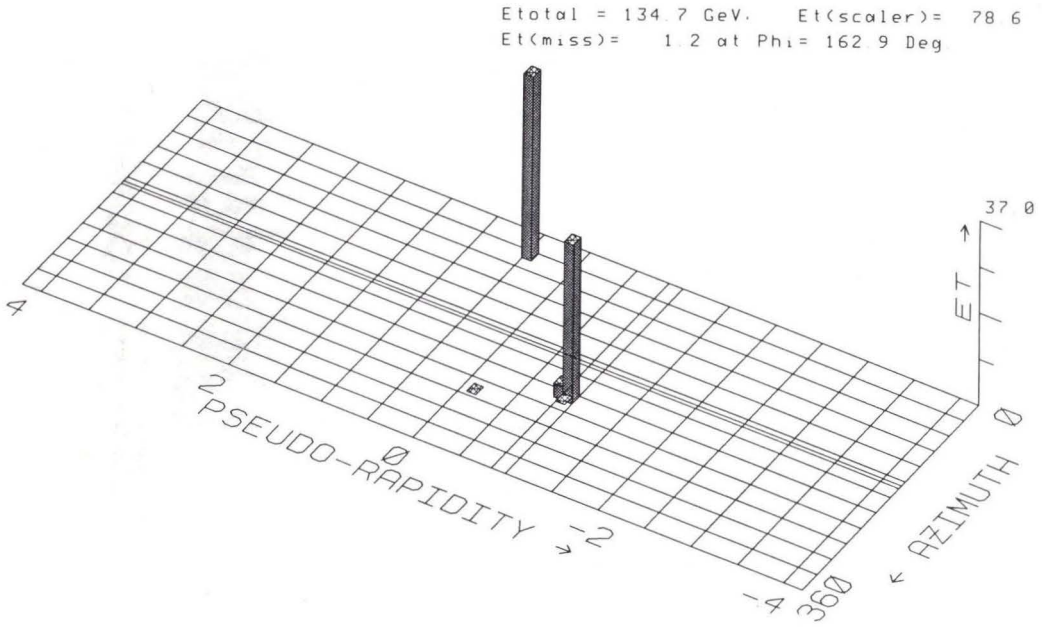
fermilab report

May/June
1989



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89/5 **Fermi National Accelerator Laboratory**

On the cover: *A "Lego" plot from the Collider Detector at Fermilab (CDF) showing an electron-positron pair resulting from the decay of a Z^0. The height of the column is proportional to the energy of the particles. On July 29, 1989, CDF announced the most precise measurement to date of the Z^0 mass.* *See page 1.*

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Table of Contents

The monitor art pictured above was created by Todd Johnson and Wally Kissel of the Fermilab Accelerator Division Operations Group to announce the end of the 1988-1989 TEVATRON Collider run on May 31, 1989. After a pause for changeover from Collider to fixed-target TEVATRON mode, magnet repair, and TEVATRON cool-down, the accelerator will come back on for fixed-target physics in early 1990. A guide to the experiments in the upcoming program will appear in the July/August Fermilab Report.

The Collider Detector at Fermilab Achieves the Most Precise Measurement to Date of the Z^0 Mass

The Collider Detector at Fermilab (CDF) collaboration has analyzed the largest sample of Z^0's ever seen and has succeeded in obtaining the most precise measurement of the mass of this once exotic particle. In a paper sent to the *Physical Review Letters* (and preprinted as FERMILAB-Pub-89/160-E) the international collaboration of 11 U.S. universities, three national laboratories, and two institutions each in Italy and Japan, reported the new mass value as 90.9 ± 0.3 (stat. and syst.) $\pm$ 0.2 (scale) Gev, six times more precise than any previous measurement. In addition, the first measurement of the Z^0 width was reported, $\Gamma_Z = 3.8 \pm 0.8 \pm 1.0$ GeV.

These measurements resulted from some 500 Z^0's detected during the just-completed run of the TEVATRON Collider at Fermilab, which is operated for the U. S. Department of Energy by Universities Research Association, Inc. These 500 Z^0's are more than 10 times the number of Z^0's previously detected and reported. The CDF collaboration has about 250 physicists and graduate students, and the co-leaders are Melvyn Shochet of the University of Chicago and Alvin Tollestrup of Fermilab. The Italian team is led by Professor Giorgio Bellettini; the Japanese team is led by Professor Kunitaka Kondo.

It is expected that later this year, the CERN machine LEP e^+ e^- collider and the Stanford Linear Accelerator Center's SLC will produce even greater numbers of Z's than are now available. However, neither of these machines can produce W's, and the difference between the W mass and the Z mass will provide an important test of the model of the electroweak force. The CDF collaboration has collected a sample of 5000 W's and is in the process of making a precise determination of the W's mass. The other major unknown in the model is the mass of the yet undiscovered sixth quark, the top quark. The CDF collaboration is currently searching for this elusive particle in its sample of data.

Physics Advisory Committee Meeting

June 17-23, 1989

General Remarks and Recommendations

Introduction

The Fermilab Physics Advisory Committee (PAC) met in Aspen from June 17 through June 23, 1989. As has been its custom since 1976, it made a number of recommendations of a general nature to the Laboratory. In the course of discussion of the fixed-target experiments, the Committee recommended that the Laboratory continue planning for the fixed-target experiments by soliciting proposals and letters of intent for experiments that could run in 1992 and beyond. Provisionally, the Laboratory will issue a call for such proposals and letters of intent in October 1989 with the expectation that they would be received by March 1990. The objective of the letters of intent and proposals is to establish a basis for planning a strong fixed-target program for 1992 and beyond. Since Fermilab will submit its budget request for FY91 to the Department of Energy in March 1990, those letters of intent and proposals will be a crucial input to that request.

The text of the General Recommendations of the PAC follows.

- John Peoples

General Remarks

In May, Fermilab completed an extremely successful Collider run that greatly exceeded original expectations. The delivered integrated luminosity was 9.8 pb^{-1} with CDF putting 4.7 pb^{-1} on tape. A peak luminosity of 2 x 10^{30} (twice the original design luminosity) was achieved. By the end of the run, CDF was running at an overall efficiency near 70%. Data from the run are being processed in a very timely fashion. Preliminary results were already reported in March at Moriond and at the beginning of May at the APS meeting. The Laboratory and the Collider users are to be congratulated on this extraordinary accomplishment.

Among the physics results expected by the end of the summer are a search for the top quark in the mass range up to 80 GeV, precise information on W and Z masses, high p_T jet data probing quark compositeness above 1 TeV, and clear observation and measurement of B-meson production in hadronic collisions.

A number of improvements are being made by the Accelerator Division to increase the luminosity by a factor of 3 to 4 for the next Collider run in 1991, when both the CDF and D0 detectors are scheduled to be running.

Fixed-Target Program

A large number of fixed-target experiments will be running early in 1990. This is an excellent program that addresses a wide variety of physics topics, including production and decay of charmed mesons, the first experiments dedicated to B-meson production, K-meson physics, polarization effects, direct photon studies, and structure function determinations from muon scattering. This very ambitious program has put great demands on the Laboratory. Unfortunately, three of the experiments will not be ready at the beginning of the run.

We are concerned at the slow rate at which the analysis of many of the experiments in the previous fixed-target runs is proceeding. One of the reasons is that many groups are carrying out ambitious programs with inadequate manpower. Groups should be encouraged to give as much effort to analysis as to preparations for the next run. The Laboratory should try to provide the necessary computational resources to help with this effort. We hope to see more results before the beginning of the 1990 run.

The 1990 fixed-target run should see the completion of a large number of experiments. It is hoped that new proposals for running in 1992 and beyond will be submitted by early next year. While it is probable that a number of 1992 experiments will be using experimental apparatus from the 1990 run, it is important that the possibility of completing new experiments for the future be considered.

Providing beams for SSC detector development is an important job of the Laboratory. The PAC will seriously consider proposals for test beams as it does proposals for fixed-target running. It is hoped that test-beam requirements can be met without harming the fixed-target program in 1992 and beyond.

Main Injector

The Committee is enthusiastic about the Laboratory proposal to construct a new Main Injector in a separate tunnel. This project will immediately enhance the Fermilab physics program in several ways:

- The luminosity available at the Collider will be increased by a factor of 5.
- The flux available for fixed-target running will increase up to a factor of 2. This gain is especially significant for experiments that are currently flux limited, such as those using tertiary beams.
- Moderate-energy secondary beams will be available year-round both for test beams and for physics. We note that a recent workshop on "Physics at the Main Injector" was widely attended and explored a number of interesting possibilities, including kaon and neutrino physics. We anticipate an active physics program utilizing the Main Injector.

- Backgrounds from the Main Ring will be eliminated at the TEVATRON collider detectors. This directly benefits the experiments and additionally relieves significant operational constraints during antiproton production.

In addition, the Main Injector project allows for the possibility of building a third high-luminosity region at the Collider. The Committee recommends the construction of a third region. We believe that there is much interesting physics that could be explored with one or more special-purpose detectors there. One attractive possibility is the study of b physics. We have already received a Letter of Intent from the Bottom Collider Detector collaboration and have given Stage I approval for their R&D proposal to study the technical issues associated with b detection during high-luminosity Collider running.

Long-Range Plans

Fermilab will remain a unique high-energy physics research facility for the indefinite future. We strongly encourage long-range planning such as the recent workshop on "Physics at the Main Injector" and the Breckenridge workshop in August on "Physics at Fermilab in the 1990's."

PARS: A State-of-the-Art Electronic Tool for Managing Fermilab's Business Functions

by Kevin A. Brown

A relentless stream of purchased material flows in and out of Fermilab, fuel for the Laboratory's research explorations. Some 7000 line items each month add up to approximately $100 million worth of goods and services purchased by the Lab each year. Each of those 7000 items requires purchasing, accounting, receiving, and distribution actions, all with their accompanying record-keeping activities; a records trail to daunt even the hardiest soul.

More than ten years ago, the managers of Fermilab's business functions acknowledged that the Lab was falling behind in automating those areas. As James E. Finks, Jr., Head of the Business Services Section, put it, "At the time, we knew that our old manual systems were outdated. Although the technology was available, we relied too much on paper systems." As a result, managers and other staff overseeing Fermilab's procurement and receiving functions were hindered by slow processing time, an inability to effectively track records, and unacceptable overtime costs. Those factors were the gestation for the evolution of PARS, the Laboratory's computerized purchasing, accounting, and receiving system, implemented at Fermilab two years ago.

System Present

PARS integrates business functions into a common data base, allowing managers to electronically exchange information and track a purchase requisition through all transaction steps. A person in Fermilab's Receiving Department can use a terminal linked to a Local-Area Network, or LAN (several personal computers tied together), to read the status of nearly any procurement, including requisition number and date, requisitioner, vendor, buyer, purchase-order number, and budget code. There is also a report menu on expediting reports, open orders, open requisitions, open requisitions by administrators, and status of purchase orders. The system is unique to Fermilab in that an independent personal computer network is used to perform the Receiving function. Receiving Department data, from the network, is transmitted to the IBM 4381 mainframe for purchase-file update and inquiry information. Purchasing information is transmitted to the Receiving system to update the Receiving files during this same process.. According to Gerald Bresnahan *(Bus. Serv./Info. Systems)*, Fermilab's interactive, online PARS PC network is probably unequaled anywhere in the world.

System Development

A number of issues had to be addressed before development of the PARS system could commence. In the mid-1970's, John Pollock, then head of Information Systems, established and chaired an Advisory Committee that put together a wish list for a system to more efficiently integrate the Laboratory's business functions. In the early 1980's, the Advisory Committee became the PARS Committee, chaired by Richard J. Auskalnis, Head of Fermilab's Procurement Department, which comprehensively represented the Laboratory. James Schiltz, Accounting Department Manager, currently chairs the PARS Committee.

Initially, the Committee brought in a Data General minicomputer to handle integrated business functions. That minicomputer proved inadequate for the purpose and was replaced by the current IBM 4381 mainframe. Even with the IBM, it became obvious that the Lab couldn't develop in-house the system envisioned by the Committee. Larry Joseph, who succeeded Pollock as Head of Information Systems, proposed that an outside team develop a preliminary design for an integrated system. The design team's plan, which was approved by the steering committee, led to the development of the original module of PARS. However, Information Systems found that further developments to the system would again require outside help. Joseph then brought in two or three consultant companies. At that time, Bresnahan joined the Lab as the PARS project manager and was instrumental in developing PARS.

In theory, the PARS committees developed a functional system. In practice, there were several technical hurdles rooted in Fermilab's mainframe operating environment, VM/CMS. VM/CMS is suitable for Fermilab's research mission, but it is an atypical system environment for business applications. The Committee had to find another business application package.

The first and only choice after many hours of investigation was FOCUS, a fourth-generation language to develop the mainframe PARS programs. Because Fermilab had successfully used it in the past to develop the initial modules for PARS and other systems, the role of FOCUS was to be expanded to include Receiving Department operations. At first, Fermilab used PC FOCUS, the personal-computer version of FOCUS, with a network, but the software proved too cumbersome for high-transaction volumes. "We experimented with PC FOCUS for about three or four months with little success," Bresnahan recalled, "and we finally had the vendor, IBI, come out to the Lab. They said that what we wanted to do couldn't be done with PC FOCUS on the network, because PC FOCUS is designed for sharing files and having people report off those files, not to write programs to do the kinds of tasks that we were asking."

A solution came when Chuck Gallagher of Gallagher and Associates, from Bartlett, Illinois, a consultant hired by Fermilab to assist in PARS development, selected the data base management system MDBS III. It was selected because it lent itself to networking, or multiple simultaneous transactions, on a data base. It also ensures accuracy before business transaction records are released. MDBS III was sold primarily to vendors who would take it and write their own software on MDBS III, then distribute the software under a different software name. However, Fermilab's use for MDBS III is unique: The Lab applied it as a user tool to develop a system internally.

System Network

Personal computers (PC), such as those used by the Receiving and Accounting departments, are one key to the successful acceptance of the system by users, because PC's, which are becoming prevalent at the Lab, are multi-use and offer easy access to the PARS network. They handle the large number of detailed tranactions from Receiving and (soon) Accounting without burdening the mainframe. Another key to user acceptance is that summary information is shipped to the 4381 where it is widely available to the Lab community.

Dave Carlson *(Res. Div. Office)*, who logs onto PARS on a Macintosh to track Research Division purchasing activities, noted that, "While most of the devices at the Lab can access the IBM mainframe, the IBM is not the machine that a lot of people are accustomed to using; the experimenters and many of our Division's purchase-order people are more familiar with a DEC environment, or they have non-IBM equipment." For the Research Division, which is responsible for a huge variety of procurement activities, the ability to link a terminal or PC to the mainframe from a remote location (such as an experiment out on the beamline) is invaluable.

Convenient access to data within PARS is one of the system's strengths. From a system-user's point of view, PARS provides a better, faster way of obtaining information on requisitions and orders. Pre-PARS, a requisitioner had to wait for a paper copy of a purchase order to return via the mail before that requisitioner would know that the correct material was ordered. Now, with the PARS PC/mainframe link, a requisitioner can find the information soon after it's typed into the computer. "When we have a lot of projects ongoing," Carlson said, "it's important to get the information back to requesters and managers as quickly as possible, and now we're moving in that direction. We look forward to the time when we can do that with the Lab's cost accounting system as well. There's probably not a working day that I don't log onto the mainframe to find out the status of a purchase order." Like other users, Carlson can now rely less on a

flow of paper through the mail system and more on getting online information that's up-to-date - almost to the day. "I think the greatest advantage I see in having PARS available is reducing paper work and getting information back to the people who need it faster and more conveniently." Moreover, when the cost-accounting and accounts-payable modules are implemented, the system will be integrated to the point where a user won't have to wait until the end of the month to find out what has been spent on a task; they'll be able to find out immediately.

It is anticipated that more and more Macintoshes will be linked to the PARS network. Said Finks, "For years, the IBM PC's and the Macintoshes didn't talk to each other. More recently, interfaces have been developed that allow communication between the two. Based upon information from the industry, very shortly we should be able to use Macintoshes, as well as the IBM's, to talk to each other and to the mainframe." When Macintoshes are linked to the system, and to the IBM's, a broader spectrum of the Laboratory will benefit from PARS, especially the Laboratory's scientific community, and the number of frequent users will increase substantially.

System Benefits

Benefits multiply as the system grows and users reap those benefits. "PARS is certainly making my operations more efficient," Finks said. "It's streamlining procurement and has had a positive effect on receiving activities, because Receiving now uses an efficient, nearly paperless, bar-coding system. The Lab can also determine in approximately real-time where we stand on our procurements." Furthermore, the Receiving Department has realized an increase in the number of deliveries made per day to requesters on site, because using bar codes is a faster way of getting information into the system and producing a driver's manifest.

Rapid system response time is also a hallmark. While handling the aforementioned 7000 line items every month, the Receiving system maintains response time to within a second. "The longest response time I've seen is three seconds," Bresnahan said, "although I've seen it go longer than that for inquiries - up to five seconds. We try to keep it under three seconds response time, and we've been very successful at it."

Convenient access to data within PARS is another tangible benefit. "From a procurement-management viewpoint," Auskalnis said, "PARS can show me how many orders every single buyer places in a given time period. This helps me to prepare the detailed reports of Laboratory procurement activities required by the Department of Energy." He also has access to vendor data via the system's vendor data base, which stores the names, addresses, and phone numbers of all the vendors conducting business with Fermilab. Each vendor in the data base has a

five-digit vendor number that is used for any data relevant to that vendor, much like a social security number. Data about the vendor that is put into the database forms a vendor profile. In that vendor profile is a four-digit commodity code that indicates what items the vendor sells. The vendor data base can be searched quickly and easily to create a bid list of vendors for a particular item.

PARS improves efficiency by automating the purchase-order typing process. When a requisition is written up by a buyer, it then goes to the Purchase Order Entry Department where it is typed into the database. PARS translates the information from the requisition into a format that resembles a purchase order, and every hour a printer prints out these purchase orders to be signed and distributed by the appropriate people. PARS captures the data on each purchase order, and a mirror image of that purchase can be called up as necessary. This eliminates the need pull a hard copy from a file.

Another benefit of PARS is reduced overtime. As a result of the LAN, Fermilab has accrued considerably less overtime than in the past, cutting overtime costs in Receiving by nearly 100%. Occasionally, employees still work overtime, but only due to some very unique condition that overloads the network, usually at the end of December. But rather than working overtime for a full week, PARS cuts that time to only one or two days, if that.

System Future

Fermilab continues to develop the system. The accounts-payable system should be implemented this fiscal year, and the general ledger, cost accounting, and shipping systems should be implemented soon thereafter. Information Systems will then determine if the cost-accounting system should go on the PC's or the mainframe. In spite of the anticipated load on the network, response time will continue to be nearly instantaneous. Managers will be able to take an accounts-payable record, and in 15 or 20 seconds get a history on that particular purchase order, including date of requisition, when the bills were paid, how they were paid, shipping and payment terms, and warranty information.

Another innovative network development is optical disk technology to store and archive data. Data are stored in submicrometer-sized holes on a rotating disk, and are recorded and read by laser beams focused on that disk. To date, all inactive and active purchase orders have been archived by optical disk technology; the disks are also used for disaster recovery storage, and expanded application of this technology is on the horizon.

Although the network is relatively new, it's evolving into a model system, attracting attention from several private-sector companies including the company that distributes the software. The system received industry attention through an

unsolicited article in the February/March 1989 issue of *System Builder*. As a result of that article, Fermilab received inquiries about the system from a variety of organizations, including Argonne National Laboratory. Further, IBM is considering some changes in their networking system, and PARS has accelerated the interface between Novelle and Macintosh. By stimulating these industries in the best traditions of technology transfer, Fermilab has demonstrated that PARS is truly state-of-the-art.

The Symposium on Particle Identification at High Luminosity Hadron Colliders

by Peter H. Garbincius

Typical elementary particle experiments consist of a source of interactions, either an external beam and a fixed target or two colliding beams, and a detector system which may include most of the following components: a tracking system and analysis magnet, calorimetry, hadron and electron identification, muon detection, trigger counters and processors, and data acquisition electronics. In addition, those experiments intending to operate at future high-luminosity hadron colliders such as an upgraded TEVATRON, the Large Hadron Collider (LHC), and the Superconducting Super Collider (SSC), must ideally cover the entire solid angle and be capable of not only surviving, but providing high-resolution event information at incredible interaction rates.

(Fermilab photograph 89-488-3)

Fermilab Director-Designate John Peoples welcomes attendees at the Particle Identification at High Luminosity Hadron Colliders Symposium.

The Symposium on Particle Identification at High Luminosity Hadron Colliders was held at Fermilab on April 5-7, 1989 and was sponsored by Fermilab, the Department of Energy, and the SSC/Central Design Group. It was designed to focus on this single facet of detector technology. The symposium was attended by about 125 physicists and engineers, from the United States, Latin America, Europe, and Japan. The main goal was to foster the interchange of information on the topic of non-destructive identification of particle species in the high luminosity hadron collider environment. By non-destructive, we mean that the particle in question emerges relatively unscathed, without excessive energy loss, multiple scattering, or interaction probability. This means the particle can continue being tracked or subsequently detected in a total absorption calorimeter. Such a scheme will allow higher mo-

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mentum resolution measurements, and the combination of initial identification followed by calorimetry can further help differentiate between electrons and hadrons.

In his keynote talk on SSC Physics, Chris Quigg gave a theorist's viewpoint of which particles experimentalists should be planning to identify. He was not directly concerned with the garden variety pions, kaons, protons, neutrons, etc., except for the usefulness of pi-zero identification as a possible background for electrons, and the detection of single, direct photons which arise directly from constituent interaction. The theorist's ideal would be to detect and identify electrons, muons, tau-leptons, neutrinos, charm-quarks, and bottom-quarks. In addition, throw in W's, Z's, and top-quarks directly, and through their most likely decays into hadron jets. Especially important is the measurement and identification of leading hadron fragments and electrons within jets. This is a tall order, quite a challenge for most experimentalists, but in fact, that's what's needed to fully explore the zoo of new particles and possibly new interactions made accessible by the new machines. Experimentalists have yet, and are unlikely in the near future, to fully meet Chris's challenge. Therein lies the intrigue and the painstaking labor in exploring new territories.

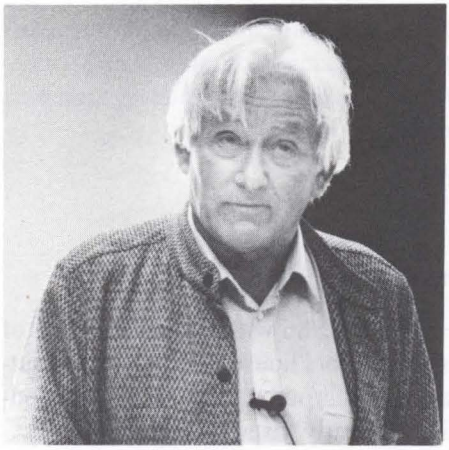
The symposium was divided into five half-day sessions concentrating on physics requirements and motivations, ring imaging Cherenkov (RICH) detectors, transition radiation detectors (TRD), and synchrotron radiation (SR), time-of-filght (TOF), and energy loss (dE/dx) techniques, in addition to electronic readout applications and designs.

The RICH technique attempts to identify electrons, pions, kaons, and protons by measuring the angle of the Cherenkov light produced by these particles in passing through either a gas, liquid, or solid radiator. This Cherenkov angle is optically imaged into a ring whose diameter is correlated with the particle's mass and momentum. If the momentum is otherwise determined, a measurement of the diameter of the Cherenkov ring provides particle identification by mass. The session on RICH counters was very fortunate to have two of the founding fathers of this technique present, T. Ypsilantis and J. Seguinot, both of College de France. They discussed the general techniques, optimizations, limitations, and outstanding problems. D. Leith of SLAC described the high technology and stringent quality control aspects going into the SLD RICH system. A. Breskin and V. Peskov spoke of R&D programs into low pressure RICH systems and the search for new photosensitive detector materials, respectively.

Transition radiation is produced when a particle passes through an interface between two media. The amount of radiation increases with the particle's relativistic gamma (momentum/mass). The emitted transition x-rays can be produced coherently from a series of thin, closely spaced polypropylene foils. Since elec-

trons give off more TR than pions, the main application is in electron/pion discrimination. The discussion on transition radiation detection (TRD) included reports of performance of existing large-aperture, low-rate or small aperture, high-rate TRD's as applied in CERN and Fermilab Collider and fixed-target experiments. Also presented were fabrication status for the VENUS TRD at KEK and initial R&D studies for an SSC TRD system. It is apparent that at the higher fixed-target and SSC energies, this technique can provide good discrimination, not only electron/pion, but also pion/kaon.

Synchrotron energy (SR) is emitted by ultra-relativistic particles bending in magnetic fields. Like the TRD, it finds its main application in electron/hadron discrimination, by detecting SR from electrons but not from hadrons. This was interesting when comparing the techniques for detecting SR photons as described by R. Handler and R. Rusak. Handler's application used a conventional analysis magnet with electron energies of 8-28 GeV. The typical SR photon energies was about 20-KeV x rays, so the xenon proportional chamber was the detector of choice. Rusak, on the other hand, is designing for 100 GeV electrons in a 5 tesla superconducting magnet, leading to gamma rays above 10 MeV. Such gammas would be detected in a very fine grained, both longitudinal and transverse, shower counter in which the photons converted into e^+e^- pairs.



(Fermilab photograph 89-489-18)

Georges Charpak (CERN) delivers closing remarks to the Symposium.

It was apparent that we are just beginning to study the application of these devices at high-luminosity colliders. Much preliminary R&D still has to be done before a full acceptance detector utilizing such particle identification techniques can be seriously considered. The overall detector R&D program sponsored by the SSC was described by Gil Gilchriese.

The symposium was summarized by Georges Charpak of CERN, the father of the multiwire proportional, drift, and gated multi-step avalanche chambers. He again re-emphasized the great technical challenges of the SSC with its 15 nanosecond crossing times, huge event multiplicities, and huge rates. Innovative high resolution detector technologies will continue to find productive application far beyond the particle physics environment. In Charpak's closing remarks he comments, "In response to the theorist's promise of gauginos and squarks, we experimentalists are supposed to provide gadgetinos and swire chambers. . . Thank God for the young people!"

Update on Fermilab's Computing Facilities Upgrade

by Jack O. Pfister

Fermilab's computing resources continue to expand to meet the growing (avalanche!) data analysis requirements from both the fixed-target and colliding-beams programs. The Central Computing Upgrade Project is entering the final phase as a formal construction project. However, the new operation is well under way. The computing facility's new Feynman Computing Center is fully operational and the computing components, save the file server, are physically installed

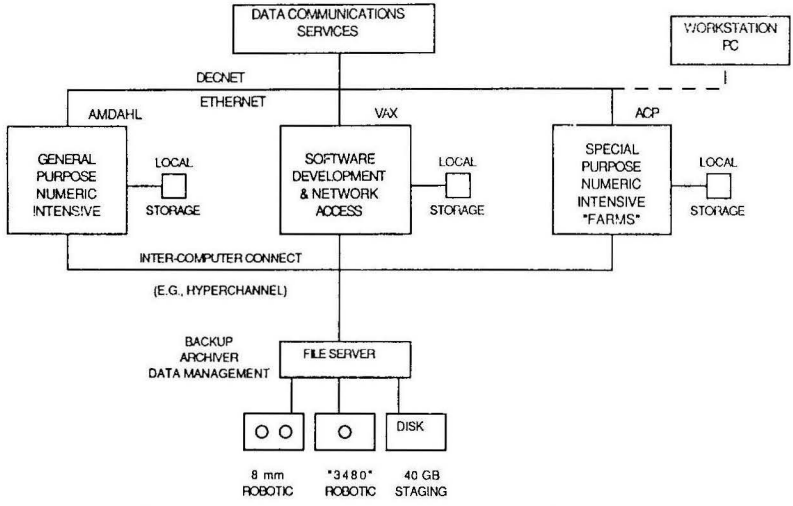


Fig. 1. *Fermilab computing-system architecture*

(see Fig. 1). The upgrade project formally began in 1986 with the construction of a new 74,000 square foot building. The first two floors house the central computing systems. It also houses a terminal area and input/output area for users needing over-the-counter services. The computing currently installed includes:

- Facilities for software development - the DEC VAX Cluster with 65 VAX equivalents. (A VAX equivalent is defined as the computing power of a VAX 11/780.)
- Numeric-intensive computing in two systems - the ACP (Advanced Computing Project) systems totaling 350 VAX equivalents and the Amdahl 600E at 120 VAX equivalents.

The author is with the Fermilab Computing Department

The Amdahl system (four processors) with 100 GBytes of direct access storage is the latest system to be installed. The system is currently split. Half the system issued for production usage is running VM/HPO (60 VAX equivalents) while the VM/XA portion of the system is currently undergoing checkout by the user support group to assure the applications compatibility of third-party software, including all libraries such as the CERN library. This checkout process is expected to be completed in June 1989, at which time the four processors will be available for production/analysis under VM/XA.

Part of the CDC Cyber complex was recently decommissioned (removal of three CDC 175's originally installed in 1978-79). The remaining CDC 875 dual processor is scheduled for removal in the fall of 1990. The 875 will continue to be used for the analysis of previously run fixed-target experiments and also the use of engineering software proprietary to the CDC machine. Fermilab has selected a new engineering software product and is in the process of migrating the engineers and drawings to the new system, which runs on various workstations, the VAX Cluster and the Amdahl. The migration of all data analysis and Monte Carlo programs of the previously run experiments is also in progress.

Although much attention has been focused upon crunchers and clusters, there has been considerable expansion in distributed workstations (over 200 added to the network) at Fermilab for both engineering and physics analysis use in the past year. The simple nomenclature ''central computing'' is probably no longer appropriate given the scope of services now provided by the department.

New I-DEAS for CAD/CAM at Fermilab

by Kevin A. Brown

In the same way that electrical power once revolutionized manufacturing, computing tools are revolutionizing engineering. Fermilab has completed the purchase of a new CAD/CAM (computer aided drafting/computer aided manufacturing) package called I-DEAS that advances this revolution at Fermilab. The Lab purchased I-DEAS from Structural Dynamics Research Corporation to replace Control Data Corporations ICEM, the Lab's original CAD program.

CAD, first developed in the 1970s, is the use of computers to develop three-dimensional representations of engineering structures, analyze those structures, and make engineering drawings. The earliest CAD systems were simple; engineering drawings of components were displayed as wire-frame models, or simple line representations, on a cathode-ray tube. Although the first CAD systems showed a visual outline of a component, they were incapable of displaying interior details. Subsequently, CAD has rapidly evolved, and wire-frame models are now used in non-destructive, computational testing of prototype structures. Computational testing helps to prevent costly modifications of full-scale, operating prototypes.

CAM, introduced in the 1950s, is the use of numerically-controlled (N/C) machines to create parts. The growth of N/C machines had been hindered by their programming complexity. Initially, N/C machines were controlled by coded paper tape, but current CAM technology has lead to N/C machines controlled by programmed tool paths on magnetic computer disks. Combined, CAD/CAM technology enables designers, engineers, manufacturers, and inspectors to work with a common data base, thereby improving manufacturing efficiency and quality.

Selecting the New CAD/CAM System

Long before Fermilab's Feynman Computing Center opened, the Computing Department knew that ICEM would be incompatible with the Lab's new Amdahl large-scale scientific computer. Therefore, a new graphics program had to be selected. Finley Markley *(Tech. Suppt./Engin.)*, Chairperson of the CAD/CAM Committee, suggested to Dick Lundy, then Associate Director for Technology at Fermilab, that a special CAD/CAM committee should be formed to advise the Lab on the selection of the new program. The objective was to arrive

at a Laboratory-wide decision in light of the fact that users of this tool would come from elements of nearly every Lab division/section.

Division Heads Ken Stanfield (Research Division), Helen Edwards (then Accelerator Division Head), Dan Green (Physics Section), and Paul Mantsch (Technical Support Section) sent representatives from their respective Divisions to serve on the committee. Committee members Mark Leininger *(Res. Div./ Comput. Dept.)* and Tom Nicol *(Tech. Suppt./Engin.)* represented the general computer-aided-design community. Additionally, committee members Charlie Matthews *(Tech. Suppt./Machine Shop)* and several of his staff represented Fermilab's machinists.

To test possible programs, the committee borrowed copies of CAD/CAM systems from major manufacturers for temporary use on Fermilab systems. Leininger and Charles Grimm *(Tech. Suppt./Engin.)* evaluated the different programs by putting them to use for at least a month. Key criteria used in evaluating the programs were (1) that the programs would run on the VAX for flexibility, as well as the new Amdahl, and (2) that the programs could be used with the Lab's Tektronix terminals.

While studying the criteria, the Committee concluded that the future of CAD was in solids modeling - programs that build a three-dimensional model of an object, which is then displayed on a computer screen. With a solids program, a designer or draftsperson can develop an image of the entire assembly, and even cut a slice through it to show what's on the inside. Solids programs can also indicate if there is any interference between parts, and CAD users can command these programs to animate an assembly.

I-DEAS best met the Committee's first criterion because it operates in virtually any computing environment, including the VAX and the Amdahl. It also has solids modeling capabilities. Primarily a suite of software products, each product within I-DEAS was created for a specific designing task. As an example, Lab engineers can use Kinematics in Design to animate systems of solid models in order to look for resulting interferences and study configuration behavior. Other products in the procurement include Model Solution, Frame, Supertab, and DMCS (data management and control system), which gives the whole Lab access to drawings, much like an electronic drawing cabinet.

I-DEAS also includes two other products, Geomod and Geodraw. Geomod is a solid modeler for engineers, designers, and machinists. In addition to three-dimensional line drawings, Geomod can create a solid model of an object. This makes the object more concrete and increases the efficiency of other designing activities because the object is a solid. After an object is created using Geomod,

it can be used to generate a working drawing in Geodraw, a drafting program.

I-DEAS Applications at Fermilab

I-DEAS applications are far and broad at Fermilab, and they include SSC magnets and the TEVATRON upgrade. Jim Schellpfeffer *(Physics Section)*, who has been using CAD for printed circuit boards of unusual design, uses Geodraw to design precise angles, where the old software for designing printed circuit boards limited the types of lines available. For Schellpfeffer's work with large drift chamber boards, some as large as 12 ft by 1 ft, I-DEAS is a tremendously efficient tool, because many of the complex calculations are done by the computer.

Among other time-saving features, I-DEAS displays command icons on-screen. For example, in Geodraw, a designer has a choice of 51 on-screen icons, including lines, arcs, circles, and other symbols. Although the system has essentially three line thicknesses - thin, medium, and thick - the computer can calculate the number of passes it needs to make to create a precise line of the desired thickness. Schellpfeffer can create an icon for several commands he uses frequently.

Networking with I-DEAS is an important aspect of the software's application. Drawings can be created by a designer and then used by a person in one of the Lab's Machine Shops to produce a part with the aid of the CAM tool. For example, a designer can first create a tool path on a computer, transfer the tool path to a magnetic disk, and carry the magnetic disk to a magnetic disk reader on a machine that will cut a part, or a portion of a part, in the Machine Shop. Then, a machinist inserts into the machine the disk with the tool path commands. Without this system, one would have to regenerate the drawing at considerable time and expense.

Grimm emphasized the role I-DEAS plays in designing physics research equipment. "I use I-DEAS for designing components for the Collider Detector at Fermilab (CDF). I'd never draw on a drawing board again, because I can draw more quickly with CAD than I can by hand." Although I-DEAS has only been in use at the Lab for two years, CDF's central calorimeters were designed using CAD technology. Additionally, "We've been working a lot with Brookhaven and SLAC on SSC cryostat drawings. We're mailing disks with hundreds of drawings instead of bulky boxes of drawings," said Grimm.

Training on the new system is done by Jose Poces *(Tech. Suppt./Engin.)*. "That really accelerated the use of the program by the other divisions," Markley believes, "because they could send people over to Jose for a one-week course on each module, such as Geomod, to learn how to use the program." Markley cited the Machine Shop as having done an excellent job of training

people without prior computer experience to start using computer-controlled machines. ''We've trained people that have never used computers before. It's basically very easy to learn, if you understand drafting terminology,'' said Grimm.

By the fall of 1990, I-DEAS will be in use throughout the Lab. Recalled Grimm, ''When I first started using CAD at Fermilab over six years ago, there were five CAD terminals on site and only a handful of people using CAD. Now, hundreds of people are using it on hundreds of terminals. It's growing rapidly.''

Lab Notes

May and June were months of convening at Fermilab: AlvinFest (May 15) in honor of Alvin Tollestrup, co-manager of the Collider Detector at Fermilab; the 23rd Fermilab Users' Annual Meeting (May 19); the Ninth Annual Fermilab Industrial Affiliates Meeting (May 25 and 26); and LeonFest (June 15), a symposium on the occasion of the retirement of Fermilab's outgoing Director

(Fermilab photograph 89-596-24)

↑ *(L. to r.) H. Bingham, H. Jensen, D. Schramm, W. C. Fowler, and honoree A. Tollestrup at AlvinFest.*

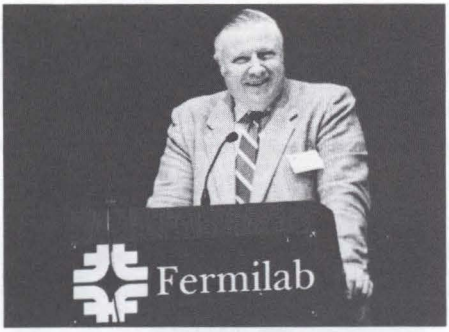
(Fermilab photograph 89-58-6)

↑ *The members of the 1988-1989 Fermilab Users Executive Committee (UEC), sponsors of the Annual Users Meeting: top, l. to r., J. Christenson, E. Engles, Jr.,*

*("**Lab Notes**" continued)*

M. Corcoran, S. Holmes, R. Brock, and M. Kreisler. Seated, l. to r., A. J. Slaughter, S. Errede (Chairperson), R. Rameika, H. Lubatti, and A. Garfinkel.

Errede, in his opening remarks, noted that Fermilab's user community now numbered 1500 official members, called 1989 a "year of great change" in light of: high expectations for SSC, a new Fermilab Director, J. D. Bjorken's pending departure from Fermilab and return to Stanford, URA reorganization, the "spectacular luminosity and reliability" of the TEVATRON Collider, and a change in perceptions of the top-quark mass that may impact on the Standard Model. Under the heading of "What have we done for you lately," Errede brought users up to date on UEC initiatives in the areas of new housing, test beams, computing needs, and safety factors. Errede made special note of the 10 new Ph. D.'s achieved in 1989 as an out-growth of Fermilab's research.



(Fermilab photograph 89-623-7)

← W. N. Hess (DOE) told Users' Meeting attendees that while the SSC "must have first priority this year and next," startup funding for Fermilab's Linac Upgrade was in the proposed budget, HEPAP had endorsed the Lab's Main Injector proposal, and that "DOE will work to keep Fermilab strong into the next century. . . You're on top of the world in a golden period for high-energy physics."

(Fermilab photograph 89-628-10)

↑ Lucy Carrera (left) and Pat Oleck welcomed registrants at the Industrial Affiliates Meeting.

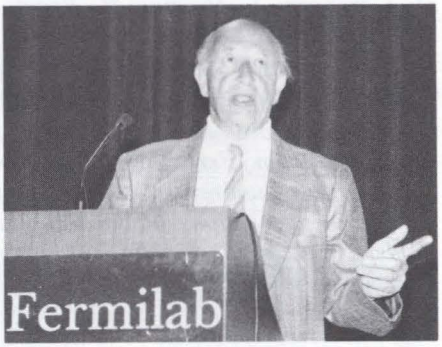
(Fermilab photograph 89-632-31a)

↑ An accelerator-control console based on MicroVAX, one of the new technologies exhibited at the Affiliates Meeting.

*("**Lab Notes**" continued)*

(Fermilab photograph 89-729-11)

↑ *R. R. Wilson, at Leon Fest, spoke of "International High Energy Physics."*



(Fermilab photograph 89-732-17)

↑ *V. Telegdi "eulogize[d] Lederman's role in the discovery of right-left symmetry, parity violation, in technical parlance" at LeonFest.*

(Fermilab photograph 89-729-5)

↑ *Fermilab's outgoing Director, the subject of LeonFest.*

(Fermilab photograph 89-546-34)↑

. . .and the children from the Fermilab Daycare Center convened with staff and visiting scientists at the revival of Fermilab's traditional Arbor Day Celebration on May 5. Sponsored by NALWO, the Lab's women's organization, and supported by various Lab elements, Arbor Day celebrants planted saplings provided by the Roads & Grounds Department.

*("**Lab Notes**" continued)*

On May 10, 1989, Stephen Hawking, Lucasian Professor of Mathematics at Cambridge University, arrived at Fermilab to participate in the Wormhole Workshop organized by the Fermilab Astrophysics Group. The workshop was attended by approximately 50 scientists from around the world. Hawking also gave a public lecture entitled "Black Holes and Their Children, Baby Universes."

Hawking's third visit to Fermilab began with a press conference. Rocky Kolb, who co-heads the Fermilab Astrophysics Group, introduced Professor Hawking: "There have been two great developments in 20th-century physics - Einstein's Theory of Gravity, and Quantum Mechanics. By the end of the 1920s, the broad outline of the modern form of these theories had been developed. For the last 60 years the two theories have existed as separate edifices, and perhaps the most fundamental challenge of modern physics is to develop a single theory of quantum gravity to encompass these two revolutionary ideas. . . No one has been more successful in exploiting physical effects of quantum gravity than Stephen Hawking."

Hawking covered topics ranging from his concept of God to the possibility of time travel. When asked about his belief in God, Hawking replied, "I don't believe in a personal God. I wouldn't claim that my view of God is new. It is rather similar to that held by Einstein."

Asked about time travel as described in science fiction, Hawking said he did not think it will be possible. Such time travel might allow us to alter our own pasts, and Hawking said, "If it were [possible], we would have seen people from the future." Hawking explained that while particles could travel back in time, they do not alter the past.

When asked if he would achieve a single theory of quantum gravity, Hawking responded, "If we find a complete unified theory, it will be as a result of the work of many people. I hope to play a part, but any individual contribution will be small. It is possible that it could come within my lifetime."

Hawking also addressed several of the major questions facing cosmology. Asked about the possibility of looking beyond, or before, the creation of the Universe, Hawking said, "You can't go back beyond the Big Bang. Time is defined only within the Universe. To ask what happened before the Big Bang is like asking what happens north of the North Pole."

The two most important cosmological problems, Hawking said, are to discover why the cosmological constant is zero and why space-time has three di-

*("**Lab Notes**" continued)*

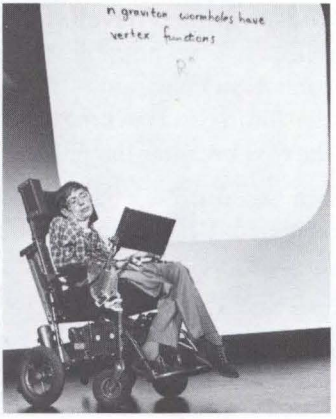
mensions of space and one of time. "Wormholes can probably answer the first question and possibly the second," he concluded.

Does Hawking ever find his work so far-fetched that his life no longer seems real? "I have enough practical problems to keep me in touch with reality," he quipped.

The press conference was marked by periods of quiet anticipation as Hawking formed his replies to questions on a special computer attached to his wheelchair. Diagnosed more than 20 years ago as suffering from ALS, or Lou Gehrig's disease, Hawking now communicates through a computer program called Living Center and a speech synthesizer. He often apologizes for the American accent of the synthesizer.

Though physically limited, Hawking has said his disability has given him more freedom to think. In 1974, Hawking showed that Black Holes, so-called because nothing, not even light, can escape their immense gravity, should actually emit radiation. In 1988, Hawking and Roger Penrose received the prestigious Wolf Prize in physics for their work on singularities - dimensionless points in space-time with infinite densities and irresistible gravitational pull.

On May 13, Professor Hawking gave a public lecture under the aegis of the Fermilab Lecture Series. His talk provided a non-technical view of the development and significance of Black Hole theory. Hawking discussed some of the implications that the existence of Black Holes might have on our lives. In particular, he addressed the possibility of using Black Holes to travel through space and time. Hawking said, "If there are objects called Black Holes, which things can fall into, but not get out, there ought to be other objects, that things can come out of but not fall into. One could call these White Holes. One might speculate that one could jump into a Black Hole in one place, and come out of a White Hole in another. This would be the ideal method of long-distance space travel."



(Fermilab photograph 89-574-19)
Stephen Hawking at his public lecture in Ramsey Auditorium.

*("**Lab Notes**" continued)*

Unfortunately, this method of space travel would be extremely unstable, Hawking explained, since "the slightest disturbance, such as the presence of the spaceship, would destroy the wormhole, or passage, leading from the Black Hole to the White Hole. The spaceship would be torn apart by infinitely strong forces. Anyone care to buy a ticket for the Titanic?"

Hawking also explained how baby Universes form from Black Holes which have evaporated, or lost their mass through emitting particles and radiation. "What will happen then to objects, including possible spaceships, that fell into the Black Hole? A small, self-contained universe branches off from our region of the universe. This baby universe may join on again to our region of space-time," he said.

Hawking has been particularly interested in Black Holes and related objects because they may duplicate conditions at the instant the universe was created, answering the question "Where did the universe come from?"

- Christine Grusak

Fermilab was dedicated as a National Environmental Research Park at an outdoor ceremony held on June 7, 1989. The guests included representatives of the Department of Energy (DOE), state and local officials, representatives from conservancy and environmental groups, as well as researchers and Fermilab employees involved in the project.

Fermilab now joins five other sites operating as research parks at scattered locations across the country (see the March/April 1989 *Fermilab Report*). With Fermilab in the middle, they provide the infrastructure for an interacting network (dubbed a ParkNet) that extends from coast to coast. The dedication program described a National Environmental Research Park as "an outdoor laboratory for probing and finding answers to the ecological relationships between humanity and nature." Research Parks are controlled and protected public land where qualified investigators can conduct various types of environmental research. The ParkNet system will enhance environmental research by providing scientists with a larger data base.

John Paulk, coordinator for the Fermilab Research Park, opened the ceremony by thanking Mitch Adamus, Sam Baker, Rudy Dorner, Margaret Pearson (all from Fermilab), Julie Jastrow, and Bob Betz for their work in proposing to DOE that the Laboratory be designated as an Environmental Research Park. Jastrow is from the Environmental Research Office at Argonne National Laboratory and is actively involved with the ParkNet effort here. Betz, a professor of Biology at Northeastern

*("**Lab Notes**" continued)*

Illinois University, has been instrumental in Fermilab's prairie restoration efforts from the very start.

Fermilab Director Leon M. Lederman welcomed the guests and emphasized the need for public awareness of environment issues. In his remarks, Lederman commented, "It seems like we hear of some new threat to the environment every time we pick up the morning paper. The multiple possibilities of ecological catastrophe may represent the major threat to natural (really planetary) security of the twenty-first century. I just hope that, by becoming a National Environmental Research Park, Fermilab can make some small contribution to the solution of these problems."

(Fermilab photograph 89-682-33)

Finley Markley, Chairman of the Fermilab Prairie Restoration Committee, places a sign along the new Fermilab Prairie Interpretive Trail.

Dr. Phil Stone, Director of the Science and Technology Affairs Staff, DOE Office of Energy Research, congratulated Fermilab for becoming part of the ParkNet, and presented Fermilab with a plaque from DOE officially noting the occasion of the dedication. Also attending from DOE Headquarters was Dr. Helen McCammon, who heads the Ecological Research Division, sponsor of the NERP program, accompanied by Dr. Walt Conley, ecology professor from New Mexico State University and currently a member of her staff. The next speaker, Dr. Christopher Reilly, Director of the Environmental Research Division

*("**Lab Notes**" continued)*

at Argonne National Laboratory, expressed the hope that Argonne could work with Fermilab in pursuing environmental research.

The keynote speaker for the afternoon ceremony was Dr. Brent M. Haglund, President of The Sand County Foundation, an organization in Madison, Wisconsin, which uses research, management, and education for private land conservation. In his talk, "A Model-T Approach to Ecosystem Restoration," Haglund noted that the parks have been established by DOE in response to the National Environmental Policy Act of 1969, which defined the nation's goals of restoring, protecting, and enhancing environmental quality. The Fermilab site is considered a unique link in ParkNet because it contains most of the major ecosystem types that are representative of the American midwest.

In conjunction with the dedication ceremonies, the new Fermilab Interpretive Trail was formally opened. The 1/2-mile-long trail, open to the public during daylight hours, offers an opportunity to experience the Illinois prairie as it was before the settlers moved west. Visitors can see and learn about the grasses, flowers, birds, and insects that populate the prairie. - *John Paulk*

Manuscripts and Notes

received between May 6, 1989, and June 30, 1989. Copies of Fermilab TM's, FN's, and preprints (exclusive of Theoretical Physics and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH6NW, or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL. For Theoretical Physics or Theoretical Astrophysics preprints, contact those departments directly. For papers with no Fermilab catalogue number, please contact the author directly.

Experimental Physics Results

Experiment #400
T. K. Kroc, "Hadroproduction of $D^* \rightarrow (K \pi) \pi$," (Ph.D. Thesis, University of Illinois at Urbana-Champaign, 1989)

Experiment #605
D. E. Jaffe et al., "High Transverse Momentum Single Hadron Production in pp and pd Collisions at $\sqrt{s}$=27.4 and $\sqrt{s}$=38.8 GeV," (FERMILAB-Pub-89/69-E; submitted to Phys. Rev. D)

Experiment #609
R. C. Moore, "Production of Jets from Proton-Nucleus Collisions at 400 GeV/c," (Ph.D. Thesis, Rice University, Houston, Texas, May 1989)

Experiment #691
M. C. Gibney, "Photoproduction of Charmed Baryons," (Ph.D. Thesis, University of Colorado, 1989)

Experiment #704
A. H. Mohammadzadeh, "Helium Gas Cherenkov Detector," (Ph.D. Thesis, Rice University, Houston, Texas, June 1989)

C. T. Nguyen, "Calibration of a Leadglass Pb-Scintillator Photon Detector at Fermilab Experiment E-704," (M.A. Thesis, Rice University, Houston, Texas, May 1988)

Experiment #711
K. Streets, "The Atomic Weight Dependence and Mass Cross Sections of Massive Hadron Pair Production in Proton-Nucleus Collisions at 800 GeV/c," (Ph.D. Thesis, Florida State University, April 1989)

Experiment #741
J. Huth and C. D. Moore, "Three-Dimensional Survey Techniques for Large Detector Systems," (FERMILAB-Pub-89/105-E; submitted to Nucl. Instrum. Methods A)

General Particle Physics

M. Atiya et al., "Kaon Physics in the 1990's: Rare Decays and CP Violations," (FERMILAB-Conf-89/56; presented by G. Bock and L. Littenburg at "High Energy Physics in the 1990's," Snowmass, Colorado, June 27-July 15, 1988)

D. Green, "$\bar{p}p$ Collider Physics," (FERMILAB-Conf-89/70; presented at the V Jorge Andre Swieca Summer School: Particles and Fields, Sao Paulo, Brazil, January 8-21, 1989)

N. Merminga et al., "Nonlinear Dynamics Experiment in the TEVATRON," (FERMILAB-Conf-89/85; presented by N. Merminga at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

J. B. Rosenzweig et al., "Argonne Plasma Wake-Field Acceleration Experiments," (FERMILAB-Conf-89/84; presented by J. B. Rosenzweig at the 1989 Lake Arrowhead Workshop on Advanced Accelerator Concepts, Lake Arrowhead, California, January 9-13, 1989)

M. Strovink et al., "Hermeticity of Three Cryogenic Calorimeter Geometries," (FERMILAB-Conf-89/109; invited talks presented at the SSC Workshop on Calorimetry for the Super Collider, University of Alabama, Tuscaloosa, Alabama, March 13-17, 1989)

Accelerator Physics

Y. Chao et al., "Understanding and Improving the High Field Orbit in the Fermilab Booster," (FERMILAB-Conf-89/103; presented by Y. Chao at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

J. L. Crisp and R. J. Ducar, "Numerically Controlled Oscillator for the Fermilab Booster," (TM-1586; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

G. Dugan, "TEVATRON Status," (TM-1576; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

D. J. Harding and A. W. Riddiford, "Automatic Steering Corrections to Minimize Injection Oscillations in the Fermilab Antiproton Source Rings," (FERMILAB-Conf-89/126; to be published in the proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

F. A. Harfoush and S. A. Bogacz, "Coherent Betatron Instability Driven by Electrostatic Separators - Stability Analysis of the TEVATRON," (FERMILAB-Conf 89/89; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

F. Harfoush et al., "Design Considerations for a Large Aperture High Field Superconducting Dipole," (TM-1584; presented by F. Harfoush and M. Harrison

at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

G. Jackson, "Tune Spectra in the TEVATRON Collider," (FERMILAB-Conf-89/88; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

Q. A. Kerns et al., "Longitudinal Damping in the TEVATRON Collider," (FERMILAB-Conf-89/82; presented by Q. A. Kerns at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

J. A. MacLachlan, "400 MeV Upgrade for the Fermilab Linac," (FERMILAB-Conf-89/81; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

S. R Mane, "Radiative Polarization in High-Energy Storage Rings," (FERMILAB-Conf-89/79; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

S. R. Mane, "Space-Charge Effects in the Fermilab Main Ring at 8 GeV," (FERMILAB-Conf-89/77; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

S. R. Mane, "Space Charge, Synchrotron Oscillations and Multiparticle Tracking," (FN-515)

S. R. Mane and G. Jackson, "Studies and Calculations of Transverse Emittance Growth in High-Energy Proton Storage Rings," (FERMILAB-Conf-89/78; presented by S. R. Mane at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

D. Martin et al., "A Resonant Beam Detector for TEVATRON Tune Monitoring," (FERMILAB-Conf-89/74; presented by D. Martin at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

D. Martin et al., "A Schottky Receiver for Non-Perturbative Tune Monitoring in the TEVATRON," (FERMILAB-Conf-89/73; presented by D. Martin at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

P. S. Martin, "Performance of the Fermilab Main Ring During the 1988-89 TEVATRON Collider Operation," (FERMILAB-Conf-89/76; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

P. S. Martin et al., "Improvements in Bunch Coalescing in the Fermilab Main Ring," (FERMILAB-Conf-89/75; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

N. Merminga and K.-Y. Ng, "Analytical Expressions for the Smear Due to Nonlinear Multipoles," (FERMILAB-Conf-89/86; presented by N. Merminga at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

L. Michelotti, "Differential Algebras Without Differentials: an Easy C++ Implementation," (FERMILAB-Conf-89/95; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

L. Michelotti, "Exploratory Orbit Analysis," (FERMILAB-Conf-89/96; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

L. Michelotti and F. Mills, "Amplitude Growth Due to Random, Correlated Kicks," (FERMILAB-Conf-89/93; to be published in the proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

L. Michelotti and S. Saritepe, "Orbital Dynamics in the TEVATRON Double Helix," (FERMILAB-Conf-89/94; to be published in the proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

C. D. Moore et al., "Single Bunch Intensity Monitoring System Using an Improved Wall Current Monitor," (TM-1577; presented by R. Webber at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

K.-Y. Ng, "Results of Short-Sample Measurements and Their Implications," (FN-513 [SSC-N-632])

K.-Y. Ng and J. Peterson, "Ground-Motion Effects on the SSC," (FN-511 [SSC-212])

K.-Y. Ng and R. Warnock, "Reactive Impedance of a Smooth Toroidal Chamber below the Resonance Region," (FN-500 [SSC-194]; submitted to Phys. Rev. D)

J. A. Palkovic et al., "Gabor Lens Focusing of a Negative Ion Beam," (FERMILAB-Conf-89/115; submitted to the proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

M. F. Shea et al., "Control System for the Neutron Therapy Facility at Fermilab," (FN-512; to be published in the proceedings of the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

S. Stahl and S. A. Bogacz, "Simulation of Coupled Bunch Mode Growth Driven by a High-Q Resonator: A Transient Response Approach," (FERMILAB-Conf-89/90; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

J. Strait et al., "Full Length SSC R&D Dipole Magnet Test Results," (TM-1575 [SSC-N-596]; presented by J. Strait at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

L. C. Teng, "High Intensity Hadron Accelerators," (TM-1598; rapporteuer report given at the Accelerator Design Workshop, Los Alamos National Laboratory, Los Alamos, New Mexico, February 22-25, 1989)

Theoretical Physics

B. Grinstein and J. Maharana, "Vertex Operators for Axionic Wormholes," (FERMILAB-Pub-89/121-T; submitted to Nucl. Phys.)

D. A. Kosower, "The Running of the Cosmological Constant," (FERMILAB-Pub-89/123-T; submitted to Phys. Lett. B)

P. B. Mackenzie, "Machines for Lattice Gauge Theory," (FERMILAB-Conf-89/125-T; presented at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

T. R. Taylor, "Macroscopic Constraints on String Unification," (FERMILAB-Conf-89/116-T; to appear in the proceedings of the XXIVth Rencontre de Moriond on Electroweak Interactions and Unified Theories, Les Arcs, Savoie, France, March 13-19, 1989)

T. R. Taylor and G. Veneziano, "Quenching the Cosmological Constant," (FERMILAB-Pub-89/141-T; submitted to Phys. Rev. Lett.)

Theoretical Astrophysics

A. D. Dolgov, "The Cosmological Constant Problem," (FERMILAB-Conf-89/112-A; talk presented at the 24th Rencontre de Moriond: Astrophysics Session, Les Arcs, France, March 5-12, 1989)

D. Eichler et al., "Coalescing Neutron Stars, Naked Neutrino Bursts, Gamma Rays, Gravitational Radiation, Millisecond Pulsars and r-Process Nucleosynthesis," (FERMILAB-Pub-89/102-A; submitted to Nature)

J. A. Frieman and A. V. Olinto, "Is the Sub-Millisecond Pulsar Strange?" (FERMILAB-Pub-89/129-A; submitted to Nature)

J. A. Frieman et al., "Cosmic Evolution of Non-Topological Solitons I.," (FERMILAB-Pub-89/128-A; submitted to Phys. Rev. D)

T. Futamase and M. Sasaki, "Light Propagation and the Distance-Redshift Relation in a Realistic Inhomogeneous Universe," (FERMILAB-Pub-89/111-A; submitted to Phys. Rev. D)

G. F. Giudice and K. Griest, "Rate for Annihilation of Galactic Dark Matter into Two Photons," (FERMILAB-Pub-89/113-A; submitted to Phys. Rev. D)

K. Griest and E. W. Kolb, "Solitosynthesis: Cosmological Evolution of Non-Topological Solitons," (FERMILAB-Pub-89/83-A; submitted to Phys. Rev. D)

K. Griest et al., "Statistical Fluctuations as the Origin of Nontopological Solitons," (FERMILAB-Pub-89/110-A; submitted to Phys. Rev. D)

H. M. Hodges, "The Formation of Topological Defects in Phase Transitions," (FERMILAB-Pub-89/108-A; to be published in Phys. Rev. D)

E. W. Kolb et al., "Astrophysical and Cosmological Constraints to Neutrino Properties," (FERMILAB-Pub-89/97-A; to be published in *Neutrino Physics*, ed. Klaus Winter, Cambridge University Press, 1989)

D. Ryu et al., "Neutron Stars and White Dwarfs in Galactic Halos?" (FERMILAB-Pub-89/119-A; submitted to Astro. Phys. J.)

M. Sasaki and T. Nakamura, "Gravitational Radiation from Extreme Kerr Black Hole," (FERMILAB-Pub-89/122-A; submitted to Phys. Rev. D)

G. Steigman et al., "Contamination of Primordial Helium in Galaxies," (FERMILAB-Pub-89/101-A; to appear in Comments on Astrophysics)

M. S. Turner, "Windows on the Axion," (FERMILAB-Conf-89/104-A; presented at the Workshop on the Detection of Cosmic Axions, Brookhaven National Laboratory, Upton, New York, April 13-14, 1989)

Computing

J. Deppe et al., "ACP/R3000 Processors in Data Acquisition Systems," (FERMILAB-Conf-89/118; presented by J. Deppe at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

J. Nicholls, "The Fermilab Central Computing Facility Architectural Model," (TM-1596; presented at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

Accelerator Health Physics

L. V. Coulson et al., "Accelerator Health Physics at DOE Laboratories: a Characterization," (FN-510)

Colloquia, Lectures, and Seminars

by Fermilab staff, at Fermilab, May-June 1989, unless otherwise noted.

April 4
D. Kowoser, "Quantum Gravity, the Cosmological Constant, and All That," at Northwestern University

April 28
A. Albrecht, "Latest News on Cosmic Strings," at the Harvard Smithsonian Center for Astrophysics

May 2
R. Gregory, "Rigid Cosmic Strings," at Imperial College, London, England

M. S. Turner, "CP Violation in Particle Physics and Astrophysics," Chateau de Blois, France

May 3
A. Olinto, "Astrophysics of Strange Matter," at the University of Chicago

A. Perez, "Helicity-Flipped Neutrino Pair Production in Supernovae," at NIKHEF (Amsterdam)

R. Rubinstein, "Results from Fermilab E-710," at the International Conference on Elastic and Diffractive Scattering, Northwestern University

May 5
A. Perez, "Pair Production of Massive Neutrinos in Supernovae," at NIKHEF (the Netherlands)

May 8
L. Michelotti, "Nonlinear Dynamics for the Blue Collar Scholar"

R. Pisarski, "Hot Stuff: Why QCD is Perturbatively Stable at High Temperature," at Northwestern University

M. S. Turner, "Dark Matter in the Universe," at Michigan State University

May 9
G. Dugan, M. Harrison, "Accelerator Division Status and Upgrade Plans"

May 10
L. Michelotti, "Nonlinear Dynamics for the Blue Collar Scholar"

May 11
S. Pruss, D. Trbojevic, "Improvements to the Main Ring Operation: Ramped Corrections (Pruss); Lattice Modifications (Trbojevic)"

May 13
A. Perez, "Introduction to Astrophysics"

May 15
L. Michelotti, "Nonlinear Dynamics for the Blue Collar Scholar"

R. Pisarski, "Hot Stuff: Why QCD is Perturbatively Stable at High Temperature," at Argonne National Laboratory

May 17
A. Perez, "Neutrino Mass Limits from Pair Production in Supernovae"

L. Michelotti, "Nonlinear Dynamics for the Blue Collar Scholar"

May 18
J. MacLachlan, "The Design of the 400 MeV Upgraded Linac"

May 21
A. Perez, "Relativistic Pion Dynamics in Nuclear Matter," at the NATO conference on "The Nuclear Equation of State," Periscola, Spain

May 22
L. Michelotti, "Nonlinear Dynamics for the Blue Collar Scholar"

May 24
P. Aurenche, "Real Photons in Hard Hadronic Collisions"

May 25
E. Copeland, "Phase Transitions in the Early Universe," at Northwestern University

M. Foley, L. Vanags, "The Accelerator Division CAD/CAM System"

D. Ryu, "Stability of Astrophysical Shock Waves," at the University of Minnesota, School of Physics and Astronomy

May 26
P. Aurenche, "Real Photons in Hard Hadronic Collisions"

E. Kolb, "Baryogenesis," at the Conference on the 25th Anniversary of CP Violation, Blois, France

May 31
P. Aurenche, "Real Photons in Hard Hadronic Collisions"

June 1
V. Bharadwaj, "Brighter Beams in the Booster"

June 5
K. Ellis, "QCD and Collider Physics"

June 6
R. Carrigan, "Extracting and Deflecting Beams with Channeling"

June 7
K. Ellis, "QCD and Collider Physics"

June 12
K. Ellis, "QCD and Collider Physics"

June 13
D. Petravick, "Improvements in VAX Online for the Next Fixed-Target Run"

G. Goderre, "Helical Orbits in the TEVATRON"

June 14
L. Lederman, "How I Won the Nobel Prize"

K. Ellis, "QCD and Collider Physics"

June 19
K. Ellis, "QCD and Collider Physics"

June 21
K. Ellis, "QCD and Collider Physics"

D. Jovanovic, "The Standard Model "

June 23
H. Jöstlein, "Toroid Magnet Measurements"

June 26
B. Grinstein, "CP Violation"

June 27
J. Deppe, R. Ducar, S. Hansen, R. Trendler, R. Wisen, "Electronics/Electrical Activities at Fermilab"

June 28
G. Jackson, "Particle Accelerators "

B. Grinstein, "CP Violation"

June 29
P. Grannis, SUNY/Stony Brook, "D0 Detector - Physics Objectives"

Submission of Articles to *Fermilab Report*

The editors of *Fermilab Report* wish to remind readers that submission of original articles to this periodical is always welcome, nay, encouraged.

As our title implies, articles should relate to any aspect of Fermilab's research mission and should be of interest to the high-energy physics community. We are particularly interested in reports, interim and otherwise, on Fermilab experiments.

Inquiries about articles, or articles themselves, should be directed to R. B. Fenner, Fermilab Publications Office, at the address/extension/VAX-mail address shown on the inside front cover of *Fermilab Report.*

Dates to Remember

June 19-30, 1989

1989 US Particle Accelerator School (graduate-level courses), University of California, Berkeley, California. For information or application, contact the Accelerator School Office, Fermilab, P.O. Box 500, MS 125, Batavia, IL 60510, (312) 840-3896 or BITnet [USPAS].

July 24-August 4, 1989

1989 US Particle Accelerator School (intensive lecture courses), Brookhaven National Laboratory, Upton, New York. For information or application, contact the Accelerator School Office, Fermilab, P.O. Box 500, MS 125, Batavia, IL 60510, (312) 840-3896 or BITnet [USPAS].

August 15-24, 1989

Physics at Fermilab in the 1990's. For information, contact Cynthia Sazama, Fermilab, P.O. Box 500, MS 322, Batavia, IL 60510, (312) 840-3082 or BITnet UPGRADE@FNAL.

October 1-4, 1989

Conference on Supercollider Physics and Experiments. Dallas, Texas. For information, contact Ms. Linda Hill, Meeting Management, Inc., 4100 McEwen, Suite 101, Dallas, Texas 75244.

October 2, 1989

Deadline for receipt of material to be considered at the October Physics Advisory Committee meeting.

October 27-28

Physics Advisory Committee meeting, Fermilab.

October 23-25, 1989

6th DOE Workshop on Computer-Aided Engineering. Santa Fe, New Mexico. For information, contact Charles Anderson, MS J576, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, (505) 667-5150, or Mark Leininger, Fermilab ext. 4776.