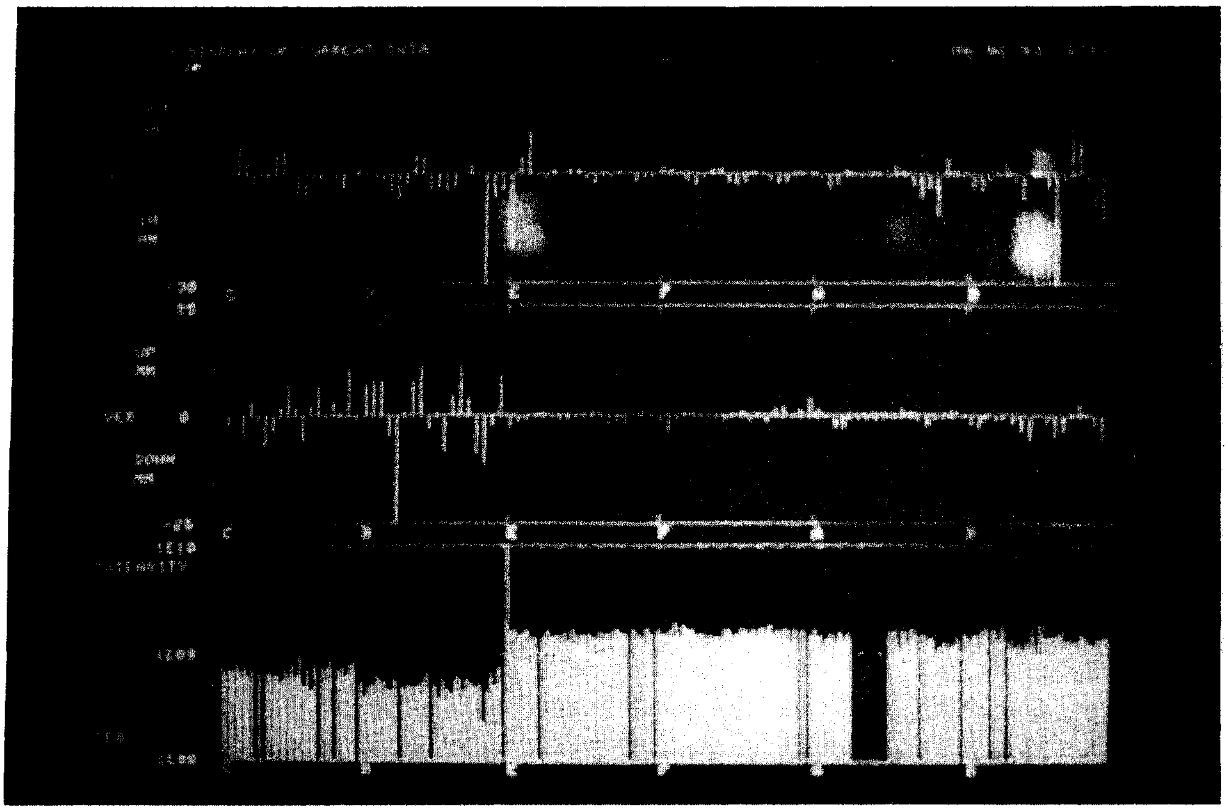
fermilab report

Fermi National Accelerator Laboratory Monthly Report

June 1983



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F. T. Cole, R. Donaldson, and L. Voyvodic, Editors

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THE COVER: First complete turn around the Energy Saver: 5:42 p.m., June 2, 1983. The top two signals are horizontal and vertical beam positions around the ring. The bottom signal is intensity.

(Photo by Curt Owen)

SAVER CIRCLES SEVERAL CYCLES

Thornton Murphy

Another giant cheer echoed through the Cross Gallery from the Main Control Room on Thursday, June 2, as about 30 people--a mixture of working experts and involved spectators--witnessed the Energy Doubler achieve its first full revolution with a proton beam, "one turn." The time was 5:42 p.m., a mere three hours after the first attempt to inject beam from the Main Ring into the now completed Energy Doubler and get it all the way around.

This first turn was achieved with the same surprising ease as was the one-third ring test of April 23--once a single barrier to progress had been identified and corrected. On April 23, the major barrier was a 1% mismatch of the Main Ring and Doubler magnetic fields. This time, the problem was a mistimed injection kicker. The kicker was turned off and its function delegated to a standard correction dipole. On the next pulse, the beam sailed two-thirds of the way around the ring before it was lost. Following a single application of the beam position correction program, the beam completed one turn on the next pulse.

For the next day, attention was focused on smoothing the orbit in the first turn and identifying instrumentation problems. In parallel, a major effort was mounted to test the higher order series correction elements (quadrupoles, sextupoles, and octupoles).

During the last shift of tuning, attempts at multiple turns were made. Several turns were achieved, but not enough to "close" the orbit well enough to achieve a true coasting beam.

Not all aspects of the Doubler are totally "go." This first turn was achieved with the injection energy reduced from 150 GeV to 100 GeV because of limitations discovered during the first power testing of Sectors A and B on May 26 and 31. In each sector, there is a localized place where spontaneous quenches occur slightly above 100 GeV. The two quarter-sectors involved have been warmed and are being repaired.

As soon as the ring is fully cooled again, tuning to close the orbit will resume, followed immediately by attempts to accelerate to 500 GeV.

PROGRESS IN THE TEVATRON II PROJECT

Tom Kirk and Roger Dixon

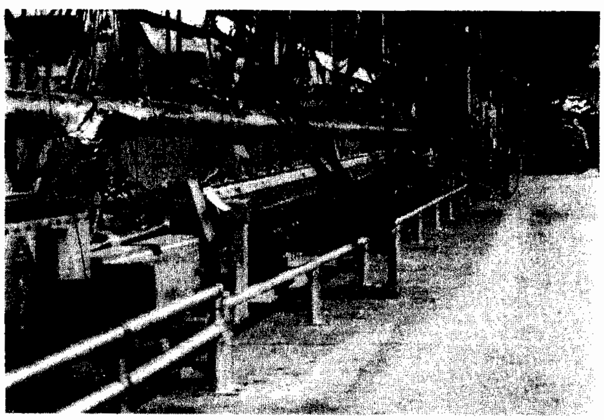
Introduction

Four more months have passed since the last report of progress on the TeV II project (upgrade of the extraction, switchyard, and fixed-target areas for 1-TeV physics). Many projects are now reaching completion and many more are well underway. A few are not really started yet, but by the time of the next report, some work will have gone forward in every one of the projects.

The TeV II upgrade began in January of 1982 and will be complete by fall of 1985. Below, we comment on the work going ahead in the various project areas.

Extraction

Significant progress has been made in completing the extraction system for the Tevatron. All the required elements have been installed in the accelerator tunnel except for two electrostatic septa, which will not be installed until beam has been accelerated. Items that are installed, shown in the accompanying photo by Roger Dixon, include five Lambertson



Looking downstream in Transfer Hall. Visible from left to right are the downstream extraction Lambertson magnet, a Saver orbit bump magnet, and the tilted Energy Doubler dipoles in the extraction channel. The Main Ring and Saver bending magnets are magnets in A0, three Doubler magnets that make up the extracted beam channel in the Transfer Hall, and ten air-core quadrupoles, some of which are pulsed to initiate fast resonant extraction and some of which are varied under computer control to smooth the spill during slow resonant extraction.

The principal activity on extraction hardware is presently concentrated on the QXR spill-feedback system. This is a microprocessor-based system that controls and smooths the extracted beam spill from the Tevatron. Much of the hardware has been completed and bench-tested. The system should be installed and operational during July for possible use at that time.

Switchyard

The Switchyard begins in the Transfer Hall and terminates with eight primary beams directed to the three experimental areas. The major projects in the Switchyard for the Tevatron II upgrade include the superconducting Right Bend to the Proton Area, an additional primary beam to the Meson Area, an additional beam to the Neutrino Area, plus upgrade of the beam electrostatic splitting stations to 1-TeV capability. Other work consists of a general energy upgrade involving the addition of bending and focusing power to all beam lines.

The Right Bend, which is the major horizontal bend to the Proton Laboratory, was the single largest effort in the Switchyard. It involved the replacement of 34 conventional dipoles in Switchyard Enclosures B and D with 14 Energy Saver dipoles. It was also necessary to construct approximately 1000 feet of liquid-helium transfer line and another 1000 feet of low-pressure helium header. Also included in the Right Bend project were the addition of a satellite refrigerator at the Switchyard Service Building and various helium connections to the Main Ring A2 Service Building that make all of the Switchyard cryogenic systems part of the Energy Saver system. This connection provides additional refrigeration to the Switchyard from the Central Helium Liquefier.

At present 99% of the Right Bend tunnel installation is complete. The only tasks remaining involve electrical hookup and some testing. Work is still proceeding on helium piping and electrical installation in the Switchyard Service Building. This work is 95% complete. The transfer lines are complete except for a few connections and the final leak check. The Switchyard compressors have run and liquid helium has been transported from A2 to the Switchyard Service Building. Cooldown of the Right Bend is expected in July.

The second major task in the Switchyard is the upgrade of the beam-splitting stations. Involved is the construction and installation of 21 electrostatic septa. At this time 11 of the new septa have been installed in the Proton split, the Meson split, and the Proton 3-way split. Seven septa for the Meson 3-way split are still under construction with a completion date projected for August. Three septa to split the new muon beam from the neutrino beam will not be built and installed until 1984.

The splitting-station upgrade has also involved the implementation of a completely redesigned septum-moving system that will eventually lead to computer-controlled alignment. It will also be possible to adjust beam splits by moving septa rather than adjusting the beam position on the septa with magnetic beam components. These improvements should result in greater beam stability for experimenters.

Upgrade of the primary Switchyard beam lines has proceeded from upstream, beginning in the Transfer Hall, to downstream. Work has been completed in the Transfer Hall and Enclosure B. These areas are presently under vacuum. The remaining primary Switchyard Enclosures (C, D, E) have 99% of the beam-line elements installed with vacuum and alignment work underway. Work is proceeding in this area while beam is tuned in the Saver. Completion of C, D, and E areas is expected in July.

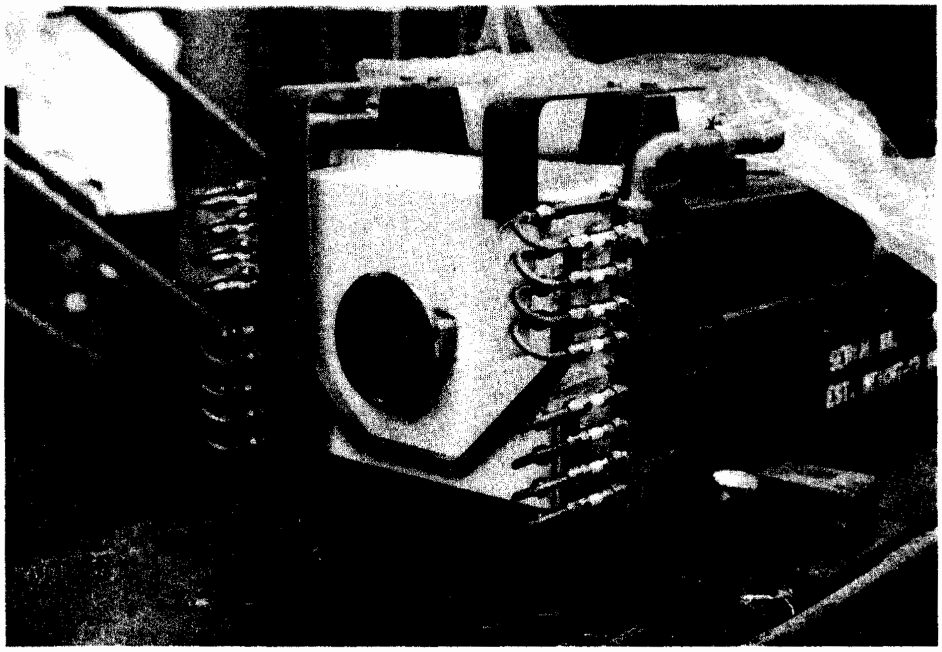
As mentioned above, the electrostatic septa for the Meson 3-way split have not been installed. Also not installed are various other beam-line components in the F and G manholes, as well as in Meshall. Final electrical installation in this area awaits the completion of a new G2 Service Building that will house power supplies and other equipment necessary to operate the meson and neutrino beams. All of this work is to be completed in September.

A last major effort for the Tevatron II upgrade of the Switchyard is the implementation of the new Tevatron control system. This work is well underway, and the new system has already been used to control the Switchyard helium compressors which were used during cooldown of the Saver. The control system should be fully operational during July.

All in all, work is nearing completion in the Switchyard and no obstacles are presently seen for delivering beam to all three experimental areas in the fall.

Meson Experimental Area

The entire primary proton beam target plan for Meson was changed to accommodate 1-TeV physics. The old philosophy of having a single primary target viewed by several secondary-beam transports has been scrapped in favor of a triple primary-beam split and three separate target stations. It is much more economical of protons to split up the primary beam and let each secondary beam enjoy 0° particle production. The first of the modified B1 dipoles that will transport the three primary beams to their targets is shown below as it came out of the Magnet Factory. In the case of Meson, there will be three primary



The first new modified B1 dipole, needed for transporting the three Meson Area primary beams to their respective targets, shown coming off the production line in the Fermilab Magnet Facility.

(Photo by Fermilab Photo Unit)

targets in three separate target-shielding piles located in the former Meson Experimental Hall. This building thus becomes the Meson Target Hall. It is in the background of the construction photo shown on the top of the next page.

Plans for the three target stations have been completed and purchase of steel shielding slabs and concrete shielding blocks has been underway for some time. A significant fraction of the steel and large numbers of concrete blocks are already here and ready for stacking. Dave Eartly of EAD has supervised the design of a modular shielding stack that will eliminate virtually all the cutting and machining of shielding steel. It will be laid in and welded essentially as it comes from the steel mill. This approach saves money without compromising function.

New primary beam focusing enclosures are being built upstream of the Meson Target Hall. The competely new M West primary line will enter the target hall through the new M West enclosure seen under construction here.
(Photo by Fermilab Photo Unit)

The precision baseplate in each target pile supports the target assembly and the target-sweeping magnets. The baseplates are the only elements built to precise tolerances; they control placement and orientation of the beam-handling elements. The plates are designed to allow convenient remote handling of highly radioactive target-system magnets and dumps in case of failure. Design is complete and fabrication is underway.

For the first Tevatron running period, an attenuation target in the old Meson target box will still be used, and the target train for this interim system is being fabricated in the EAD Target Service Building. The train will serve in later runs as a primary beam-transport and collimator system with one (or more) transmission targets to service the M Bottom test beam.

A great deal of effort on the part of EAD has gone into the Meson cryogenics system "Meson Cryo Central." A set of three Saver-type satellite helium refrigerators is grouped together in a single building, from which the seven cryo-magnet strings in the Meson primary beam area will be controlled from common helium supply and return mains. At present, the superconducting magnet strings for the interim M6 and M East proton beams are completely installed and the cryo hookup is finished. The refrigerators themselves are reaching completion and the controls system is being tested. Cooldown and power tests come later in the summer. The entire cryogenics effort is on schedule and is expected to be ready for operation for the HEP program in October.

Downstream of the Meson Target Hall where the new M-West and M Polarized secondary beams will be built, activity has focused on the final optical design for these beams. Following a preliminary review of MW in May, both the MW and MP beams are considered completely designed. Now that this step has been completed, the detailed design of the two new experimental halls can be initiated and a Title I plan for the Meson North Area started. These steps will be pursued in late summer and early fall of 1983.

Neutrino Experimental Area

Work in the Neutrino Area has focused on bringing primary protons of 1 TeV into the Neutrino Target Hall for use in the N Center, N East, and N West beams. The primary switch between NW and NE is being fabricated as are the beam-handling devices for Front Hall. Primary beam will be brought into Labs D and G for beam-commissioning tests in the second part of the first running period. A test beam will be formed using the NW beam transport viewing a target in the existing Neutrino Target Manhole. Most of the equipment for this beam is already in place and checked out. The NE beam to Labs D and G will be put in place in fall of 1983.

Plans for the Prompt Neutrino and Muon beams are essentially complete and a Title I study of the civil construction, roads, and utilities for the area containing these new beams will commence soon. The new Lab F building for the holographic 32-in. bubble chamber (E636) and the new Lab G building for experiment E690 are out for bid; construction will begin in June. Both buildings will be ready for experimental occupancy by February 1984. A small equipment room will be built as an addition to Lab B for the laser needed by the 15-ft bubble chamber holography system.

Plans for the new Muon Laboratory are being completed and the first phases of construction will commence in July. Construction of this building is a complicated operation because the large superconducting Chicago Cyclotron Magnet must be moved into position before the hall is constructed and the building then built around it. The magnet move will be done this summer, and preliminary preparations are already underway for the project.

The neutrino experimental program will start in the second Tevatron running period with a 600-GeV broad-band triplet run. Construction of the triplet and dichromatics trains is proceeding steadily, and it is expected that a test of a train at the end of the first running period will be possible. A new feature of neutrino beams in the Tevatron will be the location of the primary target about 300 feet upstream of the old target station. The new target method will not only increase neutrino yields via a longer decay path but will also permit more effective monitoring of the parent hadron-beam intensities and phase-space properties. This function is critical to the effective functioning of the 1-TeV era dichromatic neutrino beams.

Proton Experimental Area

The primary beam handling for the upgraded existing beams in the Proton Area has already been completed and checked out, including the satellite refrigerator for the superconducting bends in Enclosure H. The magnets themselves have not yet been cooled down, due to a problem in welding of components, but this difficulty is now repaired and the magnets are to be tested in the near future.

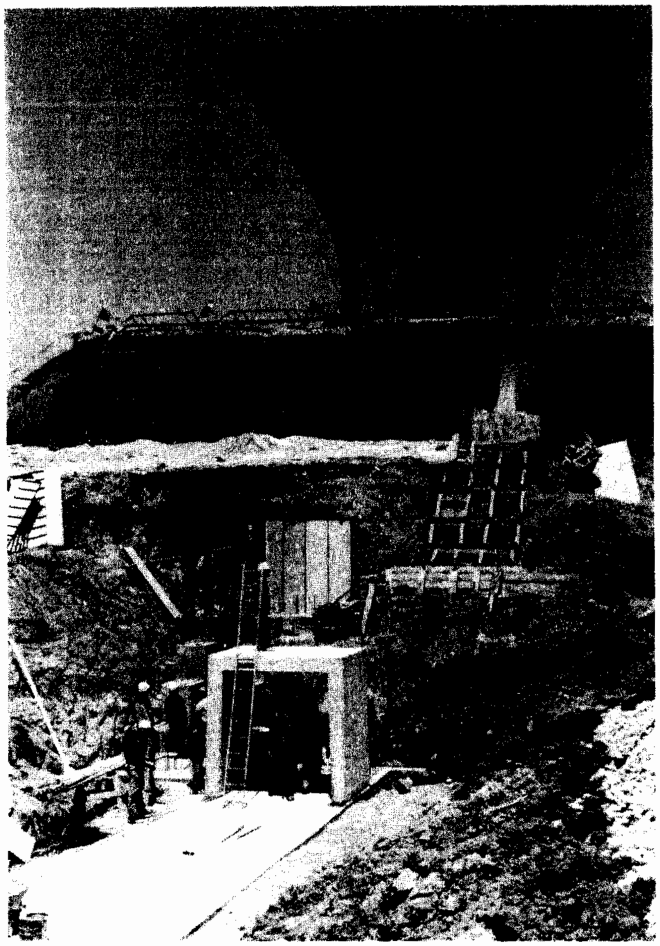
The second cryogenic refrigerator, used to feed magnets for the P East beam, is now being installed. When this installation is complete, the cryogenic refrigeration for the Proton Area will be finished.

A large amount of civil construction is in progress or complete in the Proton Area. The formerly open EE1 pit is now rebuilt as an earth-shielding primary-beam handling area for the P East and wide-band beams. Construction of the new Enclosures K and P Center is presently underway with completion expected by October 1 (or earlier). The photograph on the next page shows their state in the middle of May.

A new primary-beam pipe is being installed between Enclosure K and the P East tunnel to accommodate the new 1-TeV wide-band beam. Design of the wide-band target system is going ahead at present, together with a comparable system for the new muon beam. Both target piles will be of the earth-shielded underground type.

The target-pile steel shielding for wide band will be located in a rebuilt version of the EE4 pit in Proton. Again, as in Meson, a plan has been developed that exploits commercially available steel slabs with virutally no machining or cutting needed to form the necessary radiation shield. Remote handling of the radioactive target components will be possible using an overhead crane in the target tunnel. The target plan is reaching completion and will be shortly followed by civil design of the new EE4 enclosure.

In recent weeks, the secondary-beam design of the wide-band beam has been improved by decreasing the power needed for the sweeping magnets downstream of the photon radiator target. Dipole magnets of the same design used in the antiproton accumulator ring will be used as electron-sweeping magnets, taking advantage of their energy-efficient design and conserving electric power relative to the magnets planned earlier for this use. A useful bonus from the design change was a decreased tunnel size in the final stage of the wide-band beam.



A view of the Proton Area civil construction underway. A new underground enclosure, P Center, is being built to accommodate Tevatron primary beam which will be focused onto the P Center primary target. The Proton Pagoda is seen above the excavation.

(Photo by Fermilab Photo Unit)

At the same time as the design is being finalized for the wide-band beam, the criteria are being assembled for the new experimental hall to be built at the end of this beam. In a short time, detailed design by the Tevatron Construction Group will begin on this building. It is expected that the hall will be ready for occupancy by the experimenters next summer.

The P West high-intensity beam will be ready for primary protons up to 1 TeV by October 1983. The secondary beam will go to 300 GeV and concentrate on negative pions and antiprotons for the first running periods.

Other Relevant Topics

One activity that is almost invisible to users of Fermilab beams, but that is essential to their success, is the production of conventional and superconducting magnets for them by the Fermilab Magnet Facility, a part of the Technical Sevices Section under Dick Lundy. In this area, the TeV II project is well **ahead** of schedule.

All the Saver-type superconducting magnets needed for the fixed-target upgrade are already completed and most are installed. A much larger number of new conventional magnets also had to be made. The organization for this effort was begun two years ago and the magnets are now rolling off the assembly lines. If all goes as presently planned, **all** the TeV II magnets will be completed by June 1984.

The rapid pace set in all the areas of activity will enable the TeV II project, if properly funded, to come in ahead of schedule and get 1-TeV physics with the new secondary beams into operation in advance of current plans. At present, we envision first operation of the new wide-band and Muon beams near the end of the second Tevatron running period in the spring of 1985. We certainly intend to continue dedicating ourselves and our resources to this goal!

FERMILAB INDUSTRIAL AFFILIATES ANNUAL MEETING

Dick Carrigan

The third annual meeting of the Fermilab Industrial Affiliates took place May 19 and 20. The annual meeting provides an opportunity for research directors and senior technical personnel from the Affiliates and other companies to visit Fermilab. This year's meeting focused on super-computers, the large control systems at the Laboratory, and the other technologies of the Energy Saver/Doubler.

The Fermilab Industrial Affiliates was established by Leon Lederman in 1980 in order to improve university-industry research communications and to foster technology transfer from Fermilab. By now the Affiliates number more than 30 institutions including many research-oriented companies in the Fortune 500 list as well as several companies formed by Fermilab staff members and users. Roughly half of them are in Illinois.

Direct activities of the Affiliates include visits of company representatives to Fermilab and Fermilab personnel to Affiliates. The annual meeting is one of the principal opportunities for such visits. Affiliates also receive selected Fermilab reports and other information about on-going work at the Laboratory.

Specific technology innovations are only one facet of the work of the Laboratory that is emphasized. The "scientific culture" related to particle physics is given heavy weight as well as the long range potential of activities such as the development of superconductivity technology. The participation of more than a hundred universities in all phases of the Laboratory is also important to Affiliate members.

Often, an Affiliate's interests in the Laboratory is hard to gauge. One major farm equipment manufacturer turned out to be one of the heaviest users of large computers in the United States.

This year's participation numbered 85 from outside Fermilab. There were 41 representatives from 16 Affiliate companies as well as 16 representatives from other companies. Representatives of the U.S. Department of Energy, the State of Illinois, and the Valley Industrial Association as well as the **Tribune, Sun Times,** and **Scientific American** also participated.

The highlight of the meeting was a Round Table on super-computer developments in the universities. The Round Table grew out of the establishment of an advanced computer program at Fermilab headed by Tom Nash. That program has studied the possible approaches to super-computers over the last year. An active seminar series brought in many university and industrial

Participants in the Round Table on Super-Computers (left to right) include Jack Schwartz, David Wallace, and Ken Wilson.
(Photograph by Fermilab Photo Unit)

speakers. At the same time, there has been growing national recognition that the U.S. must continue to play a role in the development of very powerful computers in the force of determined foreign competition.

The Round Table was spearheaded by Dr. Ken Wilson of Cornell, the 1982 Nobel Prize winner in physics. He emphasized that universities were good prospective buyers for the first model of a computer. They can do prototype software development and undergraduates do not mind the problems associated with getting the bugs out.

Other participants besides Wilson and Nash included Dr. Burton Smith of Denelcor, the moderator and token industrialist, Dr. Arvind of MIT, Dr. Norman Christ of Columbia, Dr. Jack Schwartz of NYU, and Dr. David Wallace of Edinburgh.

In summing up the Round Table, Burt Smith asked where super-computers would be by the year 2000. Most responses ranged in the region of 1000 to 10,000 times the present power but one distinguished participant stated that it was impossible to make an overestimate and guessed at a factor of a hundred trillion. A brochure is now being prepared on the Round Table and should be available later in the summer.

Tours and exhibits were important facets of the meeting. A comprehensive tour of the accelerator control system was arranged by Dixon Bogert with the good offices of Bob Mau. Tour leaders included Jim Zagel, Dave Beechy, Lee Chapman, Kevin Cahill, Charles Briegel, Mike Shea, Bob Goodwin, and Tom Groves. In the afternoon the Affiliates visited the Magnet Facility and Experiment #605 in the Meson Area with Paul Mantsch, Gene Fisk, Steve Smith, and Henry Glass serving as hosts.

A special set of exhibits was set up on the second floor crossover to give the participants an opportunity to see and work "person-sized" technology developed at Fermilab. Some of these exhibits featured the Laboratory's expertise in the superconducting technology area such as laminar tooling, carbon resistor thermometry, and fast acting valves and oxygen monitors. Others were controls oriented: Fastbus components, the Linac control system, and a special high speed modular processor. A number of exhibits illustrated the diversity of the technology at Fermilab--silicon diodes, a current shunt, and a special precision drill developed by the Physics Section.

Other talks included a stirring banquet address by Robert Pry, Vice Chairman for Technology at Gould, calling for a concerted attack by industry and government on basic education. Dr. James Decker of DOE explained the government's role in technology transfer while Dr. Mel Schwartz of Digital Pathways described the realities of starting a new electronic company.

Fermilab Industrial Affiliates view "person-sized" technology exhibits.

(Photograph by Fermilab Photo Unit)

On Thursday afternoon Dixon Bogert, Claus Rode, and Al McInturff summarized examples of Energy Saver/Doubler technology. The silicon strip development of particle detectors was reviewed by Dr. Bill Reay of Ohio State. Al Brenner expounded on large scale computers and the Fastbus data transfer system.

Jonathan Schonfeld explained some of the applications of particle theory while Dr. Frank Hendrickson of Rush Medical College illustrated the interesting results obtained with the Fermilab Neutron Therapy Facility.

Perhaps most interesting of all, Dick Lundy explored the technology required for a 20 trillion electron volt accelerator twenty times the size of the Doubler, the so-called Desertron. The need for mass production and heavy industrial participation was emphasized.

Affiliate participants were uniformly pleased with the meeting. The wide spectrum of Affiliate interests emphasized the need to report on new Fermilab technology. Often others can see valuable ways to exploit a device developed for a very particular need.

NEUTRINO PHYSICS IN A FINE-GRAINED CALORIMETER

Frank Taylor, Northern Illinois University

D. Bogert, R. Burnstein, R. Fisk, S. Fuess, J. Morfin, T. Ohska, M. Peters, L. Stutte, J. K. Walker, and H. Weerts, Fermilab; J. Bofill, W. Busza, T. Eldridge, J. I. Friedman, M. Goodman, H. W. Kendall, I. G. Kostoulas, T. Lyons, R. Magahiz, T. Mattison, A. Mukherjee, L. Osborne, R. Pitt, L. Rosenson, A. Sandacz, M. Tartaglia, R. Verdier, S. Whitaker, and G. P. Yeh, Massachusetts Institute of Technology; M. Abolins, R. Brock, A. Cohen, J. Ernwein, D. Owen and J. Slate, Michigan State University

Introduction

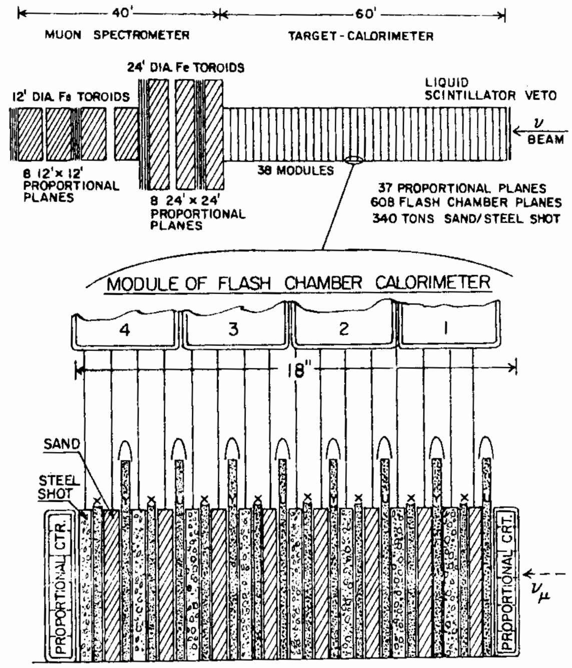
How do neutrinos interact with quarks and electrons? Do neutrinos couple through the neutral current to the same objects inside the nucleon as they do through the charged-current interaction? These are some of the questions being probed with a fine grained neutrino detector in Lab C. Although the weak neutral current has been studied for the last ten years, there is a level of experimentation on the weak neutral current which is comparatively unexplored. That level of experimentation is to study the weak neutral current interaction with full kinematic reconstruction. These experiments require a special type of neutrino detector which is capable of determining the direction of energy flow, the nature of the neutrino reaction products as well as the energy of these products. Since many reactions of interest have extremely small cross sections, the detector must be massive. We have recently constructed such a detector and have used it to obtain data, presently being analyzed, on the weak neutral current.

The Detector

To build a massive fine-grained neutrino detector requires the construction of an enormous number of detection elements. Unless these detection elements are made cheaply and simply, the costs of such a dectector would be prohibitively large. Our detector is based on plastic flash chambers (originally developed by M. Conversi)[1] and on proportional tube chambers, both of which are straightforward to construct and operate, and allow fine-grained sampling of the neutrino reaction products. Our detector has roughly 445,000 active detection elements in the form of 5mm×5mm flash chamber cells.[2]

The flash chamber-proportional tube calorimeter, is 60 feet long and has a 12ft×12ft cross section and a mass of approximately 340 metric tons. The flash chambers are used to determine the pattern of the neutrino reaction products thereby furnishing an identification of the event type as well as determining the energy and angle of energy flow. The proportional tube chambers are used to trigger the flash chambers and to provide an additional measurement of the energy of the shower. The layout of the detector is shown in the figure below.

E-594 NEUTRINO DETECTOR



Layout of the detector.

The flash chambers are arranged in three views (x,y,u) with cells which run 0°, 80°, 100° relative to the horizontal plane. The flash chambers are read out electronically by means of a magnetostrictive wand. Each flash chamber plane is sandwiched between a sand-filled plastic extrusion plane and a steel shot filled extrusion plane which forms the mass of the detector.

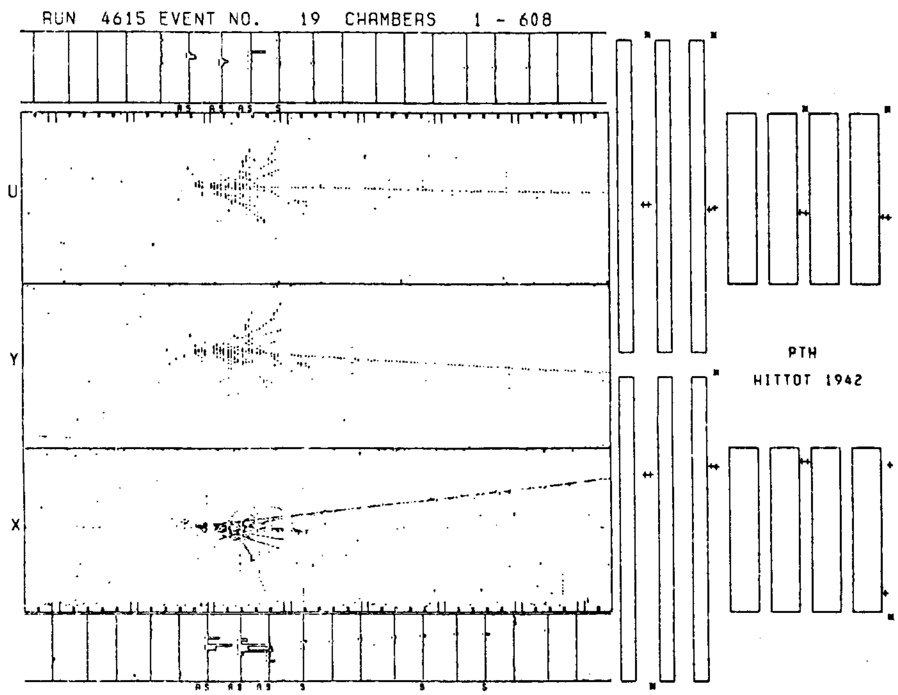
The proportional tube planes are located every 16 flash chamber planes (one module) in an alternating horizontal-vertical pattern. Each module weighs approximately 9 tons.

The proportional tube chambers are instrumented with an amplifier for every 4 wires with a wire separation of 1 inch. This high level of segmentation gives pattern recognition at the trigger level as well as analog information on the energy deposition.

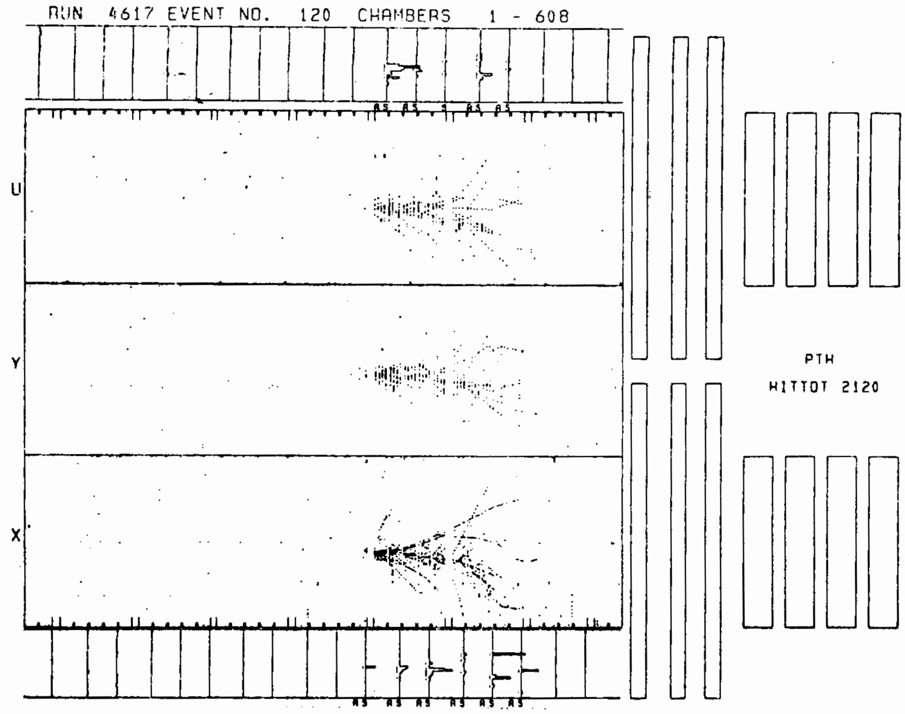
This arrangement of flash chambers-proportional tube chambers-sand and steel shot has an average radiation length X_0 of 12 cm sampled every 0.22 X_0 by the flash chambers and every 3.5 X_0 by the proportional tube chambers. The average absorption length λ is 96 cm (135 g/cm^2) and is sampled every 0.03 λ by the flash chambers and every 0.50 λ by the proportional tube chambers. The average density is 1.4 g/cm^3 and the average Z is approximately 21. This property of low density and low Z is important in achieving good energy flow measurements for hadron showers.

Downstream of the flash chamber-proportional tube chamber calorimeter is an iron toroid muon spectrometer. This spectrometer is instrumented with double plane proportional tube chambers with a one-inch resolution. These toroid proportional tube planes are being upgraded with a drift system to give a 1 mm resolution.

The pattern recognition capabilities of the detector are evident in the figure below, which shows a display of a typical charged-current interaction and a typical neutral current interaction.



Typical charged-current event showing the hit pattern in the flash chambers and the proportional tubes.



Typical neutral-current event.

Shown are the 3 views of flash-chamber planes (x,y,u on the display). Each dot drawn on the display represents a struck cell in a flash chamber. The total number of hit flash chamber cells is roughly proportional to the energy of the shower. Thus the energy of the shower is determined from the number of hit cells.

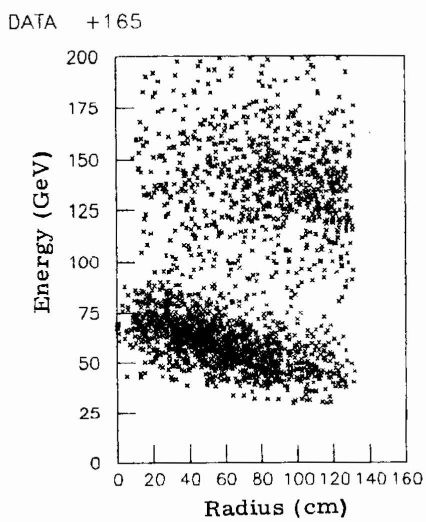
Also shown in the figure are the pulse heights of the proportional tube planes which provided the trigger of this event. These pulse heights appear as bar graphs along the lower and upper edges of the picture for the horizontal and vertical plane orientations, respectively.

The toroids are shown at the right of the figure. The "+" signs indicate the track of the muon through the spectrometer in the horizontally (bottom) and vertically (top) oriented proportional planes.

The Experimental Program

There are two major objectives of the program to study neutrino interactions in our fine-grained neutrino detector. These objectives are 1) to study the $x = Q^2/2m\nu$ dependence of deep inelastic neutral current interactions, and to compare this with the corresponding dependence of charged current interactions, and 2) to study pure leptonic neutrino interactions such as $\nu_\mu e^- \to \mu^- \nu_e$ and $\nu_\mu e \to \nu_\mu e$ and neutrino oscillations by searching for missing energy in events with a ν_μ or ν_e quasi-elastic scattering signature. These studies will test the standard gauge theory of electro-weak interactions and search for the exotic in high-energy neutrino interactions.

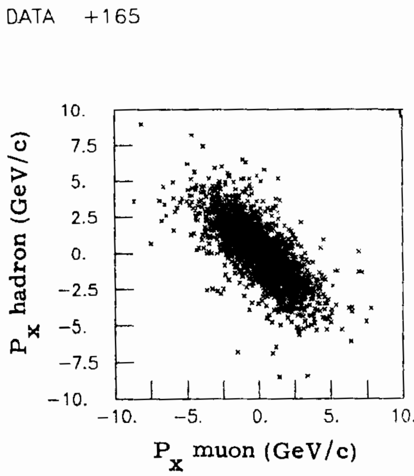
These analysis projects are in progress and thus at the present time various tests are being performed on the data. To demonstrate the energy reconstruction of the incident narrow band beam used in the deep inelastic scattering experiment, we show in the figure on the right, the energy versus radius correlation. The π and K bands are clearly visible. To demonstrate the energy flow technique for the recoil hadron shower (the essence of the x-scaling variable measurement for neutral current events) we show in the figure on the left of the next page, the transverse momentum of the hadron shower versus the transverse momentum of the muon for charged current events. We see that the transverse momentum is balanced and thus the energy flow of the hadron shower can be determined.



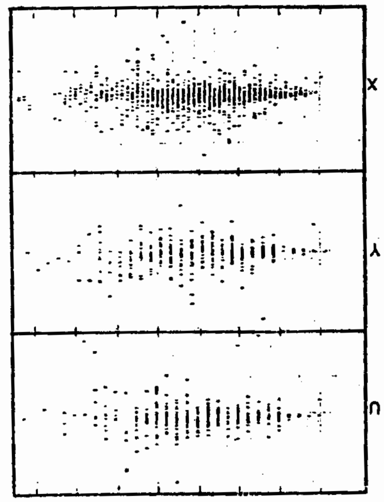
The energy versus radius correlation of the reconstructed incident neutrino energy from charged current interactions.

In our 1982 narrow band data sample of deep inelastic events we have approximately 19K ν_μ reconstructed events and 4.3K $\bar{\nu}_\mu$ reconstructed events. These should allow a good comparison of the neutral current/charged current x-distributions.

The study of pure leptonic neutrino interactions has been focused on the study of $\nu_\mu e^- \to \mu^- \nu_e$ scattering in the narrow-band beam, and on a demonstration of the resolution of the detector by studying $\nu_\mu e \to \nu_\mu e$ in data taken during an engineering run in 1981. Additional effort has been invested in setting a limit on $\nu_\mu \to \nu_x$ oscillations which exploits the pattern recognition and the selective triggering capabilities of the detector.[3]



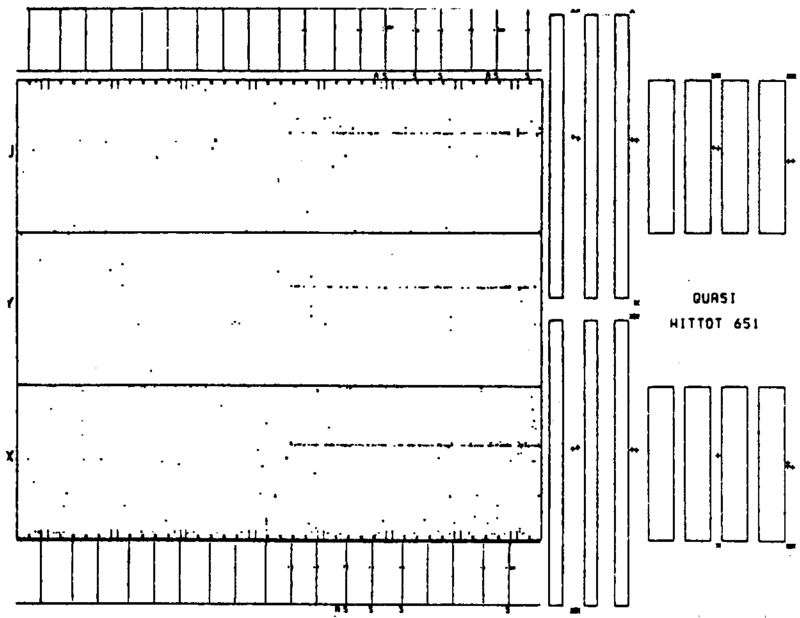
The transverse momentum (X-view) of the hadron shower versus the transverse momentum of the muon for charged current events.



A typical $\nu_\mu e \rightarrow \nu_\mu e$ candidate event. An expanded scale is used.

The most difficult aspect of studying these rare neutrino interactions is to identify the events in the prescence of a very large background. The fine-grained sampling and selective triggering schemes of our detector enable us to do this.[4] The figure on the right shows a $\nu_\mu e \rightarrow \nu_\mu e$ candidate event which has the signature of a clean recoil electron shower and no hadronic debris. The figure on the next page shows a $\nu_\mu e^- \rightarrow \mu^- \nu_e$ candidate event which has a clean muon track and no other visible recoil particles.

In summary, the fine-grained flash chamber-proportional tube neutrino detector we have built is yielding data on deep inelastic scattering and on rare neutrino interactions. A concentrated effort is now underway to exploit fully its unique sampling properties.



A $\nu_\mu e^- \to \mu^- \nu_e$ candidate event.

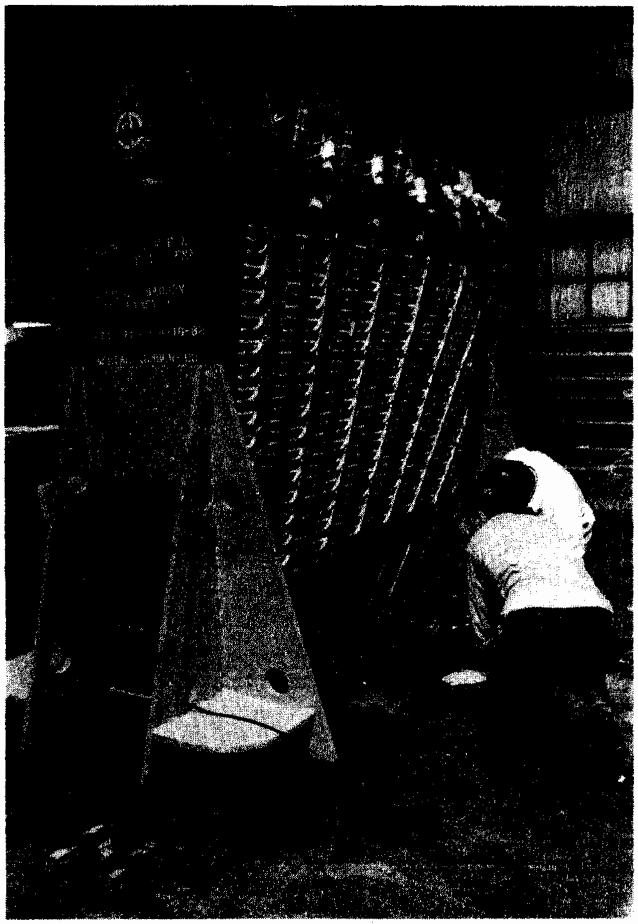
References

[1]M. Conversi and L. Federici, Nuclear Instrum. Methods **151**, 93 (1978).

[2]D. Bogert et al., IEEE Trans. Nucl. Sci. **NS-29**, 363 (1982).

[3]D. Bogert et al., Proceedings of the XVIII Rencontre de Moriond, La Plagne, France, March 1983.

[4]D. Bogert et al., Proceedings of the XVII Rencontre de Moriond, Les Arcs, France, March 1982.



Assembly of the first production central calorimeter module for CDF in Industrial Building 4. The steel was cut and welded at Purdue. The hadron scintillator and light pipes were cut and fabricated in Italy. The shower counter scintillator was made and cut in Japan. The shower counter light pipes were made at ANL. The muon counters were made at the University of Illinois. All of these pieces came together and were assembled at Fermilab. (Photograph by Fermilab Photo Unit)

[Editors' Note: Many of our readers may be interested in the recent Symposium, held in the Vatican, honoring the 350th anniversary of the publication of Galileo's famous "Dialogues." We reproduce here the remarks made to an audience of scientists by his Holiness, Pope John Paul II.]

DISCOURSE OF HIS HOLINESS POPE JOHN PAUL II FOR THE INAUGURATION OF THE SYMPOSIUM ORGANIZED ON THE OCCASION OF THE 350TH ANNIVERSARY OF THE PUBLICATION OF THE BOOK BY GALILEO GALILEI ENTITLED **DIALOGHI SUI DUE MASSIMI SISTEMI DEL MONDO**

Ladies and Gentlemen,

In addressing myself to you, who represent with honour the rich horizons of modern science, I wish in the first place to thank you cordially for your visit, and to tell you that your presence here this morning seems to me to have a deeply symbolic value, for you attest to the fact that between the Church and Science a fruitful dialogue is being developed.

And I am not alone in welcoming you. My brothers, the Cardinals of the Holy Roman Church present in Rome, and other leading figures of the Holy See - whom I am pleased to greet with you and whom I likewise thank for being here - testify to the importance that the Church attributes to this dialogue.

We cast our minds back to an age when there had developed between science and faith grave incomprehension, the result of misunderstandings or errors, which only humble and patient re-examination succeeded in gradually dispelling. And so we should rejoice together that the world of science and the Catholic Church have learned to go beyond those moments of conflict, understandable no doubt, but nonetheless regrettable. This was the result of a more accurate appreciation of the methods proper to the different orders of knowledge and the fruit of bringing to research a more rigorous attitude of mind.

The Church and science itself have reaped great profit from this and have discovered through reflection and sometimes painful experience the paths that lead to truth and objective knowledge.

To you who are preparing to mark the 350th anniversary of the publication of Galileo Galilei's great work, **Dialoghi sui due massimi sistemi del mondo**, I would like to say that the Church's experience, during the Galileo affair and after it, has led to a more mature attitude and to a more accurate grasp of the authority proper to her. I repeat before you what I stated before the Pontifical Academy of Sciences on 10 November 1979:

"I hope that theologians, scholars and historians, animated by a spirit of sincere collaboration, will study the Galileo case more deeply and, in frank recognition of wrongs, from whichever side they come, will dispel the mistrust that still forms an obstacle, in the minds of many, to a fruitful concord between science and faith, between the Church and the world. I give all my support to this task, which will be able to honour the truth of faith and of science and open the door to future collaboration" (**AAS** (1979), pp. 1464-1465).

As you know, I have asked for the formation of an interdisciplinary research team for the careful study of the whole question. Its work is progressing very encouragingly, and there are good grounds for hoping that it will make an important contribution to the examination of the whole matter.

The Church herself learns by experience and reflexion, and she now understands better the meaning that must be given to freedom of research, as I said to the representatives of the Spanish Universities on 3 November 1982:

"The Church upholds freedom of research, which is one of the most noble attributes of man. It is through research that man attains to Truth - one of the most beautiful names that God has given himself. This is why the Church is convinced that there can be no real contradiction between science and faith, for the reason that the whole of reality ultimately comes from God the Creator. This is what is stated by the Second Vatican Council (cf. **Gaudium et Spes**, 36). I have stated this myself on a number of occasions in addressing men and women of science. It is certain that science and faith represent two different orders of knowledge, autonomous in their processes, but finally converging upon the discovery of reality in all its aspects, which has its origin in God" (cf. Discourse in Cologne Cathedral, 15 November 1980, No. 8, **L'Osservatore Romano**, 4 November 1982, p. 2).

One thus preceives more clearly that divine Revelation, of which the Church is the guarantor and witness, does not of itself involve any particular scientific theory, and the assistance of the Holy Spirit in no way lends itself to guaranteeing explanations that we would wish to profess concerning the physical constitution of reality.

The fact that the Church has been able only with difficulty to make advances in such a complex sphere should neither surprise nor scandalize us. The Church, founded by Christ who called himself the Way, the Truth and the Life, still remains made up of individuals who are limited and who are closely bound up with the culture of the time they live in. So it is that she declares that she is always interested in research concerning the knowledge of the universe, whether physical, biological, or psychological. It is only through humble and assiduous study that she learns to dissociate the essentials of faith from the scientific systems of a given age, especially when a culturally influenced reading of the Bible seemed to be linked to an obligatory cosmogony.

To return to the case of Galileo, we certainly recognize that he suffered from departments of the Church. But in his time, there were not lacking Catholic centres which were already cultivating with great competence, over and above theology and philosophy, disciplines such as history, geography, archaeology, physics, mathematics, astronomy, and astrophysics; and these studies were considered necessary for a better knowledge of the historical evolution of man and of the secrets of the universe. Brilliant forerunners had even put Catholics on the guard, urging them not to set up an opposition between science and faith. This is what I wished to affirm, on 15 December 1979, at the Gregorian University, whose researches and professors were known, in his own time, to Galileo:

> "And while we must recognize that students of that time were not unaffected by their cultural milieu, we can nevertheless note that there were brilliant forerunners and freer minds, like Saint Robert Bellarmine in the case of Galileo Galilei, who wished that useless tensions and harmful rigidities between faith and science could be avoided" (**AAS** (1979), p. 1541).

These facts confirm us in the indispensable need for a frank and open dialogue between theologians, scientific specialists and those who exercise leadership in the Church.

Hence we can see that the age-old relationships between the Church and science have brought Catholics to a more correct understanding of the sphere of their faith, to a sort of intellectual purification and to a conviction that scientific study deserves a commitment to unbiassed research which, in the final analysis, is a service to truth and to man himself. We should add that the Church recognizes with gratitude all that she owes to research and science. I had occasion to say this to the Pontifical Council for Culture on 18 January 1983:

> "Let us think of how the results of scientific research help us to know the universe better, to understand better, to understand better the mystery of man; think of the advantages which the new means of communication and contact among people offer to society and to the Church; let us think of the ability to produce incalculable economic and cultural wealth, and especially to promote the education of the masses, and to cure diseases previously thought incurable. What admirable achievements! All this is to man's credit. And all this has greatly benefitted the Church herself, in her life, her organization, her work and her own activity" (No. 6 **L'Osservatore Romano**, 19 January 1983, p. 2).

And if we address ourselves now more directly to the scientific world, does one not see today how the greater sensitivity of scholars and researchers to spiritual and moral values brings to your disciplines a new dimension and a more generous openness to what is universal? This attitude has greatly facilitated and enriched the dialogue between science and the Church.

It is of course required that you adopt a method of advanced specialization so as to carry ever further forward your discoveries and your experiences, and one cannot help but admire the rigour and intellectual honesty, the disinterestedness and self-denial which so many researchers bear witness to as they dedicate themselves to their studies with a real spirit of mission.

Moreover, the scientific world, having now become one of the principal sectors of activity in modern society, is itself discovering, in the light of reflection and experience, the extent and at the same time the seriousness of its responsibilities. Modern science and the technology that derives from it have become a veritable power and form the object of socio-economic policies or strategies, which are not neutral as regards the future of man.

Ladies and gentlemen, you who are engaged in the sciences: you possess considerable power and responsibility, and these can become decisive for the orientation of tomorrow's world. On many occasions I have expressed the Church's great esteem for the collective effort made by people of science to ensure that the urgent objectives which are required by the pursuit of the development of man and peace may prevail. You know that a moral transformation is needed if we want the scientific and technical resources of today's world to be effectively placed at the service of man. At Hiroshima, before the United Nations University on 25 February 1981, I stated:

> "The people of our times possess, in the first place, tremendous scientific and technological resources. And we are convinced that these resources could be far more effectively used for the development and growth of peoples...All of this obviously presupposes political choices, and, more fundamentally, moral options. The moment is approaching when priorities will have to be redefined. For example, it has been estimated that about a half of the world's research workers are at present employed for military purposes. Can the human family morally go on much longer in this direction?" (**AAS** 73 (1981), pp. 424-425).

Ladies and gentlemen, you enjoy immense moral influence in order to assert the properly humanistic and cultural objectives of science. Strive to defend man and his dignity at the centres of decision-making which govern scientific policies and social planning. You will always find an ally in the Church, each time that you strive to promote man and his authentic development.

It is also assuredly from within that the Church concerns herself with your work. For none of the things that can deepen knowledge of man, nature and the universe can leave us indifferent. All scientific progress, pursued with rectitude, honours humanity, and is a tribute to the Creator of all things. Your investigations constitute an extension of the marvellous revelation that God gives us in his work of creation. The Church does not first turn to your discoveries in order to draw from them facile apologetic arguments for strengthening her beliefs. Rather she seeks, thanks to you, to expand the horizon of her contemplation and of her admiration for the clarity with which the infinitely powerful God shines through his creation.

For the believer, the most specialized research can thus become a highly ethical and spiritual act. For the saints, study was prayer and contemplation.

Yes, the Church appeals to your capacities for research in order that no limit may be placed upon our common quest for knowledge. Your specialization of course imposes upon you certain rules and indispensable limitations in investigation; but beyond these epistemological limits, let the inclination of your spirit carry you towards the universal and the absolute. More than ever before, our world needs intellects capable of grasping the whole picture and of enabling knowledge to advance towards humanistic understanding and towards wisdom. In a word, your knowledge must blossom into wisdom; that is, it must become the growth of man and of the whole man. Open your minds and hearts fully to the imperatives of today's world, which aspires to justice and to dignity founded on truth. And you yourselves, be ready to seek all that is true, convinced that the realities of the spirit form part of what is real and part of the whole Truth.

Ladies and gentlemen, your task is noble and very great. The world looks to you and expects from you a service which matches your intellectual capacities and ethical responsibilities.

May God, the Creator of all things, who is present in the immensity of the universe and in each of our hearts, accompany you in your work and inspire your admirable work.

NOTES AND ANNOUNCEMENTS

BRUCE CHRISMAN TO LEAVE FERMILAB. . .

Bruce Chrisman, Business Manager and Head of Business Services, has accepted an appointment as the Vice President for Administration at Yale University, New Haven, Connecticut, and will leave Fermilab in July.

Ken Stanfield, presently head of the Experimental Areas Department, will replace Chrisman about October, 1983, after the first phase of Tevatron II beam-line commissioning is completed.

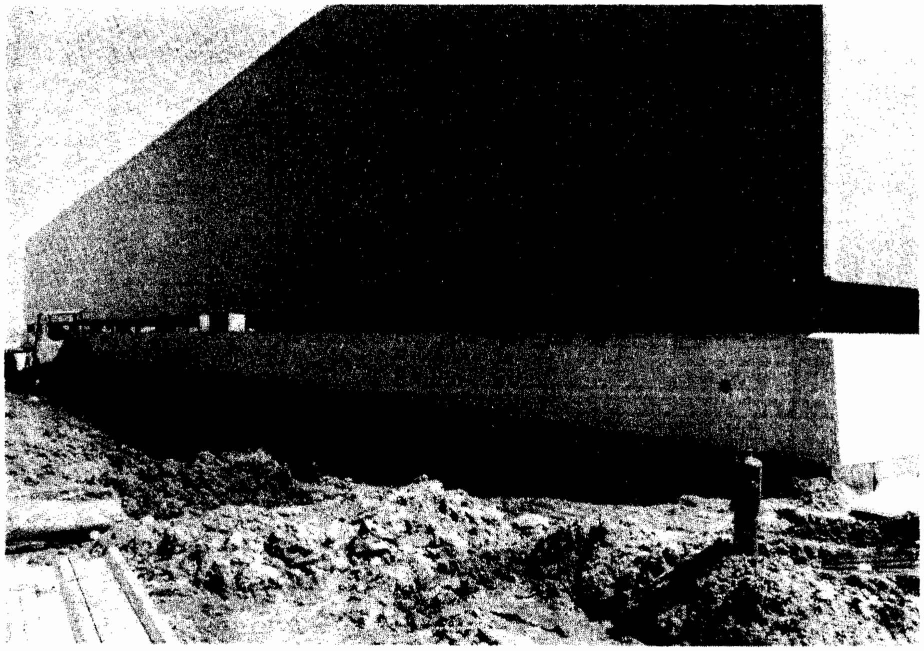
Jim Finks will serve as Acting Head of the Business Services Section until Stanfield takes over and then will continue as Deputy Head.

Roger Dixon will succeed Stanfield as Head of the Experimental Areas Department.

1982 FERMILAB ANNUAL REPORT AVAILABLE. . .

Copies of the 1982 Annual Report may be obtained by writing to the Fermilab Library, M. S. #109. The Library also has copies available of the 1980 and 1981 Annual Reports.

The following conference proceedings are available for purchase (make check payable to Fermilab) from the Library: Physics of High Energy Particle Accelerators (Fermilab Summer School, 1981) Volume 1, $30.00, and Volume 2, $25.25; Proceedings of the Drell Yan Workshop (October 7 and 8, 1982), $12.00; Proceedings of the Gas Calorimeter Workshop (October 28 and 29, 1982), $10.00.



A recent view of the Collider Detector Building at B0.
(Photograph by Fermilab Photo Unit)

MANUSCRIPTS, NOTES, LECTURES, AND COLLOQUIA PREPARED OR PRESENTED FROM MAY 16, 1983 TO JUNE 19, 1983

Copies of preprints with Fermilab publication numbers can be obtained from the Publications Office or Theoretical Physics Department, 3rd floor east, Central Laboratory. Copies of some articles listed are on the reference shelf in the Fermilab Library.

Experimental Physics

G. N. Taylor et al. Experiment #388	$\bar{\nu}_\mu$ Nucleon Charged Current Total Cross Section for 5-250 GeV (Submitted to Phys. Rev. Lett.)
R. Rubinstein Experiment #577	Hadron-Hadron Elastic Scattering at Large Momentum Transfers (FERMILAB-Conf-83/50-EXP; invited talk at the Baltimore meeting of the American Physical Society, April 18, 1983)
M. W. Arenton et al. Experiment #609	Hadron Jets in 400 GeV pp Collisions (Submitted to Phys. Rev. Lett.)

Theoretical Physics

J. F. Schonfeld	The Effects of Beam-Beam Collisions on Storage-Ring Performance--A Pedagogical Review (FERMILAB-Conf-83/17-THY; invited lectures at the 1982 Summer School on High-Energy Particle Accelerators, SLAC, August 2-13, 1982)
M. Fischler and J. Oliensis	Detailed Calculation of the Complete Two Loop Higgs-Yukawa Beta Function in an Arbitrary α-Gauge (FERMILAB-Pub-83/24-THY; submitted to Phys. Rev. D)
C. Quigg	Topics in Quarkonium Physics (FERMILAB-Pub-83/25-THY; lectures presented at the XXIInd Krakow School of Theoretical Physics, Zakopane, June 1982)

C. T. Hill and D. N. Schramm	Evolution of the Ultra High Energy Cosmic Ray Spectrum by Transport Equation (FERMILAB-Conf-83/32-THY; contributed paper to the 18th International Cosmic Ray Conference, Bangalore, India, August 22, 1983)
M. K. Gaillard	Issues in the Standard Model (FERMILAB-Conf-83/35-THY; talk presented at the Theoretical Symposium on Intense Medium Energy Sources of Strangeness, Santa Cruz, March 19-21, 1983)
D. N. Schramm and C. T. Hill	The Origin of the Ultra High Energy Cosmic Rays (FERMILAB-Conf-83/36-THY; contributed paper to the 18th International Cosmic Ray Conference, Bangalore, India, August 22, 1983)
M. Hwang and R. J. Oakes	Limits on the Strength of a Left-Right Symmetric Electroweak Interaction (FERMILAB-Pub-83/38-THY; submitted to Phys. Rev. D)

Physics Notes

J. A. Appel and W. K. Dawson	FASTBUS Implementation Review (FN-384; submitted to the Third Biennial Conference on Real-Time Computer Applications in Nuclear and Particle Physics, Berkeley, California, May 16-19, 1983)
T. Regan	A Sensitive Instrument for Measuring Wire Tension in Multiwire Proportional and Drift Chambers (FN-385)
D. Neuffer	Chaos, Beam Blow-Up, and Resonance Overlap in the Beam-Beam Interaction (FN-386)
R. Pordes	FASTBUS Software Review (FN-387; paper submitted to the Third Biennial Conference on Real-Time Computer Applications in Nuclear and Particle Physics, Berkeley, California, May 16-19, 1983)

Colloquia, Lectures, and Seminars

C. Ankenbrandt, R. Gerig, and R. Raja	"Orbit Studies of the First 1/3 Turn of the Tevatron" (Fermilab, May 17, 1983)
J. O. Ingebretsen	"Introduction to the Fermilab Central Computing Facility" (Fermilab, June 3, 1983)
L. M. Lederman	"Survey of Particle Physics" (Fermilab, June 6, 1983)
R. Auskalnis, J. Finks, and E. West	"Discussions of Procurement Procedures" (Fermilab, June 7, 1983)
F. T. Cole	"Particle Accelerators" (Fermilab, June 8, 1983)
K. Sliwa	"First Results from the Tagged γ Spectrometer" (Fermilab, June 10, 1983)
R. Rameika	"Elementary Particles and Their Properties" (Fermilab, June 13, 1983)
F. Bartlett, P. Heinicke, F. Nagy, and M. Storm	"VAX/VMS and PDP/RT, RSX Systems" (Fermilab, June 14, 1983)
T. Nash	"Fermilab Advanced Computer Program" (Fermilab, June 14, 1983)

Some of those who contributed to the Tevatron two-sector beam studies (left to right) front row: Ray Yarema, Rajendran Raja, Mike Harrison, Bob Shafer, Dave Beechy, Dixon Bogert; second row: Frank Nagy, Howie Pfeffer, Rod Gerig, Al Russell, and Jim Lackey; third row: Dave Johnson, Chuck Ankenbrandt, Curt Owen, Stan Pruss, and Rol Johnson.

(Photograph by Fermilab Photo Unit)

DATES TO REMEMBER

August 11-16, 1983	12th International Conference on High-Energy Accelerators [for information contact Rene Donaldson, Conference Secretary, Fermilab (312) 840-3278]