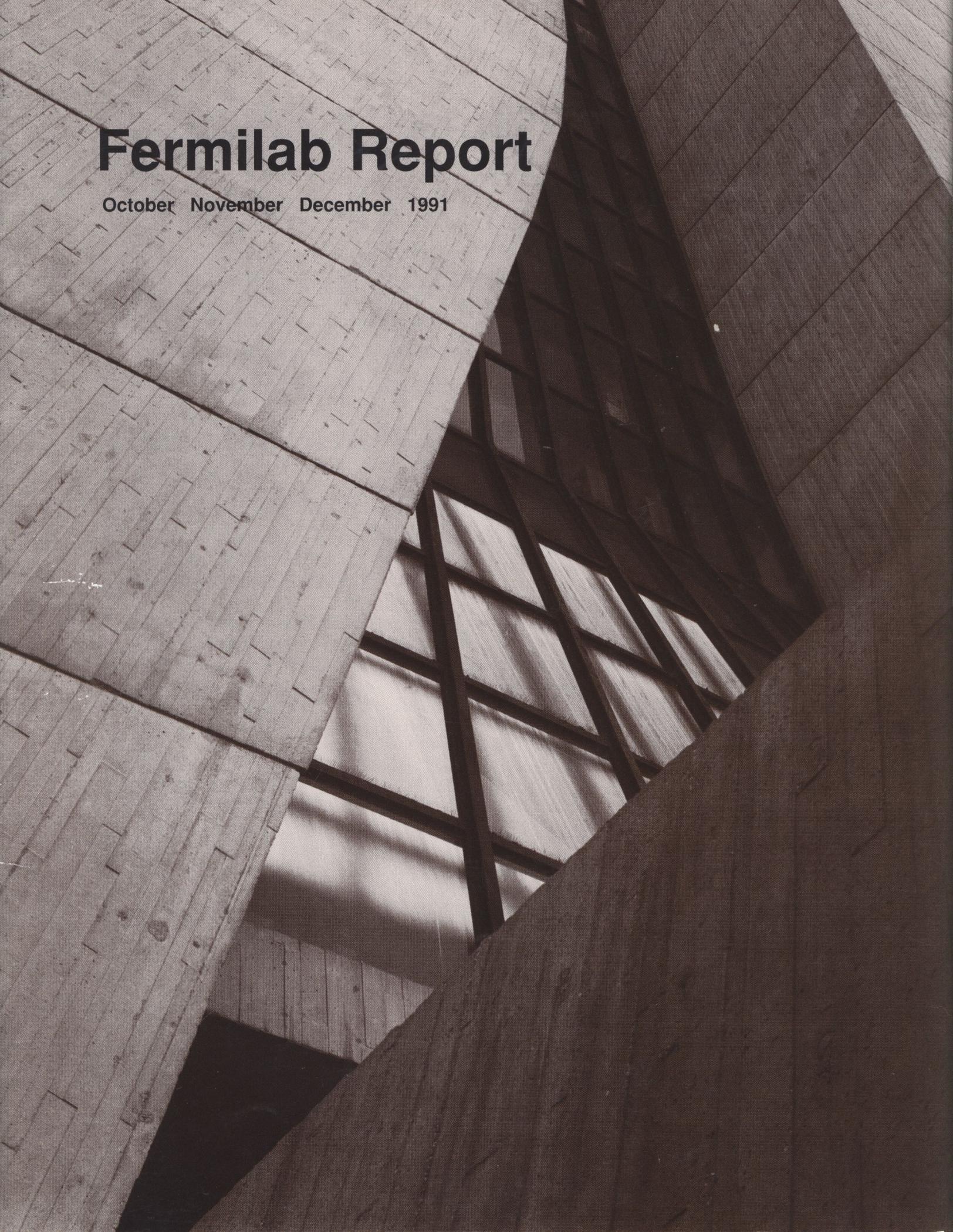
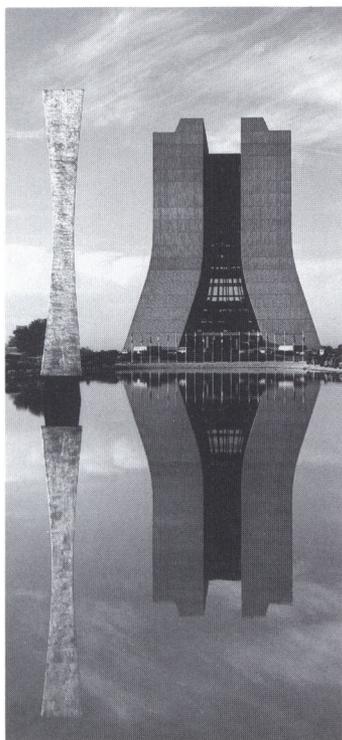


Fermilab Report

October November December 1991





Fermilab

Fermi National Accelerator Laboratory, popularly known as Fermilab, is one of the world's foremost laboratories dedicated to research in high energy physics. The Laboratory is operated by Universities Research Association, Inc. under a contract with the U. S. Department of Energy.

Since its founding in 1967, Fermilab's mission has remained unchanged: to understand the fundamental particles of matter and the forces acting between them. The principal scientific tool at Fermilab is the Tevatron—the world's first superconducting accelerator and currently the highest energy collider in the world. Protons and antiprotons travel at nearly the speed of light in the Tevatron's tunnel which is four miles in circumference.

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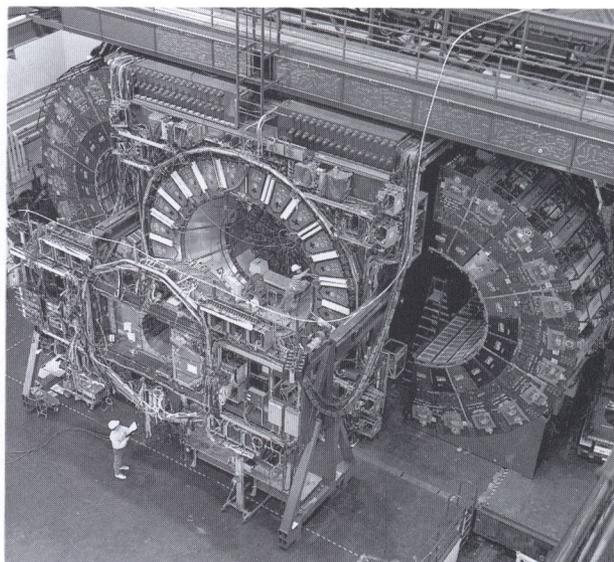
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... much of the recent CDF effort has been aimed at optimizing the detector to insure we either find the top quark or send the theorists back to the blackboard!



The improved Collider Detector at Fermilab

by Robert M. Harris

This Spring the Tevatron will resume proton-antiproton collisions at the world's highest energy and at rates well above its original design goals. Peak luminosities are expected to reach $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$ which could provide a fivefold increase in total integrated luminosity over the previous run. The CDF detector has been improved and expanded to handle these high rates and to exploit them to make precision tests of the Standard Model and to search for exciting new phenomena.

Proton-antiproton collider experiments at CERN and the Tevatron have played a major role in testing the Standard Model. This includes exploring the electroweak

unification of the electromagnetic interaction (mediated by photons and responsible for most everyday phenomena) and the weak interaction (mediated by W and Z bosons and responsible for radioactive decay). This also includes testing Quantum Chromodynamics (QCD), the theory of the strong interactions, which is mediated by gluons and responsible for binding quarks together in hadrons like the proton. So far the Standard Model has been able to explain most observed phenomena. However the top quark, the last quark predicted by the Standard Model, has so far eluded detection. We have searched for the top quark and determined it must be more massive than 91 GeV (with a 95% probability). Why the top quark is so much more massive than other quarks remains a

mystery. Current theory requires the top quark to have a mass within the range of discovery of the upgraded Tevatron Collider program at Fermilab, and much of the recent CDF effort has been aimed at optimizing the detector to insure we either find the top quark or send the theorists back to the blackboard!

In addition to searching for the top quark, CDF has many important measurements planned. We will improve on our existing studies of the electroweak and strong interactions, and collect large samples of particles containing the bottom quark, the electroweak partner to the top quark. Searching beyond the Standard Model we will continue to look for heavy gauge bosons which might mediate new interactions, for supersymmetric partners to the quark

and gluon required by some grand unified theories, and for possible structure within supposedly pointlike quarks and leptons. Also, according to the widely accepted big bang model, by exploring the highest energy interactions we are probing backward in time to the earliest moments of the universe, studying particles and interactions which dominated the universe one trillionth of a second after creation!

Many of the upgrades to the CDF detector were required so that the detector can continue to run efficiently at high luminosity. One such upgrade, the Vertex Tracking System (VTX) replaces the Vertex Time Projection Chambers (VTPC). A single VTPC module works by making ionization along the path of a charged particle drift a distance in the gas before being collected. From the drift time, the particle's track was measured. However, at high collision rates, the amount of ionization in a single module would distort its electric field. To avoid this, the VTX employs almost four times as many modules as the VTPC, each with roughly one quarter of the drift distance. New low noise preamplifiers, custom readout electronics, and commercial TDCs are in place to readout 8600 channels from the VTX. The VTX will be used to locate the collision point, measure event topologies, point tracks at forward muon and electron candidates, and detect photon conversions.

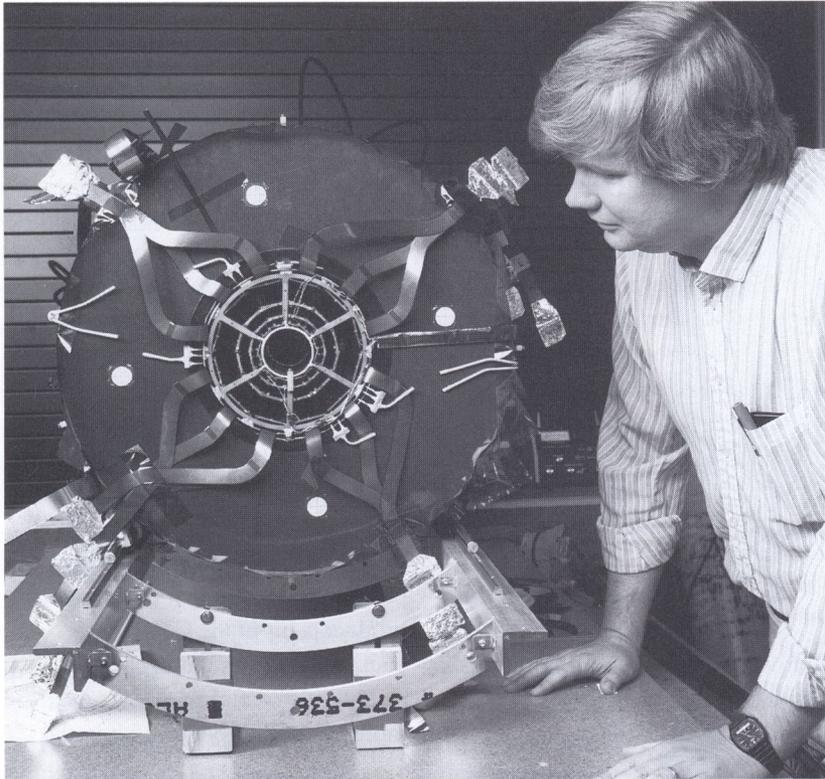
The first level of the CDF trigger, which previously took twice the time between beam crossings to make a decision, is now able to make a decision every time the beams cross. The faster trigger

decision has necessitated a shorter charge integration time for the gas calorimeters, and modifications to all electronics at the first stage of amplification. Also, the higher luminosity has required new ADC cards to allow event digitization and readout more than a factor of ten times faster than last run. To accommodate the increased rate of digital information from an increased number of detector components, the number of FASTBUS cable segments has been increased, the number of boards in the CDF event builder has doubled, and we will have to employ two event builders instead of one. The rate of events from the event builder, after the second level of CDF trigger decision, has increased by a factor of four from last run. Consequently, the ACP computer farm which made the third and final level of CDF trigger decision had to be replaced with a

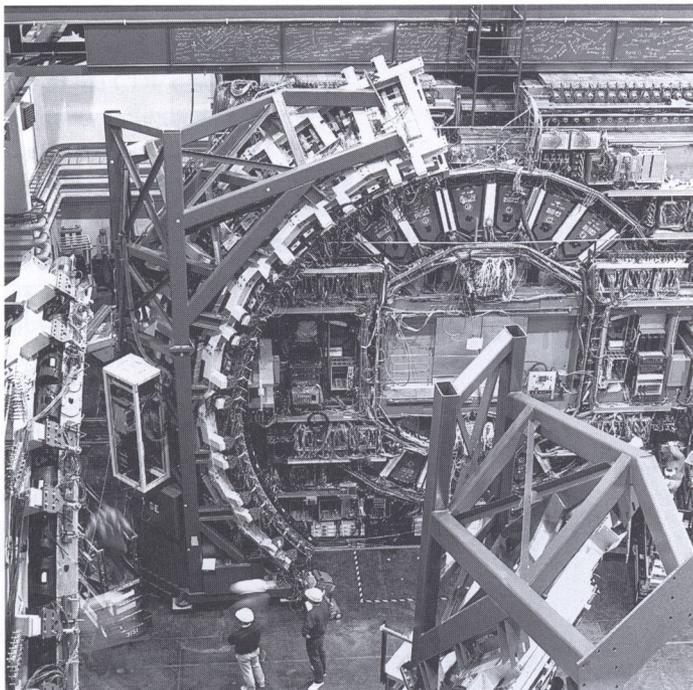
more powerful collection of Silicon Graphics processors using the UNIX operating system. Modifying CDF code to run in this new environment was a significant task. After all trigger decisions have been made, writing to tape at four times the rate of the previous run has required four times as many VAX computers even after the larger data set has been compressed by a factor of two. Finally, the offline computer farm, which reconstructs and categorizes events so that physicists can more easily analyze them, has been greatly expanded to process the increased number of events at the same rate as it is produced. To insure we find and publish the top quark and other exciting physics as soon as possible, the most interesting events will be categorized and processed separately and written to disk where physicists can access and analyze them quickly and conveniently.



Physicist Umeshwar Joshi pictured with Silicon Graphics computers used for the new level three trigger. Similar computers are used in the offline analysis to reconstruct CDF events.



Physicist Bob Wagner inspects the SVX inside the VTX as seen along the beam direction.



An arch of the Central Muon Extension in place in front of the central detector.

In addition to upgrades necessary to handle higher event rates, CDF has added new detectors to improve on existing measurements and to make new ones which were previously impossible. The Silicon Vertex Detector (SVX) will enable CDF to identify the decay vertex of hadrons containing the bottom quark. These decays occur inside the beam pipe, so the SVX is located just outside, to immediately measure the V-shaped tracks and be able to distinguish their vertex (the so called secondary vertex) from the nearby collision point of the proton and antiproton (primary vertex). The SVX employs four concentric layers of silicon microstrip detectors. When viewed along the proton beam each layer is a dodecagon (12 sides) surrounding the beam, and each layer is divided into strips which run parallel to the beam. The SVX contains 46080 silicon strips individually microbonded to 360 custom VLSI amplifier chips (MICROPLEX) and readout into special FASTBUS memory modules. To perform the delicate measurement of secondary vertices the strips in the innermost layer are only 60 microns wide. The SVX is expected to have an impact parameter resolution of 30 microns, which should allow the collection of a large sample of events with an unambiguously identified secondary vertex (a meson containing a bottom quark will usually decay after traveling about 300 microns). The CDF collaboration is enthusiastic about the prospect of finding large samples of bottom quark mesons, including those coming from the decay of the top quark!

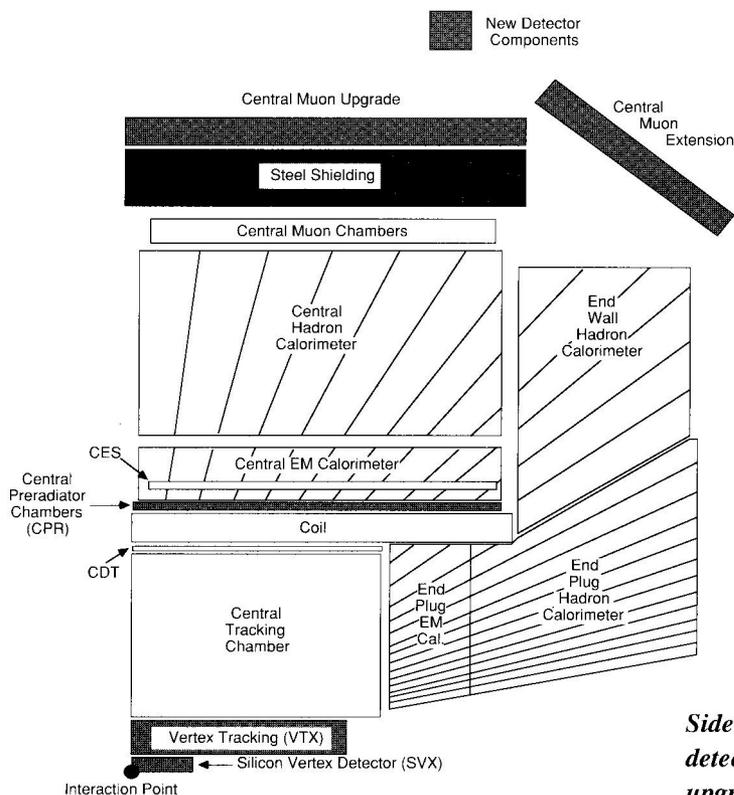
We have significantly upgraded the capability of the CDF

central muon system. Part of this upgrade was driven by the anticipated higher luminosities and part by the desire to increase the coverage of the system. To decrease jet backgrounds, two steel walls are being placed on the north and south side of the central detector, and a total of 856 new muon chambers and also trigger counters are mounted on the outside of each wall. New chambers and trigger counters are also placed above and below the steel magnet flux return, completely covering the existing central muon system with a second layer of muon detection. This central muon upgrade (CMUP) should substantially reduce systematic uncertainties in muon identification, and help CDF make even more precise tests of the electro-

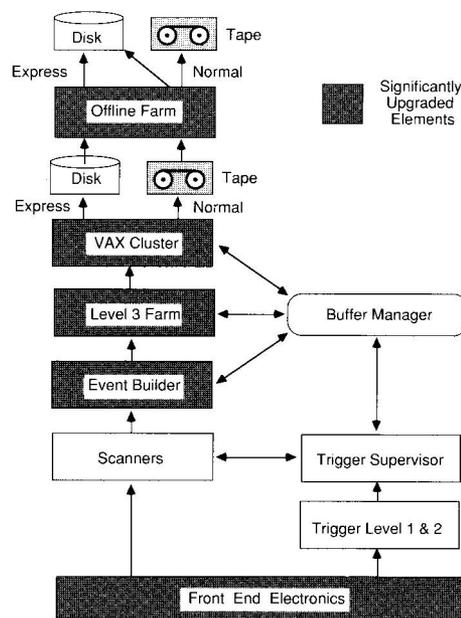
weak sector of the Standard Model. In addition, the central muon extension (CMEX) consists of 1632 new chambers which extend the existing muon coverage by over 50% in the critical central region. The increased muon coverage, coupled with the higher luminosity and a lower trigger threshold for muons in a new hardware track finder and the existing track processor, should provide a substantially larger sample of muons from ψ decay. With this sample we will study bottom quark physics from completely reconstructed B meson decays, and hopefully find rare bottom quark meson states like $B_s!$ Of course, the additional muon coverage will also increase our chances of finding top quarks which produce muons via their electroweak decays.

Understanding the gluon content of the proton, so important to every QCD prediction at the Tevatron and even more so at the SSC, is the prime motivation behind increasing our ability to detect prompt photons with the new central preradiator (CPR) chambers. These gas and wire chambers are located in front of the central calorimeter and behind 1.1 radiation lengths of material (primarily in the solenoidal coil and cryostat). Hard collisions of quarks and gluons in the beam can produce prompt photons (those not from meson decay) which are likely to convert into electron-positron pairs in the coil which in turn produce a hit in the CPR. The background from multi-photon decays of π^0 and η mesons is even more likely to produce a hit in the

The Upgraded CDF Central Detector



The Upgraded CDF Online/Offline

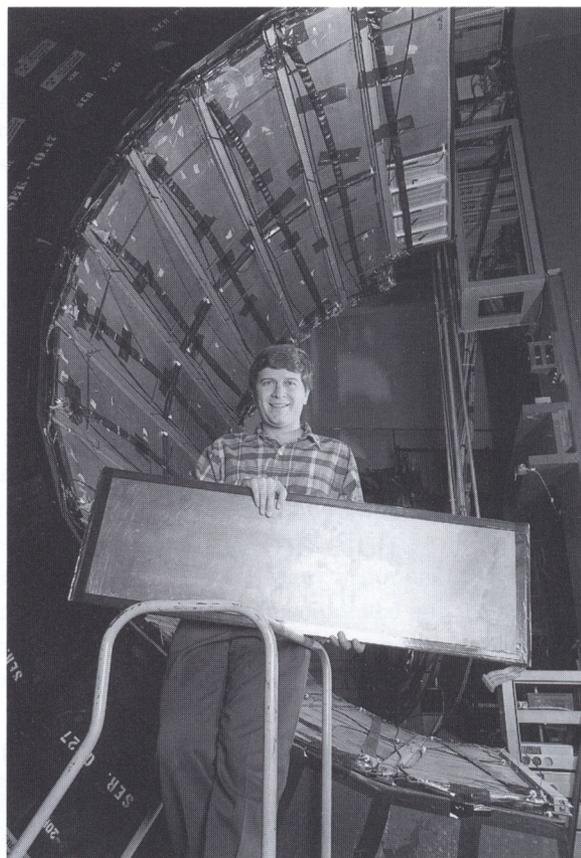


Side view of a quarter of the upgraded CDF central detector and online/offline system with significantly upgraded components shaded.

CPR, which will allow us to count and remove the background since we can easily figure out the relative probabilities. Coupled with improved QCD calculations, CDF measurements of prompt photons should constrain the gluon content of the proton in a unique range of fractional momentum, lower than those probed by fixed target experiments yet higher than those accessible at HERA. The CPR will also improve electron identification substantially. Many charged pions are changed into neutral pions by the material behind the CPR but in front of the central electromagnetic strip (CES) chambers. Such pions, which without the CPR look like electrons, will produce a smaller signal in the CPR than do electrons, allowing them to be removed. The CPR should improve all CDF measurements which use electrons, including precision electroweak tests, bottom quark physics, and the search for the top quark.

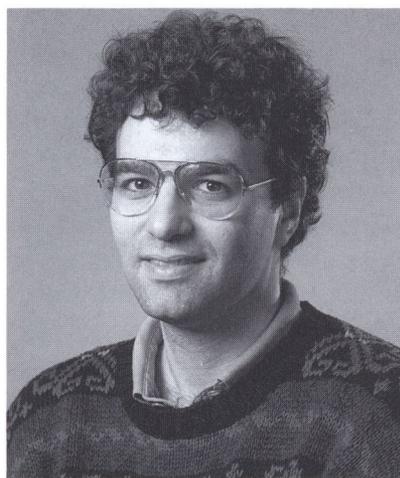
Although the CDF detector has been substantially upgraded, the operation and response of most of the detector will be similar to previous runs, and we should benefit from our past experience in the coming run. Electronic modifications and new components have been tested in the MTEST beam facility, and are being read out with the rest of the detector during continuous cosmic ray shifts which starts in January. The upgraded CDF detector builds on the success of the old detector during the 1987 and 1988/89 runs, which produced over 30 journal articles and over 40 Ph.D. theses. The CDF collaboration, which now includes 30 institutions and 350 collaborators from four

countries, is ready for the 1992 run to commence. Since truth in science is determined by making repeated and independent measurements, we welcome our colleagues at DØ, the newest Tevatron Collider experiment. During this next Tevatron run, CDF and DØ will engage in friendly competition, but we will never forget that the quality of our measurements are more important to science than which experiment publishes first. ■



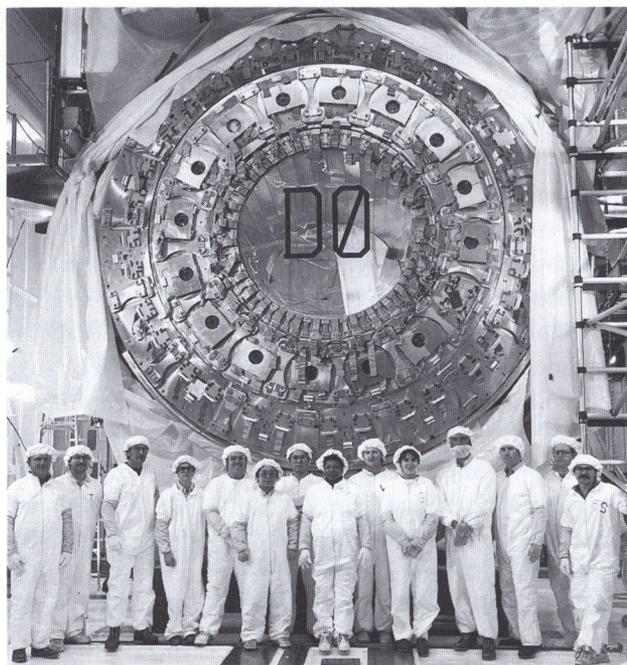
A central preradiator chamber held by Steve Kuhlmann with an arch of installed chambers in the background.

The contributor



Robert Harris joined Fermilab in 1989 as a post-doctoral research associate in the Fermilab Physics Department. He received his doctoral degree from U.C. Berkeley, where his Ph.D. thesis was the measurement of the two jet differential cross section at CDF. He is currently investigating QCD and the gluon content of the proton with measurements of prompt photons at CDF. As a hobby Harris enjoys tournament chess and is a member of the Fermilab chess team.

. . . most of the topics for which DØ was conceived are still open for exploitation. It seems some hard nuts are waiting for the DØ hammer!



DØ Collaboration prepares for first run

by Paul Grannis

In mid-1983, then Director Leon Lederman issued a charge to a non-existent collaboration to build a world-class detector for the study of the highest energy collisions between hadrons. The virtual collaboration became real and grew to over 300 physicists from 31 institutions around the globe (Brazil, Colombia, France, India, Mexico and Russia in addition to the 25 U.S. labs and universities).

The design DØ detector was designed in 1983-1984. It was given first funds in fiscal year 1985, and was built, tested and installed over the succeeding six years. Now, the most modern major general detector for short distance physics is ready to go.

Since inception, DØ has focused upon the simplest objects produced in hadronic collisions. The detector was strongly influenced by the experience of CERN collider experiments and the emerging Collider Detector at Fermilab (CDF) design. Since new particles which are known or suspected to exist at very large mass typically have appreciable decay branching fractions into leptons, while the dominant QCD (Quantum Chromodynamics) background processes do not, detection of leptons is a good way to enhance interesting new physics. DØ took as a central goal the efficient and accurate detection of both electrons and muons to capitalize on this window of opportunity. Similarly, we recognized the quarks and gluons produced in energetic collisions as the primary

objects of interest, with the hadrons into which they fragment of lesser interest. Thus, DØ chose to focus on the detection of the primary quark/gluon parton jets through a sensitive and finely segmented calorimeter. This focus also fits with the plan to optimize the detector for sensitivity to missing transverse energy which could be carried from the collision by non-interacting particles such as neutrinos.

In the time during DØ completion, many experiments studied short-distance hadron collisions. Early on, the CERN experiments UA1 and UA2 cemented their discovery of the W and Z bosons which transmit the weak force, and which with the photon, allow unification with the electromagnetic force. The CDF experiment and the

early running of the Tevatron were important milestones and allowed a rapid advance in pushing back the limits on the expected top quark mass, on possible new objects as the gluino and squark superpartners of ordinary partons, on new heavier bosons, etc. But somewhat surprisingly, most of the topics for which DØ was conceived are still open for exploitation. It seems that some hard nuts are waiting for the DØ hammer!

The main elements of the DØ detector have been described in earlier *Fermilab Reports*. The innermost is a set of tracking detectors and a transition radiation detector within a rather small ($\gamma \geq 75$ cm) non-magnetic volume. Since the particle trajectories are straight, relatively few measurements on a track suffice. An added innovation that reduces the number of wires in the tracker is a flash ADC readout system which provides both time and charge information from each signal electrode.

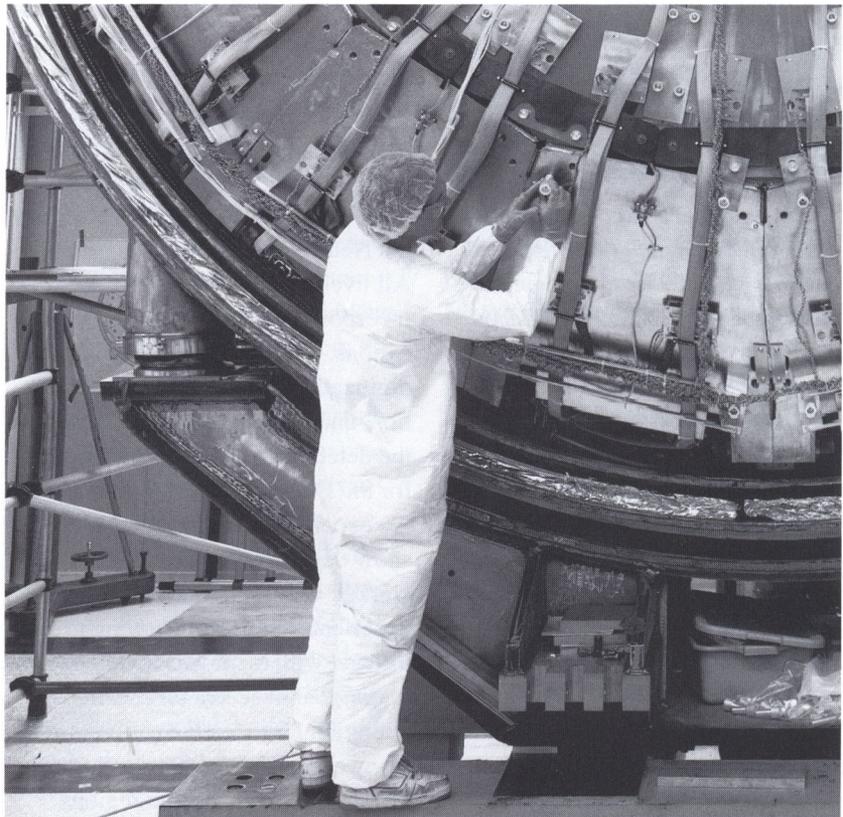
The surrounding calorimeter system has a number of important features which distinguish DØ from its collider detector brethren: the ionization medium is liquid argon which offers good radiation hardness and unit gain (with corresponding ease of calibration). Since the calorimeter signals are taken directly in electronic form (not scintillation light) from signal collection pads between absorber plates, the subdivision of signals can conform closely to both the longitudinal and lateral electromagnetic and hadronic shower dimensions. Typically, the DØ calorimeters have four EM and four to five hadronic sections, with

transverse segmentation as fine as $\Delta\eta = \Delta\phi = 0.05$. (The rapidity variable η is related to the angle with respect to the beam lines.) The DØ calorimetry uses uranium absorber plates in the sensitive EM and fine hadronic layers; in addition to nearly equalizing EM and hadronic response, this dense metal allows the calorimetry to be squeezed into the smallest possible annular space.

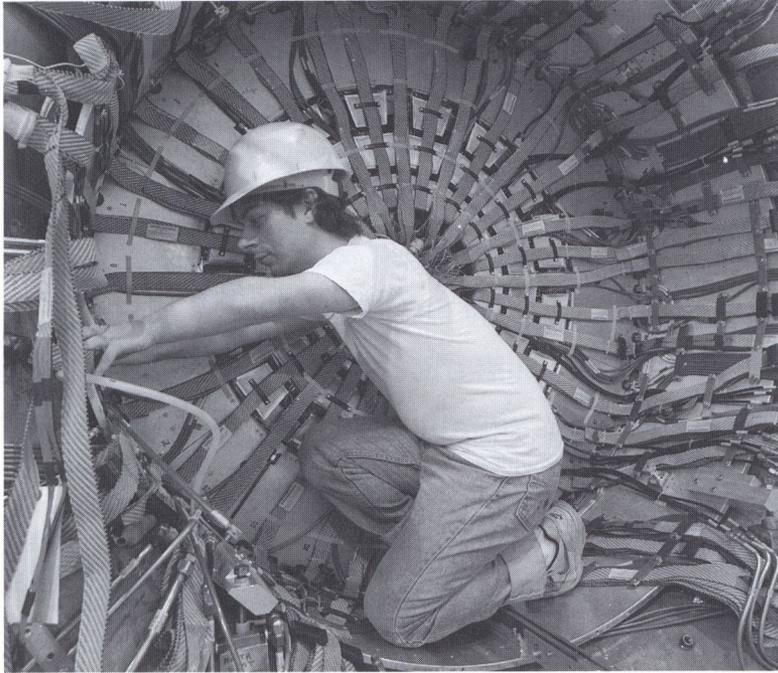
Outside is a set of five thick solid iron toroidal magnets which bend the muons emerging from the calorimeters at angles greater than 3° . Since the thickness of the calorimeters and the toroids varies between 13 and 18 absorption lengths, the amount of hadronic debris left to confuse the muon

identification is minimal. Large proportional drift tube chambers with 10 cm wide cells give an effective point (four nearby measurements) before the magnet and a line (two sets of three measurements) after the magnet to determine the muon track and momentum at large angles. These chambers give an accurate determination of the coordinate along the wire so that each chamber provides a space point on a track. At small angles, a finer grained system provides similar information.

Many important new features were incorporated into the DØ trigger and data acquisition systems. The trigger occurs in four increasingly complex levels, starting with



ECN from EM side with technician in clean room.



CD cables from CDC, TRD, VTX.

scintillation hodoscopes registering the presence of an inelastic collision. The next level decisions are made within the $3.5 \mu\text{s}$ bunch-crossing time using fast flash digitizations of calorimeter EM and hadronic signals and coarse patches of the muon chamber hits. Refined decision is made by electronics at the next level which further decodes the muon chambers and adds information from the transition radiation detector. The highest level trigger occurs after all digital information from the detector is transferred to a farm of μVAX 4000-60 processors. Events flow to multiported memory in these nodes where the final building of events into ZEBRA data structures occurs and the attached processors perform detailed algorithms allowing final reduction of unwanted events. The total power of the online farm is about 600 MIPs. The environment for all of these electronics is the VME standard. The detector that is

now poised ready for first collisions has undergone an exhaustive period of checking and testing while waiting for completion of funding and the end of fixed target operations. Parts of all major detectors have been studied with particles in the Neutrino West-A beam facility. All lived up to the expectations incorporated in the original specifications. Electronics for readout, digitization, triggering, data acquisition, and online software systems of the detectors were the same as built for the $D\emptyset$ experiment. Not only did the experimenters get the chance to show that these crucial systems worked very well, but also the experience gained in learning to interact with them was invaluable. A major goal of recent test beam operation has been the calibration of many aspects of the detector. Calorimeter response, in regions with supports, boundaries or containment vessel walls, was carefully studied. Data was obtained

with π^0 beams and low energy electrons and pions. Calibration of response to contaminated argon was logged to cover the possibility of poisoning in $D\emptyset$.

In addition to the beam tests, $D\emptyset$ conducted major runs of the full detector, *in situ* in the $D\emptyset$ Assembly Hall using cosmic ray muons. These tests verified that the detectors were in good working order after installation and gave essential workouts to the signal shaping, digitization, calibration, and data acquisition electronics with final cables, power and monitoring. The cosmic ray commissioning runs were seen as very near approximations of actual collider running, so the operation of the software event filtering, online data collection and logging, event and trigger monitoring, and express line analysis of interesting events was important. A side sociological benefit was that full-scale shift operation could be started and training of the physicists to run and diagnose the detector occurred before real collisions arrived.

What does the $D\emptyset$ collaboration see as its most interesting physics opportunities during the first run? We now expect that this run, conducted in two parts, will result in accumulation of close to 100 pb^{-1} integrated luminosity. Since $D\emptyset$ has had extensive testing of all its systems, we do not expect this to be an engineering or shakedown run. Indeed, many physics analyses should emerge and about 40 graduate students are preparing theses from the data taken in the first half of the run.

Among the red-lined topics: $D\emptyset$ hopes to find the elusive top

quark; the top is quite likely to decay solely into a W boson and a bottom quark. In this case, there are only a few potential channels for discovery. Some involve lepton identification, some jets, and some, combinations of the two. Missing E_T is an important ingredient as well. The $D\bar{O}$ focus on all of these entities is expected to allow confirmation in several channels; indeed, the top search is ideally suited to $D\bar{O}$'s strengths.

A second major area is the precision study of the Electroweak sector that formed so much of the original impetus of the $D\bar{O}$ design. Among these is the precision determination of the W/Z mass ratio, aided by the precise and well-calibrated $D\bar{O}$ calorimeter. We also look forward to measurements of the $WW\gamma$ coupling which characterizes the Electroweak theory; measurement of the W boson width in order to seek non-standard top quark and Higgs boson possibilities; and studies of W decays to taus as a measure of lepton universality.

The $D\bar{O}$ detector will enable many studies of the strong QCD interaction. Gluon emission can be studied through the dependence of jet containment in variable sized cones in the fine-grained $D\bar{O}$ calorimeters. Identification of moderate transverse momentum single photons at all rapidities, enabled by the $D\bar{O}$ calorimeters' longitudinal and lateral segmentation, offers a unique probe of the gluon content of hadrons. Such information is not of just passing interest since it determines the size of cross-sections for most new objects at Tevatron and Superconducting Super Collider (SSC) energies. Combination of missing

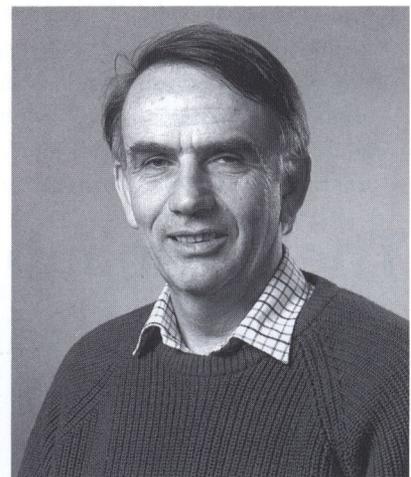
E_T and multilepton signatures will be used to raise the search limit for the gluinos expected in the minimal supersymmetric models now popular as candidates for grand unification schemes. The excellent control of calorimeter systematics in $D\bar{O}$ should allow improved searches for substructure of quarks and leptons. And, if the past is any guide, the emphasis in $D\bar{O}$ on quality measurement of electrons, muons, photons, and jets should translate into extending searches for new phenomena into *terra incognita*.

With $D\bar{O}$, as with any new experiment, some degree of learning is necessary at the beginning to interpret the data and refine the analyses. While impatiently watching the flow of exciting new data from the CDF experiment for several years, the $D\bar{O}$ collaboration went through a most valuable exercise with fake data! Some 100,000 QCD events were generated in a Monte Carlo with all scattering, showering, and decay processes simulated to give the appropriate raw digitized hits in the detector elements. A small number of events were covertly sprinkled in from a variety of interesting physics signatures. The full $D\bar{O}$ reconstruction programs and physics analysis chains were developed to analyze these events; the culmination was a 'McPhysics Conference' held in Summer 1991. Although the report card was not perfect, most of the hidden physics were uncovered and the exercise played a major role in preparing the collaboration for physics in the collider run.

With all due regard for the impressive achievements of UA1, UA2, and CDF over the past decade, it now is the time to welcome the

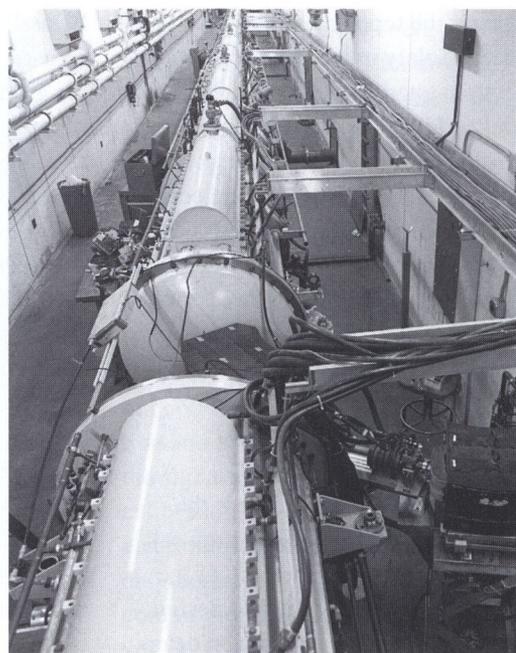
most modern of the collider detectors. We expect an intense and friendly competition from the two Fermilab experiments in uncovering the next layers of Nature's secrets. We are confident that the special advantages of the new $D\bar{O}$ detector will give a large new impetus to the Fermilab program and provide much of the opportunity for discoveries throughout the 1990s. ■

The contributor



Paul Grannis is Professor of Physics at the State University of New York where he has been on the staff since 1966 and, since 1983, Guest Scientist at Fermilab in the $D\bar{O}$ Construction Department of the Research Division. His graduate student career was spent measuring polarization phenomena in two body scattering at Berkeley; his subsequent experiments were conducted at the Brookhaven National Laboratory AGS, the CERN ISR and NIMROD at the Rutherford Laboratory. As the only member of $D\bar{O}$ at its inception, he was appointed spokesperson. Since then, 300 capable physicists from 31 institutions have joined him and made possible the achievements recorded in this article.

The Fermilab linear accelerator produced its first 200 MeV beam of accelerated protons 21 years ago and has run without major interruption since.



The Fermilab Linac Upgrade

by Robert Noble

Greater demands have steadily been placed on the Fermilab linear accelerator (Linac) by the added complexity of the downstream chain of accelerators. To improve the beam intensity at injection into the Booster synchrotron, an upgrade of the Linac was begun in 1989.

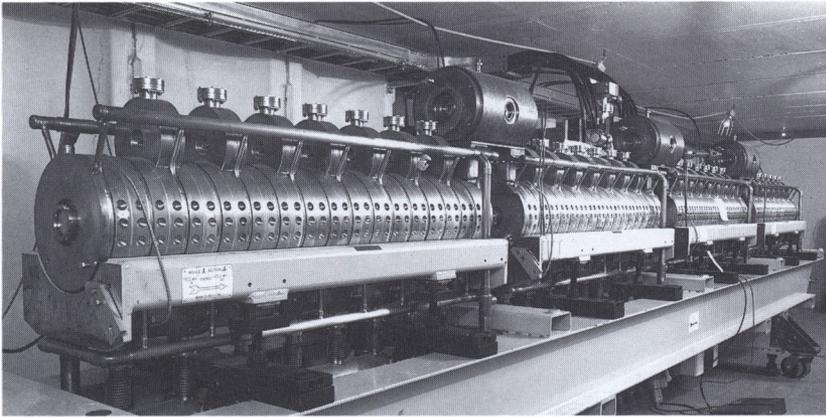
The plan for the Linac Upgrade is to replace the last four drift-tube accelerator tanks (total 60 meters long) of the nine in the present Linac with seven new accelerator modules operating at a higher frequency and higher accelerating field. This will permit the final beam energy to be doubled from 200 MeV to 400 MeV. The higher Linac energy will reduce the tune spread due to beam space-charge forces at injection in the

Booster, thereby improving the ratio of the total number of particles in the accelerator (N) to the normalized transverse emittance (ϵ). At 400 MeV this ratio, N/ϵ , should be increased by 75% compared with the ratio at 200 MeV. A higher brightness beam is expected to produce a higher luminosity in the Collider.

The accelerator structure for the Linac Upgrade is the side-coupled cavity structure originally used on the Los Alamos Meson Physics Facility (LAMPF) linac 20 years ago. The basic fabrication unit for the new Linac is a set of coupled resonant cavities brazed together into a 16-cavity section. Four such sections are connected in a series with bridge couplers to form an accelerator module, which is then powered by one klystron. Charged particles passing through the beam

hole are accelerated across the voltage gap in each cavity. There will be a total of 448 cavities in the new Linac, each providing an energy gain of about 600 KeV.

During 1991 the fabrication of accelerator sections was completed on schedule. Copper for the accelerator cavities was supplied by Hitachi Industries, Japan. All accelerator sections were brazed together in hydrogen furnaces (1800°F) at the industrial firm of Pyromet in San Carlos, California. Brazing of production sections began in November 1990 at a rate of two sections per month. A 100% success rate was achieved in brazing, and no scheduled braze date was ever missed. Each of the seven side-coupled accelerator modules will be powered by a 12 megawatts (peak power) klystron manufactured



Accelerator Module 1 in x-ray shield cave at AØ Central Lab for power testing during July 1991.

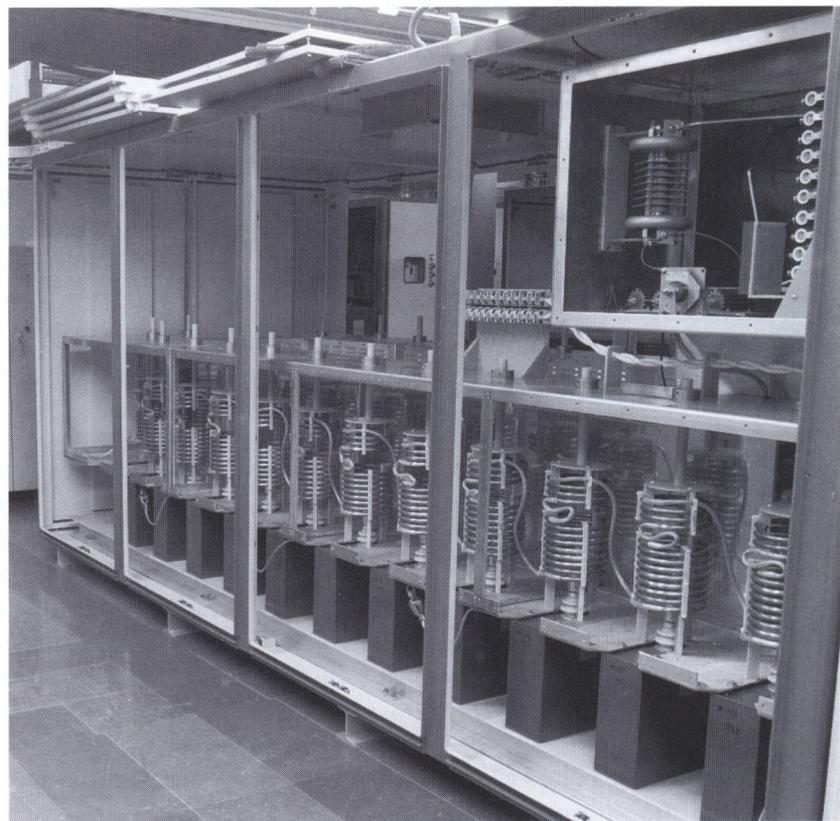
by Litton Electron Devices. The prototype klystron was delivered in early 1991 and has been operated for about 5000 hours. It is being used to voltage condition completed accelerator modules prior to their installation in the Linac tunnel. Two production klystrons were shipped in 1991, and the remaining twelve are scheduled to arrive by January 1993 (one per month). The 14 tubes represent seven operating units and seven spares. The charging supplies and pulse forming networks to power the klystrons are being fabricated in the new Linac Power Supply Gallery. The seven radio frequency (rf) stations are 80% complete, and all are scheduled to be operational by July 1992.

In order to support the high electric fields in the new Linac (7.5MV/m), accelerator modules are voltage conditioned in a concrete x-ray shield cave at the AØ Central Lab. X-ray shielding is necessary because field emitted electrons produce bremsstrahlung radiation in the copper cavities. During 1991, four of the seven accelerator modules for the new Linac were voltage conditioned. The goal for

the sparking rate for a complete Linac was set to be in the range 10^{-2} to 10^{-3} sparks per rf pulse. Those modules conditioned to date have reached a spark rate (extrapo-

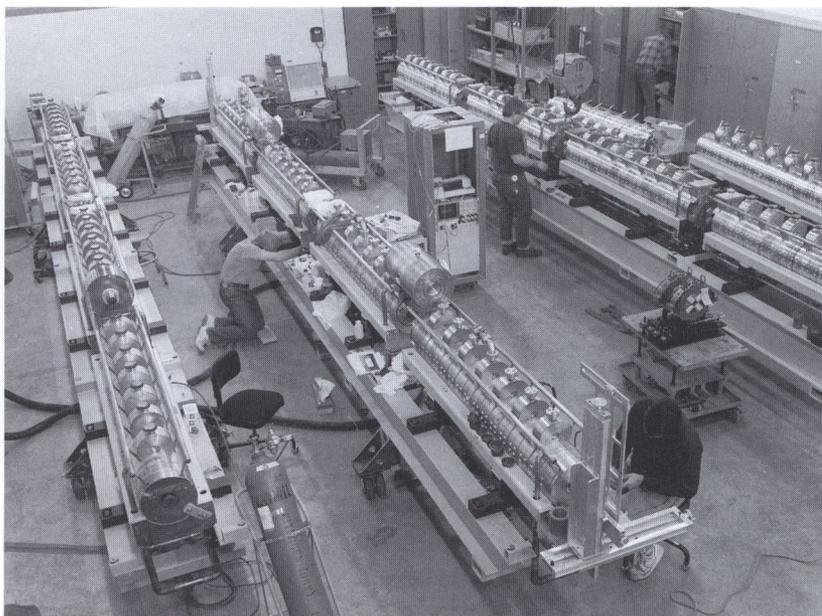
lated to a full Linac) of about 2×10^{-3} sparks/pulse after about 10 million rf pulses and then show a gradual improvement. Voltage conditioning is now terminated once the spark rate reaches the 2×10^{-3} level since continued improvement is then expected during operation in the Linac tunnel.

Accelerator Modules 5, 6 and 7 and an 805 megahertz transition section (used for beam matching between the old drift-tube Linac and new Linac) will be voltage conditioned by March 1992. An access pit and ramp will be completed by then at the downstream end of the Linac tunnel. All accelerator modules will be installed via this access into the Linac tunnel in March. They will be



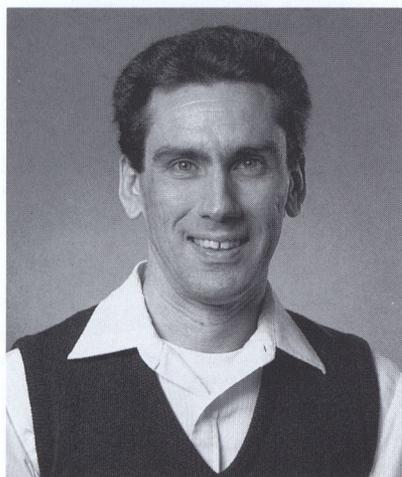
Radio frequency modulators (for powering 12MW klystrons) being fabricated in the new Linac Power Supply Gallery.

put into a temporary position parallel to the existing 200 MeV Linac. Waveguide runs from the rf stations in the Linac gallery will allow modules to be powered in this temporary location without beam until final conversion. Conversion to 400 MeV operation will involve removal of the last four drift-tube Linac tanks and moving the new Linac transversely into the beam line. The date for this final conversion will be determined by the Laboratory operating schedule. The conversion and commissioning of the new Linac are expected to take about three months. ■



Accelerator Modules 4, 5 and 6 under construction in the AØ Central Lab.

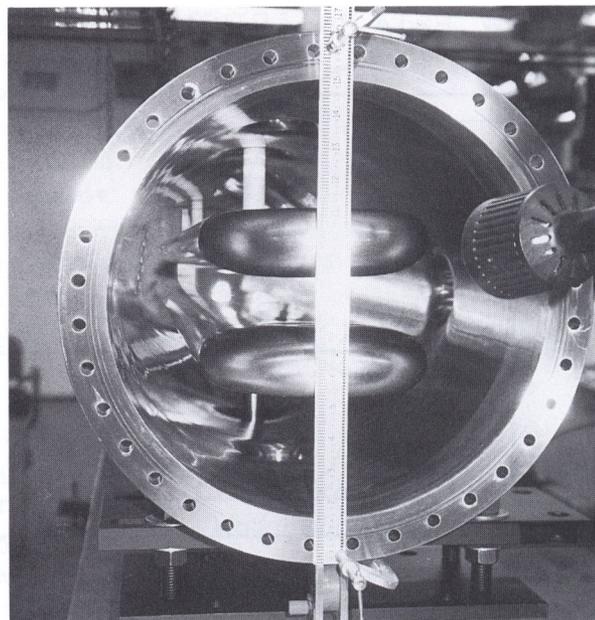
The contributor



Robert Noble is a physicist in the Linac Department of the Accelerator Division and is the Project Manager of the Linac Upgrade. He joined the Linac Department in 1986 and has worked on low-energy beam transport calculations, linac beam dynamics and linac cavity design. Before coming to Fermilab, he was a research associate in the Accelerator Physics Department at SLAC where he worked on bremsstrahlung

calculations for electron-positron colliders, plasma physics and plasma-wave generation for the beat-wave accelerator concept, and studied other advanced accelerators schemes. He was a postdoctoral research fellow at the International Centre for Theoretical Physics in Trieste, Italy from 1981-1983 during which time he began his accelerator physics studies. He received his Ph.D. in Physics from the University of Illinois, Urbana in 1981.

The 1992 collider run will be the first time that the Tevatron will have two proton-antiproton low beta interaction regions in simultaneous operation.



New Tevatron lattices and separators

by Karl Koepke

The Laboratory is committed to an evolutionary improvement in the performance and utilization of the accelerator complex; witness, among others, improvements in the Antiproton Source, the Linac energy upgrade, and the proposed Main Injector. These projects have as their objective an increase in the number of protons and antiprotons injected into the Tevatron.

The latest modifications to the Tevatron lattice are part of this process and enable the Tevatron, as a collider, to more effectively utilize present and future beam currents while maintaining a strong fixed target capability.

Two new low beta¹ insertions and electrostatic separators² have been added to the Tevatron.

The function of the low beta insertions is to focus ("squeeze") the opposing beams as they cross in the center of their interaction regions. The function of the electrostatic separators is to prevent crossings everywhere except at the interaction regions.

The 1992 collider run will be the first time that the Tevatron will have two proton-antiproton low beta interaction regions in simultaneous operation. The first remains at the BØ long straight section and continues to serve the Collider Detector at Fermilab (CDF); the second will serve a new detector scheduled to come on line at the DØ straight section.

The low beta insertions will increase the luminosity of these interaction regions by lowering the beta functions at their collision

points. The electrostatic separators will increase the luminosity of these interaction regions by reducing the proton-antiproton beam-beam tune shift, thereby enabling the acceleration of more and brighter beam bunches.

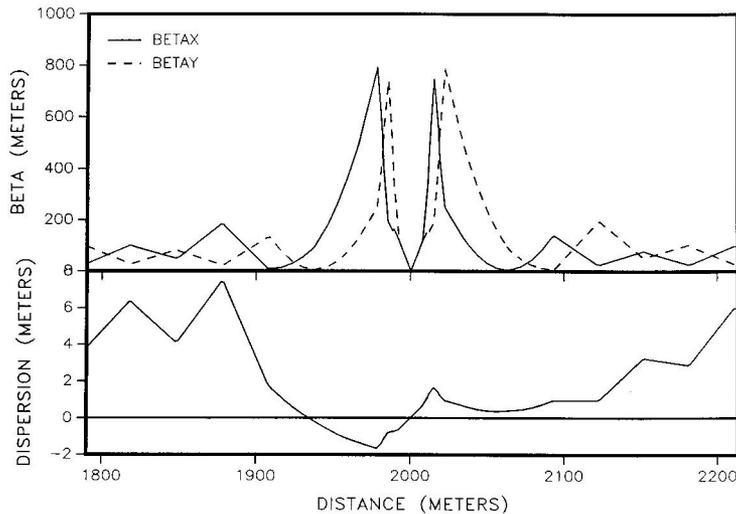
Low beta insertions

There were two compelling reasons for adopting a new low beta insertion design. One was the need to provide space for electrostatic separators on both sides of the interaction regions. The second was the requirement that the low beta insertion be matched to the rest of the lattice.

Past data collection at BØ by the CDF experimenters has been with the original low beta insertion installed. This insertion functioned well and could "squeeze" the beta functions at the collision point (β^*)

LOW BETA INSERTION BETASTAR=.5 M

FILE ATC1.STEP12



Low beta insertion.

down to 0.5 m. However, the insertion was not matched and introduced large beta and dispersion waves into the lattice. That made it difficult to add additional low beta insertions to the ring or to obtain uniform beam separation with electrostatic separators.

The new low beta design does not have these drawbacks. Due to the use of higher gradient quadrupoles and the additional adjustment flexibility afforded by the larger number of quadrupoles, the new insertion can reduce β^* down to 0.25 m with zero dispersion at the collision point. The insertions are completely matched in beta and dispersion to the rest of the lattice and two 9 m spaces have been reserved for electrostatic separators.

The two low beta insertions are geometrically identical when configured for colliding beam operation. However, during fixed target operation, the low beta insertion quadrupoles at $B\bar{O}$ are

reprogrammed to approximate the lattice of a standard straight section. At $D\bar{O}$, the central low beta components are physically removed. The standard straight section quadrupoles and beam extraction components are then installed in their place. The interchange operation is facilitated by mounting the components on moveable girders.

Each of the new low beta insertions uses 18 superconducting quadrupoles placed symmetrically relative to the center of the interaction region. The magnet gradients and the beta functions of the insertion are antisymmetric relative to the center of the interaction region. The inner 12 quadrupoles are a 7.5 cm bore, 2-shell design with a maximum gradient of 1.4 T/cm at 4.8 kA. The remaining six "trim" quadrupoles have single-shell coils capable of .58 T/cm at 1 kA.

The functions of the low beta quadrupoles can be approximated as

follows: Starting at the center of the interaction region and going outward in either direction, the first three quadrupoles (triplet) focus the beams at the center of the interaction region, the next two quadrupoles primarily determine the value of β^* by adjusting the beam sizes as they enter the triplet, and the outer quadrupoles are required to match the insertion.

Each low beta insertion has five independent 5 kA circuits and six independent 1 kA circuits. These are programmed to adjust a low beta insertion's quadrupole gradients during injection and acceleration; and to "squeeze" the beams once the peak accelerator energy has been reached. The insertion's β^* adjustment range is 1.7 m (at injection) to 0.25 m (at low beta). Compared to the 70 m beta value of a normal straight section, this represents a 280 improvement factor to the luminosity. Additional dipole correctors, beam detectors and controls to monitor and adjust the hardware and beam have also been installed.

Separators

A magnetic lattice guides the counter-rotating protons and antiprotons onto the same closed orbit. This results in the needed beam bunch crossings at the two interaction regions but also in unwanted crossings at other locations of the Tevatron. The proton and antiproton bunches experience a mutual attractive force as they cross. The nonlinear part of this focusing introduces a tune spread (beam-beam tune shift) to the beams that is proportional to the number of particles in the other bunch and to the number of crossings. As the beam currents are increased, the

tune spread eventually forces the tunes onto resonances, resulting in increased beam sizes, possible beam loss, and therefore a decreased luminosity. The separators reduce the beam-beam tune shift by reducing the number of beam bunch crossings to a minimum.

The addition of 22 electrostatic separator modules forces the proton and antiproton orbits onto separate helical paths. Each separator module is nominally 3 m long and has an electrode separation of 5 cm. The design voltage is 50 KV/cm. The separators can maintain a 5 sigma separation between 1 TeV proton and antiproton beams whose normalized emittance is 24π mm-mr.

The separated orbits are achieved with electrostatic "3-bumps." The orbiting beams are on the unseparated closed orbit as they traverse and collide in the BØ and DØ straight sections. As they exit these straight sections and enter the electrostatic separators that flank BØ and DØ, they experience vertical and horizontal kicks that force them to oscillate about the unseparated closed orbit until they reach the next collision region,

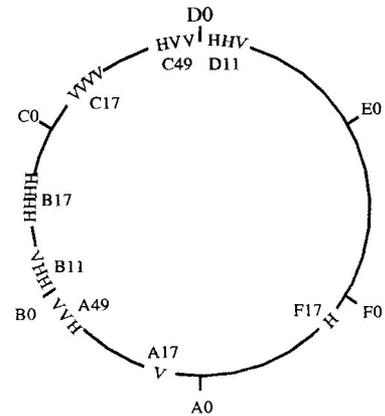
either BØ or DØ, where they again pass through electrostatic separators whose kick angles force the beams parallel to the unseparated orbit for the next collision. Vertical and horizontal separators located between the BØ and DØ straight sections are adjusted to place the beams on the unseparated orbit as they enter the separators before each collision region.

The beams are injected into the Tevatron, accelerated to the peak energy of the accelerator, and "squeezed" with only two horizontal and one vertical separator. This configuration keeps the beams separate and prevents any collisions. Then all the separator voltages are adjusted to permit collisions at BØ and/or DØ.

Fixed target operation

The BØ low beta insertion, the DØ low beta insertion configured in fixed target mode, and approximately half of the electrostatic separators were installed and commissioned in the fall of 1990.

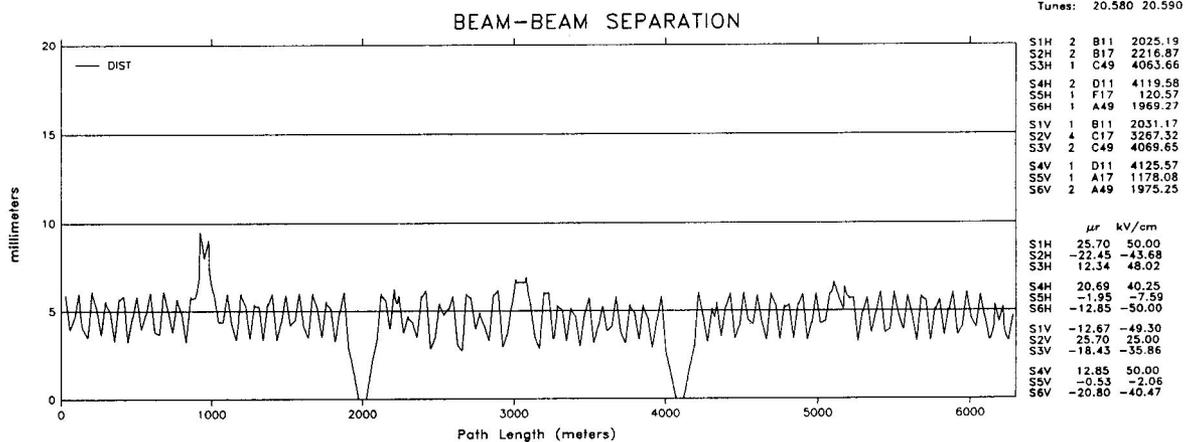
It had been anticipated that the external beam extraction system would need to be readjusted because



Tunnel locations of the electrostatic separators.

of the new low beta insertions. The phase between DØ (the location of the electrostatic extraction septa) and AØ (the location of the extraction septum magnets and the location at which the beam leaves the Tevatron) has changed by 11 degrees. The half-cell dipoles adjacent to the DØ straight section were also moved to make the low beta insertions identical in collider mode.

"It took an eight-hour shift of tuning to reduce the losses at the extraction septum by a factor of two," according to Pat Colestock, head of the Main Accelerator



Beam-beam separation chart generated by A. Russell.

Department and Craig Moore, head of Switchyard Department.

The successful completion of the 1991 fixed target run indicates that the changes made to the lattice to optimize the collider operating mode have not degraded the Tevatron's fixed target operation.

Colliding beam operation

Since the new low beta insertions are matched, the BØ insertion can be operated with the DØ insertion in fixed target mode. Only the tune correctors need to be adjusted as each of the low beta insertions adds approximately half a unit of tune to the lattice. This configuration was tested with protons during the 1990 commissioning and with colliding beams and separators during beam studies scheduled prior to the Spring 1992 shutdown. The most recent studies were aided by two computer programs, a new orbit smoothing program (TOP) and a new sequencer program.

The studies achieved three significant successes:

- The orbit smoothing program succeeded in obtaining a smooth closed orbit with the separators off and with acceptably low currents in the dipole orbit correctors.
- The sequencer successfully controlled proton and antiproton injection into separated orbits, accelerated the beams with separated orbits, and squeezed the beam at the BØ interaction region.

- The separators were successfully reprogrammed to bring the beams into collision at BØ only.

The sparking rate of the electrostatic separators was tested earlier with beam in the tunnel during the 1991 fixed target run. Six separator modules, in concert with adjacent dipole correction magnets, were powered close to maximum voltage to form a local 3-bump. No sparking occurred with a 200 KV electrode voltage. With a 250 KV electrode voltage, one spark occurred during a week long test. This performance is expected to improve with continued conditioning.

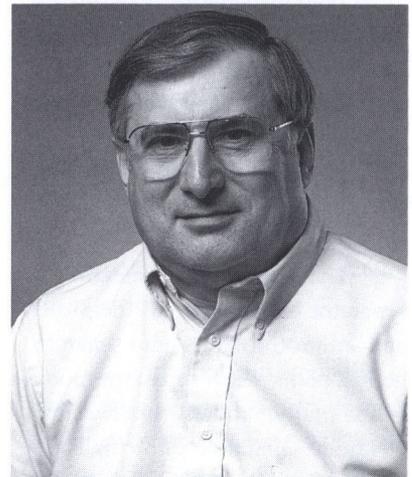
The remainder of the DØ low beta insertion and separators will be installed during the Spring 1992 shutdown. After their commissioning, the first collider run with two detectors at low beta and separated orbits will start. The successful operation of these lattices is the next challenge for the accelerator staff. ■

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² E. Malamud, "Tevatron Orbit Separator Design," Snowmass, 1988.

The Contributor



Karl Koepke received his undergraduate degree in physics from M.I.T. in 1960. After graduation, he worked for Sloan Kettering Institute and Sperry Gyroscope Company. In 1968, while employed by the Princeton-Penn Accelerator, he continued his education and received a Ph.D. in Physics from New York University in 1973.

Koepke came to Fermilab in 1972 to join the Main Ring Operations Group at a time when new accelerator beam records were continuously set.

In 1975, Koepke joined the Tevatron superconducting dipole development effort in time to wind the first 30 cm long, 7.5 cm bore test magnet. He returned to the Accelerator Division in 1978 to head the Tevatron magnet string test at B12.

Since then, he has contributed to the development of the Tevatron abort system, the Booster transition-jump system, and the Tevatron low beta and separator systems. He is currently a member of the Cornell, DESY and Fermilab collaboration to develop a superconducting rf linac.

Test results on these prototypes show that the design requirements for this magnet can be met and this critical part of the Main Injector project is on course.

The Fermilab Main Injector dipole

by B.C. Brown, N.S. Chester, H.D. Glass and D.J. Harding

Upgrades of the Fermilab facility are required to continue to provide leading-edge physics research opportunities.

Beginning with studies in 1988 ^{1,2} upgrade plans which are designated Fermilab III have been developed. The Fermilab Main Injector^{3,4} is the centerpiece of this plan. The Main Injector is designed to replace the Fermilab Main Ring. For Tevatron injection, it will provide 150 GeV beams of both protons and antiprotons. For production of antiprotons, it will provide a rapid cycling, high intensity source of 120 GeV protons. The 120 GeV protons can also be used for particle physics or as a source of test beams during collider physics operations.^{5,6}

In Table 1⁵ we show some of the operational modes in which the Main Injector will be used.

High beam intensities, high beam quality, high repetition rate and high reliability characterize the requirements for this new injector synchrotron. To bend protons around this new machine, a new dipole

magnet has been designed and prototypes constructed. Using two 6-meter prototype magnets, design features and fabrication details have been developed for these dipoles. Test results on these prototypes show that the design requirements for this magnet can be met and this critical part of the Main Injector project is on course.

Operational Mode	Energy (GeV)	Cycle (Sec)	Flattop (Sec)
Antiproton Production	120	1.5	0.04
Fixed Target Injection	150	2.4	0.25
Collider Injection	150	4.0	1.45
High Intensity Slow Spill	120	2.9	1.0

Table 1. Main Injector operational modes.

Length	6.1 m	4.1 m
Sagitta	16 mm	7 mm
Color	light blue	
Gap	5.08 cm (2 inch)	
Maximum field	1.73 T	
Weight	17000 kg	12000 kg
Laminations	8000	5333
Conductor	25.4 x 101.6 mm ² copper	
Cooling water	12.7 mm dia. hole, 0.68 l/s	
Maximum current	9375 A	
Resistance	0.8 mΩ	0.6 mΩ
Inductance	2.0 mH	1.3 mH
Maximum ramp	240 GeV/sec (15000 A/sec)	
Peak power	75 kW	50 kW

Table 2. Main Injector dipole parameters.

used in the Main Ring. This makes the remanent field effects proportionately smaller for this ring. They are further reduced by the selected pole tip profile in the new lamination design. When the field is rapidly changing, eddy currents (mostly in the beam pipe) create significant field shape errors. At the highest fields, iron saturation also causes the field to be less uniform. The non-uniformity in both cases is almost entirely correctable by the sextupole correctors.

The lattice design uses two dipole magnet lengths: a 6-meter dipole and a 4-meter dipole. Two hundred sixteen of the 6-meter and 128 of the 4-meter dipoles are required to complete the lattice. The basic magnet parameters are presented in Table 2.

Building a dipole

Using the 20 years of magnet building experience at Fermilab's Conventional Magnet Facility, the design and manufacturing process requirements for the dipole are being detailed and documented under the guidance of Nelson Chester. In this step the reliability of the magnets will be created. The fabrication process begins with copper bars 20 feet long which have been extruded with a 1 inch by 4 inch cross section and a half inch diameter hole for cooling water. To minimize the number of joints in the magnet, the bars are bent into J-shaped coil segments and brazed together to make the four turn coil. A reliable joining technique has been selected based on more than 15 years of use. It employs a brazed butt joint with a ferrule insert. Since the coil is

entirely outside the plane of the beam pipe, its shape can be a simple flat 'racetrack' (or pancake) design. Once the 4 turn coil has been bent and brazed, it is cleaned, then insulated with G10 (fiber glass epoxy) strips and fiber glass tape. This package is then vacuum impregnated in a mold with an insulating epoxy under elevated temperatures to create a strong, water-tight coil package.

To finish the electrical circuit, the coils are connected within the magnet and then connected magnet to magnet. To minimize the cost of the tunnel installation, one of the two magnet coils in each dipole includes a return bus to complete the circuit back to the power supply. This "four terminal" magnet design follows a feature of the Tevatron magnets and saves installation of 12,000 feet of copper bus in the Main Injector. Connecting the current paths (busing) and water paths (manifolding) at the ends of magnets often adds substantially to the cost and reduces the reliability of a magnet design. Careful attention to these details by both the magnet designers (Dave Harding, Nelson Chester, and Arnie Knauf) and the group planning the installation (led by Larry Sauer, Fritz Lange, and Phil Martin) resulted in the design shown in Figure 2. The symmetric bus which connects the top and bottom coils is compact to minimize stray magnetic fields and includes simple, reliable water connections.

The critical magnetic field shape is provided by the laminated core. Special iron is obtained in 16 gauge thickness (1.5 mm) and coated with insulation to avoid eddy

currents in the core. A precision die then stamps the laminations to the required shape. Sample laminations have been examined in the Technical Support Section quality control lab.

The pole faces at the end of the core are shaped to avoid field shape errors. Stan Snowdon and Francios Ostiguy provided a suitable iron profile. Prototypes of that shape were created using a numerically controlled milling technique. A lower cost fabrication technique is under development. Regular laminations were modified using a mechanical “nibbler” to create special shapes which can then be stacked to replicate the shape of the machined end core. In addition to the mechanical “nibbler”, new tools, including laser cutters and high pressure water cutters, are being considered to modify standard laminations.

As shown in Figure 3, the laminations are assembled to create half cores. The curvature of the magnet is maintained by stacking against a curved template rail. The

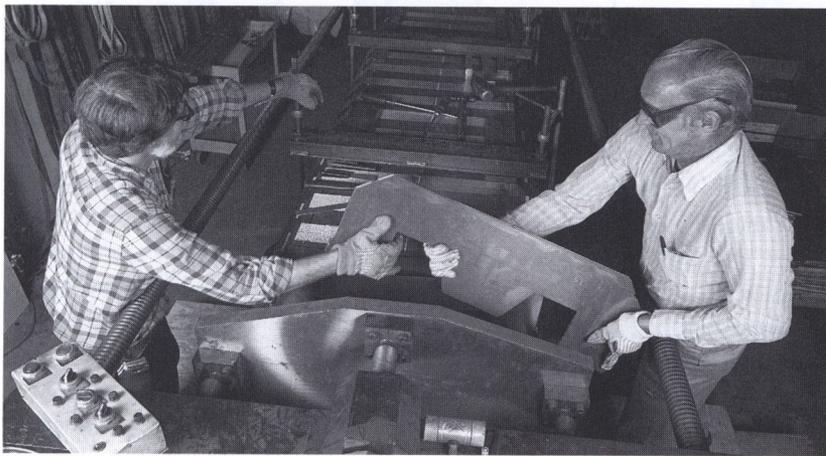


Figure 3. Bill King and Claude Dugger stacking laminations to make a half core.

laminations are clamped mechanically and plates are welded to the top and sides to complete the half-core assembly, providing stiffness and rigidity. Detailed measurements of core shape are required before acceptance of the half core for magnet assembly.

The assembly of two half cores, two coils with bus work and water manifolds, and a beam pipe with vacuum flanges and pumpout ports into an assembled magnet, ready for tunnel installation, must now proceed. A series of steps which will actually allow all the pieces to fit in the puzzle must now be devised. Then, each step must be perfected with consideration of normal accelerator operation, various maintenance cycles, assembly difficulty and requirements for quality assurance testing.

The final steps in coil installation involve decisions fundamental to insulation integrity. The coils must withstand magnetic forces on each of millions of accelerator cycles. Also, hundreds of cycles of

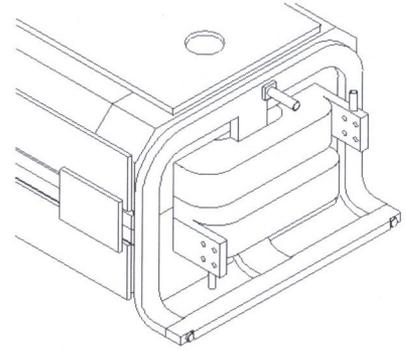


Figure 2. End view of Main Injector dipole.

accelerator shutdown will subject the magnet parts to stresses from temperature changes. To accommodate these two conditions, a slip plane is created using a kapton sheet between the coil and the core. The kapton is held firmly against the coil by an epoxy filler. This supports the outward force of the coil against the iron core. When the coil and core experience differential elongation due to temperature differences, the coil can slip along the kapton without damaging friction. The coil is held centered in the core by epoxy placed over a 24" length in the center of the core.

Special fixturing is required to permit assembly of all the pieces. G10 blocks with urethane “springs” will support the coils. The urethane withstands the weight during assembly after which a thin layer of epoxy will dry in place to provide the final support. A thin-walled beam pipe with the desired curved shape appeared to be a difficult challenge. It has been found that the forces required to create the curvature during assembly are modest. A straight pipe is procured and special spacers are placed between the sides of the beam pipe and the inner core walls.

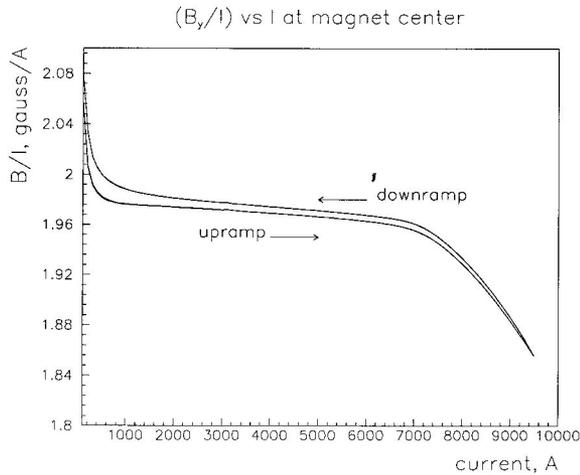


Figure 4. Magnetic field/current for Main Injector dipole as measured with a Hall probe. NMR probe data provides cross-calibration above 5000 A.

Following this step, the half cores are clamped and welded together with side plates. Bus and manifold installation follow. After painting, the magnet is ready for testing.

Testing dipole magnets

The Magnet Test Facility (MTF) is responsible for testing the prototype magnets and creating the production testing system. Bruce Brown and Hank Glass are leading an effort to develop new measurement systems using UNIX computers with VME and VXI data acquisition hardware, new mechanical hardware and a SYBASE database for data storage. The existing MTF system uses VAX-based software with CAMAC and GPIB hardware. Measurements of the prototype dipoles have been carried out with the existing system supplemented with the new equipment where available.

The fundamental items to measure are the strength and shape of the magnetic field. The bending strength is $\int B dl$ for particles in the center of the aperture. The shape is

the relative strength variation for particles which are away from the design center line. The shape, when expressed as a function of the distance from the center of the aperture, can be expanded in terms of a harmonic series. For dipoles a few terms (sextupole, decapole, etc.) typically dominate the series. Accelerator magnets can typically be conceptually subdivided into a body field region and its two end field regions. The magnetic parameters which have been the subject of

precision measurement include body field strength vs. excitation current (B vs. I), total field integral vs. current ($\int B dl$ vs. I), harmonic components of the body field, strength of the end fields vs. current, shape of the body field and end field over the useful aperture, and a detailed point-by-point mapping of the end fields.

To perform these measurements, MTF has employed a suite of probes. Some of these probes were used in previous magnets⁹, while others were newly developed for use with the Main Injector dipoles. We measure harmonics using cylindrical probes. Axially wound coil sets are embedded in the surface with cross sections chosen to permit separation of strength measurements and shape measurements. "Tangential" coils are sensitive to many harmonic terms; Morgan coils to a few selected ones. Rotating coil harmonics measure the field at constant current by measuring flux changes while the coil is rotated. A Fast Fourier Transform performed on the data is used to extract harmonics.

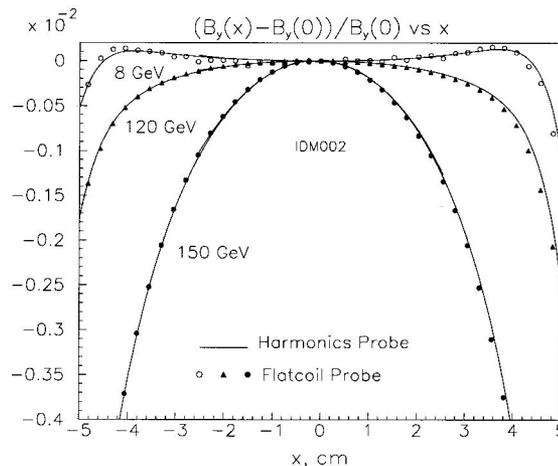


Figure 5. Body field shape for Main Injector dipole at injection, 120 GeV and 150 GeV.

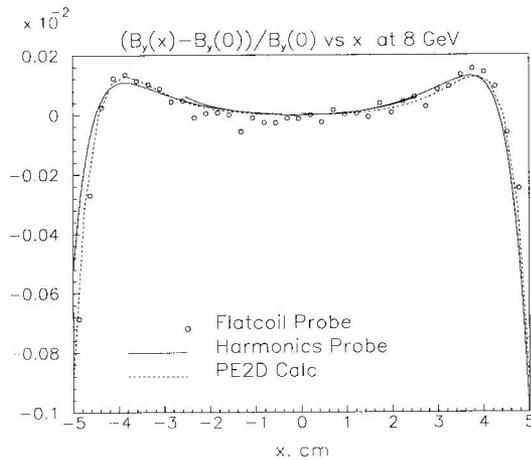


Figure 6. Shape of injection body field as measured and calculated.

Ramped Harmonics collects flux change data during a ramp and steps through angles between ramps. Harmonic shape measurements used an existing 80" long rotating "tangential" coil.

Field shapes and field strengths were measured using new "Flatcoil" probes built by Steve Helis and Cervando Castro. These probes use coils wound around a rectangular bar which is curved to match the dipole's curvature. They come in two sizes: a 16 foot probe to measure body field only, and a 24 foot probe to measure body and end fields combined. In addition, an 80 inch flatcoil probe was built to do end field studies. Ramped harmonic measurements were performed with an AC "Harmonics" probe which was built employing a combination of tangential coils with 6-pole and 10-pole Morgan coils. In addition to coil systems, which measure magnetic flux, NMR probes and Hall probes were used to perform point measurements of the magnetic field, particularly in the end field regions.

Body field strength was measured as a function of current

using Hall probe, NMR, and rotating coil and Flatcoil techniques. The transfer function, B/I is plotted in Figure 4 from the Hall Probe data. The measured magnetic field shape is plotted in Figure 5 for the body of the magnet at injection, 120 GeV, and 150 GeV.

Figure 6 shows the body field variation of $B_y(x)$ at $y=0$ for $B(0)=0.10$ T. Shown are the field as calculated¹⁰, as measured with the flatcoil system, and as reconstituted from three rotating coil harmonic

measurements. The agreement is strikingly good among measurements at all field strengths. Calculations also agree, both on and off the midplane except at the highest fields where precise calculation of saturation effects is more difficult.

To assist in understanding the end pack design we have studied the magnetic field in the end using a Hall probe system which is scanned in the end field volume. A typical result is shown in Figure 7. Systematic studies with FLATCOIL and rotating coil systems inserted to various depths have measured the integrated error field contributions of the end. We are using these measurements to perfect the iron shape for the end packs.

Calculations of the fields due to eddy currents shows them to be important sources of sextupole field errors. The magnetic field they produce is proportional to the ramp rate thus their relative importance decreases at high fields. To confirm the calculations, Dana Walbridge at MTF led an effort to measure these

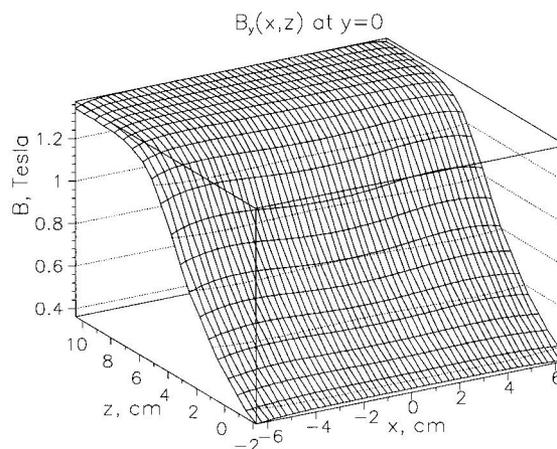


Figure 7. Hall probe map of B_y in an end field region on the $y=0$ plane.

fields in sample beam pipes. This work used a sample pipe constructed from common (Type 316) stainless steel and one constructed from a higher resistance (Type 330) stainless steel. Figure 8 shows the sextupole flux induced in our AC Harmonics probe during ramps when the probe was in the magnet without a beam pipe and with the two sample beam pipes. The measurements confirm the calculations. We conclude that the sextupole component calculations are correct and that higher order shape errors are small.

It is not enough to get one magnet to work. The first two dipoles have now been through extensive tests. How alike are they? We show two aspects. In Figure 9, we examine the largest harmonic term—the sextupole. The lamination shape has made it small and positive at low fields but it becomes increasingly negative with current at the highest fields when the iron saturates. The sextupole magnets required to correct natural chromaticity will be used to correct for this

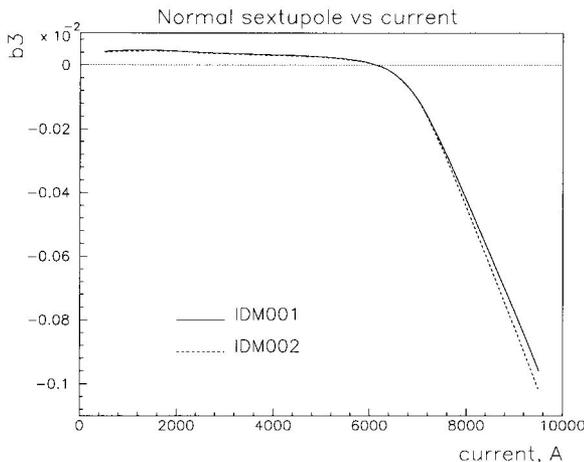


Figure 9. Sextupole harmonic component vs. current for the first two Main Injector dipole prototypes.

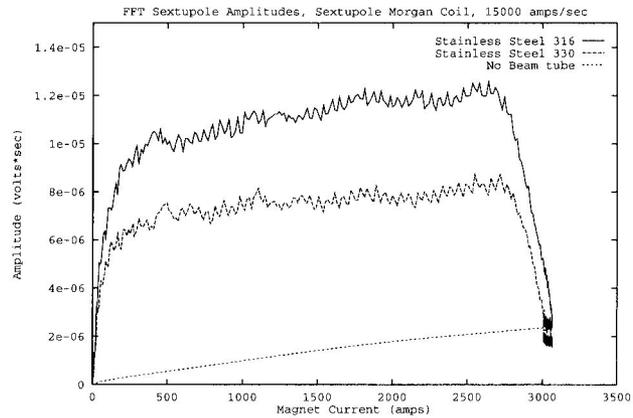


Figure 8. Sextupole flux vs. magnet current with 316 stainless beam pipe, 330 stainless beam pipe and without beam pipe. The graph shows the different eddy current contributions with a 15000 A/sec ramp.

saturation effect. Studies of the end pack design are underway to improve the integrated shape.

Summary

A team of Accelerator Division and Technical Support Section personnel are detailing and documenting the requirements and methods of fabrication for the Main Injector dipoles. Contacts have been established with vendors for each of the many specialized components.

Prototypes have been built and tested. Examination of the complete set of measurement results provides assurance that the arrival of construction funds will result in a ring full of magnets ready to use. ■

Acknowledgements

Many people have contributed significantly to the Main Injector dipole project. The following is by no means a complete list:

Accelerator Division:

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Magnet Test Facility:

Shree Agrawal, Mimi Bleadon, Cervando Castro, Mike Cherry, Gene Desavouret, Jim Garvey, Richard

Glosson, Pennie Hall, Dave Hartness, Steve Helis, Peter Mazur, Darryl Orris, Jim Pachnik, Ed Schmidt, Jim Sim, Mark Thompson, Kelley Trombly-Freytag and Dana Walbridge.

Other Technical Support areas: Gregg Kobliska, Arie Lipski, Jim Kerby, Arnie Knauf, Don Olson, John Zweibohmer, Bill Prichard and Ron Evans.

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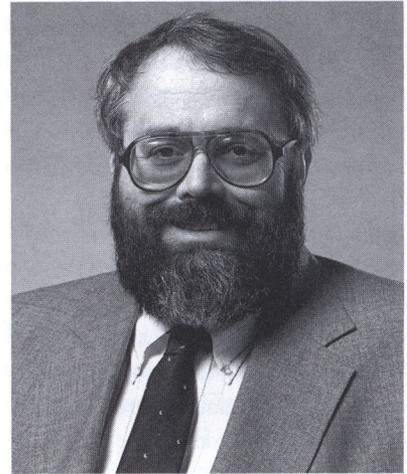
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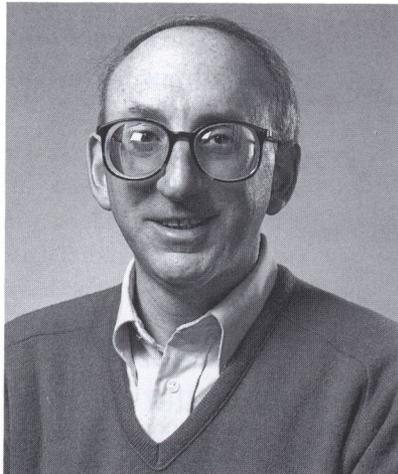
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The contributors

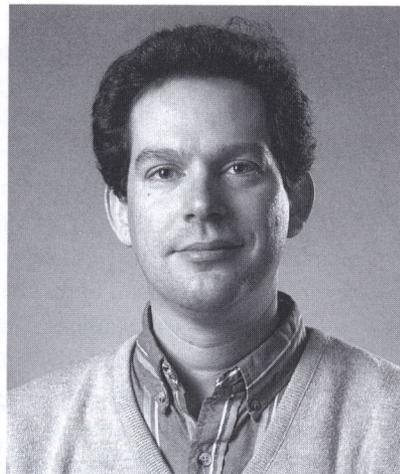


Bruce Brown received a B.S. in physics from the University of Rochester in 1966 and a Ph.D. from the University of California, San Diego. Following his degree he worked at Argonne National Laboratory on the polarized proton experiments with the University of Michigan group. In 1973 he became a Research Associate in the Fermilab group that was collaborating on the lepton, lepton pair and hadron pair production experiments (E70, E288 and E494). While that experimental program was still at its height, Brown joined the Fermilab staff in the Accelerator Division. He worked on beam extraction from the Main Ring and then on various aspects of the Booster and joined the E557 collaboration. For the last ten years Brown has been associated with the Fermilab Magnet Test Facility (MTF). During this time measurements of nearly 2000 magnets for the Tevatron, P-bar Source and Main Ring, plus development for the SSC have been carried out.

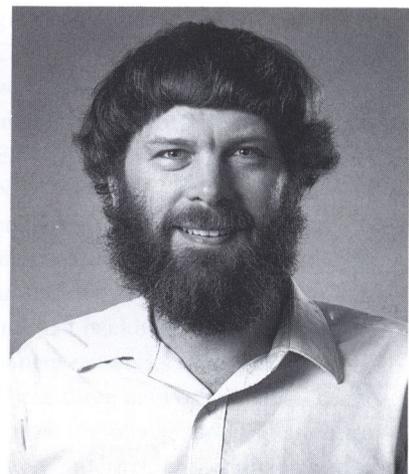


Nelson Chester earned a B.S. in electrical engineering from Fairleigh Dickinson University in New Jersey in 1968. His graduate studies were in business law and mathematics at Northeastern University in Boston, Massachusetts; Johns Hopkins, Baltimore, Maryland; and State University of New York, New York.

Chester joined the Fermilab staff in February 1990 as a group leader in the Technical Support Section, Conventional Magnet Facility and project engineer for the Main Injector magnet project. Prior to joining the Laboratory, Chester was a design engineer with General Electric for three years, a development engineer at Black and Decker for ten years and an engineering manager at Milwaukee Electric Tool for ten years.



Hank Glass received his B.S. in physics from Rensselaer Polytechnic Institute in 1978 and a Ph.D. from SUNY at Stony Brook in 1985. Following the completion of his graduate work on Fermilab experiment E605, he joined the technical staff of the Aerospace Corporation in Los Angeles, where he worked from 1985 to 1989 on projects in digital image processing and remote sensing. After leaving Aerospace, he worked briefly at Northwestern University's new Basic Industrial Research Lab (BIRL), and then returned to Fermilab in 1990, where he joined the Magnet Test Facility (MTF). Since joining Fermilab he has principally worked on magnetic measurements of the prototype Main Injector dipoles. In his new role as deputy head of MTF, he has become responsible for the department's budget and has also become involved in MTF's activities regarding the SSC 50-mm dipole program. He has also managed to take a few shifts on E789 (grandson of E605). He is best remembered at Fermilab, however, for his acclaimed portrayal of poet Reginald Bunthorne in the Not-Ready-for-Beam-Time Player's 1984 production of Gilbert & Sullivan's *Patience*.



David Harding earned his BA, MS, and Ph.D. from Cornell University. He claims the distinction of running the last shift of fixed target particle physics data-taking at the Cornell Synchrotron. Harding joined the Fermilab Physics Department as a Research Associate in 1978. There he worked on experiments in the Wide Band Neutral Beamline in the Proton Area: E401, photoproduction of J/ψ , ψ' , and lighter vector mesons; and E400, hadroproduction of charm with a high energy neutron beam. He was active in designing E687, photoproduction of heavy quarks, for the Broad Band Beam. In 1983 Harding accepted a staff position building the Antiproton Source with the Tevatron I Section, which later became the Anti-proton Source Department of the Accelerator Division. He worked on the magnet prototype development program and in the magnet construction. After the machines were complete, he participated in the commissioning and then operation of the P-bar Source. In September 1990 Harding joined the Main Injector Department with the assignment of guiding the magnet development and production.

Twenty years ago computer networks existed mostly as ideas about which the computer science community wrote papers.

The Explosion of computer networking

by Bill Lidinsky

Introduction

Twenty years ago computer networks existed mostly as ideas about which the computer science community wrote papers. A few experimental networks such as Arpanet and Alohanet were being put into place. A young MIT graduate named Bob Metcalf had just joined Xerox PARC where he and Dave Boggs began to create something that they would later call Ethernet.

Ten years ago computer networks were exotic research tools used only by a few specialists. No networking standards existed and the design of computer networks was a black art. IBM's SNA and DEC's DECnet had recently been announced but these were more concept than substance.

Today, systems ranging from personal computers to supercomputers are more likely to be part of a network than not. Almost every organization that uses computers has them connected by a local area network, and often these local networks are in turn connected to a wide area network. Electronic mail is a part of the daily work ritual for tens of millions of people worldwide. File transfer is becoming so. Mega-corporations and voice network providers like AT&T, MCI, Sprint, and British Telecom, as well as the European PTTs are scrambling to provide computer network services. Standards have been developed by many organizations including the Institute of Electrical and Electronics Engineers, Inc. (IEEE), International Standards Organization (ISO), International

Consultation Committee on Telegraphy and Telephony (CCITT), and the Internet community. The federal government of the United States has begun to move toward the Government Open System Interconnect Profile (GOSIP) standard, and in recently passed legislation has provided substantial funds for NREN, the National Research Education Network.

In a few years proprietary networks like SNA and DECnet will disappear except in name, for they will all conform to standards, allowing computers from different vendors and different organizations to communicate and even interoperate, thus stimulating network usage even more. Computer networks have become almost as important as the computers themselves.

Some network technology

Geography and ownership

One way of classifying computer networks is according to geographical scope and ownership. Thus local area networks or LANs span a kilometer or so and are owned by the organization that uses it. In contrast, wide area networks (WANs) span continents and are usually owned not by the user but by another organization that is in the business of providing such a network for others to use. Examples of these "common carriers" include Sprint/British Telecom, AT&T, Tymenet, and MERIT.

There is a need for networks that are geographically in between LANs and WANs. Sites such as universities, national laboratories, and manufacturing complexes have interconnected their local area

networks with bridges and routers in order to achieve greater connectivity. Figure 1 shows a greatly simplified example of such an arrangement - often referred to as a campus area network or CAN. At large sites like Fermilab, CANs have grown to the point where they are becoming difficult to manage. Technology is emerging that promises to support unified and manageable CANs.

In contrast, a WAN is often composed of several other wide area networks. For instance the Internet (note the capital "I") consists of a set of core backbones including NSFnet (the National Science Foundation Network), ESnet (the Energy Sciences Network), NSI (the NASA Science Internet), and national backbone networks such as CA*net in Canada. The Internet also encompasses many regional networks that operate over a more limited geo-

graphical area. Some of these are CICnet (a network connecting mid-western universities and research institutions), CERFnet (California Education and Research Federation Network), and THEnet (Texas Higher Education Network). Campus area networks that connect either to an Internet regional network or to an Internet backbone also become component networks of the Internet. These three network classes - backbones, regionals, and CANs - make up the Internet. By sending a packet with an Internet address into the local area network to which it is connected, a computer is able to send information to any other computer "on the Internet."

Overlaying these WANs and using them in turn as a component network are mission-specific networks. One of these is HEPnet (High Energy Physics Network).

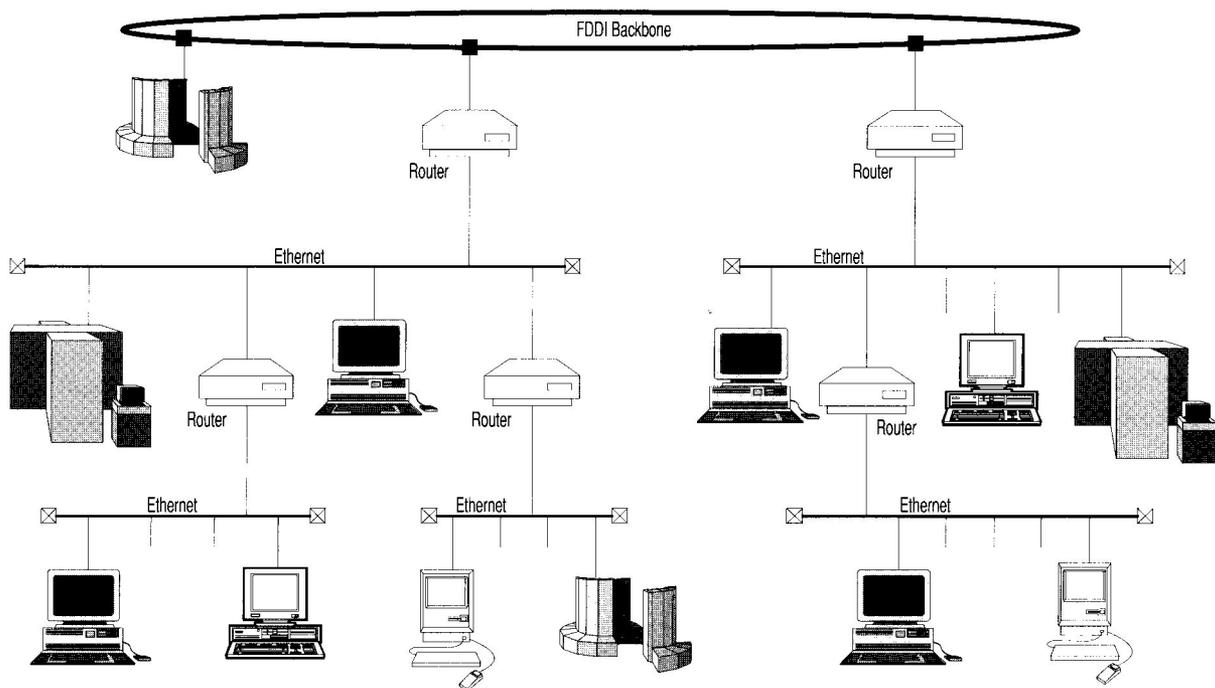


Figure 1. Simplified Campus AMA Network Configuration.

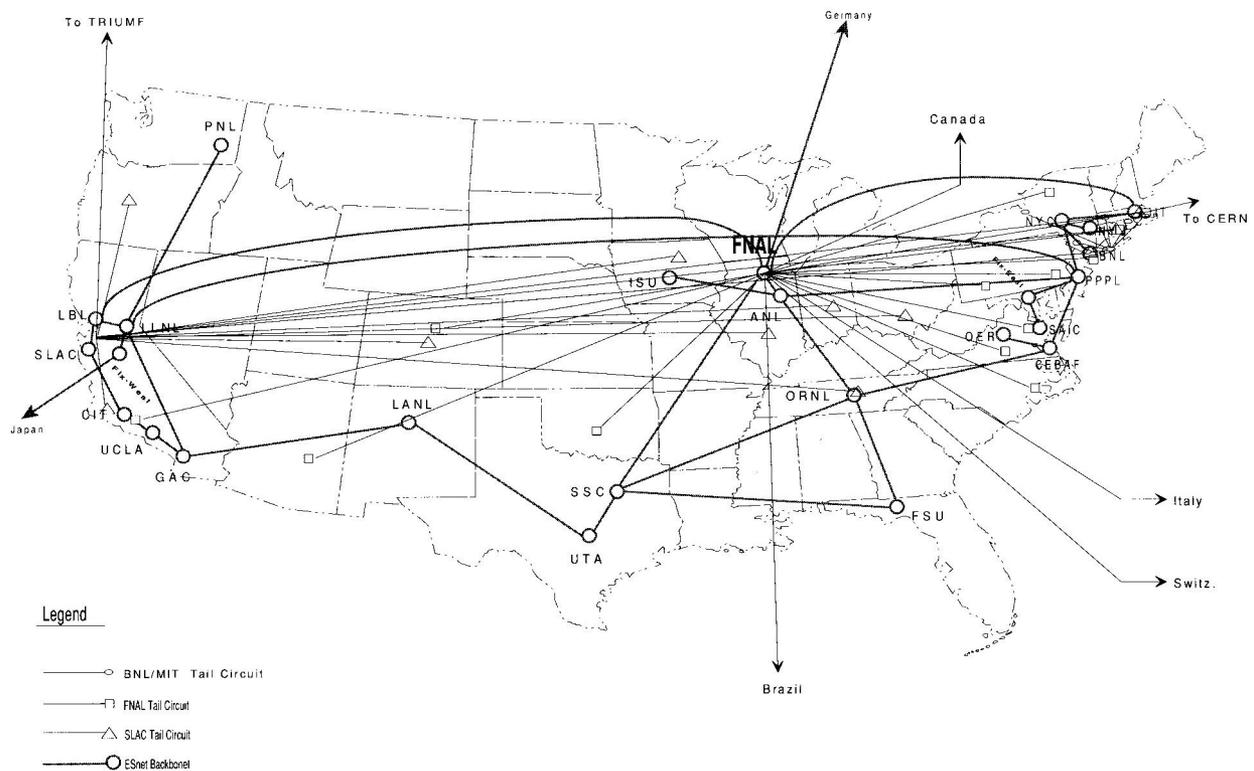


Figure 2. Partial HEPnet topology.

Figure 2 shows part of the HEPnet topology including ESnet which is a HEPnet backbone. HEPnet consists of network facilities provided by many other networks including ESnet, the Internet, and commercial networks; and nodes and CANs provided by national laboratories, research universities, and private institutions involved in high energy or nuclear physics research.

Performance

Today’s local area networks have bit rates ranging from a few megabits per second (Mbps) to a few tens of megabits per second. This aggregate bit rate must be shared among the computers attached to a LAN. Fortunately, because of the bursty nature of computer information (computers don’t transmit continually but send bursts of information called

messages or packets), time sharing is possible. On lightly loaded LANs computers only rarely need to transmit simultaneously and therefore seldom interfere with each other. On heavily loaded LANs, however, need for simultaneous transmission occurs frequently. For token ring type LANs heavy loading increases network access delay thus decreasing the effective bit rate, while for Ethernet-style local area networks, the effective bit rate of the network is additionally degraded due to collisions between packets simultaneously transmitted from several sources.

The emerging generation of LANs, as exemplified by the FDDI (Fiber Distributed Data Interface), have aggregate bit rates of around 100 megabits per second and better methods of handling heavy loads.

FDDI rings are increasingly being used both as the backbone and for specific high performance needs within LANs. At Fermilab, FDDI rings are being installed for these reasons.

Wide area networks today usually have bit rates ranging from a few kilobits per second to 1.5 megabits per second. They consist of 1.5 Mbps “T1” links combined with router nodes capable of supporting these rates. As transmission costs decrease and need increases, bit rates will gradually increase to 45 megabits per second. NFSnet already has as many as 45 Mbps “T3” links, and ESnet is moving in that direction.

One last thought about performance. While bit rate is the most often quoted measure of

network performance, delay or response time is the parameter that is really most important to the user of interactive network services. Bit rate is usually the only performance parameter discussed because in the past it was the major component of delay. In WANs, bit rate is still the major delay component although router delay is also a significant factor. However within CANs, the delays incurred in bridges and routers, accessing networks, and in the network interface software within the computers themselves have become in many cases the major contributors to delay. For interactive services, this will become increasingly true as network bit rates for both local and wide area networks increase.

Networks— more than connectivity

Up to now our discussion has centered on issues of bit rate, delay, and connectivity. But computer networks are more than complex digital paths connecting physically separate sites. Networks provide a number of high level or application level services. Probably the most commonly used network service of this type is electronic mail. "Email" has been used extensively within many major corporations and within the research and academic communities over networks like Bitnet, SPAN, and USENET. More recently with the growth of the Internet, email using the Simple Message Transfer Protocol (SMTP) has become extremely widespread and reliable. In time a set of CCITT standards - X.400/X.500 will come into wide and perhaps universal use.

Beyond connectivity and email, computer network application

protocols have supported file transfer, remote character-oriented terminal access, and remote job execution. However other capabilities now exist including remote procedure calls and distributed file systems where parts of a single file structure reside on separate computers each with its own internal file arrangement. These capabilities are personified across different computers on UNIX-based systems in the widely implemented de facto standards including RPC (Remote Procedure Call) and NFS (Network File System). Another distributed file system, AFS (Andrew File System), promises more robust operation than NFS in wide area network settings.

Remote network access is no longer limited to characters. Windowing and graphics are now possible using the X window

protocols. These high-level network capabilities form the basis for distributed work group clusters that may be key to future high energy physics collaborations. In addition, combined with new common carrier offerings such as ISDN (Integrated Services Digital Network), they may allow reasonable cost "telecomputing" where a low-cost personal computer or workstation in a home can be part of a distributed computing environment. This would allow Fermilab employees working from their homes to function in a manner similar to the way that they function on site.

Collaborations and computer networks

Collaborations are an integral part of big science such as climate modeling, the genetics mapping research, astrophysics, and high energy and nuclear physics. They

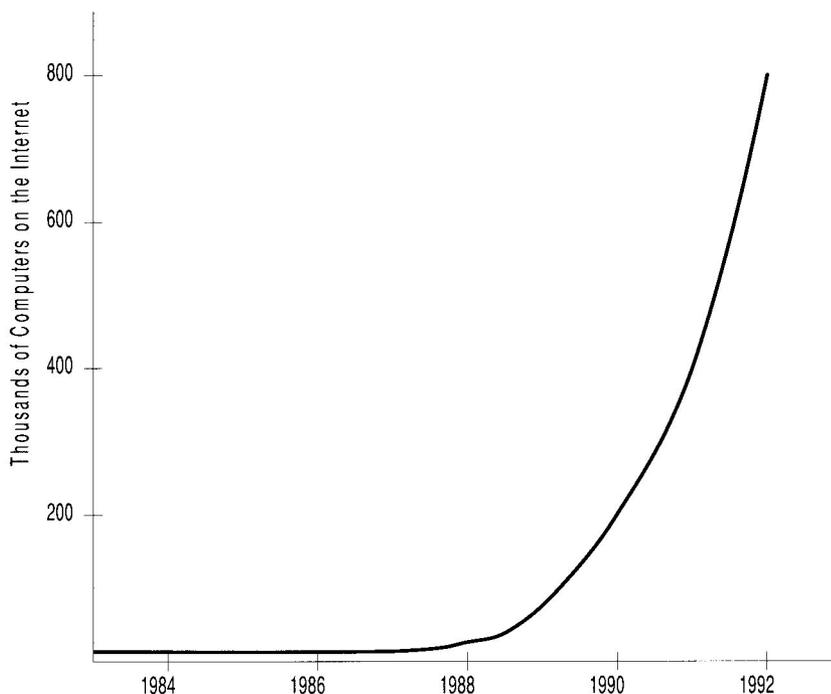


Figure 3. Growth of the Internet.

range in size from a dozen or so members to several hundred. They are geographically dispersed - often worldwide. Collaborators do their work at different institutions which have dissimilar business styles and cultures. They use different computers and software. Yet members work together to design experimental equipment, develop software, share code, retrieve and analyze data, distribute and update programs and command procedures, and produce and exchange documents. They also interact in scientific debate.

Computer networks are essential to collaborations today. Electronic mail is used daily as are remote login, remote job initiation, and file transfer. A logical evolution in the collaborative use of computers and computer networks is toward geographically dispersed computing clusters similar in capability to the localized systems now in operation. Current localized clusters, which in a sense are a collaboration's intellectual workplace, have rapid and transparent access to files and databases, support for media of interest to the collaboration, possess rich unified tool sets, and are cost-effective. These capabilities are now or soon will be possible in networked systems.

Conclusions

Computer networks of all types are now widely deployed and used. They have "gone non-linear" in growth of connectivity, capabilities, and services (see Figure 3). And there's much more to come. Technology has moved into the Mbps low-delay wide area network world, and has also allowed us to

begin to contemplate the time when the user won't need to think about sending and receiving information—it will just be there.

Present computer networks are intrinsic to modern scientific research. Email, file transfer, remote computer access, and remote job execution are used daily. Transparent access to files on a multiplicity of media along with the easy availability of a wealth of software tools have made first the computer and now the locally networked computer cluster a researcher's intellectual workplace. Such network capabilities are now being extended to large geographical areas where they will increasingly be available wherever the researcher chooses to work. ■

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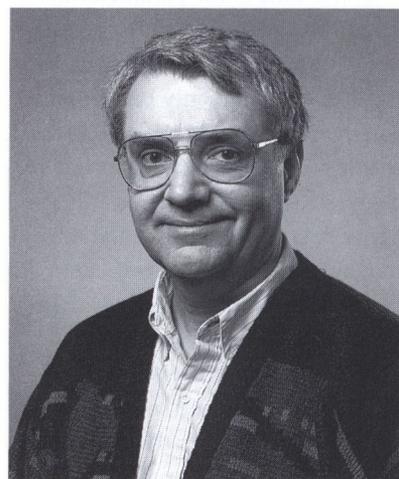
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The contributor



Bill Lidinsky is the manager of HEPnet, the nation-wide high energy physics computer network; and also the Head of Technology Tracking and Transfer for Fermilab's Computing Division. Prior to joining Fermilab he was the supervisor of research groups at AT&T Bell Laboratories where his interests centered around computer-aided software engineering; integrated video/data/voice systems; and 100 gigabit/second local, campus, and metropolitan area computer networks. Prior to Bell Laboratories, he was the manager of the Networks and Real-time Systems Department at International Harvester's Science and Technology Laboratory and a supervisor at Argonne National Laboratory. He has also worked in biomedical and military electronics. Currently Lidinsky is the chairperson of the IEEE 802.1 Local Area Network Standards Committee and is an Adjunct Associate Professor at Illinois Institute of Technology. He holds an MSEE degree from IIT and an MBA from the University of Chicago. He is a senior member of the IEEE and a member of the Association for Computing Machinery (ACM).

There is a saying “Those who can, do. Those who can’t, teach.” I now respond confidently to such unenlightened critics of the teaching profession with the statement, “I can do, and choose to teach too.”

Bringing “real science” into the classroom via teacher research associates

by Kristin Ciesemier with James Mashek

By the year 2000: U.S. students will be first in the world in science and mathematics achievement.¹ How can our high school graduates be their best in the year 2000 when 69 to 88 percent of our science and mathematics teachers at the middle and high school levels have not had sufficient preparation to meet the standards established by professional associations of mathematics and science educators?²

How do we bridge the gap between where we are now and where we hope to be in the year 2000? Who is our offensive line that will turn on young people to mathematics, science and technology and encourage them to achieve and to pursue careers in these fields? For

most young people it will be our teachers. How do we inspire these teachers, help them understand the excitement and true nature of science and enable them to bring science alive in the classroom?

The United States Department of Energy (DOE) Teacher Research Associates (TRAC) program is designed to give teachers the opportunity to experience scientific research firsthand by participating directly in research being conducted at DOE national laboratories and facilities. The goals of the TRAC program are to:

- provide outstanding seventh through twelfth grade science and math-

ematics teachers with professional scientific and engineering experiences through summer research opportunities.

- enhance their leadership skills.
- increase their awareness and understanding of current science and technology.
- promote the transfer of this knowledge to the classroom.
- provide the opportunity for renewal.



James Mashek, Teacher Research Associate, and his supervisor Finley Markley review experimental data at Fermilab.

Fermi National Accelerator Laboratory has placed midlevel and high school teachers into 139 summer research positions in the last nine years. The impetus for the program came from Jeffrey A. Appel, Physics Department Head, Arlene Lennox, Neutron Therapy Department Head and other physicists who felt that students would be better served if teachers had exposure to the scientific workplace. In 1983 with the support of Fermilab's Director, Leon Lederman and Deputy Director Philip Livdahl, the framework was laid and the program begun.

In the early years TRAC teachers were selected from a regional pool and lived within driving distance of the Laboratory. A national program sponsored by DOE began in 1989, opening

Fermilab's program to teachers from throughout the United States. This coincided with the formation of the Fermilab Education Office which currently administers the program with guidance from Regina Rameika, Deputy Head of Research Division. Fermilab currently places both regional and national participants. Since 1989 teachers from eight states Alaska, Arizona, California, Colorado, Georgia, Maryland, Minnesota, and Nebraska have come to Fermilab. Seven additional states, Maine, Mississippi, Nevada, New Hampshire, North Dakota, South Carolina and Wyoming will be represented by participants in the 1992 program.

The teacher's academic background in chemistry, computer science, engineering, industrial technology, mathematics or physics

along with relevant work experience is reviewed and matched to appropriate research opportunities at Fermilab. TRAC teacher appointments have been made to the Accelerator Division, Research Division, Physics Section, Computing Division, Business Services Section, Technical Support Section and Laboratory Services Section.

The teachers typically spend eight to ten weeks at the Laboratory; a week or two is required for orientation and the remaining weeks are devoted to actual research. Research assignments that are well defined and structured but not contrived have proven to be the most satisfying and beneficial for teacher and supervisor alike. Teachers also have had the opportunity to return to Fermilab in subsequent summers as TRAC graduates. The familiarity and confidence of the TRAC graduates eliminates or significantly reduces the orientation time allowing for an expanded period of research and increased benefit to the Laboratory.

TRAC teachers and TRAC graduates are given the opportunity to participate in what they call "real science." They become contributing members of teams composed of scientists, graduate and undergraduate students, and technicians. The TRAC teachers may also fill a unique niche at Fermilab by assisting their supervisors as mentors for talented minority high school students who participate in a summer research apprentice program called Target.

What follows is a presentation given by James E. Mashek at the Partners in Science conference in

Tuscon, Arizona January 18, 1991. It describes his first and second year experiences in the TRAC program working with Target students. Mashek, a veteran teacher of 26 years, has taught earth science, physical science, chemistry and physics in a small rural Nebraska school. The Oakland-Craig Public School has approximately 180 students enrolled in seventh through twelfth grade.

James Mashek:

To better understand the interaction of the teacher, researcher and student in this project, some background information should be helpful.

The researcher was Finley Markley, Director of the Materials Testing Laboratory at Fermilab. Through his efforts and preplanning, useful and meaningful projects were designed for the participants in this collaboration. All projects which were undertaken by the teacher and students were within the ability of those involved and sufficient assistance was available to enable the participants to continue the project successfully.

The students in the collaboration come from the Target program. Students in this program are minority students who come from the Chicago and Aurora area and have demonstrated an interest in science and mathematics. One half of their day is spent at Fermilab where they have a work experience for which they are paid. The other half of the day is spent at a local high school where the students conduct their own research projects in electronics, chemistry, biology, physics or com-

puters under the supervision of high school teachers.

At the Material Testing Laboratory, the Target student's work experience is beyond the "bolt sorting" category. Tasks are designed by Markley that are within the student's capabilities and are such that the data collected by the students is useful. That is to say, the data obtained will be used in an ongoing program at Fermilab, such as the Superconducting Super Collider or the Fermilab upgrade project. Staff members assist the students with their tasks.

I would like to relate personal experiences which may be helpful in explaining how a teacher from a small rural community in Nebraska can contribute to a research project of this magnitude.

Upon being selected I recognized that I would not be expected to know everything about the project. When I first arrived at the Materials Testing Laboratory, I was given a careful overview of the ongoing projects in the laboratory. My specific role the first summer I was at Fermilab was to design an apparatus which could be used to calibrate an extensometer at liquid helium temperatures. This was a challenging project for me because, at that time, no one in the lab was familiar with liquid helium, and so we all had to learn about it together. Another obstacle was the apparatus. It was to be designed by me, and parts of it were to be fabricated by me.

I became discouraged at the thought of having to fabricate the device. I do not have much experi-

ence with machine tools and became frustrated at the thought of having to work with them. Mr. Markely assured me that most of the fabrication would be done by skilled machinists and that my limited work would be conducted under their supervision.

This episode illustrates how easily a TRAC teacher can be overwhelmed due to lack of knowledge and experience. Mr. Markley, however, was able to alleviate my apprehensions and gave me encouragement.

Another factor which should be addressed is the full time staff. They were aware of the "summer people" and very open and helpful when approached with questions. Their cooperation is essential and ranges from finding a piece of wire to the operation of a computer system.

About the fourth week at the Materials Testing Laboratory, three Target students arrived. My job was to assist the students in the Materials Testing Lab to insure that they adjusted to the situation and were functioning well with the tasks that they were assigned. Their assignments were important since their results would be used to make decisions about multi-million dollar projects.

The work environment at the Material Testing Lab is foreign to a school teacher. It was pointed out to me many times that the projects undertaken in a research and development lab usually don't work out the first time. It is a process of

trial and error, and most of the time it's error. To someone who is not used to the constant roadblocks to progress, it can be very frustrating and discouraging. By the end of my first summer however, I became accustomed to roadblocks and started to see them as challenges.

My second summer at the Materials Testing Laboratory was more enjoyable and interesting than the first. I was to complete the task that I was assigned the first summer, the liquid helium extensometer calibration apparatus, and I was also able to work on a new project. The new project was to assemble an apparatus which measures the thermal expansion properties of a series of related insulating materials which are to be used in the construction of the massive coils for the main ring dipole Main Injector magnets.

The apparatus consists of an oven, which has a computer control unit which is able to control the rate at which the oven heats up, a dilatometer, which is composed of an outer pyrex tube in which the sample is placed, a linear variable differential transducer (LVDT) to determine the change in length, and an X-Y chart recorder.

During this summer I again worked with students in the Target program. One student worked with me in the coefficient of thermal expansion experiment, while two others students worked together determining the index of refraction of samples of the same epoxy resins. The student that I was working with helped make and test samples.

As the summer came to an end and I was preparing to return to my teaching assignment, Finley Markley asked if I would be interested in continuing the research that I had started that summer in my own community of Oakland, Nebraska. After obtaining permission from my superintendent, arrangements were made and the apparatus was shipped from Fermilab to Oakland, where it was assembled and samples were tested.

I have involved several of my science students in this experiment. Some students are involved in the determining of the coefficient of thermal expansion, while others from the computer class are attempting to determine how to collect data directly from a computer link which will allow direct communication with Fermilab.

I believe that the TRAC program has helped me grow professionally and made me more aware of my potential as a scientist. As a teacher I know the value that I have to the society in which I live. The TRAC program and Mr. Markley also recognize the value of my teaching abilities which enhanced my usefulness at the Laboratory. Knowing that I have contributed to the research taking place at Fermilab makes it easier for me to stay in teaching. There is a saying "Those who can, do. Those who can't, teach." I now respond confidently to such unenlightened critics of the teaching profession with the statement, "I can do, and choose to teach too."

Kris Ciesemier:

Today's teaching environment, much the same as it was 100 years ago, is a far cry from the cutting edge science taking place at Fermilab. The TRAC program provides a unique bridge linking these two separate yet interdependent entities.

As one TRAC teacher put it, "The entire program is one of the most positive forces in education today." They find it "a refreshing change of pace" and enjoy the opportunity to "put conceptual ideas presented in the classroom to work in the real world." When teachers return to school, the mathematics and science they teach comes alive because of their renewed interest and enthusiasm, enhanced self-image and ability to provide "concrete examples from first-hand knowledge."

It is not only the teachers and students who benefit; for everyone involved it is a win/win situation. Supervisors readily admit that the teachers are extremely dedicated and perform their assignments very well. They indicate that the TRAC "teacher can be the dedicated co-worker that provides the momentum and the continuity on a project which can be only part time for the mentor" and that "the teacher stimulates the evolutionary thought process and problem solving." In the words of Finley Markley, teachers provide a "real contribution to the research effort" and supervisors can make "effective use of their teaching experience to guide students" who participate in the Target program.

Arlene Lennox, former TRAC coordinator, cites the “formation of personal relationships between teachers and researchers” as a key outcome of the program.

For each teacher impacted by participation in the TRAC/TRAC Graduate programs there will be many students who are influenced, and the influence grows with each passing year. There is great satisfaction in knowing that like the teachers in the classroom who inspire the students, Fermilab has inspired many teachers. We shall reap what we have sown when today’s students are tomorrow’s scientists and scientifically literate adults who understand the value of and will support scientific research. ■

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The contributor



Kristin Fillman Ciesemier, Fermilab Education Office Program Leader, administers the TRAC program at Fermilab. Ciesemier has a B.S. in the Teaching of Biology from the University of Illinois at Urbana-Champaign and a Master of Education degree from National College of Education in Evanston, Illinois. Her thesis project was Biology for Learning Disabled Students. She is a member of the Glenbard Township High School District #87 Board of Education and is currently serving on the TECH 2000 Steering Committee, ED-RED (Education Research and Development), Des Plaines, Illinois. Prior to her position at Fermilab she taught biology and physical science for 11 years at Naperville North High School, Naperville, Illinois.

Lab notes

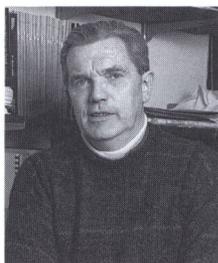
Lincoln Read named manager of the Office of Self-Assessment

Director John Peoples appointed Lincoln Read manager of the newly created Office of Self-Assessment.

This new office within the Directorate evolved from the Laboratory's response to a directive issued by Secretary of Energy James D. Watkins. In a memorandum dated July 31, 1990, Secretary Watkins called for all line organizations to implement a comprehensive self-assessment program to identify and characterize ES&H concerns relating to their operations. This Department of Energy (DOE) initiative developed from reviewing the preliminary trend analysis of the first six Tiger Team Assessments. Among the key findings was that all six facilities lacked adequate programs to ensure that ES&H deficiencies were identified, reported and corrected.

Fermilab's first step in response to this directive was to conduct an internal self-assessment. Chaired by Deputy Director Ken Stanfield, the Internal Self-Assessment Group thoroughly and systematically evaluated the Laboratory's ES&H and management programs. The outcome of this appraisal was a report to the Director regarding the status of the Laboratory's ES&H program.

As an outgrowth of the internal self-assessment, a Lab-wide



Lincoln Read

evaluate and organize the Laboratory's approach and response to ES&H issues. The committee consists of one representative of each Laboratory Division and Section and is chaired by Associate Director for Technology Dennis Theriot. The alternate chairperson is Ken Stanfield and Lincoln Read serves as secretary. The committee was given nine charges to which to respond. It was determined that these charges would best be addressed in subcommittees. One of the subcommittees formed was the Self-Assessment Program Plan subcommittee. The responsibility of this subcommittee was to prepare an ongoing self-assessment plan for the Laboratory. Lincoln Read was named chairperson of this subcommittee and its other members included Carl Swoboda, Don Cossairt and Hans Jostlein. The result of the work done by this subcommittee was the Fermilab ES&H Self-Assessment Program Plan which was completed in September 1991.

In the Fermilab Self-Assessment Program Plan, new duties were assigned to the Directorate. These duties included organizing audits of the ES&H management of Divisions and Sections; reporting annually to DOE on the entire self-assessment program at the Laboratory; and conducting a triennial review of the

committee called the Environment, Safety and Health Policy Advisory Committee (ESH-PAC) was established to

scope and the effectiveness of the ES&H self-assessment program.

In response to these new duties, the Directorate established the Office of Self-Assessment and appointed Lincoln Read manager. In his letter of appointment, John Peoples asked Read to "continue to assist Fermilab to achieve the same level of excellence in our ES&H programs as presently characterizes our research program."

Read's recent appointment is a continuation of goals he has been working hard to achieve over the past several months as a member and secretary of ESH-PAC and chairperson of the Self-Assessment Program Plan subcommittee. "Work can be done better, faster, more cost effectively and more efficiently when attention is given in a responsible, methodical fashion to environment, health and safety issues. In a sense, I feel I may be 'more royalist than the king' in my belief in this program," said Read.

According to Read, implementation of the self-assessment program will take time, because it will involve education and a new way of thinking to completely move into Secretary Watkins' "new Culture." "The method in which we will approach ES&H policies and procedures in our work is not just for Fermilab employees, but also graduate students, users, contract workers. Anyone who comes to Fermilab to work must know that the work must be carried out in a way that aggressively respects and protects the health and safety of everyone and also the environment which is so vital to all of us," said Read. ■

Staff physicists elected APS fellows

The American Physical Society (APS) recently elected Fermilab Associate Director for Technology Dennis Theriot and Solenoid Detector Collaboration (SDC) Head Dan Green to the rank of Fellow in its organization. The Council of the American Physical Society made the announcement at its November 3, 1991 meeting.

Theriot was elected "for his crucial leadership in the construction of the CDF detector." Between 1981 and 1989, Theriot served as Deputy Department Head, Deputy Operations Group Leader, Experimental Support Group Leader and during construction Deputy Project Manager of the Collider Detector Department.

Green was elected "for his leadership in particle physics experiments including the muon system for the Fermilab DØ detector, the SSC Solenoid Detector Collaboration and in several physics administrative positions at the Laboratory." His recent work includes conducting SSC physics and serving as SDC deputy spokesperson. He has been a staff scientist at Fermilab since 1979, serving as Research Division Facilities Support Group Head from 1982 to 1984, Physics Department Deputy Head from 1984 to 1986 and Physics Department Head from 1986 to 1990.

Only APS members who have contributed to the advancement of physics by independent, original



Dan Green



Dennis Theriot



Hugh Montgomery

research, or who have rendered some other special service to the cause of science are elected into Fellowship. Less than one-half of one percent of the APS membership obtain Fellowship each year.

The March 1992 Bulletin of the American Physical Society will publish Theriot and Green's election and citation. Formal announcement of their election will take place at the 1992 Division of Particles and Fields business meeting. ■

Hugh Montgomery named to HEPAP subpanel

Hugh Montgomery, Fermilab Research Division and co-leader of the DØ Upgrade Group, was appointed to serve on the High Energy Physics Advisory Panel (HEPAP) Subpanel on the U.S. Program of High Energy Physics Research. The seventeen member subpanel held its organizational meeting in Washington DC on December 16, 1991.

The HEPAP subpanel was formed to study long-rang high

energy physics priorities and is chaired by Michael Witherell, University of California, Santa Barbara. William Happer, the Director of the Office of Energy Research, charged the subpanel with addressing two key issues: what emphasis should be placed on university-based research compared to the operation of accelerator facilities at the DOE national laboratories; and whether construction of new or upgraded facilities should be initiated or pursued. The subpanel was asked to concentrate its efforts on the structure of the program for the next five years.

The subpanel is to make recommendations on the priorities of the national high energy physics program under three budget scenarios: level funding in constant dollars; level funding with no adjustment for inflation; and modest growth in funding above inflation. Their report is to be presented April 15 to the Department of Energy after a series of presentation meetings held at laboratories across the country to solicit input from the physics community. ■

DOE and URA sign contract

The U.S. Department of Energy (DOE) has extended its contract with the Universities Research Association, Inc. (URA) for the continued operation of Fermilab National Accelerator Laboratory. The five-year contract will extend to December 30, 1996.

DOE and its predecessor agencies have funded the construction, operation and continuing research programs at Fermilab since 1967. "Fermilab is one of our nation's treasures," said David Goldman, manager of the DOE Chicago Field Office. "Under this contract, the Laboratory can

enhance its reputation as the best place in the world to do high energy physics research. This research will bolster our understanding of the composition of the world around us and of the fundamental forces of nature."

Universities Research Association, Inc. is a consortium of 78 major research-oriented universities in the United States and Canada.

Under a separate contract, URA is also the management and operating con-



Seated are John Toll, President of URA, (left) and John Kennedy, Acting Deputy Manager, DOE Field Office, Chicago. Standing, Fermilab Director John Peoples (left) and Andrew Mravca, Manager of DOE's Batavia Area Office, witness the signing.

tractor for the Superconducting Super Collider in Texas. ■

Dates to remember

- *May 19, 1992* Deadline for receipt of material to be considered at the June PAC meeting.
- *May 28-29, 1992* 12th Annual Fermilab Industrial Affiliates Meeting and Industry Briefing. Topic: Medical Technology. For further information, contact Richard Carrigan Jr., Fermilab Office of Research and Technology Application (ORTA), P.O. Box 500, MS 200, Batavia, Illinois 60510-0500, 708-840-3333.
- *June 20-26, 1992* Physics Advisory Committee Meeting.
- *May 27-June 3, 1992* Summer School on QCD Analysis and

Phenomenology, organized by the CTEQ Collaboration (Coordinated Theoretical/Experimental Project on Quantitative QCD Phenomenology and Tests of the Standard Model); Mission Point Resort, Mackinac Island, Michigan; Jorge Morfin, Fermilab chairperson; Contact Treva Gourlay or Cynthia Sazama, CTEQ School, Fermilab, MS 122, P.O. Box 500, Batavia, Illinois 60510-0500; Telex: 373-6609; Telefax: 708-840-3867; BITnet:CTEQSCHOOL@FNAL.

- *July 13-17, 1992* 1992 Gordon Research Conference, "Particle Physics in the 90s," Proctor Academy, Andover, New Hampshire; John Elias, Fermilab Chairperson; Contact: C. M. Sazama, Fermilab, P. O.

Box 500, Batavia, IL 60510-0500, Telefax: 708-840-3867, Email: SAZAMA@FNAL.

- *October 6-9, 1992* III International Conference on Calorimetry in High Energy Physics, Corpus Christi, Texas. Further information can be obtained from INTERCAL@SSCVX1.
- *Nov 10-14, 1992* Particles & Fields 92: 7th Meeting of the Division of Particles and Fields of the APS (DPF92), Fermilab, Batavia Illinois; Rajandran Raja/John Yoh, Fermilab, Co-Chair; Contact: C. M. Sazama, Fermilab, P. O. Box 500, Batavia, IL 60510-0500, Telefax: 708-840-3867, Email: SAZAMA@FNAL.

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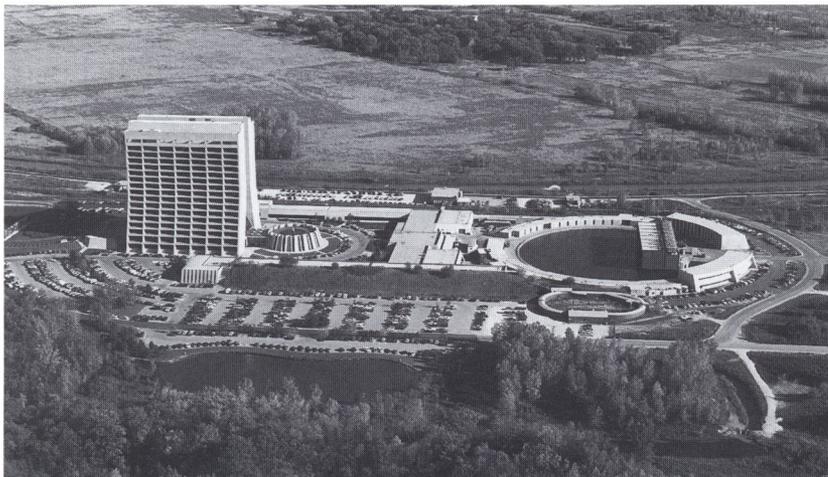
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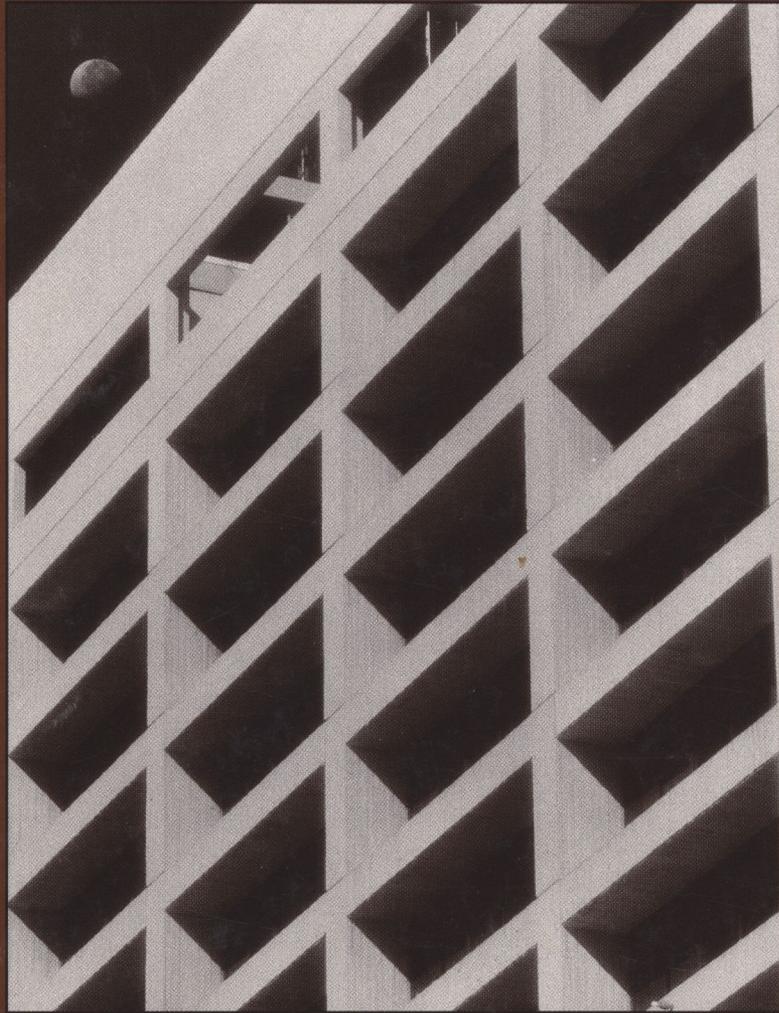


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