$K^*(890)^+ \rightarrow K^+ \gamma$	~ 60	Preliminary (agrees with $K^*(890)^-$)
$K^*(1430)^+ \rightarrow K^+ \gamma$	~ 300	Preliminary
$A_1^- \rightarrow \pi^- \gamma$	observed	
$B^+(1235) \rightarrow \pi^+ \gamma$	observed	
$A_2^+ \rightarrow \pi^+ \gamma$	observed	

Results to date from the E-272 (Rochester, Minnesota, Fermilab collaboration) in M1 measuring the radiative decay widths of mesons using the inverse Primakoff effect.



Neutrino Department

Heavy quarks and heavy cranes were the touchstones in the Neutrino Area in 1980. Half the year was spent running high-energy physics experiments and half in a large construction effort aimed at improving the capability of the Neutrino Area to do new and better neutrino experiments.

Heavy quarks were the subject under study for two experiments that were active in the area from January through June. (Neither experiment, by the way, used a neutrino beam, pointing up directly the need for the subsequent improvement program.) The principal data run for Experiment E-595 took place in this period. Led by Arie Bodek, University of Rochester, and Frank Merritt, University of Chicago, the E-595 group mounted a determined and sophisticated effort to measure the number of free charmed quarks created from the so-called quark sea by the collision of high-energy pions and protons with heavy target nuclei.

Once separated from its antiquark partner, the rarely produced and still mysterious charmed quark settles down to a comparatively long life (at least 10^{-13} seconds) in a charmed meson or nucleon. When the charmed particle finally decays, it often creates a muon in its place. By measuring the energies and angles of the muons emerging from the apparatus, useful information can be inferred about the parent quarks. It is, a tribute to the cleverness and persistence of the experimenters that so much can be learned by this indirect method.

A second heavy-quark hunting expedition (E-610) was led by Lee Holloway from the University of Illinois and Thomas Kirk of Fermilab. They sought as their quarry not the free version of charmed quarks, but the even rarer bound variety. The bound states of charmed quarks and antiquarks are called "charmonium" by analogy with "positronium," the bound state of electron and positron. Some of the charmonium states (psi family) have been extensively studied in hadron events. Others (chi family) have barely been glimpsed and their very existence is only weakly established. The E-610 effort will represent a large improvement over previous attempts in the U. S. and Europe to study hadron production of chi mesons. From this study will emerge new information helpful for understanding the binding forces of strong interactions (gluons).

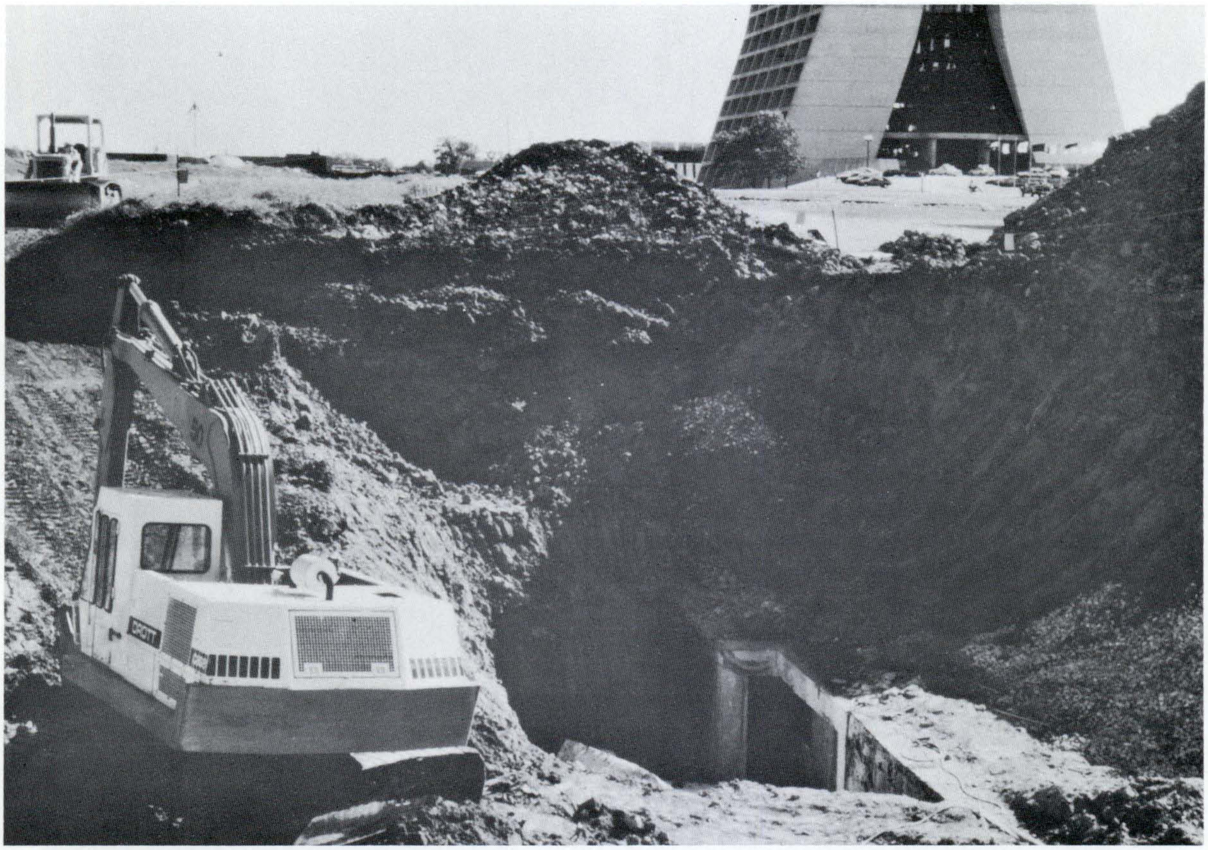
Hours after the hadron beams to E-595 and E-610 were turned off on June 23, bulldozers, earth scrapers, and front-end loaders began chewing their way into the massive earth shielding berms in the Neutrino Area, and the Neutrino Area summer improvement project was underway. From the early days of the Laboratory, the earth shield for neutrino experiments has suffered from a "Swiss cheese" effect caused by large beam-line enclosures located near the neutrino beam center. These large voids have frustrated neutrino experimenters in two ways, inhibiting the monitoring of actual neutrino fluxes and lowering the primary proton energy used in some neutrino experiments. All that is now repaired.

More than 14,000 tons of iron were stacked in place of earth in the shielding berm and the offending beam line was moved safely out of the way (together with its enclosures). The Swiss cheese is now an iron cylinder. In addition to removing two long-standing problems for neutrino experiments, the summer construction work will ready the area for the expected Tevatron neutrino-physics program, an example of killing multiple birds with a single stone.

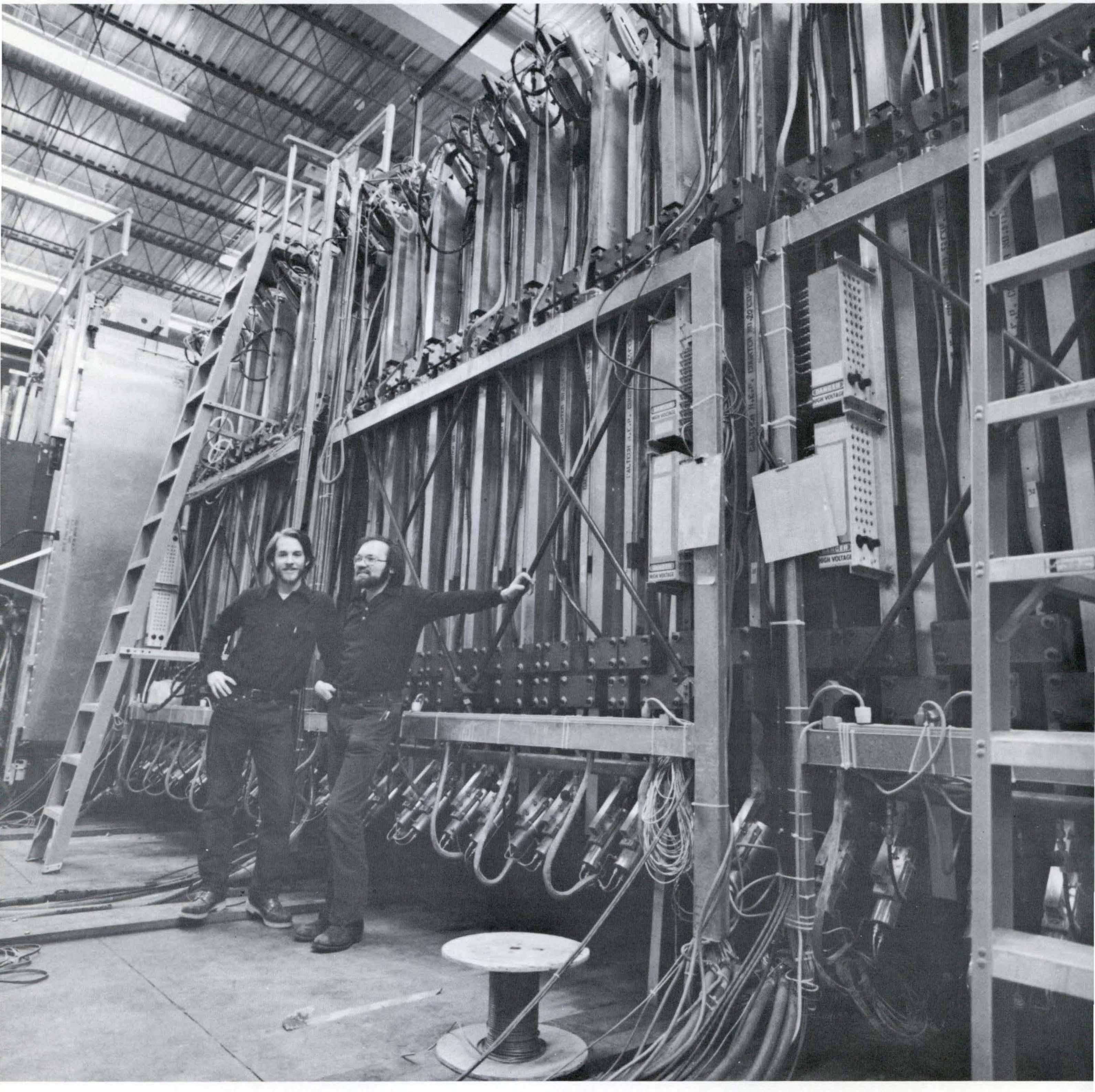
In order to accomplish the relocation of the beam noted above and to upgrade the energy capability of the shield for neutrino experiments, over 20,000 cubic yards of earth had to be moved and replaced, 14,000 tons of steel pieces stacked, 5000 feet of beam pipe laid, and several new enclosures built, two of them more than 300 feet long. After the construction upheaval, all the beam-transport and control elements had to be replaced and made to function effectively again. This was accomplished through the dedicated efforts of the Architectural Services and Neutrino Department staffs working in close cooperation.

As the beam returns for the fall 1980 high-energy physics running period, Bill Reay, Ohio State University, will begin a second phase of his neutrino emulsion experiment to measure directly the lifetime of charmed mesons and baryons (another interesting aspect of the heavy charmed quark). The experiment will get a substantial boost in neutrino flux with the new steel installation and with an improved horn-focusing system for neutrinos.

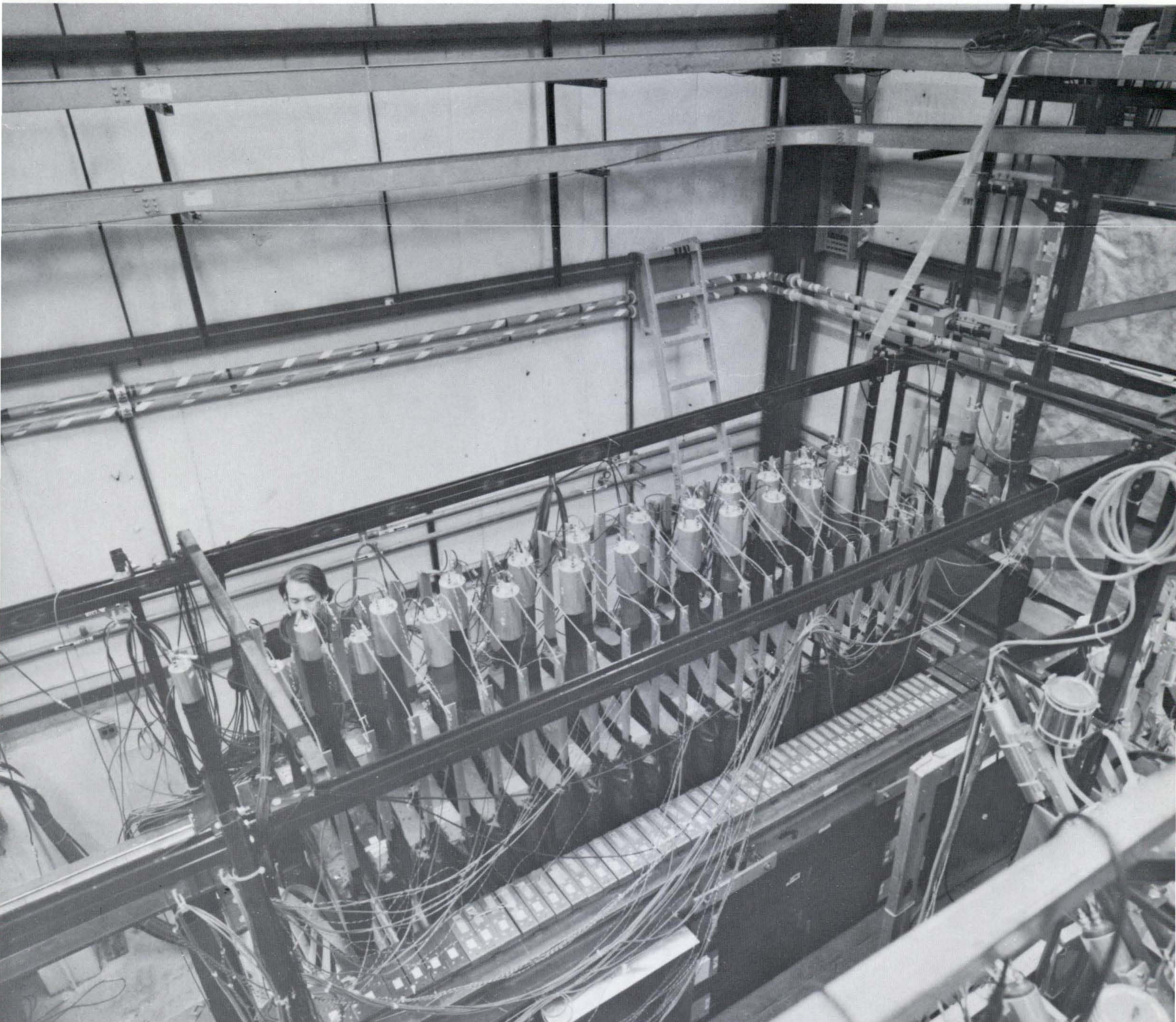
In addition Charles Baltay, E-53A, Columbia University, and Louis Voyvodic, E-564, Fermilab, will head experiments to study neutrino interactions in the 15-foot bubble chamber. The E-53A group will study neutrino-electron elastic scattering, a very important fundamental process; the E-564 group will search for charmed-meson and baryon production in cryogenic emulsion.



A Sunday break from the furious pace of construction that transformed large parts of the Switchyard and Neutrino Target Area during the July-November accelerator shutdown.
(Photograph by Tom Kirk)

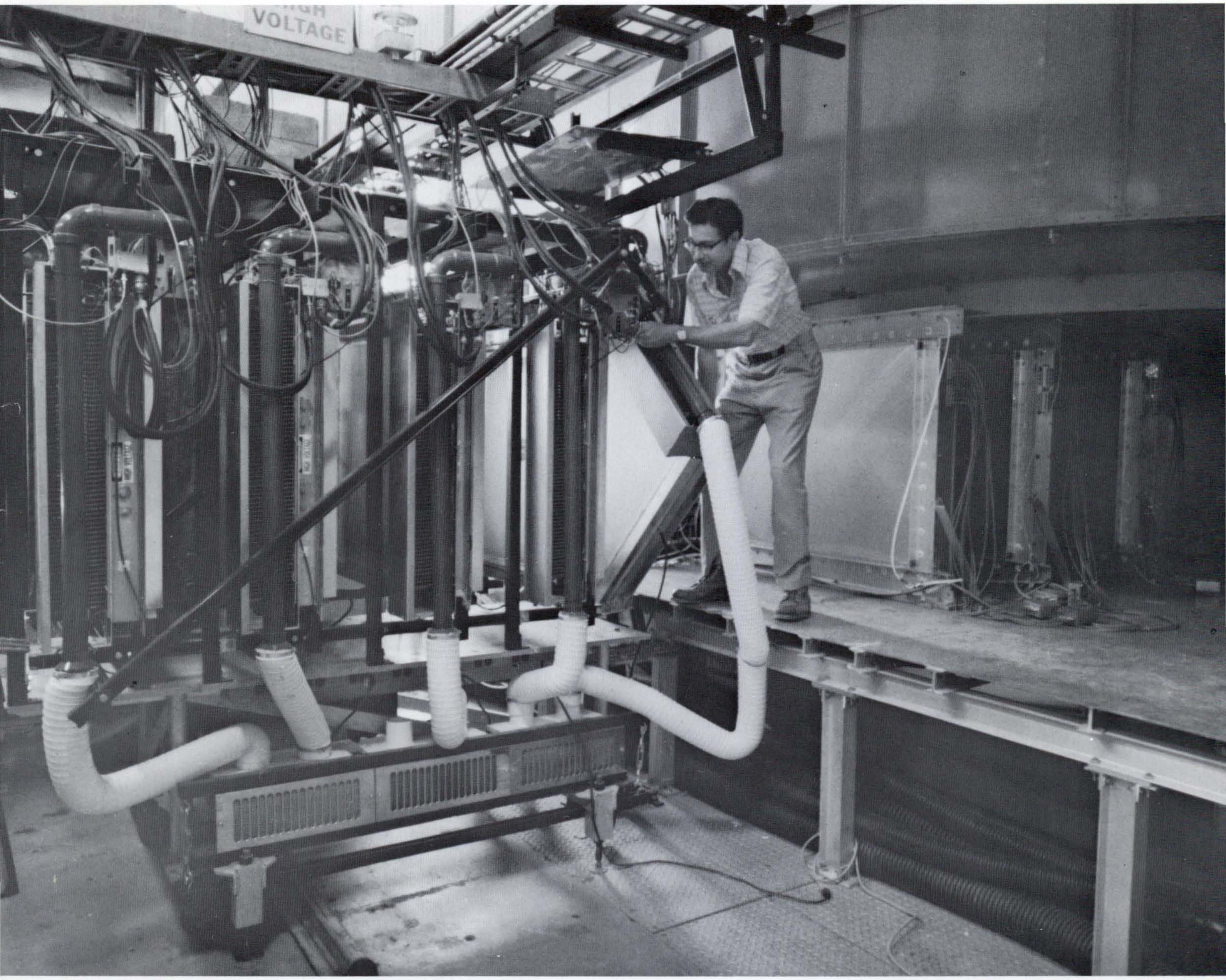


Ari Bodek (right), University of Rochester, discusses completion of the hadron calorimeter preparation for E-595 with Jack Richie also from Rochester.

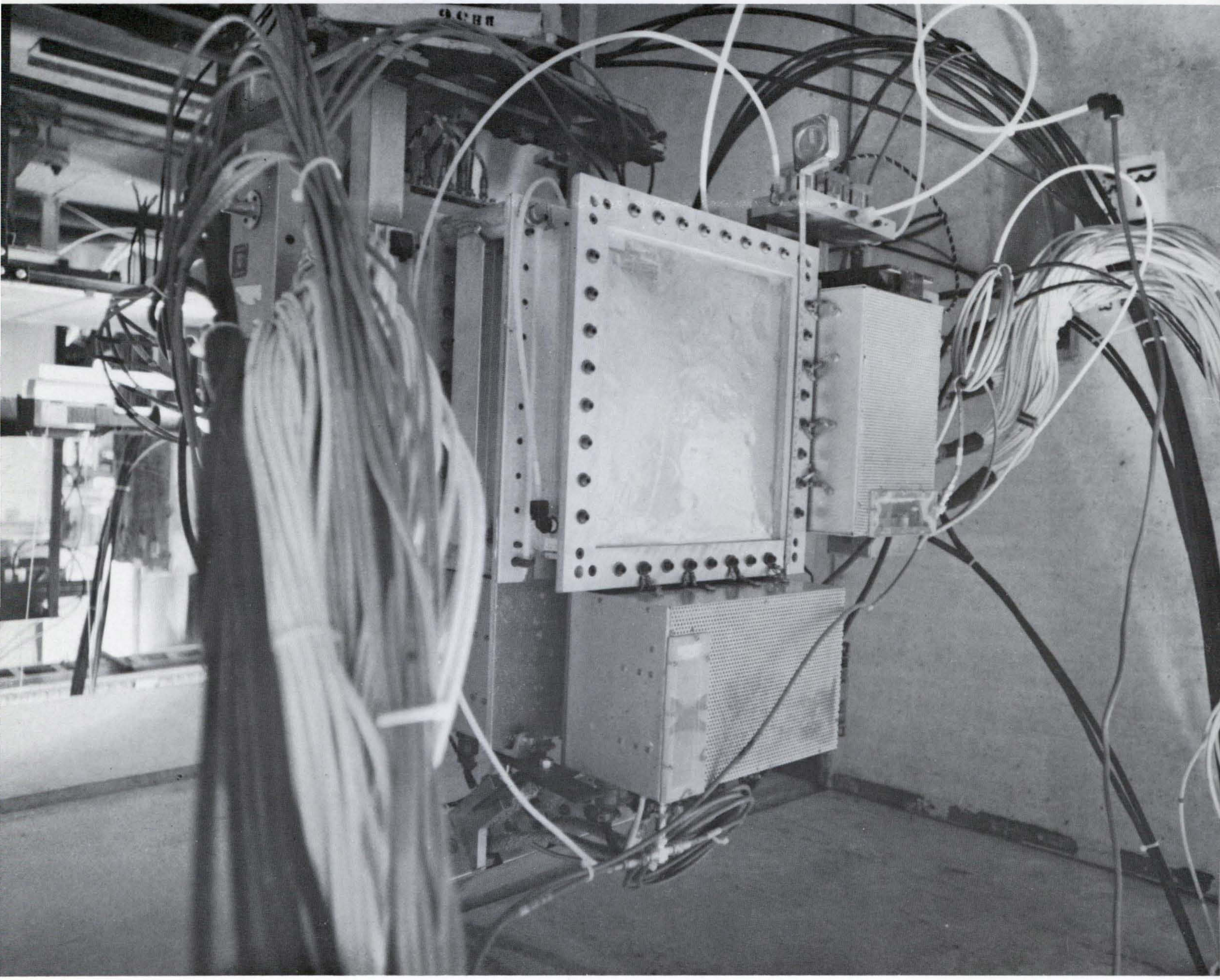


Jack Richie, University of Rochester, from E-595 inspects one of the hundreds of signal cables bringing information from the target calorimeter to the on-line data-acquisition computer.

A large mobile crane provides the added tugging power to remove a 70-ton copper coil from the old Chicago cyclotron magnet. A new set of energy-conserving superconducting coils has been installed in the old magnet first used by Enrico Fermi.

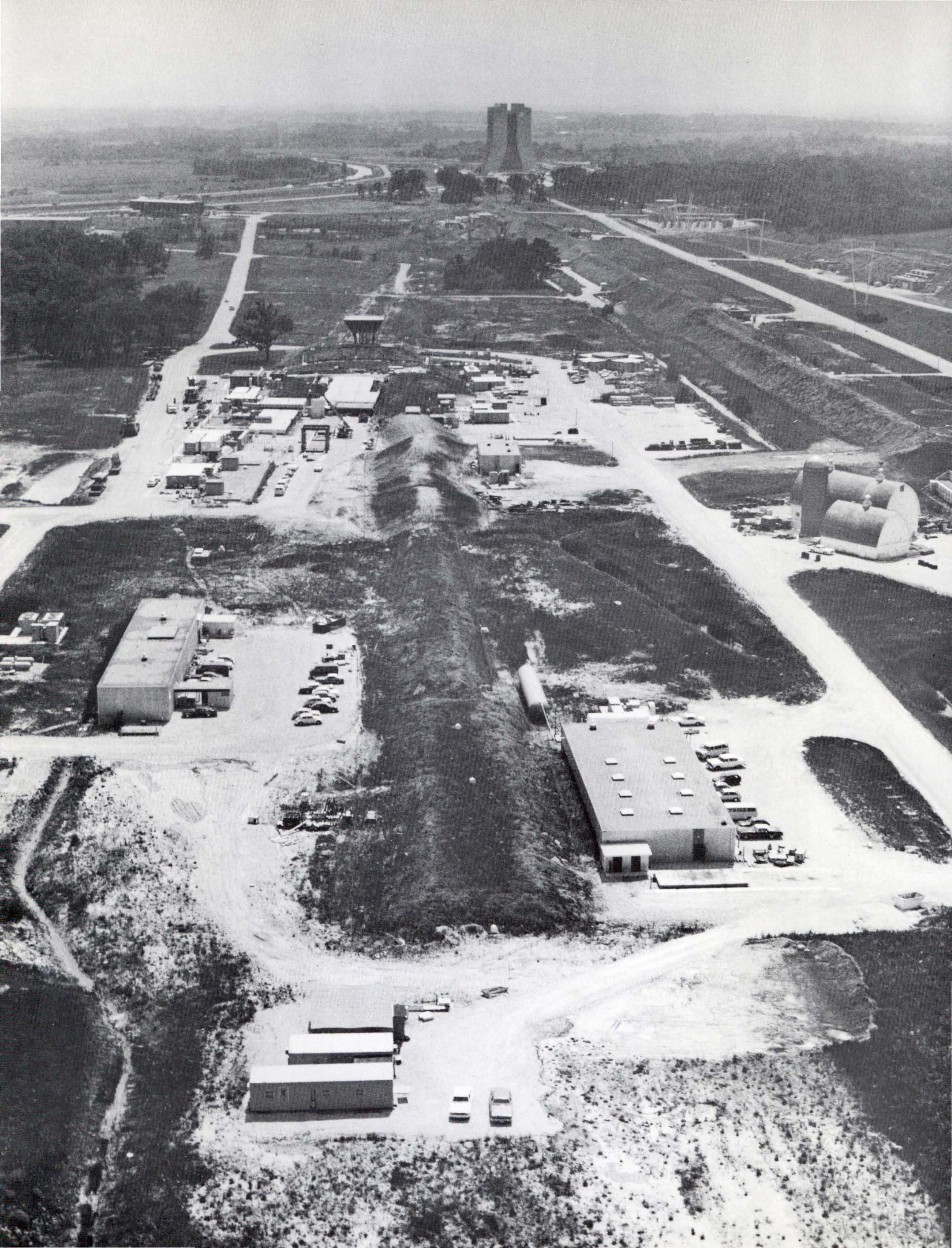


Louis Koester from the University of Illinois verifies that cooling air is flowing properly into the electronic amplifiers of a large multiwire proportional chamber from E-610.



Even before striking the target, beam particles entering E-610 in the Muon Laboratory pass through a complicated set of trajectory-measuring devices. Here is shown a beam multiwire proportional chamber.

Particles from a neutrino-generated event in a stack of nuclear emulsion plates burst into the liquid of the 15-ft bubble chamber. Could this event contain one of the rare charmed particle decays? ⟶



Proton Department

Major accomplishments this year in the Proton Area include the completion of one experiment, E-401, in the broad band neutral beam, and the completion of construction and installation of four large new detectors in the various beam lines. In the Tagged Photon Beam, construction and installation was completed this year on a large multiparticle spectrometer for E-516. In Proton Center, the charged hyperon channel and the first experiment, E-497, were installed. In the High Intensity Beam, two dimuon experiments, E-326 and E-537, completed construction work. All four of these large detectors made use of the beam to debug components and demonstrate the feasibility of their techniques. The coming year is therefore of great importance to the 400-GeV program in the Proton Area. Each of these experiments is expected to have a successful data run and thereby reap the benefits of large investments in time and equipment. In addition, the Proton Department successfully operated a low-current superconducting dipole with 900 feet of transfer line and a satellite refrigerator in the High Intensity Beam Line. This magnet was operated during the spring run as part of the beam transport. It has therefore been demonstrated that the low-current dipole technology developed for large-aperture secondary beams will allow flexible secondary-beam design while minimizing refrigeration costs. There was no major construction activity in the Proton Area during the long shut down in 1980, so the Department was able to help other areas with their projects. Proton personnel assisted in the improvement of the Neutrino muon shield by providing radiation-safety supervision for portions of the project and by helping with supervision of the construction of the steel shield. Proton aided Meson construction by installing much of the new power required for these projects. In addition, help was provided for the Left Bend project by participating in Energy Saver magnet retrofitting, magnet installation in the tunnel, and construction of some power-supply components.

During the winter running period, a Fermilab and University of Illinois collaboration, running in the Broad Band Photon Beam, completed E-401. This experiment studied the photoproduction of vector mesons decaying into two leptons or two hadrons. Over 2000 examples of the reaction

$$\gamma + p \rightarrow \psi + X$$

$$\hookrightarrow \mu^+\mu^-$$

$$\hookrightarrow e^+e^-$$

were recorded. These data will reveal the energy dependence of ψ-photoproduction from 50 to 250 GeV. The characteristics of this process are currently of great theoretical interest. The photoproduction of the ψ', ρ^0, ω^0, ψ vector mesons was also measured. Another experiment, E-400, which uses this beam as a source of neutrons to study charmed-particle production by hadrons, was given the go-ahead to run. It will begin next year.

In the High Intensity Beam a collaboration from the University of Chicago and Princeton University completed installation of a large solid-iron toroidal magnet system for the detection and analysis of muon pairs produced in pion nucleon collisions. This experiment, E-326, took first data this year and will have its major data run in 1981 with the goal of detecting muon pairs with masses up to 15 GeV.

Also in the High Intensity Beam, a collaboration of physicists from Fermilab, University of Athens, University of Michigan, and the People's Republic of China completed installation of a large dipole spectrometer for the purpose of studying the production of dimuons off nuclei in an antiproton beam. The data run expected in 1981 will yield several thousand events above a dimuon mass of 4 GeV.

A collaboration of physicists from Princeton, Saclay, Torino, Brookhaven, and Texas A&M completed analysis of a charm search, E-567, in the High Intensity Pion Beam. The results indicate a signal for D* production that is limited statistically. This group is approved for an additional experiment, E-650, which is expected to improve upon the previous result.

A large new detector has been approved for construction in the High Intensity Beam. A collaboration from Chicago, Iowa State, and Princeton will construct a spectrometer whose major elements are two large dipole magnets. The design for the first of these, whose gap dimensions are 25.5 in. × 54 in. × 24 ft long, was begun by the Proton Department this year. Experiment E-615 is another dimuon experiment whose goal is to study scale-breaking phenomena at large Feynman x.

Installation of the multiparticle spectrometer in the Tagged Photon Laboratory was completed during the past year. E-516, a collaboration of Fermilab, Toronto, Santa Barbara, Colorado, Oklahoma, and Carleton/NRC groups, will study the dynamics of charmed-particle photoproduction. The event trigger for this study will involve sophisticated recoil detector data preprocessing to select event candidates with a large forward missing mass. Each component system has been tested and calibrated and the experimenters are eager to begin data taking during FY81.

A group from Rockefeller University and the People's Republic of China has developed a recoil detector using high-pressure hydrogen gas, both as a target and as a detector to measure and identify slow recoil protons. This device has been set up in the Fermilab Village and successfully tested. It will be used in E-612 to study vector mesons photoproduced in the Tagged Photon Laboratory.

The refurbishing of Proton Center and the installation of a major new short-lived beam facility designed for hyperon physics was completed in 1980. A large 35-kG magnet, which houses the production target and magnetic channel, is its key element.

The first experiment using this beam, E-497, will measure hyperon-production cross sections and their associated polarization. A successful test run in the spring allowed this group to commission the beam, debug their detector system, and generate sufficient data to develop analysis programs. The versatility of this beam will be demonstrated later in the winter, when E-630 will use the same magnet to produce a high-intensity neutron beam. This neutron beam must be very free of halo particles and will be used to study charmed-particle production in a high-resolution streamer chamber.

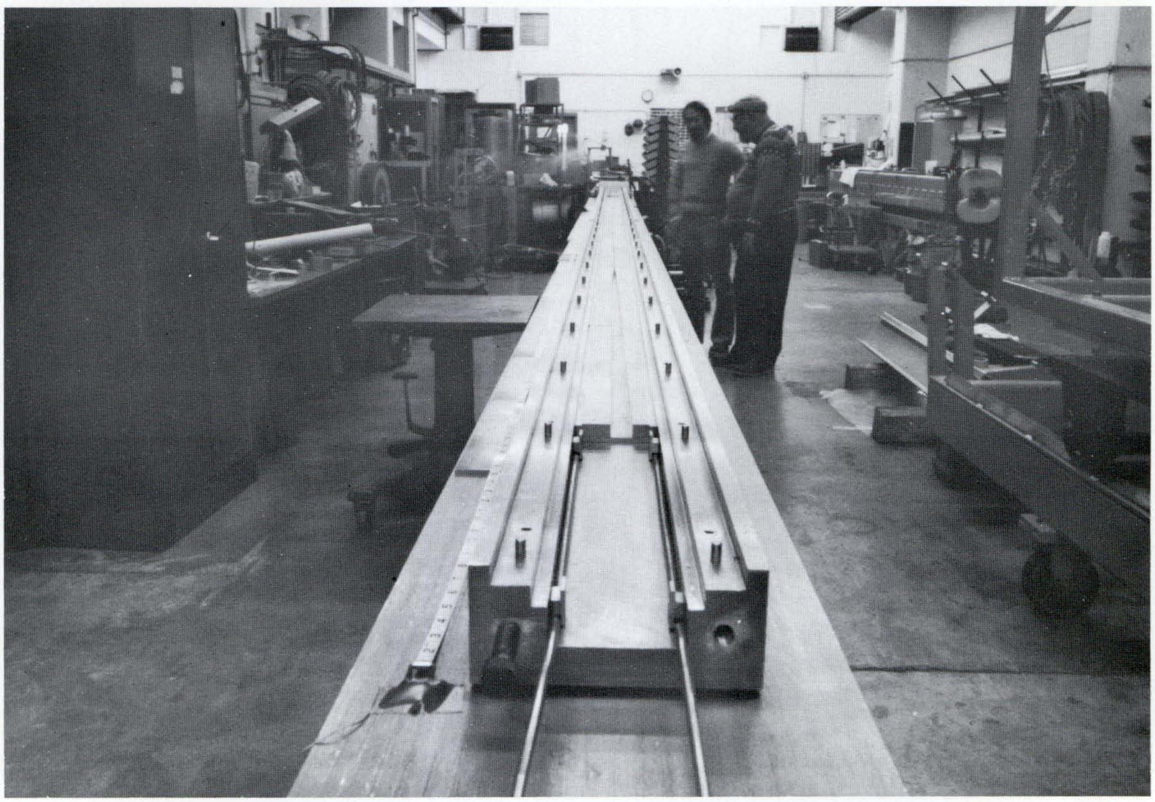
This year the first low-current superconducting dipole magnet developed by the Proton Department was installed in the high-intensity secondary beam line of Proton West. The installation consisted of the superconducting magnet, a 500-watt helium refrigerator in the P-4 service building, and 900 feet of helium transfer line (the longest and most complicated ever built) to connect the two. The high-intensity beam cryogenic system is now approximately 50% complete.

The dipole produces 42 kilogauss over a 6-in. cold bore at 210 amperes. For the initial beam-line test, it was augmented by two conventional dipoles providing complete redundancy in the event of system failure. During a two-month run for E-326 and E-537, the refrigeration and magnet systems were operational for 90% of the available beam time. This shakedown run indicated improvements which will be made to further reduce lost beam time and provided an opportunity to measure heat loads and other properties of the cryogenic system. The high-intensity beam line is ready to accept more superconducting magnets as they become available.

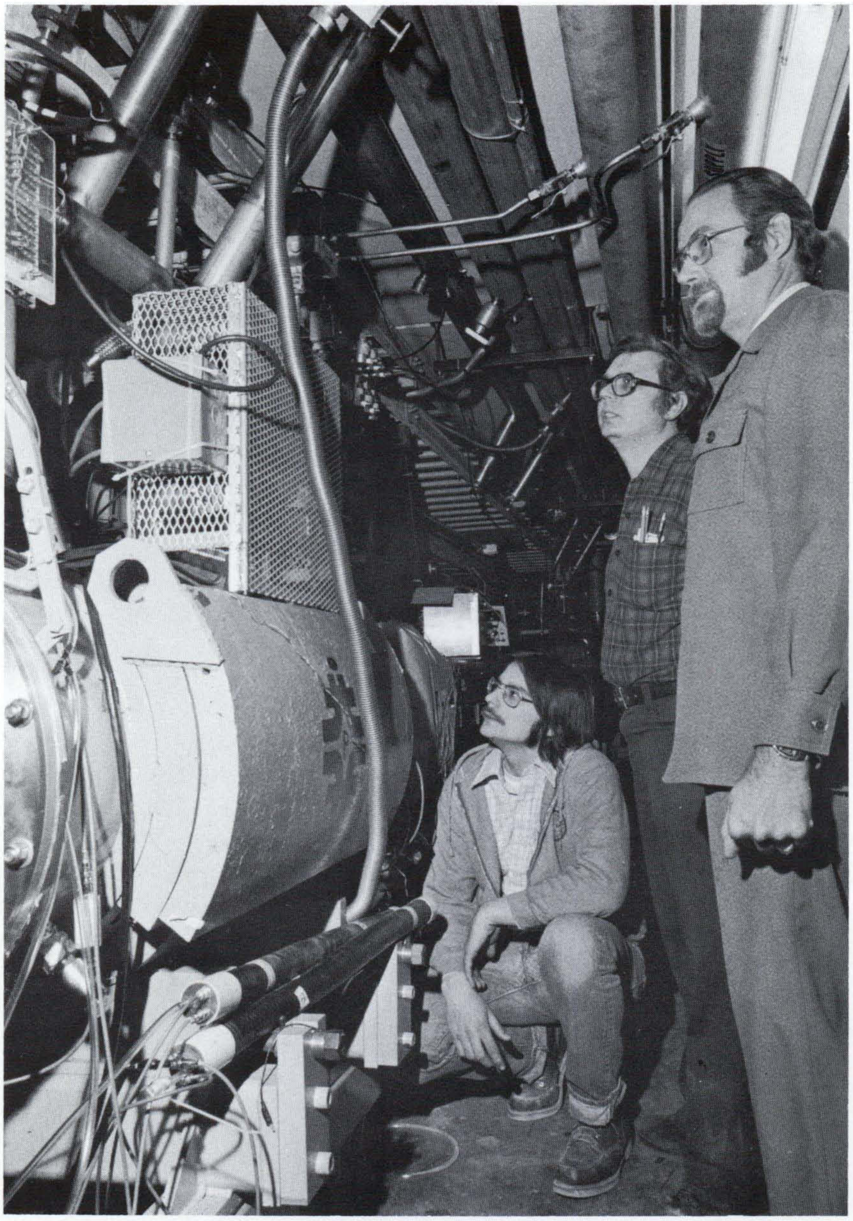
Another similar dipole coil was completed and successfully tested to refine further the low-current superconducting-magnet technology. The coil has been made ready for installation into its cryostat in preparation for beam-line use.

The Proton Department is scheduled for major construction during summer 1981 at Enclosure H (location of three-way split) and in the Proton East Enclosures. These improvements projects will lead to improved reliability and improved radiation safety in the area. A major effort was expended this year in developing the conceptual designs for these projects and for the Proton Area Tevatron II upgrade.

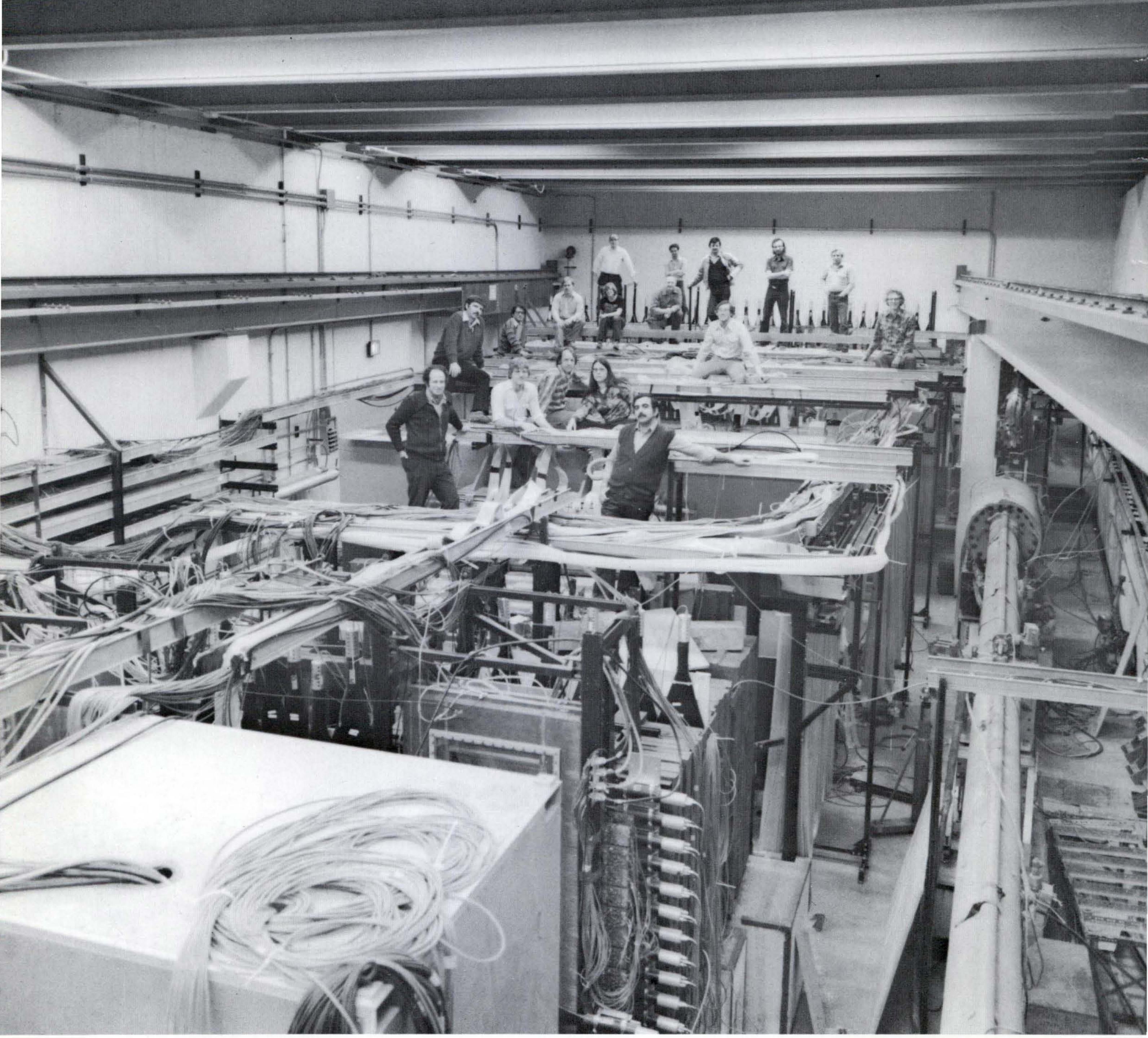
During 1980 the Proton Department has also completed plans for transporting, splitting, and targeting 1-TeV primary proton beams. The splitting of the primary beams into three independent beams will be accomplished in the enlarged Enclosure H. There is adequate space in the east branch to install electrostatic septa that will allow further subdivision of the east beam into two independently targetable beams. Solutions for targeting protons on each of three existing target stations have been developed. In addition, a design for a new high-energy broad-band electron-pion beam has been completed. This beam would replace the existing Broad Band Neutral Beam in Proton East.



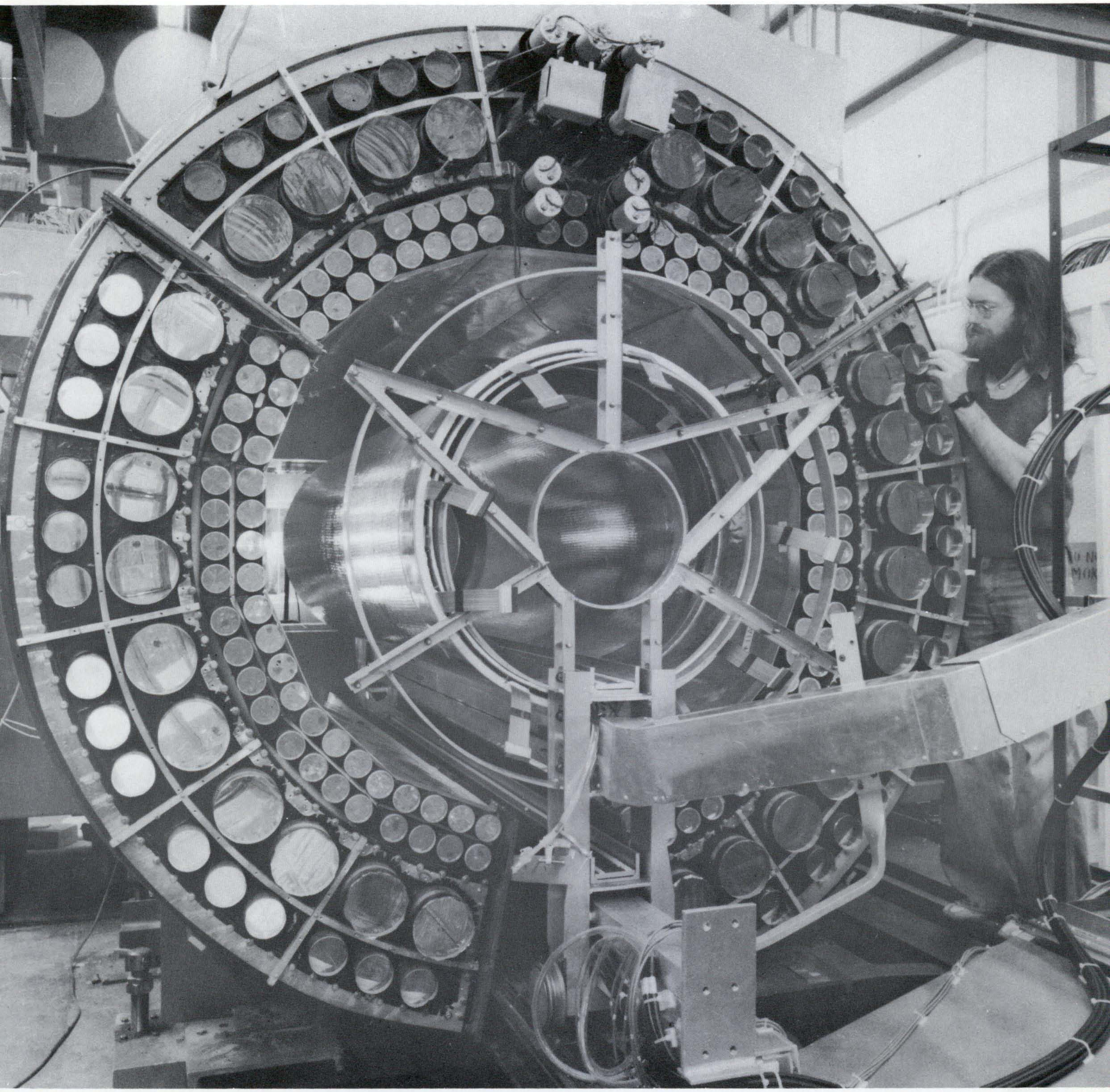
Peter Cooper (left) from Yale University and Bill Thomas from Fermilab inspect the hyperon channel for Experiment 497.



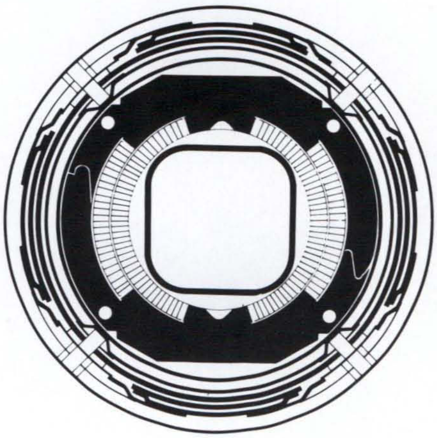
Rich Stanek, Peter Garbincius, and Peter Mazur (left to right) inspect the low-current superconducting dipole magnet in the High Intensity Beam Line developed by the Proton Department.



Removable core (lower right) of the large 35-kG magnet that houses the production target and magnetic channel during assembly in the Proton Department shop. A "proton's eye view" of the slightly curved channel, defined by precisely aligned tungsten blocks, is shown. A target will normally be located at the channel entrance.



John Martin, experimenter from the University of Toronto, finishes work on the recoil spectrometer for Experiment 516.



Professor Margaret Burbidge, colloquium speaker, in a pre-colloquium conversation with Fermilab physicists Alan Wehmann, Jim Griffin, Carlos Hojvat, and Ivan Rosenberg.

Physics Department

The Physics Department mandate is to act **in lieu** of a university physics department, concerning itself with the professional well-being of Laboratory physicists, supporting their research, and enhancing the intellectual environment of the Fermilab physics community.

In response to the Laboratory's increased activities in construction and operation, the number of Ph.D. physicists at Fermilab grew from 160 to 170 over the past year. In addition to the construction projects, operation of the 400-GeV program continued to make large demands on physicists' time. Several score research physicists also staffed approximately twenty experiments at the Laboratory.

A series of Academic Lectures is organized by the Physics Department in collaboration with the Theory Group. These lectures are primarily intended for graduate students residing at the Laboratory to replace the courses they are missing at their "home" universities. Some 50 graduate students and an equal number of young research associates, as well as staff members and visiting faculty, have been attending these short lecture courses in the frontiers of current particle theory and accelerator physics. Lecture series topics this year have included gauge theories, QCD, and accelerator theory.

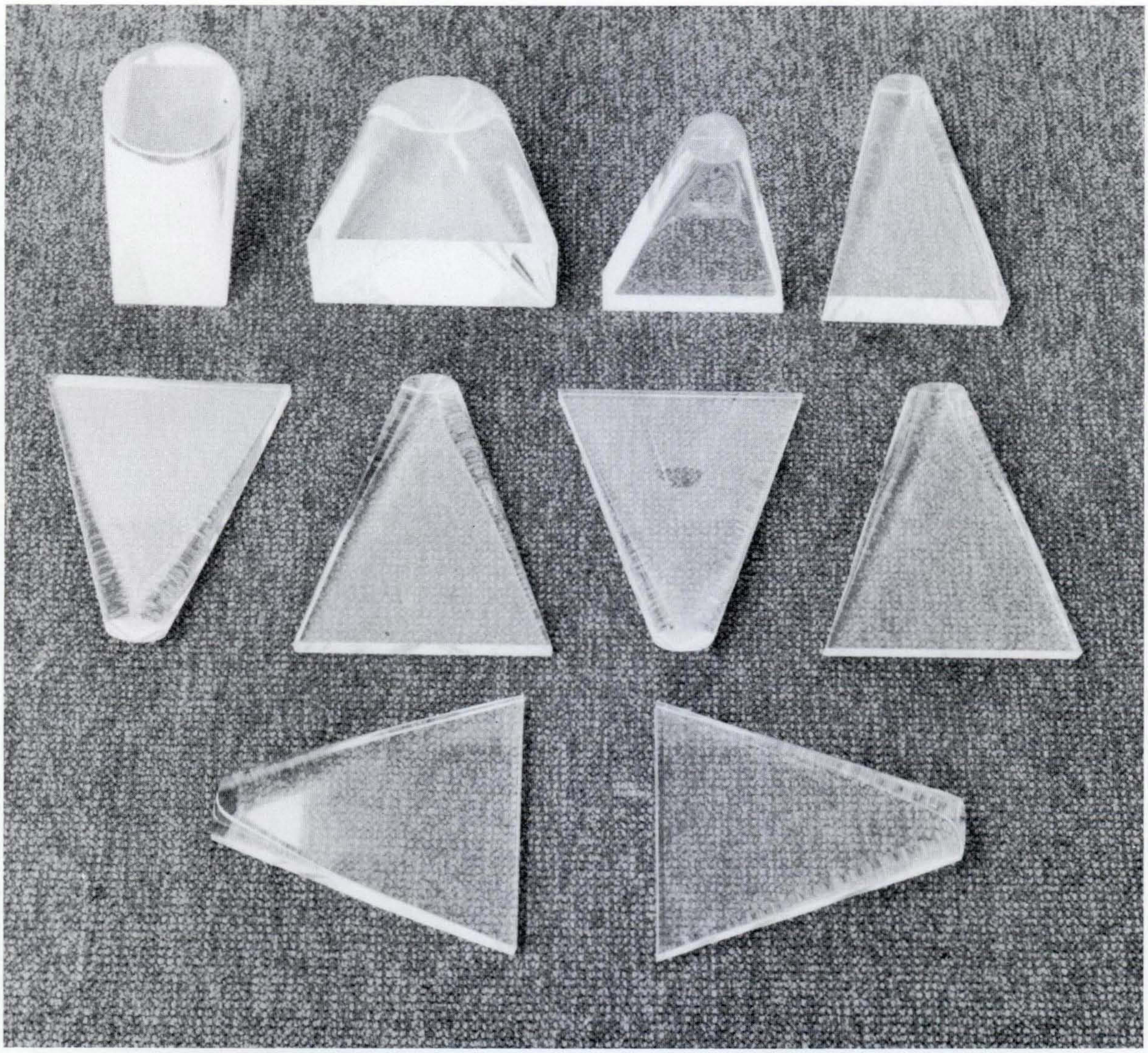
Informal experimental-theoretical research seminars, usually on the subject of current local research, are given weekly and are well complemented by a broad range of topics covered by invited speakers at the Wednesday Colloquium Series. Modest but nonetheless significant, a sabbatical and senior research program is also maintained by the Physics Department, which includes visitors from the U. S. and abroad.

In the past year, several major Physics Department research projects completed construction and began operation. Here we highlight several because of their innovative nature. We mention first the E-594 Fermilab-Michigan State-MIT-Northern Illinois University collaboration. This experiment is designed to study neutrino physics involving neutral currents. It has a 300-ton fine-grained instrumented detector. The experiment uses flash chambers developed in the Physics Department by James Walker and colleagues with magnetostrictive readout to obtain a million spatial digitizations of charged-particle tracks per event. Thus it combines large mass with fine space resolution, a technique not yet attained anywhere else. The whole 300-ton mass of the detector is constructed of low-cost, commercially available extruded plastic, normally used as corrugated packing material. These plastic sheets are filled with Ne gas, sand, and iron buckshot in alternate layers. In this fashion, low cost and high resolution were achieved. Successful calibration runs were taken this summer and presently the experiment is gearing up for a major run. In comparison, a similar experiment at CERN used expensive polished slabs of Italian marble instead of the inexpensive filled plastic sheets. The performance of the detector as indicated by the test runs was up to design specifications.

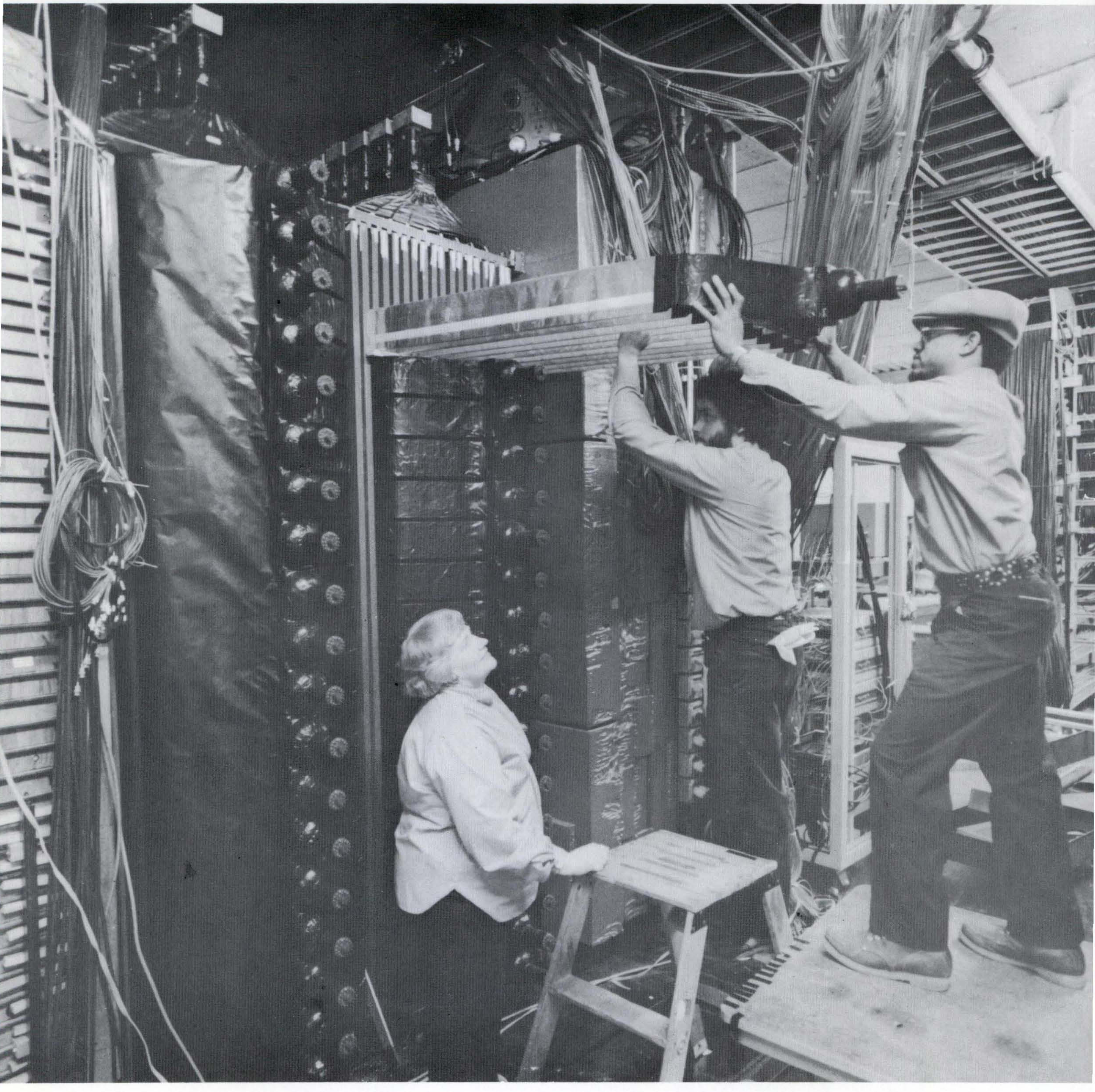
Another innovative Fermilab experimental device is the ECL-CAMAC Trigger Processor system developed for the Tagged Photon Spectrometer (E-516). To study photon interactions at the Tagged Photon Lab, a very intense high-energy photon beam is used. Such a beam results in hundreds of thousands of interactions on a hydrogen target. Employing modern super high speed electronics technology, Thomas Nash of the Physics Department and Edward Barsotti of Research Services and colleagues have developed an extremely fast programmable processor. This computer-like device sifts through thousands of interactions and picks out the few that are of sufficient interest to warrant reading out to the on-line computer the large amounts of data from this very complex experiment. Similar devices are employed in several other experiments at Fermilab, notably E-537 and E-594. The latter one uses a processor developed jointly by Cordon Kerns of the Physics Department and MIT to distinguish hadron and electron showers.

Another noteworthy Physics Department effort is the experiment E-497 hyperon facility. At present 400-GeV incident proton energies, the short-lived particles, Λ, $\Sigma^{\pm}$, and Ξ are produced with energies and velocities sufficient to extend their life by an order of magnitude or more. Thus, beams of these particles can be made, much like pion or kaon beams at lower-energy accelerators. At the Proton Lab P-Center beam line, one such beam is designed and installed, producing up to 10^7 Σ^- baryons per pulse with a rather small contamination of π^-.

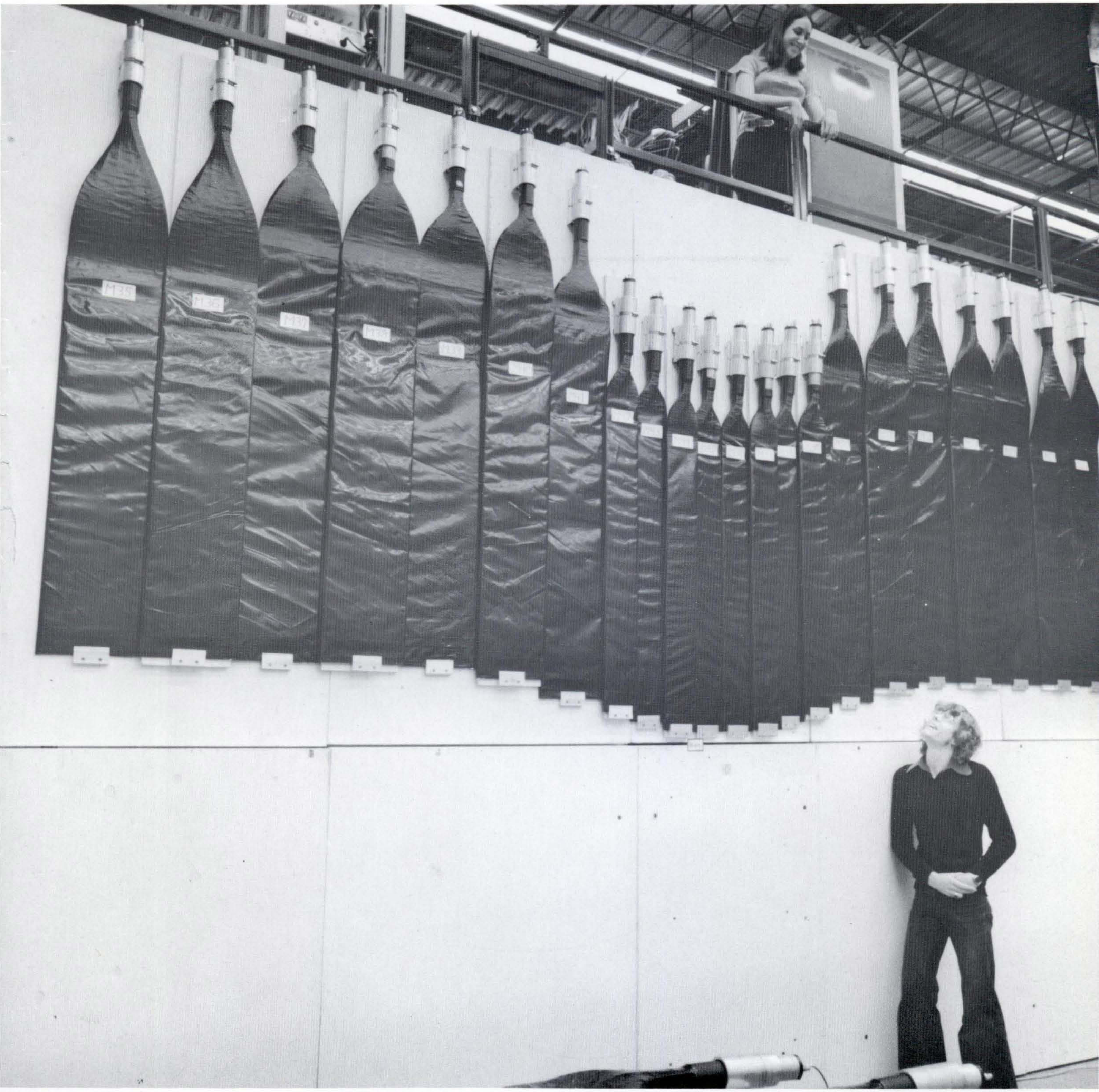
Physics Department technicians and engineers have built a complete spectrometer including several clusters of drift chambers and readout electronics. This set up is in testing now and slated to have first data early in the spring of 1981.



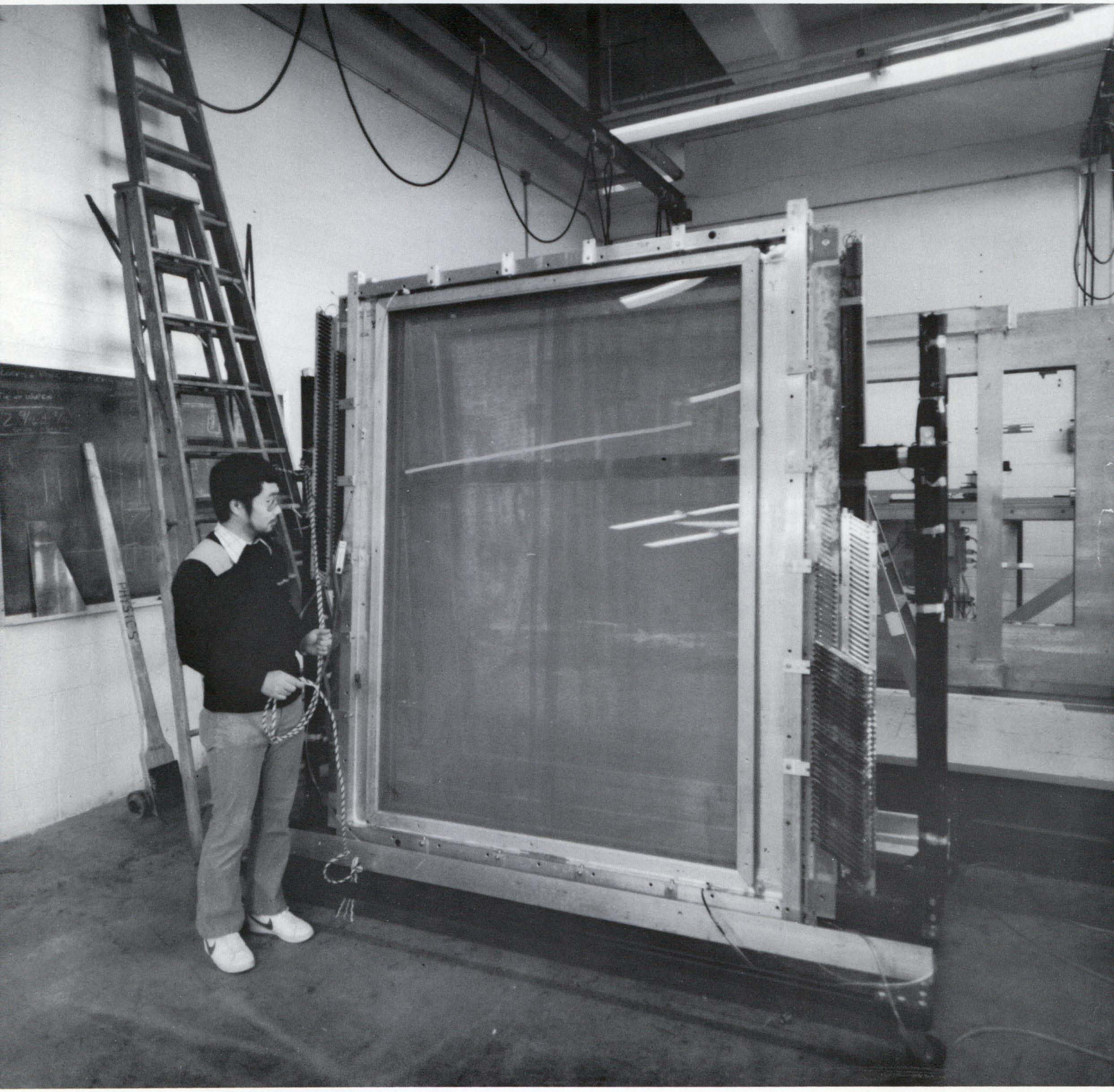
Light guides for scintillation counters manufactured in the Physics Department plastic planar machine shop.



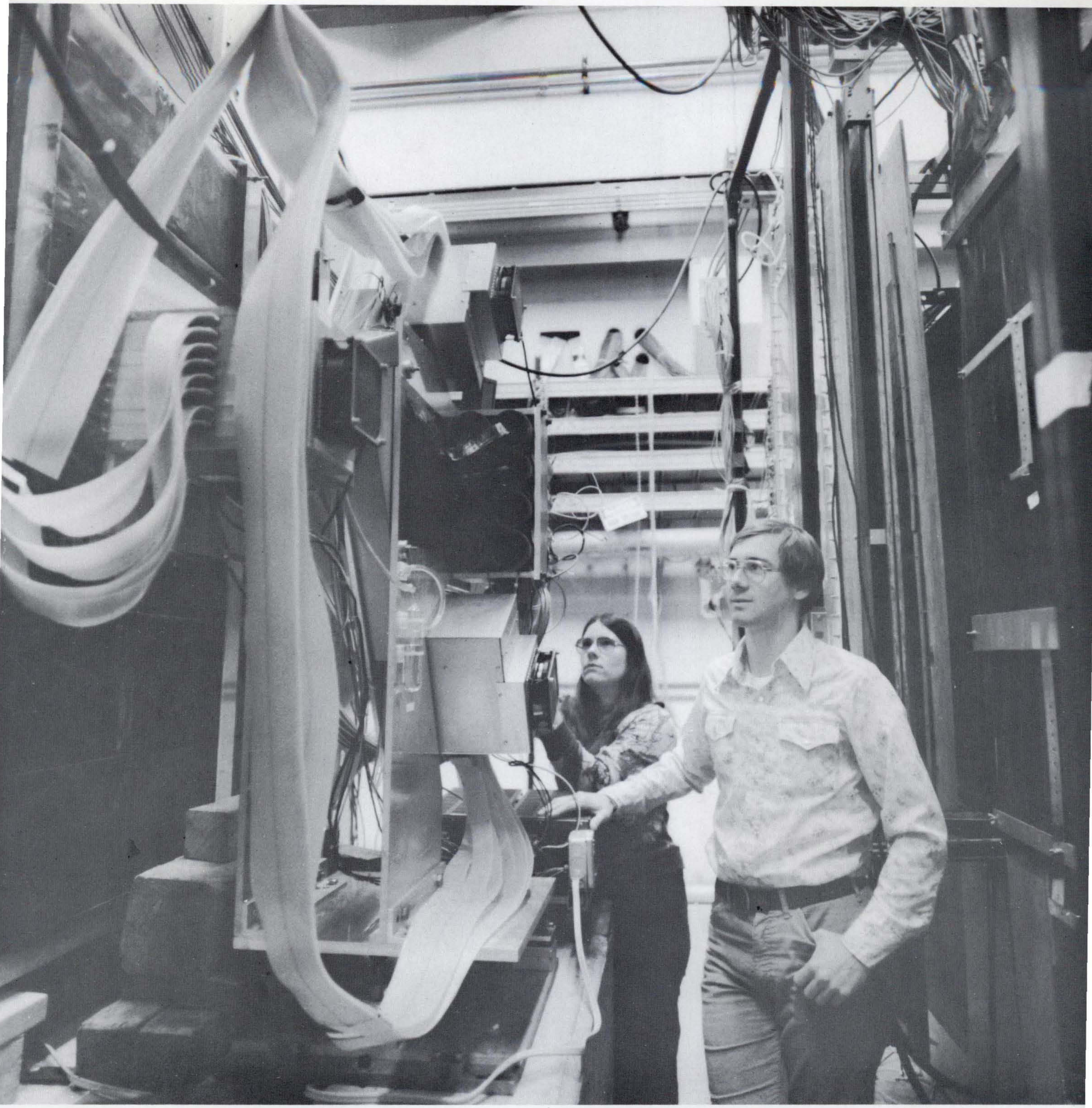
Sally Smith, Rich Rivera, and Ron Davis (left to right) insert the scintillation counter into an E-516 hadron calorimeter.



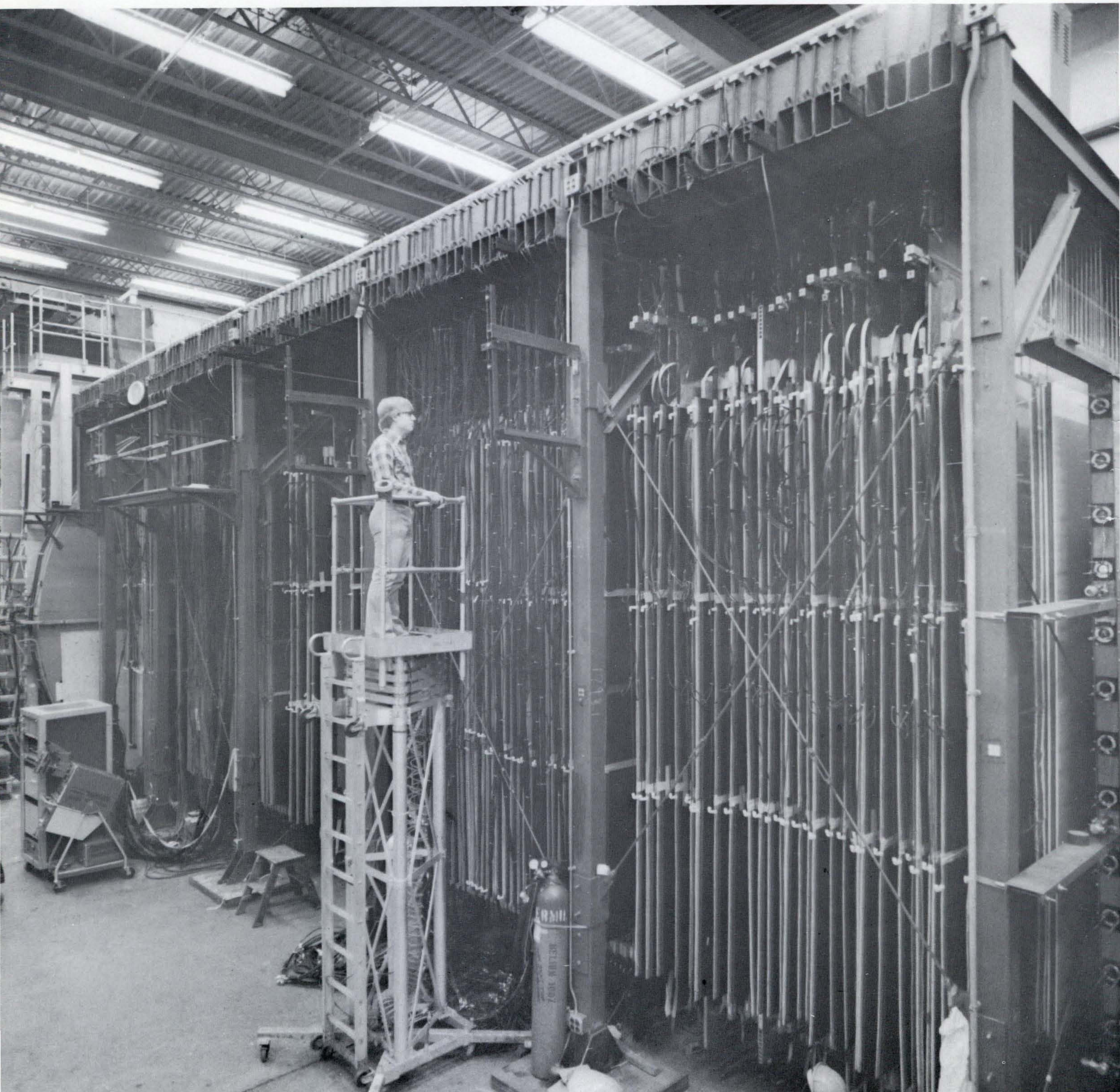
Mu-meson trigger counters for E-610. Pictured are (top) Dee Hahn from the University of Illinois and Chris Davis, Purdue University.



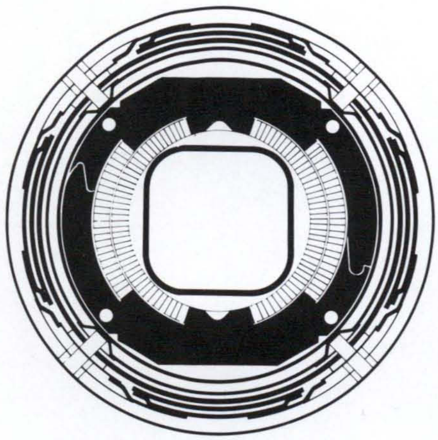
Katsu Sugano supervises the transportation of a just completed wire chamber for E-605.

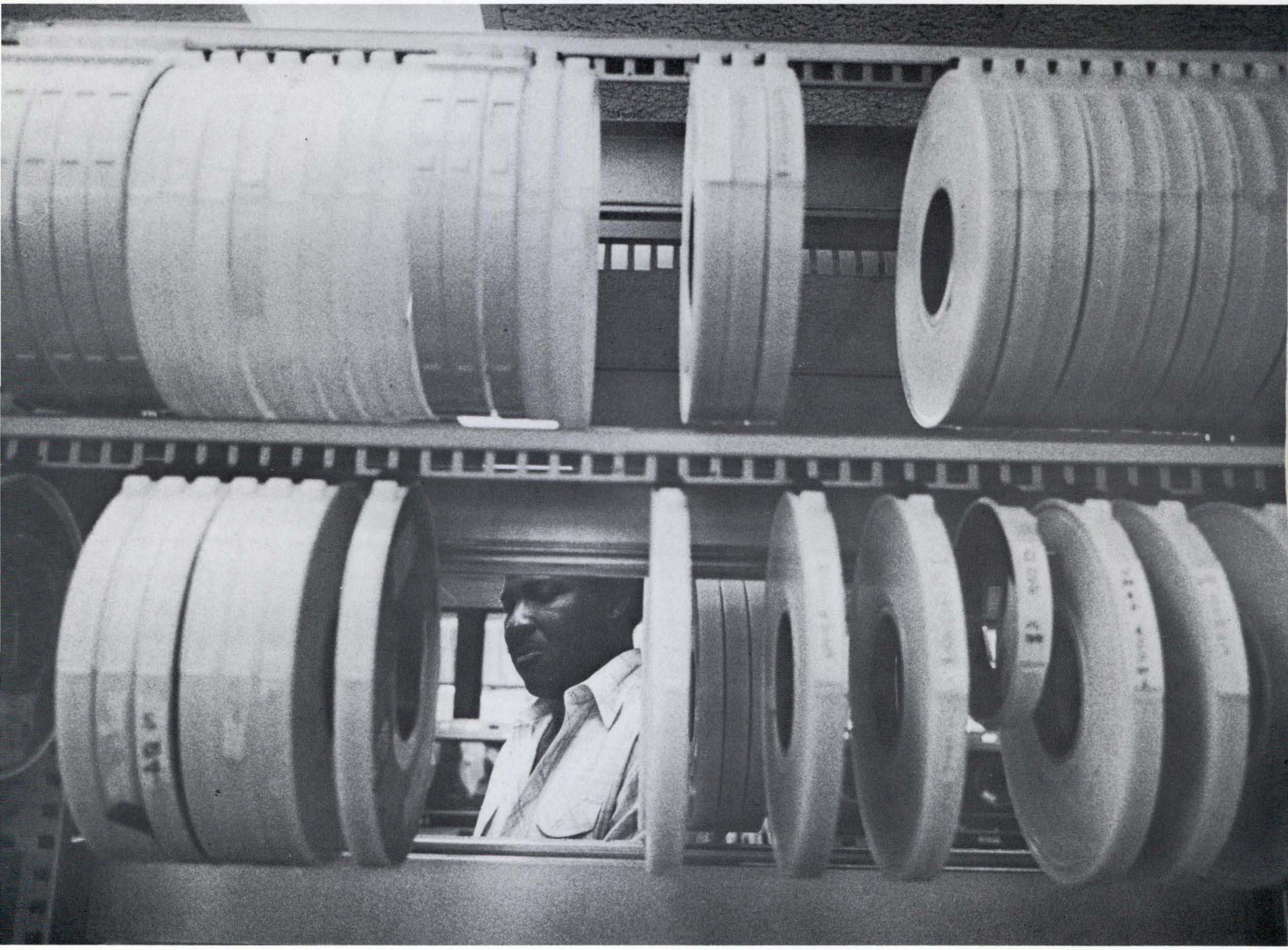


Karen Marie Kephart and Robert Kephart observe the fit of the multiwire detector in the E-537 setup.



John Slate, student from Michigan State University, inspects the flash-chamber assembly of E-594.





Computer Operator, Floyd Sample, retrieving magnetic tapes for analysis on the Cyber 175 computers.

Computing Department

In response to major new technical opportunities, the Computing Department underwent a management reorganization and expansion of responsibilities during 1980. The most visible evidence of these events was the inclusion of PREP (Physics Research Electronics Pool) and Instrument Repair in the Computing Department and the relocation of these activities on the 6th floor west of Wilson Hall. Less visible, but even more significant, is the recognition of the increasingly intimate relationship of data-acquisition electronics and mini-computer data-acquisition systems. With this in mind, the Research Division has begun the commitment to more immediate coordination of these activities within the Laboratory.

The advent of distributed intelligence using microprocessor and hard-wired devices, trigger-processor systems, and the new FASTBUS electronic standards are all opening new capabilities in data acquisition. The effective and economical application of these devices and our concomitant opportunities require a coherent approach. The Laboratory is moving in this direction through the centralization of system design. This is the role the Computing Department has played in the past in the more limited data-acquisition systems which have led to extensive use of PDP-11 computers and the MULTI/DA data-acquisition software developed in the Department. The application of these systems to the major portion of experiments at Fermilab will serve as a model for the application of the new systems to as large a variety of experiments as possible.

Another important event during the year was the initiation of a Users Forum. The first meetings of this type were held during this past year. At these meetings, users are invited to interact directly with members of the Computing Department and suggest areas of current difficulties and future support needs.

In the area of central computing, which received particular attention at the first Users Forum, efforts are ongoing to tailor the still-new Cyber computer operation to the particular needs of the Fermilab community. Those areas receiving particular attention at this time are improving the job-scheduling and job-flow management algorithms, computer graphics and microfiche output, file management, and eventually tape staging. In addition to supporting the off-line analysis needs of the many running experiments at the Laboratory, the Cyber system is also now used on-line by the Physics Department Film Analysis Facility. The Cybers replace the dated and operationally expensive PDP-10 that was formerly used for this purpose. The Cyber computing system is also being widely used throughout the Laboratory for word-processing systems. These common systems increase the power of the secretarial staff and, through the use of more uniformity of hardware and procedures, allow greater flexibility in responding to fluctuations in the distribution of secretarial workloads.

In the area of support services, a new IBM 4331 computer system has been delivered to the Laboratory. This system is intended primarily to support the business computing activity and remote job entry to Argonne National Laboratory formerly done on the IBM 360/50. Business applications will now have available a Data Base Management System (MRI System 2000). This hardware and software capability will be used to support such diverse groups as the Business Office, Program Planning Office, and PREP. The applications include inventory control, cost accounting, property records, and budget reporting.

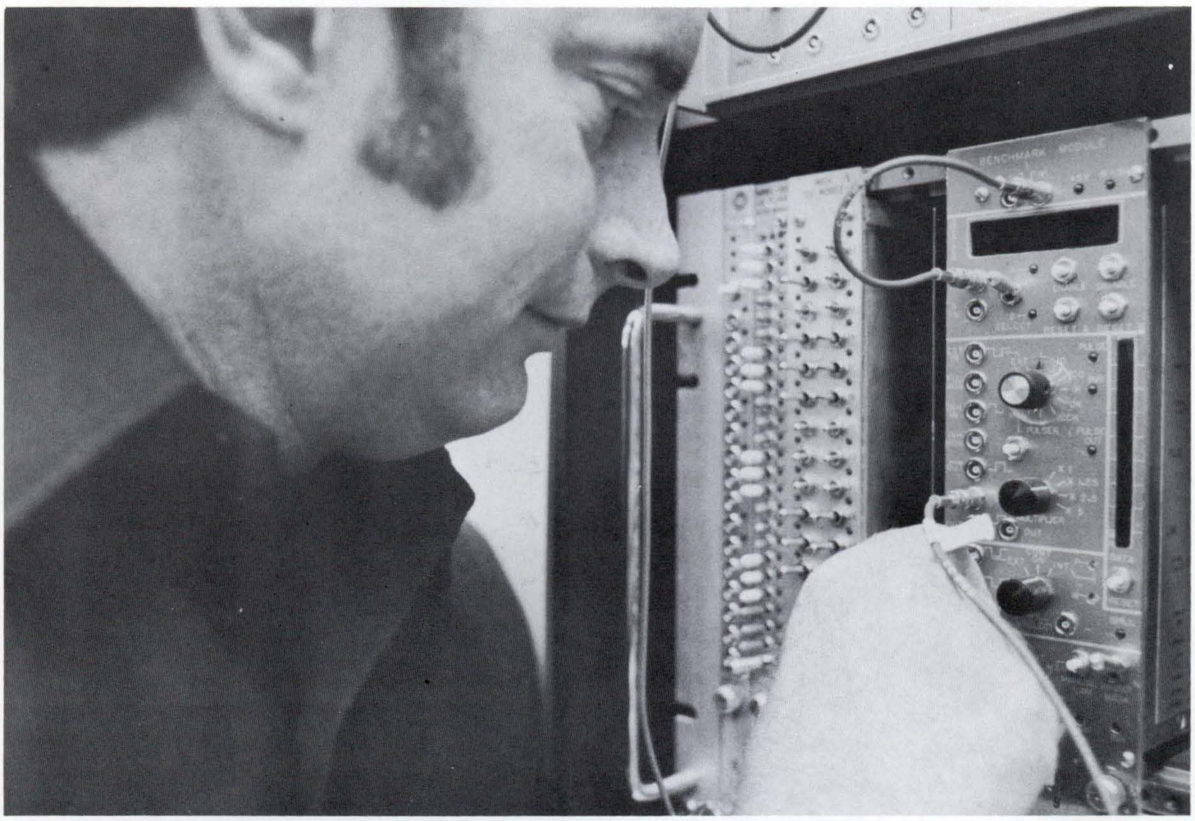
In the area of applications software support, a number of additional and new activites have taken significant efforts this year. Of particular note is the support of the simulation studies for the Energy Saver Cryogenic system. In this activity, an attempt is being made to understand the future cryogenic system of the Energy Saver through the application of computer studies of the operation, instabilities and other time-dependent features of this wholly new technological system. More traditional simulation studies are also being performed in conjunction with the Colliding Detector Facility group.

A number of significant innovations have occurred in the area of data-acquisition computing during the year. The first is the delivery to a series of experiments of the new 6250-bpi magnetic tape drives to enhance the data-writing capability of the highest rate experiments. In addition, a bank-switchable bulk-memory device is receiving its first test in an actual experimental situation. This hardware, developed from specifications by the Computing Department, is coupled to a new data-acquistition software package that is linked directly to an existing MULTI monitoring program. This new hardware-software system is expected to provide significant improvement in data throughput over existing systems.

An interesting device developed in the Computing Department, a "benchmark module," was used in developing both the high-density tape-drive software and the bulk-memory software. This device simulates the experimental interrupts and data of typical Fermilab experiments so that software can be tested and debugged. Since this device simulates an actual experiment, it allows members of the BISON Software Group to test out new developments in advance of their implementation in experiments. In this way, the time required to bring up a new system, especially during valuable beam time, is reduced to a minimum.

Three new developments in data-acquisition systems are receiving software design attention at this time. They are the use of coupled computers in a single integrated data-acquisition system, the application of 32-bit mini-computers in the data-acquisition activity and the implementation of the FASTBUS electronics standard. The design studies for coupled computers is being done in a way that allows a staged progression of enhanced capability. The coupling may include a number of 16-bit PDP-11 computers or even one of the 32-bit VAX computers. This year marked placing of the first order for a VAX computer by the Laboratory. Finally, software support for FASTBUS hardware engineering activities by two separate groups at the Laboratory has become a regular part of the Computing Department activity this year.

The year 1980 saw a large increase in the dependence of experiments on systems-based data-acquisition electronics. Among the systems being more widely used in experiments are drift-chamber time digitizers, computer-controlled high-voltage distribution networks, and analog-to-digital converters (ADC's). In this last area, the concentrated work of the Laboratory Evaluation Group in the PREP area resulted in a new ADC system being delivered to a half-dozen experiments. This system has finally become available after several years of coordinated effort by the Laboratory staff and the outside vendor. This integrated subsystem approach to data acquisition using new distributed intelligence coupled to data-acquisition computers has motivated the expanded Computing Department responsibilities.



Technical Specialist Larry Bays connects "Benchmark Module" for use simulating a high-energy physics experiment to allow development of new software.

Ignacia Cuevas and Jim Meadows prepare to test one of the new 6250 bpi tape drives before delivery to a data acquisition computer for one of the high-energy physics experiments.

Central Computing Operations Manager, Gene Dentino (left), and Manager of Computing Services Jack Pfister stand near disk drives in the Cyber computer area. →

Lois Psonak, Pat Oleck, Mary Hill, and Elaine Moore (left to right) are familiarizing themselves with the centralized word processing facility now in growing use throughout the Laboratory.

Theoretical and experimental physicists from different institutions frequently interact at Fermilab, like this impromptu gathering during the Colliding Detector Facility workshop held at Fermilab in November. Participating in this discussion are (left to right) Roy Schwitters from Fermilab and Harvard University, Chris Quigg, head of Fermilab's Theoretical Physics Department, Art Garfinkel, Purdue University, and Willy Chinowsky, University of California at Berkeley.

Theoretical Physics Department

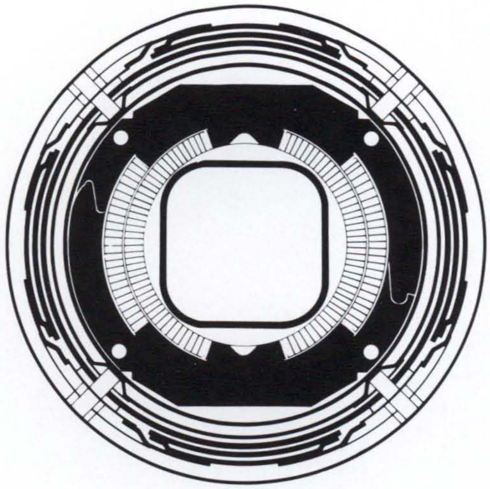
Recent research activity has covered many of the most timely and important topics in high-energy physics. Members of the group have continued to elaborate the predictions of perturbative Quantum Chromodynamics (QCD), the theory of the strong interactions among quarks and gluons, and to investigate the consequences of QCD in the nonperturbative regime. The experimental success of gauge theories of the strong, weak, and electromagnetic interactions has led to attempts to further unify the fundamental interactions. Several aspects of grand unification, includng schemes based upon the idea of dynamical symmetry breaking, have been actively studied. The proliferation of apparently fundamental constituents--the quarks and leptons--has led some to question whether the quarks and leptons might not themselves be composite. Speculations of this sort, and the challenges they encounter, have been studied as well. Interest in the systematics of weak decays has been reinvigorated at Fermilab as elsewhere by the discovery of charmed particles and the examination of new possibilities for the origin of CP-violation. There has continued to be intensive effort to learn the properties of the force between quarks through the study of quarkonium systems such as the ψ and Υ families of heavy mesons. Fermilab remains a center for the study of the quantum-inverse problem of two-dimensional field theories. Beyond the intrinsic interest these theories hold, it is hoped that this work may guide the way to an exact solution of QCD.

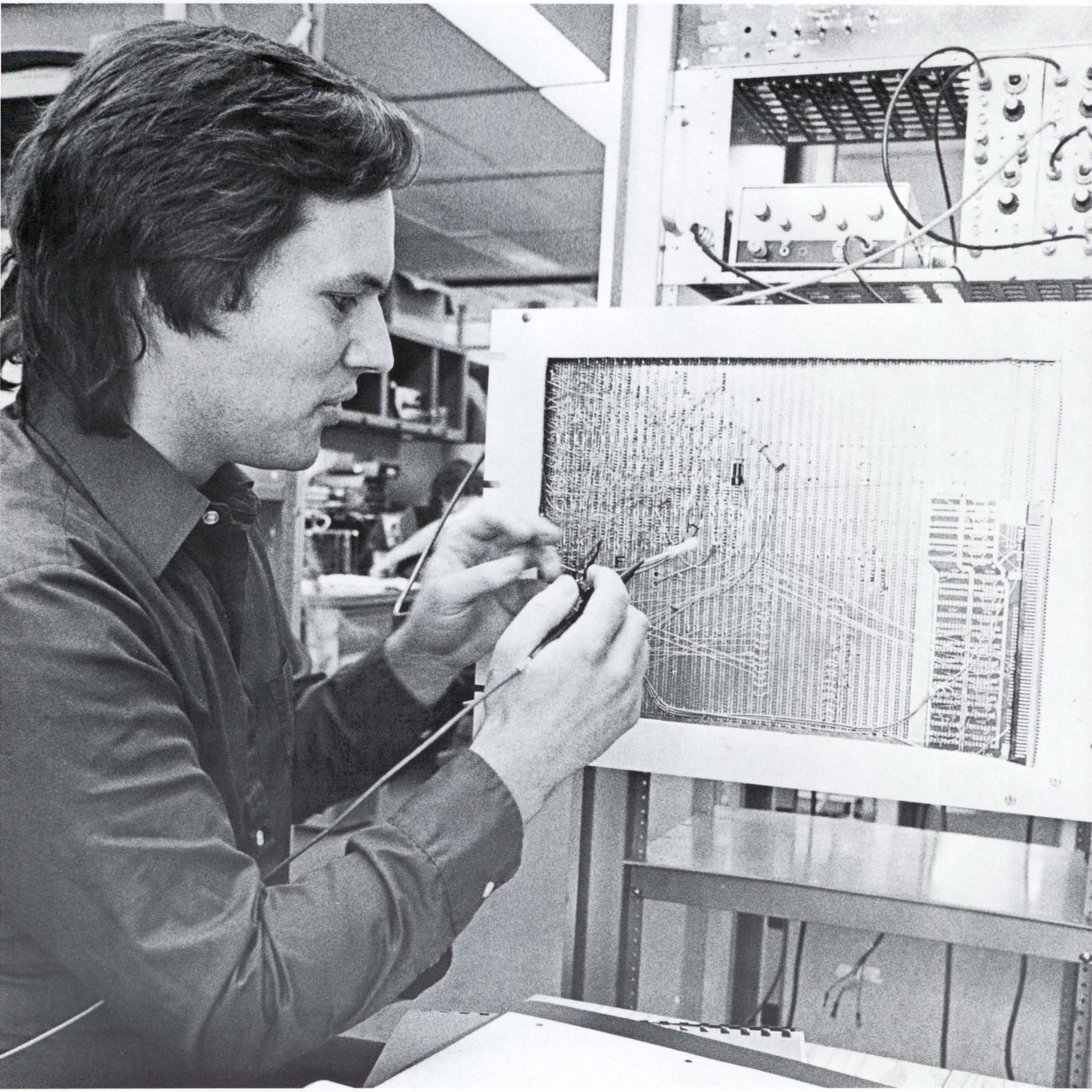
During 1980, the Theoretical Physics Department continued its steady growth in numbers and in reputation and maintained a visitors' program of high vitality. The group now has four permanent members, three five-year members, six research associates, and eight long-term visitors. Several faculty members at nearby universities are also active participants in the research program. The level of theoretical activity at Fermilab will continue to increase over the coming years.

More than 200 visitors have been provided facilities (and in many cases, support) during the past year. In most cases, visits last for periods of a few days to a month. This vigorous program is one of Fermilab's most significant contributions to the well-being of theoretical research in the universities. The stimulation, both theoretical and experimental, provided by these visits has been of considerable value to many visitors.

The large flux of visitors also benefits Fermilab in important ways. It enriches the in-house theoretical activity and exposes experimentalists to a wide range of theoretical ideas and opinions. A special effort has been made to involve promising young theorists, as well as established senior theorists, in activities of the Laboratory.

The Theoretical Physics Department makes key contributions to the intellectual life of the Laboratory, and of the international scientific community. Members of the department organize weekly theoretical seminars and the weekly joint experimental-theoretical ("wine and cheese") seminars, as well as occasional workshops and special lecture series. An expanded series of Academic Lectures on current research topics is heavily dependent upon Fermilab theorists. Members of the group are frequently called upon to speak at Laboratory workshops or informal soirees on specific physics topics. A few members of the group regularly participate in meetings of the Laboratory's Physics Advisory Committee. Others have become involved with particular proposals or experiments. Of course, informal interaction with experimentalists takes place constantly. Members of the department are also constantly in demand as invited speakers at international symposia and as lecturers at summer schools.





Richard Kadel with a FASTBUS scanner card.

Colliding Detector Department

The completion of the Tevatron I construction project will bring a unique opportunity to Fermilab, the possibility of investigating $\bar{p}p$ collisions at 2 TeV in the center of mass. This will represent the highest-energy man-made collisions yet achieved and will remain so for some time in the future. This opportunity carries with it the unique technical challenge of designing and constructing a powerful yet flexible detector that will respond both to the expected discoveries (W and Z bosons) and unexpected new phenomena existing at these high energies.

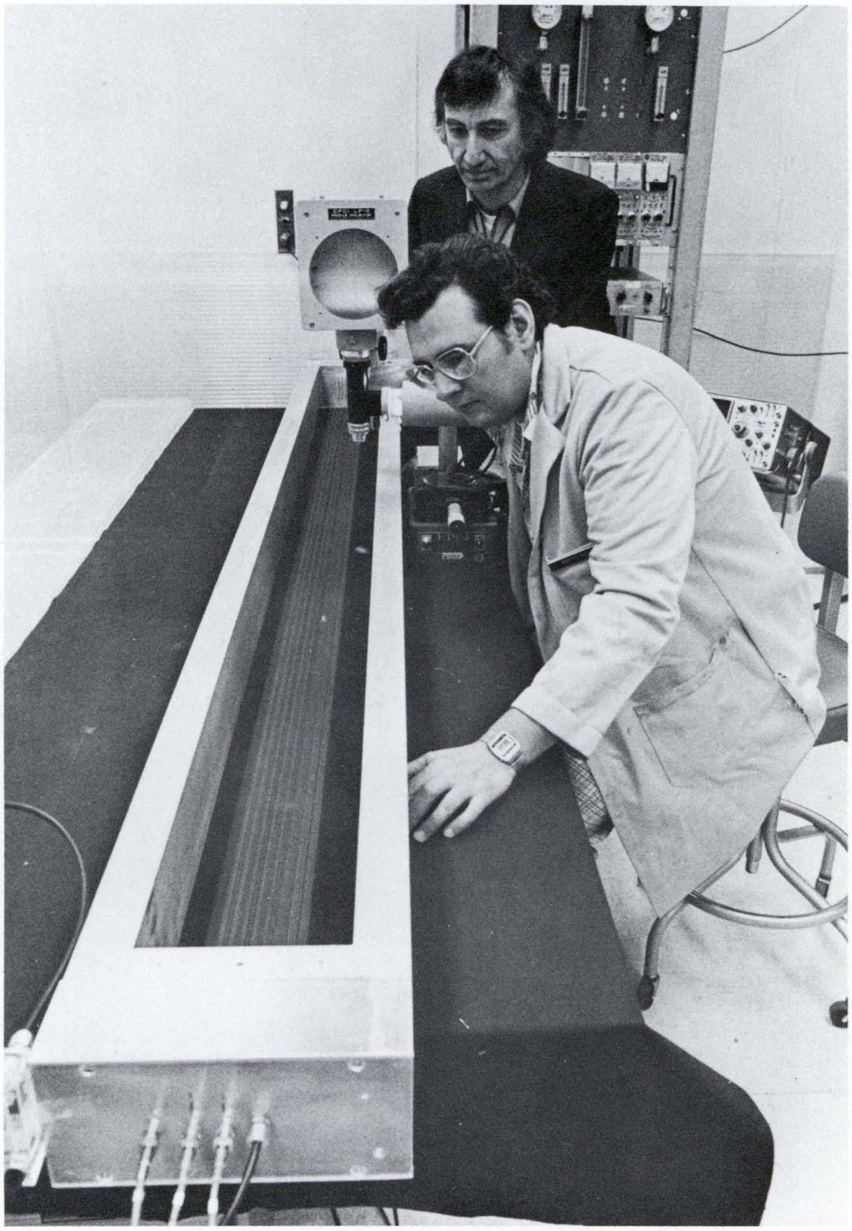
An international multi-laboratory collaboration headed by the Fermilab Colliding Detector Facility Department has been formed to meet these challenges. Present collaborators include the University of Chicago, Harvard University, University of Illinois, Purdue University, Texas A&M, University of Wisconsin, Argonne National Laboratory, KEK and University of Tsukuba in Japan, and Frascati and University of Pisa in Italy.

Current activites include final design of the overall detector and extensive prototype work on various subsystems. Among the significant technical problems confronting the group requiring innovations in detector design are

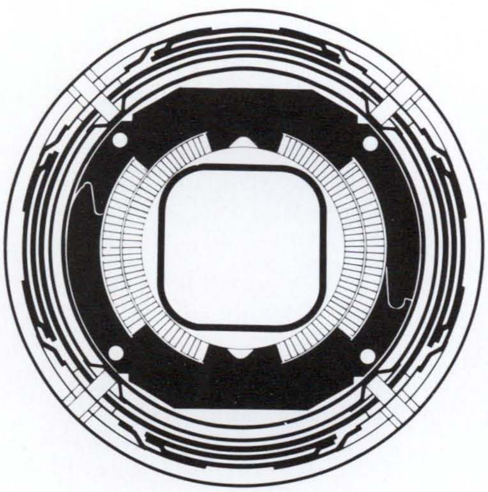
1. The superconducting solenoid magnet. A central feature of the detector is the 5-m long, 3-m diameter, 1.5-Tesla thin-coil superconducting magnet. Construction of a 1-m long, 1-m diameter model, using a new technique, extrusion with front tension, to bond the superconducting wire to the aluminum stabilizer, is under way in Japan.

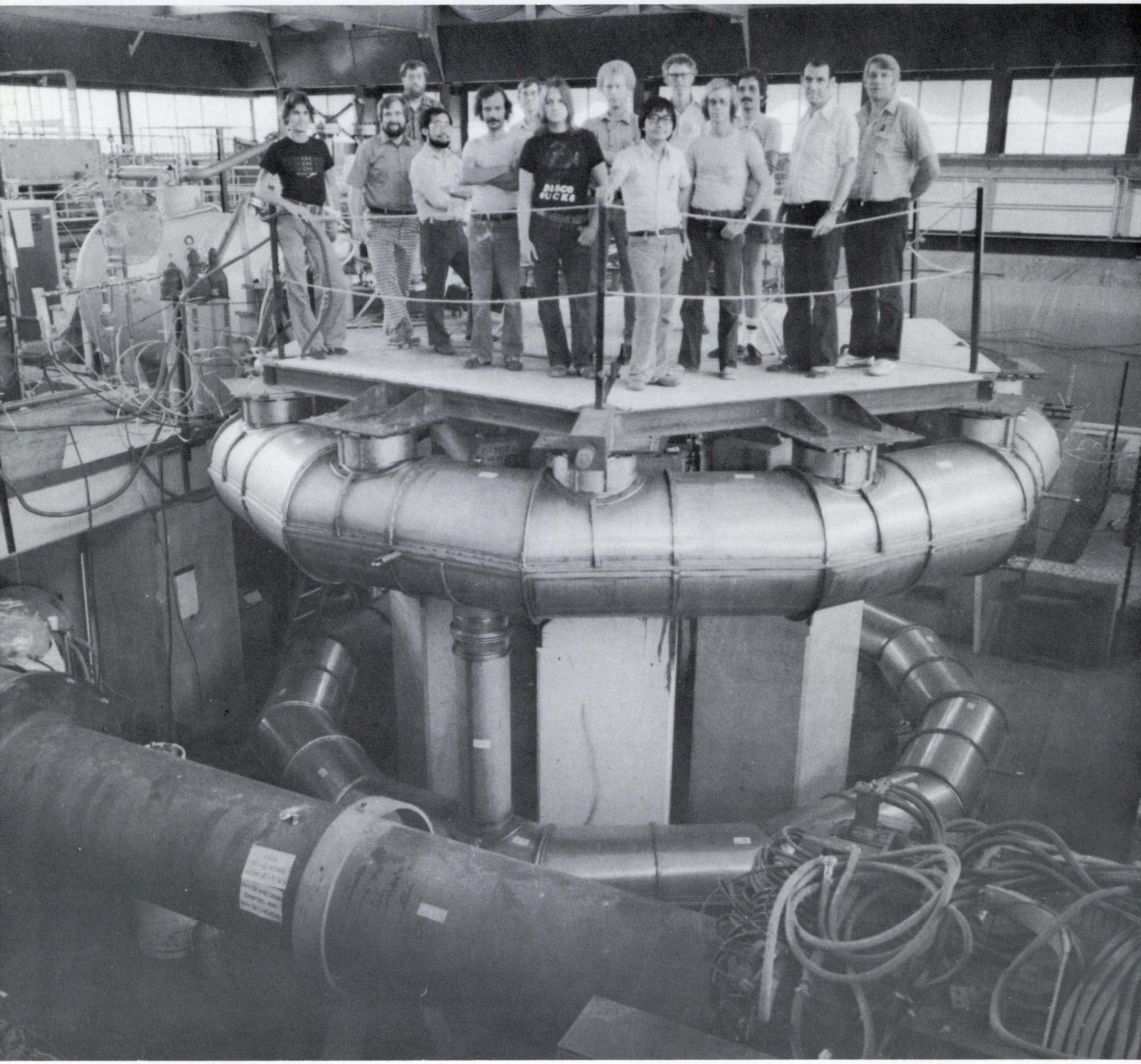
2. Data collection. The large number of electronic readout channels and the high data rates require a very powerful data-collection system. A system, based on the FASTBUS standard, that makes extensive use of distributed intelligence is now under consideration.

A workshop dedicated to the physics of 2-TeV $\bar{p}p$ collisions was held on November 5-8 at Fermilab. About 20 phenomenologists and theoretical physicists joined with the experimental physicists in the CDF collaboration to work out questions of relevance to the detector design. Expected processes of particular interest and their experimental signatures were identified, and the requirements to the detector for efficient detection were discussed. As a follow-up, rates of several reactions will be calculated with programs now available on the Fermilab Cyber. Working topics include: W,Z physics, heavy quark production, hard jets and QCD tests, new particles, and physics at small angles to the beams.



Muzaffer Atac (background) and Michael Hrycyk check wire deflections in a drift-chamber prototype.





Superconducting Chicago cyclotron magnet for E-610. Standing on a temporary platform built over the superconducting coils are (left to right) Kevin Havemann, Phil Calahan, Bob Bennett, Albert Ito, Jim Monaco, Bob Kephart, Barry Skinner, Jim Pace, Eddie Leung, Morris Binkley, Steve Gordon, Steve Dochwat, Howard Hart, and Gene Smith.

Research Services Department

Research Services provides engineering and other technical support for the research program as well as other sections of the Laboratory. This support includes such things as mechanical and electrical engineering, construction and operation of hydrogen targets, surveying and prototype printed circuit board fabrication.

The mechanical engineering effort is concentrated primarily on the development of large analysis magnets for experiments. The department builds both conventional and superconducting magnets, but the main emphasis is on the latter. The electrical engineering support covers control systems, specialized high-speed electronics for data acquisition, and power supplies for both superconducting and conventional magnets. Presently the department is divided roughly equally between mechanical and electrical engineering.

Last August marked the successful test of one of the largest superconducting magnets in the world (the coil diameter is approximately 20 feet). This magnet was built by replacing the conventional coils in the Chicago cyclotron magnet with superconducting ones. The test indicated that the projected consumption of liquid helium will be only 13 liters an hour which also makes this a very economical magnet.

The design of a superconducting coil for the 30-in. hydrogen bubble-chamber magnet was also completed in 1980. This conversion, together with the Chicago cyclotron magnet mentioned above, is part of a long-range Laboratory program designed to enhance the experimental facilities while also making a significant contribution to energy conservation.

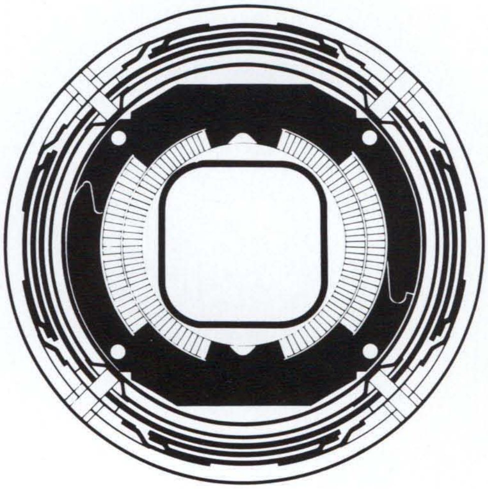
The number of interesting events that an experiment can record per hour may determine the success or failure of an experiment and it certainly affects the number of experiments that the Laboratory can run in a year. Thus a major effort of the electronic groups is to devise instruments that will select the interesting data from the background. These devices are called "trigger processors" because they are a type of high-speed computer that determines if an event is interesting before triggering the data-recording part of the experiment.

Two rather different types of trigger processors were commissioned in 1980. The first was used to measure the effective mass of muon pairs for Experiment E-400. This design is quite similar to an ordinary computer except that its instruction set was optimized for the specific problem and dedicated hardware was used for some calculations.

The E-516 trigger processor was also used to measure the effective mass of a collection of particles. This one was built from a series of modules doing a specific type of operation. The processor is programmed by connecting various modules together in a particular way. This method appears to be faster than the previous one but it is also less flexible.

Research Services also operates the controls systems for the experimental areas. It provides both the hardware and software necessary to measure and control particle beams. In 1980 the final steps in implementing a new computer system were completed. The new software system has many aids, such as a user-programmable language, that should improve the Laboratory's ability to deliver useful beam to the experiments.

Other electronic projects include the successful operation of a very low noise amplifier (300 to 500 attocoulombs) for the E-515 liquid argon calorimeter. To set the scale for this, one attocoulomb is about 6 electrons. Development is continuing in an effort to reduce the noise level to 100 attocoulombs or less. These amplifiers will be needed for the new generations of solid-state detectors that are now being developed.



"M7" trigger processor for E-400. Pictured are (left to right) Merle Watson, Kathy Turner, Tom Droege, Dave Harding, Tom Wesson, Irwin Gaines, and John Peoples.

Members of the Fermilab Users Executive Committee for 1980-81 are (left to right) Frank Turkot, Fermilab; Melvin Schwartz, Stanford University; John Rootherford, University of Washington; Thomas J. Devlin (secretary), Rutgers University; Vincent Peterson, University of Hawaii; Sharon Hagopian, Florida State University; Charles M. Ankenbrandt, Fermilab; Phyllis Hale (secretary to the chairperson), Fermilab; Thomas Romanowski, Ohio State University; Lawrence W. Jones (chairperson), University of Michigan; Richard Gustafson, University of Michigan; and Konstantin Goulianos, Rockefeller University. Not pictured are George Brandenburg, Harvard University, and Henry Frisch, University of Chicago.

Users Organization

The Fermilab Users Organization is a nationwide 800-member group of particle physicists, together with graduate students and senior engineers who share a serious interest in the Fermilab program. A thirteen-member Users Executive Committee (UEC) meets bimonthly to represent the Users interests and to explore concerns that arise in the interaction of the users with the Laboratory. Six members of the UEC are elected annually for a two-year term (the retiring chairman serves three years). It may be remarked that this body is the only elected group of elementary-particle physicsts representing the nation as a whole except the officers of the Division of Particles and Fields of the American Physical Society. During 1980-81, the members of the UEC were Charles Ankenbrandt, George Brandenberg, Thomas Devlin, Secretary; Henry Frisch, John Rutherfoord, Konstantin Goulianos, H. Richard Gustafson, Sharon Hagopian, Lawrence Jones, Chairman; Vincent Peterson, Thomas Romanowski, Melvin Schwartz, and Frank Turkot.

Concerns of the UEC generally fall into three classes: the interaction of the users with the technical facilities of the Laboratory, the external affairs of the Laboratory, and the non-technical amenities of the Laboratory as they affect users. A perception of these functions may be found in some specific recent examples.

The UEC meets with the Laboratory Director and other Laboratory senior staff periodically to maintain close contact with Laboratory planning, programs, and operations. Concerns such as reliability of accelerator operations and communication between experimentalists and the main control room are shared and discussed with the appropriate people. As an example of one initiative that is currently being pursued, the UEC has asked the Laboratory to explore the feasibility of broadcasting the internal channel-13 TV signal (accelerator status, ramp, spill, and general information) at low power on an available UHF TV channel.

The UEC does not involve itself in program decisions, but the Director does seek from the UEC a slate of candidates for the Program Advisory committee, from which some of its members are selected. The UEC has also conferred with the Director on a policy statement concerning non-U. S. group proposals to Fermilab. This was stimulated by a policy proposal authored by John Adams and circulated by the International Committee on Future Accelerators.

The annual meeting of the Fermilab Users Organization last spring coincided with a visit to the Laboratory by members of the HEPAP subpanel on future facilities (the Woods Hole Panel), and the UEC had discussions with the Panel members on the occasion. Part of the program on the following day was a round-table discussion by UEC members and others on the Fermilab program. It is tempting to believe that this interaction with the Woods Hold Panel helped to improve their perception of the Fermilab program.

The broad constituency of the UEC and the users in general may also be called upon to interact with Washington on matters affecting Fermilab support and related government policies. For example, last spring the budgetary crisis led to action in the House Appropriations Committee that threatened serious cutbacks in the DOE high energy physics program. Together with similar groups, members of the UEC interacted with their local representatives to clarify the interest of the widespread community of university scientists in the vitality of the Fermilab program. The UEC is also interested in maintaining and strengthening close ties with the Universities Research Association Board of Trustees and executive officers. Officers and members of the UEC have also participated with other senior Laboratory staff in discussions with the URA review committee and with visiting DOE executives.

A frequent concern of the UEC is the problem of on-site housing for Fermilab users. Housing is perennially tight, especially during summer months and the UEC works with the Laboratory in efforts to expand the available housing, to monitor the quality, and to advise the Laboratory management on questions of allocation, procedures, and rates. In recent years, a Quality of Life Committee has been established at the Laboratory to represent the interests of visitors and employees in non-technical matters. The UEC nominates members to this committee and works with it in seeking solutions to user problems.

The UEC is effective if the Director and his staff are receptive to the Committee input and if the Committee membership gives serious, responsible, and intelligent consideration to the issues before it. Under such circumstances the Users Organization and its Executive Committee can work very effectively with the Laboratory management for the best interests of the Laboratory, its program and its user community. Fortunately, this seems to accurately portray the present situation.

Physics Advisory Committee

The experimental program at Fermilab is determined by the Director after consulting with the Physics Advisory Committee (PAC), which is composed of twelve members appointed by the Director. Six of the members were appointed to the PAC after being nominated by the Users Executive Committee.

Proposals received by Fermilab are referred to the PAC for their consideration. The majority of these are presented in open meetings of the PAC. After these presentations, the PAC discusses the proposals and raises, if necessary, additional questions for the experimenters to answer. After receiving the responses, the PAC makes a recommendation to the Director. With its recommendations in 1980, the PAC made a major contribution to the present 400-GeV program as well as to the future Tevatron program.

The year 1980 saw the response of the high-energy physics community to the first call for Tevatron proposals. In response to the call, Fermilab received 26 proposals for experiments using Tevatron neutrino and muon beams, in addition to 14 proposals for experiments at the present 400-GeV accelerator. The PAC met three times in 1980 and had an additional proposal presentation meeting to review these proposals. In the course of their deliberations, they concluded that the size of some experiments and their potential call on Laboratory resources meant that a simple approval was not appropriate. Rather, the PAC concluded that these experiments, which the PAC felt should be performed at Fermilab, could be approved only if adequate resources were available to do the experiments within the context of the entire Fermilab program. For this reason some proposals would receive final approval in two stages. The new approval procedure was defined by the PAC as follows:

Approval Procedure

The Committee recommends that a new two-stage approval procedure be adopted. This procedure need not be used uniformly for all proposals, but only for those where it is appropriate.

(a) The Committee may recommend Stage I Approval if:
(i) the proposed physics goals are worthwhile
(ii) the experiment seems technically feasible, and
(iii) the cost in Laboratory resources and running time of the experiment appear to be appropriate for the expected physics results.

(b) Following a Stage I approval the experimenters and the Laboratory will carry out a careful technical design and cost study for the experiment, and a first draft of the Agreement between the Laboratory and the experimenters will be prepared. If the results of this procedure are acceptable to the PAC, and the experiment fits into the overall priorities of the experimental program, Stage II Approval would normally be recommended.

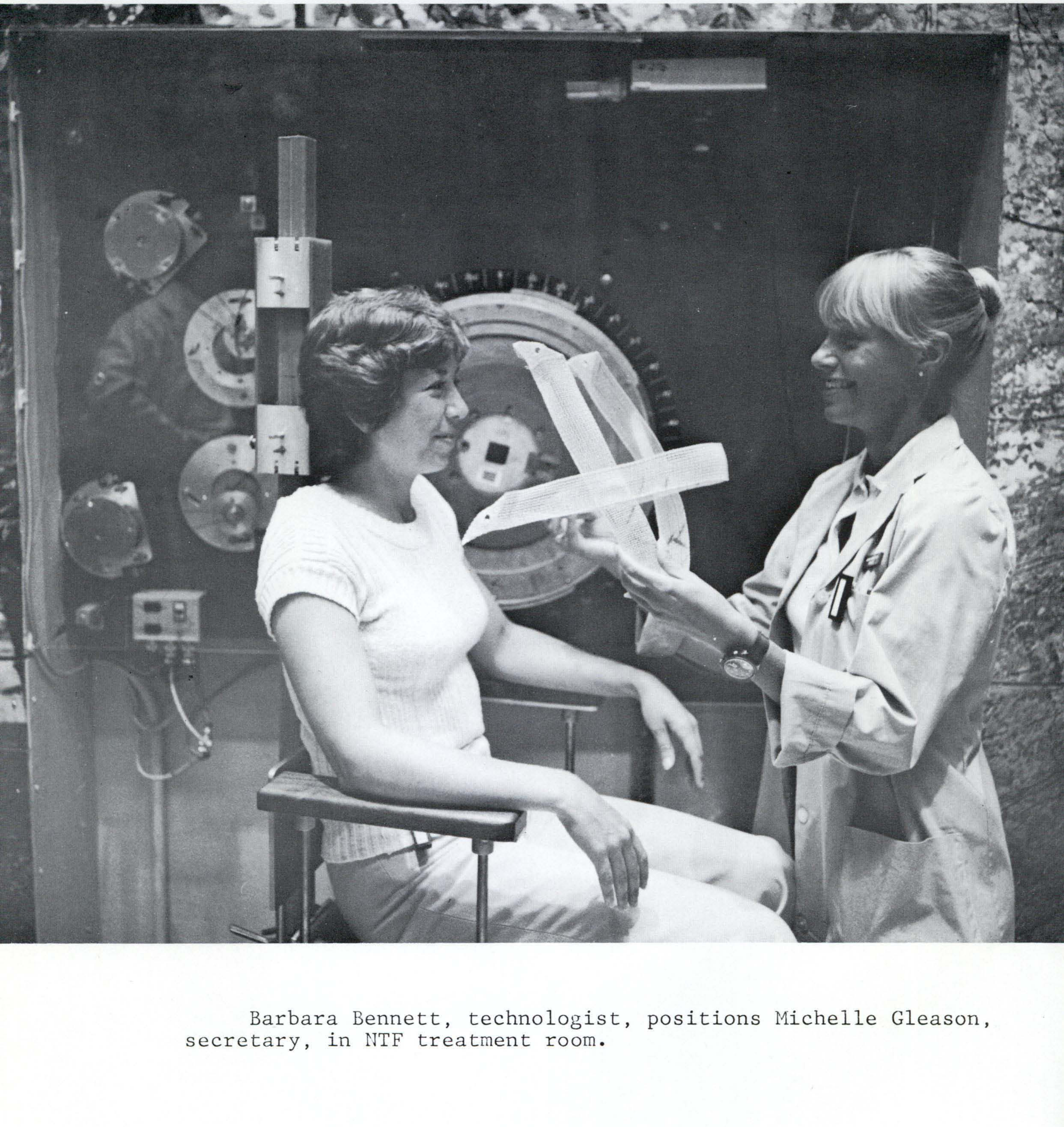
It must be recognized that Stage I approval does not represent a commitment of Laboratory resources, either in support for setting up the experiment or in running time. Rather, it is a mechanism for aiding Laboratory staff and experimenters in the planning of long-range projects. It is essential that the detailed PAC review precede Stage II consideration just as with any normal proposal.

In 1980 the PAC recommended that 9 experiments be approved and that 7 be rejected. Of the approvals, three were Stage I utilizing the new procedure. In addition, decisions on 13 proposals were deferred and 9 proposals remain unconsidered. Two proposals were withdrawn. The recommendations were accepted by the Director.

Physics Advisory Committee Membership 1980

Name	Institution	Term Expires
Stephen Adler	Institute for Advanced Study	3/80
Charles Baltay	Columbia University	3/81
Edmond Berger	Argonne National Laboratory	3/83
Karl Berkelman	Cornell University	3/82
Wit Busza	MIT	3/83
William Carithers	LBL	3/81
Malcolm Derrick	Argonne National Laboratory	3/80
Frederick Gilman	SLAC	3/81
Myron Good	SUNY, Stony Brook	3/82
Francis Low	MIT	3/80
Martin Perl	SLAC	3/82
James Pilcher	University of Chicago	3/81
Lee Pondrom	University of Wisconsin	3/82
Roy Schwitters	Harvard University	3/81
Edward Witten	Harvard University	3/83

Ivan Rosenberg, medical physicist, adjusts NTF controls.



Barbara Bennett, technologist, positions Michelle Gleason, secretary, in NTF treatment room.

Neutron Therapy Facility

A total of 259 patients were referred to the Neutron Therapy Facility for consideration for treatment during the twelve-month period ending on October 3, 1980; 116 of these patients have been entered in the national neutron studies, 25 were not treated for various reasons, and 124 were treated as either local-protocol patients or pilot patients. Local-protocol or pilot-study patients are those who refuse to participate in the national study, have relatively unusual tumors, or are not eligible for the national studies because of previous treatment.

Although the national trials began in 1975, the Fermilab NTF treated its first patient in September 1976. Despite a late start, the NTF has entered more patients into the national trials than any other neutron facility in the United States.

Drs. Cohen and Hendrickson are the authors of 6 of the 13 currently active national neutron studies. In addition, they are working on new protocols for glioma (brain), esophagus, pancreas, and head and neck. The new generation of protocols for these tumors will be designed to optimize treatment with or without radiosensitizers.

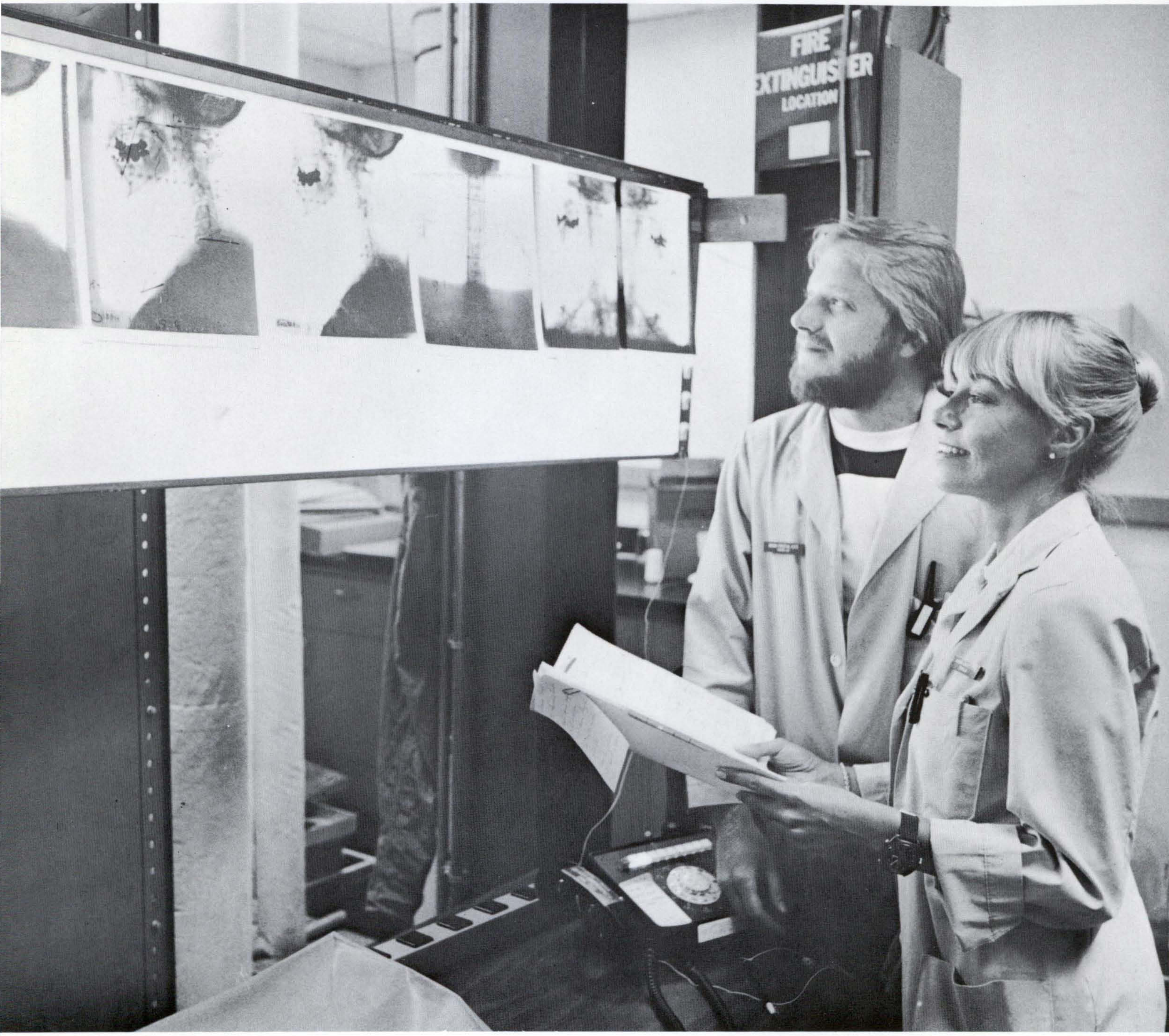
The National Cancer Institute has awarded Fermilab a five-year extension to the present six-year grant. This means that clinical research may continue until June, 1985.

As more experience is gained at the NTF, it has become clear that medical research should be carried out in a medical environment. In particular, the drawbacks of the present installation are

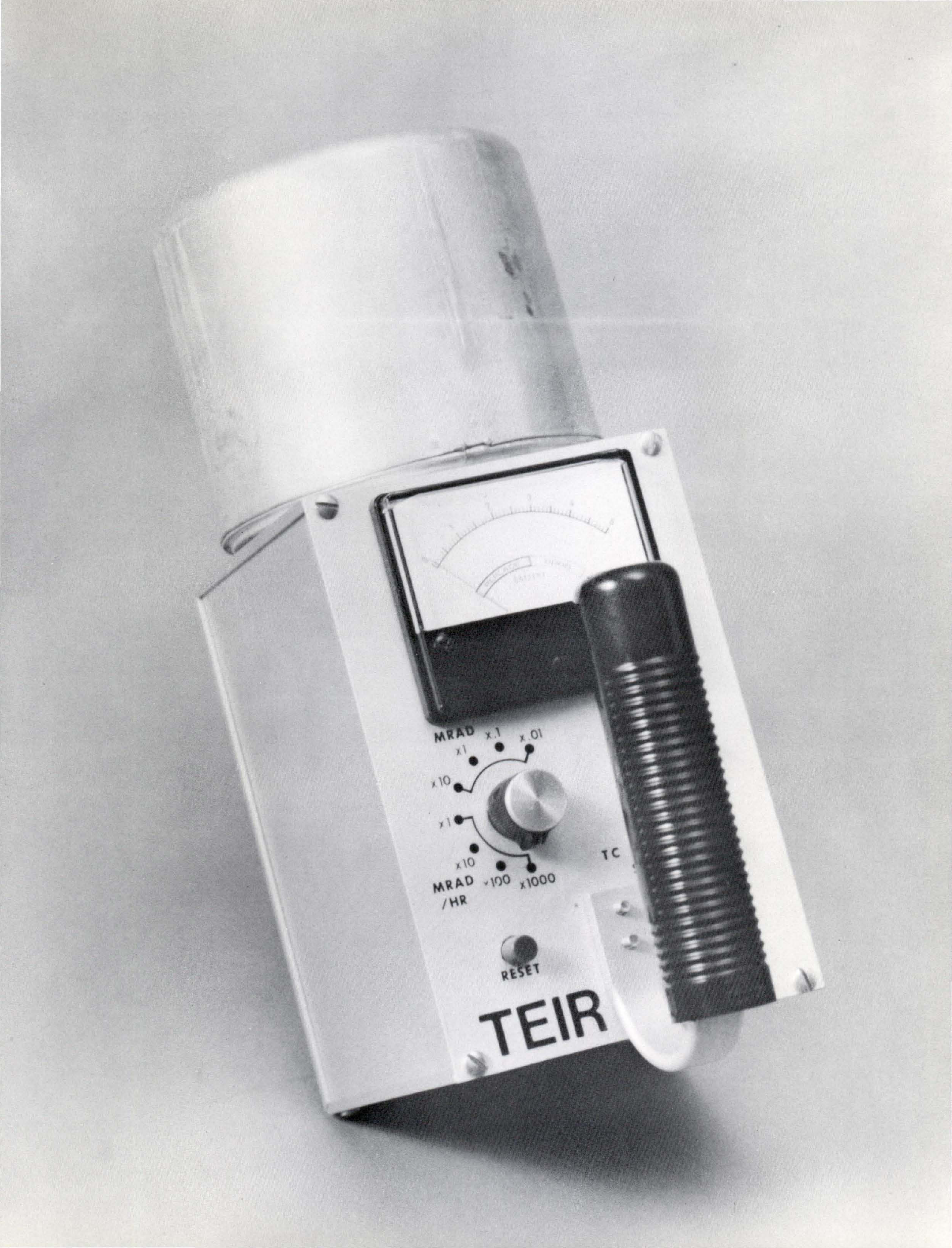
(i) a fixed horizontal beam that does not allow the use of CT information for tumor localization in the abdominal volume, and

(ii) a bias in the patient population sample because it is effectively divided into groups strong and not strong enough to travel long distances.

Fermilab is therefore assisting a consortium of hospitals and medical schools in Chicago, as well as three major hospitals in the Midwest and East, in drawing specifications for a most-modern system for neutron radiation therapy and production of radionuclide-labeled pharmaceuticals. One of these systems would be installed in downtown Chicago.



Brian Pientak and Barbara Bennett, radiation therapy technologists, check patient X rays.


MRAD
x1
x.1
x.01
x10
x1
x10
x100
x1000
MRAD
/HR
TC
RESET
TEIR

Tom Anderson (left) and Fred Krueger with the new DEMUX chassis and TEIR.

Safety Section

The Safety Section is composed of the General Safety Group, the Radiation Physics Group, and the Environmental Protection Group.

General Safety

The General Safety Group monitors the construction projects, electrical and mechanical safety, safety of experiments, target reviews, and liaison with all Laboratory departments.

A new Safety Manual has been developed, printed, and distributed to Safety Officers and first-line management. Involvement in the Safety program begins with the Safety Manual, which outlines the philosophy of the program, describes required activities, and reviews the need for safety communications such as meetings, indoctrination procedures, and safety and health facilities. Special instructions on accident investigations and facilities inspections are also included.

Added programs were begun by the General Safety Group during 1980. Greater emphasis was placed on accident investigation and analysis as a defense against hazards and illnesses. A number of studies were made of work areas to detect and eliminate or control physical or environmental hazards which contribute to accidents. The training program was improved to increase the education, instruction, and training in an effort to minimize human factors which contribute to accidents.

Radiation Physics

The total Laboratory radiation dose this past year was 160 person-rems. The prior year was 180 person-rems. This is a continuation of the gradual decrease since 1974 when the total dose was 440 person-rems. This continued reduction reflects the improvements in equipment design, remote-handling equipment, and better training of the personnel involved in work in radioactive areas. An additional factor this past year has been the administrative goal announced by the Director to limit individual annual radiation doses to 2500 mrem/year. An alert system was devised to implement this goal.

Much of the staff time has been spent in reviewing and helping with the design of the many construction projects in the Neutrino and Accelerator Areas. In addition, three of the four new area Radiation Safety Officers came from the Radiation Physics Group.

A major improvement in the thermoluminescent dosimeter program was made by bringing a new, faster reading system on line and computerizing the data analysis.

A program to upgrade the central radiation-monitoring system (DEMUX) has begun. Already-completed improvements include chassis that allow the experimental areas to select locally the radiation detectors which they wish to monitor closely. The analogue output can be displayed on a rate meter and alarm levels may be set. Future improvements of the central system will include expanding the number of channels for detectors to accommodate the new and larger experimental facilities being planned.

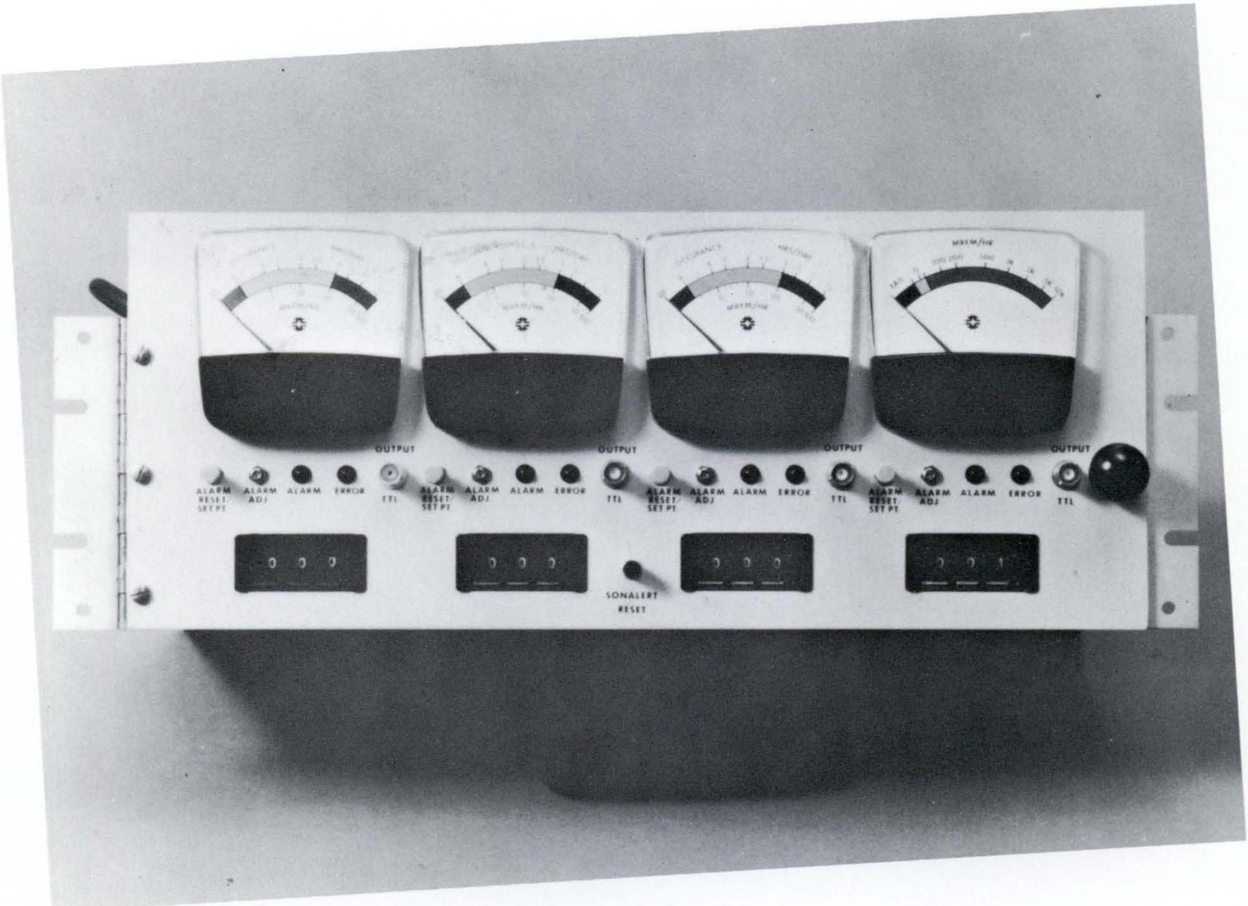
The arsenal of portable, beam-on, radiation survey meters was upgraded by the development of a "tissue equivalent integrating rate meter" (TEIR). This instrument utilizes commercially available ionization chambers and in-house electronics. It can be used as either a rate meter or integrating device.

Environmental Protection

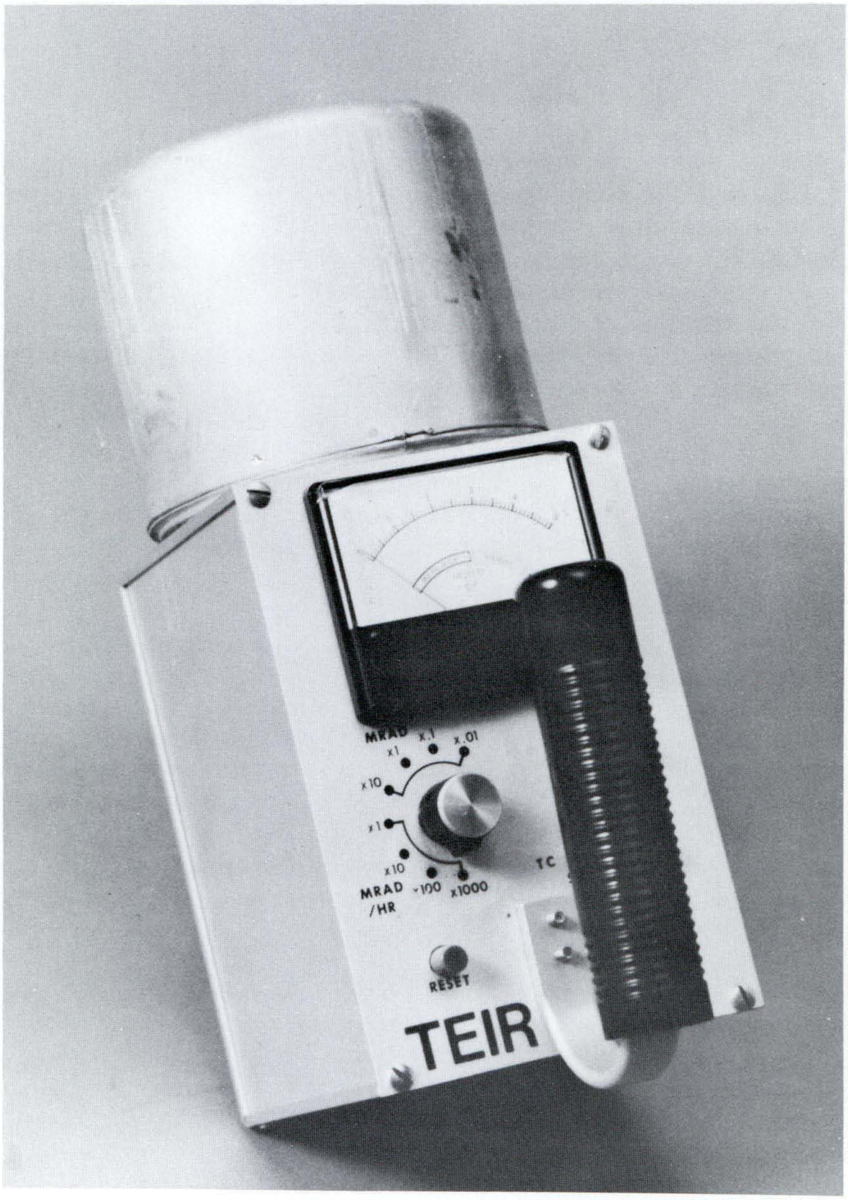
The Environmental Protection Program, covering both radioactive and non-radioactive environmental pollutants, is under the direction of the Senior Environmental Protection Officer. Support is given by the Environmental Protection Group within the Safety Section and by Environmental Protection Officers and Radiation Safety Officers who have been appointed by the operating groups at the Laboratory.

The Environmental Protection Group has expanded its activities in hazardous waste storage and disposal this year. A new storage area with spill containment was completed. Efforts were increased in spill prevention, control, and countermeasures throughout the Laboratory.

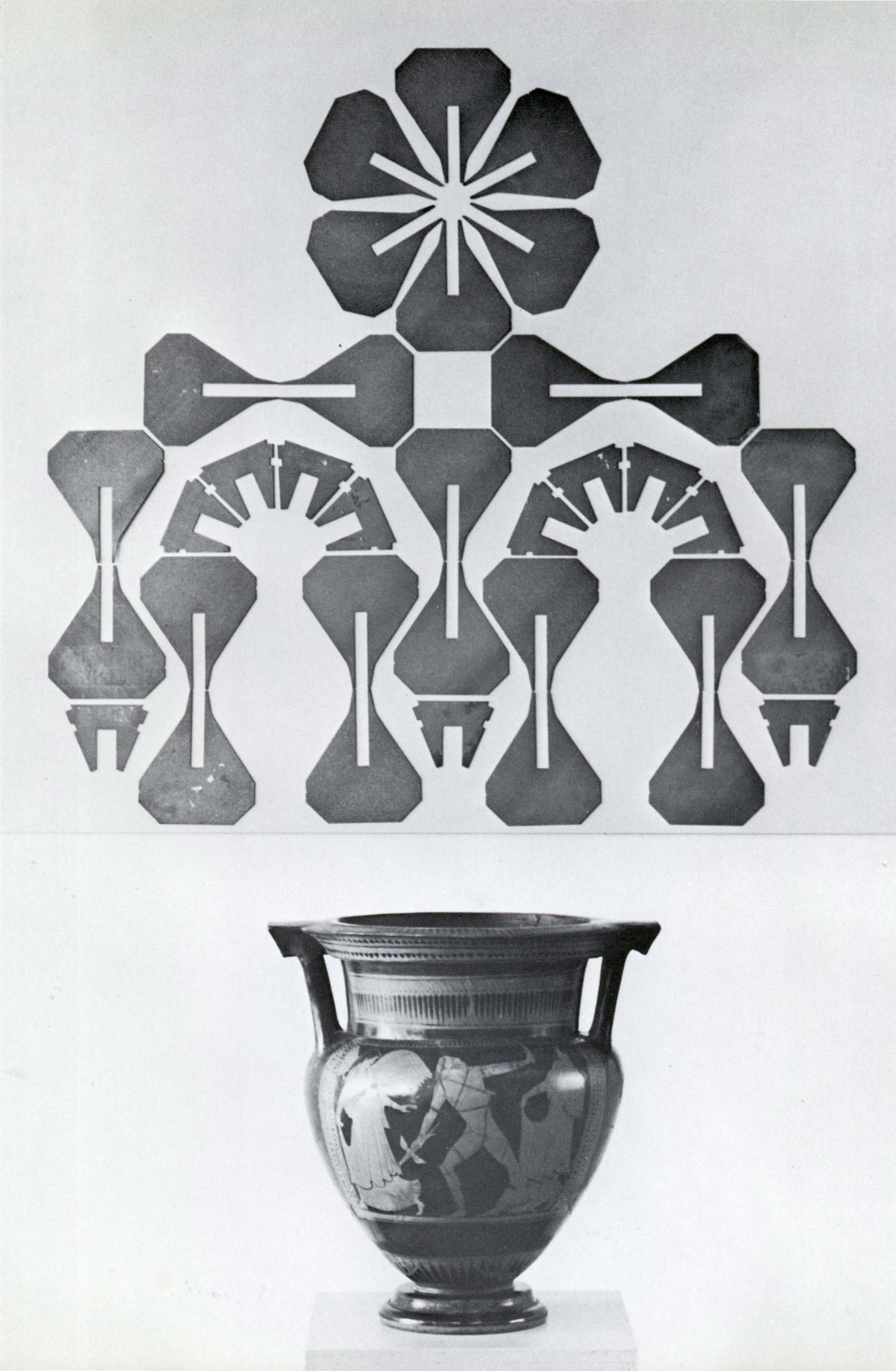
A new Health and Environment Subcommittee of the Laboratory Safety Committee was appointed this year with the Senior Environmental Protection Officer as its first chairman. This committee has taken an active role in the development, implementation and review of the Environmental Protection Program.

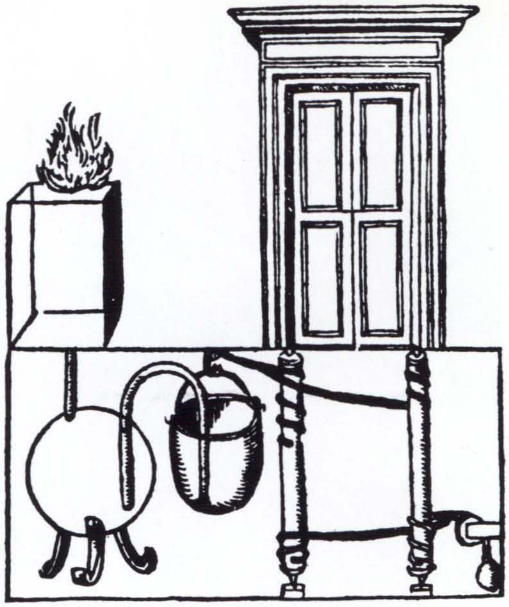


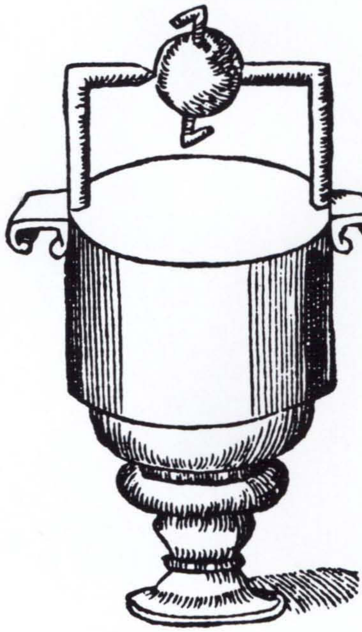
The new DEMUX chassis that allows the operating areas to closely monitor radiation levels.

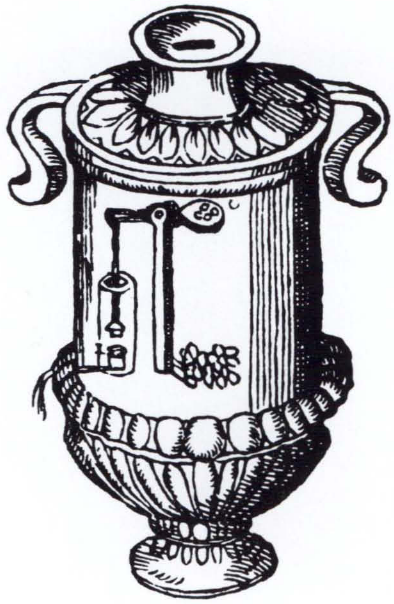


TEIR, the new portable beam-on radiation survey instrument.



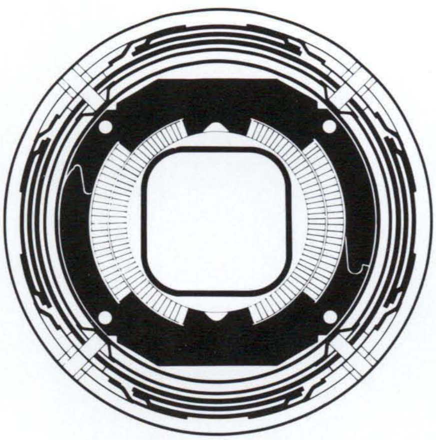


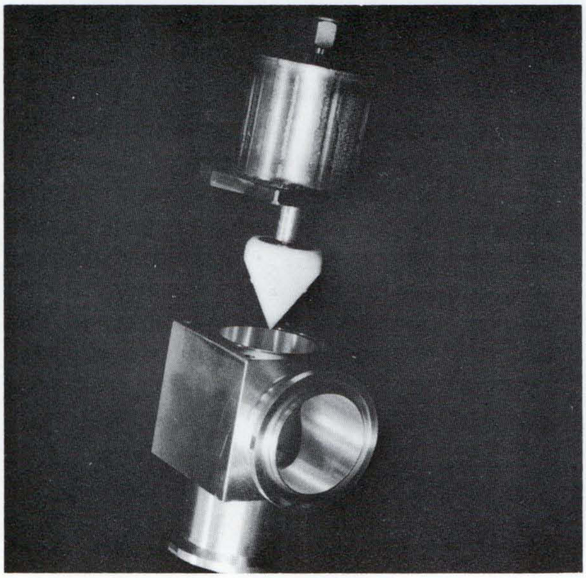




Technical Innovations

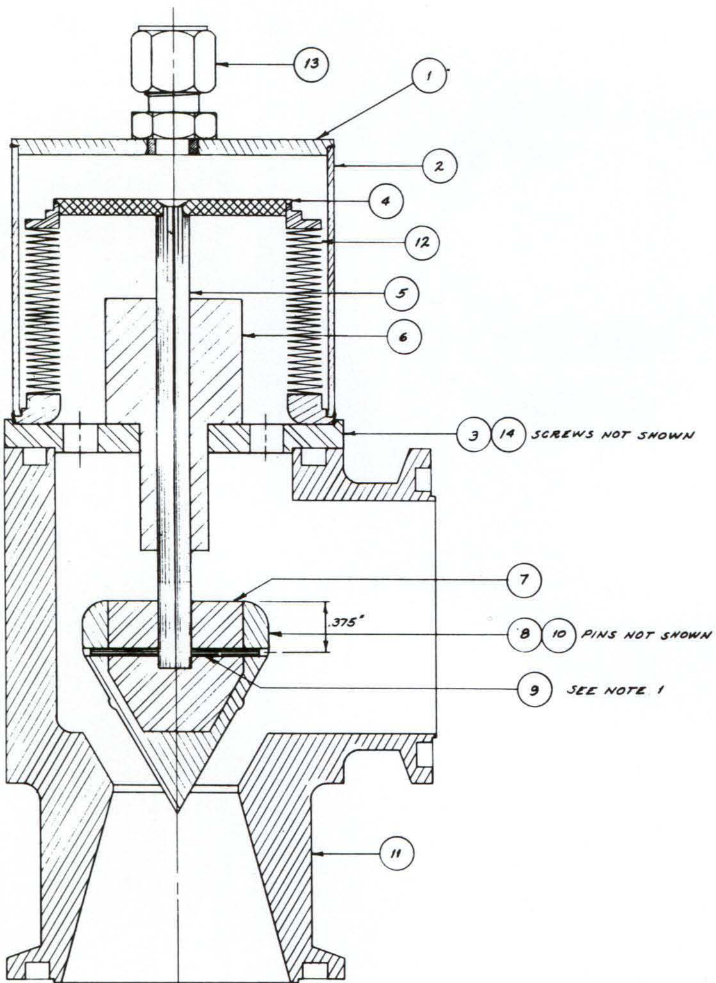
In the course of furthering the work of the Laboratory, engineers and scientists frequently conceive and develop new, innovative devices. These ideas may not always lead to publication or patents, but they are vital to the work of Fermilab. It is this continual flow of new ideas that makes it possible to operate and improve our systems for physics research. In this section, we salute a few of the technical innovations made at Fermilab.





1

2



3

SUGGESTED WELDING SEQUENCE:

1. SHAFT TO BELLOW TOP FOR CONCENTRICITY
2. BELLOW BOTTOM TO FLANGE.
3. BELLOW TOP TO SHAFT ASS'Y.
4. CYLINDER TO FLANGE.
5. SWAGELOCK TO UPPER LID.
6. CYLINDER TO UPPER LID.

NOTE: CUT FLANGE BOTTOM SEAL STEP LAST TO FIGHT DISTORTION (TAPE CLOSE HOLES NO CHIPS IN BELLOWS)

NOTES:

1. AFTER ASS'Y ONLY, DRILL THRU ON CENTER ITEMS 5, 7 & 8 FOR 1/16" SS. PIN (ITEM 9) & THEN INSERT PIN (PRESS FIT).

NOTE: VALVE SHOWN IN HALF OPEN POS.

NOTE: ALL MATERIAL STAINLESS STEEL 304 EXCEPT FOR THE FOLLOWING:
1. VALVE BODY - ALUMINUM
2. SEAL SUPPORT - ALUMINUM
3. GUIDE - BRASS
4. SEAL - TEFLON
5. CYLINDER - 2" SCHED 5 STAINLESS STL.

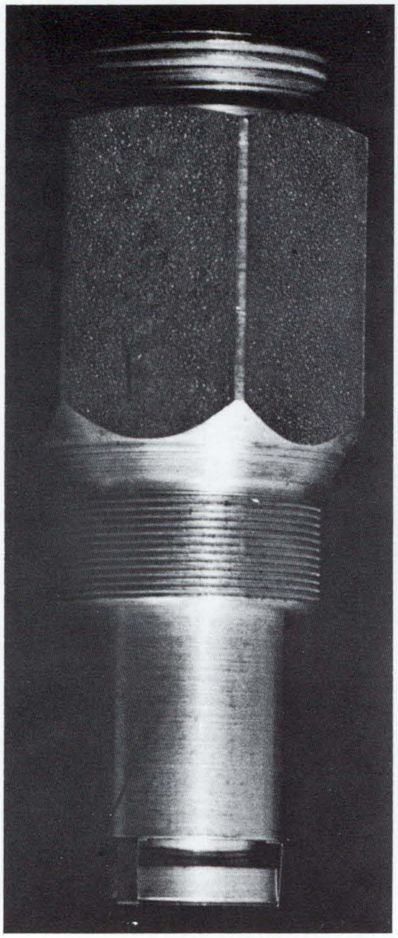
DOUBLER MAGNET QUENCH PROTECTION RELIEF VALVE

To avoid damage of cryostats during a quench caused by increased pressure of the cooling medium, a fast-acting cryogenic relief valve was needed. Commercial units failed to close reliably after a quench or did not perform under the most difficult conditions. The valves shown, designed by Hans Kautzky will be mounted on every magnet around the Superconducting Ring. They are smaller in size than most piloted valves, more flow-efficient, and completely passive, protecting magnets without being opened on command (in other words, fail safe).

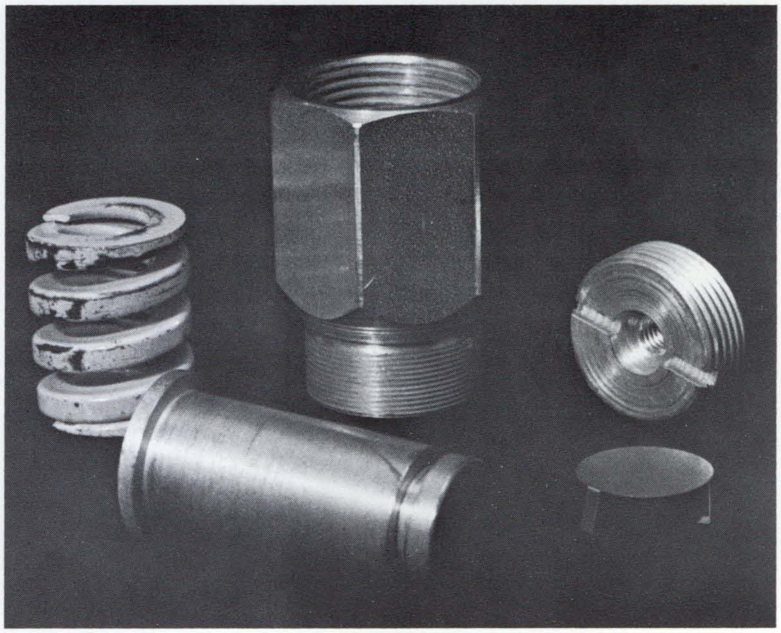
1 - Actuator and valve body.

2 - Quench protection relief valve assembly.

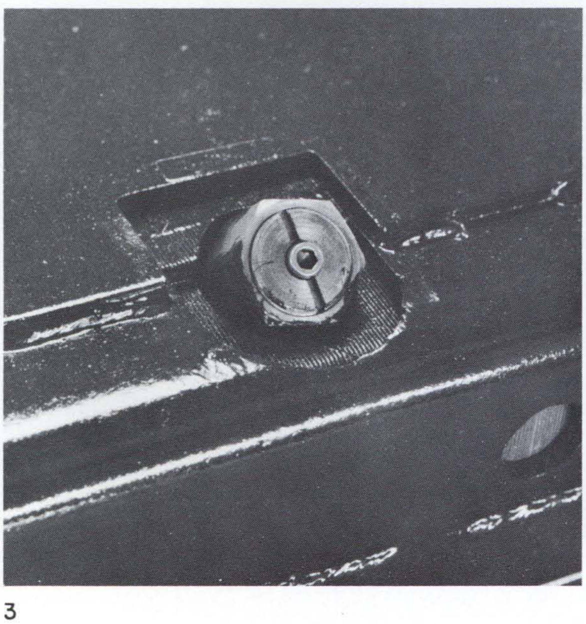
3 - Schematic of valve cross section.



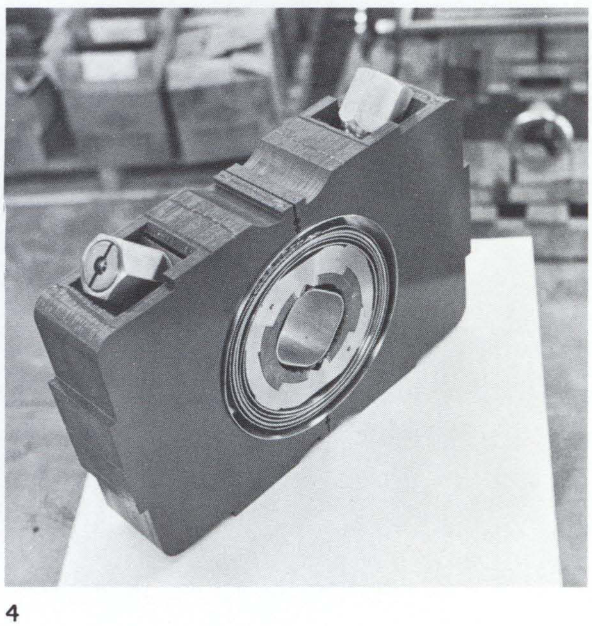
1



2



3



4

SMART BOLT

The difficult problem of the motion of the vertical plane of the magnetic field in an Energy Saver dipole cryostat under cooldown, which was a significant Laboratory problem for most of 1980, was finally solved by Richard Lundy using four opposed anchors at the center of the cryostat and a series of "smart" bolts containing spring-loaded pistons to maintain the preload on the cryostat at a constant pressure (1,000 psi), independent of the changes in size of the collared coil due to temperature, on the warm iron yoke suspension blocks.

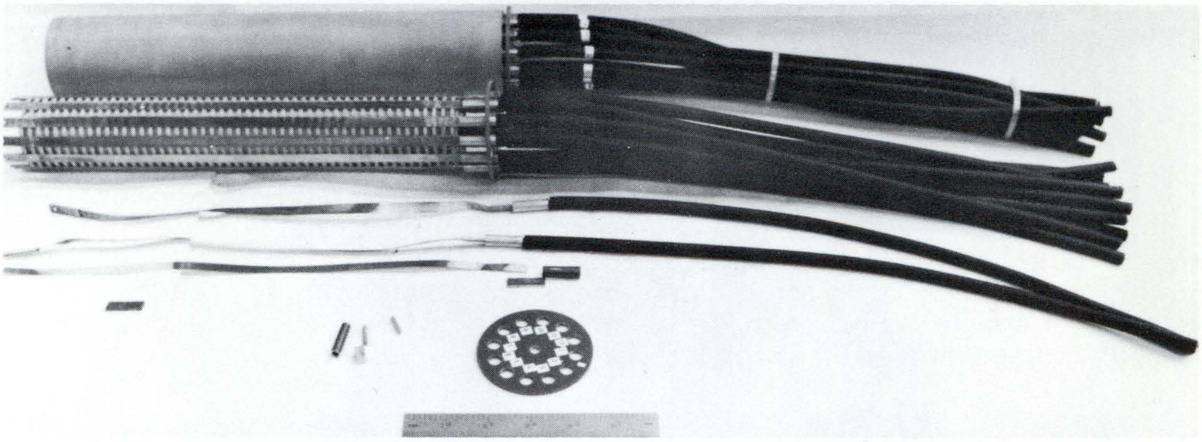
An additional advantage of the bolts added to the magnet yokes comes from the ability to move the collared coil inside the yoke by means of these bolts even after final assembly and measurement. If the collared coil is not centered in the warm iron yoke, quadrupole and skew quadrupole error fields are induced in the magnet aperture. The bolts can be used to center the coil in the yoke to eliminate these error fields.

2 - Smart bolt disassembled.

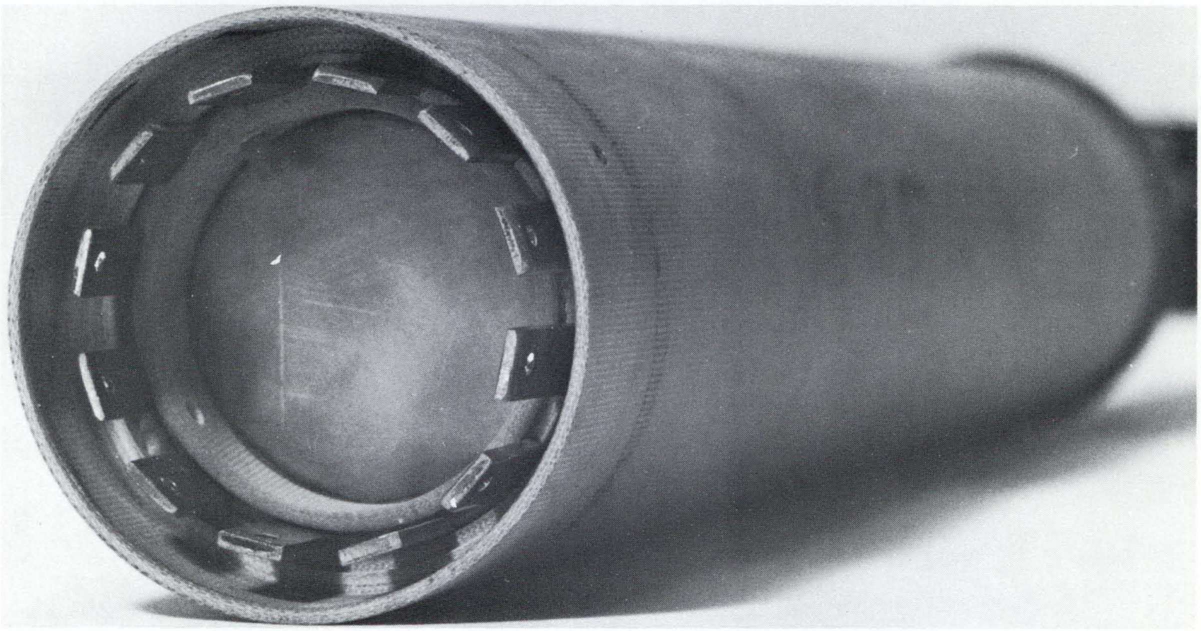
1 - Smart bolt assembled.

3 - Smart bolt installed in dipole magnet.

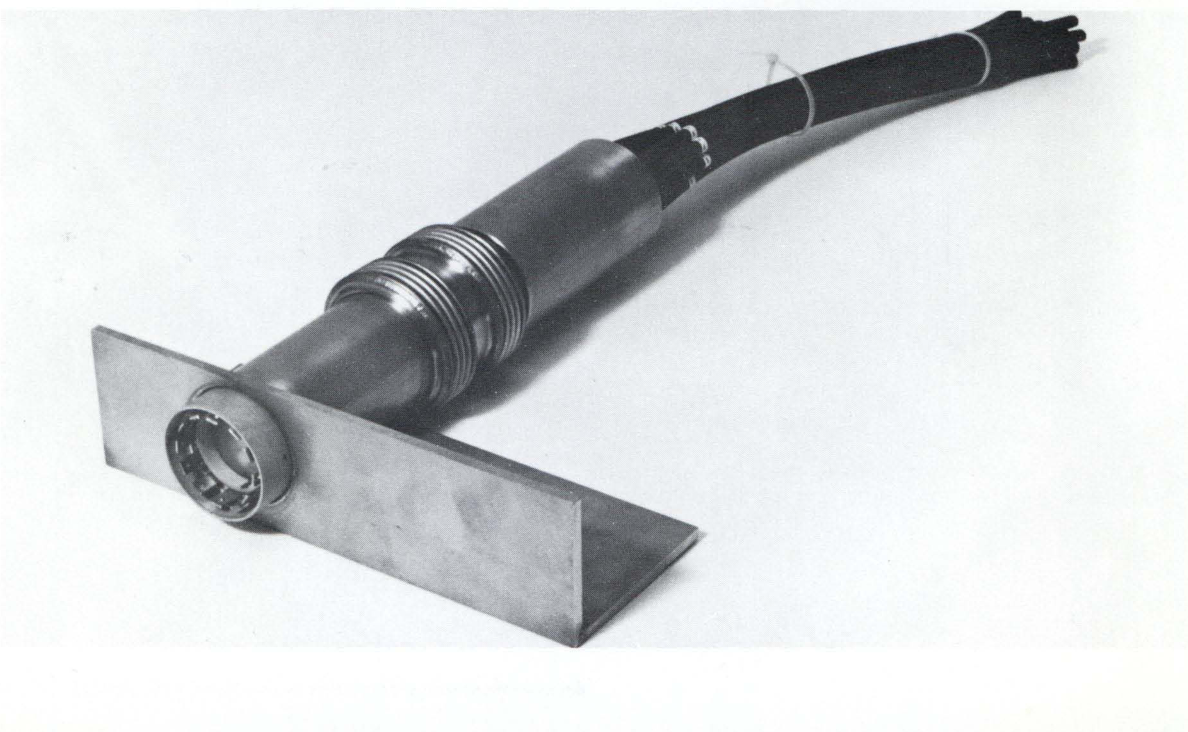
4 - Smart bolts in position and in relationship to magnet shown in a cutaway view of magnet model.



1



2



3

VAPOR-COOLED CURRENT LEAD

The correction-element power leads supply current for up to six pairs of correction coils at each Energy Saver quadrupole package. These leads must impose an extremely small heat load on the helium system and yet carry a current of 50 amperes. To accomplish this, each conductor has a small copper cross section (to minimize heat flow) which is cooled by a stream of helium boil-off along the lead length. In effect, virtually all the heat, both that transferred from room temperature and that generated in the lead, is carried out by this gas rather than entering the magnet system.

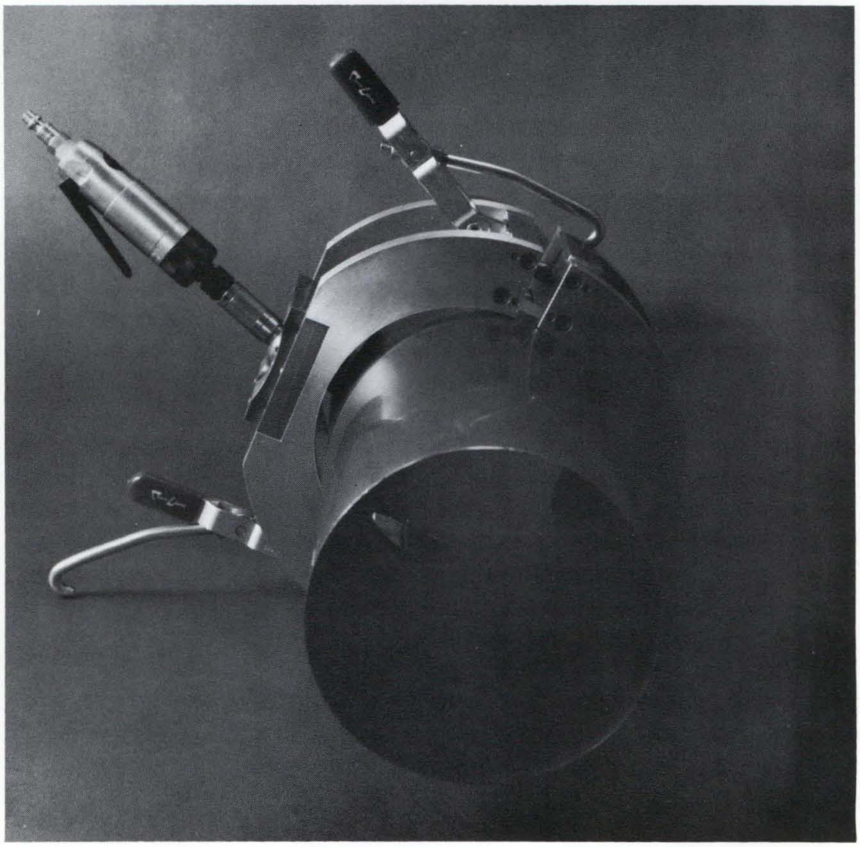
In early prototypes, this power was supplied by twelve discrete leads, each with its own cooling stream and flow-control device. The current design by Tom Nicol incorporates all twelve leads in a common package sharing one cooling stream and one flow-control device.

The possibility of plugging the gas passage is greatly reduced, as is the total number of required components.

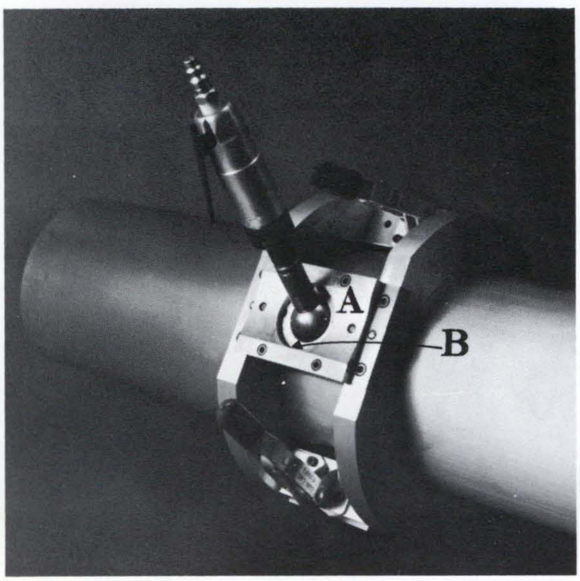
1 - Partially assembled leads showing internal construction. Note the helical helium cooling passage.

2 - "Cold" end of a completed unit. The copper tabs are magnet hook-up points.

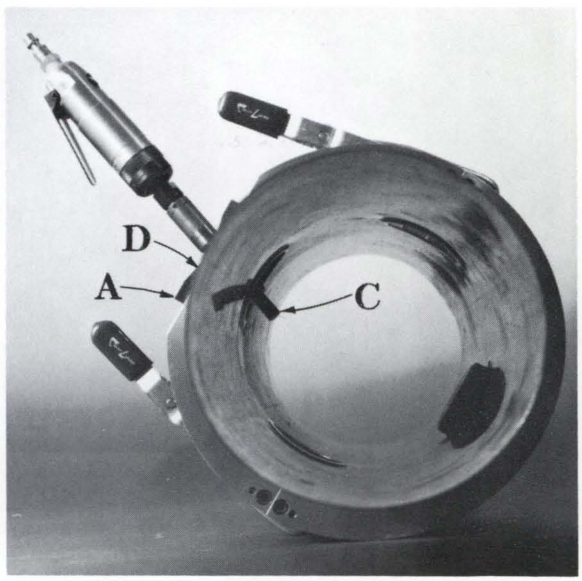
3 - Complete lead/vacuum jacket passage.



1



2



3

CRYOSTAT TUBE DEBURRING TOOL

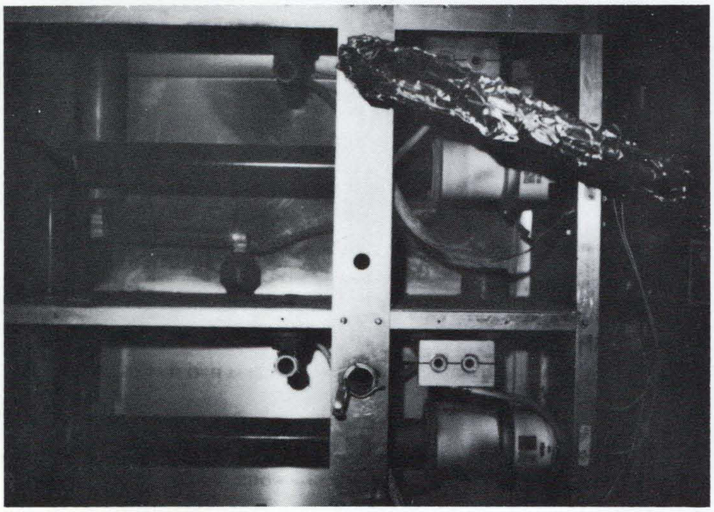
The cryostat tube deburring tool designed by Earl Bowker removes burrs from the inner wall of a piece of tubing after a hole is bored through the wall. The idea that the path of the cutting tool is generated by a guide plate that has the proper configuration to follow the inside contour of a piece of tubing is new and has cut deburring time in half.

The deburring tool consists of three main parts: the bracket or locating fixture, the cutter spindle, and the guide plate. When the spindle is held against the guide plate and rotated in a circle it will cause the cutter to follow the inside configuration of the tube and remove any burrs from the edge of the hole.

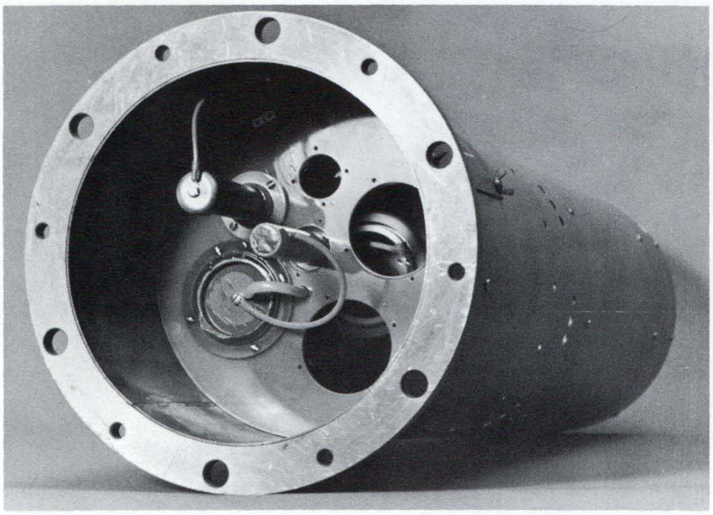
1 - Deburring tool partially clamped on a cryostat tube.

2 - Deburring tool clamped on a cryostat tube. The hole "B" in the guide plate "A" determines the depth of cut which the cutter can take.

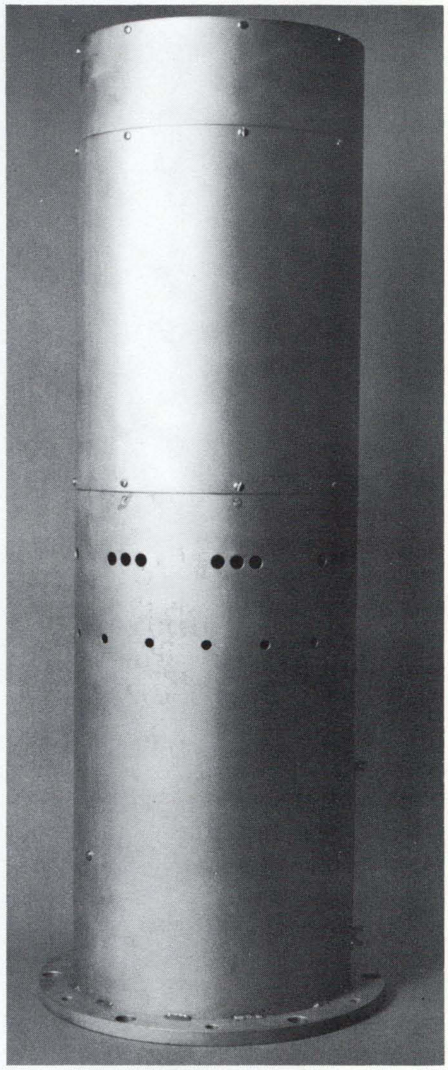
3 - The cutter "C" can be seen inside the cryostat tube. End view of guide plate "A" shows the concave surface "D." The surface "D" determines the path of the cutter as it is moved through 360°.



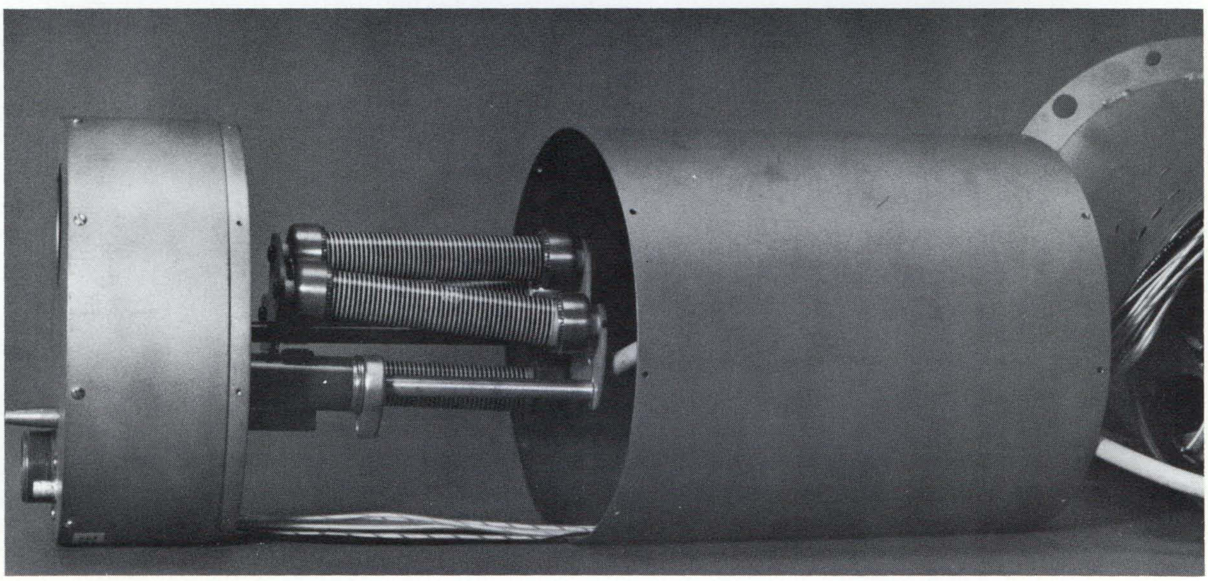
1



2



3



4

750-keV CHOPPER

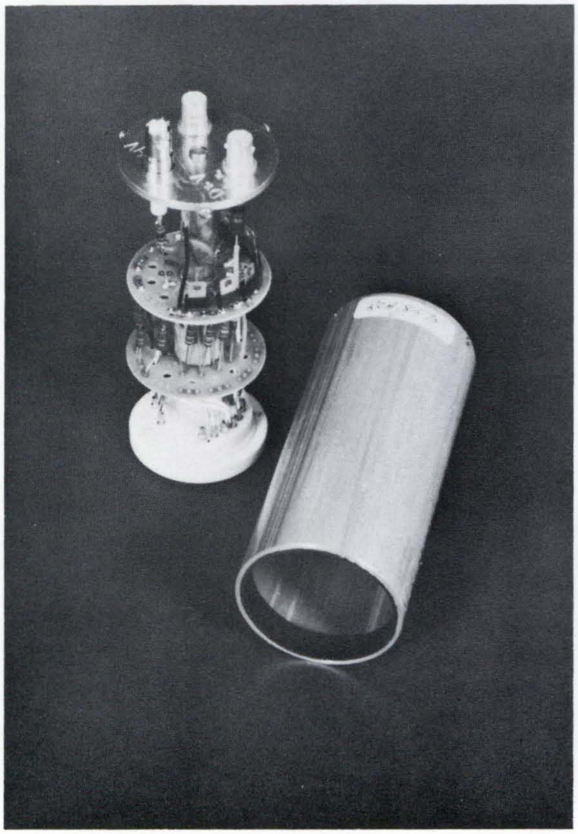
The chopper is used to trim the leading and trailing edges of the preaccelerator beam pulse into the Linac. The old unit was unreliable for long-term service and gave maintenance problems. Ken Bourkland designed a new chopper that increases the lifetime of the thyratron, improves noise rejection, and offers better performance.

1 - The old unit, mounted remotely from the deflection-electrode vacuum box, is shown with its perforated cover removed. Because of insufficient shielding, the lower section was never able to operate independently of the upper sections and, as a result, system performance was a compromise. The output cable from the unit was wrapped with aluminum foil in an attempt to reduce radio-frequency interference. Further, over-cooling by large fans (not shown in photo) contributed to reduced life expectancy of the thyratron switch tubes.
(Photograph by Ken Bourkland)

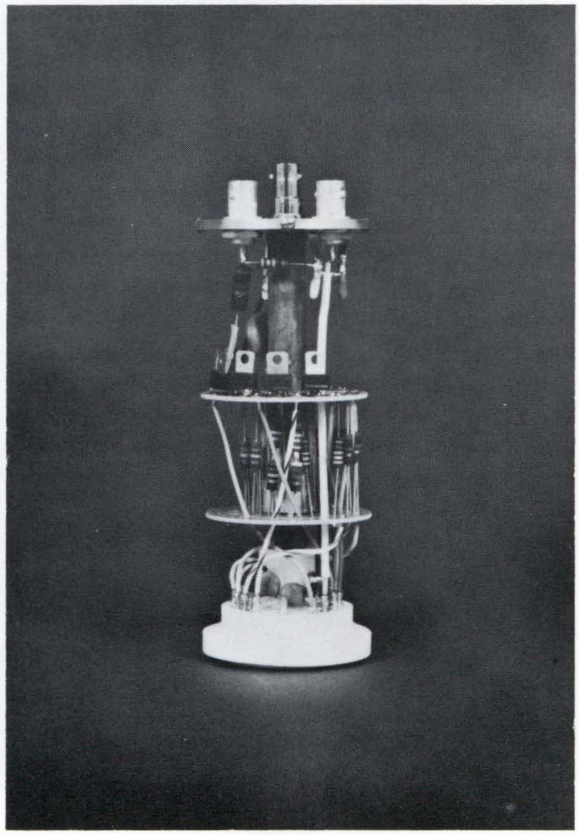
3 - The modularized packaging concept used in the new 750-keV choppers has contributed to improved radio-frequency interference, improved switch-tube cooling, and less Linac downtime because all the active components of the beam-deflection system are contained within and can be replaced as a package in a matter of minutes. This quick-change capability for the 10-in. diam. by 34-in. long cylindrical copper unit is accomplished by mounting the units directly to the deflection-electrode vacuum box by six bolts; all power to the unit is via three quick-disconnect connectors.

2 - In this internal view, the anode of the 30-kV thyratron switch tube is visible. In the foreground, an interchangeable 30-kV subchassis with components for use with the "beam on" deflection electrode can be seen. A differently configured subchassis replaces this one when the modular unit is used in conjunction with the "beam-off" deflection electrode. The interchangeable subchassis allows a single spare chopper unit to fill either "socket."

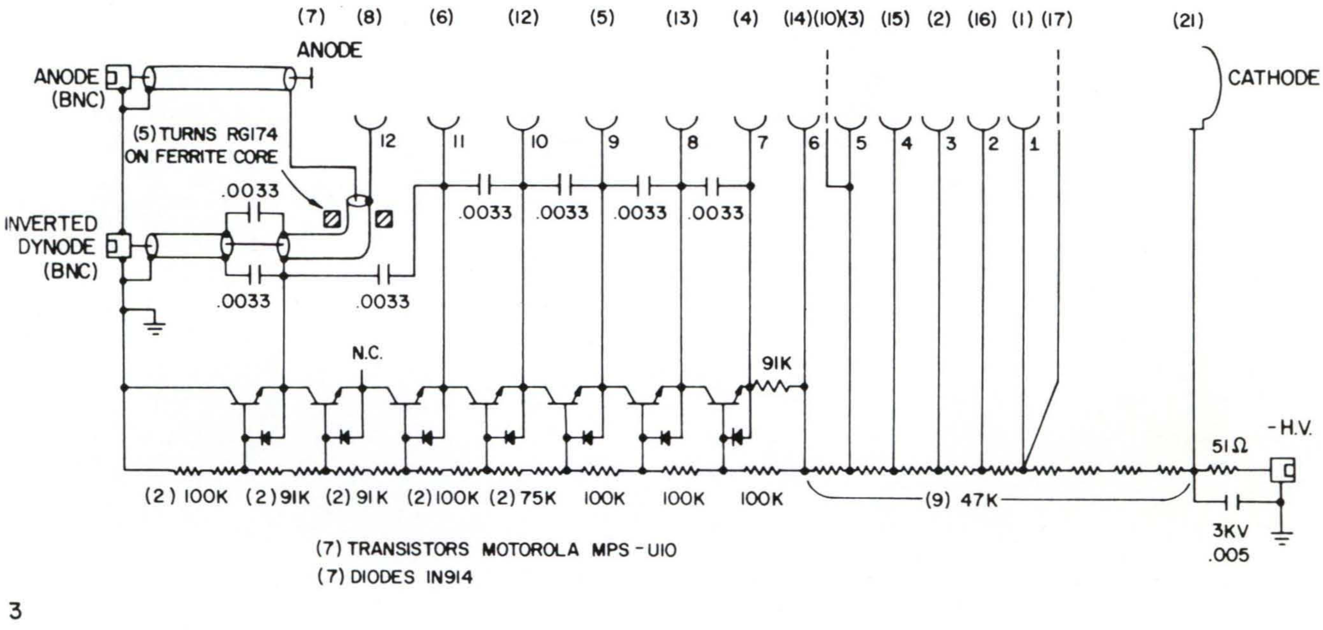
4 - The modular unit breaks down into three sections for servicing. The section on the left contains the thyratron trigger circuit, electrical connectors, a cooling fan, and provides the support for the 30-kV components housed in the center section. Partially visible on the right is the lower section containing the thyratron switch tube and the high-voltage subchassis.



1



2


(7) (8) (6) (12) (5) (13) (4) (14)(10)(3) (15) (2) (16) (1) (17) (21)
ANODE
ANODE (BNC)
CATHODE
(5) TURNS RG174 ON FERRITE CORE
INVERTED DYNODE (BNC)
12 11 10 9 8 7 6 5 4 3 2 1
.0033
N.C.
91K
51Ω
-H.V.
(2) 100K (2) 91K (2) 91K (2) 100K (2) 75K 100K 100K 100K
(9) 47K
3KV .005
(7) TRANSISTORS MOTOROLA MPS-U10
(7) DIODES IN914

3

PHOTOMULTIPLIER TUBE BASE

A photomultiplier tube base designed by Cordon Kerns to minimize voltage changes at the phototube's dynodes under high-rate conditions is presently in general use at Fermilab.

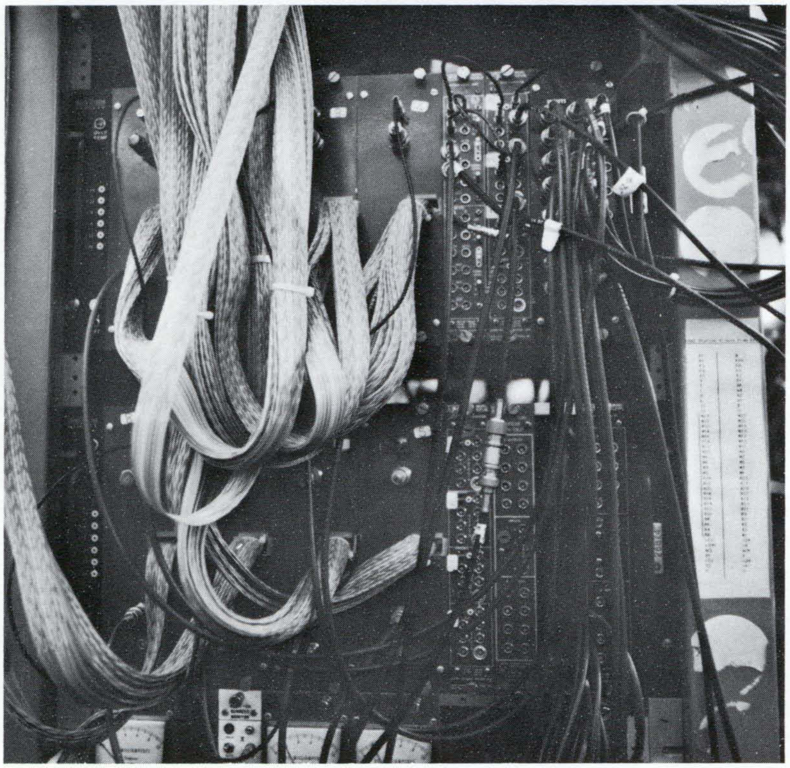
Historically, phototube bases designed for high-rate applications made use of various techniques, some of which were voltage-regulator tubes, capacitor banks, large divider string currents, and so-called after-burners employing additional power supplies.

This base design provides stiff voltage sources for dynodes by making use of emitter-follower characteristics of high-beta, high-voltage, and video transistors (see schematic). Not only will this design work well for high-plus or high-minus power supplies, but, because it does not have a high current string, it also works effectively from the present high-voltage Zener divider panels available at Fermilab.

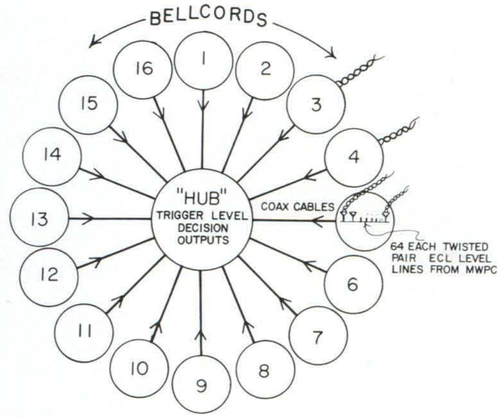
Hundreds of these inexpensive transistorized bases are in continuing use on lead glass and other calorimeter phototubes, not only at Fermilab but at other high-energy physics laboratories around the country.

1,2 - High-rate phototube base.

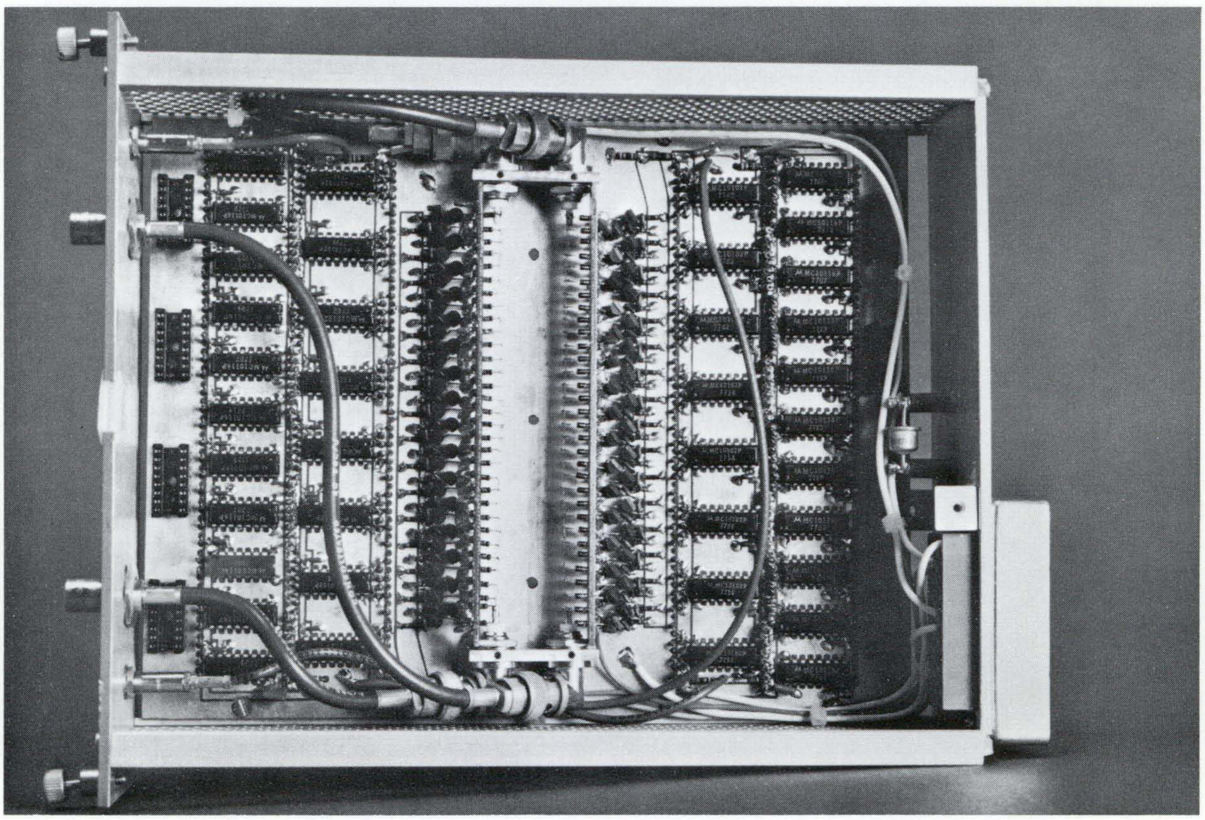
3 - Schematic of a typical high-rate phototube base.



1


BELLCORDS
16
1
2
3
15
4
14
"HUB"
TRIGGER LEVEL
DECISION
OUTPUTS
COAX CABLES
13
64 EACH TWISTED
PAIR ECL LEVEL
LINES FROM MWPC
12
6
11
7
10
9
8

2



3

THE BELLCORD

To provide a fast decision trigger on multiple tracks passing through multiwire proportional chambers, a high-speed (arriving at an answer in 60 nanoseconds) track-counting system was developed by Cordon Kerns. The circuit is capable of selecting the track multiplicities utilizing a coaxial cable "bus" (the Bellcord) on which fast pulses are summed. Up to 16 Bellcord coax cables, each having 64 inputs, are fanned into a central "hub" processor where the trigger level decision is made.

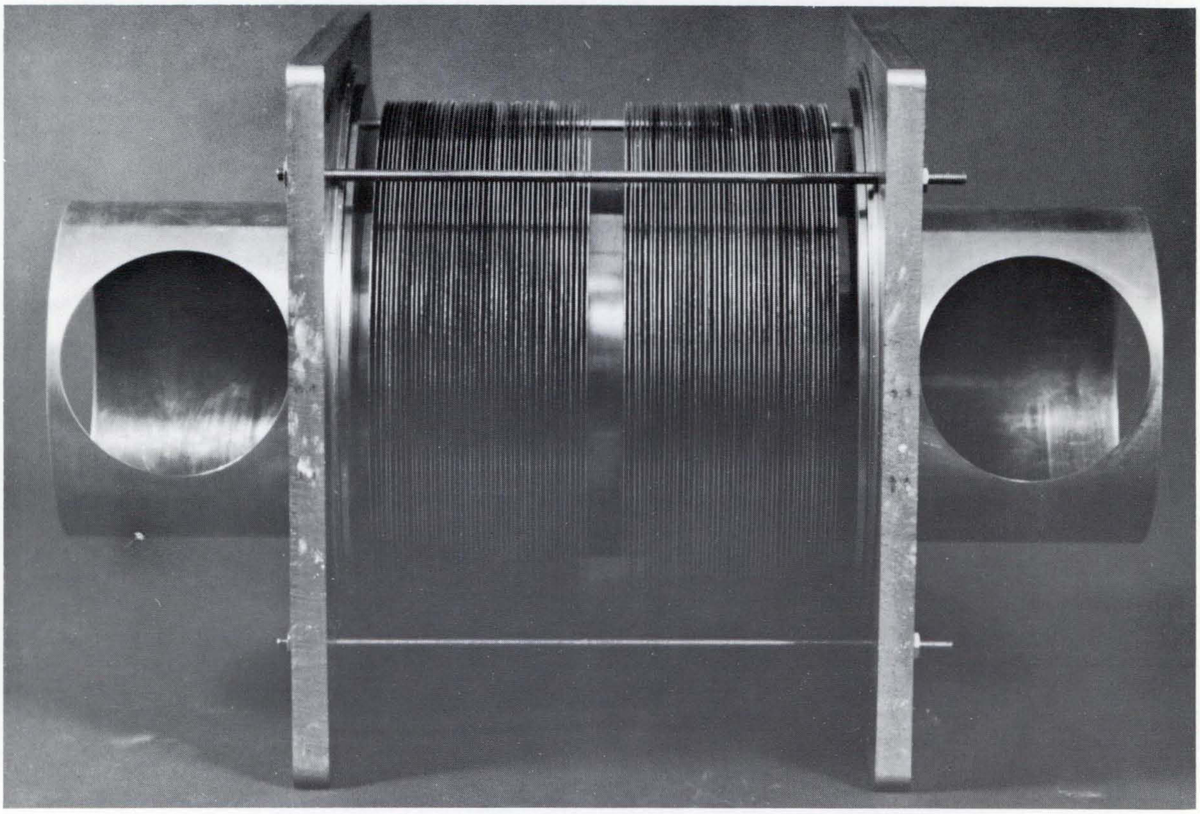
The electronic problem to be solved was one of detecting and enumerating a few coincident hits (1 to 5, or more) from about 1000 possible sense-wire sources and arriving at the level decision within 60 nanoseconds or less. The fast pulses necessarily involved dictated that wide-bandwidth pulse techniques be used, with little time for signal-propagation delays.

This system was named for the bellcord in service on most buses where passengers (distributed signal sources) are each capable of making their destination requests known to the bus driver (detector) via the bus bellcord. If the bellcord had bandwidth (a coax cable) and the requests were fast pulses introduced at many points along its length, summing could occur on the bellcord together with propagation along the cord toward the level detector. In order to know just how many requests are being made simultaneously, each "request" is a standardized pulse. The pulses are added linearly to produce quantized multilevel pulses that are finally evaluated at the level detector.

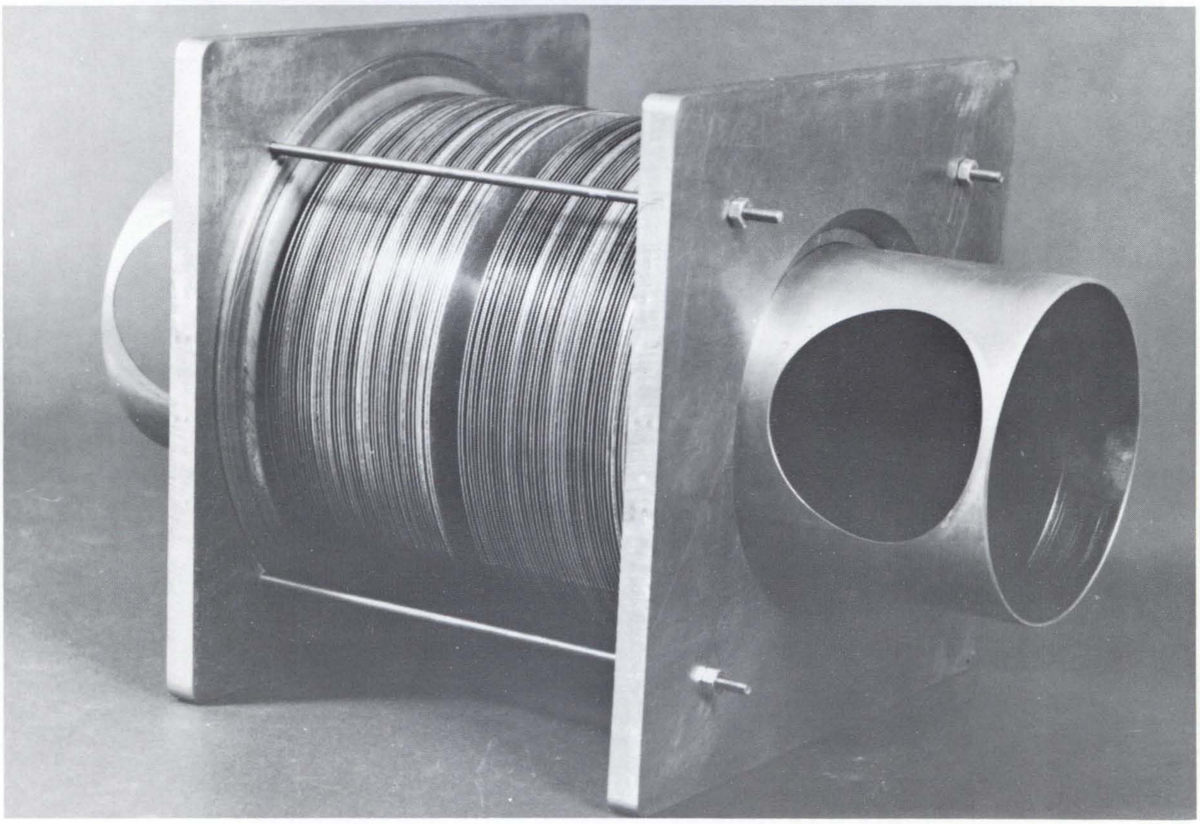
1 - Bellcord close-up view.

2 - Bellcord/Hub interconnections.

3 - Bellcord track-counting system.



1

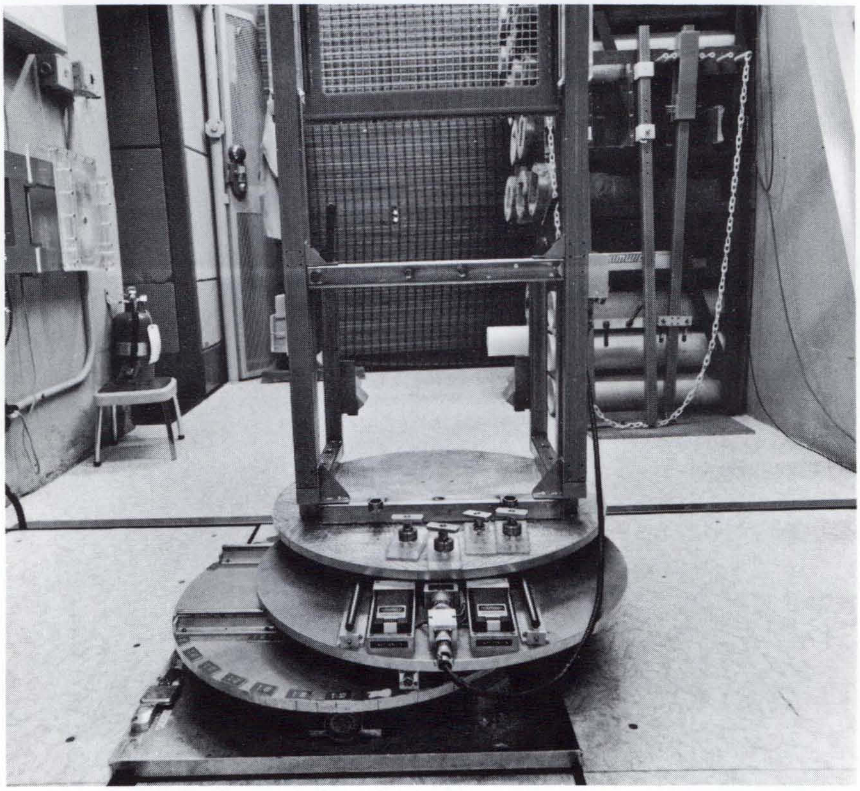


2

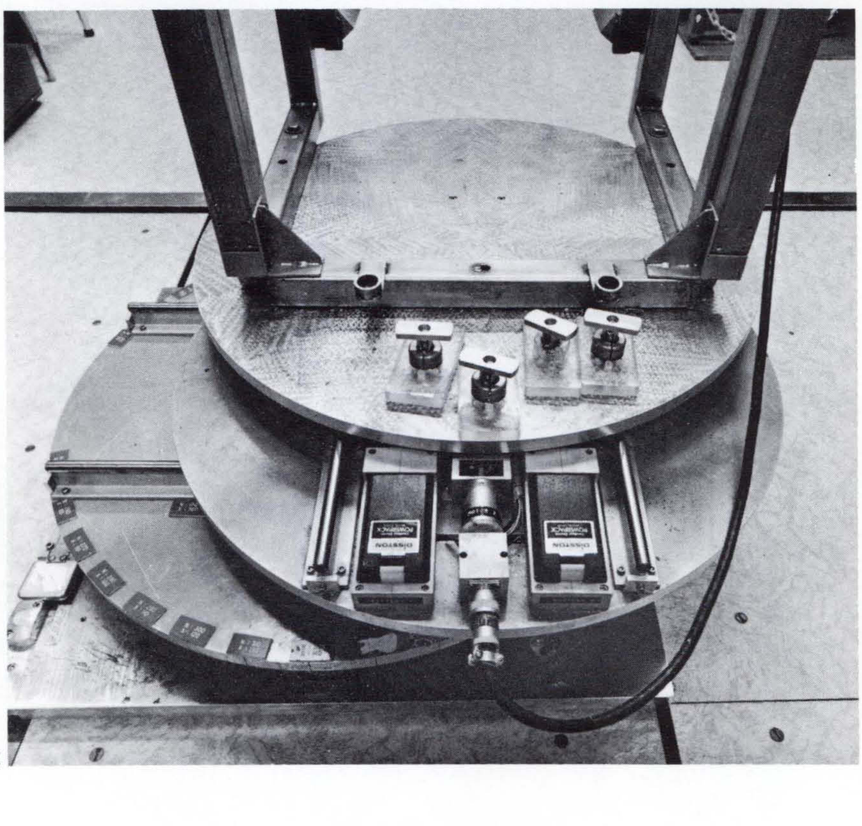
RF CAVITY RESISTOR

Quentin Kerns and Bill Miller are responsible for the design of a water-cooled high-power radio-frequency resistor to work in vacuum in an Energy Saver cavity. The resistor is a new piece of equipment that will damp unwanted cross modes in the cavity. The resistor minimizes distortion of the rf bucket and prevents one type of cavity-beam instability. Incorporating the resistor in line with the center drift tube will allow independent adjustment of the pole-zero response of the two cavity halves. The resistor is fabricated with disks of high permeability nickel alloy 0.025-in. thick with a 5-in. inside diameter and an 8-in. outside diameter.

1,2 - RF cavity resistor.



1



2

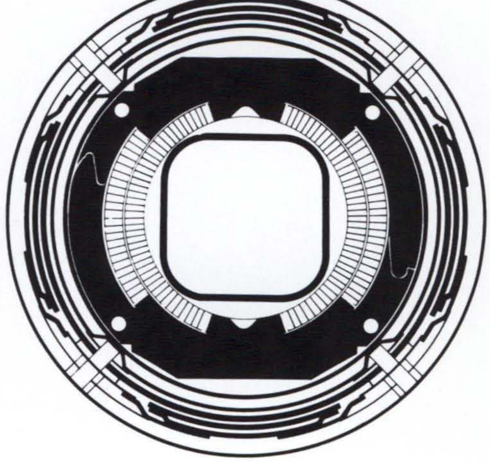
NEUTRON THERAPY FACILITY PATIENT TREATMENT CHAIR

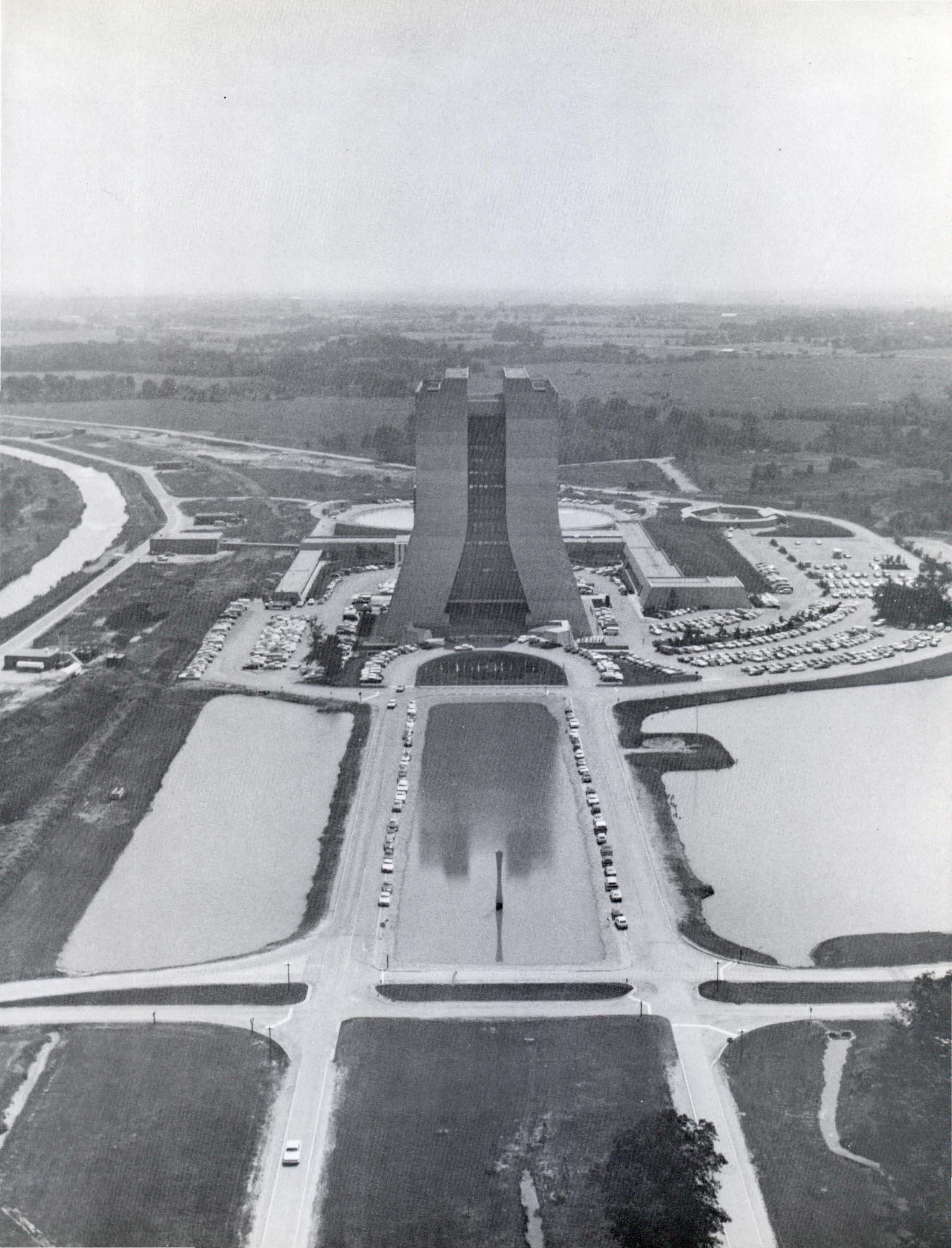
Patients treated at the Neutron Therapy Facility are positioned in a specially designed chair to immobilize them for the time of treatment. This chair is motorized for adjustment in all directions to properly align the patient. Limited space requirements prevented the installation of commutators or other devices to transmit necessary power for the X-Y positioning motors.

The problem was solved by Glenn Lee using motors and power packs from Disston grass shears. The motors are powerful and inexpensive, and the power packs have built-in battery chargers. The power pack is re-energized by plugging them in a standard wall outlet. The units position the chair quickly and accurately in all horizontal directions.

1 - Neutron Therapy Facility treatment chair.

2 - Closeup of positioning motors and power packs for the Neutron Therapy Facility's treatment chair.





Helen Crow, Fermilab On-Call employee, samples the cafeteria's new 15 cents an ounce salad bar as Pam Bosch replenishes the salad dressings.

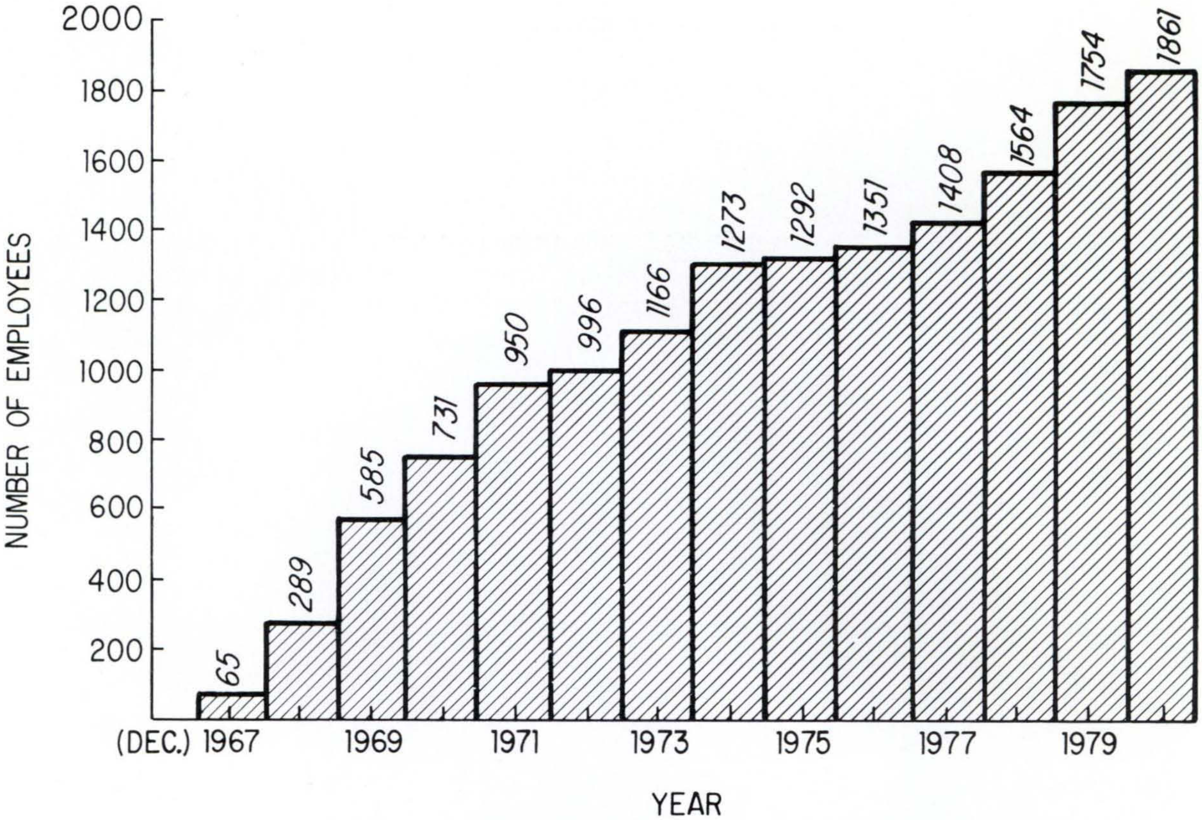
Laboratory Support Sections

Laboratory Services Section

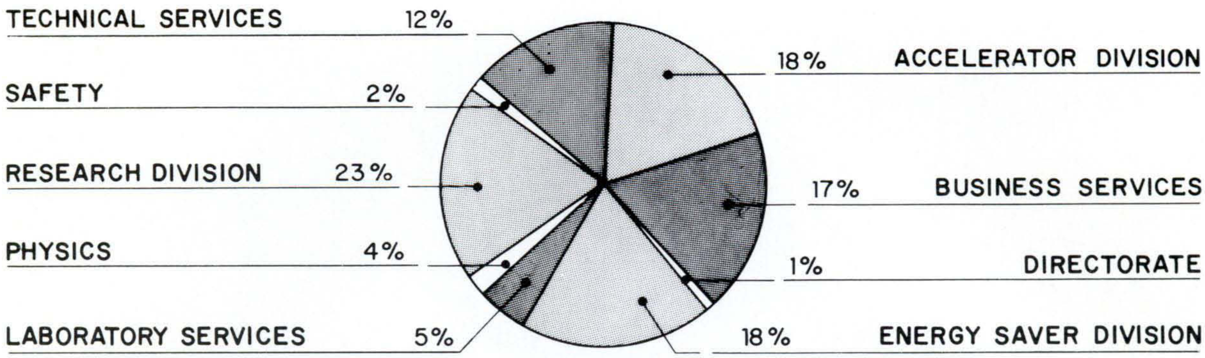
A research center such as Fermilab is staffed not only by scientists, but also by individuals in a wide variety of occupations needed to support the research program. An organization is needed to find all these people and to keep them happy at Fermilab. The Laboratory Services section is responsible for personnel recruiting, compensation, benefits, employee training and relations, all aspects that are vital in maintaining the high quality of Fermilab's work force. Laboratory Services is also responsible, through the Equal Opportunity Office, for sponsoring a summer program for minority students to foster an interest in scientific careers. Eighteen students participated in 1980, the tenth year this program had been offered. The Public Information Office and the Technical Publications Office have as major functions the communication of information about Fermilab's scientific achievements and activities to the public and dissemination of scientific information generated by Fermilab scientists to the high-energy physics community, respectively.

The section comprises nine units: Accommodations (includes Food Services, Housing Office, Chez Leon, Recreation, Users Center, Users Support); Benefits, Compensation, and Training; Employment Records and Medical; Equal Opportunity Office; Guest Office; Personnel; Public Information Office; Technical Information (consisting of the Library, Technical Publications, Photography, and Duplicating Services); and Travel Office.

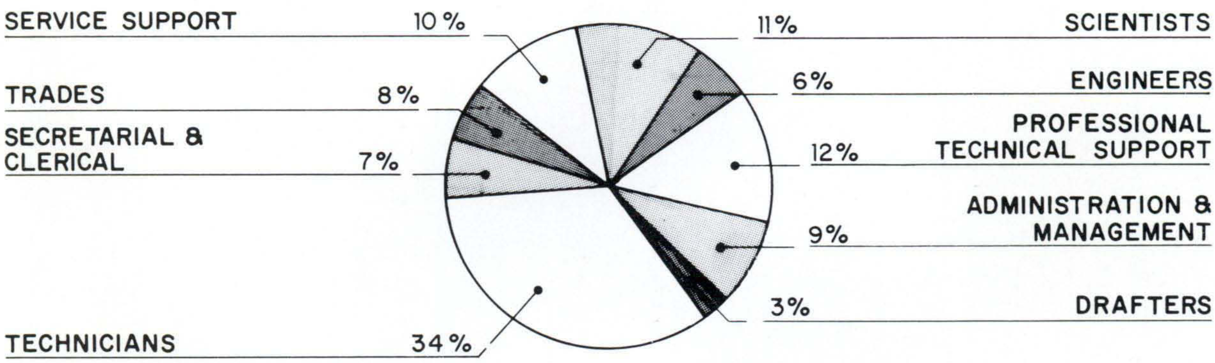
A few of the changes that occurred within this section during the year include the hiring of 418 persons, most for the Energy Saver Division, increasing the Laboratory's total work force by 218; revised retirement-plan repurchase features; improved shift premiums; and beginning of the Fermilab's Children Center, which is located in the Fermilab Village and is available to employees and users of Fermilab with children 3 to 6 years on either a half-day or full-day arrangement.



HISTORY OF LABORATORY EMPLOYMENT



CURRENT STAFF DISTRIBUTION



OCCUPATIONAL DISTRIBUTION

1 - Linda Braddy, Fermilab's Children Center director, and friends enjoy snack time in addition to the photographer's visit.

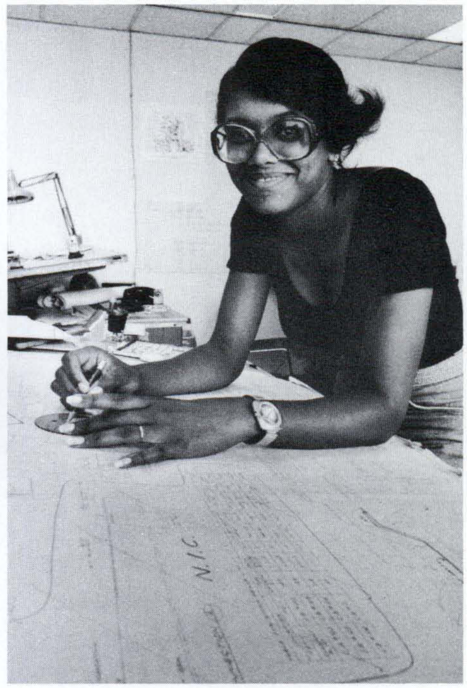
2 - Thalia Brackett, undergraduate at Virginia State University, was employed as an engineering trainee in Architectural Services with the Summer Program for Minority Students. She is working on a drawing for the Transfer Gallery addition.

3 - Lois Psonak instructs Marilyn Paul on the intricacies of the Laboratory's computer word-processing system. Elaine Moore (standing in the background), instructor for the training class, helps another trainee at the terminal.

4 - Crystal Michael and Marc Ernwein, enrollees in the Fermilab Children Center, have found a quiet spot to sit and read.

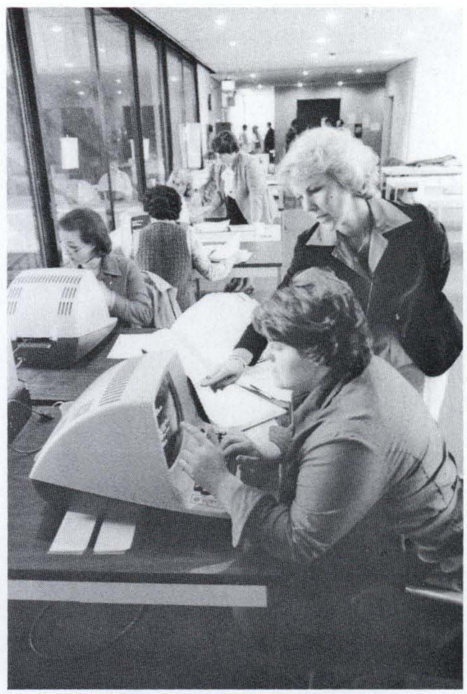
5 - Philip Adderley, undergraduate at Morehouse College, Atlanta, Georgia, solders parts for the Energy Saver refrigeration system. Philip was employed as a laboratory technician in the Energy Saver Accelerator Systems group with the Summer Program for Minority Students.

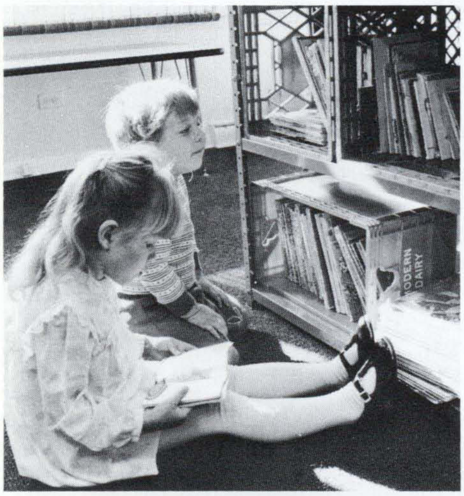
1



2

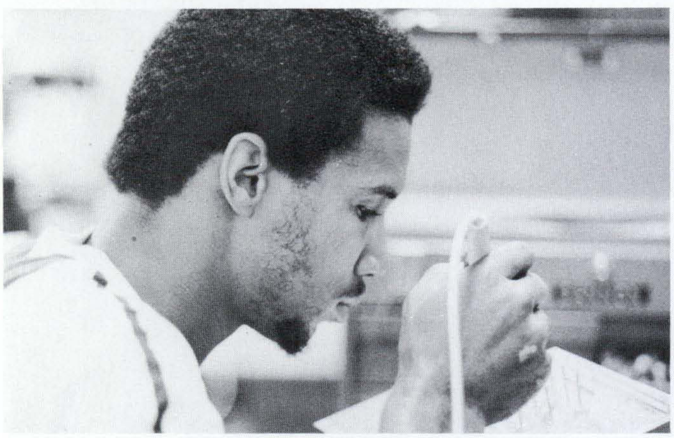
3





4

5



Laboratory Support Sections
Business Services Section

The Business Services Section has been primarily involved this year in intensifying management support for the Energy Saver. This support is not only in the area of procurement but extends to finance and planning as well. A special group has been established to meet this requirement.

The Contracts Department has processed over 2,000 procurement actions totaling approximately $20.5 million. Over 400 actions, with over $7.4 million, were awarded in the second quarter of the calendar year. Twelve actions in excess of $500,000 each were solicited and awarded, and over $320,000 worth of business was placed with disadvantaged firms. The total value of procurements increased approximately 21% over the previous calendar year.

The Purchasing Department made over 19,000 awards for goods and services worth $35.5 million. The dollar volume represented a 46% increase over fiscal year 1979. The Fabrication Procurement Section, with particularly heavy activity from the Energy Saver program, awarded $7.2 million of the above total.

A similar high level of activity is reported in the Accounting Department where 83,500 payroll checks and 30,700 checks to vendors were processed. Their combined total amounted to $109,570,000.

The inventory group that transferred from the Accelerator Division to the Accounting Department at the end of FY79 had a successful year in managing over $9,000,000 of "technical components." In addition, the group implemented a sophisticated computerized "Work In Process" system to monitor the fabrication of superconducting wire.

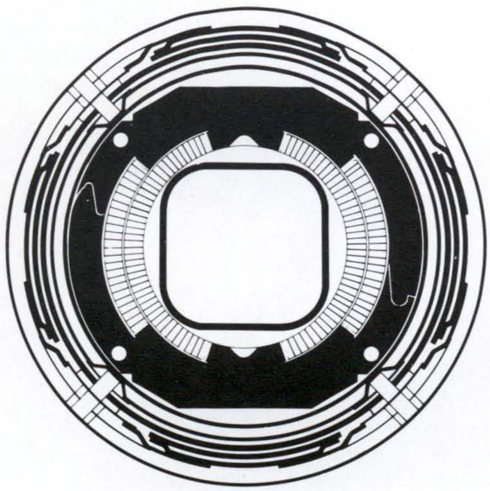
In addition to their routine caretaker functions, Site Services Department established centralized shop facilities for the carpenters, painters, electricians, mechanics, and locksmiths. The Roads and Grounds crew planted and harvested a 14-acre sunflower crop to provide additional food for wildlife and experimented with sunflower oil as a fuel alternative for diesel engines. A total of 450 additional acres were leased to local farmers for corn production.

The Information Systems Department procured and installed a Data General Eclipse M600 minicomputer. The minicomputer will provide the data processing resources required as part of a long range project to upgrade Fermilab's business system. Located on the fourth floor of Wilson Hall, this facility will permit operators using video terminals to enter and process business transactions as they occur.

The Support Services Department has continued to reduce the Laboratory's gasoline consumption primarily through the use of gasohol. Fermilab was awarded a conservation citation by the Department of Energy in recognition of this and other energy conserving measures. A new Vehicle Maintenance facility is now in operation near the warehouse, and a 32,000 sq. ft warehouse has been leased in support of Energy Saver fabrication work. This warehouse is located at Paramount Park, an industrial area about a half mile north of the Laboratory. Support Services also reports materials receiving activity of over 85,000 parcels. This is a 9% increase over FY79 activity and is attributed to the Energy Saver effort. A record receipt of over $80,000 from the sale of recyclable materials and scrap was also achieved.

During the year, a final settlement was reached on the UNITED STATES OF AMERICA, UNIVERSITIES RESEARCH ASSOCIATION, INC. AND DUSAF v. M. J. MCDERMOTT AND CO., et al., in which Fermilab was seeking damages for the fire that occurred in the Meson Detector Building which was under construction by M. J. McDermott.

Mary Jane Nicholls (left) and Lucy Reuter mount a tape on the new Data General Eclipse M600 minicomputer in the computer room on the fourth floor of Wilson Hall. John Pollock supervises the installation and Gerry Jones in the background stands at the operator's console. The printer for the system is on the right.



New beam dump and beam-transport pipe for the Main-Ring abort system near service building C0.

Laboratory Support Sections

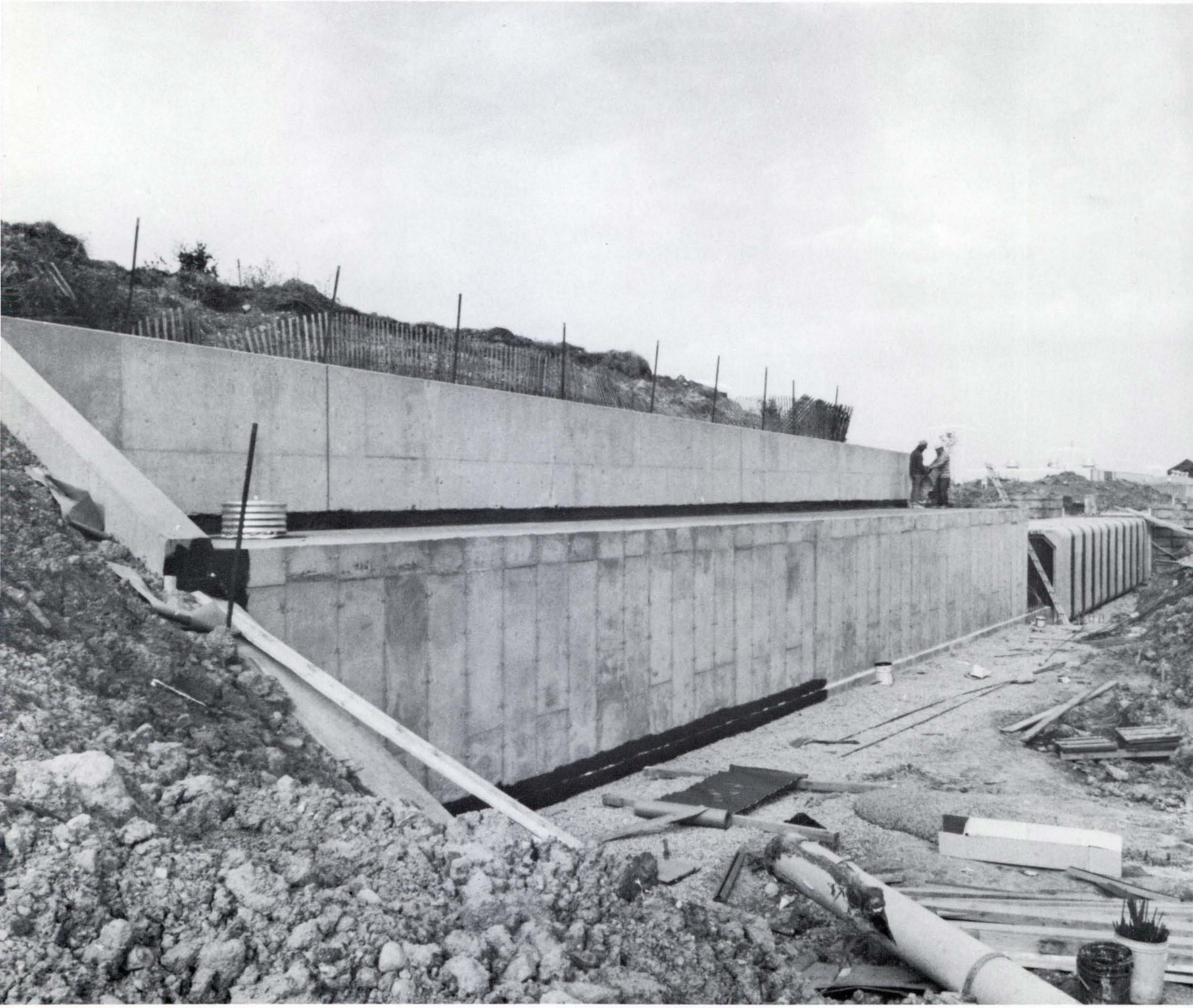
Technical Services Section

The Technical Services Section has had a part in many of the Laboratory's activities, in many ways. This year the Section has been particularly busy with projects for the Energy Saver, Fermilab's step into the future of high-energy physics.

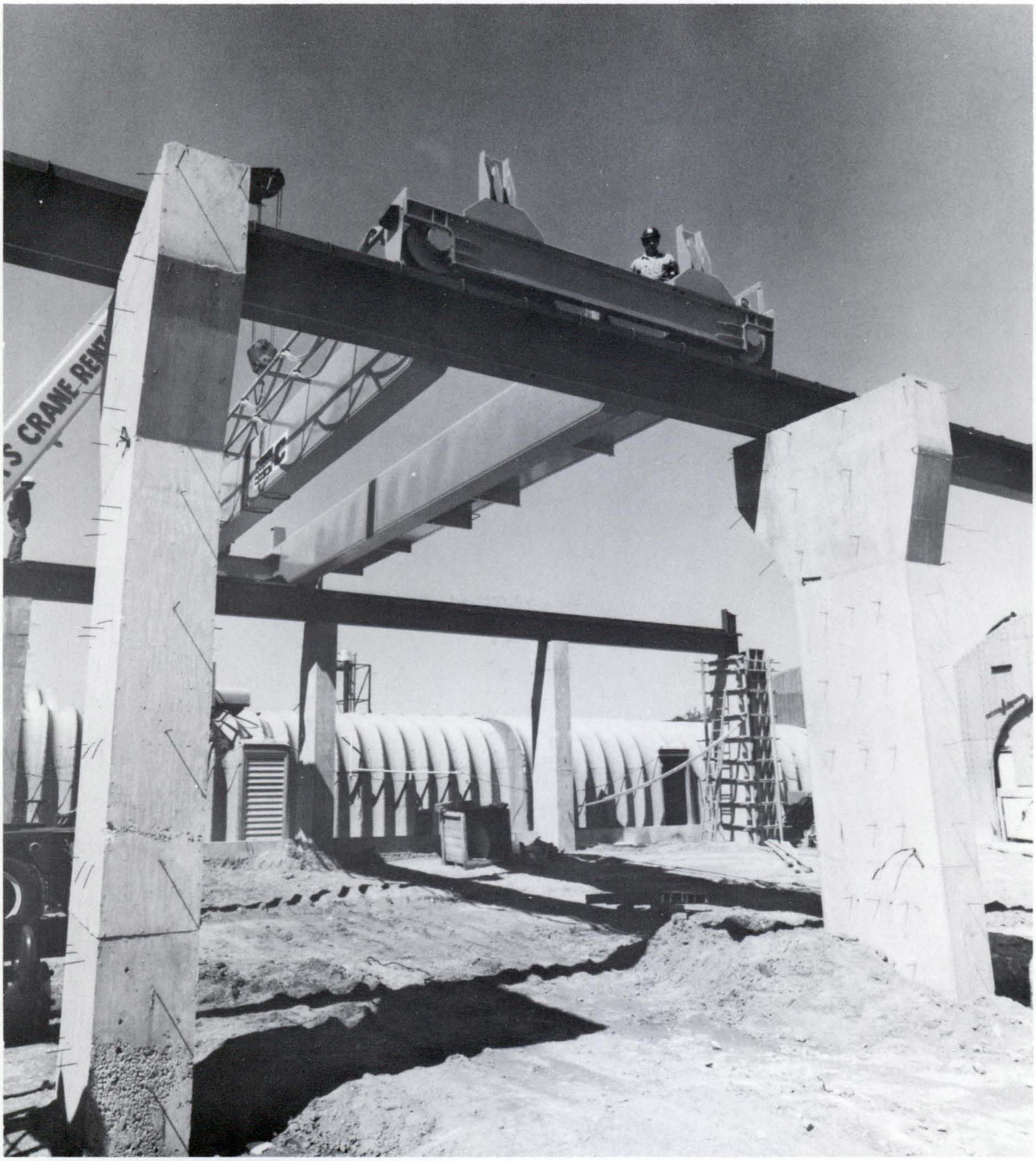
Machine-Shop personnel are doing major work on the Energy Saver cryostats. The tooling used to fabricate these cryostats was developed and built in the machine shop. In production, each of the 1000 cryostats has five concentric tubes, each with precise length and numerous precise holes or bumps. All these tubes are fabricated in the machine shop.

Architectural Services designed and supervised construction of approximately $3.5 million of new buildings and structures, mostly for the 1000-GeV physics program. There is a new beam dump in the Main Ring, a major addition to the Neutrino Target Hall, 2600 feet of new beam pipe in the Neutrino Area, additions to the Switchyard, an enlarged building in the Meson Area, a new Industrial Building, and many new service buildings around the Main Ring for Energy-Saver equipment. Finally, a new protective canopy for the main entrance of Wilson Hall was designed and built.

Members of the Technical Services Section have in addition to their interests in the physics program, a long-standing interest in energy conservation and have made many designs to improve Fermilab's energy usage that are being carried out where possible. The activites of the Section's Energy Conservation Committee culminated in October being proclaimed Energy Conservation month.

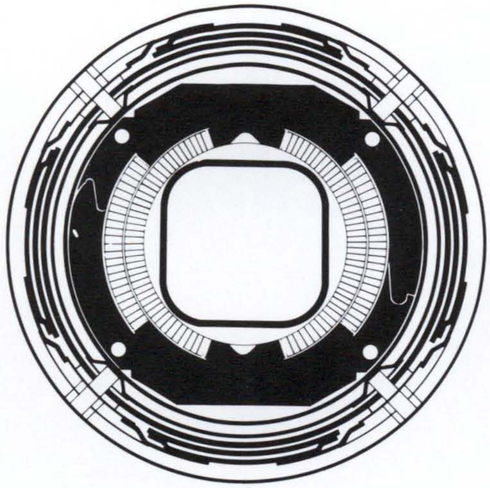


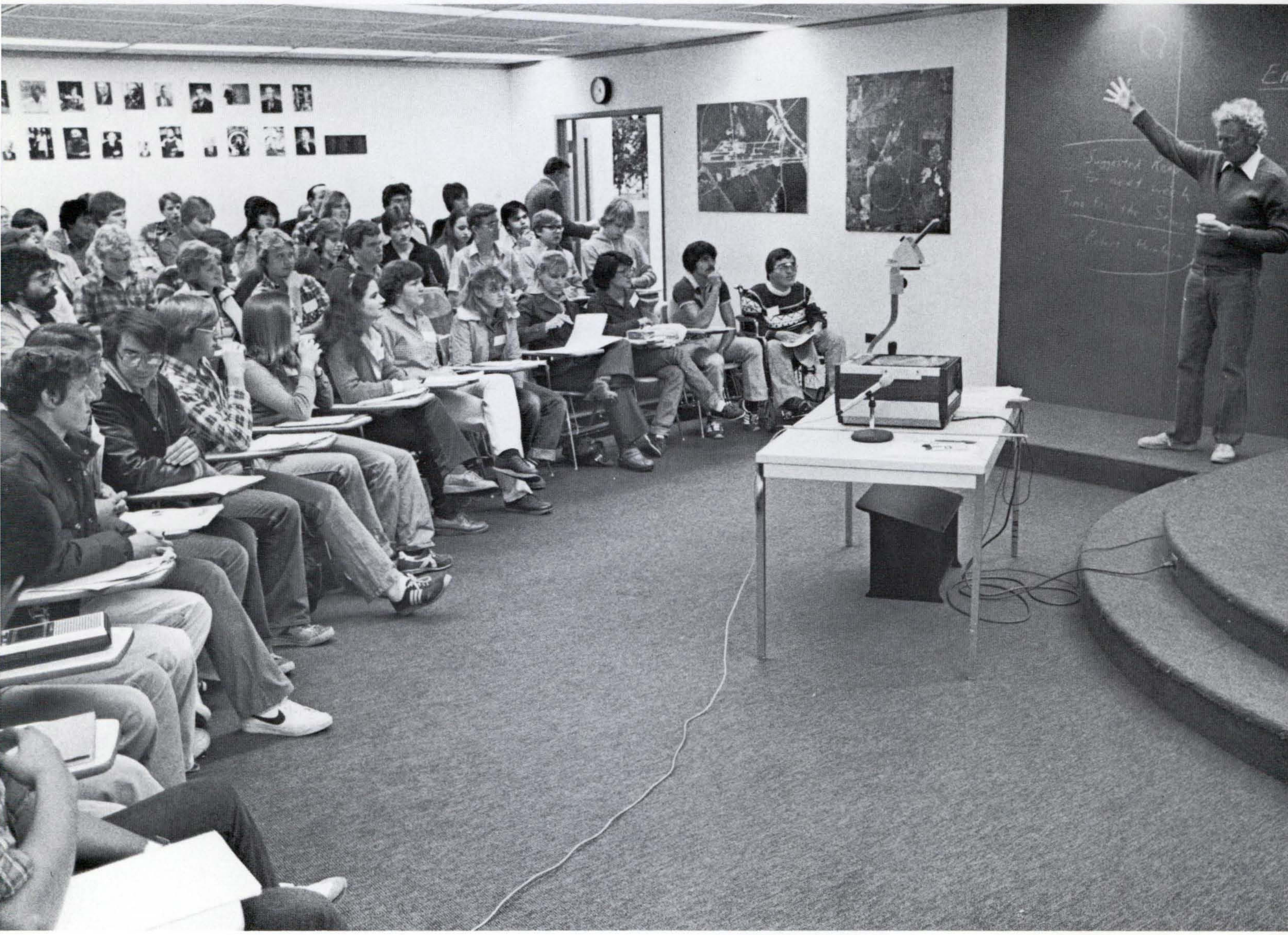
Additions and modifications to Neutrino Enclosure 103 including several ancillary equipment enclosures along the beam line.



Construction of an enlarged building north of the Meson Detector Building to house new experiments on the M1 beam line.

Installation of 2600 feet of beam pipe for the projected Neutrino N7 beam. Included in this project was an addition to Enclosure 100, and three monitoring stations along the beam line.





Fermilab Director, Leon Lederman, lectures students enrolled in the Saturday Morning Physics Program.

Saturday Morning Physics Program

In August the Laboratory inaugurated a new program called Saturday Morning Physics at Fermilab. The purpose of the program is to further the understanding and appreciation of modern physics among high school seniors and juniors with strong interests in mathematics, physics, chemistry, and science in general. Students were eligible to participate who were enrolled in a public, private, or parochial school within the general vicinity of Fermilab and who were nominated by their principals. Students were selected from a school community of over 80,000.

Volunteer Fermilab scientists and engineers serve as instructors for the ten-week curriculum offered three times during the year. Typical classes consist of two hours of lecture and discussion, followed by tours of the Laboratory's accelerator and research facilities.

Course content is interesting and broad in scope, ranging from Elementary Particles and the Special Theory of Relativity, to Quantum Theory and Cosmological Connections. The level of instruction is designed to stimulate the students and complement their other formal instruction.

Saturday Morning Physics at Fermilab is provided as a community service at no cost to the participants. Schools participating have enthusiastically endorsed the program. Three classes with 80 students each attest to the program's success.

Drasko Jovanovic (left), Physics Department head, explains a site model to Saturday Morning Physics students.

Fermilab Industrial Affiliates Program

Early in 1980 the Board of Trustees approved the Director's plan to inaugurate the Fermilab Industrial Affiliates program. This program was designed to enhance the transfer to industry of the high technology developed by Fermilab in the course of its research program. The program was also a way to encourage wide use of the technology developed at Fermilab for the ultimate benefit of the public, which provided funding support.

Areas of Fermilab technology that are of particular interest and importance to industries include fast electronics, ultra high vacuum systems, data acquisitions and processing systems, rf power, particle beam optics, control systems, particle detectors, ion beams, cancer therapy, superconductivity, and cryogenic systems. Some of these are worth special mention.

In superconductivity, for instance, the intensive R&D effort undertaken at particle-physics laboratories in the late 60's and early 70's had a profound effect on the fledgling superconducting-alloy industry. Fermilab was responsible for the greatest push to industry when the decision was made to proceed with the Energy Saver. Subsequently, companies such as Teledyne Wah Chang Magnetic Corp. of America, Intermagnetics General Corporation, New England Electric, and AirCo developed improved superconducting alloys, wire, and cable. It is fair to say that Fermilab research was a significant factor in keeping these firms in the forefront of superconducting technology.

For nearly a decade Fermilab has worked with Lecroy Research Systems and others in the fast electronics and data-acquisition field to specify new modules and systems that have become standards throughout the world. These include a series of fast logic modules developed in the 1970's and a data sparsifying, high-density, precision analog-to-digital converter (ADC) system in 1979. Most recently, the in-house development of a very sophisticated, extremely high-speed, emitter couple logic (ECL) trigger processing system has influenced and encouraged the first commercial marketing of some elements of such a system by Lecroy.

In the area of industrial controls, Fermilab's development of the world's largest standardized control system using the international CAMAC standard helped spawn several small new companies in the field such as KineticSystems Inc. CAMAC, which is now used by such industrial giants as General Motors, Alcoa, Westinghouse, General Electric, Corning Glass, Inland Steel, and a number of other companies in the Fortune 500, received a primary impetus from Fermilab's massive system.

A new sophisticated distributed processing system is being developed by Fermilab and other similar laboratories under the auspices of the U. S. Bureau of Standards. This standard, called FASTBUS, is needed to meet the high-speed data acquisition and parallel-processing requirements in the high-energy physics experiments of the 80's and 90's. Commercial implementation of this standard will begin this coming year. An industrial standardization committee is currently reviewing FASTBUS in its efforts to develop a nation-wide industrial distributed processing standard.

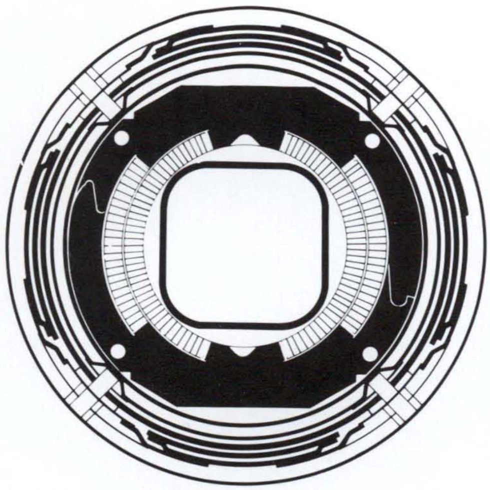
U. S. industry capability in the field of cryogenic engineering has also broadened because of Fermilab work in superconductivity. The Laboratory needed expansion engines, screw compressors, turbomolecular vacuum pumps, and cryogenic controls and instrumentation to support a system of unprecedented size. Today, Fermilab has completed a liquefication plant that doubles the world's capacity to liquefy helium. In the process, industry has gained appreciably in the technological exchange.

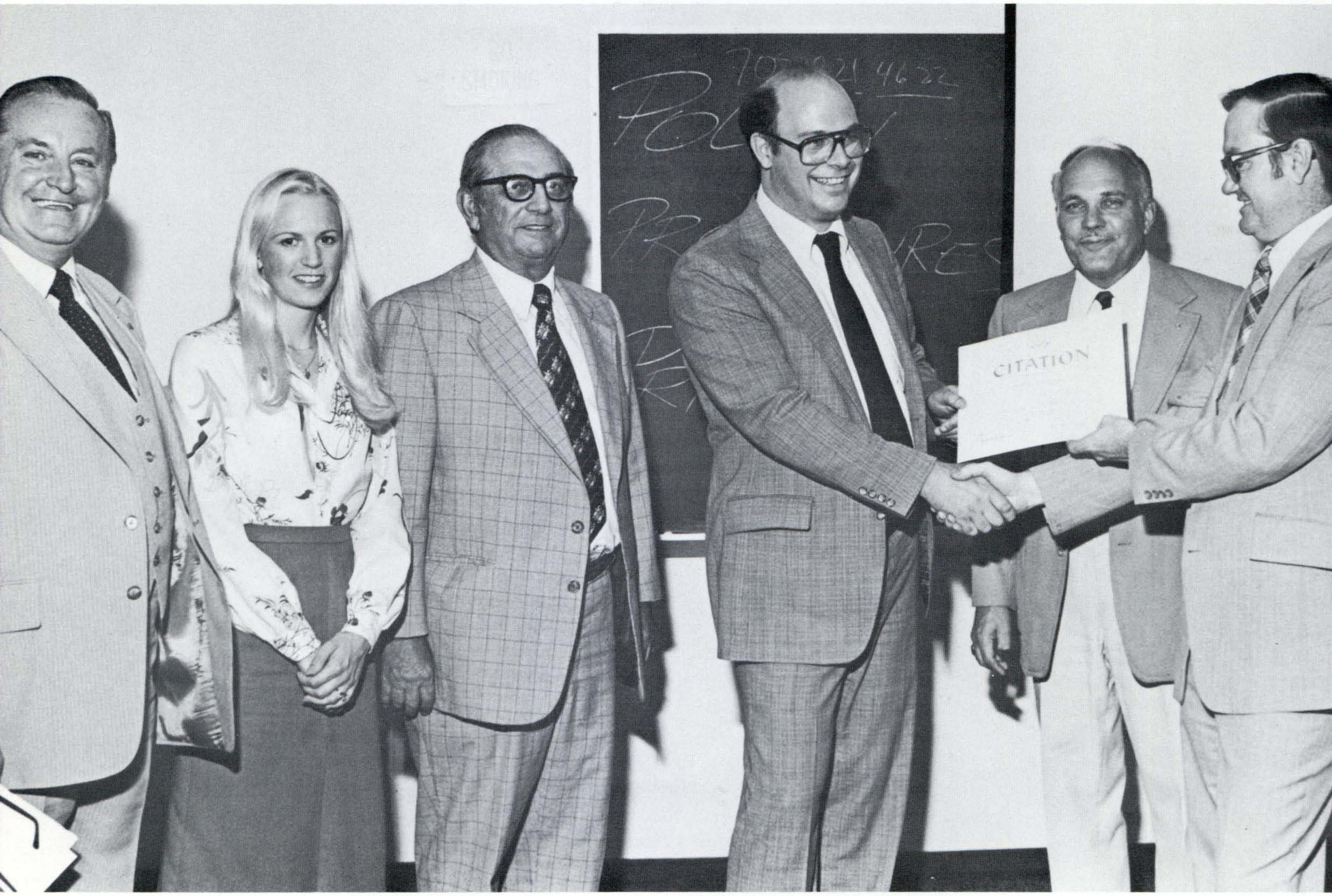
Solicitation for Affiliate membership began in early April 1980. A membership fee of $1000 per year was requested to defray the cost of the program. Representative members include

Bell Laboratories
Caterpillar Tractor Company
Chicago Bridge & Iron Company
Combustion Engineering, Inc.
Commonwealth Edison
Deere & Company
Digital Pathways, Inc.
General Electric Corporation
The Harshaw Chemical Company
International Harvester
KineticSystems Corporation
Lester B. Knight & Associates, Inc.
Litton Industries
Nalco Chemical Company
Nuclear Data, Inc.
Raychem Corporation
Sargent-Welsh Scientific Company
Shell Development Company
Standard Oil Company (Indiana)
State of Illinois Department of Commerce and Community Affairs
Texaco, Inc.
Westinghouse Electric Corporation

The first annual conference of Fermilab Industrial Affiliates will be held in the spring of 1981.

A list of Affiliates and brief descriptions of their business is displayed on the 15th floor of Wilson Hall.



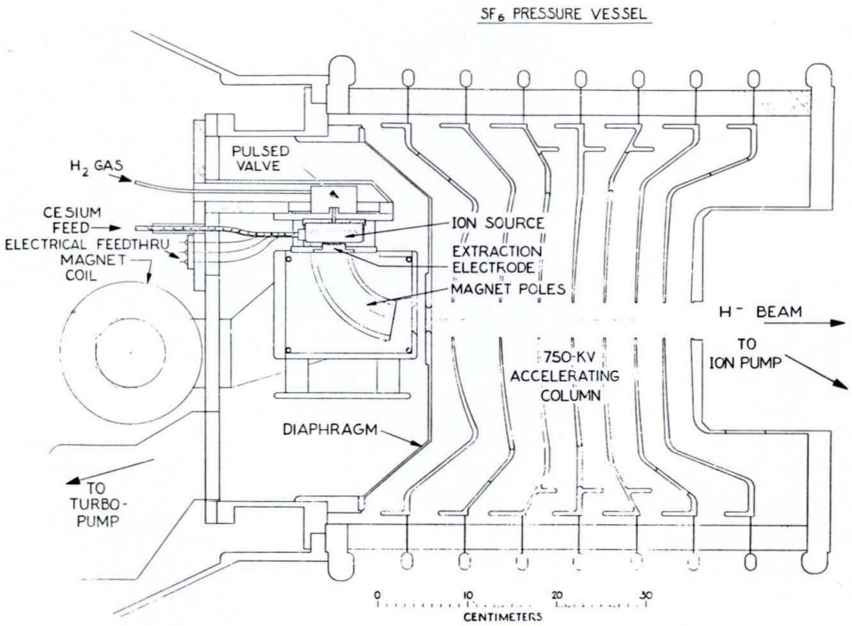


Business Manager Bruce Chrisman (left), accepts citation from John Kennedy of the Department of Energy for the Laboratory's energy conservation programs. John Colson, Support Services Manager (center), observes the award presentation.

(Photograph courtesy of Argonne National Laboratory)

Awards

Two recent technical developments at Fermilab, the negative hydrogen ion source for acceleration in the Linac and charge-exchange injection in the Booster and the mass-produced large-scale application of superconductivity as exhibited by the superconducting dipole magnet, were given the IR-100 award by **Industrial Research and Development Magazine** as among the 100 best technical developments of 1980. This display, originally at the Museum of Science and Industry in Chicago where the awards were presented in September, describes the winners.



ION SOURCE ASSEMBLY

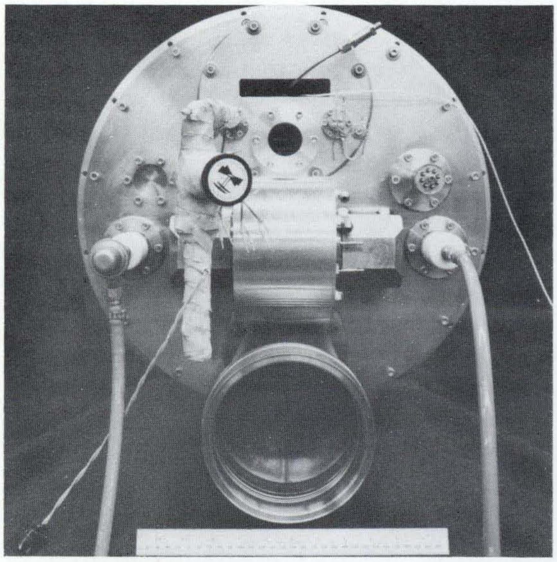
Schematic of the negative hydrogen ion source assembly designed by Chuck Schmidt.

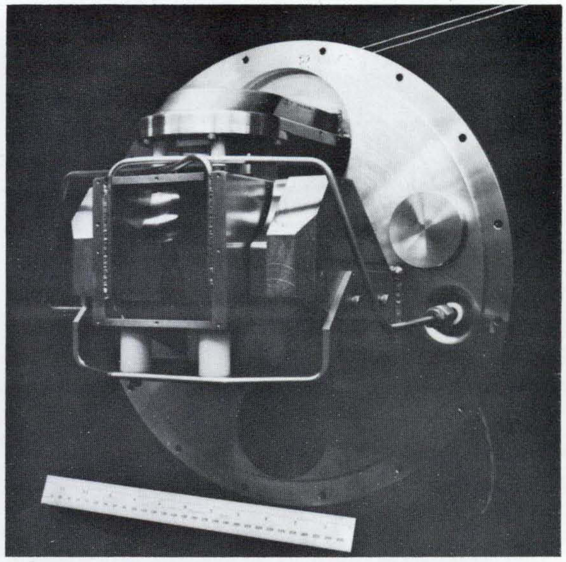
1 - Rear view of the ion-source assembly as it would mount in the high-voltage terminal. Visible parts are the port for vacuum pumping, magnet coil, cesium boiler and feed-throughs for refrigeration and extraction high voltage. The plasma source is inside the circular window.

2 - Internal view of the ion-source assembly. The plasma source is at the top beneath the mounting assembly. Magnet poles are for focusing the beam and for providing magnetic field for the plasma source.

3 - Plasma source disassembled.

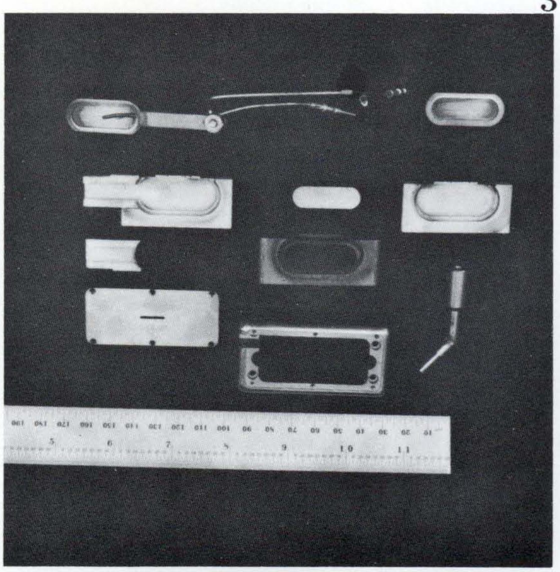
4 - High-voltage terminal in which the ion source and the electronics are located. Ion-source designer Chuck Schmidt stands at the controls.

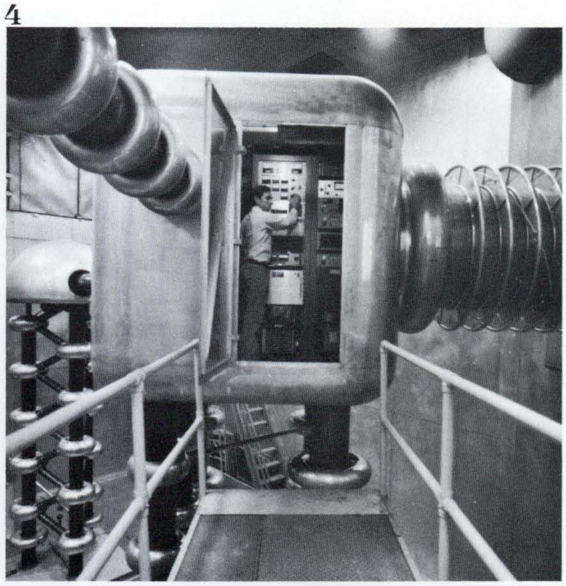




1 2

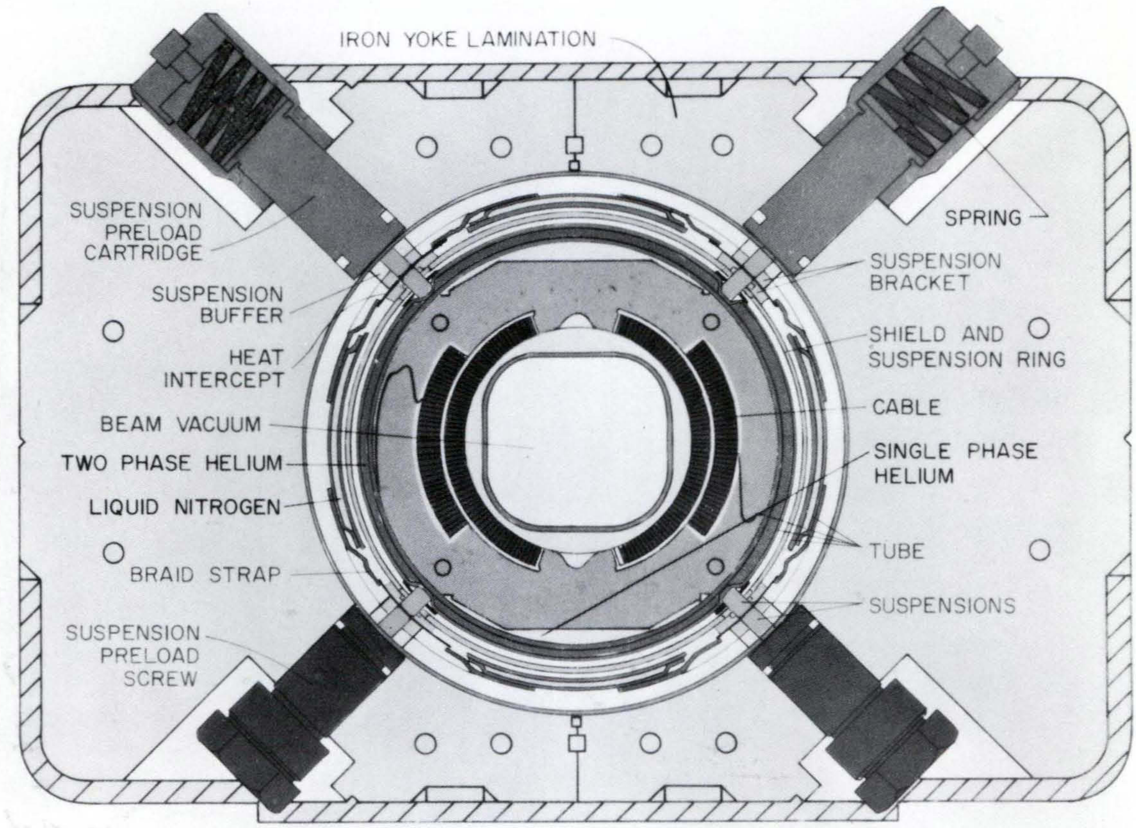
3 4



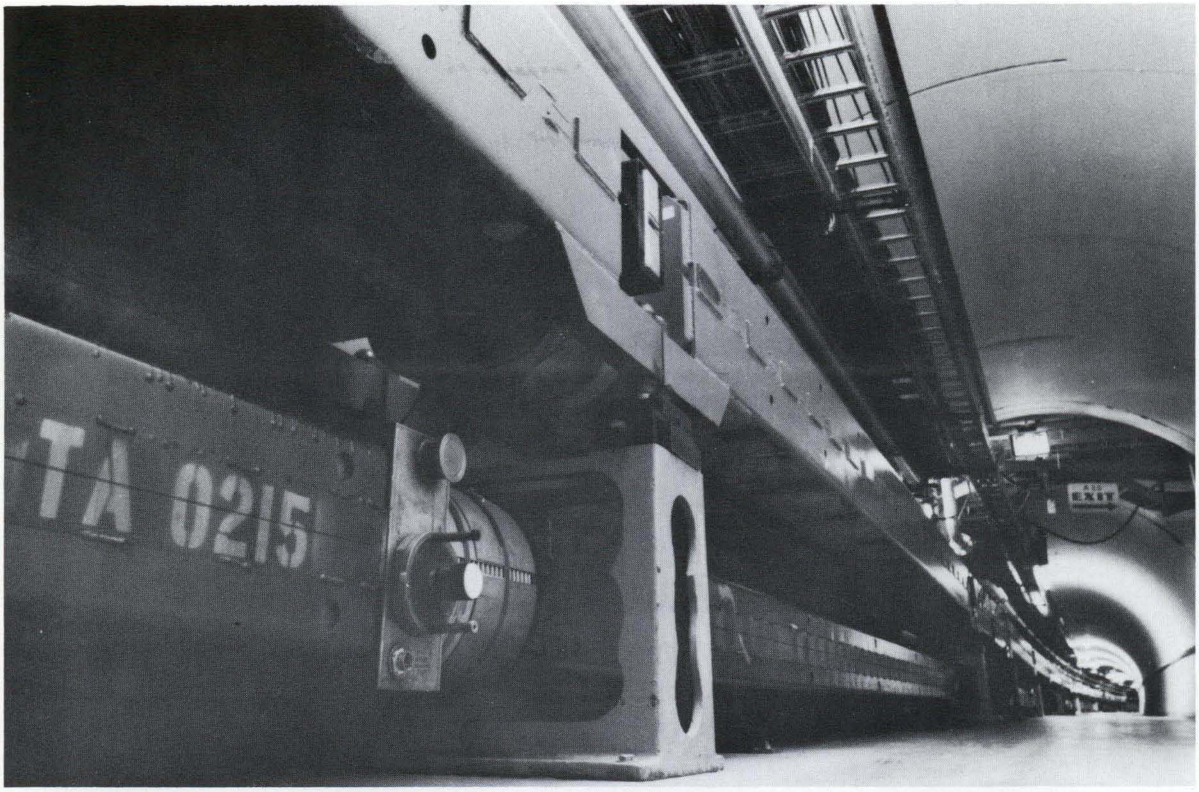


Fermilab's 6.4-m long Energy Saver superconducting dipole magnet provides a uniform vertical magnetic field to bend the beam of protons. Together with other superconducting magnets (for focusing and trimming), 776 of these magnets will form a closed ring of 1 km radius in which the protons will circulate. Radio-frequency rf stations accelerate the protons. The intensity of the magnetic field is programmed to keep the beam in an orbit inside the vacuum tube. The intensity of this field at maximum beam energy (1 TeV) is 4.3 Tesla.

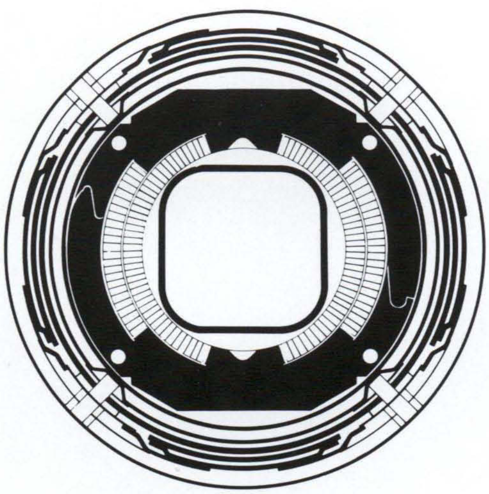
Superconductivity is not new, but its large-scale application opens a new frontier in high-energy physics research. The energy consumption of conventional electromagnets with the same capabilities would be prohibitive.



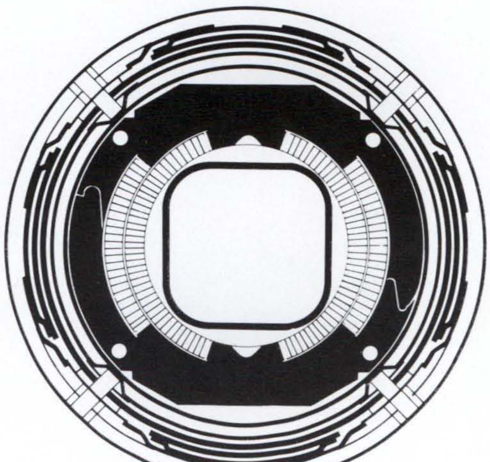
Cross section of a superconducting dipole magnet.



Main-accelerator tunnel showing two sets of magnets; the upper ones form the present synchrotron and the lower ones will form the Energy Saver.



"It's Our Future!" was the theme of the poster painted by the Fermilab Children's Center. It won the Energy Conservation Employee Awareness Committee's contest during October, energy awareness month. For their achievement, the young artists were treated to lunch in the Fermilab cafeteria and each presented with a certificate and blue ribbon.



Signing of the new collaboration agreement between the People's Republic of China and the U. S. by James Leiss of the Department of Energy and Zhang Wen-Yu, Director of the Institute for High Energy Physics, Beijing. Members of the joint committee of the collaboration observe.

International Collaboration

Japan—United States

An agreement was signed at the Laboratory on May 20 for continued collaboration between Japan and the United States in high-energy physics. Fermilab is one of the U. S. laboratories participating. The work at Fermilab will include participation in experiments (principally E-605, E-513, and E-650), in work on the Colliding Detector Facility, and in superconducting-magnet development. The magnet work is development of second-generation accelerator magnets that will reach fields of 10 Tesla, twice that of the Tevatron magnets. Work has proceeded vigorously since the signing.

China—United States

An agreement was signed at the Laboratory on June 19 for continued collaboration in high-energy physics between the People's Republic of China and the United States. Fermilab is headquarters for the United States effort. More than 100 Chinese scientists have visited Fermilab for long periods, and Fermilab scientists have visited China, where a 50-GeV proton synchrotron is being constructed.

USSR—United States

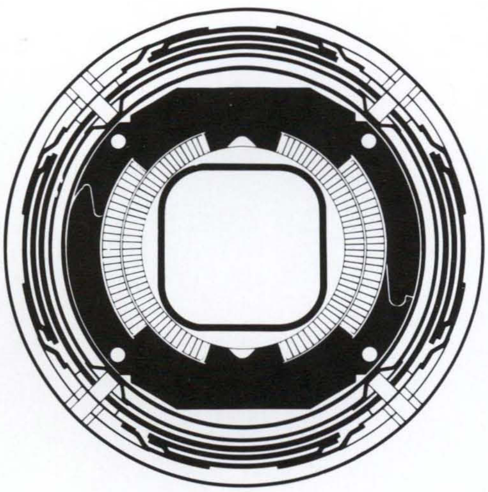
The collaboration between Fermilab and the USSR comes under the formal agreement between the two governments and is controlled by a Joint Coordinating Committee on Fundamental Particles of Matter (JCC-FPM).

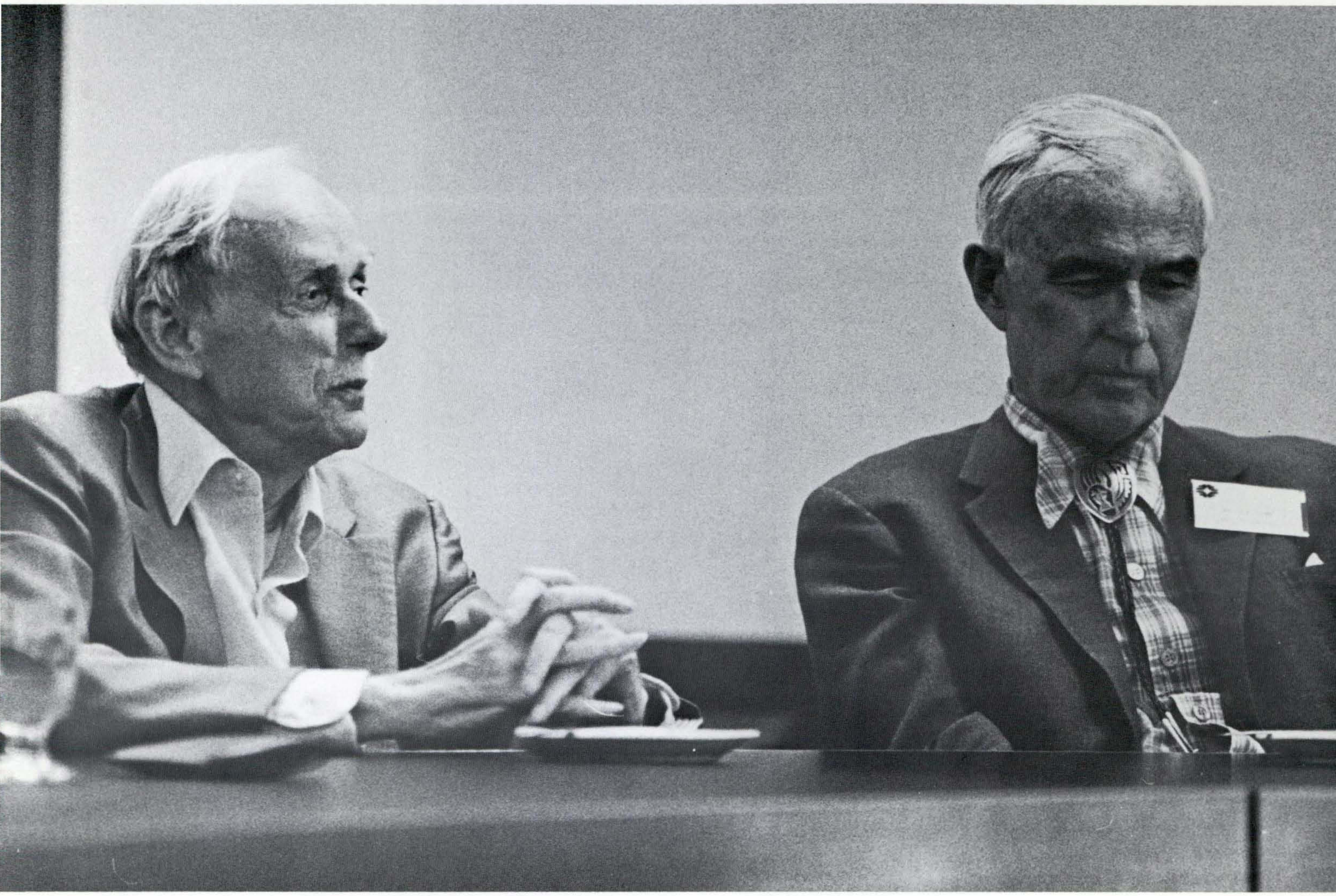
In 1980, activity fell to the lowest level in the eight-year history of the collaboration. This was due in part to an informal directive from the DOE to "show displeasure" at Soviet activity in Afghanistan, but also because of Fermilab scientists' feelings of frustration over treatment of some of their Soviet colleagues (Sakharov, Orlov, etc.) who are being denied rights guaranteed under the Helsinki Agreement. A meeting of the JCC-FPM was held in Moscow on December 8-9, 1980, to list items for collaboration in 1981. The meeting was characterized by both formal and informal communications of the fact that many U. S. scientists are strongly in favor of limiting collaboration. This is because Soviet colleagues whose only transgression appears to be the exercise of their human rights, are imprisoned, exiled, or prevented from attending international conferences. It is the policy of Fermilab to continue the long tradition of collaboration with the USSR, at the same time using all powers of persuasion to exert pressure on the Soviet establishment, to moderate actions that are in effect scientifically counterproductive. Collaboration with the INP at Novosibirsk remains good and we hope to improve this as we proceed into the Tevatron I program. A large number of other areas for potential collaboration are noted in the minutes of the meeting. The scientific value of the collaboration will very largely depend on receiving good proposals from Soviet laboratories for work in the Tevatron era. It should be noted that the Soviet UNK accelerator (3 TeV) is based very closely on the Tevatron, with a 400-GeV conventional accelerator injecting into a superconducting ring of Fermilab-style magnets scaled up to a larger aperture and located in the same tunnel.

Other Foreign Collaboration

Fermilab continues to attract scientists from all parts of the world. In 1980 about 100 scientists from Western Europe, representing 18 institutions, have been involved in the 400-GeV program. The April 1980 call for Tevatron proposals in the Neutrino and Muon areas brought responses from six largely European collaborations representing about 200 physicists. Exchanges with CERN continue (F. Krienen at Fermilab and R. Johnson at CERN). Fermilab, through Director L. Lederman and Director Emeritus R. Wilson, is active in the International Committee for Future Accelerators, which monitors interregional facilities and explores steps towards an eventual World Laboratory.

Finally, efforts are underway to establish a center at Fermilab where scientists from developing countries (especially Latin America) can come to learn frontier science and technology.



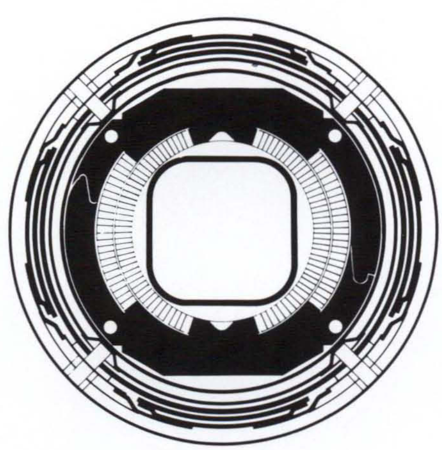


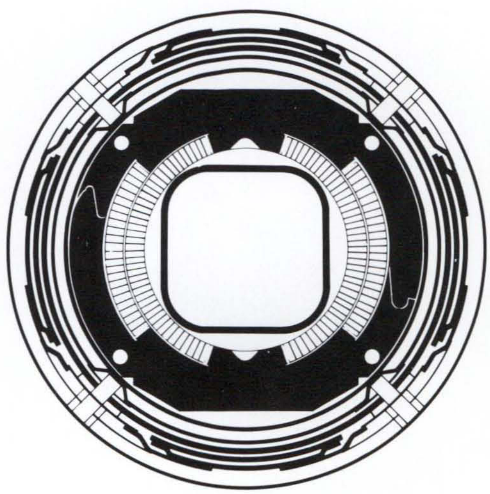
Paul Dirac (left) and Willis Lamb at the History of Particle Physics Symposium.

History of Particle Physics Symposium

An international symposium on the history of particle physics was held at the Laboratory in May, with joint sponsorship by the Laboratory, the Sloan Foundation, The Division of Particles and Fields of the American Physical Society, and The Center for History of Physics of the American Institute of Physics.

Participants included Herbert Anderson, Gilberto Bernardini, P. A. M. Dirac, Satio Hayakawa, Willis Lamb, Robert Marshak, M. G. K. Menon, Oreste Piccioni, Bruno Rossi, Julian Schwinger, Robert Serber, and Victor Weisskopf. The conference was a unique opportunity to hear these eminent people tell of their own participation in the beginnings of the field of Fermilab's research, particle physics.





1980 Publications

HIGH ENERGY PHYSICS PROGRAM EXPERIMENTAL PUBLICATIONS*

30-In. Hybrid #2B/#281

INCLUSIVE PRODUCTION OF π^0, K^0_S, Λ^0, AND $\bar{\Lambda}^0$ IN 100, 200 AND 360-GeV/c π^-p INTERACTIONS. N. N. Biswas et al., Nucl. Phys. **B167**, 41 (1980).

Neutrino #21A/#254

EXPERIMENTAL COMPARISON OF NEUTRINO, ANTINEUTRINO, AND MUON VELOCITIES. G. R. Kalbfleisch et al., Phys. Rev. Lett. **43**, 1361 (1979).

Muon #23/#391

DEEP INELASTIC MUON SCATTERING AT FERMILAB. M. Mugge, SLAC Summer Institute 1979, p. 360.

Photon Total Cross Section #25A

MEASUREMENT OF ω^- MESON PHOTOPRODUCTION ON PROTONS FROM 46 TO 180 GeV. R. M. Egloff et al., Phys. Rev. Lett. **43**, 1545 (1979), Erratum-**ibid. 44**, 690 (1980).

15-Ft $\bar{\nu}/H_2$ #31A

PROPERTIES OF THE HADRONIC SYSTEM PRODUCED IN $\bar{\nu}p$ INTERACTIONS. Argonne-Carnegie Mellon-Purdue Collaboration (B. Musgrave et al.), contributed to Neutrino '79, Bergen, Norway, June 18-22, 1979; published in Neutrino 79, v.2, p. 556.

COMPARISON OF JET SIZE IN $\bar{\nu}p$ INTERACTIONS WITH THAT IN e^+e^- ANNIHILATION. M. Derrick et al., Phys. Lett. **88B**, 177 (1979).

STUDY OF THE REACTION $\bar{\nu}p \to \mu^+ p \pi^-$. S. J. Barish et al., Phys. Lett. **91B**, 161 (1980).

INCLUSIVE ρ^0 PRODUCTION IN $\bar{\nu}p$ CHARGED-CURRENT INTERACTIONS. M. Derrick et al., Phys. Lett. **91B**, 307 (1980).

15-Ft ν/H_2 & Ne #53A

OBSERVATION OF A VISIBLE CHARMED PARTICLE DECAY IN NEUTRINO INTERACTIONS. A. M. Cnops et al., contributed to Neutrino '79, Bergen, Norway, June 18-22, 1979; published in Neutrino 79, v.2, p. 14.

Elastic Scattering #69A

HADRON-NUCLEUS ELASTIC SCATTERING AT 70, 125, AND 175 GeV/c. A. Schiz et al., Phys. Rev. **D21**, 3010 (1980).

Nuclear Chemistry #81A

NUCLEAR REACTIONS OF SILVER WITH 25.2 GeV ^{12}C IONS AND 300 GeV PROTONS. N. T. Porile et al., Phys. Rev. **C19**, 2288 (1979).

Photoproduction #87A

EVIDENCE FOR THE HIGH-ENERGY PHOTOPRODUCTION OF CHARMED MESONS. M. S. Atiya et al., Phys. Rev. Lett, **43**, 414 (1979).

HIGH-ENERGY PHOTOPRODUCTION OF THE D^{*+}. P. Avery et al., Phys. Rev. Lett. **44**, 1309 (1980).

A STUDY OF THE ZWEIG-OKUBO-IIZUKA RULE IN EXCLUSIVE PHOTOPRODUCTION REACTIONS. M. C. Goodman et al., Phys. Rev. **D22**, 537 (1980).

---

*This list was compiled using 1979 journal articles that did not appear in last year's report, plus 1980 journal articles, theses, and conference papers. Some conference papers were submitted to a conference in 1978 or 1979 and the proceedings were not published until 1980. If there are changes, omissions, or comments, please notify the Publications Office.

Photon Search #95A

INCLUSIVE π^0 PRODUCTION OVER LARGE $X_\perp$ AND X_F RANGES IN 200-, 300-, AND 400-GeV/c PROTON-BERYLLIUM INTERACTIONS. R. M. Baltrusaitis et al., Phys. Rev. Lett. **44**, 122 (1980).

A SEARCH FOR DIRECT PHOTON PRODUCTION AT FERMILAB ENERGIES AND COMPARISON WITH DIRECT PHOTON MEASUREMENTS AT ISR ENERGIES. B. Cox, Phys. Lett. **88B**, 372 (1979).

Emulsion/Protons @ 200 GeV #103/#232

EARLY CASCADE DEVELOPMENT OF ENERGETIC ELECTRONS. D. T. King, Phys. Rev. **D20**, 1 (1979).

Emulsion/Protons @ 200 GeV #105

STUDY OF PARTICLE PRODUCTION THROUGH CLUSTERS IN PROTON NUCLEUS INTERACTIONS AT 200 GeV/c. I. K. Daftari et al., J. Phys. Soc. Japan **47**, 349 (1979).

Inclusive Scattering #118A

EXPERIMENTAL STUDY OF LOW-p_t HADRON FRAGMENTATION. D. Cutts et al., Phys. Rev. Lett. **43**, 319 (1979).

A DETERMINATION OF THE PION AND KAON STRUCTURE FUNCTIONS. W. Aitkenhead et al., Phys. Rev. Lett. **45**, 157 (1980).

30-In. p-p @ 400 GeV #138

INCLUSIVE ρ^0 AND f PRODUCTION IN pp INTERACTIONS AT 405 GeV/c. A. Suzuki et al., Lett. Nuovo Cim. **24**, 449 (1979).

OBSERVATION OF K*(890) AND K*(1420) PRODUCTION IN 405 GeV/c pp INTERACTIONS. H. Kichimi et al., Lett. Nuovo Cim. **24**, 129 (1979).

HIGH MASS MESON RESONANCE PRODUCTION IN pp INTERACTIONS AT 405-GeV/c. A. Suzuki et al., Nucl. Phys. **B172**, 327 (1980).

30-In. Hybrid #154

NEUTRAL-PARTICLE PRODUCTION IN π^-p INTERACTIONS AT 147 GeV/c AND COMPARISON TO CHARGED-PARTICLE PRODUCTION. D. Brick et al., Phys. Rev. **D20**, 2123 (1979).

TRIPLE-REGGE ANALYSIS OF THE REACTIONS $\pi^-p \to$ pslow X AND $\pi^-p \to \pi^-$fast X AT 147 GeV/c. D. Brick et al., Nucl. Phys. **B150**, 109 (1979).

INCLUSIVE AND SEMI-INCLUSIVE CHARGE STRUCTURE IN π^-p MULTIPARTICLE PRODUCTION AT 147 GeV/c. D. Brick et al., Nucl. Phys. **B152**, 45 (1979).

LEADING PARTICLES AND DIFFRACTION DISSOCIATION IN 150 GeV/c π^-p INTERACTIONS. D. Brick et al., Phys. Rev. **D21**, 1726 (1980).

CLUSTER "CREATION" IN 147 GeV/c π^-p INTERACTIONS. I. A. Pless, invited talk at IX Int. Symp. on High Energy Multiparticle Dynamics, Tabor, Czechoslovakia, July 2-7, 1978; published in Tabor Symp. 1978, p. A1.

15-Ft $\bar{\nu}/H_2$ & Ne #172

QUARK FRAGMENTATION FUNCTIONS FROM NEUTRINO NUCLEUS INTERACTIONS. Berkeley-Hawaii-Washington Collaboration (H. J. Lubatti et al.), contributed to Neutrino '79, Bergen, Norway, June 18-22, 1979; published in Neutrino 79, v.**2**, p. 543.

Multiplicities #178

AN EXPERIMENTAL STUDY OF MULTIPARTICLE PRODUCTION IN HADRON-NUCLEUS INTERACTIONS AT HIGH ENERGY. J. E. Elias et al., Phys. Rev. **D22**, 13 (1980).

15-Ft $\bar{\nu}/H_2$ & Ne #180

PROPERTIES OF K^0 AND Λ INCLUSIVE PRODUCTION IN CHARGED CURRENT ANTINEUTRINO-NUCLEON INTERACTIONS. V. Ammosov et al., Nucl. Phys. **B162**, 205 (1980).

NET CHARGE IN DEEP INELASTIC ANTINEUTRINO-NUCLEON SCATTERING. Fermilab-IHEP-ITEP-Michigan Collaboration (J. P. Berge et al.), Phys. Lett. **91B**, 311 (1980).

INCLUSIVE PRODUCTION OF NONSTRANGE RESONANCES IN HIGH-ENERGY νp CHARGED-CURRENT INTERACTIONS. J. P. Berge et al., Phys. Rev. **D22**, 1043 (1980).

MEASUREMENT OF THE SU(3) SYMMETRY VIOLATION IN THE QUARK JET. Fermilab-IHEP-ITEP-Michigan Collaboration (V. V. Ammosov et al.), Phys. Lett. **93B**, 210 (1980).

Emulsion/Protons @ 200 GeV #183

ANALYSIS OF FOUR-PRONG pp INTERACTIONS AT 25 AND 200 GeV/c USING PARAMETER INVARIANT QUANTITY (in Russian). S. A. Azimov et al., Yad. Fiz. **29**, 931 (1979).

STUDY OF QUASINUCLEON INTERACTIONS OF 400 GeV/c PROTONS IN NUCLEAR PHOTOEMULSION (in Russian). Alma-Ata-Gatchina-Moscow-Tashkent Collboration (E. G. Boos et al.), Yad. Fiz. **30**, 407 (1979).

EXPERIMENTAL VERIFICATION OF THE DUAL UNITARIZATION SCHEME. Alma-Ata-Dubna-Helsinki-Moscow-Prague-Tbilisi Collaboration (E. G. Boos et al.), Phys. Lett. **85B**, 424 (1979).

STUDY OF pN INTERACTIONS BY MEANS OF THE PARAMETRICALLY INVARIANT QUANTITIES R(1) AND R(2) AT 200 GeV/c (in Russian). S. A. Azimov et al., Izv. Akad. Nauk. Uzb. SSR Fiz., No. 3, 65 (1979).

STUDY OF PARTICLE CLUSTERIZATION IN SIX-PRONG pp INTERACTIONS AT 25 AND 200 GeV/c USING PARAMETER-INVARIANT QUANTITIES (in Russian). S. A. Azimov et al., Yad. Fiz. **30**, 164 (1979).

30-In. pd @ 100 GeV #194

SLOW PROTON PRODUCTION FROM NEUTRON TARGETS AT 100-GeV/c AND 400-GeV/c. J. Hanlon et al., Phys. Rev. **D20**, 2135 (1979).

30-In. pd @ 400 GeV #196

CHARGED PARTICLE MULTIPLICITY DISTRIBUTIONS IN pd AND pn INTERACTIONS AT 400-GeV/c. S. Dado et al., Phys. Rev. **D20**, 1589 (1979).

Muon #203A

MUOPRODUCTION OF MULTIMUON FINAL STATES AT FERMILAB: PRELIMINARY RESULTS. (Talk). A. R. Clark et al., presented at the 14th Rencontre de Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. II Current Hadron Interactions, p. 503.

MUON SCATTERING INTO 1-5 MUON FINAL STATES. A. R. Clark et al., invited paper given at the 9th Int. Symp. on Lepton and Photon Interactions at High Energy, Batavia, Ill., August 23-29, 1979, published in Lepton/Photon Symp. 1979, p. 135.

LIMIT ON Υ MUOPRODUCTION AT 209 GeV. A. R. Clark et al., Phys. Rev. Lett. **45**, 686 (1980).

Form Factor #216

DIRECT MEASUREMENT OF THE NEGATIVE-KAON FORM FACTOR. E. B. Dally et al., Phys. Rev. Lett. **45**, 232 (1980).

30-In. π^-d @ 200 GeV #218

STUDY OF $\pi^-\pi^-$ SCATTERING IN π^-n INTERACTIONS AT HIGH ENERGIES. H. Abramowicz et al., Nucl. Phys. **B166**, 62 (1980).

Emulsion/Protons @ 400 GeV #243

X-PARTICLES AND THEIR BACKGROUNDS IN 400 GeV/c PROTON INTERACTIONS. H. Fuchi et al., Nuovo Cim. **51A**, 18 (1979).

Particle Search #247

AN ATTEMPT TO DETECT PARTICLES OF VERY SHORT LIFETIMES PRODUCED IN HIGH-ENERGY NEUTRINO INTERACTIONS. G. Baroni et al., Lett. Nuovo Cim. **24**, 45 (1979).

Neutrino #253

MEASUREMENT OF THE CROSS SECTION FOR $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$. R. H. Heisterberg et al., Phys. Rev. Lett. **44**, 635 (1980).

Pion Inclusive #258

THE RELATIVE PRODUCTION OF π^+, K^+, p, AND $\bar{p}$ AT LARGE TRANSVERSE MOMENTUM IN 200- AND 300-GeV π^--p COLLISIONS. H. J. Frisch et al., Phys. Rev. Lett. **44**, 511 (1980).

Hadron Jets #260

HIGH p_t JET STUDIES AT FERMILAB. W. Selove, presented at the 14th Rencontre Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. I Quarks, Gluons, and Jets, p. 401.

CORRELATIONS BETWEEN HIGH TRANSVERSE MOMENTUM HADRONS IN π^+-p, K^-p, AND pp COLLISIONS AT 200-GeV/c. R. W. Stanek, Ph.D. Thesis, University of Illinois, Chicago Circle, 1980.

STRUCTURE OF EVENTS IN 200-GeV INTERACTIONS ON HYDROGEN AND ALUMINUM TARGETS IN BOTH SOFT AND HARD COLLISIONS. C. Bromberg et al., Nucl. Phys. **B171**, 38 (1980).

JET PRODUCTION IN HIGH-ENERGY HADRON-PROTON COLLISIONS. C. Bromberg et al., Nucl. Phys. **B171**, 1 (1980).

MEASUREMENT OF FORWARD JETS PRODUCED IN HIGH TRANSVERSE MOMENTUM HADRON-PROTON COLLISIONS. C. Bromberg et al., Phys. Rev. Lett. **45**, 769 (1980).

Inclusive Photon #268

OBSERVATION OF INCLUSIVE ω PRODUCTION AT LARGE TRANSVERSE MOMENTUM. G. J. Donaldson et al., Phys. Rev. **D21**, 828 (1980).

Hadron Dissociation #272

RADIATIVE WIDTHS OF VECTOR AND TENSOR MESONS AND SU(3). (Talk) A. Jonckheere, presented at the 14th Rencontre de Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. I Quarks, Gluons, and Jets, p. 643.

RADIATIVE WIDTHS OF THE ρ^- MESON. D. Berg et al., Phys. Rev. Lett. **44**, 706 (1980).

MEASUREMENT OF THE RADIATIVE DECAY WIDTH OF THE ρ^0 MESON. T. C. Jensen, Ph.D. Thesis, Rochester University, 1980.

Di-Lepton #288

RESONANT AND CONTINUUM DILEPTON PRODUCTION. L. M. Lederman, Phys. Scr. **20**, 227 (1979).

Backward Scattering #290

MEASUREMENT OF $\pi^\pm$p BACKWARD ELASTIC SCATTERING BETWEEN 30 AND 90 GeV/c. W. F. Baker et al., Phys. Rev. Lett. **43**, 1635 (1979).

Emulsion/Protons @ 400 GeV #292

PROTON TUNGSTEN REACTIONS AT 400 GeV. J. Cincheza et al., Nucl. Phys. **B158**, 280 (1979).

GENERAL PROPERTIES OF HADRON-NUCLEUS REACTION MULTIPLICITIES. B. Andersson et al., Phys. Lett. **84B**, 469 (1979).

30-In. π^+ & pd @ 200 GeV #295

INCLUSIVE π^+ TO π^- RATIOS AND QUARK DISTRIBUTIONS OF PIONS AND NUCLEONS. Y. Eisenberg et al., Phys. Lett. **83B**, 127 (1979), Erratum-**ibid. 84B**, 529 (1979).

30-In. Hybrid #299

AVERAGE CHARGED-PARTICLE MULTIPLICITIES IN π^-p INCLUSIVE REACTIONS AT 147 GeV/c. D. Brick et al., Phys. Rev. **D19**, 743 (1979).

INCLUSIVE Δ^{++} PRODUCTION IN pp, K^+p, π^+p, AND π^-p INTERACTIONS AT 147 GeV/c. D. Brick et al., Phys. Rev. **D21**, 632 (1980).

INCLUSIVE AND EXCLUSIVE RESULTS IN K+p, π+p, AND pp INTERACTIONS AT 147 GeV/c. International Hybrid Spectrometer Consortium (R. T. Van de Walle et al.), presented at the 10th Int. Symp. on Multiparticle Dynamics, Goa, India, September 25-29, 1979.

INCLUSIVE PRODUCTION OF NEUTRAL STRANGE PARTICLES BY 147 GeV/c $\pi^+/K^+/p$ INTERACTIONS IN HYDROGEN. D. Brick et al., Nucl. Phys. **B164**, 1 (1980).

30-In. $\bar{p}p$ @ 100 GeV #311

GENERAL FEATURES OF CHARGED PARTICLE PRODUCTION IN $\bar{p}p$ INTERACTIONS AT 100 GeV/c. C. P. Ward et al., Nucl. Phys. **B153**, 299 (1979).

INCLUSIVE PARTICLE PRODUCTION IN 100 GeV/c π^-p AND $\bar{p}p$ INTERACTIONS. A. K. Nandi et al., Nucl. Phys. **B169**, 20 (1980).

Muon #319

MULTIMUON FINAL STATES IN MUON-NUCLEON SCATTERING AT 270 GeV. D. Bauer et al., Phys. Rev. Lett. **43**, 1551 (1979).

Di-Muon #331

PRODUCTION OF MUON PAIRS BY 225 GeV/c $\pi^{\pm}$, K^+, $p^{\pm}$ BEAMS ON NUCLEAR TARGETS. K. J. Anderson et al., Phys. Rev. Lett. **42**, 944 (1979).

Emulsion/Protons @ 400 GeV #336

A DEPENDENCE IN PROTON NUCLEUS INTERACTIONS AT 400 GeV. F. Fumuro et al., Nucl. Phys. **B152**, 376 (1979).

30-In. $\bar{p}p$ @ 50 GeV #344

STUDY OF ANTIPROTON-PROTON ANNIHILATIONS USING THE TOPOLOGICAL-CROSS-SECTION DIFFERENCES BETWEEN $\bar{p}p$ AND pp INTERACTIONS AT 48.9 GeV/c. R. M. Robertson et al., Phys. Rev. **D21**, 3064 (1980).

EXPERIMENTAL DETERMINATION OF ELASTIC AND TOPOLOGICAL CROSS SECTIONS IN 48.9-GeV/c $\bar{p}p$ INTERACTIONS. D. E. Zissa et al., Phys. Rev. **D21**, 3059 (1980).

30-In. $\bar{p}d$ @ 100 GeV #345

ANTIPROTON NEUTRON INTERACTIONS AT 100 GeV/c. Liverpool-Stockholm-Vanderbilt Collaboration (J. R. Fry et al.), Nucl. Phys. **B152**, 27 (1979).

Neutrino #356

FLUX NORMALIZED CHARGED CURRENT NEUTRINO CROSS SECTIONS UP TO NEUTRINO ENERGIES OF 260 GeV (Talk). J. Ludwig et al., published in Geneva 1979, Proceedings of the Int. Conf. on High Energy Physics, v.**1**, p. 163.

Particle Search #365

MISSING-MASS SEARCH FOR NEGATIVE-CHARGE BOSONS WITH MASSES BETWEEN 2 AND 12.5 GeV. G. J. Blanar et al., Phys. Rev. **D20**, 615 (1979).

RECENT EXPERIMENTAL MEASUREMENTS OF THE NEUTRINO CHARGED CURRENT CROSS SECTIONS. D. Theriot, presented at the 9th Int. Symp. on Lepton and Photon Interactions at High Energy, Batavia, Ill., August 23-29, 1979; published in Lepton/Photon Symp., p. 337.

Particle Search #369

PRODUCTION OF PHOTONS ASSOCIATED WITH THE ψ BY 217 GeV/c π^- MESONS. T. B. W. Kirk et al., Phys. Rev. Lett. **42**, 619 (1979).

Particle Search #379

PRODUCTION OF ψ(3100) IN 400-GeV/c PROTON INTERACTIONS. E. J. Siskind et al., Phys. Rev. **D21**, 628 (1980).

SEARCH FOR POSSIBLE SIGNATURES OF BOTTOM-MESON PRODUCTION IN p-Fe INTERACTIONS AT 400 GeV/c. A. Diamont-Berger et al., Phys. Rev. Lett. **44**, 507 (1980).

Particle Search #382

A TECHNIQUE FOR LOCATING MUON DEEP INELASTIC SCATTERING EVENTS IN A NUCLEAR EMULSION TARGET. L. Hand et al., Nucl. Instrum. Methods **167**, 261 (1979).

Emulsion/Protons @ 400 GeV #385

AZIMUTHAL ASYMMETRY IN 400 GeV/c p-N INTERACTIONS. P. K. Sengupta et al., Lett. Nuovo Cim. **25**, 203 (1979).

STUDY OF ANGULAR DISTRIBUTIONS OF SECONDARIES IN PROTON-NUCLEUS INTERACTIONS AT 400 GeV. M. M. Aggarwal et al., Lett. Nuovo Cim. **24**, 183 (1979).

Emulsion/π^- @ 200 GeV #387

INTERACTIONS OF 200 GeV PIONS IN NUCLEI. M. Y. Lee et al., Phys. Rev. **D19**, 55 (1979).

Hadron Jets #395

A TWO-JET CALORIMETER EXPERIMENT AT FERMILAB. M. D. Corcoran et al., Phys. Scr. **19**, 95 (1979).

EVIDENCE THAT HIGH-p_T JET PAIRS GIVE DIRECT INFORMATION ON PARTON-PARTON SCATTERING. M. D. Corcoran et al., Phys. Rev. Lett. **44**, 514 (1980).

A STUDY OF PARTON TRANSVERSE MOMENTUM USING JETS FROM HADRON INTERACTIONS. M. D. Corcoran et al., Phys. Rev. **D21**, 641 (1980).

Muon #398

TRANSVERSE MOMENTUM AND ANGULAR DISTRIBUTIONS OF HADRONS IN MUON-PROTON SCATTERING AND TESTS OF QUANTUM CHROMODYNAMICS. C. Tao et al., Phys. Rev. Lett. **44**, 1726 (1980).

Inclusive Neutron #404

INCLUSIVE NEUTRON PRODUCTION BY 400 GeV PROTONS. L. W. Jones et al., presented at the X Int. Symp. on Multiparticle Dynamics, Fort Aguada Beach Resort, Goa, India, September 25-29, 1979; published in Goa Symp. 1979, p. 71.

Lambda Magnetic Moment #440

POLARIZATION OF Λ's AND $\bar{\Lambda}$'s PRODUCED BY 400-GeV PROTONS. K. Heller et al., Phys. Rev. Lett. **41**, 607 (1978), Erratum-**ibid. 45**, 1043 (1980).

THE FIRST MEASUREMENT OF THE Ξ^0 MAGNETIC MOMENT. G. Bunce et al., Phys. Lett. **86B**, 386 (1979).

Nuclear Fragments #442

STUDY OF HIGH ENERGY P-Xe AND P-Kr COLLISIONS (Talk). J. A. Gaidos et al., published in Singapore 1978, proceedings 1978 Int. Meeting on Frontier of Physics, Singapore, v.**2**, p. 797.

OBSERVATION OF NEUTRAL HEAVY ATOM ACCELERATION VIA COLLISION HEATING (Talk). L. J. Gutay and F. Turkot, published in Singapore 1978, proceedings 1978 Int. Meeting on Frontier of Physics, Singapore, v.**2**, p. 807.

Inclusive Scattering #451

CONSTRUCTION AND OPERATION OF AN ELECTROMAGNETIC SHOWER DETECTOR. P. H. Garbincius et al., IEEE Trans. Nucl. Sci. **27**, 79 (1980).

Emulsion/Protons @ 400 GeV #463

POSSIBLE EXAMPLE OF CHARMED-PARTICLE DECAY AS THE RESULT OF (WEAK) NEUTRAL CURRENTS BY THE CHANNEL $B_c \to e^+e^-$ + HADRONS. A. A. Komar et al., Sov. J. Nucl. Phys. **29**, 50 (1979).

Nuclear Fragments #466

SPALLATION OF ALUMINUM BY 300-GeV PROTONS. S. B. Kaufman et al., Phys. Rev. **C19**, 962 (1979).

UNUSUAL BACKWARD ENHANCEMENT IN THE ANGULAR DISTRIBUTION OF PRODUCTS FROM THE INTERACTION OF ^{238}U WITH 400-GeV PROTONS. N. T. Porile et al., Phys. Rev. Lett. **43**, 918 (1979).

Particle Search #490

OBSERVATION OF THE PRODUCTION OF SHORT-LIVED PARTICLES IN A HIGH-RESOLUTION STREAMER-CHAMBER EXPERIMENT. J. Sandweiss et al., Phys. Rev. Lett. **44**, 1104 (1980).

Di-Hadron #494

INCLUSIVE PRODUCTION OF LARGE-TRANSVERSE-MOMENTUM HADRONS AND HADRON PAIRS. H. Jöstlein et al., Phys. Rev. **D20**, 53 (1979).

High Energy Channeling #507

CONTROL OF CHARGED PARTICLE TRAJECTORIES BY MEANS OF A BENT MONOCRYSTAL (in Russian). Dubna-Swierk-Kharkov-Tomsk-Batavia-New York-Leningrad Collaboration (A. S. Vodopyanov et al.), Pisma Zh. Eksp. Teor. Fiz. **30**, 474 (1979).

DIGITAL SCATTERING ANGLE PREPROCESSORS. Z. Guzik et al., Nucl. Instrum. Methods **166**, 351 (1979).

MODULATION OF NUCLEAR INTERACTIONS USING CHANNELING AT MULTI-HUNDRED GeV ENERGIES. R. A. Carrigan, Jr., et al., Nucl. Phys. **B163**, 1 (1980).

Neutrino #531

DETECTION METHOD OF NEUTRINO INTERACTION IN THE VERTICAL EMULSION TARGET OF HYBRID APPARATUS. H. Fuchi et al., J. Phys. Soc. Japan **47**, 687 (1979).

MEASUREMENT OF THE D^0 LIFETIME. N. Ushida et al., Phys. Rev. Lett. **45**, 1049 (1980).

MEASUREMENT OF THE D^+, F^+, AND Λ_c^+ CHARMED-PARTICLE LIFETIMES. N. Ushida et al., Phys. Rev. Lett. **45**, 1053 (1980).

15-Ft Neutrino/H_2 & Ne #546

DIMUON PRODUCTION BY NEUTRINOS IN THE FERMILAB 15-FT BUBBLE CHAMBER. H. C. Ballagh et al., Phys. Rev. **D21**, 569 (1980).

OBSERVATION OF SHORT-LIVED PARTICLES PRODUCED IN HIGH-ENERGY NEUTRINO INTERACTIONS. H. C. Ballagh et al., Phys. Lett. **89B**, 423 (1980).

15-Ft & Emulsion/Neutrino #564

PRODUCTION AND DECAY OF F^+(2030) OBSERVED IN ν_μ INTERACTIONS IN EMULSION. R. Ammar et al., Phys. Lett. **94B**, 118 (1980).

Particle Search #595

PROMPT MUON PRODUCTION AT SMALL X_F AND P_T IN 350-GeV p-Fe COLLISIONS. J. L. Ritchie et al., Phys. Rev. Lett. **44**, 230 (1980).

Beam Dump #613

PROMPT NEUTRINO AND AXION EXPERIMENTS AT FERMILAB. L. W. Jones et al., presented at the X Int. Symp. on Multiparticle Dynamics, Fort Aguada Beach Resort, Goa, India, September 25-29, 1979; published in Goa Symp. 1979, p. 684.

General Fermilab Experimental Program

RT-RSX MULTI: PACKAGES FOR DATA ACQUISITION AND ANALYSIS IN HIGH-ENERGY PHYSICS (Talk). J. F. Bartlett et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4427 (1979).

EXPERIMENTAL STUDY OF LOW-p_T INCLUSIVE SCATTERING AND COMPARISON WITH QUARK-PARTON MODELS (Talk). G. W. Brandenburg, presented at the 14th Rencontre de Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. I Quarks, Gluons, and Jets, p. 507.

PRECISE MEASUREMENTS OF HIGH-p_T SINGLE PARTICLE SPECTRA IN π^-p COLLISIONS AT FERMILAB (Talk). H. J. Frisch, presented at the 14th Rencontre de Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. I Quarks, Gluons, and Jets, p. 393.

VERY-HIGH-ENERGY ANTIPROTON PHYSICS: COLLIDING 1 TeV "ANTIQUARKS" ON HEAVY NUCLEI. F. Halzen and P. McIntyre, Phys. Rev. **D21**, 726 (1980).

AFFECTS OF TECHNOLOGICAL ADVANCES IN COMPUTING ON HIGH ENERGY PHYSICS EXPERIMENTS (Talk). M. Johnson, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4433 (1979).

HYPERON BEAM PHYSICS. J. Lach and L. Pondrom, Ann. Rev. Nucl. Part. Sci. **29**, 203 (1979).

THE CONSTRUCTION AND PERFORMANCE OF LARGE FLASH CHAMBERS. F. E. Taylor et al., Submitted to the IEEE 1979 Symposium on Nuclear Power Systems, San Francisco, October 17-19, 1979; published in IEEE Trans. Nucl. Sci. **27**, 30 (1980).

THE CRISIS DETECTOR (Talk). B. F. Wadsworth et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 120 (1979).

Experimental Not Related to Fermilab Program

TECHNIQUES TO SEARCH FOR PROTON INSTABILITY TO 10^{34} YEARS. D. B. Cline, published in Coral Gables 1979, Proceedings, High Energy Physics in the Einstein Centennial Year, p. 157.

OBSERVATION OF THE Υ''' AT THE CORNELL ELECTRON STORAGE RING. L. M. Lederman et al., Phys. Rev. Lett. **45**, 222 (1980).

ULTRA HIGH-ENERGY INELASTIC NEUTRINO-NUCLEON SCATTERING IN DUMAND. A. Roberts, presented at the 16th Int. Cosmic Ray Conf., Kyoto, Japan, August 6-18, 1979; published in Kyoto Cosmic Ray 1979, v.**10**, p. 367.

THEORETICAL PUBLICATIONS

EVALUATION OF A TEST FOR THE TAU NEUTRINO IN THE ZERO-MUON CHANNEL. C. H. Albright et al., Phys. Lett. **90B**, 465 (1980).

POSSIBLE INDICATIONS OF NEUTRINO OSCILLATIONS. V. Barger et al., Phys. Lett. **93B**, 194 (1980).

MASS AND MIXING SCALES OF NEUTRINO OSCILLATIONS. V. Barger et al., J. Phys. **G6**, 165 (1980).

WHY MASSES AND MAGNETIC MOMENTS SATISFY NAIVE QUARK MODEL PREDICTIONS. I. Cohen and H. J. Lipkin, Phys. Lett. **93B**, 56 (1980).

QUANTUM GELFAND-LEVITAN METHOD AS A GENERALIZED JORDAN-WIGNER TRANSFORMATION. D. B. Creamer et al., Phys. Lett. **92B**, 144 (1980).

GLUON CONDENSATION FROM TRACE ANOMALY IN QUANTUM CHROMODYNAMICS. R. Fukuda and Y. Kazama, Phys. Rev. Lett. **45**, 1142 (1980).

PENQUINS IN $\Delta S = 1$ NONLEPTONIC WEAK DECAYS. C. T. Hill and G. G. Ross, Phys. Lett. **94B**, 234 (1980).

LARGE DISTANCE EFFECTS IN CP-VIOLATION AND THE K^0-$\bar{K}^0$ MASS MATRIX. C. T. Hill, Phys. Lett. **97B**, 275 (1980).

TESTING THE SPIN OF THE GLUON IN LARGE TRANSVERSE MOMENTUM LEPTON PAIR PRODUCTION. P. W. Johnson and Wu-Ki Tung, Phys. Rev. Lett. **45**, 1382 (1980).

SHORT-RANGE CORRELATIONS AND BARYON DECAY. G. Karl and H. J. Lipkin, Phys. Rev. Lett. **45**, 1223 (1980).

A DUAL FORMULATION OF NON-ABELIAN GAUGE THEORIES. Y. Kazama and R. Savit, Phys. Rev. **D21**, 2916 (1980).

EFFECTIVE LAGRANGIAN DUE TO HEAVY QUARKS IN QUANTUM CHROMODYNAMICS. Y. Kazama and Y. P. Yao, Phys. Rev. **D22**, 514 (1980).

TROUBLES WITH NONLEPTONIC CHARM DECAYS. H. J. Lipkin, Phys. Rev. Lett. **44**, 710 (1980).

SU(5) WITHOUT SU(5): CONSERVATION LAWS IN UNIFIED MODELS OF QUARKS AND LEPTONS. H. J. Lipkin, Nucl. Phys. **B171**, 301 (1980).

WHY IS B-L CONSERVED AND BARYON NUMBER NOT IN UNIFIED MODELS OF QUARKS AND LEPTONS? H. J. Lipkin, Phys. Rev. Lett. **45**, 311 (1980).

SPACE-TIME STRUCTURE OF JET HADRONIZATION. H. Minakata, Phys. Rev. Lett. **45**, 325 (1980).

HOW TO CALCULATE THE HEAVY QUARK FRAGMENTATION FUNCTION: AN APPLICATION OF CUT VERTICES. J. Oliensis, Ph.D. Thesis, University of Chicago, 1980.

PERTURBATIVE QCD CORRECTIONS TO THE HADRONIC DECAY WIDTH OF THE HIGGS BOSON. N. Sakai, Phys. Rev. **D22**, 2220 (1980).

CONSEQUENCES OF FLAVOR AS A DYNAMICAL QUANTUM NUMBER. V. Visnjic-Triantafillou, Phys. Lett. **95B**, 47 (1980).

SEMILEPTONIC DECAY OF CHARMED PARTICLES AND WEAK FORM-FACTORS. K. Yamada, Phys. Rev. **D22**, 1676 (1980).

K* DOMINANCE OF K-L-3 FORM-FACTOR AND SIRLIN'S RELATION. K. Yamada, Phys. Lett. **97B**, 156 (1980).

ACCELERATOR PUBLICATIONS

CENTRAL LIQUEFIER FOR THE FERMILAB TEVATRON (Talk). R. S. Ahlman et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4105 (1979).

PROCESS CONTROL SYSTEM FOR THE TEVATRON LIQUEFIER. R. S. Ahlman et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4099 (1979).

HELIUM REFRIGERATION SYSTEM AND CRYOGENIC SYSTEM FOR SUPERCONDUCTING SWITCHYARD MAGNETS AT FERMILAB (Talk). R. A. Andrews et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4093 (1979).

THE FERMILAB CANCER THERAPY FACILITY: STATUS REPORT AFTER 2.5 YEARS OF OPERATION (Talk). M. Awschalom et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3068 (1979).

A MICROPROCESSOR BASED BEAM INTENSITY AND EFFICIENCY DISPLAY SYSTEM FOR THE FERMILAB ACCELERATOR (Talk). R. Biwer, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3448 (1979).

BIPOLAR OPERATION OF THE MAIN RING MAGNET SUPPLIES (Talk). K. R. Bourkland, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4063 (1979).

A 34 KILO-AMPERE RAPID CYCLING PFN POWER SUPPLY FOR DRIVING INJECTION MAGNETS (Talk). K. R. Bourkland, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3974 (1979).

MODIFICATIONS TO THE FERMILAB BOOSTER-MAIN RING BEAM TRANSFER PHASE LOCK CIRCUIT (Talk). J. F. Bridges, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3337 (1979).

THE MULTIPLE MAGNET TEST PROGRAM (Talk). P. Brindza, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3888 (1979).

ENERGY DOUBLER REFRIGERATION SYSTEM (Talk). P. D. Brindza, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4102 (1979).

THE FERMILAB BOOSTER AS A KAON FACTORY (Talk). B. Brown and C. Hojvat, published in Kaon Factory Workshop Proceedings, Vancouver, 1979, p. 178.

DESIGN OF AN ADDITIONAL EXTRACTION/INJECTION AREA FOR THE FERMILAB BOOSTER (Talk). B. C. Brown et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3173 (1979).

HIGH-ENERGY ELECTRON COOLING TO IMPROVE THE LUMINOSITY AND LIFETIME IN COLLIDING BEAM MACHINES. D. Cline et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3472 (1979).

PROTON BEAM DIAGNOSTICS IN THE FERMILAB ELECTRON COOLING EXPERIMENT (Talk). D. Cline et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3302 (1979).

INITIAL OPERATION OF THE FERMILAB ANTIPROTON COOLING RING (Talk). D. Cline et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3158 (1979).

LINAC H^--BEAM OPERATION AND USES AT FERMILAB (Talk). C. D. Curtis et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3760 (1979).

CURRENT TO FREQUENCY CONVERTER FOR DIGITIZATION OF MILLISECOND BEAM SIGNALS (Talk). A. R. Donaldson, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3439 (1979).

A FAST FIRST PASS AT THE FUTURE FASTBUS (Talk). T. F. Droege and K. J. Turner, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4543 (1979).

FAST EVENT RECORDER UTILIZING A CCD ANALOG SHIFT REGISTER (Talk). R. J. Ducar and P. M. McIntyre, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 251 (1979).

A CAMAC BASED HIGH-RESOLUTION REPETITIVE WAVEFORM GENERATOR (Talk). R. J. Ducar et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4149 (1979).

IMPROVED CHROMATICITY CONTROL FOR 100 GeV STORAGE AT FERMILAB (Talk). S. Ecklund et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3547 (1979).

DOUBLER-TEVATRON μP QUENCH PROTECTION SYSTEM (Talk). R. H. Flora and G. S. Tool, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3451 (1979).

INJECTION, MAGNET, AND VACUUM SYSTEMS FOR THE FERMILAB ANTIPROTON COOLING RING (Talk). J. C. Gannon et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3241 (1979).

A REPORT ON THE OPERATIONAL RELIABILITY OF THE FERMILAB MAIN RING MAGNETS (Talk). R. E. Gerig, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3161 (1979).

A DISTRIBUTED LINAC CONTROL SYSTEM FEATURING SDLC LOOP COMMUNICATION. R. W. Goodwin and M. F. Shea, Submitted to the 1979 Linear Accelerator Conference, Montauk, New York, September 10-14, 1979; published in Linear Accel. Conf., p. 274.

A REVIEW OF SOME DYNAMIC LOSS PROPERTIES OF Ni-Zn ACCELERATOR RF SYSTEM FERRITE. J. E. Griffin and G. Nicholls, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3965 (1979).

THE EFFECT OF LARGE DELAYS ON BEAM RF PHASE LOCK LOOPS (Talk). J. E. Griffin, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3944 (1979).

AZIMUTHAL REDISTRIBUTION OF BEAM IN THE FERMILAB MAIN RING (Talk). J. E. Griffin and F. E. Mills, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3589 (1979).

THE ELECTRON BEAM FOR THE FERMILAB ELECTRON COOLING EXPERIMENT (Talk). W. B. Herrmannsfeldt et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3237 (1979).

BEAM DETECTOR ASSEMBLY FOR THE FERMILAB ENERGY DOUBLER (Talk). E. F. Higgins and T. H. Nicol, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3246 (1979).

A BROADRANGE BEAM SIGNAL LIMITER FOR THE FERMILAB BOOSTER (Talk). E. F. Higgins, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3373 (1979).

THE MULTITURN CHARGE EXCHANGE INJECTION SYSTEM FOR THE FERMILAB BOOSTER ACCELERATOR (Talk). C. Hojvat et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3149 (1979).

STRIPPING FOILS FOR MULTITURN CHARGE EXCHANGE INJECTION INTO THE FERMILAB BOOSTER. C. Hojvat et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4009 (1979).

DECELERATION OF ANTIPROTONS IN THE FERMILAB BOOSTER (Talk). C. Hojvat et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3586 (1979).

POWER FOR THE FERMILAB TEVATRON HELIUM LIQUEFIER (Talk). J. Hoover et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3938 (1979).

A HIGH-SPEED VOLTAGE-CONTROLLED OSCILLATOR FOR THE FERMILAB BOOSTER LOW-LEVEL RF SYSTEM (Talk). S. P. Jachim, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3953 (1979).

A SIMPLE COMMUNICATION NETWORK WITHIN A HIERARCHICAL CONTROL SYSTEM (Talk). M. Johnson and T. Lahey, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 725 (1979).

ELECTRON BEAM DIAGNOSTICS IN THE FERMILAB ELECTRON COOLING EXPERIMENT (Talk). W. Kells and P. M. McIntyre, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3300 (1979).

THE BELLCORD - A MULTILEVEL FAST PREPROCESSOR FOR 1024 ECL CHANNELS (Talk). C. R. Kerns, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 239 (1979).

30-53 MHZ SUPER CAVITIES FOR 10-GeV ACCELERATION IN THE FERMILAB BOOSTER RING (Talk). Q. A. Kerns et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4111 (1979).

CONSTRUCTION OF ENERGY DOUBLER CORRECTION MAGNETS (Talk). F. Kircher and M. Leininger, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3931 (1979).

PRESSURE DEVELOPMENT DURING ENERGY DOUBLER QUENCHES (Talk). M. Kuchnir and K. Koepke, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4045 (1979).

THE $\bar{p}p$ PROGRAM AT FERMILAB (Talk). P. M. McIntyre, presented at the 14th Rencontre Moriond, Les Arcs, France, March 11-23, 1979; published in Vol. I Quarks, Gluons, and Jets, p. 683.

A NEW LOW LEVEL RF SYSTEM FOR THE FERMILAB BOOSTER (Talk). K. G. Meisner et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4061 (1979).

MEASUREMENT OF MOMENTUM COOLING RATES WITH ELECTRON COOLING AT NAP-M (Talk). V. V. Parchomchuk et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3487 (1979).

MAGNET PROTECTION USING ZNR SURGE SUPPRESSORS (Talk). H. Pfeffer and D. A. Wolff, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3934 (1979).

ELECTRON PROTON COLLIDING BEAMS AT FERMILAB (Talk). A. G. Ruggiero, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3258 (1979).

A 50 MILLI-AMPERE NEGATIVE HYDROGEN-ION SOURCE (Talk). C. W. Schmidt and C. D. Curtis, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4120 (1979).

STRESSES IN WARM IRON SUPERCONDUCTING DIPOLES UTILIZING GENERAL ELASTIC CONSTANTS. S. C. Snowdon, published in Part. Accel. **10**, 83 (1980).

STRESS ANALYSIS FOR WARM IRON SUPERCONDUCTING DIPOLES (Talk). S. C. Snowdon, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3928 (1979).

HOW TO MASS PRODUCE RELIABLE CRYOSTATS FOR LARGE PARTICLE ACCELERATORS (Talk). B. P. Strauss et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3941 (1979).

THE 10 MILLISECOND 150 KILOAMPERE PULSED POWER SUPPLY FOR THE FERMILAB NEUTRINO FOCUSSING HORN (Talk). R. C. Trendler, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3977 (1979).

A FAST ENERGY DUMP FOR BEAM LINE MAGNETS (Talk). R. C. Trendler, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3936 (1979).

THE MICROPROCESSOR-BASED CONTROL FACILITY OF THE HE REFRIGERATOR SYSTEM USED IN THE 1000 GeV FERMILAB SWITCHYARD (Talk). A. F. Tummillo et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3316 (1979).

RECENT MEASUREMENT RESULTS OF ENERGY DOUBLER MAGNETS (Talk). M. Wake et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3894 (1979).

A SUPERCONDUCTING DIPOLE FOR THE FERMILAB SWITCHYARD (Talk). J. Walton et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4056 (1979).

MEASUREMENT OF THE ELECTRON LOSS CROSS SECTIONS FOR NEGATIVE HYDROGEN IONS ON CARBON AT 200 MeV. R. C. Webber et al., Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 4012 (1979).

SUBHARMONIC RIPPLE REDUCTION IN SCR-TYPE MAGNET POWER SUPPLIES (Talk). R. J. Yarema, Submitted to the 1979 Particle Accelerator Conference, San Francisco, California, March 12-14, 1979; published in IEEE Trans. Nucl. Sci. **26**, 3986 (1979).